CAPSULE
ENVIRONMENTAL ENGINEERING INC.

1-800-328-8246

TELEFAX TRANSMITTAL COVER SHEET

Date: February 13, 1998
Time: 7:00 CST

To: Scott Seery
Company: Alameda County
Fax #: 1-510-337-9335

From: John M.
CAPSULE ENVIRONMENTAL ENGINEERING, INC.
No. Pages: 19 (including Transmittal Cover Sheet)

Comments:

Scott, in reponse to your February 11 requests, enclosed please find:

1) Copy of the appropriate **nine** pages from the GSI Guidance Manual, Appendix A, describing the equations and softwar utilities software steps used to calculate NAFs.

2) A run of Tier II, SSTL, Site-Specific Parameters, using the 1989 soil concentrations (maximum) listed on page C10 of Appendix C, Low Risk Determination. I also enter the highest concentrations for the period of record for MW-3. The highest results were the April 1995 results.

The pages I am faxing you are in the same order as the 7% run and are hand numbered in the lower right hand corner. There is a total of **nine** pages.

The risk calculations are linear equations. This explains why the risk is approximately 14 times greater than the 7% run. The source term is approximately 14 times greater. The volatilization from ground water adds little because the concentrations are below the solubility limits.

Call with comments. Thanks. John

If there is a problem with receipt of this Telefax, please call 612/636-2644.

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RBCA SITE ASSESSMENT | Tier 2 Worksheet 9.2

Site Name: Ingersoll-Rand Equipment Sales (Max. Concentrations) Completed By: John McDermott

Site Location: San Leandro, California Date Completed: 2/12/1998

SUBSURFACE SOIL SSTL VALUES (> 3 FT BGS)

Target Risk (Class A & B) 1.0E-6
Target Risk (Class C) 1.0E-5
Target Hazard Quotient 1.0E+0

☐ MCL exposure limit?
☐ PEL exposure limit?

Calculation Option: 1

SSTL Results For Complete Exposure Pathways ("x" if Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	Soil Leaching to Groundwater			X Soil Volatilization to Indoor Air		X Soil Volatilization to Outdoor Air		Applicable SSTL	SSTL Exceeded ?	Required CRF
CAS No.	Name	(mg/kg)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)	Residential: (on-site)	Commercial: (on-site)	Residential: (on-site)	Commercial: (on-site)	(mg/kg)	"■" If yes	Only if "yes" left
71-43-2	Benzene	3.9E+1	NA	NA	NA	NA	6.2E-1	NA	1.8E+2	6.2E-1	■	6.3E+01
100-41-4	Ethylbenzene	8.3E+1	NA	NA	NA	NA	>Res	NA	>Res	>Res	☐	<1
108-88-3	Toluene	2.4E+2	NA	NA	NA	NA	7.4E+2	NA	>Res	7.4E+2	☐	<1
1330-20-7	Xylene (mixed isomers)	4.7E+2	NA	NA	NA	NA	>Res	NA	>Res	>Res	☐	<1

>Res indicates risk-based target concentration greater than constituent residual saturation value

Software: GSI RBCA Spreadsheet Serial: G-457-IKX-532
Version: 1.0.1

RBCA SITE ASSESSMENT | Tier 2 Worksheet 9.3

Site Name: Ingersoll-Rand Equipment Sales (Max. Concentrations) Completed By: John McDermott
Site Location: San Leandro, California Date Completed: 2/12/1998

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-6 ☐ MCL exposure limit? Calculation Option: 1
Target Risk (Class C) 1.0E-5 ☐ PEL exposure limit?
Target Hazard Quotient 1.0E+0

SSTL Results For Complete Exposure Pathways ("x" if Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	Groundwater Ingestion			X Groundwater Volatilization to Indoor Air		X Groundwater Volatilization to Outdoor Air		Applicable SSTL	SSTL Exceeded ?	Required CRF
CAS No.	Name	(mg/L)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)	Residential: (on-site)	Commercial: (on-site)	Residential (on-site)	Commercial: (on-site)	(mg/L	"■" if yes	Only if "yes" left
71-43-2	Benzene	1.2E+0	NA	NA	NA	NA	1.4E+0	NA	3.9E+2	1.4E+0	☐	<1
100-41-4	Ethylbenzene	7.2E-1	NA	NA	NA	NA	>Sol	NA	>Sol	>Sol	☐	<1
108-88-3	Toluene	1.7E+0	NA	NA	NA	NA	>Sol	NA	>Sol	>Sol	☐	<1
1330-20-7	Xylene (mixed isomers)	3.0E+0	NA	NA	NA	NA	>Sol	NA	>Sol	>Sol	☐	<1

>Sol indicates risk-based target concentration greater than constituent solubility

Software: GSI RBCA Spreadsheet Serial: G-457-IKX-532
Version: 1.0.1

page 2 of 9

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.1**

Site Name: Ingersoll-Rand Equipment Sales (Max. Con Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998 *1 OF 9*

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

OUTDOOR AIR EXPOSURE PATHWAYS ☐ CHECKED IF PATHWAY IS ACTIVE

SURFACE SOILS: VAPOR AND DUST INHALATION	Exposure Concentration								
	1) Source Medium	2) NAF Value (m^3/kg) Receptor		3) Exposure Medium Outdoor Air: POE Conc. (mg/m^3) (1) / (2)		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (m^3/kg-day)		5) Average Daily Intake Rate (mg/kg-day) (3) X (4)	
Constituents of Concern	Surface Soil Conc. (mg/kg)								
Benzene	0.0E+0								
Ethylbenzene	0.0E+0								
Toluene	0.0E+0								
Xylene (mixed isomers)	0.0E+0								

