

RADIATION DOSE ASSESSMENT FOR FIREFIGHTERS DURING A GRASS FIRE

Introduction

A radiation dose assessment was performed for firefighters at the Rocky Flats Environmental Technology Site (RFETS) trying to extinguish a grass fire. This dose assessment is being performed to assure that firefighters would not exceed any radiation dose limits. This radiation dose assessment will be used to delineate areas at RFETS where firefighters would be advised to not follow a grass fire based on increased radiation dose potential.

Radiation dose could be received by the firefighter through the inhalation of resuspended radioactive material. This resuspended radioactive material augments naturally occurring radioactive material in the air. For the purposes of this study, the radiation dose to firefighters located adjacent to a grass fire will be assessed so that the maximum radiation dose to the firefighter is estimated. Conservative assumptions were made in the dose assessment to assure that radiation dose to the firefighter was overestimated in the calculations.

It is recommended that the "Soil Contamination Area" (SCA) radiological posting limits be used as the demarcation where firefighters should not follow a grass fire based on potential radiation dose. SCA posting limits for Pu-239/Am-241, enriched uranium and depleted uranium in surface soils have been set at 115 pCi Pu-239/gram soil, 188 pCi Total Enriched U/gram soil and 102 pCi Total Depleted U/gram soil, respectively, based on soil action levels prescribed presently in the Rocky Flats Cleanup Agreement (RFCA). By following this recommendation, a firefighter should not receive more than 1 mrem of radiation dose while extinguishing a grass fire at RFETS (See Table 1, "Allowable Soil Concentration Based on Radiation Dose to Firefighters From Grass Fires.").

The radiation dose assessment was performed by: 1) defining the locations where individuals could receive radiation dose, 2) calculating the amount of radioactive material in air at this location during grass fires and 3) computing the radiation dose with its associated acceptable soil concentration. Each of these steps is discussed below.

Location of Individuals

In order to assess the radiation dose to a firefighter, the location of the firefighter must first be defined. The maximum radiation dose would be received by a firefighter directly adjacent to the grass fire and downwind since these individuals would be exposed to the highest air concentrations of radioactive material. For conservatism, it is assumed that a firefighter is located immediately downwind of the burning grass for the duration of the grass-burning episode. It is also assumed that this firefighter is not wearing any type of

respiratory protection. It should be noted that normal fire fighting methods do not place the firefighters in the path of the fire or the direct smoke plume from the fire.

Air Concentrations at Firefighter Location

Radioactive material present in the environment is resuspended and transported downwind during a grass burning episode. By knowing the amount of radioactive material in the grass, the concentration of radioactive material in air can be calculated using resuspension factors applicable to a fire. The firefighter can subsequently inhale some fraction of this radioactive material in the air.

This dose assessment is based on a computer model of emissions from a series of hypothetical fire and atmospheric conditions (See Attachment A – "Hypothetical Wildfire Air Modeling Analysis."). For this radiation dose assessment, the concentration of radioactive material in air is maximized. By modeling, the firefighter immediately downwind of the fire is exposed for several different time-periods and for several different wind conditions in this assessment. To capture a range of air concentrations, a grass fire duration of 1, 2 and 5 hours is assessed for average and worst-case conditions.

Radiation Dose

To calculate radiation dose, the concentration of radioactive material in the air is initially multiplied by the firefighters breathing rate and the duration of the grass fire. This product will be the estimated amount of radioactive material inhaled. This amount inhaled is then multiplied by a dose conversion factor to calculate radiation dose. The radiation dose to the firefighters from plutonium, americium and uranium are outlined in Table 2, "Radiation Dose from Plutonium & Americium to Firefighters Due to Inhalation of Particulates During a Grass Fire," Table 4, "Radiation Dose from Enriched Uranium to Firefighters Due to Inhalation of Particulates During a Grass Fire," and Table 5, "Radiation Dose from Depleted Uranium to Firefighters Due to Inhalation of Particulates During a Grass Fire."

