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Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities

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APPENDIX B

ESTIMATING MEDIA CONCENTRATION EQUATIONS AND VARIABLE VALUES

Screening Level Ecological Risk Assessment Protocol

August 1999

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APPENDIX B

LIST OF VARIABLES AND PARAMETERS

γ	=	Empirical constant (unitless)
λ_z	=	Dimensionless viscous sublayer thickness (unitless)
μ_a	=	Viscosity of air (g/cm-s)
μ_w	=	Viscosity of water corresponding to water temperature (g/cm-s)
ρ_a	=	Density of air (g/cm^3 or g/m^3)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)
θ	=	Temperature correction factor (unitless)
θ_{bs}	=	Bed sediment porosity (L volume/L sediment)—unitless
θ_{sw}	=	Soil volumetric water content (mL water/cm^3 soil)
a	=	Empirical intercept coefficient (unitless)
A	=	Surface area of contaminated area (m^2)
A_I	=	Impervious watershed area receiving COPC deposition (m^2)
A_L	=	Total watershed area receiving COPC deposition (m^2)
A_W	=	Water body surface area (m^2)
b	=	Empirical slope coefficient (unitless)
BD	=	Soil bulk density (g soil/cm^3 soil)
$BCFr$	=	Plant-soil biotransfer factor (mg COPC/kg DW plant)/(mg COPC/kg soil)—unitless
BS	=	Benthic solids concentration (g sediment/cm^3 sediment)
Bs	=	Soil bioavailability factor (unitless)
Bv	=	Air-to-plant biotransfer factor (mg COPC/kg DW plant)/(mg COPC/kg air)—unitless
c	=	Junge constant = 1.7×10^{-4} (atm-cm)
C	=	USLE cover management factor (unitless)
C_d	=	Drag coefficient (unitless)
C_{dw}	=	Dissolved phase water concentration (mg COPC/L water)
C_{hp}	=	Unitized hourly air concentration from vapor phase (µg-s/g-m^3)
C_{hv}	=	Unitized hourly air concentration from particle phase (µg-s/g-m^3)
Cs	=	COPC concentration in soil (mg COPC/kg soil)
C_{sed}	=	COPC concentration in bed sediment (mg COPC/kg sediment)
C_{wctot}	=	Total COPC concentration in water column (mg COPC/L water column)
C_{wtot}	=	Total water body COPC concentration including water column and bed sediment (g COPC/m^3 water body) or (mg/L)
Cyp	=	Unitized yearly average air concentration from particle phase (µg-s/g-m^3)
Cyv	=	Unitized yearly average air concentration from vapor phase (µg-s/g-m^3)
$Cywv$	=	Unitized yearly average air concentration from vapor phase (over water body or watershed) (µg-s/g-m^3)
D_a	=	Diffusivity of COPC in air (cm^2/s)
d_{bs}	=	Depth of upper benthic sediment layer (m)

Ds	=	Deposition term (mg COPC/kg soil-yr)
d_{wc}	=	Depth of water column (m)
D_w	=	Diffusivity of COPC in water (cm^2/s)
$Dydp$	=	Unitized yearly average dry deposition from particle phase (s/m^2-yr)
$Dytwp$	=	Unitized yearly average total (wet and dry) deposition from particle phase (over water body or watershed) (s/m^2-yr)
$Dywp$	=	Unitized yearly average wet deposition from particle phase (s/m^2-yr)
$Dywv$	=	Unitized yearly average wet deposition from vapor phase (s/m^2-yr)
$Dywwv$	=	Unitized yearly average wet deposition from vapor phase (over water body or watershed) (s/m^2-yr)
d_z	=	Total water body depth (m)
ER	=	Soil enrichment ratio (unitless)
E_v	=	Average annual evapotranspiration (cm/yr)
f_{bs}	=	Fraction of total water body COPC concentration in benthic sediment (unitless)
Fd	=	Fraction of diet that is soil (unitless)
Fw	=	Fraction of COPC wet deposition that adheres to plant surfaces (unitless)
f_{wc}	=	Fraction of total water body COPC concentration in the water column (unitless)
F_v	=	Fraction of COPC air concentration in vapor phase (unitless)
H	=	Henry's Law constant ($atm\text{-}m^3/mol$)
I	=	Average annual irrigation (cm/yr)
k	=	Von Karman's constant (unitless)
K	=	USLE erodibility factor (ton/acre)
k_b	=	Benthic burial rate constant (yr^{-1})
Kd_{bs}	=	Bed sediment/sediment pore water partition coefficient (cm^3 water/g bottom sediment or L water/kg bottom sediment)
Kd_s	=	Soil-water partition coefficient (cm^3 water/g soil)
Kd_{sw}	=	Suspended sediment-surface water partition coefficient (L water/kg suspended sediment)
K_G	=	Gas phase transfer coefficient (m/yr)
K_L	=	Liquid phase transfer coefficient (m/yr)
K_{oc}	=	Soil organic carbon-water partition coefficient (mL water/g soil)
K_{ow}	=	Octanol-water partition coefficient (mg COPC/L octanol)/(mg COPC/L octanol)—unitless
kp	=	Plant surface loss coefficient (yr^{-1})
ks	=	COPC soil loss constant due to all processes (yr^{-1})
kse	=	COPC loss constant due to soil erosion (yr^{-1})
ksg	=	COPC loss constant due to biotic and abiotic degradation (yr^{-1})
ksl	=	COPC loss constant due to leaching (yr^{-1})
ksr	=	COPC loss constant due to surface runoff (yr^{-1})
ksv	=	COPC loss constant due to volatilization (yr^{-1})
k_v	=	Water column volatilization rate constant (yr^{-1})
K_v	=	Overall COPC transfer rate coefficient (m/yr)
k_{wt}	=	Overall total water body dissipation rate constant (yr^{-1})

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L_{DEP}	=	Total (wet and dry) particle phase and wet vapor phase COPC direct deposition load to water body (g/yr)
L_{Dif}	=	Vapor phase COPC diffusion (dry deposition) load to water body (g/yr)
L_E	=	Soil erosion load (g/yr)
L_R	=	Runoff load from pervious surfaces (g/yr)
L_{RI}	=	Runoff load from impervious surfaces (g/yr)
L_T	=	Total COPC load to the water body (including deposition, runoff, and erosion) (g/yr)
LS	=	USLE length-slope factor (unitless)
OC_{sed}	=	Fraction of organic carbon in bottom sediment (unitless)
p^{o}_{L}	=	Liquid phase vapor pressure of chemical (atm)
p^{o}_{S}	=	Solid phase vapor pressure of chemical (atm)
P	=	Average annual precipitation (cm/yr)
PF	=	USLE supporting practice factor (unitless)
Pd	=	Plant concentration due to direct deposition (mg COPC/kg DW)
Pr	=	Plant concentration due to root uptake (mg COPC/kg DW)
Pv	=	Plant concentration due to air-to-plant transfer (µg COPC/g DW plant tissue or mg COPC/kg DW plant tissue)
Q	=	COPC-specific emission rate (g/s)
r	=	Interception fraction—the fraction of material in rain intercepted by vegetation and initially retained (unitless)
R	=	Universal gas constant (atm-m^3/mol-K)
RO	=	Average annual surface runoff from pervious areas (cm/yr)
RF	=	USLE rainfall (or erosivity) factor (yr^{-1})
Rp	=	Interception fraction of the edible portion of plant (unitless)
SD	=	Sediment delivery ratio (unitless)
ΔSf	=	Entropy of fusion [$\Delta S_f/R$ = 6.79 (unitless)]
SF	=	Slope factor (mg/kg-day)$^{-1}$
S_T	=	Whitby's average surface area of particulates (aerosols) = 3.5×10^{-6} cm^2/cm^3 air for background plus local sources = 1.1×10^{-5} cm^2/cm^3 air for urban sources
T_a	=	Ambient air temperature (K)
T_1	=	Time period at the beginning of combustion (yr)
T_2	=	Length of exposure duration (yr)
tD	=	Time period over which deposition occurs (or time period of combustion) (yr)
T_m	=	Melting point of chemical (K)
Tp	=	Length of plant exposure to deposition per harvest of edible portion of plant (yr)
TSS	=	Total suspended solids concentration (mg/L)
T_{wk}	=	Water body temperature (K)
$t_{1/2}$	=	Half-time of COPC (days)

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u	=	Current velocity (m/s)
Vdv	=	Dry deposition velocity (cm/s)
Vf_x	=	Average volumetric flow rate through water body (m^3/yr)
W	=	Average annual wind speed (m/s)
X_e	=	Unit soil loss (kg/m^2-yr)
Yh	=	Dry harvest yield = 1.22×10^{11} kg DW, calculated from the 1993 U.S. average wet weight Yh of 1.35×10^{11} kg (USDA 1994b) and a conversion factor of 0.9 (Fries 1994)
Yh_i	=	Harvest yield of *i*th crop (kg DW)
Yp	=	Yield or standing crop biomass of the edible portion of the plant (productivity) (kg DW/m^2)
Z_s	=	Soil mixing zone depth (cm)
0.01	=	Units conversion factor (kg cm^2/mg-m^2)
10^{-6}	=	Units conversion factor (g/µg)
10^{-6}	=	Units conversion factor (kg/mg)
0.31536	=	Units conversion factor (m-g-s/cm-µg-yr)
365	=	Units conversion factor (days/yr)
907.18	=	Units conversion factor (kg/ton)
0.1	=	Units conversion factor (g-kg/cm^2-m^2)
0.001	=	Units conversion factor (kg-cm^2/mg-m^2)
100	=	Units conversion factor (mg-cm^2/kg-cm^2)
1000	=	Units conversion factor (mg/g)
4047	=	Units conversion factor (m^2/acre)
1×10^3	=	Units conversion factor (g/kg)
3.1536×10^7	=	Units conversion factor (s/yr)

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

Description

The equation in this table is used to calculate the highest annual average COPC concentration in soil resulting from wet and dry deposition of particles and vapors to soil. COPCs are assumed to be incorporated only to a finite depth (the soil mixing depth, Z_s).

The highest annual average COPC concentration in soil is assumed to occur at the end of the time period of combustion. The following uncertainty is associated with this variable:

(1) The time period for deposition of COPCs resulting from hazardous waste combustion is assumed to be a conservative, long-term value.
(2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *Cs*.

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

Equation

Highest Annual Average Soil Concentration

$$Cs = \frac{Ds \cdot [1 - \exp(-ks \cdot tD)]}{ks}$$

where:

$$Ds = \frac{100 \cdot Q}{Z_s \cdot BD} \cdot [F_v\ (0.31536 \cdot Vdv \cdot Cyv + Dywv) + (Dydp + Dywp) \cdot (1 - F_v)]$$

For mercury modeling:

$$Ds_{Mercury} = \frac{100 \cdot (0.48 Q_{TotalMercury})}{Z_s \cdot BD} \cdot [F_{v_{Hg^{2+}}}\ (0.31536 \cdot Vdv \cdot Cyv + Dywv) + (Dydp + Dywp) \cdot (1 - F_{v_{Hg^{2+}}})]$$

In calculating *Cs* for mercury comounds, *Ds(Mercury)* is calculated as shown above using the total mercury emission rate (*Q*) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated *Ds(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 98% Hg^{2+} and 2% MHg speciation split in dry land soils, and a 85% Hg^{2+} and 15% MHg speciation split in wetland soils (see Chapter 2).

For Calculating *Cs* in Dry Land Soils		**For Calculating *Cs* in Wetland Soils**	
Ds (Hg^{2+}) =	0.98 *Ds(Mercury)*	*Ds* (Hg^{2+}) =	0.85 *Ds(Mercury)*
Ds (MHg) =	0.02 *Ds(Mercury)*	*Ds* (MHg) =	0.15 *Ds(Mercury)*
Ds (Hg^0) =	0.0	*Ds* (Hg^0) =	0.0

Calculate *Cs* for divalent and methyl mercury using the corresponding (1) fate and transport parameters for mercuric chloride (divalent mercury) and methyl mercury (provided in Appendix A-2), and (2) *Ds* (Hg^{2+}) and *Ds* (MHg) as calculated above. After calculating species specific *Cs* values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

Variable	Description	Units	Value
Cs	COPC concentration in soil	mg COPC/kg soil	

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION
(SOIL EQUATIONS)

Variable	Description	Units	Value
Ds	Deposition term	mg COPC/kg soil/yr	**Varies (calculated - Table B-1-1)** Consistent with U.S. EPA (1994a; 1998), U.S. EPA OSW recommends incorporating the use of a deposition term into the *Cs* equation. Uncertainties associated with this variable include the following: (1) Five of the variables in the equation for *Ds (Q, Cyv, Dywv, Dywp* and *Dydp*) are COPC- and site-specific measured or modeled variables. The direction and magnitude of any uncertainties should not be generalized. Uncertainties associated with these variables will probably be different at each facility. (2) Based on the narrow recommended ranges, uncertainties associated with *Vdv*, F_v, and *BD* are expected to be small. (3) Values for Z_s vary by about one order of magnitude. Uncertainty is greatly reduced if it is known whether soils are tilled or untilled.
tD	Time period over which deposition occurs (time period of combustion)	yr	**100** U.S. EPA (1990a) specified that this period of time can be represented by 30, 60 , or 100 years. U.S. EPA OSW recommends that facilities use the conservative value of 100 years unless site-specific information is available indicating that this assumption is unreasonable.
ks	COPC soil loss constant due to all processes	yr^{-1}	**Varies (calculated - Table B-1-2)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-1-2. Soil loss constant is the sum of all COPC removal processes. Uncertainties associated with this variable are discussed in Table B-1-2.
100	Units conversion factor	m^2-mg/cm^2-kg	

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

Variable	Description	Units	Value
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This variable is COPC- and site-specific (see Chapters 2 and 3). Uncertainties associated with this variable are site-specific.
Z_s	Soil mixing zone depth	cm	**1 or 20** Z_s should be computed for two depth intervals. U.S. EPA OSW recommends the following values for this variable: Soil — Depth (cm) Untilled — 1 Tilled — 20 The following uncertainty is associated with this variable: (1) For soluble COPCs, leaching might lead to movement to below soil depths and justify a greater mixing depth. This uncertainty may overestimate *Cs*. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution, in comparison to that of other residues. This uncertainty may underestimate *Cs*.
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized in U.S. EPA (1990a). A proposed range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994c) recommends a default *BD* value of 1.5 g/cm^3, based on a mean value for loam soil that was obtained from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3 (U.S. EPA 1993a). The following uncertainty is associated with this variable: (1) The recommended range of *BD* values may not accurately represent site-specific soil conditions.

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

Variable	Description	Units	Value
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Values are also presented in U.S. EPA (1993), RTI (1992), and NC DEHNR (1997) based on the work of Bidleman (1988), as cited in U.S. EPA (1994c). The following uncertainty is associated with this variable: (1) It is based on the assumption of a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources, and it would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable c (Junge constant) is constant for all chemicals. However, the value of c depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of c to vary, uncertainty is introduced if a constant value of c is used to calculate F_v.
0.31536	Units conversion factor	m-g-s/cm-µg-yr	
Vdv	Dry deposition velocity	cm/s	**3** U.S. EPA (1994c) recommended the use of 3 cm/s for the dry deposition velocity, based on median dry deposition velocity for HNO_3 from an unspecified U.S. EPA database of dry deposition velocities for HNO_3, ozone, and SO_2. HNO_3 was considered the most similar to the COPCs recommended for consideration. The value should be applicable to any organic COPC with a low Henry's Law Constant. The following uncertainty is associated with this variable: (1) HNO_3 may not adequately represent specific COPCs with high Henry's Law Constant values. Therefore, the use of a single value may under- or overestimate estimated soil concentration.

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION
(SOIL EQUATIONS)

(Page 6 of 9)

Variable	Description	Units	Value
Cyv	Unitized yearly average air concentration from vapor phase	µg-s/g-m^3	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Dywv	Unitized yearly average wet deposition from vapor phase	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Dydp	Unitized yearly average dry deposition from particle phase	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Dywp	Unitized yearly average wet deposition from particle phase	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology*. Volume 22. Number 4. Pages 361-367.

This reference is for the statement that the equation used to calculate the fraction of air concentration in vapor phase (F_v) assumes that the variable c (the Junge constant) is constant for all chemicals. However, this document notes that the value of c depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. The following equation, presented in this document, is cited by U.S. EPA (1994c) and NC DEHNR (1997) for calculating the variable F_v:

$$F_v = 1 - \frac{c \cdot S_T}{P^\circ_L + c \cdot S_T}$$

where:

F_v	=	Fraction of chemical air concentration in vapor phase (unitless)
c	=	Junge constant = 1.7 E-04 (atm-cm)
S_T	=	Whitby's average surface area of particulates = 3.5 E-06 cm^2/cm^3 air (corresponds to background plus local sources)
P°_L	=	Liquid-phase vapor pressure of chemical (atm) (see Appendix A-2)

If the chemical is a solid at ambient temperatures, the solid-phase vapor pressure is converted to a liquid-phase vapor pressure as follows:

$$\ln \frac{P^\circ_L}{P^\circ_S} = \frac{\Delta S_f}{R} \cdot \frac{(T_m - T_a)}{T_a}$$

where:

P°_S	=	Solid-phase vapor pressure of chemical (atm) (see Appendix A-2)
$\frac{\Delta S_f}{R}$	=	Entropy of fusion over the universal gas constant = 6.79 (unitless)
T_m	=	Melting point of chemical (K) (see Appendix C)
T_a	=	Ambient air temperature = 298 K (25°C)

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Vol. 2. Pages 11-24.

This reference is cited by U.S. EPA (1994b) as the source for a mean soil bulk density value of 1.5 g/cm^3 for loam soil.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, Inc. New York.

This document is cited by U.S. EPA (1990a) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes, 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NOREG/TM-882.

This document presents a soil bulk density range, *BD*, of 0.83 to 1.84.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This is one of the source documents for for the equation in Table B-1-1. This document also recommends the use of (1) a deposition term, *Ds*, and (2) COPC-specific F_v (fraction of COPC air concentration in vapor phase) values.

Research Triangle Institute (RTI). 1992. *Preliminary Soil Action Level for Superfund Sites.* Draft Interim Report. Prepared for U.S. EPA Hazardous Site Control Division, Remedial Operations Guidance Branch. Arlington, Virginia. EPA Contract 68-W1-0021. Work Assignment No. B-03, Work Assignment Manager Loren Henning. December.

This document is a reference source for COPC-specific F_v (fraction of COPC air concentration in vapor phase) values.

U.S. EPA. 1990a. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document is a reference source for the equation in Table B-1-1, and it recommends that (1) the time period over which deposition occurs (time period for combustion), *tD*, be represented by periods of 30, 60, and 100 years, and (2) undocumented values for soil mixing zone depth, Z_s, for tilled and untilled soil.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Working Group Recommendations. Office of Solid Waste. Office of Research and Development. Washington, D.C. September 24.

This document is a reference for the equation in Table B-1-1. It recommends using a deposition term, *Ds*, and COPC-specific F_v values (fraction of COPC air concentration in vapor phase) in the *Cs* equation.

U.S. EPA 1994a. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* Office of Emergency and Remedial Response. Office of Solid Waste. April 15.

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TABLE B-1-1

SOIL CONCENTRATION DUE TO DEPOSITION (SOIL EQUATIONS)

This document is a reference for the equation in Table B-1-1; it recommends that the following be used in the *Cs* equation: (1) a deposition term, *Ds*, and (2) a default soil dry bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988).

U.S. EPA. 1994b. *Estimating Exposure to Dioxin-Like Compounds. Volume III: Site-Specific Assessment Procedures.* Review Draft. Office of Research and Development. Washington, D.C. June. EPA/600/6-88/005Cc.

U.S. EPA. 1994c. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

The value for dry deposition velocity is based on median dry deposition velocity for HNO_3 from a U.S. EPA database of dry deposition velocities for HNO3 ozone, and SO_2. HNO_3 was considered the most similar to the constituents covered and the value should be applicable to any organic compound having a low Henry's Law Constant. The reference document for this recommendation was not cited. This document recommends the following:

- F_v values (fraction of COPC air concentration in vapor phase) that range from 0.27 to 1 for organic COPCs
- *Vdv* value (dry deposition velocity) of 3 cm/s (however, no reference is provided for this recommendation)
- Default soil dry bulk density value of 1.5 g/cm^3, based on a mean for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988)
- *Vdv* value of 3 cm/s, based on median dry deposition velocity for HNO_3 from an unspecified U.S. EPA database of dry deposition velocities for HNO_3, ozone, and SO_2. HNO_3 was considered the most similar to the COPCs recommended for consideration.

U.S. EPA. 1998. "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilitites." External Peer Review Draft. U.S. EPA Region 6 and U.S. EPA OSW. Volumes 1-3. EPA530-D-98-001A. July.

US EPA ARCHIVE DOCUMENT

TABLE B-1-2

COPC SOIL LOSS CONSTANT DUE TO ALL PROCESSES (SOIL EQUATIONS)

Description

This equation calculates the soil loss constant (*ks*), which accounts for the loss of COPCs from soil by several mechanisms.

Uncertainties associated with this equation include the following:

(1) COPC-specific values for *ksg* are empirically determined from field studies. No information is available regarding the application of these values to the site-specific conditions associated with affected facilities.

Equation

$$ks = ksg + kse + ksr + ksl + ksv$$

Variable	Description	Units	Value
ks	COPC soil loss constant due to all processes	yr^{-1}	
ksg	COPC loss constant due to biotic and abiotic degradation	yr^{-1}	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. "Degradation rate" values are also presented in NC DEHNR (1997). However, no reference or source is provided for the values. U.S. EPA (1994a and 1994b) state that *ksg* values are COPC-specific; however, all *ksg* values are presented as zero (U.S. EPA 1994a) or as "NA" (U.S. EPA 1994b). The basis of these assumptions is not addressed. The following uncertainty is associated with this variable: (1) COPC-specific values for *ksg* are empirically determined from field studies. No information is available regarding the application of these values to the site-specific conditions associated with affected facilities.

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TABLE B-1-2

COPC SOIL LOSS CONSTANT DUE TO ALL PROCESSES (SOIL EQUATIONS)

Variable	Description	Units	Value
kse	COPC loss constant due to soil erosion	yr^{-1}	**0** This variable is COPC- and site-specific, and is further discussed in Table B-1-3. Consistent with U.S. EPA (1994a; 1994b; 1998) and NC DEHNR (1997), U.S. EPA OSW recommends that the default value assumed for *kse* is zero because of contaminated soil eroding onto the site and away from the site. Uncertainties associated with this variable include the following: (1) The source of the equation in Table B-1-3 has not been identified. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *kse*.
ksr	COPC loss constant due to surface runoff	yr^{-1}	**Varies (calculated - Table B-1-4)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-1-4. No reference document is cited for this equation. The use of this equation is consistent with U.S. EPA (1994b; 1998) and NC DEHNR (1997). U.S. EPA (1994a) states that all *ksr* values are zero but does not explain the basis of this assumption. Uncertainties associated with this variable include the following: (1) The source of the equation in Table B-1-4 has not been identified. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *ksr*.
ksl	COPC loss constant due to leaching	yr^{-1}	**Varies (calculated - Table B-1-5)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-1-5. No reference document is cited for this equation. The use of this equation is consistent with U.S. EPA (1993; 1994b; 1998), and NC DEHNR (1997). U.S. EPA (1994a) states that all *ksl* values are zero but does not explain the basis of this assumption. Uncertainties associated with this variable include the following: (1) The source of the equation in Table B-1-5 has not been identified. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *ksl*.