NOTE: ABS = Dermal absorption factor (dim) AF = Adherance factor (mg/cm^2) AT = Averaging time (days) BW = Body weight (kg) CF = Units conversion factor ED = Exposure duration (yrs) EF = Exposure frequency (days/yr) ET = Exposure time (hrs/day) IR = Inhalation rate (m^3/day) POE = Point of exposure SA = Skin exposure area (cm^2/day)

Software: GSI RBCA Spreadsheet Version: 1.0.1 Serial: G-457-IKX-532

RBCA SITE ASSESSMENT	Tier 2 Worksheet 8.1

Site Name: Ingersoll-Rand Equipment Sales (Max. Con Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

OUTDOOR AIR EXPOSURE PATHWAYS ■ CHECKED IF PATHWAY IS ACTIVE

SUBSURFACE SOILS: VAPOR INHALATION

	Exposure Concentration								
	1) Source Medium	2) NAF Value (m^3/kg) Receptor		3) Exposure Medium Outdoor Air: POE Conc. (mg/m^3) (1) / (2)		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (m^3/kg-day)		5) Average Daily Intake Rate (mg/kg-day) (3) X (4)	
Constituents of Concern	Subsurface Soil Conc. (mg/kg)	On-Site Commercial		On-Site Commercial		On-Site Commercial		On-Site Commercial	
Benzene	3.9E+1	3.7E+5		1.0E-4		7.0E-2		7.3E-6	
Ethylbenzene	8.3E+1	3.7E+5		2.2E-4		2.0E-1		4.3E-5	
Toluene	2.4E+2	3.7E+5		6.4E-4		2.0E-1		1.3E-4	
Xylene (mixed isomers)	4.7E+2	3.7E+5		1.3E-3		2.0E-1		2.5E-4	

NOTE:
ABS = Dermal absorption factor (dim)
AF = Adherance factor (mg/cm^2)
AT = Averaging time (days)
BW = Body weight (kg)
CF = Units conversion factor
ED = Exposure duration (yrs)
EF = Exposure frequencey (days/yr)
ET = Exposure time (hrs/day)
IR = Inhalation rate (m^3/day)
POE = Point of exposure
SA = Skin exposue area (cm^2/day)

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-532

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.1**

Site Name: Ingersoll-Rand Equipment Sales (Max. Con Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

OUTDOOR AIR EXPOSURE PATHWAYS ■ CHECKED IF PATHWAY IS ACTIVE

GROUNDWATER: VAPOR INHALATION

Exposure Concentration

Constituents of Concern	1) Source Medium: Groundwater Conc. (mg/L)	2) NAF Value (m^3/L) Receptor: On-Site Commercial		3) Exposure Medium: Outdoor Air: POE Conc. (mg/m^3) (1) / (2): On-Site Commercial		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (m^3/kg-day): On-Site Commercial		5) Average Daily Intake Rate (mg/kg-day) (3) X (4): On-Site Commercial		TOTAL PATHWAY INTAKE (mg/kg-day) (Sum intake values from surface, subsurface & groundwater routes.): On-Site Commercial	
Benzene	1.2E+0	8.0E+5		1.5E-6		7.0E-2		1.0E-7		7.4E-6	
Ethylbenzene	7.2E-1	8.0E+5		9.1E-7		2.0E-1		1.8E-7		4.4E-5	
Toluene	1.7E+0	8.2E+5		2.1E-6		2.0E-1		4.1E-7		1.3E-4	
Xylene (mixed isomers)	3.0E+0	8.8E+5		3.4E-6		2.0E-1		6.7E-7		2.5E-4	

NOTE:
- ABS = Dermal absorption factor (dim)
- AF = Adherance factor (mg/cm^2)
- AT = Averaging time (days)
- BW = Body weight (kg)
- CF = Units conversion factor
- ED = Exposure duration (yrs)
- EF = Exposure frequency (days/yr)
- ET = Exposure time (hrs/day)
- IR = Inhalation rate (m^3/day)
- POE = Point of exposure
- SA = Skin exposure area (cm^2/day)

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-532

RBCA SITE ASSESSMENT	Tier 2 Worksheet 8.2

Site Name: Ingersoll-Rand Equipment Sales Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 PATHWAY RISK CALCULATION

OUTDOOR AIR EXPOSURE PATHWAYS (CHECKED IF PATHWAYS ARE ACTIVE)

Constituents of Concern	(1) EPA Carcinogenic Classification	CARCINOGENIC RISK: (2) Total Carcinogenic Intake Rate (mg/kg/day) On-Site Commercial		(3) Inhalation Slope Factor (mg/kg-day)^-1	(4) Individual COC Risk (2) x (3) On-Site Commercial		TOXIC EFFECTS: (5) Total Toxicant Intake Rate (mg/kg/day) On-Site Commercial		(6) Inhalation Reference Dose (mg/kg-day)	(7) Individual COC Hazard Quotient (5) / (6) On-Site Commercial	
Benzene	A	7.4E-6		2.9E-2	2.1E-7		2.1E-5		1.7E-3	1.2E-2	
Ethylbenzene	D						4.4E-5		2.9E-1	1.5E-4	
Toluene	D						1.3E-4		1.1E-1	1.1E-3	
Xylene (mixed isomers)	D						2.5E-4		2.0E+0	1.2E-4	

Total Pathway Carcinogenic Risk = 2.1E-7 | 0.0E+0

Total Pathway Hazard Index = 1.4E-2 | 0.0E+0

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-532

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.1**

Site Name: Ingersoil-Rand Equipment Sales (Max. Con Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

INDOOR AIR EXPOSURE PATHWAYS ■ (CHECKED IF PATHWAY IS ACTIVE)

SUBSURFACE SOILS:

VAPOR INTRUSION TO BUILDINGS

Exposure Concentration	1) Source Medium	2) NAF Value (m^3/kg) Receptor		3) Exposure Medium Indoor Air: POE Conc. (mg/m^3) (1) / (2)		4) Exposure Multiplier (IRxEFxED)/(BWxAT) (m^3/kg-day)		5) Average Daily Intake Rate (mg/kg-day) (3) X (4)	
Constituents of Concern	Subsurface Soil Conc. (mg/kg)		On-Site Commercial		On-Site Commercial		On-Site Commercial		On-Site Commercial
Benzene	3.9E+1		1.3E+3		3.1E-2		7.0E-2		2.2E-3
Ethylbenzene	8.3E+1		1.3E+3		6.6E-2		2.0E-1		1.3E-2
Toluene	2.4E+2		1.3E+3		1.9E-1		2.0E-1		3.7E-2
Xylene (mixed isomers)	4.7E+2		1.3E+3		3.7E-1		2.0E-1		7.3E-2

NOTE:
ABS = Dermal absorption factor (dim)
AF = Adherance factor (mg/cm^2)
AT = Averaging time (days)
BW = Body weight (kg)
CF = Units conversion factor
ED = Exposure duration (yrs)
EF = Exposure frequencey (days/yr)
ET = Exposure time (hrs/day)
IR = Inhalation rate (m^3/day)
POE = Point of exposure
SA = Skin exposure area (cm^2/day)

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-532

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.1**

Site Name: Ingersoll-Rand Equipment Sales (Max. Con Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 EXPOSURE CONCENTRATION AND INTAKE CALCULATION

INDOOR AIR EXPOSURE PATHWAYS: ■ (CHECKED IF PATHWAY IS ACTIVE)

GROUNDWATER:
VAPOR INTRUSION TO BUILDINGS

Constituents of Concern	Exposure Concentration: 1) Source Medium — Groundwater Conc. (mg/L)	2) NAF Value (m^3/L) Receptor — On-Site Commercial	3) Exposure Medium — Indoor Air: POE Conc. (mg/m^3) (1) / (2) — On-Site Commercial	4) Exposure Multiplier (IRxEFxED)/(BWxAT) (m^3/kg-day) — On-Site Commercial	5) Average Daily Intake Rate (mg/kg-day) (3) X (4) — On-Site Commercial	TOTAL PATHWAY INTAKE (mg/kg-day) (Sum intake values from subsurface & groundwater routes.) — On-Site Commercial
Benzene	1.2E+0	2.9E+3	4.2E-4	7.0E-2	2.9E-5	2.2E-3
Ethylbenzene	7.2E-1	2.8E+3	2.5E-4	2.0E-1	5.0E-5	1.3E-2
Toluene	1.7E+0	2.9E+3	5.8E-4	2.0E-1	1.1E-4	3.7E-2
Xylene (mixed isomers)	3.0E+0	3.1E+3	9.5E-4	2.0E-1	1.9E-4	7.3E-2

NOTE:
ABS = Dermal absorption factor (dim)
AF = Adherance factor (mg/cm^2)
AT = Averaging time (days)
BW = Body weight (kg)
CF = Units conversion factor
ED = Exposure duration (yrs)
EF = Exposure frequency (days/yr)
ET = Exposure time (hrs/day)
IR = Inhalation rate (m^3/day)
POE = Point of exposure
SA = Skin exposure area (cm^2/day)

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-532

RBCA SITE ASSESSMENT | **Tier 2 Worksheet 8.2**

Site Name: Ingersoll-Rand Equipment Sales Site Location: San Leandro, California Completed By: John McDermott Date Completed: 2/12/1998

TIER 2 PATHWAY RISK CALCULATION

INDOOR AIR EXPOSURE PATHWAYS ■ CHECKED IF PATHWAYS ARE ACTIVE

	CARCINOGENIC RISK						TOXIC EFFECTS			
Constituents of Concern	(1) EPA Carcinogenic Classification	(2) Total Carcinogenic Intake Rate (mg/kg/day)	On-Site Commercial	(3) Inhalation Slope Factor (mg/kg-day)^-1	(4) Individual COC Risk (2) x (3)	On-Site Commercial	(5) Total Toxicant Intake Rate (mg/kg/day)	On-Site Commercial	(6) Inhalation Reference Dose (mg/kg-day)	(7) Individual COC Hazard Quotient (5) / (6)	On-Site Commercial
Benzene	A		2.2E-3	2.9E-2		6.4E-5		6.1E-3	1.7E-3		3.6E+0
Ethylbenzene	D							1.3E-2	2.9E-1		4.5E-2
Toluene	D							3.7E-2	1.1E-1		3.3E-1
Xylene (mixed isomers)	D							7.3E-2	2.0E+0		3.7E-2

Total Pathway Carcinogenic Risk = 0.0E+0 | 6.4E-5

Total Pathway Hazard Index = 0.0E+0 | 4.0E+0

Software: GSI RBCA Spreadsheet
Version: 1.0.1

Serial: G-457-IKX-632

iii) **Help and Roadmap:** Each dialog box is equipped with i) a help button to access context-sensitive, on-line help and ii) a "roadmap" to show the user his/her location in the input process.

iv) **Input Error Check:** The system checks each dialog box for inappropriate data entries (e.g., porosity >1) and alerts the user.

v) **Default Modeling Parameters:** Non-sensitive transport parameters are equipped with conservative default values that can be used if no measured value is available.

vi) **Standard Exposure Factors:** The user can enter site-specific exposure factors or select default values consistent with EPA Reasonable Maximum Exposure (RME) values.