The firefighters at the boundary of the burn site will inhale at a rate of 3.2 m³/hr. The firefighters inhalation rate is indicative of a short term, heavy activity inhalation rate. This inhalation rate was taken from EPA's "Exposure Factors Handbook," dated August 1997 (EPA/600/P-95/002).

The radiation Dose Conversion Factor (DCF) is used to convert the amount of radioactive material taken into the body into a radiation dose. The inhalation DCF used to calculate radiation dose for Am-241, Pu-239, U-234, U-235 and U-238 were taken from EPA's Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," dated September, 1988 (EPA-520/1-88-020). The inhalation DCF used to calculate

radiation dose was the highest DCF available and corresponded to the Committed Effective Dose Equivalent.

It was assumed that the Am-241/Pu-241 activity ratio is 18%. This is consistent with the median Am-241/Pu-241 activity ratio seen in surface soils east of RFETS (Health Physics, Vol. 70, No. 4, April 1996). For assessing uranium isotope ratios, typical values for depleted and enriched uranium were taken from the "Health Physics and Radiological Health Handbook." Uranium isotope ratios are outlined in Table 3, "Uranium Isotope Characterization."

The acceptable soil concentration was then calculated by dividing a radiation dose limit by the radiation dose calculated for a unit concentration of activity. This will give the soil concentration that would give the firefighter the designated radiation dose limit for the given burn conditions (See Table 1).

Recommendations

The results of this assessment indicate that the maximum dose will be less than 1 mrem to any individual downwind of a fire if the fire is not in an area exceeding the SCA radiological posting limit. It is therefore recommended that the SCA radiological posting limit be used as the demarcation where firefighters should not follow a grass fire. SCA posting limits for Pu-239/Am-241, enriched uranium and depleted uranium in surface soils are at 115 pCi Pu-239/gram soil, 188 pCi Total U/gram soil and 102 pCi Total U/gram soil, respectively. By following this proposal, a firefighter should not receive more than 1 mrem of radiation dose.

Attachments

Attachment A – Hypothetical Wildfire Air Modeling Analysis

Tables

- Table 1 - Allowable Soil Concentration Based on Radiation Dose to Firefighters from Grass Fires
- Table 2 - Radiation Dose from Plutonium & Americium to Firefighters Due to Inhalation of Particulates during a Grass Fire
- Table 3 - Uranium Isotope Characterization
- Table 4 - Radiation Dose from Enriched Uranium to Firefighters Due to Inhalation of Particulates during a Grass Fire
- Table 5 - Radiation Dose from Depleted Uranium to Firefighters Due to Inhalation of Particulates during a Grass Fire

ATTACHMENT A

Hypothetical Wildfire Air Modeling Analysis

Introduction

A wildfire may release radionuclides to the environment if radionuclides are present on or in the vegetation, or on soil attached to the vegetation surfaces. Airborne radionuclides may then be inhaled by fire fighters, resulting in a radiation dose to the individual.

Studies at the Rocky Flats Environmental Technology Site (RFETS or Site) and elsewhere have shown that plants do not readily uptake actinides such as plutonium (Pu) and americium (Am) from soil (Arthur and Alldredge, 1982). However, radionuclide-contaminated soil may be resuspended by wind or rain splash and become attached to vegetation surfaces. Measurements conducted at RFETS show that both standing vegetation and litter may trap radionuclide-contaminated soils, with litter showing a higher radionuclide content than the standing vegetation (Langer, 1986).

To look at radiation dose from a hypothetical wildfire, a dispersion model was used to calculate downwind concentrations of particulate matter. Assuming that airborne soil particles released from the burning plants have the same radionuclide concentrations as the surrounding contaminated surface soils allowed an estimate of airborne radionuclides that might be released during a wildfire. The dispersion modeling and subsequent radiation exposure calculations are described below.

Fire Scenario Modeling

A series of hypothetical wildfires was modeled, based on fire durations of 1, 2, or 5 hours and a variety of wind speed/stability combinations. The 54 wind speed/stability combinations that were used for this study were taken from the U.S. Environmental Protection Agency's (EPA's) SCREEN dispersion model (EPA, 1995a) and represent the probable range of wind speed and stability that are likely to occur in nature. For each wind speed and fire duration, the U.S. Forest Service's fire behavior model BEHAVE was used to predict the area and length-to-width ratio of the burned area.

