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OPERABLE UNIT 4 FINAL REMEDIAL INVESTIGATION REPORT

05/20/94

DOE-1724-94
DOE-FN FERMCO
19
RESPONSES

Department of Energy
Fernald Environmental Management Project
P.O. Box 398705
Cincinnati, Ohio 45239-8705

MAY 20 1994
DOE-1724-94

Mr. James A. Saric, Remedial Project Manager
U. S. Environmental Protection Agency
Region V - 5HRE-8J
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Tom Schneider, Project Manager
Ohio Environmental Protection Agency
40 South Main Street
Dayton, Ohio 45402-2086

Dear Mr. Saric and Mr. Schneider:

OPERABLE UNIT 4 FINAL REMEDIAL INVESTIGATION REPORT

As a result of comments received on April 27, 1994, from the United States Environmental Protection Agency (USEPA) on the subject report, enclosed are changed pages for your incorporation into the report. In addition, a comment response document has also been enclosed.

If you have any additional concerns with the report, please contact Randi Allen at (513) 648-3102.

Sincerely,

Jack R. Craig
Fernald Remedial Action
Project Manager

FN:Allen

Enclosures: As Stated

Recycled and Recyclable

cc w/enc:

K. A. Chaney, EM-424, TREV
D. R. Kozlowski, EM-424, TREV
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Operable Unit 4 Remedial Investigation Final Report

Response to Comments From
United States Environmental Protection Agency
Region V
May 1994

Operable Unit 4 Remedial Investigation Final Report

Response to Comments From
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Region V
May 1994

Commenting Organization: U.S. EPA Commentor:
Section #: D.3.4.1 Pg. #: D-3-68 Line #: NA Code:
Comment: The editorial change is not the change provided in the prior response/action (see 10/27/93.rev7). This was the response we agreed upon, and it is more correct. I agree that there was no "final" version of the EPA uptake biokinetic model for lead available in 1992; however, there were interim versions of the model (0.50/0.60), and there is a new interim version (0.99D) now. All appropriate for use at Superfund sites.

Response: Agreed.

Action: The phraseology used in the toxicity profile on lead (Section D.4.2.11.2), which apparently was satisfactory to the reviewer, will be adapted to this section, the first sentence of which will be changed to read as follows:

Toxicity values are not available for lead. The most recent EPA (1991d) directive stated that the EPA UBK model is the best available approach for evaluating lead in soil, but expressed concern regarding the use of site-specific versus default values. Because reliable site-specific values are not available for this site, the EPA UBK model is not used. Instead, the concentrations of lead in soil and sediment are compared to the EPA (1989d, 1991d) cleanup levels of 500-1000 ppm.

Commenting Organization: U.S. EPA Commentor: PVL
Section #: Table D.4-1, footnote f Pg. #: Line #: NA Code:
Comment: The phrase "Chemical/Wilmington, Delaware)," dated Octer (sic) 9, 1990" is superfluous. Please remove.

Response: DOE disagrees with the reviewer, believing that the information provided may expedite retrieval of the reference, because it is an intra-agency memorandum, not a formal report or article in a published journal. However, we will comply with your request.

Action: The phrase "(Halby Chemical, Wilmington, Delaware), dated October 9, 1990" will be removed.

Commenting Organization: U.S. EPA Commentor: PVL
Section #: Table D.7-2 Pg. #: Line #: NA Code:

Comment: The HI totals listed as "ALL MEDIA" are incorrect. Unfortunately, this error will require corresponding changes in Tables 6.2 and 7.2, as well as text changes. This will be a difficult correction. Please check HI totals in the Section D.II Tables as well.

Response: DOE agrees that Table D.7-2 is confusing but it is not incorrect. In keeping with U.S. EPA guidance, DOE presents all hazard indices (HIs) rounded to one significant figure. DOE does not round hazard quotients (HQs) to one significant figure, rather these are displayed with two significant figures to assist the reader during the summing process. DOE does not round to one significant figure until all summing of HQs has been completed. The apparent "error" in the sum of HQs by all media results from presenting rounded HQs for each medium, while using unrounded HQ values to calculate a total HI for the receptor.