- ***Software Utilities***
  The system also contains several utilities to assist the user in development and calculation of key input parameters:

i) **Transport Parameter Calculations:** Based on user input, the software can calculate groundwater flow velocities, groundwater dispersivity coefficients, and air dispersion coefficients for direct entry into internal transport models.

ii) **Statistical Calculator:** A statistical calculator is provided to calculate the mean, maximum, and upper 90% or 95% confidence limits of source zone concentrations, based on input data values.

iii) **Empirical NAF Calculator:** For sites under steady-state or diminishing plume conditions, the software can convert existing groundwater concentration vs. distance information into an empirical natural attenuation factor (NAF) for each constituent.

iv) **Units Conversion:** An overall units calculator has been incorporated into the system to allow for easy conversion of site data into the units required by the models.

RUN CALCULATIONS

After the data are entered, the user can complete all calculations by selecting the *Run Calculations* option. Pressing this button will transfer any new data to the appropriate spreadsheet, select the desired models, and update all cell formulas. Based upon site information provided by the user, the RBCA spreadsheet system conducts the following calculations as required for completion of a Tier 1 or Tier 2 site evaluation:

- ***Exposure Concentrations:*** Based on representative concentrations of constituents of concern (COCs) present in the affected source media, the spreadsheet system calculates the maximum steady-state concentrations likely to occur at the point of exposure (POE). To perform these calculations, the system accounts for cross-media partitioning (e.g., volatilization from soil to air) and lateral transport from the source to the POE (e.g., dissolved contaminant transport via air or groundwater flow). The source media and exposure pathways included in the software are as follows:

SOURCE MEDIA	EXPOSURE PATHWAYS
Surface Soils	• Inhalation of Volatiles and Particulates • Dermal Contact with Soil • Ingestion of Soil and Dust • Leaching to Groundwater/Ingestion
Subsurface Soils	• Inhalation of Volatiles • Leaching to Groundwater/Ingestion
Groundwater	• Ingestion of Potable Water • Inhalation of Volatiles

- ***Baseline Risk Results***: For each complete exposure pathway, baseline intake rates and risk levels associated with current site conditions are tabulated for both individual and cumulative constituent exposure. To identify critical exposure pathways, a graphical plot is provided comparing cumulative risks for air, water, and soil exposure pathways.
- ***Media Cleanup Values***: Site-Specific Target Levels (SSTLs) for each complete exposure pathway are provided both for individual constituent and cumulative constituent risk limits (if applicable). The software automatically identifies the critical SSTL value for each constituent and calculates the constituent reduction factor (CRF) required to meet the cleanup goal.

EXIT TO EXCEL WORKBOOK

If desired, the user can bypass the software interface and directly access the Excel workbook structure. This feature allows the user to inspect the detailed calculation steps conducted in the various worksheets or review the modeling equations. This option is recommended only for users experienced with direct operation of Excel. Further discussion of the worksheet environment is provided in Section A.4 of this Appendix.

A.3 Fate and Transport Modeling Methods

The RBCA Spreadsheet System contains a series of fate and transport models for predicting COC concentrations at the point of exposure (POE) for indirect exposure pathways, such as air and groundwater. Under Tier 2, relatively simple analytical models are to be employed for this calculation, representing a minor incremental effort relative to Tier 1. The spreadsheet modeling system is consistent with Appendix X.2 of ASTM E-1739, although selected algorithms and default parameters have been updated to reflect advances in evaluation methods.

The idealized schematic shown on Figure A.2 illustrates the steps included in the RBCA software for predicting transport of contaminants from the source zone to the POE for air and groundwater exposure pathways. (Please note that POE attenuation factors and surface water exposure pathways are not included in the software at this time. See Volume 1, Figure 10.) Each element in Figure A.2 represents a step-specific attenuation factor, corresponding to either a cross-media transfer factor (CM) or a lateral transport factor (LT). The effective NAF value for each COC on each pathway is then calculated as the arithmetic product of the various attenuation factors occurring along the flow path from source to receptor. These steady-state NAF values are then used for calculation of baseline risks and back-calculation of Site-Specific Target Levels (SSTLs), as discussed in Section A.2 above. Please note that fate and transport modeling is *not* required for direct exposure pathways, such as soil ingestion or dermal contact, where the source and exposure concentrations are equal (i.e., NAF = 1). Analytical models used for conservative estimation of each transport factor are described below.

CROSS-MEDIA TRANSFER FACTORS

Exposure pathways involving transport of COCs from one medium to another (e.g., soil-to-air, soil-to-groundwater) require estimation of the corresponding cross-media transfer factor. Various analytical expressions are available for estimating soil-to-air *volatilization factors* as a function of site soil characteristics and the physical/chemical properties of volatile organic COCs. *Leaching factors* for organic and inorganic constituent releases from soil to groundwater can similarly be estimated as a function of COC characteristics, soil conditions, and annual rainfall infiltration. Cross-media transfer equations incorporated in the RBCA Spreadsheet System are presented in Figure A.3 beginning on Page A-11. Detailed discussion of each of these cross-media factors is provided below.