Particulate emissions (and therefore actinide emissions) from the hypothetical fires were maximized by assuming that the fire would begin in late September, when fuel loading would be at a maximum. Subsequent dispersion was assumed to occur under each of the 54 wind speed/stability combinations. Dispersion from the fire was modeled for the 1-hour case for each of the 54 meteorological combinations. Worst-case impacts were found to occur under light winds (1 meter per second [m/s]) and stable conditions (nighttime stability, F). The 2- and 5-hour fires were modeled for the worst case conditions and also under annual average wind speed and stability conditions (4 m/s and

neutral [D] stability). These meteorological conditions were assumed to persist for the full 2 or 5 hours for the longer duration fires.

Dispersion from each fire was simulated using a model developed by the EPA, the Industrial Source Complex Short-Term model (ISCST3). Each hypothetical wildfire was represented by a rectangular area with dimensions based on the total acreage and the length-to-width ratios predicted by BEHAVE. The fire was input as a ground-based area source with an initial vertical dimension based on the expected height to which a smoke plume would rise (described below). The "regulatory default" options were used, along with rural dispersion coefficients. The model essentially assumed that the entire fire area would be burning simultaneously, which would not be the case in a real fire.

Winds were assumed to blow from west to east during each fire. Receptors (points at which the model will calculate a concentration) were established in a rectangular grid pattern over the eastern half of the fire and for some distance beyond the burned area to the north, south, and east. Receptor spacing was 100 m in the north-south direction and 50 m east-west. Because each fire was represented as a ground-based source, the receptors near the eastern edge of the fire will show the maximum concentrations that would be produced anywhere by a hypothetical fire. All receptors were assumed to be located 2 m above the ground (breathing level).

Fire Scenario Particulate Emissions

Particulate emissions from fires have been estimated by a number of researchers. Emission factors for a grass fire similar to the hypothetical wildfires generally range from approximately 3 grams (g) of particulate matter per kilogram (kg) of grass burned to around 18 g/kg. For this study, emission factors were taken from Leenhouts (1998). These factors have been used in a recent update to the Bureau of Land Management's (BLM's) *Simple Approach Smoke Estimation Model* (SASEM) (Sestak and Riebau, 1988) and are specific to western perennial grassland fires. The particulate emissions calculated represent emissions of particles smaller than 10 micrometers aerodynamic diameter (PM₁₀).

Equations given in the SASEM documentation (Sestak and Riebau, 1988) were used to estimate heat release and plume rise from each of the hypothetical fires. The SASEM approach assumes that a fire line will produce multiple small plumes, with horizontal dimensions governed by the depth of the fire line, rather than a single, massive plume. The expected plume rise for each individual plume is then largely a function of how hot the fire is (heat release) and the wind speed (higher winds inhibit plume rise).

The plume rise was calculated for a 1-hour fire for each of the 54 wind speed/stability combinations. Based on equations in the ISCST User's Guide (EPA, 1995b), these plume rise figures were used to estimate the initial vertical dimension of the fire plume for each meteorological condition. Once the worst-case dispersion conditions were identified by modeling each 1-hour fire with ISCST3, plume rise and initial vertical

dimension were also calculated for the 2- and 5-hours fires for the worst-case and average conditions.

Fire Scenario Radionuclide Emissions

Measurements have been taken on Site of the amount of soil attached to vegetation and litter. An autumn maximum figure plus one standard deviation of 134 milligrams of soil per gram of plant mass (mg/g) was used for this study (Arthur and Alldredge, 1982). The attached soil was assumed to be radiologically contaminated at a level of 1 picocurie per gram of soil (1 pCi/g). In addition, a small amount of radioactivity was assumed to be present within the plant material itself, based on transfer coefficients from Baes, et al. (1984).

Fire Scenario Results

The maximum and average 1-hour, 2-hour, and 5-hour particulate and radionuclide concentrations predicted by the modeling are shown in Table 1.