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TABLE B-1-2

COPC SOIL LOSS CONSTANT DUE TO ALL PROCESSES (SOIL EQUATIONS)

(Page 3 of 4)

Variable	Description	Units	Value
ksv	COPC loss constant due to volatilization	yr^{-1}	**Varies (calculated - Table B-1-6)** This variable is COPC- and site-specific, and is calculated using the equation in Table B-1-6. Uncertainties associated with this variable include the following: (1) Deposition to hard surfaces may result in dust residues that have negligible dilution, (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *ksv*.

US EPA ARCHIVE DOCUMENT

TABLE B-1-2

COPC SOIL LOSS CONSTANT DUE TO ALL PROCESSES (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is one of the reference documents for the equations in Tables B-1-4, B-1-5, and B-1-6. No source for these equations has been identified. This document is also cited as (1) the source for a range of COPC-specific degradation rates (*ksg*), and (2) one of the sources that recommend using the assumption that the loss resulting from erosion (*kse*) is zero because of contaminated soil eroding onto the site and away from the site.

U.S. EPA. 1993. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Office of Health and Environmental Assessment. Office of Research and Development. EPA-600-AP-93-003. November 10.

This document is one of the reference documents for the equations in Tables B-1-4 and B-1-5.

U.S. EPA. 1994a. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* April 15.

This document is cited as a source for the assumptions regarding losses resulting from erosion (*kse*), surface runoff (*ksr*), degradation (*ksg*), and leaching (*ksl*), and volatilization (*ksv*).

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is one of the reference documents for the equations in Tables B-1-4 and B-1-5. This document is also cited as one of the sources that recommend using the assumption that the loss resulting from erosion (*kse*) is zero and the loss resulting from degradation (*ksg*) is "NA" or zero for all compounds.

U.S. EPA. 1998. "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilitites." External Peer Review Draft. U.S. EPA Region 6 and U.S. EPA OSW. Volumes 1-3. EPA530-D-98-001A. July.

US EPA ARCHIVE DOCUMENT

TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION (SOIL EQUATIONS)

Description

This equation calculates the constant for COPC loss resulting from erosion of soil. Consistent with U.S. EPA (1994), U.S. EPA (1994b), NC DEHNR (1997), and U.S. EPA (1998), U.S. EPA OSW recommends that the default value assumed for *kse* is zero because of contaminated soil eroding onto the site and away from the site. In site-specific cases where the permitting authority considers it appropriate to calculate a *kse*, the following equation presented in this table should be considered along with associated uncertainties. Additional discussion on the determination of *kse* can be obtained from review of the methodologies described in U.S. EPA NCEA document, *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (In Press).

Uncertainties associated with this equation include:

(1) For soluble COPCs, leaching might lead to movement below 1 cm in soils and justify a greater mixing depth. This uncertainty may overestimate *kse*.
(2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials) in comparison to that of other residues. This uncertainty may underestimate *kse*.

Equation

$$kse = \frac{0.1 \cdot X_e \cdot SD \cdot ER}{BD \cdot Z_s} \cdot \left(\frac{Kd_s \cdot BD}{\theta_{sw} + (Kd_s \cdot BD)} \right)$$

Variable	Description	Units	Value
kse	COPC loss constant due to soil erosion	yr^{-1}	**0** Consistent with U.S. EPA (1994), U.S. EPA (1994b), U.S. EPA (1998), and NC DEHNR (1997), U.S. EPA OSW recommends that the default value assumed for *kse* is zero because of contaminated soil eroding onto the site and away from the site.
0.1	Units conversion factor	$g\text{-}kg/cm^2\text{-}m^2$	

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TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION (SOIL EQUATIONS)

Variable	Description	Units	Value
X_e	Unit soil loss	kg/m^2-yr	**Varies (calculated - Table B-2-7)** This variable is site-specific and is calculated by using the equation in Table B-2-7. The following uncertainty is associated with this variable: (1) All of the equation variables are site-specific. Use of default values rather than site-specific values for any or all of these variables will result in unit soil loss (X_e) estimates that are under- or overestimated to some degree. Based on default values, X_e estimates can vary over a range of less than two orders of magnitude.
SD	Sediment delivery ratio	unitless	**Varies (calculated - Table B-2-8)** This value is site-specific and is calculated by using the equation in Table B-2-8. Uncertainties associated with this variable include the following: (1) The recommended default values for the empirical intercept coefficient, *a*, are average values that are based on studies of sediment yields from various watersheds. Therefore, those default values may not accurately represent site-specific watershed conditions. As a result, use of these default values may under- or overestimate *SD*. (2) The recommended default value for the empirical slope coefficient, *b*, is based on a review of sediment yields from various watersheds. This single default value may not accurately represent site-specific watershed conditions. As a result, use of this default value may under- or overestimate *SD*.
ER	Soil enrichment ratio	unitless	**Inorganics: 1** **Organics: 3** COPC enrichment occurs because (1) lighter soil particles erode more than heavier soil particles, and (2) concentration of organic COPCs—which is a function of organic carbon content of sorbing media—is expected to be higher in eroded material than in in-situ soil (U.S. EPA 1993). In the absence of site-specific data, U.S. EPA OSW recommends a default value of 3 for organic COPCs and 1 for inorganic COPCs. This is consistent with other U.S. EPA guidance (1993), which recommends a range of 1 to 5 and a value of 3 as a "reasonable first estimate." This range has been used for organic matter, phosphorus, and other soil-bound COPCs (U.S. EPA 1993); however, no sources or references were provided for this range. *ER* is generally higher in sandy soils than in silty or loamy soils (U.S. EPA 1993). The following uncertainty is associated with this variable: (1) The default ER value may not accurately reflect site-specific conditions; therefore, *kse* may be over- or underestimated to an unknown extent.

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TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION (SOIL EQUATIONS)

Variable	Description	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized in U.S. EPA (1990). A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994) recommends a default BD value of 1.5 g/cm^3, based on a mean value for loam soil that was taken from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3 (U.S. EPA 1993). The following uncertainty is associated with this variable: (1) The recommended range of soil dry bulk density values may not accurately represent site-specific soil conditions.
Z_s	Soil mixing zone depth	cm	**1 or 20** U.S. EPA OSW recommends the following values for this variable: Soil — Depth (cm) Untilled — 1 Tilled — 20 The following uncertainty is associated with this variable: (1) For soluble COPCs, leaching might lead to movement to below 1 cm in soils and justify a greater mixing depth. This uncertainty may overestimate *kse*. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *kse*.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are determined as described in Appendix A-2.

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TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION
(SOIL EQUATIONS)

(Page 4 of 6)

Variable	Description	Units	Value
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure. θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point, if a representative watershed soil can be identified. However, U.S. EPA OSW recommends the use of 0.2 mL/cm^3 as a default value. This value is the midpoint of the range 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils) recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, *kse* may be under- or overestimated to a small extent, based on the limited range of values.

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TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Carsel, R.F., R.S. Parish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Vol. 2. Pages 11-24.

This document is cited by U.S. EPA (1994) as the source for a mean soil bulk density, *BD*, value of 1.5 g/cm^3 for loam soil.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, Inc. New York.

This document is cited by U.S. EPA (1990) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84.

NC DEHNR. 1997. *Draft NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document presents a range of values for soil mixing zone depth, Z_s, for tilled and untilled soil. The basis or source of these values is not identified.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Research and Development. Washington, D.C. November 1993.

This document is the source of a range of COPC enrichment ratio, *ER*, values. The recommended range, 1 to 5, has been used for organic matter, phosphorous, and other soil-bound COPCs. This document recommends a value of 3 as a "reasonable first estimate," and states that COPC enrichment occurs because lighter soil particles erode more than heavier soil particles. Lighter soil particles have higher ratios of surface area to volume and are higher in organic matter content. Therefore, concentration of organic COPCs, which is a function of the organic carbon content of sorbing media, is expected to be higher in eroded material than in in-situ soil.

This document is also a source of the following:

- A "relatively narrow range" for soil dry bulk density, *BD*, of 1.2 to 1.7 g/cm^3
- COPC-specific (inorganic COPCs only) Kd_s values used to develop a proposed range (2 to 280,000 mL/g) of Kd_s values
- A range of soil volumetric water content (θ_{sw}) values of 0.1 mL/cm^3 (very sandy soils) to 0.3 mL/cm^3 (heavy loam/clay soils) (however, no source or reference is provided for this range)

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TABLE B-1-3

COPC LOSS CONSTANT DUE TO SOIL EROSION
(SOIL EQUATIONS)

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* April 15.

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-Like Compounds. Volume III: Site-specific Assessment Procedures.* External Review Draft. Office of Research and Development. Washington, D.C. EPA/600/6-88/005Cc. June.

This document is the source of values for soil mixing zone depth, Z_s, for tilled and untilled soil, as cited in U.S. EPA (1993).

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends (1) a default soil bulk density value of 1.5 g soil/cm^3 soil, based on a mean value for loam soil that is taken from Carsel, Parrish, Jones, Hansen, and Lamb (1988), and (2) a default soil volumetric water content, θ_{sw}, value of 0.2 mL water/cm^3 soil, based on U.S. EPA (1993).

U.S. EPA. 1998. "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilitites." External Peer Review Draft. U.S. EPA Region 6 and U.S. EPA OSW. Volumes 1-3. EPA530-D-98-001A. July.

US EPA ARCHIVE DOCUMENT

TABLE B-1-4

COPC LOSS CONSTANT DUE TO RUNOFF (SOIL EQUATIONS)

Description

This equation calculates the constant for COPC loss resulting from runoff of soil. Uncertainties associated with this equation include the following:

(1) For soluble COPCs, leaching might lead to movement to below 1 cm in soils and resulting in a greater mixing depth. This uncertainty may overestimate *ksr*.
(2) Deposition to hard surfaces may result in dust residues that have negligible dilution, in comparison to that of other residues. This uncertainty may underestimate *ksr*.

Equation

$$ksr = \frac{RO}{\theta_{sw} \cdot Z_s} \cdot \left(\frac{1}{1 + \left(Kd_s \cdot BD / \theta_{sw}\right)} \right)$$

Variable	Description	Units	Value
ksr	COPC loss constant due to surface runoff	yr^{-1}	
RO	Average annual surface runoff	cm/yr	**Varies (site-specific)** This variable is site-specific. According to U.S. EPA (1993; 1994b) and NC DEHNR (1997), average annual surface runoff can be estimated by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973). According to NC DEHNR, (1997), estimates can also be made by using more detailed, site-specific procedures for estimating the amount of surface runoff, such as those based on the U.S. Soil Conservation Service curve number equation (CNE). U.S. EPA (1985) is cited as an example of such a procedure. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local average annual surface runoff information is not available, default or estimated values may not accurately represent site-specific or local conditions. As a result, *ksl* may be under- or overestimated to an unknown degree.

US EPA ARCHIVE DOCUMENT

TABLE B-1-4

COPC LOSS CONSTANT DUE TO RUNOFF (SOIL EQUATIONS)

Variable	Description	Units	Value
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure; if a representative watershed soil can be identified, θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point. However, U.S. EPA OSW recommends the use of 0.2 mL/cm^3 as a default value. This value is the midpoint of the range 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils), which is recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994b). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, *kse* may be under- or overestimated to a small extent, based on the limited range of values.
Z_s	Soil mixing zone depth	cm	**1 or 20** U.S. EPA OSW recommends the following values for this variable: Soil — Depth (cm) Untilled — 1 Tilled — 20 The following uncertainty is associated with this variable: (1) For soluble COPCs, leaching might lead to movement to below 1 cm in soils and justify a greater mixing depth. This uncertainty may overestimate *ksr*. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *ksr*.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are calculated as described in Appendix A-2.

US EPA ARCHIVE DOCUMENT

TABLE B-1-4

COPC LOSS CONSTANT DUE TO RUNOFF (SOIL EQUATIONS)

Variable	Description	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized by U.S. EPA 1990. A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994) recommended a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil that is taken from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3 (U.S. EPA 1993). The following uncertainty is associated with this variable: (1) The recommended range of soil dry bulk density values may not accurately represent site-specific soil conditions.

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TABLE B-1-4

COPC LOSS CONSTANT DUE TO RUNOFF (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Vol. 2. Pages 11-24.

This document is cited by U.S. EPA (1994) as the source of a mean soil bulk density, *BD*, value of 1.5 g/cm^3 for loam soil.

Geraghty, J.J., D.W. Miller, F. Van der Leeden, and F.L. Troise. 1973. *Water Atlas of the United States*. Water Information Center, Port Washington, New York.

This document is cited by U.S. EPA (1993), U.S. EPA (1994c), and NC DEHNR (1997) as a reference to calculate average annual runoff, *R*. This reference provides maps with isolines of annual average surface water runoff, which is defined as all flow contributions to surface water bodies, including direct runoff, shallow interflow, and ground water recharge. Because these values are total contributions, and not only surface runoff, U.S. EPA (1994c) recommends that they be reduced by 50 percent to estimate surface runoff.

Hillel, D. 1980. Fundamentals of Soil Physics. Academic Press, Inc. New York.

This document is cited by U.S. EPA (1990) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is one of the source documents that cites the use of the equation in Table B-1-4; however, this document is not the original source of this equation (this source is unknown). This document also recommends the following:

- Estimation of annual current runoff, *RO* (cm/yr), by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973) or site-specific procedures, such as using the U.S. Soil Conservation Service curve number equation (CNE) (U.S. EPA [1985]) is cited as an example of the use of the CNE
- Default value of 0.2 mL/cm^3 for soil volumetric water content (θ_{sw})
- Range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs (the original source of the values is not identified)

U.S. EPA. 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water—Part I (Revised. 1985)*. Environmental Research Laboratory. Athens, Georgia. EPA/600/6-85/002a. September.

This document is cited by NC DEHNR (1997) as an example of the use of the U.S. Soil Conservation Service CNE to estimate site-specific surface runoff.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Assocated with Indirect Exposure to Combustor Emissions*. Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

US EPA ARCHIVE DOCUMENT

TABLE B-1-4

COPC LOSS CONSTANT DUE TO RUNOFF (SOIL EQUATIONS)

This document presents the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November.

This document recommends the following:

- A "relatively narrow range" for soil dry bulk density, *BD*, of 1.2 to 1.7 g./cm^3
- A range of soil volumetric water content, θ_{sw}, values of 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils) (the original source of, or reference for, these values is not identified)
- A range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs
- Use of the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973) to calculate average annual runoff

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-Like Compounds. Volume III: Site-specific Assessment Procedures.* External Review Draft. Office of Research and Development. Washington, D.C. EPA/600/6-88/005Cc. June.

This document presents a range of values for soil mixing zone depth, Z_s, for tilled and untilled soil as cited in U.S. EPA (1993).

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes.* Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities. Offices of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends the following:

- Estimation of average annual runoff, *RO*, by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973)
- Default soil dry bulk density, *BD*, value of 1.5 g/cm^3, based on the mean for loam soil that is taken from Carsel, Parrish, Jones, Hansen, and Lamb (1988)
- Default soil volumetric water content, θ_{sw}, value of 0.2 mL/cm^3, based on U.S. EPA (1993)

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TABLE B-1-5

COPC LOSS CONSTANT DUE TO LEACHING (SOIL EQUATIONS)

Description

This equation calculates the constant for COPC loss resulting from leaching of soil. Uncertainties associated with this equation include the following:

(1) For soluble COPCs, leaching might lead to movement to below 1 or 20 cm in soils; resulting in a greater mixing depth. This uncertainty may overestimate *ksl*.
(2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with in-situ materials), in comparison to that of other residues. This uncertainty may underestimate *ksl*.
(3) The original source of this equation has not been identified. U.S. EPA (1993) presents the equation as shown here. U.S. EPA (1994) and NC DEHNR (1997) replaced the numerator as shown with "*q*", defined as average annual recharge (cm/yr).

Equation

$$ksl = \frac{P + I - RO - E_v}{\theta_{sw} \cdot Z_s \cdot \left[1.0 + \left(BD \cdot Kd_s / \theta_{sw}\right)\right]}$$

Variable	Description	Units	Value
ksl	COPC loss constant due to leaching	yr^{-1}	
P	Average annual precipitation	cm/yr	**18.06 to 164.19 (site-specific)** This variable is site-specific. This range is based on information, presented in U.S. EPA (1990), representing data for 69 selected cities (U.S. Bureau of Census 1987; Baes, Sharp, Sjoreen and Shor 1984). The 69 selected cities are not identified. However, they appear to be located throughout the continental United States. U.S. EPA OSW recommends that site-specific data be used. The following uncertainty is associated with this variable: (1) To the extent that a site is not located near an established meteorological data station, and site-specific data are not available, default average annual precipitation data may not accurately reflect site-specific conditions. As a result, *ksl* may be under- or overestimated. However, average annual precipitation data are reasonably available; therefore, uncertainty introduced by this variable is expected to be minimal.

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TABLE B-1-5

COPC LOSS CONSTANT DUE TO LEACHING (SOIL EQUATIONS)

Variable	Description	Units	Value
I	Average annual irrigation	cm/yr	**0 to 100 (site-specific)** This variable is site-specific. This range is based on information, presented in U.S. EPA (1990), representing data for 69 selected cities (Baes, Sharp, Sjoreen, and Shor 1984). The 69 selected cities are not identified; however, they appear to be located throughout the continental United States. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local average annual irrigation information is not available, default values (generally based on the closest comparable location) may not accurately reflect site-specific conditions. As a result, *ksl* may be under- or overestimated to an unknown degree.
RO	Average annual surface runoff	cm/yr	**Varies (site-specific)** This variable is site-specific. According to U.S. EPA (1993; 1994) and NC DEHNR (1997), average annual surface runoff can be estimated by using the Water Atlas of the United States (Geraghty, Miller, Van der Leeden, and Troise 1973). Also according to NC DEHNR (1997), this estimate can also be made by using more detailed, site-specific procedures, such as those based on the U.S. Soil Conservation Service CNE. U.S. EPA (1985) is cited as an example of such a procedure. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local average annual surface runoff information is not available, default or estimated values may not accurately represent site-specific or local conditions. As a result, *ksl* may be under- or overestimated to an unknown degree.
E_v	Average annual evapotranspiration	cm/yr	**35 to 100 (site-specific)** This variable is site-specific. This range is based on information, presented in U. S. EPA (1990), representing data from 69 selected cities. The 69 selected cities are not identified; however, they appear to be located throughout the continental United States. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local average annual evapotranspiration information is not available, default values may not accurately reflect site-specific conditions. As a result, *ksl* may be under- or overestimated to an unknown degree.

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TABLE B-1-5

COPC LOSS CONSTANT DUE TO LEACHING (SOIL EQUATIONS)

Variable	Description	Units	Value
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure. θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point, if a representative watershed soil can be identified. However, U.S. EPA OSW recommends the use of 0.2 mL/cm^3 as a default value. This value is the midpoint of the range of 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils) recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, *ksl* may be under- or overestimated to a small extent, based on the limited range of values.
Z_s	Soil mixing zone depth	cm	**1 or 20** U.S. EPA OSW recommends the following values for this variable: Soil — Depth (cm) Untilled — 1 Tilled — 20 Uncertainties associated with this variable include the following: (1) For soluble COPCs, leaching might lead to movement to below 1 or 20 cm in soils; resulting in a greater mixing depth. This uncertainty may overestimate *ksl*. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution, in comparison to that of other residues. This uncertainty may underestimate *ksl*.

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TABLE B-1-5

COPC LOSS CONSTANT DUE TO LEACHING (SOIL EQUATIONS)

Variable	Description	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized in U.S. EPA (1990). A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994) recommended a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3 (U.S. EPA 1993). The following uncertainties is associated with this variable: (1) The recommended range of soil dry bulk density values may not accurately represent site-specific soil conditions.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are calculated as described in Appendix A-2.

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TABLE B-1-5

COPC LOSS CONSTANT DUE TO LEACHING (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Baes, C.F., R.D. Sharp, A.L. Sjoreen and R.W. Shor. 1984. "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture." Prepared for the U.S. Department of Energy under Contract No. DEAC05-840R21400.

For the continental United States, as cited in U.S. EPA (1990), this document is the source of a series of maps showing: (1) average annual precipitation (*P*); (2) average annual irrigation (*I*); and (3) average annual evapotranspiration isolines.

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Vol. 2. Pages 11-24.

This document is cited by U.S. EPA (1994b) as the source for a mean soil bulk density value of 1.5 g/cm^3 for loam soil.

Geraghty, J.J., D.W. Miller, F. Van der Leeden, and F.L. Troise. 1973. *Water Atlas of the United States*. Water Information Center, Port Washington, New York.

This document is cited by U.S. EPA (1993), U.S. EPA (1994), and NC DEHNR (1997) as a reference for calculating average annual runoff, *RO*. This document provides maps with isolines of annual average surface runoff, which is defined as all flow contributions to surface water bodies, including direct runoff, shallow interflow, and ground water recharge. Because these volumes are total contributions—and not only surface runoff—U.S. EPA (1994) notes that they need to be reduced by 50 percent to estimate average annual surface runoff.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84. U.S. EPA has not completed its review of this document.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, Inc. New York, New York.

This document is cited by U.S. EPA (1990) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is one of the source documents that cites the use of the equation in Table B-1-5; however, the document is not the original source of this equation. This document also recommends the following:

- Estimation of average annual surface runoff, *RO* (cm/yr), by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973) or site-specific procedures, such as using the U.S. Soil Conservation Service CNE; U.S. EPA 1985 is cited as an example of the use of the CNE.

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- A default value of 0.2 mL/cm^3 for soil volumetric water content, θ_{sw}.
- A range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs; the original source of these values is not identified.

U.S. Bureau of the Census. 1987. *Statistical Abstract of the United States:* 1987. 107th edition. Washington, D.C.

This document is a source of average annual precipitation (*P*) information for 69 selected cites, as cited in U.S. EPA (1990); these 69 cities are not identified.

U.S. EPA. 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Groundwater*. Part I (Revised 1985). Environmental Research Laboratory. Athens, Georgia. EPA/600/6-85/002a. September.

This document is cited by NC DEHNR (1997) as an example of the use of the U.S. Soil Conservation Service CNE to estimate site-specific average annual surface runoff.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document presents ranges of (1) average annual precipitation, (2) average annual irrigation, and (3) average annual evapotranspiration. This document identifies Baes, Sharp, Sjoreen, and Shor (1984) and U.S. Bureau of the Census (1987) as the original sources of this information.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Research and Development. Washington, D.C. November.

This document is one of the reference sources for the equation in Table B-1-5; this document also recommends the following:

- A range of soil volumetric water content, θ_{sw}, values of 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils); the original source or reference for these values is not identified.
- A range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs
- A "relatively narrow range" for soil dry bulk density, *BD*, of 1.2 to 1.7 g/cm^3

This document is one of the reference source documents for equation in Table B-1-5. The original source of this equation is not identified.

