Appendix A-2: Media Cleanup Standards Calculations for Theoretical ILCR = 10^{-4} and HI = 1

APPENDIX A: GROUNDWATER AND SOIL MEDIA CLEANUP STANDARD CALCULATION SUMMARY

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Input Parameters for all MCS Calculations	
Cancer Risk	1.00E-04
Hazard Quotient	1
η*	0.002
Depth to Groundwater (feet)	5
Depth to Soil Source (feet)	5

Risk Estimates

Groundwater COPCs	Groundwater				Soil COPCs	Soil	
	Indoor Workers		Intrusive Workers			Indoor Workers	
Compound	Calculated Target Cancer Risk Cw (µg/L)	Calculated Target Non-Cancer Risk Cw (µg/L)	cancer Cw (µg/L) [g/]	Non-cancer Cw (µg/L) [g/]		Calculated Target Cancer Risk Cs (mg/kg)	Calculated Target Non-Cancer Risk Cs (mg/kg)
Organic Compounds							
1,1,1-Trichloroethane	--	1,570,783	--	2,596,355	1,1,1-Trichloroethane	--	690
1,1,2-Trichloroethane	190,489	--	1,483,269	61,026			
1,1-Dichloroethane	366,345	1,025,767	27,763,973	2,260,781	1,1-Dichloroethane	127.3	364
1,1-Dichloroethene	--	28,873	--	639,607	1,1-Dichloroethene	--	7.9
1,2-Dichloroethane	102,956	3,088,688	5,371,358	1,081,945	1,2-Dichloroethane	23.24	8.5
1,2-Dichloroethene, cis-	--	98,405	--	199,358	1,2-Dichloroethene, cis-	--	38.1
1,2-Dichloroethene, trans-	--	94,405	--	320,269	1,2-Dichloroethene, trans-	--	49.6
1,2-Dichloropropane	107,116	15,302	2,768,767	--			
Benzene	17,514	108,838	809,157	46,238	Benzene	9.81	6.0
Carbon tetrachloride	2,732	1,004	308,365	4,625	Carbon tetrachloride	4.76	1.7
Chloroform	120,582	684,732	876,996	38,838	Chloroform	49.23	0.28
Methylene chloride	1,038,071	1,482,958	23,580,445	2,829,653	Methylene Chloride	184.2	1974
Tetrachloroethene	34,258	25,265	38,450	29,661	Tetrachloroethene	45.19	380
Trichloroethene	159,356	682,956	5,501,542	3,065	Trichloroethene	225.4	966
Vinyl chloride	1,213	33,798	723,647	83,736	Vinyl chloride	0.3468	9.7

*Areal fraction of cracks in foundations/walls (cm^2-cracks/cm^2-total area)

[a/] Refer to the Model Unit Definition table for all associated unit definitions.

Risk-Based MCS

APPENDIX A: GROUND...TER RISK CALCULATIONS
MODELING VOLATILIZATION FROM GROUNDWATER INTO INDUSTRIAL/COMMERCIAL INDOOR AIR (ASTM MODEL)

LAWRENCE BERKELEY NATIONAL LABORATORY CMS

Equations	Input Parameter Definition[a/]		Commercial Input Parameters
1i) Enclosed Space (Indoor) Air Concentration Due to Volatilization from Ground Water	Cair-indoor	Modeled COPC indoor air concentration (µg/m3)	Calculated (Eq. 1i)
Cair-indoor = CwVFwesp	Cw	Groundwater COPC concentration (µg/L)	Measured
	VFwesp	Cross-media groundwater-to-enclosed (indoor) space volatilization factor(mg/m3-air)/(mg/L-water)	Calculated (Eq. 2i)
2i) Cross-Media Groundwater-to-Enclosed (Indoor) Space Air Volatilization Factor	H	Henry's law constant (cm3-water)/(cm3-air)	Chemical-specific
	Deffws	Effective diffusion coefficient between ground water and soil surface (cm2/s)	Calculated (Eq. 3 on Page: Cair-gw outdoor)
	LGW	Depth to ground water = hcap + hv (cm)	152
	ER	Enclosed-space air exchange rate (1/sec)	0.00023
	LB	Enclosed-space volume/infiltration area ratio (cm)	300
	Deffcrack	Effective diffusion coefficient through foundation cracks (cm2/s)	Calculated (Eq. 3i)
3i) Effective Diffusion Through Foundation Cracks	Lcrack	Enclosed-space foundation or wall thickness (cm)	15
	η	Areal fraction of cracks in foundations/walls (cm2-cracks/cm2-total area)	0.002
	Dair	Diffusion coefficient in air (cm2/s)	Chemical-specific
	θ acrack	Volumetric air content in foundation/wall cracks (cm3-air/cm3 total volume)	0.26
	θ T	Total soil porosity (cm3/cm3-soil)	0.38
	θ wcrack	Volumetric water content in foundation/wall cracks (cm3-water/cm3 total volume)	0.12
	Dwat	Diffusion coefficient in water (cm2/s)	Chemical-specific
		Target Cancer Risk (user defined)	1.00E-04