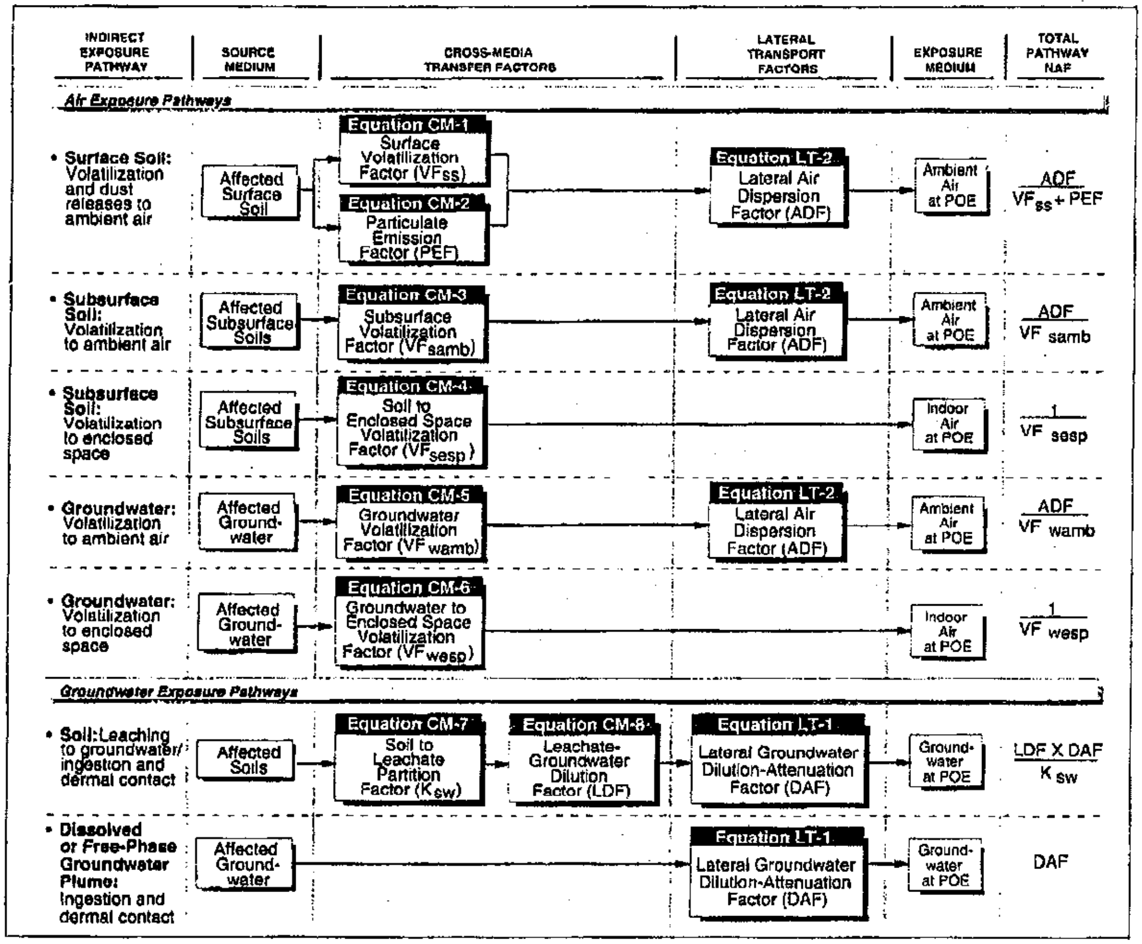


FIGURE A.2. NAF CALCULATION SCHEMATIC FOR INDIRECT EXPOSURE PATHWAYS IN RBCA SPREADSHEET SYSTEM

- ***VF_{SS}: Surface Soil Volatilization Factor (Equation CM-1)***
  The surface volatilization factor is the steady-state ratio of the concentration of an organic constituent in the ambient air breathing zone to the source concentration in the surface soil. The surface volatilization factor incorporates two cross-media transfer elements: i) organic vapor flux from the surface soil mass to ground surface and ii) mixing of soil vapors in the ambient air breathing zone directly over the affected surface soil. For each site, the applicable VF_{SS} value corresponds to the lesser result of two calculation methods (termed CM-1a and CM-1b on Figure A.3, page A-11). Equation CM-1a typically controls for low-volatility organics, as it assumes there is an infinite source of organics in the surface soils and uses a volatilization rate based primarily on chemical properties. Equation CM-1b, which typically controls for volatile organics, is based on a mass balance approach. In this equation, a finite amount of organics is assumed to be present in the surface soil (based on the representative COC concentration), volatilizing at a constant rate over the duration of the exposure period (e.g., 25-30 years). Both expressions account for the dilution of organics in ambient air above the source zone due to mixing with ambient air moving across the site. A simple box model is used for this dilution calculation, based on the following adjustable default assumptions: 2-meter mixing zone height and 225 cm/sec (5 mph) lateral wind speed. The length of the mixing zone is set equal to the lateral dimension of the exposed affected surface soil area parallel to the assumed wind direction.

Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{ss}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations:** Constituent levels uniformly distributed in soil and constant over exposure period.	----
• **No COC Decay:** No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term:** Source term mass adjusted for constant volatilization over exposure period.	----

- ***PEF: Soil Particulate Emission Factor (Equation CM-2)***
The Particulate Emission Factor (PEF) is the steady-state ratio of the concentration of organics in particulates in the ambient air breathing zone to the source concentration of organics in the surface soil. The factor incorporates two cross-media transfer elements: i) the release rate of soil particulates (dust) from ground surface and ii) mixing of these particulates in the ambient air breathing zone directly over the affected surface soil. The particulate release rate is commonly matched to a conservative default value of 6.9×10^{-14} g/cm^2-sec (approximately 0.2 lbs/acre-year), unless a more appropriate site-specific estimate is available. (If the site is paved, the particulate release rate and resultant PEF value for the covered soil area will be zero.) Particulates are assumed to be diluted by lateral air flow directly over the source zone. For this purpose, a simple box model is employed, based on the following adjustable default assumptions: 2-meter mixing zone height and 225 cm/sec (5 mph) lateral wind speed. The length of the mixing zone is matched to the lateral dimension of the exposed affected surface soil area parallel to the assumed wind direction.

Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: PEF	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations:** Constituent levels uniformly distributed in soil and constant over exposure period.	----
• **No COC Decay:** No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Default Emission Rate:** Conservative particulate emission rate.	⇩

- ***VF_{samb}: Subsurface Soil Volatilization Factor (Equation CM-3)***
The subsurface soil volatilization factor is comparable to the surface volatilization equation, except that the algorithm has been adjusted to account for vapor flux from greater soil depths. The volatilization factor accounts for two cross-media transfer elements: i) organic vapor flux from the subsurface affected soil mass to ground surface and ii) mixing of soil vapors in the ambient air breathing zone directly over the affected soil zone. As with the surface soil volatilization factor, VF_{SS}, the applicable subsurface soil volatilization factor, VF_{samb}, corresponds to the lesser result of two calculation methods (termed CM-3a and CM-3b on Figure A.3, page A-12). Equation CM-3a, which corresponds to the expression given in Appendix X.2 of ASTM E-1739, assumes a constant source mass in the subsurface and can severely overpredict the soil vapor flux rate. To correct for this problem, Equation CM-3b, which accounts for a mass balance of the volatilized source mass over the exposure period (similar to Equation CM-1b) has been incorporated in the RBCA Spreadsheet. With either equation (CM-3a or CM 3-b), dilution of soil vapors in the ambient air breathing zone is estimated using the same box model described for Equation CM-1.

Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{samb}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations:** Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay:** No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term:** Source term mass adjusted for constant volatilization over exposure period.	-----

- ***VF_{sesp}: Subsurface Soil-to-Enclosed-Space Volatilization Factor (Equation CM-4)***
  This factor is the steady-state ratio of the source concentration of an organic constituent in indoor air due to the concentration in underlying subsurface soils. Again, two expressions are evaluated: i) Equation CM-4a, which assumes an infinite source mass and is of the same form as Equation CM-3a with a term added to represent diffusion through cracks in the foundation of the building, and ii) Equation CM-4b which accounts for a finite source mass volatilizing at a constant rate over the exposure period. The applicable VF_{sesp} value corresponds to the lesser of these two expressions. The soil-to-enclosed-space volatilization factor incorporates two cross-media transfer elements: i) organic vapor flux from the underlying soil mass through the building floor and ii) mixing of soil vapors with indoor air. Tier 1 default assumptions in the software include: i) a 1% open crack space in the foundation allowing vapors to diffuse into the building and ii) a building air exchange rate of one exchange every 20 days. When used with these default values, the expression yields very conservative results and can represent the controlling pathway for SSTL calculations for many sites. In such case, users are advised to conduct direct air or soil vapor measurements prior to proceeding with remedial measures for this pathway.

  Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{sesp}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations:** Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay:** No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term:** Source term mass adjusted for constant volatilization over exposure period.	-----
• **Default Building Parameters:** Conservative default values for foundation crack area and air exchange rate.	⇩

- ***VF_{wamb}: Groundwater Volatilization Factor (Equation CM-5)***
  The groundwater volatilization factor is the steady-state ratio of the concentration of an organic constituent in ambient air to the source concentration in underlying affected groundwater. Vapor flux rates from groundwater to soil vapor and thence from soil vapor to ground surface are generally lower than those associated with direct volatilization from affected soils. Consequently, this groundwater-to-ambient-air volatilization factor is typically not significant in comparison to soil volatilization factors (i.e., Equations CM-1 or CM-3). This factor accounts for i) steady-state partitioning of dissolved organic constituents from groundwater to the soil vapor phase, ii) soil vapor flux rates to ground surface, and iii) mixing of soil vapors in the ambient air breathing zone directly over the plume. Dilution of organic vapors in the breathing zone is estimated using a box model, as described for Equation CM-1 above.

Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{wamb}	EFFECT ON CLEANUP STANDARD
• **Vapor Equilibrium:** Soil vapor concentrations reach immediate equilibrium with groundwater source.	⇩
• **No COC Decay:** No biodegradation or other loss mechanism in groundwater or vapor phase.	⇩
• **Infinite Source:** COC mass in source term constant over time.	⇩

- ***VF_{wesp}: Groundwater to Enclosed Space Volatilization Factor (Equation CM-6)***
  This factor is the steady-state ratio of the concentration of an organic constituent in indoor air to the source concentration in the underlying affected groundwater. The algorithm is equivalent to Equation CM-5, modified to address vapor diffusion through a building floor and enclosed space accumulation. Tier 1 default values are the same as those specified for Equation CM-4 and, as noted previously, can provide a relatively conservative (upper-range) estimate of indoor vapor concentrations. If this pathway produces the controlling (minimum) RBSL or SSTL value for a given site, the user is advised to conduct direct air or soil vapor measurements to evaluate the actual need for remedial measures.

Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{wesp}	EFFECT ON CLEANUP STANDARD
• **Vapor Equilibrium:** Soil vapor concentrations reach immediate equilibrium with groundwater source.	⇩
• **No COC Decay:** No biodegradation or other loss mechanism in groundwater or vapor phase.	⇩
• **Infinite Source:** COC mass in source term constant over time.	⇩
• **Default Building Factors:** Conservative default values for foundation crack area and air exchange rate.	⇩

- ***K_{sw}: Soil Leachate Partition Factor (Equation CM-7)***
  The soil leachate partition factor is the steady-state ratio between the concentration of an organic constituent in soil pore water and the source concentration on the affected soil mass. This factor is used to represent the release of soil constituents to leachate percolating through the affected soil zone.

Key assumptions used in this equation and their effect on the SSTL calculation are as follows:

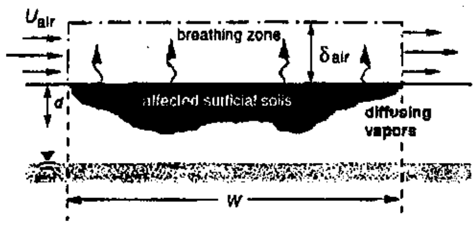
KEY ASSUMPTIONS: K_{sw}	EFFECT ON CLEANUP STANDARD
• **Leachate Equilibrium:** Leachate concentrations reach immediate equilibrium with affected soil source.	⇩
• **No COC Decay:** No biodegradation or other loss mechanism in soil or leachate.	⇩
• **Infinite Source:** COC mass in soil constant over time.	⇩

- ***LDF: Leachate-Groundwater Dilution Factor (Equation CM-8)***
The LDF factor accounts for dilution of organics as leachate from the overlying affected soil zone mixes with groundwater in the underlying water-bearing unit. As indicated on Figure A.2, the leachate dilution factor (LDF) divided by the soil-leachate partition factor (K_{sw}) represents the steady-state ratio between the concentration of an organic constituent in the groundwater zone and the source concentration on the overlying affected soil. To estimate the leachate dilution factor, a simple box model is used to estimate mass dilution within a mixing zone in the water-bearing unit directly beneath the affected soil mass (see Equation CM-8, Figure A.3 on page A-13). The leachate volume entering the water-bearing unit is represented by the deep infiltration term, I, which typically falls in the range of 0.5% - 5% of annual site precipitation. For the Tier 1 RBSL calculation, a conservative default infiltration value of 30 cm/year is used, consistent with the example provided in ASTM E-1739, Appendix X.2. For many sites, this default value (equivalent to an annual rainfall rate of over 200 in/year) may significantly overestimate actual leachate rates.

Key assumptions used in this equation and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: LDF	EFFECT ON CLEANUP STANDARD
• **Rainfall Infiltration**: Deep percolation through affected soil assumed to reach water-bearing unit regardless of soil thickness or permeability.	⇩
• **No COC Decay**: No biodegradation or other loss in mechanism groundwater zone.	⇩
• **Default Dilution Parameters**: Conservative default value for infiltration rate.	⇩

Equation CM-1: Surface Soil Volatilization Factor (VFss)



CM-1a:

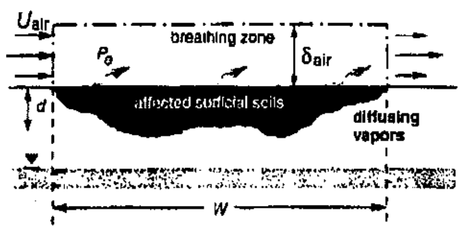
$$VF_{ss}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{2W\rho_s}{U_{air}\delta_{air}}\sqrt{\frac{D_s^{eff}H}{\pi\tau(\theta_{ws}+k_s\rho_s+H\theta_{as})}}\times 10^3$$

or CM-1b:

$$VF_{ss}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{W\rho_s d}{U_{air}\delta_{air}\tau}\times 10^3$$

whichever is less

Equation CM-2: Soil Particulate Emission Factor (PEF)

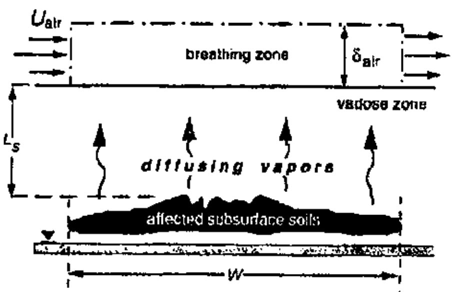


$$PEF\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{P_e W}{U_{air}\delta_{air}}\times 10^3$$

FIGURE A.3 CROSS-MEDIA PARTITIONING EQUATIONS IN THE RBCA SPREADSHEET SYSTEM ***Continued***

Continued

Equation CM-3: Subsurface Soil Volatilization Factor (VFsamb)



CM-3a:

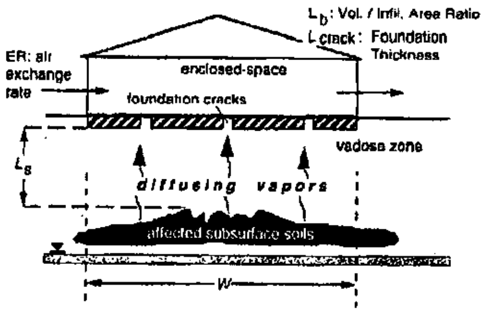
$$VF_{samb}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]\left[1+\frac{U_{air}\delta_{air}L_s}{D_s^{eff}W}\right]}\times 10^3$$

or CM-3b:

$$VF_{samb}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{W\rho_s d_s}{U_{air}\delta_{air}\tau}\times 10^3$$

whichever is less

Equation CM-4: Subsurface Soil to Enclosed Space Volatilization Factor (VFsesp)



CM-4a:

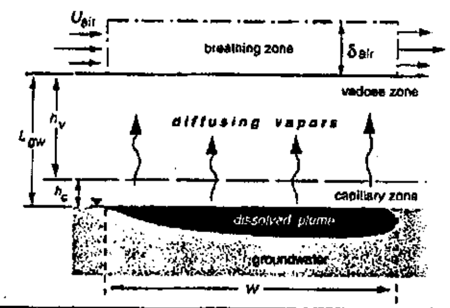
$$VF_{sesp}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{\frac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]}\left[\frac{D_s^{eff}/L_s}{ER\ \ L_B}\right]}{1+\left[\frac{D_s^{eff}/L_s}{ER\ \ L_B}\right]+\left[\frac{D_s^{eff}/L_s}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\times 10^3$$

or CM-4b:

$$VF_{sesp}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{\rho_s d_s}{L_B ER\tau}\times 10^3$$

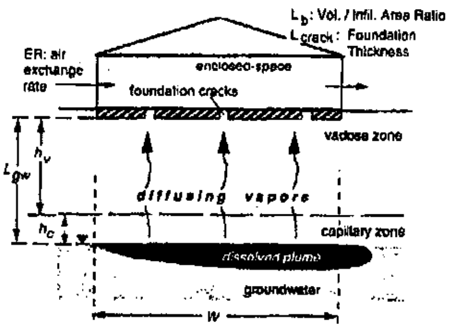
whichever is less

Equation CM-5: Groundwater Volatilization Factor (VFwamb)



$$VF_{wamb}\left[\frac{(mg/m^3-air)}{(mg/L-H_2O)}\right]=\frac{H}{1+\left[\frac{U_{air}\delta_{air}L_{GW}}{WD_{ws}^{eff}}\right]}\times 10^3$$

Equation CM-6: Groundwater to Enclosed Space Volatilization Factor (VFwesp)



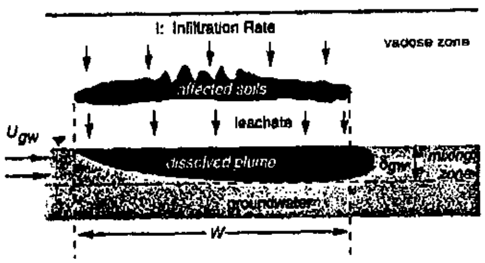
$$VF_{wesp}\left[\frac{(mg/m^3-air)}{(mg/L-H_2O)}\right]=\frac{H\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\ \ L_B}\right]}{1+\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\ \ L_B}\right]+\left[\frac{D_{ws}^{eff}/L_{GW}}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\times 10^3$$

FIGURE A.3 CROSS-MEDIA PARTITIONING EQUATIONS IN THE RBCA SPREADSHEET SYSTEM *Continued*

Continued

Equation CM-7: Soil Leachate Partition Factor(Ksw)

Equation CM-8: Leachate-Groundwater Dilution Factor (LDF)



$$K_{sw}\left[\frac{(mg/L-H_2O)}{(mg/kg-soil)}\right]=\frac{\rho_s}{\theta_{ws}+k_s\rho_s+H\theta_{as}}$$

$$LDF[dimensionless]=1+\frac{V_{gw}\delta_{gw}}{IW}$$

Definitions for Cross-Media Transfer Equations

D_s^{eff} Effective diffusivity in vadose zone soils:

$$D_s^{eff}\left[\frac{cm^2}{s}\right]=D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2}+\left[\frac{D^{wat}}{H}\right]\left[\frac{\theta_{ws}^{3.33}}{\theta_T^2}\right]$$

D_{ws}^{eff} Effective diffusivity above the water table:

$$D_{ws}^{eff}\left[\frac{cm^2}{s}\right]=\left(h_{cap}+h_v\right)\left[\frac{h_{cap}}{D_{cap}^{eff}}+\frac{h_v}{D_s^{eff}}\right]^{-1}$$

D_{crack}^{eff} Effective diffusivity through foundation cracks:

$$D_{crack}^{eff}\left[\frac{cm^2}{s}\right]=D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2}+\left[\frac{D^{wat}}{H}\right]\left[\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}\right]$$

D_{cap}^{eff} Effective diffusivity in the capillary zone:

$$D_{cap}^{eff}\left[\frac{cm^2}{s}\right]=D^{air}\frac{\theta_{acap}^{3.33}}{\theta_T^2}+\left[\frac{D^{wat}}{H}\right]\left[\frac{\theta_{wcap}^{3.33}}{\theta_T^2}\right]$$

d	Lower depth of surficial soil zone (cm)
d_s	Thickness of affected subsurface soils
D^{air}	Diffusion coefficient in air (cm^2/s)
D^{wat}	Diffusion coefficient in water (cm^2/s)
ER	Enclosed-space air exchange rate (L/s)
f_{oc}	Fraction of organic carbon in soil (g-C/g-soil)
H	Henry's law constant (cm^3-H_2O)/(cm^3-air)
h_{cap}	Thickness of capillary fringe (cm)
h_v	Thickness of vadose zone (cm)
I	Infiltration rate of water through soil (cm/year)
k_{oc}	Carbon-water sorption coefficient (g-H_2O/g-C)
k_s	Soil-water sorption coefficient (g-H_2O/g-soil)
L_B	Enclosed space volume/infiltration area ratio (cm)
L_{crack}	Enclosed space foundation or wall thickness (cm)
L_{GW}	Depth to groundwater = $h_{cap}+h_v$ (cm)
L_s	Depth to subsurface soil sources (cm)
P_e	Particulate emission rate (g/cm^2-s)
U_{air}	Wind speed above ground surface in ambient mixing zone (cm/s)
V_{gw}	Groundwater Darcy velocity (cm/s)
W	Width of source area parallel to wind, or groundwater flow direction (cm)
δ_{air}	Ambient air mixing zone height (cm)
δ_{gw}	Groundwater mixing zone thickness (cm)
η	Areal fraction of cracks in foundations/walls (cm^2-cracks/cm^2-total area)
θ_{acap}	Volumetric air content in capillary fringe soils (cm^2-air/cm^3-soil)
θ_{acrack}	Volumetric air content in foundation/wall cracks (cm^3-air/cm^3 total volume)
θ_{as}	Volumetric air content in vadose zone soils (cm^3-air/cm^3-soil)
θ_T	Total soil porosity (cm^3-pore-space/ cm^3-soil)
θ_{wcap}	Volumetric water content in capillary fringe soils (cm^3-H_2O/cm^3-soil)
θ_{wcrack}	Volumetric water content in foundation/wall cracks (cm^3-H_2O)/cm^3 total volume)
θ_{ws}	Volumetric water content in vadose zone soils (cm^3-H_2O/cm^3-soil)
ρ_s	Soil bulk density (g-soil/cm^3-soil)
τ	Averaging time for vapor flux (s)

FIGURE A.3 CROSS-MEDIA PARTITIONING EQUATIONS IN THE RBCA SPREADSHEET SYSTEM

Tier2 RBCA

A-13

LATERAL TRANSPORT FACTORS

During lateral transport within air or groundwater, COC concentrations in the flow stream will be diminished due to mixing and attenuation effects (see Figure A.2). Site-specific attenuation factors