U.S. EPA. 1994. *Review Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends (1) a default soil volumetric water content, θ_{sw}, value of 0.2 mL/cm^3, based on U.S. EPA (1993), and (2) a default soil bulk density, *BD*, value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988).

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TABLE B-1-6

COPC LOSS CONSTANT DUE TO VOLATILIZATION (SOIL EQUATIONS)

Description

This equation calculates the COPC loss constant from soil due to volatilization, and was obtained from *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (U.S. EPA In Press). The soil loss constant due to volatilization (*ksv*) is based on gas equilibrium coefficients and gas phase mass transfer. The first order decay constant, *ksv*, is obtained by adapting the Hwang and Falco equation for soil vapor phase diffusion (Hwang and Falco 1986).

Uncertainties associated with this equation include the following:

(1) For soluble COPCs, leaching might lead to movement to below 1 centimeter in untilled soils, resulting in a greater mixing depth. This uncertainty may overestimate *ksv*.
(2) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with *in situ* materials) in comparison to that of other residues. This uncertainty may underestimate *ksv*.

Equation

$$ksv = \left[\frac{3.1536 \times 10^7 \cdot H}{Z_s \cdot Kd_s \cdot R \cdot T_a \cdot BD}\right] \cdot \left(\frac{D_a}{Z_s}\right) \cdot \left[1 - \left(\frac{BD}{\rho_s}\right) - \theta_{sw}\right]$$

Variable	Definition	Units	Value
ksv	COPC loss constant due to volatilization	yr^{-1}	
3.1536 x 10^7	Units conversion factor	s/yr	
H	Henry's Law constant	atm-m^3/mol	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Values for this variable, estimated by using the parameters and algorithms in Appendix A-2, may under- or overestimate the actual COPC-specific values. As a result, *ksv* may be under- or overestimated.

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TABLE B-1-6

COPC LOSS CONSTANT DUE TO VOLATILIZATION (SOIL EQUATIONS)

Variable	Definition	Units	Value
Z_s	Soil mixing zone depth	cm	**1 or 20** U.S. EPA OSW recommends the following values for this variable: Soil — Depth (cm) Untilled — 1 Tilled — 20 The following uncertainty is associated with this variable: (1) For soluble COPCs, leaching might lead to movement to below 1 or 20 cm in soils and justify a greater mixing depth. This uncertainty may overestimate *ksv*. (2) Deposition to hard surfaces may result in dust residues that have negligible dilution, in comparison to that of other residues. This uncertainty may underestimate *ksv*.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are calculated as described in Appendix A-2.
R	Universal gas constant	$atm\text{-}m^3/mol\text{-}K$	**8.205×10^{-5}** There are no uncertainties associated with this parameter.
T_a	Ambient air temperature	K	**298** This variable is site-specific. U.S. EPA (1990) recommended an ambient air temperature of 298 K. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local values for the variable are not available, default values may not accurately represent site-specific conditions. The uncertainty associated with the selection of a single value from within the temperature range at a single location is expected to be more significant than the uncertainty associated with choosing a single ambient temperature to represent all localities.

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TABLE B-1-6

COPC LOSS CONSTANT DUE TO VOLATILIZATION (SOIL EQUATIONS)

Variable	Definition	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980; Miller and Gardiner 1998), as summarized in U.S. EPA (1990). A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994) recommended a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3 (U.S. EPA 1993). The following uncertainty is associated with this variable: (1) The recommended range of soil bulk density values may not accurately represent site-specific soil conditions.
ρ_s	Solids particle density	g/cm^3	**2.7** U.S. EPA OSW recommends the use of this value, based on Blake and Hartage (1996) and Hillel (1980). The solids particle density will vary with location and soil type.
D_a	Diffusivity of COPC in air	cm^2/s	**Varies (see Appendix A-2)** This value is COPC-specific and should be determined from the COPC tables presented in Appendix A-2. The following uncertainty is associated with this variable: (1) The default D_a values may not accurately represent the behavior of COPCs under site-specific conditions. However, the degree of uncertainty is expected to be minimal.

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TABLE B-1-6

COPC LOSS CONSTANT DUE TO VOLATILIZATION (SOIL EQUATIONS)

(Page 4 of 6)

Variable	Definition	Units	Value
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure. θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point, if a representative watershed soil can be identified. However, U.S. EPA OSW recommends the use of 0.2 mL/cm^3 as a default value. This value is the midpoint of the range of 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils) recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, *ksl* may be under- or overestimated to a small extent, based on the limited range of values.

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TABLE B-1-6

COPC LOSS CONSTANT DUE TO VOLATILIZATION (SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Blake, G.R. and K.H. Hartge. 1996. *Particle Density. Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods*. Second Edition. Arnold Klute, Ed. American Society of Agronomy, Inc. Madison, WI., p. 381.

Carsel, R.F., R.S, Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Vol. 2. Pages 11-24.

This document is cited by U.S. EPA (1994) as the source of a mean soil bulk density value, *BD*, of 1.5 g/cm^3 for loam soil.

Hillel, D. 1980. *Fundamentals of Soil Physics.* Academic Press, Inc. New, New York.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides.* ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84.

Hwang S. T. and Falco, J. W. 1986. "Estimation of multimedia exposures related to hazardous waste facilities", In: *Pollutants in a Multimedia Environment*. Yoram Cohen, Ed. Plenum Publishing Corp. New York.

Miller, R.W. and D.T. Gardiner. 1998. In: *Soils in Our Environment*. J.U. Miller, Ed. Prentice Hall. Upper Saddle River, NJ. pp. 80-123.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is one of the source documents that cites the use of the equation in Table B-1-6; however, the original source of this equation is not identified. This document also recommends the following:

- A range of COPC-specific Henry's Law Constant (atm-m^3/mol) values
- A range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs; however, the sources of these values are not identified.
- A range (9.2 E-06 to 2.8 E-01 cm^2/sec) of values for diffusivity of COPCs in air; however, the sources of these values are not identified.

U. S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document recommends the following:

- A default ambient air temperature of 298 K

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- An average annual wind speed of 3.9 m/s; however, no source or reference for this value is identified.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November.

This document is one of the reference source documents for the equation in Table B-1-6; however, the original reference for this equation is not identified.

This document also presents the following:

- COPC-specific Kd_s values that were used to establish a range (2 to 280,000 mL/g) of Kd_s values for inorganic COPCs
- a "relatively narrow range" for soil dry bulk density, *BD*, of 1.2 to 1.7 g/cm^3

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Waste. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends a default soil density, *BD*, value of 1.5 g/cm^3, based on a mean value for loam soil that is taken from Carsel, Parrish, Jones, Hansen, and Lamb (1988).

U.S. EPA. 1994b. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* April 15.

U.S. EPA. 1998. "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilitites." External Peer Review Draft. U.S. EPA Region 6 and U.S. EPA OSW. Volumes 1-3. EPA530-D-98-001A. July.

U.S. EPA. In Press. "*Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions*." Internal Review Draft. Environmental Criteria and Assessment Office. ORD. Cincinnati, Ohio.

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TABLE B-2-1

TOTAL COPC LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the total average water body load from wet and dry vapor and particle deposition, runoff, and erosion loads.

The limitations and uncertainties incorporated by using this equation include the following:

(1) The greatest uncertainties are associated with the site-specific variables in Tables B-2-2, B-2-3, B-2-4, B-2-5, and B-2-6 (used to estimate values for the variables in the below equation for L_T). These variables include Q, $Dywwv$, $Dytwp$, A_w, $Cywv$, A_I, A_L, Cs, and X_e. Values for many of these variables are estimated through the use of mathematical models and the uncertainties associated with values for these variables may be significant in some cases.

(2) Uncertainties associated with the remaining variables in Tables B-2-2, B-2-3, B-2-4, B-2-5, and B-2-6 are expected to be less significant, primarily because of the narrow ranges of probable values for these variables or because values for these variables (such as Kd_s) were estimated by using well-established estimation methods.

Equation

$$L_T = L_{DEP} + L_{Dif} + L_{RI} + L_R + L_E$$

Variable	Description	Units	Value
L_T	Total COPC load to the water body	g/yr	
L_{DEP}	Total (wet and dry) particle phase and wet vapor phase direct deposition load to water body	g/yr	**Varies (calculated - Table B-2-2)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-2. Uncertainties associated with this variable include the following: (1) Most of the uncertainties associated with the variables in Table B-2-2, specifically those associated with Q, $Dywwv$, $Dytwp$, and A_w, are site-specific and may be significant in some cases.

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TABLE B-2-1

TOTAL COPC LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 2 of 4)

Variable	Description	Units	Value
L_{Dif}	Vapor phase COPC diffusion (dry deposition) load to water body	g/yr	**Varies (calculated - Table B-2-3)** This variable is calculated by using the equation in Table B-2-3. Uncertainties associated with this variable include the following: (1) Most of the uncertainties associated with the variables in the equation in Table B-2-3, specifically those associated with *Q*, *Cywv*, and A_W, are site-specific and may be significant in some cases.
L_{RI}	Runoff load from impervious surfaces	g/yr	**Varies (calculated - Table B-2-4)** This variable is calculated by using the equation in Table B-2-4. Uncertainties associated with this variable include the following: (1) Most of the uncertainties associated with the variables in this equation, specifically those associated with *Q*, *Dywwv*, *Dytwp*, and A_I, are site-specific.
L_R	Runoff load from pervious surfaces	g/yr	**Varies (calculated - Table B-2-5)** This variable is calculated by using the equation in Table B-2-5. Uncertainties associated with this variable include the following: (1) Most of the uncertainties associated with the variables in the equation in Table B-2-5, specifically those for A_L, A_I, and *Cs*, are site-specific and may be significant in some cases. (2) Uncertainties associated with the remaining variable in the equation in Table B-2-5 are not expected to be significant, primarily because of the narrow ranges of probable values for these variables or the use of well-established estimation procedures (Kd_s).

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TABLE B-2-1

TOTAL COPC LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 3 of 4)

Variable	Description	Units	Value
L_E	Soil erosion load	g/yr	**Varies (calculated - Table B-2-6)** This variable is calculated by using the equation in Table B-2-6. Uncertainties associated with this variable include the following: (1) Most of the uncertainties associated with the variables in the equation in Table B-2-6, specifically those for X_e, A_L, A_I, and Cs, are site-specific and may be significant in some cases. (2) Uncertainties associated with the remaining variables in the equation in Table B-2-6 are not expected to be significant, primarily because of the narrow range of probable values for these variables or the use of well-established estimation procedures (Kd_s).

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TABLE B-2-1

TOTAL COPC LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology*. Volume 22. Number 4. Pages 361-367.

For discussion, see References and Discussion in Table B-1-1.

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TABLE B-2-2

DEPOSITION TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the average load to the water body from direct deposition of wet and dry particles and wet vapors onto the surface of the water body.

Uncertainties associated with this equation include the following:

(1) Most of the uncertainties associated with the variables in this equation, specifically those associated with Q, $Dywwv$, $Dytwp$, and A_W.
(2) It is calculated on the basis of the assumption of a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower.

Equation

$$L_{DEP} = Q \bullet [F_v \bullet Dywwv + (1 - F_v) \bullet Dytwp] \bullet A_W$$

For mercury modeling:

$$L_{DEP_{Mercury}} = 0.48 Q_{TotalMercury} \cdot [F_{v_{Hg^{2+}}} \cdot Dywwv + (1 - F_{v_{Hg^{2+}}}) \cdot Dytwp] \cdot A_w$$

In calculating L_{DEP} for mercury comounds, L_{DEP}*(Mercury)* is calculated as shown above using the total mercury emission rate (Q) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated L_{DEP}*(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 85% Hg^{2+} and 15% MHg speciation split in the water body (see Chapter 2).

$L_{DEP}(Hg^{2+})$ = 0.85 L_{DEP} *Mercury*
$L_{DEP}(MHg)$ = 0.15 L_{DEP} *Mercury*

After calculating species specific L_{DEP} values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

Variable	Description	Units	Value
L_{DEP}	Total (wet and dry) particle-phase and wet vapor phase direct deposition load to water body	g/yr	

US EPA ARCHIVE DOCUMENT

TABLE B-2-2

DEPOSITION TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This variable is COPC- and site-specific (see Chapters 2 and 3). Uncertainties associated with this variable are site-specific.
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Uncertainties associated with this variable include the following: (1) It is based on the assumption of a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable c (Junge constant) is constant for all chemicals; however, the value of c depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of c to vary, uncertainty is introduced if a constant value of c is used to calculate F_v.
Dywwv	Unitized yearly average wet deposition from vapor phase (over water body)	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Dytwp	Unitized yearly average total (wet and dry) deposition from particle phase (over water body)	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
A_W	Water body surface area	m^2	**Varies (modeled)** This variable is COPC- and site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.

US EPA ARCHIVE DOCUMENT

TABLE B-2-2

DEPOSITION TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology*. Volume 22. Number 4. Pages 361-367.

Junge, C.E. 1977. *Fate of Pollutants in Air and Water Environments, Part I*. Suffet, I.H., Ed. Wiley. New York. Pages 7-26.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is a reference source for the equation in B-2-2. This document also recommends by using the equations in Bidleman (1988) to calculate F_v values for all organics other than dioxins (PCDD/PCDFs). However, the document does not present a recommendation for dioxins. Finally, this document states that metals are generally entirely in the particulate phase ($F_v = 0$) except for mercury, which is assumed to be entirely in the vapor phase. The document does not state whether F_v for mercury should be calculated by using the equations in Bidleman (1988).

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is a reference source for the equation in Table B-2-2. This document also presents values for organic COPCs that range from 0.27 to 1. F_v values for organics other than PCDD/PCDFs are calculated by using the equations presented in Bidleman (1988). The F_v value for PCDD/PCDFs is assumed to be 0.27, based on U.S. EPA (no date). Finally, this document presents F_v values for inorganic COPCs equal to 0, based on the assumption that these COPCs are nonvolatile and assumed to be 100 percent in the particulate phase and 0 percent in the vapor phase.

US EPA ARCHIVE DOCUMENT

TABLE B-2-3

DIFFUSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the load to the water body due to dry vapor diffusion. Uncertainties associated with this equation include the following:

(1) Most of the uncertainties associated with the variables in this equation, specifically those associated with K_v, Q, Cyv, and A_w, are site-specific.
(2) This equation assumes a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower.

Equation

$$L_{Dif} = \frac{K_v \cdot Q \cdot F_v \cdot Cywv \cdot A_W \cdot 1.0\times10^{-6}}{\dfrac{H}{R \cdot T_{wk}}}$$

For mercury modeling:

$$L_{Dif_{Mercury}} = \frac{K_{v_{Hg^{2+}}} \cdot 0.48Q_{TotalMercury} \cdot F_{v_{Hg^{2+}}} \cdot Cywv \cdot A_w \cdot 1.0\times10^{-06}}{\dfrac{H_{Hg^{2+}}}{R \cdot T_{wk}}}$$

In calculating L_{Dif} for mercury comounds, L_{Dif}*(Mercury)* is calculated as shown above using the total mercury emission rate (Q) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated L_{Dif}*(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 85% Hg^{2+} and 15% MHg speciation split in the water body (see Chapter 2).

$L_{Dif}(Hg^{2+})$ = 0.85 L_{Dif} *Mercury*
$L_{Dif}(MHg)$ = 0.15 L_{Dif} *Mercury*

After calculating species specific L_{Dif} values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

US EPA ARCHIVE DOCUMENT

TABLE B-2-3

DIFFUSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
L_{Dif}	Dry vapor phase diffusion load to water body	g/yr	
K_v	Overall transfer rate coefficient	m/yr	**Varies (calculated - Table 2-13)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-13.
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This variable is COPC- and site-specific (see Chapters 2 and 3). Uncertainties associated with this variable are site--specific.
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Uncertainties associated with this variable include the following: (1) This equation assumes a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable c is constant for all chemicals; however, the value of c depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of c to vary, uncertainty is introduced if a constant value of c issued to calculate F_v.
Cywv	Unitized yearly average air concentration from vapor phase (over water body)	µg-s/g-m^3	**Varies (modeled)** This variable is COPC- and site-specific, and is determined for each water body by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.

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TABLE B-2-3

DIFFUSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 3 of 4)

Variable	Description	Units	Value
A_W	Water body surface area	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific. However, it is expected that the uncertainty associated with this variable will be limited, because maps, aerial photographs, and other resources from which water body surface areas can be measured, are readily available.
H	Henry's Law constant	atm-m^3/mol	**Varies (see Appendix A-2)** This variable is COPC-specific, and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Values for this variable, estimated by using the parameters and algorithms in Appendix A-2, may under- or overestimate the actual COPC-specific values. As a result, L_{Dif} may be under- or overestimated to a limited degree.
R	Universal gas constant	atm-m^3/mol-K	**8.205×10^{-5}**
T_{wk}	Water body temperature	K	**298** This variable is site-specific. U.S. EPA OSW recommends the use of this default value in the absence of site-specific information, consistent with U.S. EPA (1993 and 1994). The following uncertainty is associated with this variable: (1) To the extent that the default water body temperature value does not accurately represent site-specific or local conditions, L_{Dif} will be under- or overestimated.

US EPA ARCHIVE DOCUMENT

TABLE B-2-3

DIFFUSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Bidleman, T.F. 1988. *"Atmospheric Processes." Environmental Science and Technology.* Volume 22. Number 4. Pages 361-367.

NC DEHNR. 1997. NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units. January.

This document is a reference source for the equation in Table B-2-3. This document also recommends using the equations in Bidleman (1988) to calculate F_v values for all organics other than dioxins (PCDD/PCDFs).

U.S. EPA. 1993. *Addendum to Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Solid Waste and Office Research and Development. Washington, D.C. November 10.

This document recommends a range (10°C to 30°C, 283 K to 303 K) for water body temperature, T_{wk}. No source was identified for this range.

U.S. EPA 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities.* Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is cited as the reference source for $T_{wk,}$ water body temperature (298 K); however, no references or sources are identified for this value. This document is a reference source for the equation in Table B-2-2.

US EPA ARCHIVE DOCUMENT

TABLE B-2-4

IMPERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the average runoff load to the water body from impervious surfaces in the watershed from which runoff is conveyed directly to the water body.

Uncertainties associated with this equation include the following:

(1) Most of the uncertainties associated with the variables in this equation, specifically those associated with *Q*, *Dywwv*, *Dytwp*, and A_I, are site-specific.
(2) The equation assumes a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower.

Equation

$$L_{RI} = Q \cdot \left[F_v \cdot Dywwv + (1 - F_v) \cdot Dytwp \right] \cdot A_I$$

For mercury modeling:

$$L_{RI_{Mercury}} = 0.48 Q_{TotalMercury} \cdot \left[F_{v_{Hg^{2+}}} \cdot Dywwv + (1.0 - F_{v_{Hg^{2+}}}) \cdot Dytwp \right] \cdot A_I$$

In calculating L_{RIP} for mercury comounds, L_{RI}*(Mercury)* is calculated as shown above using the total mercury emission rate (*Q*) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated L_{RI}*(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 85% Hg^{2+} and 15% MHg speciation split in the water body (see Chapter 2).

$L_{RI}(Hg^{2+})$ = 0.85 L_{RI} *Mercury*
L_{RI}(MHg) = 0.15 L_{RI} *Mercury*

After calculating species specific L_{RI} values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

US EPA ARCHIVE DOCUMENT

TABLE B-2-4

IMPERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
L_{RI}	Runoff load from impervious surfaces	g/yr	
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapters 2 and 3). Uncertainties associated with this variable are site-specific.
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Uncertainties associated with this variable include the following: (1) The equation assumes a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable c is constant for all chemicals; however, the value of c depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of c to vary, uncertainty is introduced if a constant value of c is used to calculate F_v.
Dywwv	Unitized yearly average wet deposition from vapor phase (over watershed)	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Dytwp	Unitized yearly average total (wet and dry) deposition from particle phase (over watershed)	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
A_I	Impervious watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is COPC- and site-specific. Uncertainties associated with this variable are site-specific.

US EPA ARCHIVE DOCUMENT

TABLE B-2-4

IMPERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology.* Volume 22. Number 4. Pages 361-367.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is a reference source for the equation in Table B-2-4. This document also recommends using the equations in Bidleman (1988) to calculate F_v values for all organics other than dioxins (PCDD/PCDFs). However, the document does not present a recommendation for dioxins. Finally, this document states that metals are generally entirely in the particulate phase ($F_v = 0$) except for mercury, which is assumed to be entirely in the vapor phase. The document does not state whether F_v for mercury should be calculated by using the equations in Bidleman (1988).

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is a reference source for the equation in Table B-2-4.

US EPA ARCHIVE DOCUMENT

TABLE B-2-5

PERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the average runoff load to the water body from pervious soil surfaces in the watershed.

Uncertainties associated with this equation include the following:

(1) To the extent that site-specific or local average annual surface runoff information is not available, default or estimated values may not accurately represent site-specific or local conditions. As a result, L_R may be under- or overestimated to an unknown degree.
(2) The recommended range of soil bulk density values may not accurately represent site-specific soil conditions; specifically, this range may under- or overestimate site-specific soil conditions to an unknown degree.
(3) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, L_R may be under- or overestimated to a small extent, based on the limited range of values.
(4) Various uncertainties are associated with Cs; see the equation in Table B-1-1.

Equation

$$L_R = RO \cdot \left(A_L - A_I\right) \cdot \frac{Cs \cdot BD}{\theta_{sw} + Kd_s \cdot BD} \cdot 0.01$$

For mercury modeling:

For mercury modeling, $L_{R\,(Initial)}$ values are calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective Cs and Kd_s values; then as indicated below, these values are apportioned based on a 85% Hg^{2+} and 15% MHg speciation split in the water body (see Chapter 2).

$$L_{R_{Hg^{2+}}} = L_{R_{Hg^{2+}\,(Initial)}} \cdot 0.85$$

$$L_{R_{MHg}} = L_{R_{MHg\,(Initial)}} + (L_{R_{Hg^{2+}\,(Initial)}} \cdot 0.15)$$

After calculating species specific L_R values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

US EPA ARCHIVE DOCUMENT

TABLE B-2-5

PERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
L_R	Runoff load from pervious surfaces	g/yr	
RO	Average annual surface runoff	cm/yr	**Varies (site-specific)** This variable is site-specific. According to U.S. EPA (1993), U.S. EPA (1994), and NC DEHNR (1997), average annual surface runoff can be estimated by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973). According to NC DEHNR, (1997), more detailed, site-specific procedures for estimating the amount of surface runoff, such as those based on the U.S. Soil Conservation Service CNE may also be used. U.S. EPA (1985) is cited as an example of such a procedure. The following uncertainty is associated with this variable: (1) To the extent that site-specific or local average annual surface runoff information is not available, default or estimated values may not accurately represent site-specific or local conditions. As a result, K_R may be under- or overestimated to an unknown degree.
A_L	Total watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.
A_I	Impervious watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.
Cs	COPC concentration in soil	mg/kg	**Varies (calculated - Table B-1-1)** This value is COPC-and site-specific and should be calculated using the equation in Table B-1-1. For calculation of *Cs* in watersheds, the maximum or average of air parameter values at receptor grid nodes located within the watershed may be used (see Chapter 4). Uncertainties associated with this variable are site-specific.