$$VF_{wesp} = \frac{H\left[\frac{D^{eff}_{ws}/L_{GW}}{ER\,L_B}\right]}{1+\left[\frac{D^{eff}_{ws}/L_{GW}}{ER\,L_B}\right]+\left[\frac{D^{eff}_{ws}/L_{GW}}{(D^{eff}_{crack}/L_{crack})\eta}\right]} x10^3 \frac{L}{m^3}$$

$$D^{eff}_{crack} = D^{air}\frac{\theta^{3.33}_{acrack}}{\theta^2_T} + D^{wat}\frac{1}{H}\frac{\theta^{3.33}_{wcrack}}{\theta^2_T}$$

Compound	Calculated Cw based on Target Cancer Risk (µg/L)	Calculated Cw based on Target Non-Cancer Risk (µg/L)	H	Dair (cm^2/s)	Dwat (cm^2/s)	Deffcrack (cm^2/s)	Deffws (cm^2/s)	VFwesp	Target Cancer Risk Cair-indoor (µg/m^3)	Target Non-Cancer Risk Cair-indoor (µg/m^3)
Organic Compounds										
1,1,1-Trichloroethane	--	1,570,783	7.05E-01	7.80E-02	8.80E-06	6.09E-03	3.59E-04	6.17E-03	--	9.69E+03
1,1,2-Trichloroethane	190,489	--	3.74E-02	7.80E-02	8.80E-06	6.09E-03	1.34E-03	4.03E-04	7.67E+01	--
1,1-Dichloroethane	366,345	1,025,767	2.30E-01	7.42E-02	1.05E-05	5.79E-03	5.14E-04	2.09E-03	7.67E+02	2.15E+03
1,1-Dichloroethene	--	28,873	1.07E+00	9.00E-02	1.04E-05	7.02E-03	3.90E-04	1.06E-02	--	3.07E+02
1,2-Dichloroethane	102,956	3,088,688	4.01E-02	1.04E-01	9.90E-06	8.12E-03	1.53E-03	5.68E-04	5.85E+01	1.75E+03
1,2-Dichloroethene, cis-	--	98,405	1.67E-01	7.36E-02	1.13E-05	5.74E-03	6.19E-04	1.56E-03	--	1.53E+02
1,2-Dichloroethene, trans-	--	94,405	3.85E-01	7.07E-02	1.19E-05	5.52E-03	4.27E-04	3.25E-03	--	3.07E+02
1,2-Dichloropropane	107,116	15,302	1.15E-01	7.82E-02	8.73E-06	6.10E-03	6.76E-04	1.15E-03	1.23E+02	1.75E+01
Benzene	17,514	108,838	2.28E-01	8.80E-02	9.80E-06	6.87E-03	5.54E-04	2.42E-03	4.23E+01	2.63E+02
Carbon tetrachloride	2,732	1,004	1.25E+00	7.80E-02	8.80E-06	6.09E-03	3.30E-04	1.07E-02	2.92E+01	1.07E+01
Chloroform	120,582	684,732	1.50E-01	1.04E-01	1.00E-05	8.12E-03	7.34E-04	1.92E-03	2.32E+02	1.32E+03
Methylene chloride	1,038,071	1,482,958	8.98E-02	1.01E-01	1.17E-05	7.88E-03	1.02E-03	1.18E-03	1.23E+03	1.75E+03
Tetrachloroethene	34,258	25,265	7.54E-01	7.20E-02	8.20E-06	5.62E-03	3.28E-04	6.07E-03	2.08E+02	1.53E+02
Trichloroethene	159,356	682,956	4.22E-01	7.90E-02	9.10E-06	6.16E-03	4.11E-04	3.85E-03	6.14E+02	2.63E+03
Vinyl chloride	1,213	33,798	1.11E+00	1.06E-01	1.23E-05	8.27E-03	4.57E-04	1.30E-02	1.57E+01	4.38E+02

[a/] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
INDOOR WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES - INHALATION OF VOLATILE COPCS IN INDOOR AIR FROM GROUNDWATER

LAWRENCE BERKELEY NATIONAL LABORATORY CMS

Exposure Assumptions			Risk and Hazard Equations
Receptor	Indoor Office Worker:	RME Scenario	Carcinogenic:
COPC Ambient Air Concentration (Cair-indoor)	chemical-specific	µg/m^3	$Risk = \frac{(C_{air-indoor})(EF)(ED)(ET)(URF)}{(AT_c)(365 days/year)}$
Exposure Frequency (EF)	250	days/yr	
Exposure Duration (ED)	25	yrs	
Fraction of EF breathing air at the site (ET)	0.333	unitless	Noncarcinogenic:
Averaging Time, Carcinogens (ATC)	70	yrs	
Averaging Time, Noncarcinogens (ATNC)	25	yrs	$HQ = \frac{(C_{air-indoor})(EF)(ED)(ET)}{(RfC)(AT_{nc})(365 days/year)}$
Inhalation Unit Risk Factor (URF)	chemical-specific	(µg/m3)-1	
Inhalation Reference Concentration (RfC)	chemical-specific	µg/m3	