This can best be observed by following the formation of Table D.7-2 from the base calculations for one receptor. Attached are the relevant tables for the Trespassing Child to facilitate this discussion.

Table D.7-2 displays the HIs by each medium for individual receptors assuming the future source term and also presents the HI for the receptor for all media. The column of this table representing the Trespassing Child was prepared using Table D.5-5 which in turn was a summary of Table D.II-4. Starting with Table D.II-4, the individual HQs for each exposure pathway are summed by medium and by contaminant of potential concern (CPC) to form a single HQ for a CPC which is presented in Table D.5-5. The CPC entry is still presented to two significant figures by each medium. Table D.5-5 further summarizes these values to provide an HI for each CPC (rightmost column) as well as a HI for each medium (subtotal at the bottom of each medium column) and finally a total HI for all exposure pathways for all media (lower right corner of the main table).

Attachment A to this response document is Table D.7-2 displayed with a minimum of two significant figures. As can be seen for the trespassing child, the sum of all air HQs for all contaminants yields a value of 15 which is rounded to one significant figure in Table D.7-2 and displayed as 20. Likewise, the sum of the HQs for all contaminants via the soil is 7.5 which is displayed in Table D.7-2 as 8 (one significant figure). Other media contribute insignificantly to the total. Finally, the "ALL MEDIA" total HI is listed in Attachment A as 24, which rounds to 20 in Table D.7-2 (which displays one significant figure).

Action: In order to clarify the summing of HIs, add a footnote to Table D.7-2 which states:

Due to rounding to one significant figure, the individual medium HIs may not sum exactly to the listed "ALL MEDIA" total.

Commenting Organization: U.S. EPA Commentor: PVL
Section #: Pg. #: Page D-I-12 Line #: NA Code:
Example Calculation

Comment: The body surface area (SA) parameter value (0.7m2) used in the example calculation does not match the value listed for this receptor/pathway in Table D.3-12 (0.8 m2). Which was used in the risk assessment?

Response: The body surface area variable value presented in Table 3.3-12, which is the correct value, was used in the risk assessment.

Action: The body surface area value and computations in the example calculation will be corrected.

TABLE D.7-2

SUMMARY OF TOXICITY BY RECEPTOR FOR THE FUTURE SOURCE TERM

Medium	Trespassing Child	Groundskeeper	Off-Property Resident Farmer	Receptor Surface Water User	On-Property Farmer (CT)	On-Property Farmer (RME)	Perched Water User	On-Property Resident Child
Groundwater	-	-	0.13	-	0.49	0.91	30	3.30
Air	15.00	13.0	4.60	-	55.00	95.00	95	618.00
Soil	7.50	3.6	-	-	201.00	423.00	423	1762.00
Surface Water	0.56	-	-	0.002	-	-	-	0.50
Sediment	0.20	-	-	-	-	-	-	5.90
All Media	24.00	16.0	4.70	0.002	256.00	519.00	548	2390.00

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United States Environmental Protection Agency
Region V
May 1994

Document Change Pages

EF = exposure frequency (days/yr)
BW = body weight (kg)
AT = averaging time (days); for noncarcinogens, AT equals (ED)(365 days/yr); for carcinogens, AT equals (70-year lifetime)(365 days/yr)

As discussed in Section D.3.4.2, EF is expressed as days/yr.

D.3.3.9 Inhalation of VOCs Released from Household Water

The model for estimating the inhaled dose of volatile CPC released from household use, called the Andelman model (EPA 1991a), applies several assumptions:

- The volume of water used in a residence by a family of four is 720 L/day.
- The volume of air in the dwelling is 150,000 L.
- The air exchange rate is 0.25 m^3/hr.
- The average water-to-air transfer efficiency is 0.5, i.e., half the concentration of a volatile chemical in water is transferred to air.