US EPA ARCHIVE DOCUMENT

TABLE B-2-5

PERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized in U.S. EPA (1990). A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994) recommended a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3. The following uncertainty is associated with this variable: (1) The recommended range of soil dry bulk density values may not accurately represent site-specific soil conditions.
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure. θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point, if a representative watershed soil can be identified. However, U.S. EPA OSW recommends the use of 0.2 mL/cm^3 as a default value. This value is the midpoint of the range 0.1 (very sandy soils) to 0.3 (heavy loam/clay soils) recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, L_R may be under- or overestimated to a small extent, based on the limited range of values.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are calculated as described in Appendix A-2.
0.01	Units conversion factor	$kg\text{-}cm^2/mg\text{-}m^2$	

US EPA ARCHIVE DOCUMENT

TABLE B-2-5

PERVIOUS RUNOFF LOAD TO WATER BODY (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Volume 2: pages 11-24.

Geraghty, J.J., D.W Miller, F. Van der Leeden, and F.L. Troise. 1973. *Water Atlas of the United States*. Water Information Center. Port Washington, New York.

This document is cited by U.S. EPA (1993), U.S. EPA (1994), and NC DEHNR (1997) as a reference for calculating average annual runoff, *RO*. Specifically, this reference provides maps with isolines of annual average surface water runoff, which is defined as all flow contributions to surface water bodies, including direct runoff, shallow interflow, and ground water recharge. Because these volumes are total contributions and not only surface runoff, U.S. EPA (1994) notes that they need to be reduced to estimate surface runoff. U.S. EPA (1994) recommends a reduction of 50 percent.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Pres, Inc. New York.

This document is cited by U.S. EPA (1990) for the statement that dry soil bulk density, *BD*, is affected by soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84 g/cm^3.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Assessments for Hazardous Waste Combustion Units*. January.

This document is one of the source documented that cites the use of the equation in Table B-2-5. However, the document is not the original source of this equation. This document also recommends the following:

- Estimation of average annual runoff, *RO* (cm/yr), by using the *Water Atlas of the United States* (Geraghty, Miller, Van der Leeden, and Troise 1973) or site-specific procedures, such as the U.S. Soil Conservation Service CNE; U.S. EPA (1985) is cited as an example of the use of the CNE
- A default value of 0.2 cm^3/cm^3 for soil volumetric content (θ_{sw})

U.S. EPA. 1985. *Water Quality Assessment: A Screening Procedures for Toxic and Conventional Pollutants in Surface and Ground Water - Part I (Revised - 1985)*. Environmental Research Laboratory. Athens, Georgia. EPA/600/6-85/002a. September.

US EPA ARCHIVE DOCUMENT

TABLE B-2-5

PERVIOUS RUNOFF LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document cites Hillel (1980) for the statement that only soil bulk density, *BD*, is affected by the soil structure, such as loosened or compaction of the soil, depending on the water and clay content of the soil.

U.S. EPA. 1993. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is a source of COPC-specific (inorganics only) Kd_s values used to develop a range (2 to 280,000 mL/g) of Kd_s values. This document also recommends a range of soil volumetric water content (θ_{sw}) of 0.1 cm^3/cm^3 (very sandy soils) to 0.3 cm^3/cm^3 (heavy loam/clay soils); however, no source or reference is provided for this range.

U.S. EPA. 1994. *Revised Draft Guidance of Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes*. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends (1) a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988), and (2) a default soil volumetric water content, θ_{sw}, value of 0.2 cm^3/cm^3, based on U.S. EPA (1993).

US EPA ARCHIVE DOCUMENT

TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the load to the water body from soil erosion.

Uncertainties associated with this equation include the following:

(1) Most of the uncertainties associated with the variables, specifically those for X_e, A_L, A_I, and Cs, are site-specific.
(2) Uncertainties associated with the remaining variables are not expected to be significant, primarily because of the narrow ranges of probable values for these variables or the use of well-established estimation procedures (Kd_s).

Equation

$$L_E = X_e \cdot (A_L - A_I) \cdot SD \cdot ER \cdot \frac{Cs \cdot Kd_s \cdot BD}{\theta_{sw} + Kd_s \cdot BD} \cdot 0.001$$

For mercury modeling:

For mercury modeling, $L_{E\ (Initial)}$ values are calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective Cs and Kd_s values; then as indicated below, these values are apportioned based on a 85% Hg^{2+} and 15% MHg speciation split in the water body (see Chapter 2).

$$L_{E_{Hg^{2+}}} = L_{E_{Hg^{2+}\ (Initial)}} \cdot 0.85$$

$$L_{E_{MHg}} = L_{E_{MHg\ (Initial)}} + (L_{E_{Hg^{2+}\ (Initial)}} \cdot 0.15)$$

After calculating species specific L_E values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

US EPA ARCHIVE DOCUMENT

TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
L_E	Soil erosion load	g/yr	
X_e	Unit soil loss	kg/m^2-yr	**Varies (calculated - Table B-2-7)** This variable is site-specific, and is calculated by using the equation in Table B-2-7. The following uncertainty is associated with this variable: (1) All of the equation variables (see Table B-2-7) are site-specific. Use of default values rather than site-specific values, for any or all or these variables, will result in estimates of unit soil loss, X_e, that are under- or overestimated to some degree. The range of X_e calculated on the basis of default values spans slightly more than one order of magnitude (0.6 to 36.3 kg/m^2-yr).
A_L	Total watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.
A_I	Impervious watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.
SD	Sediment delivery ratio	unitless	**Varies (calculated - Table B-2-8)** This value is site-specific and is calculated by using the equation in Table B-2-8. The following uncertainty is associated with this variable: (1) The recommended default values for the variables a and b (empirical intercept coefficient and empirical slope coefficient, respectively) are average values, based on a review of sediment yields from various watersheds. These default values may not accurately represent site-specific watershed conditions and, therefore, may contribute to the under- or over estimation of L_E.

US EPA ARCHIVE DOCUMENT

TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
ER	Soil enrichment ratio	unitless	**1 to 3** **Inorganic COPCs: 1** **Organic COPCs: 3** COPC enrichment occurs because lighter soil particles erode more than heavier soil particles and concentrations of organic COPCs which is a function of organic carbon content of sorbing media, are expected to be higher in eroded material than in-situ soil (U.S. EPA 1993). In the absence of site-specific data, U.S. EPA OSW recommends a default value of 3 for organic COPCs and 1 for inorganic COPCs. This is consistent with other U.S. EPA guidance (1993), which recommends a range of 1 to 5 and a value of 3 as a "reasonable first estimate". This range has been used for organic matter, phosphorus, and other soil-bound COPCs (U.S. EPA 1993); however, no sources or references were provided for this range. *ER* is generally higher in sandy soils than in silty or loamy soils (U.S. EPA 1993). The following uncertainty is associated with this variable: (1) The default *ER* value may not accurately reflect site-specific conditions; therefore, L_E may be over- or underestimated to an unknown, but relatively small, extent.
Cs	COPC concentration in soil	mg/kg	**Varies (calculated - Table B-1-1)** This value is COPC-and site-specific and should be calculated using the equation in Table B-1-1. For calculation of *Cs* in watersheds, the maximum or average of air parameter values at receptor grid nodes located within the watershed may be used (see Chapter 4). Uncertainties associated with this variable are site-specific.
Kd_s	Soil-water partition coefficient	cm^3/g	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Uncertainties associated with this parameter will be limited if Kd_s values are calculated as described in Appendix A-2.

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TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
BD	Soil bulk density	g/cm^3	**1.5** This variable is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil (Hillel 1980), as summarized in U.S. EPA (1990). A range of 0.83 to 1.84 was originally cited in Hoffman and Baes (1979). U.S. EPA (1994a) recommended a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988). The value of 1.5 g/cm^3 also represents the midpoint of the "relatively narrow range" for *BD* of 1.2 to 1.7 g/cm^3. The following uncertainty is associated with this variable: (1) The recommended range of soil dry bulk density values may not accurately represent site-specific soil conditions.
θ_{sw}	Soil volumetric water content	mL/cm^3	**0.2** This variable depends on the available water and on soil structure. θ_{sw} can be estimated as the midpoint between a soil's field capacity and wilting point, if a representative watershed soil can be identified. However, U.S. EPA OSW recommends the use of 0.2 cm^3 as a default value. This value is the midpoint of the range of 0.1 (very sandy soils), to 0.3 (heavy loam/clay soils), recommended by U.S. EPA (1993) (no source or reference is provided for this range) and is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The default θ_{sw} values may not accurately reflect site-specific or local conditions; therefore, L_E may be under- or overestimated to a small extent, based on the limited range of values.
0.001	Units conversion factor	g/mg	

US EPA ARCHIVE DOCUMENT

TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

Carsel, R.F., R.S. Parrish, R.L. Jones, J.L. Hansen, and R.L. Lamb. 1988. "Characterizing the Uncertainty of Pesticide Leaching in Agricultural Soils." *Journal of Contaminant Hydrology*. Volume 2. Pages 11-24.

This document is the source for a mean soil bulk density of 1.5 cm^3 for loam soil.

Hillel, D. 1980. *Fundamentals of Soil Physics*. Academic Press, Inc. New York.

This document is cited by U.S. EPA (1990) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

Hoffman, F.O., and C.F. Baes. 1979. *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*. ORNL/NUREG/TM-882.

This document presents a soil bulk density, *BD*, range of 0.83 to 1.84 g/cm^3.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is cited as one of the sources for the range of *BD* and Kd_s values, and the default value for the volumetric soil water content.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600-90-003. January.

This document cites Hillel (1980) for the statement that dry soil bulk density, *BD*, is affected by the soil structure, such as looseness or compaction of the soil, depending on the water and clay content of the soil.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November 1993.

This document is the source of the recommended range of COPC enrichment ratio, *ER*, values. This range, 1 to 5, has been used for organic matter, phosphorous, and other soil-based COPCs. This document recommends a value of 3 as a "reasonable first estimate," and states that COPC enrichment occurs because lighter soil particles erode more than heavier soil particles. Lighter soil particles have higher surface-area-to-volume ratios and are higher in organic matter content. Therefore, concentrations of organic COPCs, which are a function of the organic carbon content of sorbing media, are expected to be higher in eroded material than in in-situ soil.

This document is also the source of the following:

- COPC-specific (inorganics only) Kd_s values used to develop a proposed range (0 to 280,000 mL/g) of Kd_s values

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TABLE B-2-6

EROSION LOAD TO WATER BODY
(SURFACE WATER AND SEDIMENT EQUATIONS)

- A range of soil volumetric water content (θ_{sw}) values of 0.1 mL/cm^3 (very gravelly soils) to 0.3 mL/cm^3 (heavy loam/clay soils); however, no source or reference is provided for this range.

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes.* Attachment C, *Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends (1) a default soil bulk density value of 1.5 g/cm^3, based on a mean value for loam soil from Carsel, Parrish, Jones, Hansen, and Lamb (1988), and (2) a default soil volumetric water content, θ_{sw}, value of 0.2 cm^3, based on U.S. EPA (1993).

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TABLE B-2-7

UNIVERSAL SOIL LOSS EQUATION (USLE)
(SOIL EQUATIONS)

Description

This equation calculates the soil loss rate from the watershed by using the Universal Soil Loss Equation (USLE); the result is used in the soil erosion load equation in Table B-2-6. Estimates of unit soil loss, X_e, should be determined specific to each watershed evaluated. Information on determining site- and watershed-specific values for variables used in calculating X_e is provided in U.S. Department of Agriculture (U.S. Department of Agriculture 1997) and U.S. EPA guidance (U.S. EPA 1985). Uncertainties associated with this equation include the following:

(1) All of the equation variables are site-specific. Use of site-specific values will result in estimates of unit soil loss, X_e, that are under- or overestimated to some unknown degree.

Equation

$$X_e = RF \cdot K \cdot LS \cdot C \cdot PF \cdot \frac{907.18}{4047}$$

Variable	Description	Units	Value
X_e	Unit soil loss	kg/m^2-yr	
RF	USLE rainfall (or erosivity) factor	yr^{-1}	**50 to 300 (site-specific)** This value is site-specific and is derived on a storm-by-storm basis. As cited in U.S. EPA (1993b), average annual values have been compiled regionally by Wischmeier and Smith (1978). The recommended range reflects these compiled values. The following uncertainty is associated with this variable: (1) The range of average annual rainfall factors (50 to 300) from Wischmeier and Smith (1978) may not accurately reflect site-specific conditions. Therefore, unit soil loss, X_e, may be under- or overestimated.

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TABLE B-2-7

UNIVERSAL SOIL LOSS EQUATION (USLE)
(SOIL EQUATIONS)

(Page 2 of 5)

Variable	Description	Units	Value
K	USLE erodibility factor	ton/acre	**Varies** This value is site-specific. U.S. EPA OSW recommends the use of current guidance (U.S. Department of Agriculture 1997; U.S. EPA 1985) in determining watershed-specific values for this variable based on site-specific information. A default value of 0.36, as cited in U.S. EPA (1994), was based on a soil organic matter content of 1 percent (Droppo, Strenge, Buck, Hoopes, Brockhaus, Walter, and Whelan 1989), and chosen to be representative of a whole watershed. The following uncertainty is associated with this variable: (1) The determination and use of site-specific values for the USLE soil erodibility factor, *K*, may not accurately represent site-specific conditions. Therefore, use of this value may cause unit soil loss, X_e, to be under- or overestimated.
LS	USLE length-slope factor	unitless	**Varies** This value is site-specific. U.S. EPA OSW recommends the use of current guidance (U.S. Department of Agriculture 1997; U.S. EPA 1985) in determining watershed-specific values for this variable based on site-specific information. A value of 1.5, as cited in U.S. EPA (1994), reflects a variety of possible distance and slope conditions (U.S. EPA 1988), and was chosen to be representative of a whole watershed. The following uncertainty is associated with this variable: (1) The determination and use of site-specific values for the USLE length-slope factor, *LS*, may not accurately represent site-specific conditions. Therefore, use of this value may cause unit soil loss, X_e, to be under- or overestimated.

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TABLE B-2-7

UNIVERSAL SOIL LOSS EQUATION (USLE)
(SOIL EQUATIONS)

(Page 3 of 5)

Variable	Description	Units	Value
C	USLE cover management factor	unitless	**Varies** This value is site-specific. U.S. EPA OSW recommends the use of current guidance (U.S. Department of Agriculture 1997; U.S. EPA 1985) in determining watershed-specific values for this variable based on site-specific information. The range of values up to 0.1 reflect dense vegetative cover, such as pasture grass; values from 0.1 to 0.7 reflect agricultural row crops; and a value of 1.0 reflects bare soil (U.S. EPA 1993b). U.S. EPA (1993a) recommended a value of 0.1 for both grass and agricultural crops. This range of values was also cited in NC DEHNR (1997). However, U.S. EPA (1994) and NC DEHNR (1997) both recommend a default value of 0.1 to be representative of a whole watershed. The following uncertainty is associated with this variable: (1) The determination and use of site-specific values for USLE cover management factor, *C*, may not accurately represent site-specific conditions. Therefore, use of default value for *C* may result in the under- or overestimation of unit soil loss, X_e.
PF	USLE supporting practice factor	unitless	**Varies** This value is site-specific. U.S. EPA OSW recommends the use of current guidance (U.S. Department of Agriculture 1997; U.S. EPA 1985) in determining watershed-specific values for this variable based on site-specific information. A default value of 1.0, which conservatively represents the absence of any erosion or runoff control measures, was cited in U.S. EPA (1993a; 1994) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) The determination and use of site-specific values for the USLE supporting practice factor, *PF*, may not accurately represent site-specific conditions. Therefore, resulting in the under- or overestimation of unit soil loss, X_e.
907.18	Conversion factor	kg/ton	
4047	Conversion factor	m^2/acre	

US EPA ARCHIVE DOCUMENT

TABLE B-2-7

UNIVERSAL SOIL LOSS EQUATION (USLE)
(SOIL EQUATIONS)

REFERENCES AND DISCUSSION

Droppo, J.G. Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance: Volume 2-Guidelines for Evaluating MEPAS Input Parameters*. Pacific Northwest Laboratory. Richland, Washington. December.

This document is cited by U.S. EPA 1994 and NC DEHNR 1997 as the reference source for the default USLE erodibility factor value of 0.36, based on a soil organic matter content of 1 percent.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document recommends the following:

- A USLE erodibility factor, *K*, value of 0.36 ton/acre
- A USLE length-slope factor, *LS*, value of 1.5 (unitless)
- A range of USLE cover management factor, *C*, values of 0.1 to 1; it also recommends a default value of 0.1 to be representative of a whole watershed, not just an agricultural field.
- A USLE supporting practice factor, *P*, value of 1

U.S. Department of Agriculture. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)*. Agricultural Research Service, Agriculture Handbook Number 703. January.

U.S. EPA. 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water—Part I (Revised).* ORD. Athens, Georgia. EPA/600/6-85/002a.

U.S. EPA. 1988. *Superfund Exposure Assessment Manual*. Office of Solid Waste. Washington, D.C. April.

This document is cited by U.S. EPA 1994 and NC DEHNR 1997 as the reference source for the USLE length-slope factor value of 1.5. This value reflects a variety of possible distance and slope conditions and was chosen to be representative of a whole watershed, not just an agricultural field.

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions. Working Group Recommendations*. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document cites Wischmeier and Smith (1978) as the source of average annual USLE rainfall factors, *RF*, and states that annual values range from less than 50 for the arid western United States to greater than 300 for the southeast.

This document also recommends the following:

- A USLE cover management factor, *C*, of 0.1 for both grass and agricultural crops
- A USLE supporting practice factor, *P*, of 1, based on the assumed absence of any erosion or runoff control measures

US EPA ARCHIVE DOCUMENT

TABLE B-2-7

UNIVERSAL SOIL LOSS EQUATION (USLE)
(SOIL EQUATIONS)

U.S. EPA. 1993b. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustion Emissions.* Office of Health and Environmental Assessment. Office of Research and Development. EPA-600-AP-93-003. November 10.

This document discusses the USLE cover management factor. This factor, *C*, primarily reflects how erosion is influenced by vegetative cover and cropping practices, such as planting across slope rather than up and down slope. This document discusses a range of *C* values for 0.1 to 1; values greater than 0.1 but less than 0.2 are appropriate for agricultural row crops, and a value of 1 is appropriate for sites mostly devoid of vegetation.

U.S. EPA. 1994. *Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes.* Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document recommends the following:

- A USLE erodibility factor, *K*, value of 0.36 ton/acre
- A USLE length-slope factor, *LS*, value of 1.5 (unitless)
- A range of USLE cover management factor, *C*, values of 0.1 to 1; it recommends a default value of 0.1 to be representative of a whole watershed, not just an agricultural field.
- A USLE supporting practice factor, *P*, value of 1

Wischmeire, W.H., and D.D. Smith. 1978. *Predicting Rainfall Erosion Losses—A Guide to Conservation Planning.* Agricultural Handbook No. 537. U.S. Department of Agriculture Washington, D.C.

This document is cited by U.S. EPA (1993) as the source of average annual USLE rainfall factors, *RF*, compiled regionally. According to U.S. EPA (1993), annual values range from less than 50 for the arid western United States to greater than 300 for the southeast.

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TABLE B-2-8

SEDIMENT DELIVERY RATIO
(SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the sediment delivery ratio for the watershed. The result is used in the soil erosion load equation.

Uncertainties associated with this equation include the following:

(1) The recommended default empirical intercept coefficient, *a*, values are average values based on various studies of sediment yields from various watersheds. Therefore, these default values may not accurately represent site-specific watershed conditions. As a result, use of these default values may under- or overestimate the watershed sediment delivery ratio, *SD*.

(2) The recommended default empirical slope coefficient, *b*, value is based on a review of sediment yields from various watersheds. This single default value may not accurately represent site-specific watershed conditions. As a result, use of this default value may under- or overestimate the watershed sediment delivery ratio, *SD*.

Equation

$$SD = a \cdot (A_L)^{-b}$$

Variable	Description	Units	Value
SD	Watershed sediment delivery ratio	unitless	

US EPA ARCHIVE DOCUMENT

TABLE B-2-8

SEDIMENT DELIVERY RATIO
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
a	Empirical intercept coefficient	unitless	**0.6 to 2.1 (depends on watershed area)** This variable is site-specific and is determined on the basis of the watershed area (Vanoni 1975), as cited in U.S. EPA (1993): Watershed Area (sq. miles) / "*a*" Coefficient (unitless) ≤0.1 / 2.1 >0.1 but ≤ 1 / 1.9 >1 but ≤ 10 / 1.4 >10 but ≤ 100 / 1.2 >100 / 0.6 Note: 1 sq. mile = 2.59×10^6 m^2 The use of these values is consistent with U.S. EPA (1994a and 1994b) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) The recommended default empirical intercept coefficient, *a*, values are average values based on various studies of sediment yields from various watersheds. Therefore, these default values may not accurately represent site-specific watershed conditions. As a result, use of these default values may under- or overestimate the watershed sediment delivery ratio, *SD*.
A_L	Watershed area receiving COPC deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.

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TABLE B-2-8

SEDIMENT DELIVERY RATIO
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 3 of 4)

Variable	Description	Units	Value
b	Empirical slope coefficient	unitless	**0.125** As cited in U.S. EPA (1993), this variable is an empirical constant based on the research of Vanoni (1975), which concludes that sediment delivery ratios vary approximately with the -(1/8) power of the drainage area. The use of this value is consistent with U.S. EPA (1994a and 1994b) and NC DEHNR (1997). U.S. EPA has not completed its review of Vanoni (1975). The following uncertainty is associated with this variable: (1) The recommended default empirical slope coefficient, *b*, value is based on a review of sediment yields from various watersheds. This single default value may not accurately represent site-specific watershed conditions. As a result, use of this default value may under- or overestimate the watershed sediment delivery ratio, *SD*.

US EPA ARCHIVE DOCUMENT

TABLE B-2-8

SEDIMENT DELIVERY RATIO
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is cited as one of the reference source documents for the empirical intercept coefficient, *a*, and empirical slope coefficient, *b*, values. This document cites U.S. EPA (1993) as the source of its information.

U.S. EPA. 1993. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November.

This document is cited as one of the reference source documents for the empirical intercept coefficient, *a*, and empirical slope coefficient, *b*, values. This document cites Vanoni (1975) as its source of information.

U.S. EPA. 1994a. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the reference source documents for the empirical intercept coefficient, *a*, and empirical slope coefficient, *b*, values. This document does not identify Vanoni (1975) as the source of its information.

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is cited as one of the reference source documents for the empirical intercept coefficient, *a*, and the empirical slope coefficient, *b*, values. This document cites U.S. EPA (1993) as the source of its information.

Vanoni, V.A. 1975. *Sedimentation Engineering*. American Society of Civil Engineers. New York, New York. Pages 460-463.

This document is cited by U.S. EPA (1993) as the source of the equation in Table B-2-8 and the empirical intercept coefficient, *a*, and empirical slope coefficient, *b*, values. Based on various studies of sediment yields from watersheds, this document concludes that the sediment delivery ratios vary approximately with the -(1/8) power of the drainage ratio.

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TABLE B-2-9

TOTAL WATER BODY CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the total water body concentration; including the water column and the bed sediment.