COPC [a]	CAS Number [b]	Indoor Air Concentration for Target Cancer Risk (µg/m^3) [d]	Indoor Air Concentration for Target Non-Cancer Risk (µg/m^3) [d]	URF (µg/m^3)$^{-1}$	HHRA URF (if different)	RfC (µg/m^3)	Cancer Risk	Hazard Quotient
Organic Compounds								
1,1,1-Trichloroethane	71-55-6	--	9.69E+03	--		2.21E+03	1.00E-04	1.0
1,1,2-Trichloroethane	79-00-5	7.67E+01	--	1.60E-05		--	1.00E-04	1.0
1,1-Dichloroethane	75-34-3	7.67E+02	2.15E+03	1.60E-06		4.90E+02	1.00E-04	1.0
1,1-Dichloroethene	75-35-4	--	3.07E+02	--	5.00E-05	7.00E+01	1.00E-04	1.0
1,2-Dichloroethane	107-06-2	5.85E+01	1.75E+03	2.10E-05		4.00E+02	1.00E-04	1.0
1,2-Dichloroethene, cis-	156-59-2	--	1.53E+02	--		3.50E+01	1.00E-04	1.0
1,2-Dichloroethene, trans-	156-60-5	--	3.07E+02	--		7.00E+01	1.00E-04	1.0
1,2-Dichloropropane	78-87-5	1.23E+02	1.75E+01	1.00E-05		4.00E+00	1.00E-04	1.0
Benzene	71-43-2	4.23E+01	2.63E+02	2.90E-05		6.00E+01	1.00E-04	1.0
Carbon tetrachloride	56-23-5	2.92E+01	1.07E+01	4.20E-05		2.45E+00	1.00E-04	1.0
Chloroform	67-66-3	2.32E+02	1.32E+03	5.30E-06		3.00E+02	1.00E-04	1.0
Methylene chloride	75-09-2	1.23E+03	1.75E+03	1.00E-06		4.00E+02	1.00E-04	1.0
Tetrachloroethene	127-18-4	2.08E+02	1.53E+02	5.90E-06	5.80E-07	3.50E+01	1.00E-04	1.0
Trichloroethene	79-01-6	6.14E+02	2.63E+03	2.00E-06	1.70E-06	6.00E+02	1.00E-04	1.0
Vinyl chloride	75-1-4	1.57E+01	4.38E+02	7.80E-05		1.00E+02	1.00E-04	1.0

[a] COPC = chemical of potential concern.
[b] CAS = Chemical Abstracts Service number.
[c] Modeled indoor air concentrations are based on the COPC-specific cancer risk and hazard quotient
[d] µg/m^3 = micrograms per cubic meter.
-- = data not available.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
MODELING VOLATILIZATION FROM GROUNDWATER TO SOIL SURFACE (ASTM MODEL)
LAWRENCE BERKELEY NATIONAL LABORATORY CMS

3) Effective Diffusion Coefficient Between Ground Water and Soil Surface

$$D_{ws}^{eff} = (h_{cap} + h_v)\left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

$$D_{cap}^{eff} = D^{air}\frac{\theta_{acap}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcap}^{3.33}}{\theta_T^2}$$

5) Effective Diffusion Coefficient in Soil Based on Vapor-Phase Concentration

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

Input Parameter Definition[a/]		Input Parameters
H	Henry's law constant (cm3-water)/(cm3-air)	Chemical-specific
Deffws	Effective diffusion coefficient between ground water and soil surface (cm2/s)	Calculated (Eq. 3)
hcap	Thickness of capillary fringe (cm)	5
hv	Thickness of vadose zone (cm)	147
Deffcap	Effective diffusion coefficient through capillary fringe (cm2/s)	Calculated (Eq. 4)
Deffs	Effective diffusion coefficient in soil based on vapor-phase concentration (cm2/s)	Calculated (Eq. 5)
Dair	Diffusion coefficient in air (cm2/s)	Chemical-specific
θ acap	Volumetric air content in capillary fringe soils (cm3-air/cm3 total volume)	0.038
θ T	Total soil porosity (cm3/cm3-soil)	0.38
θ wcap	Volumetric water content in capillary fringe soils (cm3-water/cm3-soil)	0.342
Dwat	Diffusion coefficient in water (cm2/s)	Chemical-specific
θ as	Volumetric air content in vadose zone soils (cm3-air/cm3-soil)	0.26
θ ws	Volumetric water content in vadose zone soils (cm3-water/cm3-soil)	0.12