The Andelman model is applicable to chemicals that will readily volatilize from water; i.e., those with a Henry's Law constant greater than 1 x 10^{-5} atm-m^3/mole and a molecular weight less than 200g/mole. The equation is:

$$\text{(chemicals) } I_a = (C_w)(IR)(K)(EF)(ED)/(BW)(AT) \qquad \text{D.3-22}$$

where:

I_a = average inhaled dose of volatile CPC in air from household use of water (mg/kg-day)
C_w = concentration of CPC in water (mg/L)
IR = inhalation rate (m^3/day)
K = volatilization factor of 0.0005 (unitless) x 1000 L/m^3
EF = exposure frequency (d/yr)
ED = exposure duration (yr)
BW = body weight (kg)
AT = averaging time (d)

Calculation of potential intakes of contaminants is discussed in Section D.3.3. Calculated intakes are not presented because this is an interim step to risk characterization. The URFs that incorporate calculation of exposure intakes are presented in Attachment D.I. The models (and formulae) used for intake calculations are generally accepted as the most appropriate for an exposure assessment. Specific model parameters were selected to provide reasonable, upper bound estimates of intake. Discussions of the appropriateness of selected parameters are given in numerous references cited in the Work Plan Addendum (DOE 1992a). It can be concluded, however, that the selected parameters as a whole will lead to overestimates, rather than underestimates, of the potential intakes by hypothetical receptors.

D.3.4 OTHER CONSIDERATIONS

D.3.4.1 Lead

Toxicity values are not available for lead. The most recent EPA (1991d) directive stated that the EPA UBK model is the best available approach for evaluating lead in soil, but expressed concern regarding the use of site-specific versus default values. Because reliable site-specific values are not available for this site, the EPA UBK model is not used. Instead, the concentrations of lead in soil and sediment are compared to the EPA (1989d, 1991d) cleanup levels of 500 to 1000 ppm. The concentration of lead in sediment impacted by the sand lens (8400 ppm, Table D.3-4) and for soil, future source term (2400 ppm, Table D.3-5) exceeds these cleanup levels. Lead was not identified as a CPC in contaminated soil, current source term (Table D.3-6).

TABLE D.4-1

REFERENCE DOSES FOR NONCARCINOGENIC EFFECTS OF CONSTITUENTS OF POTENTIAL CONCERN IN OPERABLE UNIT 4

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Inorganics						
Ammonia	ND	0.029[b]	ND	Respiratory system	ND	30
Antimony	0.0004[b]	ND[c]	Liver	ND	1000	ND
Arsenic	0.0003[b]	ND	Skin	ND	3	ND
Barium	0.07[b]	0.00014[d]	Cardiovascular system	Fetus	3	1000
Beryllium	0.005[b]	ND	ND	ND	100	ND
Boron	0.09[b]	0.0057[d]	Testis	Respiratory system	100	100
Cadmium (food)	0.001[b]	ND	Kidney	Cancer (see Table D.4-2)	10	ND
Cadmium (water)	0.0005[b]	ND	Kidney	Cancer (see Table D.4-2)	10	ND
Chromium (VI)	0.005[b]	ND	ND	ND	500	ND
Cobalt	0.06[e]	0.0000003[f]	Cardiovascular system	Respiratory system	ND	1000
Copper	ND	ND	ND	ND	ND	ND
Cyanide	0.02[b]	ND	Central nervous system	ND	500	ND
Fluoride	0.06[b]	ND	Teeth	ND	1	ND
Lead	ND	ND	Central nervous system	Central nervous system	ND	ND
Manganese	0.14 (food)[b]	0.00011[b]	Central nervous system	Respiratory system	1	300
Manganese	0.005 (water)[b]	0.00011[b]	Central nervous system	Respiratory system	1	300
Mercury	0.0003[d]	0.000086[d]	Kidney	Central nervous system	1000	30
Molybdenum	0.005[b]	ND	Liver	ND	30	ND
Nickel	0.02[b]	ND	ND	Cancer (see Table D.4-2)	300	ND
Nitrate	1.6[b]	ND	Blood	ND	1	ND