Uncertainties associated with this equation include the following:

(1) The default variable values recommended for use in the equation in Table B-2-9 may not accurately represent site-specific water body conditions. The degree of uncertainty associated with the variables Vf_x, A_w, d_{wc}, *and* d_{bs} is expected to be limited either because the probable ranges for these variables are narrow or information allowing accurate estimates is generally available.

(2) Uncertainty associated with f_{wc} is largely the result of uncertainty associated with default organic carbon (*OC*) content values and may be significant in specific instances. Uncertainties associated with the total core load into water body (L_T) and overall total water body core dissipation rate constant (k_{wt}) may also be significant in some instances because of the summation of many variable-specific uncertainties.

Equation

$$C_{wtot} = \frac{L_T}{Vf_x \cdot f_{wc} + k_{wt} \cdot A_W \cdot \left(d_{wc} + d_{bs}\right)}$$

For mercury modeling:

Total water body concentration is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective L_T values, f_{wc} values, and k_{wt} values.

Variable	Description	Units	Value
C_{wtot}	Total water body COPC concentration (including water column and bed sediment)	g/m^3 (equivalent to mg/L)	
L_T	Total COPC load to the water body (including deposition, runoff, and erosion)	g/yr	**Varies (calculated - Table B-2-1)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-1. Uncertainties associated with L_{DEP}, L_{Dif}, L_{RI}, L_R, *and* L_E, as presented in Table B-2-1, are also associated with L_T.

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TABLE B-2-9

TOTAL WATER BODY CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
Vf_x	Average volumetric flow rate through water body	m^3/yr	**Varies (site-specific)** This variable is site-specific and should be an annual average. The following uncertainty is associated with this variable: (1) Use of default average volumetric flow rate (Vf_x) information may not accurately represent site-specific conditions, especially for those water bodies for which flow rate information is not readily available. Therefore, use of default Vf_x values may contribute to the under- or overestimation of total water body COPC concentration, C_{wtot}.
f_{wc}	Fraction of total water body COPC concentration that occurs in the water column	unitless	**0 to 1 (calculated - Table B-2-10)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. The following uncertainty is associated with this variable: (1) The default values for the variables in the equation in Table B-2-10 may not accurately represent site- and water body - specific conditions. However, the range of several variables—including d_{bs}, C_{BS}, *and* θ_{bs}—is relatively narrow. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information. The largest degree of uncertainty may be introduced by the default medium-specific organic carbon (*OC*) content values. Because *OC* content values may vary widely in different locations in the same medium, by using default values may result in insignificant uncertainty in specific cases.
k_{wt}	Overall total water body COPC dissipation rate constant	yr^{-1}	**Varies (calculated - Table B-2-11)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-11. The following uncertainty is associated with this variable: (1) All of the variables in the equation in Table B-2-11 are site-specific; therefore, the use of default values for any or all of these variables will contribute to the under- or overestimation of C_{wtot}. The degree of uncertainty associated with the variable k_b is expected to be under one order of magnitude and is associated largely with the estimation of the unit soil loss, X_e, values for the variables f_{wc}, k_v, and f_{bs} are dependent on medium-specific estimates of *OC* content. Because *OC* content can vary widely for different locations in the same medium, uncertainty associated with these three may be significant in specific instances.

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TABLE B-2-9

TOTAL WATER BODY CONCENTRATION
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 3 of 4)

Variable	Description	Units	Value
A_W	Water body surface area	m^2 (average value for the entire year)	**Varies (site-specific)** This variable is site-specific (see Chapter 4). The value selected is assumed to represent an average value for the entire year. Uncertainties associated with this variable are site-specific and expected to be limited, because maps, aerial photographs, and other resources from which water body surface areas can be measured, are readily available.
d_{wc}	Depth of water column	m (average value for the entire year)	**Varies (site-specific)** This variable is site-specific and should be an average annual value. The following uncertainty is associated with this variable: (1) Use of default depth of water column, d_{wc}, values may not accurately reflect site-specific conditions, especially for those water bodies for which depth of water column information is unavailable or outdated. Therefore, use of default d_{wc} values may contribute to the under-or overestimation of total water body COPC concentration, C_{wtot}.
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. The value selected is assumed to represent an average value for the entire year. U.S. EPA OSW recommends a default upper benthic sediment depth of 0.03 meter, which is consistent with U.S. EPA (1994) and NC DEHNR (1997) guidance. This range was cited by U.S. EPA (1993); however, no reference was cited for this range. The following uncertainty is associated with this variable: (1) Use of default depth of upper benthic layer, d_{bs}, values may not accurately represent site-specific water body conditions. However, based on the narrow recommended range, any uncertainty introduced is expected to be limited.

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TABLE B-2-9

TOTAL WATER BODY CONCENTRATION
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is also cited as one of the reference source documents for the default depth of upper benthic layer value. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993) as its source of information for the range of values for the depth of the upper benthic layer.

U.S. EPA. 1993. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by NC DEHNR (1997) and U.S. EPA (1994) as the source of the range and default value for the depth of the upper benthic layer (d_{bs}).

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the reference source documents for the default depth of the upper benthic layer value. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993) as its source of information for the range of values for the depth of the upper benthic layer.

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TABLE B-2-10

FRACTION IN WATER COLUMN AND BENTHIC SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the fraction of total water body concentration occurring in the water column and the bed sediments.

Uncertainties associated with this equation include the following:

(1) The default variable values may not accurately represent site-specific water body conditions. However, the range of several variables—including d_{bs}, BS, and θ_{bs}—is relatively narrow. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information. The largest degree of uncertainty may be introduced by the default medium-specific OC content values. OC content values can vary widely for different locations in the same medium. Therefore, the use of default values may introduce significant uncertainty in some cases.

Equations

$$f_{wc} = \frac{(1 + Kd_{sw} \cdot TSS \cdot 10^{-6}) \cdot d_{wc}/d_z}{(1 + Kd_{sw} \cdot TSS \cdot 1x10^{-6}) \cdot d_{wc}/d_z + (\theta_{bs} + Kd_{bs} \cdot BS) \cdot d_{bs}/d_z}$$

$$f_{bs} = 1 - f_{wc}$$

For mercury modeling:

The fraction in water column (f_{wc}) is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective Kd_{sw} values and Kd_{bs} values.
The fraction in benthic sediment (f_{bs}) is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective f_{wc} values.

Variable	Description	Units	Value
f_{wc}	Fraction of total water body COPC concentration in the water column	unitless	
f_{bs}	Fraction of total water body COPC concentration in the benthic sediment	unitless	

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TABLE B-2-10

FRACTION IN WATER COLUMN AND BENTHIC SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
Kd_{sw}	Suspended sediments/surface water partition coefficient	L/kg	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) The Kd_{sw} values in Appendix A-2 are based on default *OC* contents for surface water and soil. Kd_{sw} values based on default values may not accurately reflect site- and water body-specific conditions and may under- or overestimate actual Kd_{sw} values. Uncertainty associated with this variable will be reduced if site-specific and medium-specific *OC* estimates are used to calculate Kd_{sw}.
TSS	Total suspended solids concentration	mg/L	**2 to 300** This variable is site-specific. U.S. EPA OSW recommends the use of site- and waterbody specific measured values, representative of long-term average annual values for the water body of concern (see Chapter 3). A value of 10 mg/L was cited by NC DEHNR (1997), U.S. EPA (1993a), and U.S. EPA (1993b) in the absense of site-specific measured data. The following uncertainty is associated with this variable: Limitation on measured data used for determining a water body specific total suspended solids (*TSS*) value may not accurately reflect site- and water body-specific conditions long term. Therefore, the *TSS* value may contribute to the under-or overestimation of f_{wc}.
10^{-6}	Units conversion factor	kg/mg	
d_{wc}	Depth of water column	m	**Varies (site-specific)** This variable is site-specific and should be an average annual value. The following uncertainty is associated with this variable: (1) Use of default depth of water column, d_{wc}, values may not accurately reflect site-specific conditions, especially for those water bodies for which depth of water column information is unavailable or outdated. Therefore, use of default d_{wc} values may contribute to the under- or overestimation of total water body COPC concentration, C_{wtot}.

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TABLE B-2-10

FRACTION IN WATER COLUMN AND BENTHIC SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. U.S. EPA OSW recommends a default upper benthic sediment depth of 0.03 meter, which is consistent with U.S. EPA (1994) and NC DEHNR (1997) guidance. This range was cited by U.S. EPA (1993b); however, no reference was cited for this range. The following uncertainty is associated with this variable: (1) Use of default depth of upper benthic layer, d_{bs}, values may not accurately represent site-specific water body conditions. However, any uncertainly introduced is expected to be limited on the basis of the narrow recommended range.
d_z	Total water body depth	m	**Varies (calculated)** This variable is site-specific. U.S. EPA OSW recommends that the following equation be used to calculate total water body depth, consistent with NC DEHNR (1997): $d_z = d_{wc} + d_{bs}$ The following uncertainty is associated with this variable: (1) Calculation of this variable combines the concentrations associated with the two variables (d_{wc} and d_{bs}) being summed. Because most of the total water body depth (d_z) is made up of the depth of the water column (d_{wc}), and the uncertainties associated with d_{wc} are not expected to be significant, the total uncertainties associated with this variable, d_z, are also not expected to be significant.
BS	Benthic solids concentration	g/cm^3 (equivalent to kg/L)	**1.0** This variable is site-specific. U.S. EPA OSW recommends a default value of 1.0, consistent with U.S. EPA (1993a), which states that this value should be reasonable for most applications. The recommended default value is also consistent with other U.S. EPA (1993b and 1994) and NC DEHNR (1997) guidance. The following uncertainty is associated with this variable: (1) The recommended default value may not accurately represent site- and water body-specific conditions. Therefore, the variable f_{wc} may be under- or overestimated; the assumption that the under- or overestimation will be limited is based on the narrow recommended range.

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TABLE B-2-10

FRACTION IN WATER COLUMN AND BENTHIC SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
θ_{bs}	Bed sediment porosity	$L_{water}/L_{sediment}$	**0.6** This variable is site-specific. U.S. EPA OSW recommends a default bed sediment porosity of 0.6 (by using a *BS* value of 1 g/cm^3 and a solid density (ρ_s) value of 2.65 kg/L, calculated by using the following equation (U.S. EPA 1993a): $\theta_{bs} = 1 - BS/\rho_s$ This is consistent with other U.S. EPA (1993b and 1994) guidance. The following uncertainty is associated with this variable: (1) Calculation of this variable combines the uncertainties associated with the two variables (*BS* and ρ_s) used in the calculation. To the extent that the recommended default values of *BS* and ρ_s do not accurately represent site- and water body-specific conditions, θ_{bs} will be under- or overestimated.
Kd_{bs}	Bed sediment/sediment pore water partition coefficient	L/kg	**Varies (see Appendix A-2)** This variable is COPC-specific, and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) The Kd_{bs} values in Appendix A-2 are based on default *OC* contents for sediment and soil. Kd_{bs} values based on default *OC* values may not accurately represent site- and water body-specific conditions and may under- or overestimate actual Kd_{bs} values. Uncertainty associated with this variable will be reduced if site- and water body-specific *OC* estimates are used to calculate Kd_{bs}.

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TABLE B-2-10

FRACTION IN WATER COLUMN AND BENTHIC SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as one of the sources of the range of Kd_s values and assumed *OC* values of 0.075 and 0.04 for surface water and sediment, respectively. This document is also cited as one of the sources of TSS. This document cites U.S. EPA (1993b) as its source of information. This document is also cited as the source of the equation for calculating total water body depth. No source of this equation was identified. This document is also cited as one of the reference source documents for the default value for bed sediment porosity. This document cites U.S. EPA (1993b) as its source of information. This document is also cited as one of the reference source documents for the default value for depth of the upper benthic layer. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993b) as its source of information for the range of values for the depth of the upper benthic layer. This document is also cited as one of the reference source documents for the default bed sediment concentration.

U.S. EPA. 1993a. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November 1993.

This document is cited as one of the sources of the range of Kd_s values and assumed *OC* values of 0.075 and 0.04 for surface water and sediment, respectively. The generic equation for calculating partition coefficients (soil, surface water, and bed sediments) is as follows: $Kd_{ij} = Koc * OC_i$. *Koc* is a chemical-specific value; however, *OC* is medium-specific. The range of Kd_s values was based on an assumed *OC* value of 0.01 for soil. Kd_{sw} and Kd_{bs} values were estimated by multiplying the Kd_s values by 7.5 and 4, because the *OC* values for surface water and sediment are 7.5 and 4 times greater than the *OC* value for soil. This document also presents the equation for calculating bed sediment porosity (θ_{bs}); no source of this equation was identified. This document was also cited as the source for the range of the benthic solids concentration (BS); no original source of this range was identified. Finally, this document recommends that, in the absence of site-specific information, a *TSS* value of 1 to 10 be specified for parks and lakes, and a *TSS* value of 10 to 20 be specified in streams and rivers.

U.S. EPA. 1993b. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by NC DEHNR (1997) as the source of the *TTS* value. This document is also cited by NC DEHNR (1997) and U.S. EPA (1994) as the source of the default bed sediment porosity value and the equation used to calculate the variable, the default bed sediment concentration value, and the range for the depth of the upper benthic layer values.

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the reference source documents for the default value for bed sediment porosity. This document cites U.S. EPA (1993b) as its source of information. This document is also cited as one of the reference source documents for the default value for depth of the upper benthic layer. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993b) as its source of information for the range of values for the depth of the upper benthic layer. This document is also cited as one of the reference source documents for the default benthic solids concentration.

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TABLE B-2-11

OVERALL TOTAL WATER BODY DISSIPATION RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the overall dissipation rate of COPCs in surface water, resulting from volatilization and benthic burial.

Uncertainties associated with this equation include the following:

(1) All of the variables in the equation in Table B-2-11 are site-specific. Therefore, the use of default values for any or all of these variables will contribute to the under- or overestimation of k_{wt}. The degree of uncertainty associated with the variable k_b is expected to be one order of magnitude at most and is associated with the estimation of the unit soil loss, X_e. Values for the variables f_{wc}, k_v, and f_{bs} are dependent on medium-specific estimates of medium-specific *OC* content. Because *OC* content can vary widely for different locations in the same medium, uncertainty associated with these three variables may be significant in specific instances.

Equation

$$k_{wt} = f_{wc} \cdot k_v + f_{bs} \cdot k_b$$

Variable	Description	Units	Value
k_{wt}	Overall total water body dissipation rate constant	yr^{-1}	
f_{wc}	Fraction of total water body COPC concentration in the water column	unitless	**Varies (calculated - Table B-2-10)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. Uncertainties associated with this variable include the following: (1) The default variable values recommended for use in the equation in Table B-2-10 may not accurately represent site-specific water body conditions. However, the range of several variables—including d_{bs}, *BS*, and θ_{sw}—is moderate (factors of 5, 3, and 2, respectively); therefore, the degree of uncertainty associated with these variables is expected to be moderate. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information; therefore, the degree of uncertainty associated with these variables is expected to be relatively small. (2) The largest degree of uncertainty may be introduced by the default medium-specific *OC* content values. *OC* content values are often not readily available and can vary widely for different locations in the same medium. Therefore, the degree of uncertainty may be significant in specific instances.

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TABLE B-2-11

OVERALL TOTAL WATER BODY DISSIPATION RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
k_v	Water column volatilization rate constant	yr^{-1}	**Varies (calculated - Table B-2-13)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-13. Uncertainties associated with this variable include the following: (1) All of the variables in Table B-2-13 are site-specific. Therefore, the use of default values for any or all of these variables could contribute to the under- or overestimation of k_v. (2) The degree of uncertainty associated with the variables d_z and *TSS* is expected to be minimal either because information necessary to estimate these variables is generally available or because the range of probable values is narrow. (3) Values for the variable k_v and Kd_{sw} are dependent on medium-specific estimates of *OC* content. Because *OC* content can vary widely for different locations in the same medium, uncertainty associated with these two variables may be significant in specific instances.
f_{bs}	Fraction of total water body COPC concentration in the benthic sediment	unitless	**Varies (calculated - Table B-2-10)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. Uncertainties associated with this variable include the following: (1) The default variable values recommended for use in the equation in Table B-2-10 may not accurately represent site-specific water body conditions. However, the range of several variables—including d_{bs}, *BS*, and θ_{sw}—is relatively narrow; therefore, the degree of uncertainty associated with these variables is expected to be relatively small. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information. (2) The largest degree of uncertainty may be introduced by the default medium-specific *OC* contact values. *OC* content values are often not readily available and can vary widely for different locations in the same medium. Therefore, the degree of uncertainty may be significant in specific instances.
k_b	Benthic burial rate constant	yr^{-1}	**Varies (calculated - Table B-2-16)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-16. Uncertainties associated with this variable include the following: (1) All of the variables in Table B-2-16 are site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of k_b. (2) The degree of uncertainty associated with each of these variables is as follows: (1) X_e—about one order of magnitude at most, (2) *BS* , d_{bs}, Vf_x, *TSS*, and A_w—limited because of the narrow recommended ranges for these variables or because resources to estimate variable values are generally available, and (3) A_L and *SD*—very site-specific and degree of uncertainty unknown.

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TABLE B-2-12

WATER COLUMN VOLATILIZATION LOSS RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the water column of COPCs loss resulting from volatilization. Uncertainties associated with this equation include the following:

(1) All of the variables in Table B-2-12 are site-specific. Therefore, the use of default values for any or all of these variables will contribute to the under- or over estimation of k_v. The degree of uncertainty associated with the variables d_{wc}, d_{bs}, d_z, and TSS are expected to be minimal either because information necessary to estimate these variables is generally available or because the range of probable values is narrow. Values for the variables K_v and Kd_{sw} are dependent on medium-specific estimates of OC content. Because OC content can vary widely for different locations in the same medium, uncertainty associated with these two variables may be significant in specific instances.

Equation

$$k_v = \frac{K_v}{d_z \cdot (1 + Kd_{sw} \cdot TSS \cdot 10^{-6})}$$

For mercury modeling:

The water column volatilization loss rate constant is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective fate and transport parameters .

Variable	Description	Units	Value
k_v	Water column volatilization rate constant	yr^{-1}	

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TABLE B-2-12

WATER COLUMN VOLATILIZATION LOSS RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
K_v	Overall COPC transfer rate coefficient	m/yr	**Varies (calculated - Table B-2-13)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-13. Uncertainties associated with this variable include the following: (1) All of the variables in Table B-2-13—except R, the universal gas constant, which is well-established—are site-specific. Therefore, the use of default values, for any or all these variables, could contribute to the under- or overestimation of K_v. (2) The degree of uncertainty associated with the variables H and T_{wk} is expected to be minimal; values for H are well-established, and average water body temperature, T_{wk}, will likely vary less than 10 percent of the default value. (3) The uncertainty associated with the variables K_L and K_G is attributable largely to medium-specific estimates of OC content. Because OC content values can vary widely for different locations in the same medium, the use of default values may generate significant uncertainty in specific instances. Finally, the origin of the recommended θ value is unknown; therefore, the degree of associated uncertainty is also unknown.
d_{wc}	Depth of water column	m	**Varies (site-specific)** This variable is site-specific and should be an average annual value. The following uncertainty is associated with this variable: (1) Use of default values for depth of water column, d_{wc}, may not accurately reflect site-specific conditions, especially for those water bodies for which depth of water column information is unavailable or outdated. Therefore, use of default d_{wc} values may contribute to the under- or overestimation of total water body COPC concentration, C_{wtot}. However, the degree of under- or overestimation is not expected to be significant.
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. U.S. EPA OSW recommends a default upper-benthic sediment depth of 0.03 meter, which is based on the center of this range cited by U.S. EPA (1993b). This is consistent with U.S. EPA (1994) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) Use of default values for depth of upper benthic layer, d_{bs}, may not accurately represent site-specific water body conditions. However, any uncertainty introduced is expected to be limited, based on the narrow recommended range.

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TABLE B-2-12

WATER COLUMN VOLATILIZATION LOSS RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
d_z	Total water body depth	m	**Varies (calculated)** This variable is site-specific. U.S. EPA OSW recommends that the following equation be used to calculate total water body depth, consistent with NC DEHNR (1997): $d_z = d_{wc} + d_{bs}$ The following uncertainty is associated with this variable: (1) Calculation of this variable combines the concentrations associated with the two variables (d_{wc} and d_{bs}) being summed. Because most of the total water body depth (d_z) is made up of the depth of the water column (d_{wc}), and the uncertainties associated with d_{wc} are not expected to be significant, the total uncertainties associated with this variable, d_z, are also not expected to be significant.
Kd_{sw}	Suspended sediments/surface water partition coefficient	L/kg	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-3. The following uncertainty is associated with this variable: (1) The values contained in Appendix A-2 for Kd_{sw} are calculated on the basis of default *OC* contents for surface water and soil. Kd_{sw} values based on default values may not accurately reflect site-and water body-specific conditions and may under- or overestimate actual Kd_{sw} values. Uncertainty associated with this variable will be reduced if site-specific and medium-specific *OC* estimates are used to calculate Kd_{sw}.
TSS	Total suspended solids concentration	mg/L	**2 to 300** This variable is site-specific. U.S. EPA OSW recommends the use of site- and waterbody specific measured values, representative of long-term average annual values for the water body of concern (see Chapter 3). A value of 10 mg/L was cited by NC DEHNR (1997), U.S. EPA (1993a), and U.S. EPA (1993b) in the absense of site-specific measured data. The following uncertainty is associated with this variable: Limitation on measured data used for determining a water body specific total suspended solids (*TSS*) value may not accurately reflect site- and water body-specific conditions long term. Therefore, the *TSS* value may contribute to the under-or overestimation of f_{wc}.
10^{-6}	Units conversion factor	kg/mg	

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TABLE B-2-12

WATER COLUMN VOLATILIZATION LOSS RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as the source of the equation for calculating total water body depth. No source of this equation was identified. This document is also cited as one of the sources of the range of Kd_s values and an assumed *OC* value of 0.075 for surface water. This document is also cited as one of the sources of *TSS*. This document cites U.S. EPA (1993b) as its source of information.

U.S. EPA. 1993a. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November 1993.

This document is cited as one of the sources of the range of Kd_s values and assumed *OC* content value of 0.075 for surface water. The generic equation for calculating partition coefficients (soil, surface water, and bed sediments) is as follows: $Kd_{ij} = K_{ocj}\ OC_i$. K_{oc} is a chemical-specific value; however, *OC* is medium-specific. The range of Kd_s values was based on an assumed *OC* value of 0.01 for soil. This document is one of the sources cited that assumes an *OC* value of 0.075 for surface water. Therefore, the Kd_{sw} value was estimated by multiplying the Kd_s values by 7.5, because the *OC* value for surface water is 7.5 times greater than the *OC* value for soil.

U.S. EPA. 1993b. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of the range and default value for the depth of the upper benthic layer (d_{bs}). This document is also cited by NC DEHNR (1997) as the source of the *TSS* value.

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analysis at Combustion Facility Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facility*. April 15.

This document is cited as one of the reference source documents for the default value of the depth of the upper benthic layer. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993b) as its source of information.

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TABLE B-2-13

OVERALL COPC TRANSFER RATE COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the overall transfer rate of contaminants from the liquid and gas phases in surface water.