Table 1. Hypothetical Wildfire Air Modeling Results

Fire Duration and Scenario	Maximum Particulate Concentration ($\mu\text{g}/\text{m}^3$)	Maximum Pu-239/240 Concentration (pCi/m^3)	Maximum Am-241 Concentration (pCi/m^3)	Maximum Uranium Concentration (pCi/m^3)
1 hour Worst-case meteorology	2,989	4.02×10^{-4}	4.17×10^{-4}	4.26×10^{-4}
1 hour Average meteorology	728	9.79×10^{-5}	1.02×10^{-4}	1.04×10^{-4}
2 hour Worst-case meteorology	2,962	3.98×10^{-4}	4.13×10^{-4}	4.22×10^{-4}
2 hour Average meteorology	722	9.70×10^{-5}	1.01×10^{-4}	1.03×10^{-4}
5 hour Worst-case meteorology	2,883	3.88×10^{-4}	4.02×10^{-4}	4.11×10^{-4}
5 hour Average meteorology	695	9.34×10^{-5}	9.69×10^{-5}	9.90×10^{-5}

Notes:

$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter

pCi/m^3 = picocuries per cubic meter

Pu-239/240 = plutonium 239/240

Am-241 = americium 241

U = uranium species

All radionuclide concentrations based on soil contamination at 1 picocurie per gram (pCi/g)

References Cited

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TABLE 1
ALLOWABLE SOIL CONCENTRATION BASED ON RADIATION DOSE TO FIREFIGHTERS
FROM GRASS FIRES

ALLOWABLE PLUTONIUM SOIL CONCENTRATION

Burn Conditions	Radiation Dose (mrem)/(pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 0.1 mrem (pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 1 mrem (pCi Pu-239/gram soil)	Allowable Pu-239 Soil Concentration at Radiation Dose = 10 mrem (pCi Pu-239/gram soil)
Worst Case, Duration = 1 hour	6.59E-04	152	1518	15180
Average Case, Duration = 1 hour	1.61E-04	623	6229	62288
Worst Case, Duration = 2 hour	1.30E-03	77	767	7666
Average Case, Duration = 2 hour	3.18E-04	314	3144	31436
Worst Case, Duration = 5 hour	3.18E-03	31	315	3146
Average Case, Duration = 5 hour	7.65E-04	131	1307	13067

ALLOWABLE ENRICHED URANIUM SOIL CONCENTRATION

Burn Conditions	Radiation Dose (mrem)/(pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 0.1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 10 mrem (pCi Total U/gram soil)
Worst Case, Duration = 1 hour	1.77E-04	565	5653	56528
Average Case, Duration = 1 hour	4.32E-05	2315	23155	231549
Worst Case, Duration = 2 hour	3.50E-04	285	2853	28532
Average Case, Duration = 2 hour	8.55E-05	1169	11690	116898
Worst Case, Duration = 5 hour	8.53E-04	117	1172	11718
Average Case, Duration = 5 hour	2.06E-04	486	4865	48649

ALLOWABLE DEPLETED URANIUM SOIL CONCENTRATION

Burn Conditions	Radiation Dose (mrem)/(pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 0.1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 1 mrem (pCi Total U/gram soil)	Allowable Total Uranium Soil Concentration at Radiation Dose = 10 mrem (pCi Total U/gram soil)
Worst Case, Duration = 1 hour	1.63E-04	615	6153	61531
Average Case, Duration = 1 hour	3.97E-05	2520	25204	252039
Worst Case, Duration = 2 hour	3.22E-04	311	3106	31057
Average Case, Duration = 2 hour	7.86E-05	1272	12724	127243
Worst Case, Duration = 5 hour	7.84E-04	128	1276	12755
Average Case, Duration = 5 hour	1.89E-04	530	5295	52954

TABLE 2
RADIATION DOSE FROM PLUTONIUM & AMERICIUM TO FIREFIGHTERS
DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE

EXPOSURE PARAMETERS

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m ³ /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1
Am-241/Pu-239 activity ratio	unitless	0.18