TABLE D.4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Inorganics						
Phosphorus	0.00002[b]	ND	Reproductive system	ND	1000	ND
Selenium	0.005[b]	ND	Skin	ND	3	ND
Silver	0.005[b]	ND	ND	ND	3	ND
Thallium	0.00006[b,e]	ND	Central nervous system	ND	3000	ND
Uranium	0.003[b]	ND	Kidney	ND	1000	ND
Vanadium	0.007[d]	ND	ND	ND	100	ND
Zinc	0.3[b]	ND	Blood	ND	3	ND
Volatiles						
2-Butanone	0.05[d]	0.3[b]	ND	Fetus	1000	1000
2-Hexanone	0.04[k]	ND	ND	ND	ND	ND
4-Methyl-2-pentanone	0.05[d]	0.023[d]	Liver	Liver	1000	1000
Acetone	0.1[b]	ND	Liver	ND	1000	ND
Carbon tetrachloride	0.0007[b]	0.00057[b]	Liver	ND	1000	ND
Methylene chloride	0.06[b]	0.86[d]	Liver	Liver	100	100
Tetrachloroethene	0.01[b]	ND	Liver	ND	1000	ND
Toluene	0.2[b]	0.11[d]	Liver	Central nervous system	1000	300
Total xylenes	2[b]	ND	Central nervous system	ND	100	ND
Semivolatiles						
Acenaphthylene	ND	ND	ND	ND	ND	ND
Aldrin	0.00003[b]	ND	Liver	ND	1000	ND
Anthracene	0.3[b]	ND	ND	ND	3000	ND

TABLE D.4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Semivolatiles						
Benzo(a)anthracene	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	ND	ND	ND	ND	ND
Benzoic acid	4[b]	ND	ND	ND	1	ND
bis(2-Ethylhexyl)phthalate	0.02[b]	ND	Liver	ND	1000	ND
Chrysene	ND	ND	ND	ND	ND	ND
Di-n-butylphthalate	0.1[b]	ND	ND	ND	1000	ND
Di-n-octylphthalate	0.02[d]	ND	Liver	ND	1000	ND
Dibenzo(a,h)anthracene	ND	ND	ND	ND	ND	ND
Diethyl phthalate	0.8[b]	ND	ND	ND	1000	ND
Dimethyl phthalate	10[d]	ND	Kidney	ND	10	ND
Fluoranthene	0.04[b]	ND	Kidney	ND	3000	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND
4-Nitrophenol	0.008[h]	ND	ND	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND	ND	ND	ND
Phenanthrene	ND	ND	ND	ND	ND	ND
Phenol	0.6[b]	ND	Fetus	ND	100	ND
Pyrene	0.03[b]	ND	Kidney	ND	3000	ND
Tributyl phosphate	0.005[k]	ND	ND	ND	ND	ND

TABLE D.4-1
(Continued)

Chemical	Oral Reference Dose (mg/kg/day)	Inhalation Reference Dose (mg/kg/day)[a]	Target Organ		Uncertainty Factor	
			Oral	Inhalation	Oral	Inhalation
Pesticides/PCBs						
Aroclor-1248	0.00007[b,i]	ND	Fetus	ND	100	ND
Aroclor-1254	0.00007[b,i]	ND	Fetus	ND	100	ND
Aroclor-1260	0.00007[b,i]	ND	Fetus	ND	100	ND
4,4'-DDE	ND	ND	ND	ND	ND	ND
4,4'-DDT	0.0005[b]	ND	Liver	ND	100	ND
Dieldrin	0.00005[b]	ND	Liver	ND	100	ND
Endosulfan I	0.00005[j]	ND	Kidney	ND	3000	ND
Endosulfan II	0.00005[j]	ND	Kidney	ND	3000	ND
Endrin	0.0003[b]	ND	Liver	ND	100	ND
Heptachlor epoxide	0.000013[b]	ND	Liver	ND	1000	ND