Uncertainties associated with this equation include the following:

(1) All of the variables in Table B-2-13—except *R*, the universal gas constant, which is well-established—are site-specific. Therefore, the use of any or all of these variables will contribute to the under- or overestimation of K_v. The degree of uncertainty associated with the variables *H* and T_{wk} is expected to be minimal; values for *H* are well-established, and average water body temperature will likely vary less than 10 percent of the default value. The uncertainty associated with the variables K_v and K_G is attributable largely to medium-specific estimates of *OC* content. Because *OC* content values can vary widely for different locations in the same medium, the use of default values may generate significant uncertainty in specific instances.

Equation

$$K_v = \left[K_L^{-1} + \left(K_G \cdot \frac{H}{R \cdot T_{wk}} \right)^{-1} \right]^{-1} \cdot \theta^{(T_{wk} - 293)}$$

For mercury modeling:

The overall COPC transfer rate coefficient is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective fate and transport parameters .

Variable	Description	Units	Value
K_v	Overall COPC transfer rate coefficient	m/yr	

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TABLE B-2-13

OVERALL COPC TRANSFER RATE COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
K_L	Liquid-phase transfer coefficient	m/yr	**Varies (calculated - Table B-2-14)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-14. Uncertainties associated with this variable include the following: All of the variables in Table B-2-14 are site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of K_v. The degree of uncertainty associated with these variables is as follows: (1) Minimal or insignificant uncertainty is assumed to be associated with six variables —D_w, u, d_z, ρ_a, ρ_w, and μ_w—either because of narrow recommended ranges for these variables or because information to estimate variable values is generally available. (2) No original sources were identified for the equations used to derive recommended values or specific recommended values for variables Cd, k, and λ_z. Therefore, the degree and direction of any uncertainties associated with these variables are unknown. (3) Uncertainties associated with the variable W are site-specific.
K_G	Gas-phase transfer coefficient	m/yr	**Varies (calculated - Table B-2-15)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-15. Uncertainties associated with this variable include the following: All of the variables in Table B-2-15, with the exception of k, are site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of K_G. The degree of uncertainty associated with each of these variables is as follows: (1) Minimal or insignificant uncertainty is assumed to be associated with the variables D_a, μ_a, and ρ_a, because these variables have been extensively studied, and equation procedures are well-established. (2) No original sources were identified for equations used to derive recommended values or specific recommended values for variables C_d, k, and d_z. Therefore, the degree and direction of any uncertainties are unknown. (3) Uncertainties associated with the variable W are site-specific and cannot be readily estimated.

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TABLE B-2-13

OVERALL COPC TRANSFER RATE COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
H	Henry's Law constant	atm-m^3/mol	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Values for this variable, estimated by using the parameters and algorithms in Appendix A-2, may under- or overestimate the actual COPC-specific values. As a result, K_v may be under- or overestimated to a limited degree.
R	Universal gas constant	atm-m^3/mol-K	**8.205 x 10^{-5}** There are no uncertainties associated with this parameter.
T_{wk}	Water body temperature	K	**298** This variable is site-specific. U.S. EPA OSW recommends the use of this default value when site-specific information is not available; this is consistent with U.S. EPA (1993a; 1993b; and 1994). The following uncertainty is associated with this variable: (1) To the extent that the default Water body temperature value does not accurately represent site- and water body-specific conditions, K_v, will be under- or overestimated to a limited degree.
θ	Temperature correction factor	unitless	**1.026** This variable is site-specific. U.S. EPA OSW recommends the use of this default value when site-specific information is not available; this is consistent with U.S. EPA (1993a; 1993b; and 1994). The following uncertainty is associated with this variable: (1) The purpose and sources of this variable and the recommended value are unknown.

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TABLE B-2-13

OVERALL COPC TRANSFER RATE COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is the reference source for the equation in Table B-2-12, including the use of the temperature correction fraction (θ).

This document is also cited by U.S. EPA (1994) as the source of the T_{wk} value of 298 K (298 K = 25°C) and the default θ value of 1.026.

U.S. EPA. 1993b *Addendum to Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Solid Waste and Office Research and Development. Washington, D.C. November 10.

This document recommends the T_{wk} value of 298 K (298 K = 25 °C) and the value θ of 1.026. No source was identified for these values.

U.S. EPA 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes*. *Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is cited as the reference source for water body temperature (T_{wk}) and temperature correction factor (θ). This document apparently cites U.S. EPA (1993a) as its source of information.

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TABLE B-2-14

LIQUID-PHASE TRANSFER COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the rate of contaminant transfer from the liquid phase for a flowing or quiescent system.

Uncertainties associated with this equation include the following:

(1) Minimal or insignificant uncertainly is assumed to be associated with the following six variables: D_w, d_z, ρ_a, ρ_w, and μ_w.
(2) No original sources were identified for equations used to derive recommended values or specific recommended values for the following three variables: C_d, k, and d_z. Therefore, the degree and duration of any uncertainties associated with these variables is unknown.
(3) Uncertainties associated with the variable W are site-specific.

Equation

For flowing streams or rivers

$$K_L = \sqrt{\frac{10^{-4} \cdot D_w \cdot u}{d_z}} \cdot 3.1536 \times 10^7$$

For quiescent lakes or ponds

$$K_L = (C_d^{0.5} \cdot W) \cdot \left(\frac{\rho_a}{\rho_w}\right)^{0.5} \cdot \left(\frac{k^{0.33}}{\lambda_z}\right) \cdot \left(\frac{\mu_w}{\rho_w \cdot D_w}\right)^{-0.67} \cdot 3.1536 \times 10^7$$

For mercury modeling:

The liquid phase transfer coefficient is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective fate and transport parameters .

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TABLE B-2-14

LIQUID-PHASE TRANSFER COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
K_L	Liquid-phase transfer coefficient	m/yr	
D_w	Diffusivity of COPC in water	cm^2/s	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC physical and chemical parameter tables in Appendix A-2. The following uncertainty is associated with this variable: (1) The default D_w values may not accurately represent the behavior of COPCs under water body-specific conditions. However, the degree of uncertainty is expected to be minimal.
u	Current velocity	m/s	**Varies (site-specific)** This variable is site-specific. The following uncertainty is associated with this variable: (1) Sources of values for this variable are reasonably available for most large surface water bodies. Estimated values for this variable be necessary for smaller water bodies; uncertainty will be associated with these estimates. The degree of uncertainty associated with this variable is not expected to be significant.

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TABLE B-2-14

LIQUID-PHASE TRANSFER COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
d_z	Total water body depth	m	**Varies (calculated)** This variable is site-specific. U.S. EPA OSW recommends that this value be calculated by using the following equation, consistent with U.S. EPA (1994): $d_z = d_{wc} + d_{bs}$ No reference was cited for this recommendation. The following uncertainty is associated with this variable: (1) Calculation of this variable combines the concentrations associated with the two variables (d_{wc} and d_{bs}) being summed. Because most of the total water body depth (d_z) is made up of the depth of the water column (d_{wc}), and the uncertainties associated with d_{wc} are not expected to be significant, the total uncertainties associated with this variable, d_z, are also not expected to be significant.
3.1536×10^7	Units conversion constant	s/yr	
C_d	Drag coefficient	unitless	**0.0011** This variable is site-specific. U.S. EPA OSW recommends a default value of 0.0011, consistent with U.S. EPA (1993a; 1993b; 1994) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) The original source of this variable value is unknown. Therefore, any uncertainties associated with its use are also unknown.
W	Average annual wind speed	m/s	**3.9** Consistent with U.S. EPA (1990), U.S. EPA OSW recommends a default value of 3.9 m/s. See Chapter 3 for guidance regarding the references and methods used to determine site-specific values for air dispersion modeling.

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TABLE B-2-14

LIQUID-PHASE TRANSFER COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
ρ_a	Density of air corresponding to water temperature	g/cm^3	**0.0012** U.S. EPA OSW recommends this default value when site-specific information is not available, consistent with U.S. EPA (1994), both of which cite Weast (1979) as the source of this value. This value applies at standard conditions (298 K and 1 atm). There is no significant uncertainty associated with this variable.
ρ_w	Density of water corresponding to water temperature	g/cm^3	**1** U.S. EPA OSW recommends this default value, consistent with U.S. EPA (1994), both of which cite Weast (1979) as the source of this value. This value applies at standard conditions (298 K and 1 atm). There is no significant uncertainty associated with this variable.
k	von Karman's constant	unitless	**0.4** This value is a constant. U.S. EPA OSW recommends the use of this value, consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The original source of this variable value is unknown. Therefore, any uncertainties associated with its use are also unknown.
λ_z	Dimensionless viscous sublayer thickness	unitless	**4** This value is site-specific. U.S. EPA OSW recommends the use of this default value when site-specific information is not available; consistent with U.S. EPA (1994).
μ_w	Viscosity of water corresponding to water temperature	g/cm-s	**0.0169** U.S. EPA OSW recommends this default value, consistent with U.S. EPA (1994), which both cite Weast (1979) as the source of this value. This value applies at standard conditions (298 K and 1 atm). There is no significant uncertainty associated with this variable.

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TABLE B-2-14

LIQUID-PHASE TRANSFER COEFFICIENT (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is cited as one of the sources of the range of D_w values and assumed C_d, ρ_a, ρ_w, k, λ_z, and μ_w values of 0.0011, 1.2 x 10^{-3}, 1, 0.4, 4, and 1.69 x 10^{-2}, respectively. This document cites (1) Weast (1979) as its source of information regarding ρ_a, ρ_w, and μ_w; and (2) U.S. EPA (1993a) as its source of information regarding C_d, k, and d_z.

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of the recommended drag coefficient (C_d) value of 0.0011 and the recommended von Karman's constant (k) value of 0.4. The original sources of variable values are not identified.

U.S. EPA. 1993b. *Addendum to Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Solid Waste and Office of Research and Development. Washington, D.C. November 10.

This document recommends a value of 0.0011 for the drag coefficient (C_d) variable or a value of 0.4 for von Karman's constant (k). No sources are cited for these values.

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes*. *Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is cited as one of the sources of the range of D_w values and assumed C_d, ρ_a, ρ_w, k, λ_z, and μ_w values of 0.0011, 1.2 x 10^{-3}, 1, 0.4, 4, and 1.69 x 10^{-2}, respectively. This document cites (1) Weast (1979) as its source of information regarding ρ_a, ρ_w, and μ_w; and (2) U.S. EPA (1993a) as its source of information regarding C_d, k, and d_z.

Weast, R. C. 1979. *CRC Handbook of Chemistry and Physics*. 60th ed. CRC Press, Inc. Cleveland, Ohio.

This document is cited as the source of ρ_a, ρ_w, and μ_w variables of 1.2 x10^{-3}, 1, and 1.69 x 10^{-2}, respectively.

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TABLE B-2-15

GAS-PHASE TRANSFER COEFFICIENT
(SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the rate of contaminant transfer from the gas phase for a flowing or quiescent system. Uncertainties associated with this equation include the following:

(1) Minimal or insignificant uncertainty is assumed to be associated with the variables D_a, μ_a, and ρ_a.
(2) No original sources were identified for equations used to derive recommended values or specific recommended values for variables C_d, k, and λ_z. Therefore, the degree and direction of any uncertainties associated with these variables are unknown.
(3) Uncertainties associated with the remaining variables are site-specific.

Equation

Flowing streams or rivers

$$K_G = 36{,}500 \ m/yr$$

Quiescent lakes or ponds

$$K_G = (C_d^{0.5} \cdot W) \cdot \left(\frac{k^{0.33}}{\lambda_z}\right) \cdot \left(\frac{\mu_a}{\rho_a \cdot D_a}\right)^{-0.67} \cdot 3.1536 \times 10^7$$

For mercury modeling:

The gas phase transfer coefficient is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective fate and transport parameters .

Variable	Description	Units	Value
K_G	Gas-phase transfer coefficient	m/yr	

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TABLE B-2-15

GAS-PHASE TRANSFER COEFFICIENT
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 2 of 4)

Variable	Description	Units	Value
C_d	Drag coefficient	unitless	**0.0011** This variable is site-specific. U.S. EPA OSW recommends the use of this default value when site-specific information is not available, consistent with U.S. EPA (1993a; 1993b; 1994) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) The original source of this variable is unknown.
W	Average annual wind speed	m/s	**3.9** Consistent with U.S. EPA (1990), U.S. EPA OSW recommends a default value of 3.9 m/s. See Chapter 3 for guidance regarding the references and methods used to determine a site-specific value that isconsistent with air dispersion modeling. The following uncertainty is associated with this variable: To the extent that site-specific or local values for this variable are not available, default values may not accurately represent site-specific conditions. The uncertainty associated with the selection of a single value from within the range of windspeeds at a single location may be more significant than the uncertainty associated with choosing a single windspeed to represent all locations.
k	von Karman's constant	unitless	**0.4** This value is a constant. U.S. EPA OSW recommends the use of this value, consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The original source of this variable is unknown.
λ_z	Dimensionless viscous sublayer thickness	unitless	**4** This value is site-specific. U.S. EPA OSW recommends the use of this default value when site-specific information is not available, consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The original source of this variable is unknown.

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TABLE B-2-15

GAS-PHASE TRANSFER COEFFICIENT
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
μ_a	Viscosity of air	g/cm-s	**1.81×10^{-4}** U.S. EPA OSW recommends the use of this value, based on Weast (1980). This is consistent with NC DEHNR (1997). This value applies at standard conditions (20 °C or 298 K and 1 atm, or 760 mm Hg). The following uncertainty is associated with this variable: (1) The viscosity of air may vary with temperature.
ρ_a	Density of air	g/cm^3	**0.0012** U.S. EPA OSW recommends the use of this value, based on Weast (1980); this is consistent with NC DEHNR (1997). This value applies at standard conditions (20 °C or 298 K and 1 atm, or 760 mm Hg). The following uncertainty is associated with this variable: (1) The density of air will vary with temperature.
D_a	Diffusivity of COPC in air	cm^2/s	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC physical and chemical parameter tables in Appendix A-2. The following uncertainty is associated with this variable: (1) The recommended D_a values may not accurately represent the behavior of COPCs under water body-specific conditions. However, the degree of uncertainty is expected to be minimal.
3.1536×10^7	Units conversion factor	s/yr	

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TABLE B-2-15

GAS-PHASE TRANSFER COEFFICIENT
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

This document is cited as one of the sources of the variables ρ_a, k, λ_z, and μ_a values of 1.2 x 10^{-3}, 0.4, 4, and 1.81 E-04, respectively. This document cites (1) Weast (1979) as its source of information for ρ_a and μ_a, and (2) U.S. EPA (1993a) as its source of information for k and λ_z.

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustion Emissions*. Working Group Recommendations. Office of Solid Waste, and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of (1) the recommended drag coefficient (C_d) value of 0.0011, (2) the recommended von Karman's constant (k) value of 0.4, and (3) the recommended dimensionless viscous sublayer thickness (λ_z) value of 4. The original sources of these variable values are not identified.

U.S. EPA. 1993b. *Addendum to Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Solid Waste, and Office of Research and Development. Washington, D.C. November 10.

This document recommends (1) a value of 0.0011 for the drag coefficient (C_d) variable, (2) a value of 0.4 for von Karman's constant (K), and (3) a value of 4 for the dimensionless viscous sublayer thickness (λ_z) variable. The original sources of the variable values are not identified.

U.S. EPA. 1994. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes*. *Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This document is cited as one of the sources of the variables ρ_a, k, λ_z, and μ_a values of 1.2 x 10^{-3}, 0.4, 4, and 1.81 E-04, respectively. This document cites (1) Weast (1979) as its source of information for ρ_a and μ_a, and (2) U.S. EPA (1993a) as its source of information for k and λ_z.

Weast, R.C. 1979. *CRC Handbook of Chemistry and Physics*. 60th ed. CRC Pres, Inc. Cleveland, Ohio. This document is cited as the source of ρ_a, ρ_w, and μ_a variables of 1.2 x 10^{-3}, 1, and 1.69 x 10^{-2}, respectively.

US EPA ARCHIVE DOCUMENT

TABLE B-2-16

BENTHIC BURIAL RATE CONSTANT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the constant for water column loss constant due to burial in benthic sediment.

Uncertainties associated with this equation include the following:

(1) All of the variables in Table B-2-16 are site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of K_b. The degree of uncertainty associated with each of these variables is as follows: (a) X_e—about one order of magnitude at the most, (b) BS, d_{bs}, Vf_x, TSS, and A_W—limited because of the narrow recommended ranges for these variables or because resources to estimate variable values are generally available, (c) A_L and SD—very site-specific, degree of uncertainty unknown.

Based on the possible ranges for the input variables to this equation, values of k_b can range over about one order of magnitude.

Equation

$$k_b = \left(\frac{X_e \cdot A_L \cdot SD \cdot 10^3 - Vf_x \cdot TSS}{A_W \cdot TSS} \right) \left(\frac{TSS \cdot 10^{-6}}{BS \cdot d_{bs}} \right)$$

Variable	Description	Units	Value
k_b	Benthic burial rate constant	yr^{-1}	
X_e	Unit soil loss	kg/m^2-yr	**Varies (calculated - Table B-2-7)** This variable is site-specific and is calculated by using the equation in Table B-2-7. The following uncertainty is associated with this variable: (1) All of the variables in the equation used to calculate unit soil loss, X_e, are site-specific. Use of default values rather than site-specific values, for any or all of the equation variables, will result in estimates of X_e that under- or overestimate the actual value. The degree or magnitude of any under- or overestimation is expected to be about one order of magnitude or less.

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TABLE B-2-16

BENTHIC BURIAL RATE CONSTANT
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
A_L	Total watershed area receiving deposition	m^2	**Varies (site-specific)** This variable is site-specific (see Chapter 4). Uncertainties associated with this variable are site-specific.
SD	Sediment delivery ratio	unitless	**Varies (calculated - Table B-2-8)** This variable is site-specific and is calculated by using the equation in Table B-2-8. Uncertainties associated with this variable include the following: (1) The default values for empirical intercept coefficient, *a*, recommended for use in the equation in Table B-2-8, are average values based on various studies of sediment yields from various watersheds. Therefore, these default values may not accurately represent site-specific watershed conditions. As a result, use of these default values may contribute to under- or overestimation of the benthic burial rate constant, k_b. (2) The default value for empirical slope coefficient, *b*, recommended for use in in the equation in Table B-2-8 is based on a review of sediment yields from various watersheds. This single default value may not accurately represent site-specific water shed conditions. As a result, use of this default value may contribute to under-or overestimation of k_b.
10^3	Units conversion factor	g/kg	
Vf_x	Average volumetric flow rate through water body	m^3/yr	**Varies (site-specific)** This variable is site-specific and should be an annual average value. The following uncertainty is associated with this variable: (1) Use of default average volumetric flow rate, Vf_x, values may not accurately represent site-specific water body conditions. Therefore, the use of such default values may contribute to the under- or overestimation of k_b. However, it is expected that the uncertainty associated with this variable will be limited, because resources such as maps, aerial photographs, and gauging station measurements—from which average volumetric flow rate through water body, Vf_x, can be estimated—are generally available.

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TABLE B-2-16

BENTHIC BURIAL RATE CONSTANT
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
TSS	Total suspended solids concentration	mg/L	**2 to 300** This variable is site-specific. U.S. EPA OSW recommends the use of site- and waterbody specific measured values, representative of long-term average annual values for the water body of concern (see Chapter 3). A value of 10 mg/L was cited by NC DEHNR (1997), U.S. EPA (1993a), and U.S. EPA (1993b) in the absense of site-specific measured data. The following uncertainty is associated with this variable: Limitation on measured data used for determining a water body specific total suspended solids (*TSS*) value may not accurately reflect site- and water body-specific conditions long term. Therefore, the *TSS* value may contribute to the under-or overestimation of f_{wc}.
A_W	Water body surface area	m^2 (average for the entire year)	**Varies (site-specific)** This variable is site-specific (see Chapter 4), and should be an average annual value. The units of this variable are presented as they are because the value selected is assumed to represent an average value for the entire year. Uncertainties associated with this variable are site-specific, and expected to be limited, because maps, aerial photographs —and other resources from which water body surface area, A_W, can be measured—are readily available.
1×10^{-6}	Units conversion factor	kg/mg	
BS	Benthic solids concentration	g/cm^3 (equivalent to kg/L)	**1.0** This variable is site-specific. U.S. EPA OSW recommends a default value of 1.0, consistent with U.S. EPA (1993b), which states that this value should be reasonable for most applications. The recommended default value is also consistent with other U.S. EPA (1993a; 1993b; 1994) guidance. The following uncertainty is associated with this variable: (1) The recommended default benthic solids concentration, *BS*, value may not accurately represent site-specific water body conditions. Therefore, use of this default value may contribute to the under- or overestimation of k_b.

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TABLE B-2-16

BENTHIC BURIAL RATE CONSTANT
(SURFACE WATER AND SEDIMENT EQUATIONS)

(Page 4 of 5)

Variable	Description	Units	Value
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. U.S. EPA OSW recommends a default upper-benthic sediment depth of 0.03 meter, which is based on the center of this range cited by U.S. EPA (1993a; 1993b). This range is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The recommended default value for depth of upper benthic layer, d_{bs}, may not accurately represent site-specific water body conditions. Therefore, use of this default value may contribute to the under- or overestimation of k_b. However, the degree of uncertainty associated with this variable is expected to be limited because of the narrow recommended range.

US EPA ARCHIVE DOCUMENT

TABLE B-2-16

BENTHIC BURIAL RATE CONSTANT
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as one of the sources of the range of all recommended specific *BS* and d_{bs} values, and the recommended *TSS* value. This document cites U.S. EPA (1993a) as its source.

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste, and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of (1) the *TSS* value, (2) the range and recommended *BS* value, and (3) the range and recommended depth of upper benthic layer (d_{bs}) value.

U.S. EPA 1993b. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. External Review Draft. Office of Research and Development. Washington, D.C. November.

This document states that the upper benthic sediment depth, d_{bs}, representing the portion of the bed in equilibrium with the water column, cannot be precisely specified. However, the document states that values from 0.01 to 0.05 meter would be appropriate. This document also recommends a *TSS* value of 10 mg/L and a specific benthic solids concentration (*BS*) value.

U.S. EPA 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Waste*. *Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the reference sources for the d_{bs} value. The recommended value is the midpoint of an acceptable range. This document is also cited as one of the reference source documents for the default *BS* value. This document cites U.S. EPA (1993a) as its source.

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TABLE B-2-17

TOTAL WATER COLUMN CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the total water column concentration of COPCs; this includes both dissolved COPCS and COPCs sorbed to suspended solids.

Uncertainties associated with this equation include the following:

(1) All of the variables in Table B-2-17 are COPC- and site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of C_{wctot}.

The degree of uncertainty associated with the variables d_{wc} and d_{bs} is expected to be minimal either because information for estimating a variable (d_{wc}) is generally available or because the probable range for a variable (d_{bs}) is narrow. The uncertainty associated with the variables f_{wc} and C_{wtot} is associated with estimates of *OC* content. Because *OC* content values can vary widely for different locations in the same medium, the uncertainty associated with using default *OC* values may be significant in specific cases.

Equation

$$C_{wctot} = f_{wc} \cdot C_{wtot} \cdot \frac{d_{wc} + d_{bs}}{d_{wc}}$$

For mercury modeling:

Total water column concentration is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective C_{wtot} values and f_{wc} values.