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.17E-04	2.40E-04	4.44E+05	1.07E-04
Pu-239/240	4.02E-04	1.29E-03	4.29E+05	5.52E-04
TOTAL				6.59E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	1.02E-04	5.88E-05	4.44E+05	2.61E-05
Pu-239/240	9.79E-05	3.13E-04	4.29E+05	1.34E-04
TOTAL				1.61E-04

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.13E-04	4.78E-04	4.44E+05	2.11E-04
Pu-239/240	3.98E-04	2.55E-03	4.29E+05	1.09E-03
TOTAL				1.30E-03

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	1.01E-04	1.18E-04	4.44E+05	5.17E-05
Pu-239/240	9.70E-05	6.21E-04	4.29E+05	2.68E-04
TOTAL				3.18E-04

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	4.02E-04	1.16E-03	4.44E+05	5.14E-04
Pu-239/240	3.88E-04	6.21E-03	4.29E+05	2.68E-03
TOTAL				3.18E-03

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Radiation Dose (mrem)
Am-241	8.69E-05	2.79E-04	4.44E+05	1.24E-04
Pu-239/240	9.34E-05	1.49E-03	4.29E+05	6.41E-04
TOTAL				7.65E-04

TABLE 3
URANIUM ISOTOPE CHARACTERIZATION

RADIONUCLIDES	URANIUM MASS FRACTION (gram)		
	NATURAL URANIUM (1)	ENRICHED URANIUM (1)	DEPLETED URANIUM (1)
Uranium-234	0.000057	0.0003	0.000005
Uranium-235	0.007204	0.0296	0.0025
Uranium-238	0.992739	0.9701	0.9975

(1) - Typical values taken from "The Health Physics and Radiological Health Handbook." Values may vary.

RADIONUCLIDES (Ci/gram of isotope)	URANIUM SPECIFIC ACTIVITY (2)
Uranium-234	6.24E-03
Uranium-235	2.16E-06
Uranium-238	3.35E-07

(2) - Taken from "The Health Physics and Radiological Health Handbook."

RADIONUCLIDES	URANIUM ACTIVITY (Ci/gram)		
	NATURAL URANIUM	ENRICHED URANIUM	DEPLETED URANIUM
Uranium-234	3.56E-07	1.87E-06	3.12E-08
Uranium-235	1.56E-08	6.39E-08	5.40E-09
Uranium-238	3.33E-07	3.25E-07	3.34E-07
TOTAL	7.04E-07	2.26E-06	3.71E-07
URANIUM PERCENT			
Uranium-234	50.5	82.8	8.4
Uranium-235	2.2	2.8	1.5
Uranium-238	47.3	14.4	90.1

TABLE 4
RADIATION DOSE FROM ENRICHED URANIUM TO FIREFIGHTERS
DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE

EXPOSURE PARAMETERS

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m ³ /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.26E-04	1.36E-03	1.32E+05	0.83	1.49E-04
U-235	4.26E-04	1.36E-03	1.23E+05	0.03	5.03E-06
U-238	4.26E-04	1.36E-03	1.18E+05	0.14	2.25E-05
TOTAL					1.77E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.04E-04	3.33E-04	1.32E+05	0.83	3.85E-05
U-235	1.04E-04	3.33E-04	1.23E+05	0.03	1.23E-06
U-238	1.04E-04	3.33E-04	1.18E+05	0.14	5.50E-06
TOTAL					4.32E-05

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.22E-04	2.70E-03	1.32E+05	0.83	2.96E-04
U-235	4.22E-04	2.70E-03	1.23E+05	0.03	9.87E-06
U-238	4.22E-04	2.70E-03	1.18E+05	0.14	4.46E-05
TOTAL					3.50E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.03E-04	6.59E-04	1.32E+05	0.83	7.22E-05
U-235	1.03E-04	6.59E-04	1.23E+05	0.03	2.43E-06
U-238	1.03E-04	6.59E-04	1.18E+05	0.14	1.09E-05
TOTAL					8.55E-05