[a]Derived from inhalation RfC (see Section D.4.1.1).
[b]IRIS, (EPA 1993c) current as of April 1993.
[c]ND - no data.
[d]EPA, Health Effects Assessment Summary Tables, (HEAST) Annual FY 92 including July and November Supplements (EPA 1992a).
[e]EPA 1992f, ECAO "Risk Assessment Issue Paper for: Provisional RfD for Cobalt (7440-48-4)," dated 3/12/92; basis for value is the upper range of average intake for children.
[f]EPA 1990c, Memorandum from Pei-Fung Hurst, ECAO, Cincinnati, OH, to R. Riccio, U.S. EPA Region III, "Subject: Toxicity of Cobalt
[g]Derived by analogy to thallium sulfate, adjusting for differences in molecular weight.
[h]EPA 1992h.
[i]Based on anology to Aroclor-1016.
[j]EPA 1993e, Health Effects Assessment Summary Tables, (HEAST), March, 1993.
[k]EPA 1993b, Memorandum from J. Dollarhide, ECAO to P. VanLeeuwen, Region V, 7/21/93.

TABLE D.7.2

SUMMARY OF TOXICITY BY RECEPTOR FOR THE FUTURE SOURCE TERM

Medium	Receptor							
	Trespassing Child	Groundskeeper	Off-Property Resident Farmer	Surface Water User	On-Property Farmer (CT)	On-Property Farmer (RME)	Perched Water User	On-Property Resident Child
Groundwater	N/A[a]	N/A	0.1	N/A	0.5	0.9	30	3
Air	20	10	5	N/A	50	100	100	600
Soil	8	4	N/A	N/A	200	400	400	2000
Surface Water	0.6	N/A	N/A	0.002	N/A	N/A	N/A	0.5
Sediment	0.2	N/A	N/A	N/A	N/A	N/A	N/A	6
ALL MEDIA[b]	**20**	**20**	**5**	**0.002**	**300**	**500**	**500**	**2000**

[a]N/A - signifies that exposure of the receptor to the indicated medium is not applicable.
[b]Due to rounding to one significant figure, the individual medium HIs may not sum exactly to the listed "ALL MEDIA" total.

Under the future source-term scenario, the groundskeeper is exposed to air and soil exposure routes (Tables D.II-8 and D.5-9). The total HI from exposure to both these media is 20. The highest medium-specific HI (10) is for air, attributable almost entirely to the effects of cobalt on the respiratory system. As previously discussed, however, the relevance of the HQ for cobalt to environmental exposure is doubtful. The HI for soil (4) is attributable almost entirely to dermal contact with uranium.

Under the future source-term scenario, the off-property resident farmer is exposed to groundwater and air exposure routes (Tables D.II-12 and D.5-14). The total HI from exposure to both these media is 5. The HI for air (5) is attributable almost entirely to cobalt, which, as previously noted, is probably not relevant to environmental exposure. The HI for exposure to groundwater (0.1) does not represent significant hazard.

Under the future source-term scenario, the surface water user is exposed only to surface water exposure routes (Table D.II-16 and D.5-18). The total HI, 0.01, does not represent significant hazard.

Under the future source-term scenario, the CT on-property resident farmer is exposed to groundwater, air, and soil exposure routes (Tables D.II-20 and D.5-22). The total HI from exposure to all these media is 300. The highest HI (200) is for exposure to soil, attributable largely to antimony, arsenic, cadmium (food), manganese (food), nickel, selenium, silver, thallium, uranium, vanadium, and zinc via ingestion of foodstuffs impacted by soil. The next highest HI (50) is for exposure to air, which is attributable almost entirely to cobalt. As previously noted, the relevance of the HQ for cobalt to environmental exposure is doubtful. The HI for exposure to groundwater (0.5) represents no significant hazard.