Variable	Description	Units	Value
C_{wctot}	Total COPC concentration in water column	mg/L	

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TABLE B-2-17

TOTAL WATER COLUMN CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
f_{wc}	Fraction of total water body COPC concentration in the water column	unitless	**0 to 1 (calculated - Table B-2-10)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. The following uncertainty is associated with this variable: (1) The default variable values recommended for use in Table B-2-10 may not accurately represent site-specific water body conditions. However, the ranges of several variables—including d_{bs}, and θ_{bs} - is relatively narrow; therefore, the uncertainty is expected to be relatively small. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information. The largest degree of uncertainty may be introduced by the default medium specific *OC* content values. *OC* content values are often not readily available and can vary widely for different locations in the same medium. Therefore, default values may not adequately represent site-specific conditions.
C_{wtot}	Total water body COPC concentration, including water column and bed sediment	mg/L	**Varies (calculated - Table B-2-9)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-9. The following uncertainty is associated with this variable: (1) The default variable values recommended for use in the equation in Table B-2-9 may not accurately represent site--specific water body conditions. The degree of uncertainty associated with variables Vf_x, A_w, d_{wc}, and d_{bs} is expected to be limited either because the probable ranges for variables are narrow or information allowing accurate estimates is generally available. Uncertainty associated with f_{wc} is largely the result of water body associated with default *OC* content values, and may be significant in specific instances. Uncertainties associated with the total COPC load into water body (L_T) and overall total water body COPC dissipation rate constant (k_{wt}) may also be significant in some instances because of the summation of many variable-specific uncertainties.

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TABLE B-2-17

TOTAL WATER COLUMN CONCENTRATION
(SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
d_{wc}	Depth of water column	m	**Varies (site-specific)** This variable is site-specific, and should be an average annual value. The following uncertainty is associated with this variable: (1) Use of default values for depth of water column, d_{wc}, may not accurately reflect site-specific water body conditions. Therefore, use of default values may contribute to the under- or overestimation of C_{wctot}. However, the degree of uncertainty associated with this variable is expected to be limited, because information regarding this variable is generally available.
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. U.S. EPA OSW recommends a default upper-benthic sediment depth of 0.03 meter, which is based on the center of this range cited by U.S. EPA (1993a; 1993b) This range is consistent with U.S. EPA (1994). The following uncertainty is associated with this variable: (1) The recommended default value for depth of upper benthic layer, d_{bs}, may not accurately represent site-specific water body conditions. Therefore, use of this default value may contribute to the under- or overestimation of C_{wctot}. However, the degree of uncertainty associated with this variable is expected to be limited because of the narrow recommended range.

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TABLE B-2-17

TOTAL WATER COLUMN CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as one of the sources of the range of d_{bs} values. This document cites U.S. EPA (1993a) as its source.

U.S. EPA. 1993a. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as one of the sources of the ranges of d_{bs} values. No original source of this range was identified.

U.S. EPA. 1993b. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November.

This document states that the upper benthic sediment depth, d_{bs}, representing the portion of the bed in equilibrium with the water column, cannot be precisely specified. However, the document states that values from 0.01 to 0.05 meter would be appropriate.

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Waste. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facility*. April 15.

This document is cited as one of the reference sources for the default value for depth of upper benthic layer (d_{bs}). The recommended value is the midpoint of an acceptable range. This document cites U.S. EPA (1993a) as the source of its information. The degree of uncertainty associated with the variables d_{wc} and d_{bs} is expected to be minimal either because information for estimating these variables is generally available (d_{wc}) or the probable range for a variable (d_{bs}) is narrow. Uncertainty associated with the variables f_{wc} and C_{wtot} is largely associated with the use of default *OC* content values. Because *OC* content is known to vary widely in different locations in the same medium, use of default medium-specific values can result in significant uncertainty in some instances.

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TABLE B-2-18

DISSOLVED PHASE WATER CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the concentration of contaminant dissolved in the water column.

Uncertainties associated with this equation include the following:

(1) The variables in Table B-2-18 are site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of C_{dw}. The uncertainty associated with the variables C_{wCTOT} and Kd_{sw} is associated with estimates of OC content. Because OC content values can vary widely for different locations in the same medium, using default OC values may result in significant uncertainty in specific cases.

Equation

$$C_{dw} = \frac{C_{wctot}}{1 + Kd_{sw} \cdot TSS \cdot 10^{-6}}$$

For mercury modeling:

Dissolved phase water concentration is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective C_{wctot} values and Kd_{sw} values.

Variable	Description	Units	Value
C_{dw}	Dissolved phase water concentration	mg/L	
10^{-6}	Units conversion factor	kg/mg	

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TABLE B-2-18

DISSOLVED PHASE WATER CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
C_{wctot}	Total COPC concentration in water column	mg/L	**Varies (calculated - Table B-2-17)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-17. The following uncertainty is associated with this variable: (1) All of the variables in Table B-2-17 are COPC- and site-specific. Therefore, the use of default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimation of C_{wctot}. The degree of uncertainty associated with the variables d_{wc} and d_{bs} is expected to be minimal either because information for estimating a variable (d_{wc}) is generally available or because the probable range for a variable (d_{bs}) is narrow. The uncertainty associated with the variables f_{wc} and C_{wtot} is associated with estimates of *OC* content. Because *OC* content values can vary widely for different locations in the same medium, using default *OC* values may result in significant uncertainty in specific cases.
Kd_{sw}	Suspended sediments/surface water partition coefficient	L/kg	**Varies (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) Values contained in Appendix A-2 for Kd_{sw} are based on default *OC* content values for surface water and soil. Because OC content can vary widely for different locations in the same medium, the uncertainty associated with estimated Kd_{sw} values based on default *OC* content values may be significant in specific cases.
TSS	Total suspended solids concentration	mg/L	**2 to 300** This variable is site-specific. U.S. EPA OSW recommends the use of site- and waterbody specific measured values, representative of long-term average annual values for the water body of concern (see Chapter 5). A value of 10 mg/L was cited by NC DEHNR (1997), U.S. EPA (1993a), and U.S. EPA (1993b) in the absense of site-specific measured data. The following uncertainty is associated with this variable: Limitation on measured data used for determining a water body specific total suspended solids (*TSS*) value may not accurately reflect site- and water body-specific conditions long term. Therefore, the *TSS* value may contribute to the under-or overestimation of f_{wc}.

US EPA ARCHIVE DOCUMENT

TABLE B-2-18

DISSOLVED PHASE WATER CONCENTRATION (SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as one of the sources for Kd_s values and a default *TSS* value of 10. This document cites (1) U.S. EPA (1993a; 1993b) as its sources of information regarding *TSS*, and (2) RTI (1992) as its source regarding Kd_s.

U.S. EPA. 1993a. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as one of the sources of the range of Kd_s value and the assumed *OC* value of 0.075 for surface water. The generic equation for calculating partition coefficients (soil, surface water, and bed sediments) is as follows: $Kd_{ij} = K_{ocj} * OC_i$. K_{oc} is a chemical-specific value; however, *OC* is medium-specific. The range of Kd_s values was based on an assumed *OC* value of 0.01 for soil. Therefore, the Kd_{sw} values were estimated by multiplying the Kd_s values by 7.5, because the *OC* value for surface water is 7.5 times greater than the *OC* value for soil. This document is also cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of the recommended *TSS* value.

U.S. EPA. 1993b. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. November.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as one of the sources of the range of Kd_s value and the assumed *OC* value of 0.075 for surface water. The generic equation for calculating partition coefficients is as follows: $Kd_{ij} = K_{ocj} * OC_i$. K_{oc} is a chemical-specific value; however, *OC* is medium-specific. The range of Kd_s values was based on an assumed *OC* value of 0.01 for soil. Therefore, the Kd_{sw} values were estimated by multiplying the Kd_s values by 7.5, because the *OC* value for surface water is 7.5 times greater than the *OC* value for soil. This document is also cited by U.S. EPA (1994) and NC DEHNR (1997) as the source of the recommended *TSS* value.

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Waste*. *Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the sources of the range of Kd_s values, citing RTI (1992) as its source of information.

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TABLE B-2-19

COPC CONCENTRATION IN BED SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Description

This equation calculates the COPC concentration in bed sediments.

Uncertainties associated with this equation include the following:

(1) The default variable values recommended for use in the equation in Table B-2-19 may not accurately represent site-specific water body conditions. The degree of uncertainty associated with variables θ_{bs}, BS, d_{wc}, and d_{bs} is expected to be limited either because the probable ranges for these variables are narrow or because information allowing reasonable estimates is generally available.

(2) Uncertainties associated with variables f_{bs}, C_{wtot} and Kd_{bs} are largely associated with the use of default OC content values in their calculation. The uncertainty may be significant in specific instances, because OC content is known to vary widely in different locations in the same medium.

Equation

$$C_{sed} = f_{bs} \cdot C_{wtot} \cdot \frac{Kd_{bs}}{\theta_{bs} + Kd_{bs} \cdot BS} \cdot \frac{d_{wc} + d_{bs}}{d_{bs}}$$

For mercury modeling':

COPC concentration in bed sediment is calculated for divalent mercury (Hg^{2+}) and methyl mercury (MHg) using their respective C_{wtot} values; f_{bs} values; and Kd_{bs} values.

Variable	Description	Units	Value
C_{sed}	COPC concentration in bed sediment	mg/kg	
f_{bs}	Fraction of total water body COPC concentration in benthic sediment	unitless	**Varies (calculated - Table B-2-10)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. The following uncertainty is associated with this variable: (1) The default values for the variables in Table B-2-10 may not accurately represent site- and water body-specific conditions. However, the range of several variables—including d_{bs},BS, and θ_{bs}—is relatively narrow. Other variables, such as d_{wc} and d_z, can be reasonably estimated on the basis of generally available information. The largest degree of uncertainty may be introduced by the default medium-specific OC content values. Because OC content values may vary widely in different locations in the same medium, by using default values may result in significant uncertainty in specific cases.

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TABLE B-2-19

COPC CONCENTRATION IN BED SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
C_{wtot}	Total water body COPC concentration, including water column and bed sediment	mg/L	**Varies (calculated - Table B-2-9)** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-9. The following uncertainty is associated with this variable: (1) The default variable values recommended for use in the equation in Table B-2-9 may not accurately represent site--specific water body conditions. The degree of uncertainty associated with variables Vf_x, A_W, d_{wc}, and d_{bs} is expected to be limited either because the probable ranges for these variables are narrow or information allowing reasonable estimates is generally available. (2) Uncertainty associated with f_{wc} is largely the result of uncertainty associated with default *OC* content values and may be significant in specific instances. Uncertainties associated with the variable L_T and k_{wt} may also be significant because of the summation of many variable-specific uncertainties.
Kd_{bs}	Bed sediment/sediment pore water partition coefficient	L/kg	**Varies (see Appendix A-2)** This variable is COPC-specific, and should be determined from the COPC tables in Appendix A-2. The following uncertainty is associated with this variable: (1) The default range (8 to 2,100,000 L/kg) of Kd_{bs} values are based on default *OC* content values for sediment and soil. Because medium-specific *OC* content may vary widely at different locations in the same medium, the uncertainty associated with Kd_{bs} values calculated by using default *OC* content values may be significant in specific instances.
θ_{bs}	Bed sediment porosity	$L_{water}/L_{sediment}$	**0.4 to 0.8** **Default: 0.6** This variable is site-specific. U.S. EPAOSW recommends a default bed sediment porosity of 0.6 (by using a *BS* value of 1 g/cm^3 and a solids density [ρ_s] value of 2.65 kg/L), calculated by using the following equation (U.S. EPA 1993a): $\theta_{bs} = 1 - BS / \rho_s$ This is consistent with other U.S. EPA (1993b and 1994) guidance. The following uncertainty is associated with this variable: (1) To the extent that the recommended default values of *BS* and ρ_s do not accurately represent site- and water body-specific conditions, θ_{bs} will be under- or overestimated to some degree. However, the degree of uncertainty is expected to be minimal, based on the narrow range of recommended values.

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TABLE B-2-19

COPC CONCENTRATION IN BED SEDIMENT (SURFACE WATER AND SEDIMENT EQUATIONS)

Variable	Description	Units	Value
BS	Benthic solids concentration	g/cm^3	**0.5 to 1.5** **Default: 1.0** This variable is site-specific. U.S. EPA OSW recommends a default value of 1.0, consistent with U.S. EPA (1993a), which states that this value should be reasonable for most applications. No reference is cited for this recommendation. This is also consistent with other U.S. EPA (1993b and 1994) guidance. The following uncertainty is associated with this variable: (1) The recommended default value for *BS* may not accurately represent site- and water body-specific conditions. Therefore, the variable *Csed* may be under- or overestimated to a limited degree, as indicated by the narrow range of recommended values.
d_{wc}	Depth of water column	m	**Varies (site-specific)** This variable is site-specific. The following uncertainty is associated with this variable: (1) Use of default d_{wc} values may not accurately reflect site-specific conditions. Therefore, use of these default values may contribute to the under- or overestimation of the variable C_{sed}. However, the degree of uncertainty is expected to be minimal, because resources allowing reasonable water body-specific estimates of d_{wc} are generally available.
d_{bs}	Depth of upper benthic sediment layer	m	**0.03** This variable is site-specific. U.S. EPA recommends a default upper-benthic sediment depth of 0.03 meter, which is based on the center of this range cited by U.S. EPA (1993b). This is consistent with U.S. EPA (1994) and NC DEHNR (1997). The following uncertainty is associated with this variable: (1) Use of default d_{bs} values may not accurately reflect site-specific conditions. Therefore, use of these values may contribute to the under- or overestimation of the variable C_{sed}. However, the degree of uncertainty is expected to be small, based on the narrow recommended range of default values.

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TABLE B-2-19

COPC CONCENTRATION IN BED SEDIMENT
(SURFACE WATER AND SEDIMENT EQUATIONS)

REFERENCES AND DISCUSSION

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units.* January.

This document is cited as one of the reference source documents for the default value for bed sediment porosity (θ_{bs}). This document cites U.S. EPA (1993a; 1993b) as its source of information. This document is also cited as one of the reference source documents for the default value for depth of the upper benthic layer. The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993a; 1993b) as its source of information for the range of values for the depth of the upper benthic layer. This document is also cited as one of the reference source documents for the default benthic solids concentration (*BS*).

U.S. EPA. 1993a. *Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* External Review Draft. Office of Research and Development. Washington, D.C. November 1993.

This document is cited by U.S. EPA (1994) and NC DEHNR (1997) as one of the sources of the range of Kd_s values and an assumed *OC* value of 0.04 for sediment. The generic equation for calculating partition coefficients (soil, surface water, and bed sediments) is as follows: $Kd_{ij} = K_{oc} * OC_i$. K_{oc} is a chemical-specific value; however, *OC* is medium-specific. The range of Kd_s values was based on an assumed *OC* value of 0.01 for soil. Therefore, the Kd_{bs} value was estimated by multiplying the Kd_s values by 4, because the *OC* value for sediment is four times greater than the *OC* value for soil. This document is also cited as the source of the equation for calculating bed sediment porosity (θ_{bs}). No source of this equation was identified. This document was also cited as the source for the range of the benthic solids concentration (*BS*). No source of this range was identified.

U.S. EPA. 1993b. *Addendum: Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Working Group Recommendations. Office of Solid Waste and Office of Research and Development. Washington, D.C. September 24.

This document is cited by NC DEHNR (1997) and U.S. EPA (1994) as the source of the default bed sediment porosity value (θ_{bs}), the default benthic solids concentration value (*BS*), and the range for depth of upper benthic layer (d_{bs}) values.

U.S. EPA. 1994. *Draft Guidance for Performing Screening Level Risk Analyses at Combustor Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

This document is cited as one of the sources of the range of Kd_s values and an assumed *OC* value of 0.04 for sediment. This document cites RTI (1992) as its source of information regarding Kd_s values. This document is cited as one of the reference source documents for the default value for bed sediment porosity (θ_{bs}). This document cites U.S. EPA (1993a; 1993b) as its source. This document is also cited as one of the reference source documents for the default value for depth of upper benthic layer (d_{bs}). The default value is the midpoint of an acceptable range. This document cites U.S. EPA (1993a; 1993b) as its source of information for the range of values for the depth of the upper benthic layer. This document is also cited as one of the reference source documents for the default benthic solids concentration (*BS*).

US EPA ARCHIVE DOCUMENT

TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Description

This equation calculates the COPC concentration in plants, resulting from wet and dry deposition of particle phase COPCs onto the exposed plant surface.

The limitations and uncertainty associated with calculating this value include the following:

(1) Uncertainties associated with the variables *Q*, *Dydp*, and *Dywp* are site-specific.
(2) The calculation of *kp* values does not consider chemical degradation processes. Inclusion of chemical degradation process would decrease the amount of time that a compound remains on plant surfaces (half-time) and thereby increase *kp* values. *Pd* decreases with increased *kp* values. Reduction of half-time from the assumed 14 days to 2.8 days, for example, would decrease *Pd* about 5-fold.
(3) The calculation of other parameter values (for example, *Fw* and *Rp*) is based directly or indirectly on studies of specific types of vegetation (primarily grasses and forbes). To the extent that the calculated parameter values do not accurately represent all site-specific forage species, uncertainty is introduced.
(4) The uncertainties associated with the variables F_v, *Tp*, and *Yp* are not expected to be significant.

Equation

$$Pd = \frac{1000 \cdot Q \cdot (1 - F_v) \cdot [Dydp + (Fw \cdot Dywp)] \cdot Rp \cdot [1.0 - \exp(-kp \cdot Tp)] \cdot 0.12}{Yp \cdot kp}$$

For mercury modeling:

$$Pd_{Mercury} = \frac{1000 \cdot (0.48 Q_{TotalMercury}) \cdot (1 - F_{v_{Hg^{2+}}}) \cdot [Dydp + (Fw \cdot Dywp)] \cdot Rp \cdot [1.0 - \exp(-kp \cdot Tp)] \cdot 0.12}{Yp \cdot kp}$$

In calculating *Pd* for mercury comounds, *Pd(Mercury)* is calculated as shown above using the total mercury emission rate (*Q*) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated *Pd(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 78% Hg^{2+} and 22% MHg speciation split in plants (see Chapter 2).

Pd (Hg^{2+}) = 0.78 *Pd(Mercury)*
Pd (MHg) = 0.22 *Pd(Mercury)*

After calculating species specific *Pd* values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Pd	Plant concentration due to direct deposition	mg/kg WW	
1000	Units conversion factor	mg/g	
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This value is COPC- and site-specific (see Chapters 2 and 3). Uncertainties associated with this variable are also COPC- and site-specific.
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Uncertainties associated with this variable include the following: (1) Calculation is based on an assumption of a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable *c* is constant for all chemicals; however, the value of *c* depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of *c* to vary, uncertainty is introduced if a constant value of *c* is used to calculate F_v.
Dydp	Unitized yearly average dry deposition from particle phase	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Rp	Interception fraction of the edible portion of plant	unitless	**0.5** U.S. EPA OSW recommends the use of the *Rp* value of 0.5 , which is consistent with the value used by U.S. EPA (1994b; 1995) in development of values for the fraction of deposition that adheres to plant surfaces, *Fw*, for forage. As summarized in Baes, Sharp, Sjoreen, and Shor (1984), experimental studies of pasture grasses identified a correlation between initial *Rp* values and productivity (standing crop biomass [*Yp*]) (Chamberlain 1970): $$Rp = 1 - e^{-\gamma . Yp}$$ where: *Rp* = Interception fraction of edible portion of plant (unitless) γ = Empirical constant; Chamberlain (1970) presents a range of 2.3 to 3.3; Baes, Sharp, Sjoreen, and Shor (1984) uses the midpoint, 2.88, for pasture grasses. *Yp* = Yield or standing crop biomass (productivity) (kg DW/m^2) Baes, Sharp, Sjoreen, and Shor (1984) proposed using the same empirical relationship developed by Chamberlain (1970) for other vegetation classes. Class-specific estimates of the empirical constant, γ, were developed by forcing an exponential regression equation through several points, including average and theoretical maximum estimates of *Rp* and *Yp* (Baes, Sharp, Sjoreen, and Shor 1984). Uncertainties associated with this variable include the following: (1) The empirical relationship developed by Chamberlain (1970) on the basis of a study of pasture grass may not accurately represent all forage varieties of plants. (2) The empirical constants developed by Baes, Sharp, Sjoreen, and Shor (1984) for use in the empirical relationship developed by Chamberlain (1970) may not accurately represent site-specific mixes of plants.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Fw	Fraction of COPC wet deposition that adheres to plant surfaces	unitless	**Anions: 0.20** **Cations and most Organics: 0.6** Consistent with U.S. EPA (194b; 1995) in evaluating aboveground forage, U.S. EPA OSW recommends using the value of 0.2 for anions and 0.6 for cations and most organics. These values are the best available information, based on a review of the current scientific literature, with the following exception: U.S. EPA OSW recommends using an *Fw* value of 0.2 for the three organic COPC that ionize to anionic forms. These include (1) 4-chloroaniline, (2) n-nitrosodiphenylamine, and (3) n-nitrosodi-n-proplyamine (see Appendix A-2). The values estimated by U.S. EPA (1994b; 1995) are based on information presented in Hoffman, Thiessen, Frank, and Blaylock (1992), which presented values for a parameter (*r*) termed the "interception fraction." These values were based on a study in which soluble radionuclides and insoluble particles labeled with radionuclides were deposited onto pasture grass (specifically a combination of fescues, clover, and old field vegitation) via simulated rain. The parameter (*r*) is defined as "the fraction of material in rain intercepted by vegetation and initially retained" or, essentially, the product of *Rp* and *Fw*, as defined for use in this guidance: $r = Rp \cdot Fw$ The *r* values developed by Hoffman, Thiessen, Frank, and Blaylock (1992) were divided by an *Rp* value of 0.5 for forage (U.S. EPA 1994b). The *Fw* values developed by U.S. EPA (1994b) are 0.2 for anions and 0.6 for cations and insoluble particles. U.S. EPA (1994b; 1995) recommended using the *Fw* value calculated by using the *r* value for insoluble particles to represent organic compounds; however, no rationale for this recommendation is provided. Uncertainties associated with this variable include the following: (1) Values of *r* developed experimentally for pasture grass (specifically a combination of fescues, clover, and old field vegitation) may not accurately represent all forage varieties specificto a site. (2) Values of *r* assumed for most organic compounds, based on the behavior of insoluble polystryene microspheres tagged with radionuclides, may not accurately represent the behavior of organic compounds under site-specific conditions.
Dywp	Unitized yearly average wet deposition from particle phase	s/m^2-yr	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
kp	Plant surface loss coefficient	yr^{-1}	**18** U.S. EPA OSW recommends the *kp* value of 18 recommended by U.S. EPA (1993; 1994b). The *kp* value selected is the midpoint of a possible range of values. U.S. EPA (1990) identified several processes—including wind removal, water removal, and growth dilution—that reduce the amount of contaminant that has been deposited on a plant surface. The term *kp* is a measure of the amount of contaminant lost to these physical processes over time. U.S. EPA (1990) cited Miller and Hoffman (1983) for the following equation used to estimate *kp*: $kp = (\ln 2 / t_{1/2}) \cdot 365 \text{ days/yr}$ where: $t_{1/2}$ = half-time (days) Miller and Hoffman (1983) report half-time values ranging from 2.8 to 34 days for a variety of contaminants on herbaceous vegetation. These half-time values result in *kp* values of 7.44 to 90.36 yr^{-1}. U.S. EPA (1993; 1994b) recommend a *kp* value of 18, based on a generic 14-day half-time, corresponding to physical processes only. The 14-day half-time is approximately the midpoint of the range (2.8 to 34 days) estimated by Miller and Hoffman (1983). Uncertainties associated with this variable include the following: (1) Calculation of *kp* does not consider chemical degradation processes. The addition of chemical degradation processes would decrease half-times and thereby increase *kp* values; plant concentration decreases as *kp* increases. Therefore, use of a *kp* value that does not consider chemical degradation processes is conservative. (2) The half-time values reported by Miller and Hoffman (1983) may not accurately represent the behavior of all COPCs on plants. (3) Based on this range (7.44 to 90.36), plant concentrations could range from about 1.8 times higher to about 5 times lower than the plant concentrations, based on a *kp* value of 18.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Tp	Length of plant exposure to deposition per harvest of edible portion of plant	yr	**0.12** This variable is site-specific. U.S. EPA OSW recommends the use of these default values in the absence of site-specific information. U.S. EPA (1990), U.S. EPA (1994b), and NC DEHNR (1997) recommended treating *Tp* as a constant, based on the average periods between successive hay harvests and successive grazing. For forage, the average of the average period between successive hay harvests (60 days) and the average period between successive grazing (30 days) is used (that is, 45 days). *Tp* is calculated as follows: Tp = (60 days + 30 days)/ 2 ÷ 365 days/yr = 0.12 yr These average periods are from Belcher and Travis (1989), and are used when calculating the COPC concentration in cattle forage. The following uncertainty is associated with this variable: (1) Beyond the time frame of about 3 months for harvest cycles, if the *kp* value remains unchanged at 18, higher *Tp* values will have little effect on predicted COPC concentrations in plants.
0.12	Dry weight to wet weight conversion factor	unitless	**0.12** U.S. EPA OSW recommends using the value of 0.12. This default value is based on the average rounded value from the range of 80 to 95 percent water content in herbaceous plants and nonwoody plant parts (Taiz at al. 1991). The following uncertainty is associated with this variable: (1) The plant species considered in determining the default value may be different from plant varieties actually present at a site.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Yp	Yield or standing crop biomass of the edible portion of the plant (productivity)	kg DW/m^2	**0.24** U.S. EPA OSW recommends using the *Yp* value of 0.24. This default value is consistent with values presented in U.S. EPA (1994b) for forage (weighted average of pasture grass and hay *Yp* values determined in considering ingestion by an herbivorous mammal [cattle]), and with the resulting Rp value (see Table B-3-1) as determined by correlation with productivity (standing crop biomass [*Yp*]) (Chamberlain 1970). Based on a review of the currently available literature, this value appears to be based on the most complete and thorough information. The following uncertainty is associated with this variable: (1) The plant species considered in determining the default value for forage may be different from plant varieties actually present at a site. This may under- or overestimate *Yp*.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

REFERENCES AND DISCUSSION

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. *Review and Analysis of Parameters and Assessing Transport of Environmentally Released Radionuclides through Agriculture*. ORNL-5786. Oak Ridge National Laboratory. Oak Ridge, Tennessee. September.