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.11E-04	6.58E-03	1.32E+05	0.83	7.20E-04
U-235	4.11E-04	6.58E-03	1.23E+05	0.03	2.43E-05
U-238	4.11E-04	6.58E-03	1.18E+05	0.14	1.09E-04
TOTAL					8.53E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Enriched Uranium Activity Ratio	Radiation Dose (mrem)
U-234	9.90E-05	1.58E-03	1.32E+05	0.83	1.74E-04
U-235	9.90E-05	1.58E-03	1.23E+05	0.03	5.64E-06
U-238	9.90E-05	1.58E-03	1.18E+05	0.14	2.62E-05
TOTAL					2.06E-04

TABLE 5
RADIATION DOSE FROM DEPLETED URANIUM TO FIREFIGHTERS
DUE TO INHALATION OF PARTICULATES DURING A GRASS FIRE

EXPOSURE PARAMETERS

Exposure Factors Description	Units	Parameter Value
Inhalation Rate (Burn Worker)	m ³ /hr	3.2
Exposure Frequency - Short	hr/day	1
Exposure Frequency - Medium	hr/day	2
Exposure Frequency - Long	hr/day	5
Exposure Duration	days	1

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.26E-04	1.36E-03	1.32E+05	0.08	1.44E-05
U-235	4.26E-04	1.36E-03	1.23E+05	0.02	3.35E-06
U-238	4.26E-04	1.36E-03	1.18E+05	0.90	1.45E-04
TOTAL					1.63E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 1 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.04E-04	3.33E-04	1.32E+05	0.08	3.51E-06
U-235	1.04E-04	3.33E-04	1.23E+05	0.02	8.19E-07
U-238	1.04E-04	3.33E-04	1.18E+05	0.90	3.53E-05
TOTAL					3.97E-05

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.22E-04	2.70E-03	1.32E+05	0.08	2.85E-05
U-235	4.22E-04	2.70E-03	1.23E+05	0.02	6.64E-06
U-238	4.22E-04	2.70E-03	1.18E+05	0.90	2.87E-04
TOTAL					3.22E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 2 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	1.03E-04	6.59E-04	1.32E+05	0.08	8.96E-06
U-235	1.03E-04	6.59E-04	1.23E+05	0.02	1.62E-06
U-238	1.03E-04	6.59E-04	1.18E+05	0.90	7.00E-05
TOTAL					7.86E-05

RADIATION DOSE - WORST CASE CONDITIONS, BURN DURATION = 5 HOUR

Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	4.11E-04	6.58E-03	1.32E+05	0.08	8.94E-05
U-235	4.11E-04	6.58E-03	1.23E+05	0.02	1.62E-05
U-238	4.11E-04	6.58E-03	1.18E+05	0.90	8.98E-04
TOTAL					7.84E-04

RADIATION DOSE - AVERAGE CONDITIONS, BURN DURATION = 5 HOUR

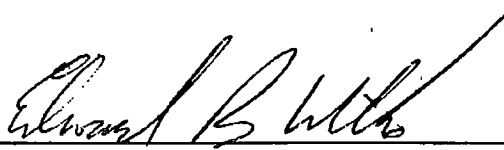
Radionuclide	Air Concentration (pCi/m ³)	Daily Intake (pCi)	Inhalation Dose Conversion Factor (mrem/uCi)	Depleted Uranium Activity Ratio	Radiation Dose (mrem)
U-234	9.90E-05	1.58E-03	1.32E+05	0.08	1.67E-05
U-235	9.90E-05	1.58E-03	1.23E+05	0.02	3.90E-06
U-238	9.90E-05	1.58E-03	1.18E+05	0.90	1.68E-04
TOTAL					1.89E-04

From 1st Qtr 2006 Report

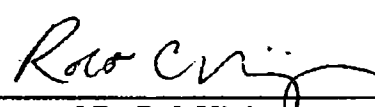
6/14/06

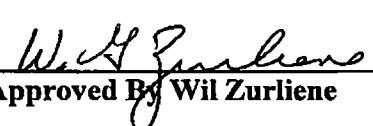
**WHITE PAPER
ON THE
RADIATION DOSE ASSESSMENT FOR FIREFIGHTERS
DURING A GRASS FIRE**


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