Under the future source-term scenario, the RME on-property resident farmer is exposed to groundwater, air, and soil exposure routes. Two analyses are provided: one for exposure to groundwater from the Great Miami Aquifer, and one for exposure to perched water. The total HI for all media, including groundwater from the Great Miami Aquifer, is 500 (Tables D.II-24 and D.5-27). The highest HI (400) is for exposure to soil, attributable largely to arsenic, cadmium (food), mercury, nickel, thallium, and uranium via ingestion of foodstuffs impacted by soil. The next highest HI (100) is for exposure to air, attributable largely to inhalation of cobalt. As noted above, the HQ for inhalation of cobalt is probably not relevant for environmental exposure. Significant hazard is also associated with arsenic via ingestion of foodstuffs impacted by deposition from air. The HI of 0.9 for groundwater is attributed entirely to uranium, largely via ingestion in drinking water and foodstuffs impacted by ingestion.

D.I.3.3 Volatiles Released by Showering and other Household Water Uses

The model for estimating the inhaled dose of volatile CPC released from household use, called the Andelman model (EPA 1991a), applied several assumptions:

- The volume of water used in a residence by a family of four is 720 L/day.
- The volume of air in the dwelling is 150,000 L.
- The air exchange rate is 0.25 m^3/hr.
- The average water-to-air transfer efficiency is 0.5, i.e., half the concentration of a volatile chemical in water is transferred to air.

The Andelman model is applicable to chemicals that will readily volatilize from water; i.e., those with a Henry's Law constant greater than 1×10^{-5} atm-m^3/mole and a molecular weight less than 200 g/mole. The equations for estimating URF are:

$$\text{(chemical cancer) URF} = (SF)(C_w)(IR)(K)(EF)(ED)/(BW)(AT) \quad \text{(D.I-29)}$$

$$\text{(chemical noncancer) UTF} = (C_w)(IR)(K)(EF)(ED)/(BW)(AT)(RfD) \quad \text{(D.I-30)}$$

where

URF	=	unit risk factor (unitless)
UTF	=	unit toxicity factor (unitless)
SF	=	slope factor (mg/kg-day)
RfD	=	reference dose (mg/kg-day)
C_w	=	concentration of CPC in water (mg/L)
IR	=	inhalation rate (m^3/hr-day)
K	=	volatilization factor of 0.0005 (unitless) x 1000 L/m^3
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (d)

For most metals, and hence most radionuclides at the FEMP site, volatilization is not a significant pathway because penetration through the skin is minimal. Therefore, it is not quantitatively presented for uranium. Exposure of the RME on-property resident farmer to methylene chloride is chosen for an example calculation of a URF. The exposure parameter (Table D.3-12) includes an inhalation rate of 15 m^3/day, exposure frequency of 350 days/year, exposure duration of 70 years. Substituting these values into Equation D.I-29, including the inhalation slope factor for methylene chloride of 0.0016/mg/kg-day, yields:

$$\text{URF} = (0.0016/\text{mg/kg-day})(1\ \text{mg/L})(15\ m^3/\text{day})(0.5)(350\ \text{d/yr})(70\ \text{yr})/(70\ \text{kg})(25550\ \text{d}) \quad \text{(D.I-31)}$$

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URF = 1.6×10^{-4}

D.I.3.4 Dermal Contact While Swimming

The URF and UTF for a chemical taken into the body upon exposure via dermal contact are based on a dermally absorbed dose and are calculated using the following equations:

$$\text{(chemical cancer) URF} = (SF)(DA_e)(SA)(CF)(ED)(EF)/(BW)(AT) \quad \text{(D.I-32)}$$

$$\text{(chemical noncancer) UTF} = (DA_e)(SA)(CF)(ED)(EF)/(BW)(AT)(RfD) \quad \text{(D.I-33)}$$