This document proposed using the same empirical relationship developed by Chamberlain (1970) for other vegetation classes. Class-specific estimates of the empirical constant, γ, were developed by forcing an exponential regression equation through several points, including average and theoretical maximum estimates of *Rp* and *Yp*.

Belcher, G.D., and C.C. Travis. 1989. "Modeling Support for the RURA and Municipal Waste Combustion Projects: Final Report on Sensitivity and Uncertainty Analysis for the Terrestrial Food Chain Model." Interagency Agreement No. 1824-A020-A1, Office of Risk Analysis, Health and Safety Research Division, Oak Ridge National Laboratory. Oak Ridge, Tennessee. October.

This document recommends *Tp* values based on the average period between successive hay harvests and successive grazing.

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology*. Volume 22. Pages 361-367. November 4.

This document is cited by U.S. EPA (1994a) and NC DEHNR (1997) as the source of the equations for calculating F_v.

Chamberlain, A.C. 1970. "Interception and Retention of Radioactive Aerosols by Vegetation." *Atmospheric Environment*. 4:57 to 78.

Experimental studies of pasture grasses identified a correlation between initial *Rp* values and productivity (standing crop biomass [*Yp*]):

Rp	=	$1-e^{-\gamma \times Yp}$
γ	=	Empirical constant; range provided as 2.3 to 3.3
Yp	=	Standing crop biomass (productivity) (kg DW/m^2)

Hoffman, F.O., K.M. Thiessen, M.L. Frank, and B.G. Blaylock. 1992. "Quantification of the Interception and Initial Retention of Radioactive Contaminants Deposited on Pasture Grass by Simulated Rain." *Atmospheric Environment*. Vol. 26A. 18:3313 to 3321.

This document developed values for a parameter (*r*) that it termed "interception fraction," based on a study in which soluble gamma-emitting radionuclides and insoluble particles tagged with gamma-emitting radionuclides were deposited onto pasture grass (specifically, a combination of fescues, clover, and old field vegetation, including fescue) via simulated rain. The parameter, *r*, is defined as "the fraction of material in rain intercepted by vegetation and initially retained" or, essentially, the product of *Rp* and *Fw*, as defined by this guidance:

$$r = Rp \cdot Fw$$

Experimental *r* values obtained include the following:

- A range of 0.006 to 0.3 for anions (based on the soluble radionuclide iodide-131 [^{131}I]); when calculating *Rp* values for anions, U.S. EPA (1994a) used the highest geometric mean *r* value (0.08) observed in the study.

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- A range of 0.1 to 0.6 for cations (based on the soluble radionuclide beryllium-7 [7Be]; when calculating *Rp* values for cations, U.S. EPA (1994a) used the highest geometric mean *r* value (0.28) observed in the study.

- A geometric range of values from 0.30 to 0.37 for insoluble polystyrene microspheres (IPM) ranging in diameter from 3 to 25 micrometers, labeled with cerium-141 [^{141}Ce], [^{95}N]b, and strontium-85 ^{85}Sr; when calculating *Rp* values for organics (other than three organics that ionize to anionic forms: 4-chloroaniline; n-nitrosodiphenylamine; and n-nitrosodi-n-propylamine, —see Appendix A-2), U.S. EPA (1994a) used the geometric mean *r* value for IPM with a diameter of 3 micrometers. However, no rationale for this selection was provided.

The authors concluded that, for the soluble ^{131}I anion, interception fraction *r* is an inverse function of rain amount, whereas for the soluble cation ^{7}Be and the IPMs, *r* depends more on biomass than on amount of rainfall. The authors also concluded that (1) the anionic ^{131}I is essentially removed with the water after the vegetation surface has become saturated, and (2) the cationic ^{7}Be and the IPMs are adsorbed to, or settle out on, the plant surface. This discrepancy between the behavior of the anionic and cationic species is consistent with a negative charge on the plant surface.

Miller, C.W. and F.O. Hoffman. 1983. "An Examination of the Environmental Half-Time for Radionuclides Deposited on Vegetation." *Health Physics*. 45 (3): 731 to 744.

This document is the source of the equation used to calculate kp:

$$kp = (\ln 2 / t_{1/2}) \cdot 365 \text{ days/year}$$
$$t_{1/2} = \text{half-time (days)}$$

The study reports half-time values ranging from 2.8 to 34 days for a variety of contaminants on herbaceous vegetation. These half-time values result in calculate *kp* values from 7.44 to 90.36 yr^{-1}.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

Shor, R.W., C.F. Baes, and R.D. Sharp. 1982. *Agricultural Production in the United States by County: A Compilation of Information from the 1974 Census of Agriculture for Use in Terrestrial Food-Chain Transport and Assessment Models.* Oak Ridge National Laboratory Publication. ORNL-5786.

This document is the source of the equation used to calculate *Yp*, as cited by U.S. EPA (1994b). Baes, Sharp, Sjoreen, and Shor (1984) also presents and discusses this equation.

Taiz, L., and E. Geiger. 1991. *Plant Physiology*. Benjamin/Cammius Publishing Co. Redwood City, California. 559 pp.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Environmental Criteria and Assessment Office. Office of Research and Development. EPA 600/6-90/003. January.

This is one of the source documents for the equation, and also states that the best estimate of *Yp* (yield or standing crop biomass) is productivity, as defined under Shor, Baes, and Sharp (1982).

U.S. EPA. 1993. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions.* Office of Health and Environmental Assessment. Office of Research and Development. EPA/600/AP-93/003. November.

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TABLE B-3-1

PLANT CONCENTRATION DUE TO DIRECT DEPOSITION (TERRESTRIAL PLANT EQUATIONS)

(Page 10 of 10)

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-Like Compounds. Volume III: Site-Specific Assessment Procedures. Review Draft.* Office of Research and Development. Washington, D.C. EPA/600/6-88/005Cc. June.

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

U.S. EPA. 1995. *Review Draft Development of Human Health-Based and Ecologically-Based Exit Criteria for the Hazardous Waste Identification Project*. Volumes I and II. Office of Solid Waste. March 3.

US EPA ARCHIVE DOCUMENT

TABLE B-3-2

PLANT CONCENTRATION DUE TO AIR-TO-PLANT TRANSFER (TERRESTRIAL PLANT EQUATIONS)

Description

This equation calculates the COPC concentration in plants, resulting from uptake of vapor phase COPCs by plants through their foliage.

The limitations and uncertainty associated with calculating this value include the following:

(1) The algorithm used to calculate values for the variable F_v assumes a default value for the parameter S_T (Whitby's average surface area of particulates [aerosols]) of background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. The S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower F_v value; however, the F_v value is likely to be only a few percent lower.

As highlighted by uncertainties described above, *Pv* is most significantly affected by the value calculated for *Bv*.

Equation

$$Pv = Q \cdot F_v \cdot 0.12 \cdot \frac{Cyv \cdot Bv}{\rho_a}$$

For mercury modeling

$$Pv_{Mercury} = (0.48 Q_{TotalMercury}) \cdot F_{v_{Hg^{2+}}} \cdot 0.12 \cdot \frac{Cyv \cdot Bv_{Hg^{2+}}}{\rho_a}$$

In calculating *Pv* for mercury comounds,
Pv(Mercury) is calculated as shown above using the
total mercury emission rate (*Q*) measured at the stack and F_v for mercuric chloride (F_v = 0.85). As presented below, the calculated *Pv(Mercury)* value is apportioned into the divalent mercury (Hg^{2+}) and methyl mercury (MHg) forms based on a 78% Hg^{2+} and 22% MHg speciation split in plants (see Chapter 2).

Pv (Hg^{2+}) = 0.78 *Pv(Mercury)*
Pv (MHg) = 0.22 *Pv(Mercury)*

After calculating species specific *Pv* values, divalent and methyl mercury should continue to be modeled throughout Appendix B equations as individual COPCs.

Variable	Description	Units	Value
Pv	Plant concentration due to air-to-plant transfer	mg/kg WW (equivalent to μg/g)	

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TABLE B-3-2

PLANT CONCENTRATION DUE TO AIR-TO-PLANT TRANSFER (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
Q	COPC-specific emission rate	g/s	**Varies (site-specific)** This variable is COPC- and site-specific (see Chapters 2 and 3). Uncertainties associated with this variable are site-specific.
F_v	Fraction of COPC air concentration in vapor phase	unitless	**0 to 1 (see Appendix A-2)** This variable is COPC-specific and should be determined from the COPC tables in Appendix A-2. Uncertainties associated with this variable include the following: (1) Calculation is based on an assumption of a default S_T value for background plus local sources, rather than an S_T value for urban sources. If a specific site is located in an urban area, the use of the latter S_T value may be more appropriate. Specifically, the S_T value for urban sources is about one order of magnitude greater than that for background plus local sources and would result in a lower calculated F_v value; however, the F_v value is likely to be only a few percent lower. (2) According to Bidleman (1988), the equation used to calculate F_v assumes that the variable *c* is constant for all chemicals; however, the value of *c* depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate. To the extent that site- or COPC-specific conditions may cause the value of *c* to vary, uncertainty is introduced if a constant value of *c* is used to calculate F_v.
Cyv	Unitized yearly air concentration from vapor phase	µg-s/g-m^3	**Varies (modeled)** This variable is COPC- and site-specific, and is determined by air dispersion modeling (see Chapter 3). Uncertainties associated with this variable are site-specific.
Bv	Air-to-plant biotransfer factor	unitless (μg/g plant tissue DW) / (μg/g air)	**Varies (see Appendix C)** This variable is COPC-specific and should be determined from the tables in Appendix C. Uncertainties associated with this variable include the following: (1) The studies that formed the basis of the algorithm used to estimate *Bv* values were conducted on azalea leaves and grasses, and may not accurately represent *Bv* for all forage species of plants.

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TABLE B-3-2

PLANT CONCENTRATION DUE TO AIR-TO-PLANT TRANSFER (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
0.12	Dry weight to wet weight conversion factor	unitless	**0.12** U.S. EPA OSW recommends using the value of 0.12. This default value is based on the average rounded value from the range of 80 to 95 percent water content in herbaceous plants and nonwoody plant parts (Taiz et al. 1991). The following uncertainty is associated with this variable: (1) The plant species considered in determining the default value may be different from plant varieties actually present at a site.
ρ_a	Density of air	g/m^3	**0.0012** U.S. EPA OSW recommends the use of this value based on Weast (1980). This reference indicates that air density varies with temperature. U.S. EPA (1990) recommended this same value but states that it was based on a temperature of 25°C; no reference was provided. U.S. EPA (1994b) and NC DEHNR (1997) recommend this same value but state that it was calculated at standard conditions of 20°C and 1 atm. Both documents cite Weast (1981). There is no significant uncertainty associated with this variable.

US EPA ARCHIVE DOCUMENT

TABLE B-3-2

PLANT CONCENTRATION DUE TO AIR-TO-PLANT TRANSFER (TERRESTRIAL PLANT EQUATIONS)

REFERENCES AND DISCUSSION

Bacci E., D. Calamari, C. Gaggi, and M. Vighi. 1990. "Bioconcentration of Organic Chemical Vapors in Plant Leaves: Experimental Measurements and Correlation." *Environmental Science and Technology*. Volume 24. Number 6. Pages 885-889.

This is the source of the equation to adjust B_{vol}, based on volume/volume basis, to *Bv* on a mass/mass basis—see Bacci, Cerejeira, Gaggi, Chemello, Calamari, and Vighi (1992) below.

Bacci E., M. Cerejeira, C. Gaggi, G. Chemello, D. Calamari, and M. Vighi. 1992. "Chlorinated Dioxins: Volatilization from Soils and Bioconcentration in Plant Leaves." *Bulletin of Environmental Contamination and Toxicology*. Volume 48. Pages 401-408.

This is the source of the algorithm based on a study of 14 organic compounds, including 1,2,3,4-TCDD, used to calculate the air-to-plant biotransfer factor (*Bv*):

$$\log B_{vol} = 1.065 \log K_{ow} - \log \left(\frac{H}{R.T_a}\right) - 1.654$$

where:

B_{vol}	=	Volumetric air-to-plant bio transfer factor ([μg/L wet leaf]/[μg/L air])
K_{ow}	=	Octanol-water partition coefficient (dimensionless)
H	=	Henry's Law Constant (atm-m^3/ mol)
R	=	Ideal gas constant, 8.2 x 10^{-5} atm-m^3/mol-deg K
T_a	=	Ambient air temperature, 298.1 K (25°C)

This volumetric transfer factor can be transformed to a mass-based transfer factor by using the following equation (Bacci, Calamari, Gaggi, and Vighi 1990):

$$Bv = \frac{\rho_a \cdot B_{vol}}{(1 - f_{wc}) \cdot \rho_{forage}}$$

where:

Bv	=	mass-based air-to-plant biotransfer factor ([μg/g DW plant]/[μg/g air])
B_{vol}	=	volumetric air-to-plant biotransfer factor ([μg/L wet leaf]/[μg/L air])
ρ_a	=	density of air, 1.19 g/L (Weast 1986)
ρ_{forage}	=	density of forage, 770 g/L (McCrady and Maggard, 1993)
f_{wc}	=	fraction of forage that is water, 0.85 (McCrady and Maggard, 1993)

Bidleman, T.F. 1988. "Atmospheric Processes." *Environmental Science and Technology*. Volume 22. Number 4. Pages 361-367.

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This is the reference for the statement that the equation used to calculate the fraction of air concentration in vapor phase (F_v) assumes that the variable *c* (the Junge constant) is constant for all chemicals; however, this reference notes that the value of *c* depends on the chemical (sorbate) molecular weight, the surface concentration for monolayer coverage, and the difference between the heat of desorption from the particle surface and the heat of vaporization of the liquid-phase sorbate.

This document is also cited by U.S. EPA (1994b) and NC DEHNR (1997) for calculating the variable F_v.

NC DEHNR. 1997. *NC DEHNR Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

Taiz, L., and E. Geiger. 1991. *Plant Physiology*. Benjamin/Cammius Publishing Co. Redwood City, California. 559 pp.

U.S. EPA. 1990. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Environmental Criteria and Assessment Office. Office of Research and Development. EPA-600-90-003. January.

This document is a source of air density values.

U.S. EPA. 1993. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Office of Health and Environmental Assessment. Office of Research and Development. EPA-600-AP-93-003. November 10.

Based on attempts to model background concentrations of dioxin-like compounds in beef on the basis of known air concentrations, this document recommends reducing, by a factor of 10, *Bv* values calculated by using the Bacci, Cerejeira, Gaggi, Chemello, Calamari, and Vighi (1992) algorithm The use of this factor "made predictions [of beef concentrations] come in line with observations."

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-Like Compounds. Volume II: Properties, Sources, Occurrence, and Background Exposures. Review Draft*. Office of Research and Development. Washington, DC. EPA/600/6-88/005Cb. June.

U.S. EPA. 1994b. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. Office of Solid Waste. December 14.

This is one of the source documents for Equation B-2-8. This document also presents a range (0.27 to 1) of F_v values for organic COPCs, based on the work of Bidleman (1988); F_v for all inorganics is set equal to zero.

Weast, R.C. 1981. *Handbook of Chemistry and Physics*. 62nd Edition. Cleveland, Ohio. CRC Press.

This document is a reference for air density values.

Weast, R.C. 1986. *Handbook of Chemistry and Physics*. 66th Edition. Cleveland, Ohio. CRC Press.

This document is a reference for air density values, and is an update of Weast (1981).

Wipf, H.K., E. Homberger, N. Neuner, U.B. Ranalder, W. Vetter, and J.P. Vuilleumier. 1982. "TCDD Levels in Soil and Plant Samples from the Seveso Area." *In: Chlorinated Dioxins and Related Compounds: Impact on the Environment*. Eds. Hutzinger, O. and others. Pergamon, NY.

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TABLE B-3-3

PLANT CONCENTRATION DUE TO ROOT UPTAKE (TERRESTRIAL PLANT EQUATIONS)

(Page 1 of 3)

Description

This equation calculates the COPC concentration in plants, resulting from direct uptake of COPCs from soil through plant roots.

The limitations and uncertainty associated with calculating this value include the following:

(1) The availability of site-specific information, such as meteorological data, may affect the accuracy of *Cs* estimates.
(2) Estimated COPC-specific soil-to-plant bioconcentration factors (BCF_r) may not reflect site-specific conditions.

Equation

$$Pr = Cs \cdot BCF_r \cdot 0.12$$

For mercury modeling:

$$Pr_{(Hg^{2+})} = Cs_{(Hg^{2+})} \cdot BCF_{r\,(Hg^{2+})} \cdot 0.12$$

$$Pr_{(MHg)} = Cs_{(MHg)} \cdot BCF_{r\,(MHg)} \cdot 0.12$$

Plant concentration due to root uptake is calculated using the respective *Cs* and BCF_r values for divalent mercury (Hg^{2+}) and methyl mercury (MHg).

Variable	Description	Units	Value
Pr	Plant concentration due to root uptake	mg/kg WW	
Cs	COPC concentration in soil	mg/kg	**Varies (calculated - Table B-1-1)** This value is COPC-and site-specific and should be calculated using the equation in Table B-1-1. Uncertainties associated with this variable are site-specific.

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TABLE B-3-3

PLANT CONCENTRATION DUE TO ROOT UPTAKE (TERRESTRIAL PLANT EQUATIONS)

Variable	Description	Units	Value
0.12	Dry weight to wet weight conversion factor	unitless	**0.12** U.S. EPA OSW recommends using the value of 0.12. This default value is based on the average rounded value from the range of 80 to 95 percent water content in herbaceous plants and nonwoody plant parts (Taiz et al. 1991). The following uncertainty is associated with this variable: (1) The plant species considered in determining the default value may be different from plant varieties actually present at a site.
BCF_r	Plant-soil biotransfer factor	unitless [(mg/kg plant DW)/(mg/ kg soil)]	**Varies (see Appendix C)** This variable is COPC-specific. Discussion of this variable and COPC-specific values are presented in Appendix C. Uncertainties associated with this variable include the following: (1) Estimates of BCF_r for some inorganic COPCs, based on plant uptake response slope factors, may be more accurate than those based on BCF values from Baes, Sharp, Sjoreen, and Shor (1984). (2) U.S. EPA OSW recommends that uptake of organic COPCs from soil and transport of the COPCs to the aboveground portions of the plant be calculated on the basis of a regression equation developed in a study of the uptake of 29 organic compounds. This regression equation, developed by Travis and Arms (1988), may not accurately represent the behavior of all organic COPCs under site-specific conditions.

US EPA ARCHIVE DOCUMENT

TABLE B-3-3

PLANT CONCENTRATION DUE TO ROOT UPTAKE (TERRESTRIAL PLANT EQUATIONS)

REFERENCES AND DISCUSSION

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. *Review and Analysis of Parameters and Assessing Transport of Environmentally Released Radionuclides through Agriculture.* ORNL-5786. Oak Ridge National Laboratory. Oak Ridge, Tennessee. September.

Taiz, L., and E. Geiger. 1991. *Plant Physiology*. Benjamin/Cammius Publishing Co. Redwood City, California. 559 pp.

Travis, C.C. and A.D. Arms. 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetation." *Environmental Science and Technology*. 22:271 to 274.

Based on paired soil and plant concentration data for 29 organic compounds, this document developed a regression equation relating soil-to-plant BCF to K_{ow};

$$\log BCF_r = 1.588 - 0.578 \log K_{ow}$$

U.S. EPA. 1995. *Review Draft Development of Human Health-Based and Ecologically-Based Exit Criteria for the Hazardous Waste Identification Project*. Volumes I and II. Office of Solid Waste. March 3.

This document recommended using the BCFs, *Bv* and *Br*, from Baes, Sharp, Sjoreen, and Shor (1984), for calculating the uptake of inorganics into vegetative growth (stems and leaves) and nonvegetative growth (fruits, seeds, and tubers), respectively.

Although most BCFs used in this document come from Baes, Sharp, Sjoreen, and Shor (1984), values for some inorganics were apparently obtained from plant uptake response slope factors. These uptake response slope factors were calculated from field data, such as metal methodologies, and references used to calculate the uptake response slope factors are not clearly identified.