Compound	H	Dair (cm^2/s)	Dwat (cm^2/s)	Deffs (cm^2/s)	Deffcap (cm^2/s)	Deffws (cm^2/s)	VFwamb
1,1,1-Trichloroethane	7.05E-01	7.80E-02	8.80E-06	6.09E-03	1.25E-05	3.59E-04	4.32E-05
1,1,2-Trichloroethane	3.74E-02	7.80E-02	8.80E-06	6.09E-03	5.58E-05	1.34E-03	5.34E-06
1,1-Dichloroethane	2.30E-01	7.42E-02	1.05E-05	5.79E-03	1.85E-05	5.14E-04	1.82E-05
1,1-Dichloroethene	1.07E+00	9.00E-02	1.04E-05	7.02E-03	1.35E-05	3.90E-04	7.21E-05
1,2-Dichloroethane	4.01E-02	1.04E-01	9.90E-06	8.12E-03	6.14E-05	1.53E-03	7.06E-06
1,2-Dichloroethene, cis-	1.67E-01	7.36E-02	1.13E-05	5.74E-03	2.27E-05	6.19E-04	1.49E-05
1,2-Dichloroethene, trans-	3.85E-01	7.07E-02	1.19E-05	5.52E-03	1.51E-05	4.27E-04	2.62E-05
1,2-Dichloropropane	1.15E-01	7.82E-02	8.73E-06	6.10E-03	2.49E-05	6.76E-04	
Benzene	2.28E-01	8.80E-02	9.80E-06	6.87E-03	1.97E-05	5.54E-04	1.99E-05
Carbon tetrachloride	1.25E+00	7.80E-02	8.80E-06	6.09E-03	1.14E-05	3.30E-04	7.17E-05
Chloroform	1.50E-01	1.04E-01	1.00E-05	8.12E-03	2.64E-05	7.34E-04	1.68E-05
Methylene chloride	8.98E-02	1.01E-01	1.17E-05	7.88E-03	3.84E-05	1.02E-03	1.24E-05
Tetrachloroethene	7.54E-01	7.20E-02	8.20E-06	5.62E-03	1.14E-05	3.28E-04	4.23E-05
Trichloroethene	4.22E-01	7.90E-02	9.10E-06	6.16E-03	1.44E-05	4.11E-04	2.87E-05
Vinyl chloride	1.11E+00	1.06E-01	1.23E-05	8.27E-03	1.58E-05	4.57E-04	8.78E-05

[a/] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
CALCULATION OF DOSE ABSORBED PER UNIT AREA PER EVENT (DAevent)
INTRUSIVE WORKER -- RME SCENARIO

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Equations	Input Parameter Definition		Input Parameters
Organics:	tevent	Duration of event (hr/event) [a]	0.25
If tevent < t*, then:	t*	Time it takes to reach steady state (hr/event)	Chemical-specific
	DAevent	Dose absorbed per unit area per event (mg/cm^2-event) [b]	Calculated
	Kp	Permeability coefficient from water (cm/hr) [c]	Chemical-specific
	Cw	Concentration of chemical in water (mg/cm^3) [d]	Measured
	τevent	Lag time per event (hr/event)	Chemical-specific
If tevent > t*, then:	B	Relative contribution of permeability coefficients in strateium corneum and viable epidermis (unitless)	Chemical-specific
	pi		3.141592654
		Target Cancer Risk (user defined)	1.00E-04

$$DA_{event} = 2K_p C_w \sqrt{\frac{6\tau_{event}\, t_{event}}{\pi}}$$

$$DA_{event} = K_p C_w \left[\frac{t_{event}}{1+B} + 2\tau_{event} \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

Inorganics:

$$DA_{event} = K_p C_w t_{event}$$

Preliminary COPC [e]	Type [f]	t*	Kp	cancer Cw (µg/L) [g]	cancer Cw (mg/cm^3) [h]	non-cancer Cw (µg/L) [g]	non-cancer Cw (mg/cm^3) [h]	τevent	B	cancer DAevent (organics)	non-cancer DAevent (organics)	DAevent (inorganics)	DAevent (all)
1,1,1-Trichloroethane	o	1.43E+00	1.30E-02	--	--	2,596,355.04	2.60E+00	6.00E-01	1.00E-01	--	3.61E-02		
1,1,2-Trichloroethane	o	1.43E+00	6.40E-03	1,483,269	1.48E+00	61,025.93	6.10E-02	6.00E-01	1.12E-02	1.02E-02	4.18E-04		
1,1-Dichloroethane	o	9.20E-01	6.70E-03	27,763,973	2.78E+01	2,260,780.63	2.26E+00	3.80E-01	6.17E-03	1.58E-01	1.29E-02		
1,1-Dichloroethene	o	8.90E-01	1.20E-02	--	--	639,606.58	6.40E-01	3.70E-01	1.35E-02	--	6.45E-03		
1,2-Dichloroethane	o	9.20E-01	4.20E-03	5,371,358	5.37E+00	1,081,945.02	1.08E+00	3.80E-01	3.02E-03	1.92E-02	3.87E-03		
1,2-Dichloroethene, cis-	o	8.90E-01	7.70E-03	--	--	199,357.89	1.99E-01	3.70E-01	7.24E-03	--	1.29E-03		5.93E-07
1,2-Dichloroethene, trans-	o	8.20E-01	1.00E-02	--	--	320,269.49	3.20E-01	3.40E-01	7.20E-03	--	2.58E-03		
1,2-Dichloropropane	o	1.00E+00	1.00E-02	2,768,767	2.77E+00	--	--	4.30E-01	1.00E-02	2.51E-02	--		
Benzene	o	7.00E-01	1.50E-02	809,157	8.09E-01	46,237.54	4.62E-02	2.90E-01	1.00E-01	9.03E-03	5.16E-04		1.34E-08
Carbon tetrachloride	o	1.86E+00	1.60E-02	308,365	3.08E-01	4,625.47	4.63E-03	7.80E-01	1.00E-01	6.02E-03	9.03E-05		
Chloroform	o	1.19E+00	6.80E-03	876,996	8.77E-01	38,838.38	3.88E-02	5.00E-01	9.33E-03	5.83E-03	2.58E-04		
Methylene chloride	o	7.60E-01	3.50E-03	23,580,445	2.36E+01	2,829,653.40	2.83E+00	3.20E-01	1.78E-03	6.45E-02	7.74E-03		
Tetrachloroethene	o	2.18E+00	3.30E-02	38,450	3.84E-02	29,661.31	2.97E-02	9.10E-01	2.00E-01	1.67E-03	1.29E-03		
Trichloroethene	o	1.39E+00	1.20E-02	5,501,542	5.50E+00	3,065.15	3.07E-03	5.80E-01	1.00E-01	6.95E-02	3.87E-05		
Vinyl chloride	o	5.10E-01	7.30E-03	723,647	7.24E-01	83,736.30	8.37E-02	2.10E-01	2.30E-03	3.35E-03	3.87E-04		1.38E-07

[a] hr/event = hours per event
[b] mg/cm^2-event = milligrams per centimeter-event
[c] cm/hr = centimeters per hour
[d] mg/cm^3 = milligrams per cubic centimeter
[e] Preliminary COPC = preliminary chemical of potential concern.
[f] "o" indicates an organic compound, "i" indicates an inorganic compound
[g] Cw is the maximum detected contaminant concentration; mg/L = micrograms per liter
[h] mg/cm^3 = milligrams per cubic centimeter

APPENDIX A: GROUNDWATER RISK CALCULATIONS
INTRUSIVE WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES -- DERMAL CONTACT WITH GROUNDWATER

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Exposure Assumptions		
Receptor	Intrusive Worker: RME Scenario	
COPC Absorbed Dose per Event (DAevent)	chemical-specific	mg/cm2-event
Event Frequency (EV)	1	events/day
Exposure Frequency (EF)	60	days/yr
Fraction of EF in Contact with Ground Water (EC)	1.0	unitless
Exposure Duration (ED)	1	yrs
Exposed Body Surface Area (SA)	3300	cm2
Averaging Time, Carcinogens (ATC)	70	yrs
Averaging Time, Noncarcinogens (ATN)	1	yrs
Oral Slope Factor Adjusted for GI Absorption (SFd)	chemical-specific	(mg/kg-day)-1
Body Weight (BW)	70	kg
Oral Reference Dose Adjusted for GI Absorption (RfDd)	chemical-specific	µg/m3
where: RfDd = RfDoral*OAF		
Gastrointestinal (oral) Absorption Fraction (OAF)	chemical-specific	unitless

Risk and Hazard Equations

Carcinogenic:

$$Risk = \frac{(DA_{event})(EV)(EF)(EC)(ED)(SA)(SF_d)}{(BW)(AT_c)(365 days/\ year)}$$

Noncarcinogenic:

$$HQ = \frac{(DA_{event})(EV)(EF)(EC)(ED)(SA)}{(RfD_d)(BW)(AT_{nc})(365 days/\ year)}$$

Preliminary COPC [a]	CAS Number [b]	Cancer DAevent (mg/cm^2-event) [c]	Non-cancer DAevent (mg/cm^2-event) [c]	SFd $(mg/kg\text{-}day)^{-1}$ [d]	RfDd (mg/kg-day)	Cancer Risk	Hazard Quotient
1,1,1-Trichloroethane	71-55-6	--	3.61E-02	--	2.80E-01	1.00E-04	1.00E+00
1,1,2-Trichloroethane	79-00-5	1.02E-02	4.18E-04	8.89E-02	3.24E-03	1.00E-04	1.00E+00
1,1-Dichloroethane	75-34-3	1.58E-01	1.29E-02	5.70E-03	1.00E-01	1.00E-04	1.00E+00
1,1-Dichloroethene	75-35-4	--	6.45E-03	--	5.00E-02	1.00E-04	1.00E+00
1,2-Dichloroethane	107-06-2	1.92E-02	3.87E-03	4.70E-02	3.00E-02	1.00E-04	1.00E+00
1,2-Dichloroethene, cis-	156-59-2	--	1.29E-03	--	1.00E-02	1.00E-04	1.00E+00
1,2-Dichloroethene, trans-	156-60-5	--	2.58E-03	--	2.00E-02	1.00E-04	1.00E+00
1,2-Dichloropropane	78-87-5	2.51E-02	--	3.60E-02	--	1.00E-04	1.00E+00
Benzene	71-43-2	9.03E-03	5.16E-04	1.00E-01	4.00E-03	1.00E-04	1.00E+00
Carbon tetrachloride	56-23-5	6.02E-03	9.03E-05	1.50E-01	7.00E-04	1.00E-04	1.00E+00
Chloroform	67-66-3	5.83E-03	2.58E-04	1.55E-01	2.00E-03	1.00E-04	1.00E+00
Chloromethane	74-87-3	5.56E-02	--	1.63E-02	--	1.00E-04	1.00E+00
Methylene chloride	75-09-2	6.45E-02	7.74E-03	1.40E-02	6.00E-02	1.00E-04	1.00E+00
Tetrachloroethene	127-18-4	1.67E-03	1.29E-03	5.40E-01	1.00E-02	1.00E-04	1.00E+00
Trichloroethene	79-01-6	6.95E-02	3.87E-05	1.30E-02	3.00E-04	1.00E-04	1.00E+00
Vinyl chloride	75-1-4	3.35E-03	3.87E-04	2.70E-01	3.00E-03	1.00E-04	1.00E+00

[a] Preliminary COPC = preliminary chemical of potential concern.
[b] CAS = Chemical Abstracts Service number.
[c] mg/cm^2-event = milligram per square centimeter per event.
[d] mg/kg-day = milligram per kilogram per day.
"--" = Data unavailable.

APPENDIX A: SOIL RISK CALCULATIONS
MODELING VOLATILIZATION FROM SOILS (0 - 20 FT BGS) INTO INDOOR AIR (ASTM MODEL)

Equations	Input Parameter Definition[a/]		Residential Input Parameters
	P_s	Soil bulk density (g-soil/cm^3-soil)	1.7
1i) Enclosed Space (Indoor) Air Concentration Due to Volatilization from Subsurface Soil	$C_{air\text{-}indoor}$	Modeled COPC indoor air concentration (µg/m^3)	Calculated (Eq. 1i)
$C_{air\text{-}indoor} = C_s VF_{sesp} \times 10^3$	C_s	Soil COPC concentration (mg/kg)	Measured
	VF_{sesp}	Cross-media subsurface soil-to-enclosed (indoor) space volatilization factor (mg/m3-air)/(mg/kg-soil)	Calculated (Eq. 2i)
2i) Cross-Media Subsurface Soil-to-Enclosed (Indoor) Space Air Volatilization Factor	H	Henry's law constant (cm^3-water)/(cm^3-air)	Chemical-specific
	θ_{ws}	Volumetric	0.12
	θ_{as}	Volumetric air content in vadose zone soils (cm^3-air/cm^3-soil)	0.26
	Ls	Depth to subsurface soil source (cm)	152.4
	ER	Enclosed-space air exchange rate (1/sec)	0.00023
	L_B	Enclosed-space volume/infiltration area ratio (cm)	300
	D^{eff}_{crack}	Effective diffusion coefficient through foundation cracks (cm^2/s)	Calculated (Eq. 3i)
3i) Effective Diffusion Through Foundation Cracks	L_{crack}	Enclosed-space foundation or wall thickness (cm)	15
	η	Areal fraction of cracks in foundations/walls (cm^2-cracks/cm^2-total area)	0.002
	D^{air}	Diffusion coefficient in air (cm^2/s)	Chemical-specific
	θ_{acrack}	Volumetric air content in foundation/wall cracks (cm^3-air/cm^3 total volume)	0.26
	θ_T	Total soil porosity (cm^3/cm^3-soil)	0.38
	θ_{wcrack}	Volumetric water content in foundation/wall cracks (cm^3-water/cm^3 total volume)	0.12
	D^{wat}	Diffusion	Chemical-specific
	K_s	coefficient in	$K_s = K_{oc} X f_{oc}$
	K_{oc}	water (cm^2/s)	Chemical-specific
	F_{oc}	Soil-water fraction of organic carbon	0.01
		Target Cancer Risk	1.00E-04

$$VF_{sesp} = \frac{\left[\dfrac{Hp_s}{\theta ws + k_s p_s + H\theta_{as}}\right]\left[\dfrac{D_s^{eff}/L_s}{ER\,L_B}\right]}{1+\left[\dfrac{D_s^{eff}/L_s}{ER\,L_B}\right]+\left[\dfrac{D_s^{eff}/L_s}{(D_{crack}^{eff}/L_{crack})\eta}\right]} x10^3 \frac{cm3-kg}{m^3-g}$$

$$D_{crack}^{eff} = D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

Compound	Koc (cm^{3}water-g-carbon)	Ks (cm^3-water/cm^3-soil)	Calculated Target Cancer Risk Cs (mg/kg)	Calculated Target Non-Cancer Risk Cs (mg/kg)	H	D^{air} (cm^2/s)	D^{wat} (cm^2/s)	D^{eff}_{crack} (cm^2/s)	D^{eff}_s (cm^2/s)	VF_{sesp}	Cair-indoor (µg/m^3) for Target Cancer Risk	Cair-indoor (µg/m^3) for Target Non-Cancer Risk
1,1,1-Trichloroethane	1.10E+02	1.10E+00	--	690.17	7.05E-01	7.80E-02	8.80E-06	6.09E-03	6.09E-03	6.35E-03	--	4.38E+03
1,1-Dichloroethane	3.13E+01	3.13E-01	127.34	364.20	2.30E-01	7.42E-02	1.05E-05	5.79E-03	5.79E-03	6.03E-03	7.67E+02	2.19E+03
1,1-Dichloroethene	5.82E+01	5.82E-01	--	7.92	1.07E+00	9.00E-02	1.04E-05	7.02E-03	7.02E-03	1.74E-02	--	1.38E+02
1,2-Dichloroethane	1.68E+01	1.68E-01	23.24	8.54	4.01E-02	1.04E-01	9.90E-06	8.12E-03	8.12E-03	2.52E-03	5.85E+01	2.15E+01
1,2-Dichloroethene, cis-	3.55E+01	3.55E-01	--	38.15	1.67E-01	7.36E-02	1.13E-05	5.74E-03	5.74E-03	4.02E-03	--	1.53E+02
1,2-Dichloroethene, trans-	5.21E+01	5.21E-01	--	49.65	3.85E-01	7.07E-02	1.19E-05	5.52E-03	5.52E-03	6.18E-03	--	3.07E+02
Benzene	5.82E+01	5.82E-01	9.81	6.04	2.28E-01	8.80E-02	9.80E-06	6.87E-03	6.87E-03	4.32E-03	4.23E+01	2.61E+01
Carbon tetrachloride	2.08E+02	2.08E+00	4.76	1.75	1.25E+00	7.80E-02	8.80E-06	6.09E-03	6.09E-03	6.14E-03	2.92E+01	1.07E+01
Chloroform	3.97E+01	3.97E-01	49.23	0.28	1.50E-01	1.04E-01	1.00E-05	8.12E-03	8.12E-03	4.70E-03	2.32E+02	1.32E+00
Methylene Chloride	1.17E+01	1.17E-01	184.25	1,974.09	8.98E-02	1.01E-01	1.17E-05	7.88E-03	7.88E-03	6.66E-03	1.23E+03	1.32E+04
Tetrachloroethene	1.56E+02	1.56E+00	45.19	379.96	7.54E-01	7.20E-02	8.20E-06	5.62E-03	5.62E-03	4.60E-03	2.08E+02	1.75E+03
Trichloroethene	1.67E+02	1.67E+00	225.44	966.19	4.22E-01	7.90E-02	9.10E-06	6.16E-03	6.16E-03	2.72E-03	6.14E+02	2.63E+03
Vinyl chloride	1.43E+01	1.43E-01	0.35	9.66	1.11E+00	1.06E-01	1.23E-06	8.27E-03	8.27E-03	4.54E-02	1.57E+01	4.38E+02

[a/] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: SOIL RISK CALCULATIONS
INDOOR WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES - INHALATION OF VOLATILE COPCS IN INDOOR AIR FROM SOILS (0-20 FT BGS)

LAWRENCE BERKELEY NATIONAL LABORATORY, CALIFORNIA

Exposure Assumptions		
Receptor	Indoor Office Worker: RME Scenario	
COPC Ambient Air Concentration ($C_{air\text{-}indoor}$)	chemical-specific $\mu g/m^3$	
Exposure Frequency (EF)	250 days/yr	
Exposure Duration (ED)	25 yrs	
Fraction of EF breathing air at the site (ET)	0.333 unitless	
Averging Time, Carcinogens (AT_C)	70 yrs	
Averging Time, Noncarcinogens (AT_{NC})	25 yrs	
Inhalation Unit Risk Factor (URF)	chemical-specific $(\mu g/m^3)^{-1}$	
Inhalation Reference Concentration (RfC)	chemical-specific $\mu g/m^3$	

Risk and Hazard Equations

Carcinogenic:

$$Risk = \frac{(C_{air-indoor})(EF)(ED)(ET)(URF)}{(AT_c)(365 days/year)}$$

Noncarcinogenic:

$$HQ = \frac{(C_{air-indoor})(EF)(ED)(ET)}{(RfC)(AT_{nc})(365 days/year)}$$

Preliminary COPC [a/]	CAS Number [b/]	Indoor Air Concentration for Target Cancer Risk ($\mu g/m^3$) [d/]	Indoor Air Concentration for Target Non-Cancer Risk ($\mu g/m^3$) [d/]	URF $(\mu g/m^3)^{-1}$	RfC ($\mu g/m^3$)	Cancer Risk	Hazard Quotient
1,1,1-Trichloroethane	71-55-6	--	4.38E+03	--	1.00E+03	1.00E-04	1.00
1,1-Dichloroethane	75-34-3	7.67E+02	2.19E+03	1.60E-06	5.01E+02	1.00E-04	1.00
1,1-Dichloroethene	75-35-4	--	1.38E+02	--	3.15E+01	1.00E-04	1.00
1,2-Dichloroethane	107-06-2	5.85E+01	2.15E+01	2.10E-05	4.90E+00	1.00E-04	1.00
1,2-Dichloroethene, cis-	156-59-2	--	1.53E+02	--	3.50E+01	1.00E-04	1.00
1,2-Dichloroethene, trans-	156-60-5	--	3.07E+02	--	7.00E+01	1.00E-04	1.00
Benzene	71-43-2	4.23E+01	2.61E+01	2.90E-05	5.95E+00	1.00E-04	1.00
Carbon tetrachloride	56-23-5	2.92E+01	1.07E+01	4.20E-05	2.45E+00	1.00E-04	1.00
Chloroform	67-66-3	2.32E+02	1.32E+00	5.30E-06	3.01E-01	1.00E-04	1.00
Methylene Chloride	75-09-2	1.23E+03	1.32E+04	1.00E-06	3.00E+03	1.00E-04	1.00
Tetrachloroethene	127-18-4	2.08E+02	1.75E+03	5.90E-06	3.99E+02	1.00E-04	1.00
Trichloroethene	79-01-6	6.14E+02	2.63E+03	2.00E-06	6.00E+02	1.00E-04	1.00
Vinyl chloride	75-1-4	1.57E+01	4.38E+02	7.80E-05	1.00E+02	1.00E-04	1.00

[a/] Preliminary COPC = preliminary chemical of potential concern.

[b/] CAS = Chemical Abstracts Service number.

[c/] Modeled indoor air concentrations (ASTM vapor intrusion model) were based on the exposure-point concentration of each COPC detected at the evaluated area.

[d/] $\mu g/m^3$ = micrograms per cubic meter.

-- = data not available.

Appendix A-3: Update on Carcinogenic Potency of Trichoroethene for Theoretical ILCR = 10^{-4} and HI = 1

Update on the Carcinogenic Potency of Trichloroethene

The trichloroethene (TCE) carcinogenic toxicity factor recommended by the California Environmental Protection Agency (CalEPA) (www.oehha.ca.gov/risk/ChemicalDB/index.asp) was used in the Human Health Risk Assessment (Berkeley Lab, 2003) and was also used to develop proposed Media Cleanup Standards (MCSs) in the Corrective Measures Study (CMS) Report. However, recent peer-reviewed articles by experts in the toxicity of TCE (Clewell and Andersen, 2004; Kester and Clewell, 2004) suggest that the carcinogenic potency of TCE may not be as great as suggested by either CalEPA, or the United States Environmental Protection Agency (USEPA) [2002] which proposed a cancer potency value approximately 60-times more conservative than the CalEPA value in their TCE Health Risk Assessment.

As discussed in Clewell and Andersen (2004), "a physiologically based pharmacokinetic (PBPK) model was applied to estimate target tissue doses for the three principal animal tumors associated with TCE exposure: liver, lung, and kidney" by USEPA (2002) in deriving cancer potency values. Clewell and Anderson (2004) state, "However, these risk estimates ignore the evidence that the human is likely to be much less responsive than the mouse to the carcinogenic effects of TCA [trichloroacetic acid] in the liver and that the carcinogenic effects of TCE are unlikely to occur at low environmental exposures ... environmental exposures below 66 µg TCE per cubic meter in air and 265 µg TCE per liter in drinking water are considered unlikely to present a carcinogenic hazard to human health." For comparison, the 10^{-6} theoretical Incremental Lifetime Cancer Risk (ILCR) used to develop the MCSs corresponds to a concentration of 6.1 µg TCE per cubic meter in air, and the Maximum Contaminant Level (MCL) for drinking water for TCE is 5 µg/L.

Kester and Clewell (2004) provide a detailed discussion of the scientific deficiencies of the USEPA (2002) draft TCE health risk assessment and state that, "As a result, its major conclusions regarding the potential health risks associated with TCE exposure are scientifically indefensible." Therefore, based on this recent scientific evidence the risks associated with potential exposure to TCE detected in soil or groundwater and the potential risks from migration of TCE into indoor air would be significantly less than estimated in the Human Health Risk

Assessment (Berkeley Lab, 2003) and the MCS proposed for TCE in the CMS Report would be overly conservative by a factor of 10 or more.

REFERENCES

Berkeley Lab, 2003. Human Health Risk Assessment for the Lawrence Berkeley National Laboratory Environmental Restoration Program, May 2003.

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