where

URF	=	unit risk factor (unitless)
UTF	=	unit toxicity factor (unitless)
SF	=	dermal slope factor (per mg/kg-day)
RfD	=	dermal reference dose (mg/kg-day)
DA_e	=	absorbed dose per event (mg/cm^2-day)
SA	=	skin surface area available for contact (m^2)
CF	=	conversion factor (1×10^4 cm^2/m^2)
ED	=	exposure duration (yr)
EF	=	exposure frequency (d/yr)
BW	=	body weight (kg)
AT	=	averaging time (d); for noncarcinogens, AT equals (ED) (365 d/yr); for chemical carcinogens, AT equals (70 y/lifetime) (365 d/yr)

DA_e is calculated as per EPA (1992e), Section 5.3. DA_e is a function of PC, the water permeability coefficient. Values for Kp are presented in Table D.3-14.

An example URF for dermal exposure is calculated for the on-property resident child exposed to arsenic. Exposure parameters include a body surface area of 0.8 m^2, event, time of 0.5 hours/day, exposure frequency of 5 days/years, exposure duration of 6 years, body weight of 15 kg, and an averaging time of 25,550 days. The permeability constant for arsenic is 1.00×10^{-3} (Table D.3-14). Using the formula for DA_e in EPA (1992e):

$$DA_e = (PC)(C_w)(ET) \quad \text{(D.I-34)}$$

when

PC	=	1.00×10^{-3} (cm/hr)
C_W	=	concentration in water (0.001 mg/cm^3)
ET	=	event time (0.5 hr/day)
DA_e	=	5.0×10^{-7} mg/cm^2-day

Substituting the value for DA_e and the exposure parameters into equation D.I-32 yields:

$$URF = (4.0/mg/kg\text{-}day)(5.0 \times 10^{-7}\ mg/cm^2\text{-}day)(0.8\ m^2)(1 \times 10^4\ cm^2/m^2)$$
$$(6\ years)(5\ days/year)/(15\ kg)(25550)$$
$$URF = 1.3 \times 10^{-6}$$

D.I.3.5 Dermal Contact While Bathing

The URF and UTF for a chemical taken into the body upon exposure via dermal contact are based on absorbed dose and are calculated using Equations D.I-32 and D.I-33.

D.I.3.6 Irrigation of Vegetables

Eating vegetables irrigated with contaminated water can contribute to the total intake of contaminants by humans. Estimating the magnitude of this intake is a two-step process. First the concentration in the vegetables must be estimated. If measured values are not available (e.g. future exposures), this concentration is estimated using Equation D.3-3:

$$C_{vwi} = d_w \left[\frac{r_w(1-e^{-\lambda_d t_e})}{Y\lambda_d} + \frac{f_w B_{iv(1)}(1-e^{-\lambda_{ri} t_{bw}})}{\rho \lambda_{ri}} \right] e^{-\lambda_{ri} t_h} \qquad \text{(D.I-35)}$$

where

C_{wvi}	=	concentration of ith contaminant in plants as a result of irrigating plants with contaminated water (pCi/g, rad) (mg/g, chem)
λ_d	=	effective depletion constant of ith contaminant on the surface plants also known as the weathering removal rate (hr^{-1})
λ_{ri}	=	radioactive or chemical decay constant of ith contaminant (hr^{-1})
$B_{iv(1)}$	=	dry soil to wet plant partitioning coefficient of ith contaminant (C_{iv}/C_s)
d_w	=	irrigation deposition rate (pCi/m^2-hr, rad) (mg/m^2-hr, chem)
f_d	=	fraction of year plant is irrigated (unitless)
ρ	=	effective dry surface density of the soil (g/m^2)
r_w	=	fraction of water borne material retained on plant surface (unitless)
t_e	=	growing season (hrs)
t_{bw}	=	duration of irrigation use (hrs)
t_h	=	duration of period between harvest and consumption (hrs)
Y	=	agricultural yield (g/m^2)

Vegetables irrigated with water containing U-238 ($C_{w\ U238}$) have been selected for the example calculation. The mean irrigation rate (d_w) per unit area is 0.081 L/m^2-hr, so the rate of constituent deposition by irrigation is ($C_{w\ U238}$ pCi/L) (0.081 L/m^2-hr), and the fraction of the growing season that the plant is irrigated (f_d) is 1. The duration of irrigation is 70 years (t_{bw} = 613,200 hrs). The fraction of waterborne material retained on the plant surface (r_w) is 0.2. The weathering removal rate (λ_w) is 0.0021 hr^{-1}. The dry soil to wet plant partitioning coefficient of U-238 in the reproductive portions of vegetables ($B_{iv(1)}$) is 4×10^{-3}. The effective dry surface density of the soil is 150,000 g/m^2. The

agricultural yield is (Y) 1500 g/m^2. The growing season t_e is 1,440 hours. The period between harvest and consumption (t_h) is 24 hours. The radiological decay constant of U-238 λ_{ri} is 1.77 x 10^{-14} hr^{-1}. This value is so small that the $\exp(-\lambda_{ri}\ t_h)$ term approaches a value of 1 (i.e. no significant decay).

Substituting these parameter values into Equation D.I-35 and simplifying yields:

$$\begin{aligned} C_{wv\ U238} &= (C_{w\ U238}\ \text{pCi/L})(0.081\ \text{L/m}^2\text{-hr}) \\ &+\{[(0.2)(1-e^{-0.0021 \times 1440})]/[(1500\ \text{g/m}^2)(0.0021\ \text{hr}^{-1})] \\ &+[(1)(4 \times 10^{-3})((1-e^{-1.77E-14 \times 613200})]/[(150000\ \text{g/m}^2)(1.77 \times 10^{-14}\ \text{hr}^{-1})]\} \\ C_{wv\ U238} &= (C_{w\ U238}\ \text{pCi/L})(6.22 \times 10^{-3}\ \text{L/g}) \end{aligned} \qquad \text{(D.I-36)}$$

Once the constituent's concentration in the vegetables is estimated, the resulting URFs and UTFs to humans can be estimated using Equations D.I-8, D.I-9, and D.I-10. Continuing the example begun in Equation D.I-36, humans ingest vegetables from the study area for a 70-year lifetime. The calculated concentration of U-238 in vegetables is ($C_{w\ U238}$ pCi/L) (6.22 x 10^{-3} L/g). The exposure frequency is 350 days out of per year (EF = 350 d/y). The consumption rate of vegetables and fruit grown in the study area is 122 grams per day. The exposure duration (ED) is 70 years per lifetime. The lifetime unit risk from this food supply may be estimated by Equation D.I-8 and assuming a unit water concentration. Using the presented parameter values, this becomes:

$$\begin{aligned} \text{URF} &= (2.8 \times 10^{-11}\ \text{risk/pCi})(C_{w\ U238}\ \text{pCi/L})(6.22 \times 10^{-3}\ \text{L/g})(122\ \text{g/d}) \\ &(350\ \text{d/y})(70\ \text{y/lifetime}) \\ \text{URF} &= 5.2 \times 10^{-7} \end{aligned} \qquad \text{(D.I-37)}$$

D.I.3.7 Ingestion of Meat and Milk Produced with River Water

This scenario assumes that river water is used for stock water and irrigation of feed. Animals drinking the water ingest contaminants directly. Plants irrigated with water take up constituents via root uptake, and direct deposition onto exposed surfaces by irrigation water. Ingestion of these plants by livestock also contributes to the body burden of these contaminants in the animals. Humans using animal products from these animals can ingest the contamination contained in them.

The magnitude of the contaminant exposure by humans depends, in part, on the concentration of the constituent in the animal products. If measured values are not available (e.g. future exposures), this concentration can be calculated using the methodology set forth in the FEMP Risk Assessment Work Plan Addendum (DOE 1992a). The concentration of a contaminant in animal products, such as beef or milk, is estimated using the following equation: