APPENDIX C
RISK CHARACTERIZATION EQUATIONS

Table	Equation
C-1-1	COPC INTAKE FROM SOIL
C-1-2	COPC INTAKE FROM PRODUCE
C-1-3	COPC INTAKE FROM BEEF, MILK, PORK, POULTRY, AND EGGS
C-1-4	COPC INTAKE FROM FISH
C-1-5	COPC INTAKE FROM DRINKING WATER
C-1-6	TOTAL DAILY INTAKE
C-1-7	INDIVIDUAL CANCER RISK
C-1-8	HAZARD QUOTIENT
C-1-9	TOTAL CANCER RISK
C-1-10	TOTAL HAZARD INDEX
C-1-11	SEGREGATED HAZARD INDEX FOR SPECIFIC ORGAN EFFECTS
C-2-1	INHALATION CANCER RISK FOR INDIVIDUAL CHEMICALS
C-2-2	INHALATION HAZARD QUOTIENT FOR COPCS
C-2-3	TOTAL INHALATION CANCER RISK
C-2-4	HAZARD INDEX FOR INHALATION
C-3-1	CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK
C-3-2	AVERAGE DAILY DOSE TO THE EXPOSED INFANT
C-4-1	ACUTE HAZARD QUOTIENT

TABLE C-1-1

COPC INTAKE FROM SOIL

(Page 1 of 4)

Description

This equation calculates the daily intake of COPC from soil consumption. The soil concentration will vary with each scenario location, and the soil consumption rate varies for children and adults. Uncertainties associated with this equation include:

(1) Assume that the amount of soil intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{soil}.
(2) The standard assumptions regarding period exposed might not be representative of an actual exposure situation. This assumption may under- or overestimate I_{soil}.

Equation

$$I_{soil} = \frac{Cs \cdot CR_{soil} \cdot F_{soil}}{BW}$$

Variable	Description	Units	Value
I_{soil}	Daily intake of COPC from soil	mg/kg-day	
Cs	Average soil concentration over exposure duration	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table B-1-1. *Cs* varies based on whether the COPC is carcinogenic or noncarcinogenic. For carcinogenic COPCs, this value is equal to the soil concentration averaged over the exposure duration (Table B-1-1) (U.S. EPA 1994 and NC DEHNR 1997). For noncarcinogenic COPCs, this value is equal to the highest annual soil concentration occurring within the exposure duration. The highest annual soil concentration would most likely occur at the end of the time period of combustion (Table B-1-1) (U.S. EPA 1994 and NC DEHNR 1997). The following uncertainties are associated with this variable: (1) We assume that the time period for deposition of COPCs resulting from hazardous waste combustion is a conservative, long-term value. This assumption may overestimate *Cs* and Cs_{tD}. (2) Exposure duration values (T_2) are based on historical mobility studies and won't necessarily remain constant. Specifically, mobility studies indicate that most receptors that move remain in the vicinity of the combustion unit; however, it is impossible to accurately predict the probability that these short-distance moves will influence exposure, based on factors such as atmospheric transport of pollutants. (3) Using a value of zero for T_1 doesn't account for exposure that may have occurred from historic operations and emissions from hazardous waste combustion. This may underestimate *Cs* and Cs_{tD}. (4) For soluble COPCs, leaching might lead to movement to below the mixing depth, resulting in lower concentrations within the mixing depth. This uncertainty may overestimate *Cs* and Cs_{tD}. (5) Deposition to hard surfaces may result in dust residues that have negligible dilution (as a result of potential mixing with *in situ* materials) compared to other residues. This may underestimate *Cs* and Cs_{tD}.

TABLE C-1-1

COPC INTAKE FROM SOIL

Variable	Description	Units	Value
CR_{soil}	Consumption rate of soil	kg/day	**0.0001 to 0.0002** The soil consumption rate varies for the adult and child receptors (U.S. EPA 1997). Receptor — Intake Rate (kg/day) Adult — 0.0001 Child — 0.0002 U.S. EPA (1997) recommends using a child intake rate of 0.0002 kg/day for a child receptor as a conservative estimate of exposure. These values are consistent with U.S. EPA (1991). U.S. EPA (1997) references studies done by Hawley (1985) and Calabrese (1990) as the sources used to derive soil consumption rates. Uncertainties associated with this variable include: (1) Tracer studies have resulted in wide ranging estimates of the amount of soil and dust ingested by young children, making it difficult to identify a single value to use. It is also extremely difficult to separate the contribution of exposure resulting from exterior soil vs. interior dust. As a result, the intake rate is reported as the combined rate for soils and dusts. This uncertainty may under- or overestimate CR_{soil}. (2) Our recommended intake rates may not accurately represent behavioral characteristics since they are upper estimates. This uncertainty may overestimate CR_{soil}. (3) The intake rates represent normal mouthing tendencies. Some children exhibit abnormal mouthing (i.e. "pica") behavior and would have much higher intake rates. This uncertainty may considerably underestimate CR_{soil}.
F_{soil}	Fraction of soil that is contaminated	unitless	**1.0** We recommend assuming that all consumed soil is contaminated. This is consistent with NC DEHNR (1997) and U.S. EPA (1994), which assume the fraction of consumed soil contaminated is 1.0 for all exposure scenarios. Uncertainty associated with this variable include: U.S. EPA guidance recommends the fraction of consumed soil contaminated is equal to 1.0. However, due to variations in the proximity of the receptor to the contaminated source, size of the contaminated source, receptors of concern, mobility of receptors, and nature of exposure, this assumption may underestimate or overestimate F_{soil}.

TABLE C-1-1

COPC INTAKE FROM SOIL

(Page 3 of 4)

Variable	Description	Units	Value
BW	Body weight	kg	**15 or 70** We recommend using default values of 70 (adults) and 15 (children). These default values are consistent with U.S. EPA (1991; 1994). Uncertainty associated with this variable include: These body weights represent the average weight of an adult and child. However, depending on the actual receptor, body weights may be higher or lower. These default values may overestimate or underestimate actual body weights. However, the degree of under- or overestimation is not expected to be significant.

REFERENCES AND DISCUSSION

Calabrese, E.J., Stanek, E.J., Gilbert, C.E., and Barnes, R.M. 1990. Preliminary adult soil ingestion estimates; results of a pilot study. *Regul. Toxicol. Pharmacol.* 12:88-95.

This document is cited by U.S. EPA (1997) as a source of information used to derive soil consumption rates.

Hawley, J.K. 1985. Assessment of health risk from exposure to contaminated soil. *Risk Analysis* 5:289-302.

This document is cited by U.S. EPA (1997) as a source of information used to derive soil consumption rates.

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

This document is one of the sources for the equation in Table C-1-1. This document also states that (1) for carcinogenic COPCs, *Cs* is equal to the soil concentration averaged over the exposure duration; however, no reference document is cited and (2) for noncarcinogenic COPCs, *Cs* is equal to the highest annual soil concentration occurring within the exposure duration; the highest annual soil concentration would occur at the end of the time period of emissions.

U.S. EPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C. March 21.

This document is cited as the reference source document of soil ingestion rates, and the exposure frequency and body weight variables.

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 one of the sources for the equation in Table C-1-1. This document also states that (1) for carcinogenic COPCs, *Cs* is equal to the soil concentration averaged over the exposure duration; however, no reference document is cited and (2) for noncarcinogenic COPCs, *Cs* is equal to the highest annual soil concentration occurring within the exposure duration; the highest annual soil concentration would occur at the end of the time period of emissions.

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document is the source for soil consumption rates.

TABLE C-1-2

COPC INTAKE FROM PRODUCE

Description

This equation calculates the daily intake of COPC from ingestion of exposed aboveground, protected aboveground, and belowground produce. The consumption rate varies for children and adults, and for the type of produce. The concentration in exposed aboveground, protected aboveground, and belowground produce will also vary with each scenario location.

Consumption rates were derived from the *Exposure Factors Handbook* (U.S. EPA 1997). U.S. EPA (1997) presents consumption rates based on body weight; therefore, body weight is not included as a variable in the calculation of I_{ag}.

Uncertainties associated with this equation include the following:

(1) The amount of produce intake is assumed to be constant and representative of the exposed population. This assumption may under- or overestimate I_{ag}.

(2) The standard assumptions regarding period exposed may not be representative of any actual exposure situation. This assumption may under- or overestimate I_{ag}.

Equation

$$I_{ag} = [((Pd + Pv + Pr) \cdot CR_{ag}) + (Pr \cdot CR_{pp}) + (Pr_{bg} \cdot CR_{bg})] \cdot F_{ag}$$

Variable	Description	Units	Value
I_{ag}	Daily intake of COPC from produce	mg/kg-day DW	
Pd	Aboveground exposed produce concentration due to direct (wet and dry) deposition onto plant surfaces	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-7. Uncertainties associated with this variable include the following: (1) The recommended equation for calculating *kp* does not consider chemical degradation processes. Adding chemical degradation processes would decrease half-lifes and thereby increase *kp* values; plant concentration decreases as *kp* increases. Using a *kp* value that does not consider chemical degradation processes is protective. (2) Estimating other parameter values (for example, *Fw* and *Rp*) is based directly or indirectly on studies of vegetation other than aboveground produce (primarily grasses). Uncertainty is introduced to the extent that the calculated parameter values do not accurately represent aboveground produce-specific values.

TABLE C-1-2

COPC INTAKE FROM PRODUCE

Variable	Description	Units	Value
Pv	Aboveground exposed produce concentration due to air-to-plant transfer	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-8. Uncertainties associated with this variable include the following: (1) The range of values for the variable *Bv* (air-to-plant biotransfer factor) is about 19 orders of magnitude for organic COPCs. (2) 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.
Pr	Aboveground exposed and protected produce concentration due to root uptake	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-9. Uncertainty associated with this variable include the following: Estimated COPC-specific soil-to-plant bioconcentration factors (*Br*) may not be representative of site-specific conditions.
Pr_{bg}	Belowground produce concentration due to root uptake	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-2-10. Uncertainty associated with this variable include the following: Estimated COPC-specific soil-to-plant bioconcentration factors (*Br*) may not be representative of site-specific conditions.

TABLE C-1-2

COPC INTAKE FROM PRODUCE

(Page 3 of 4)

<table>
<tr><th>Variable</th><th>Description</th><th>Units</th><th>Value</th></tr>
<tr><td>CR_{ag};
CR_{pp};
CR_{bg}</td><td>Consumption rate of aboveground, protected aboveground, and belowground produce, respectively</td><td>kg/kg-day DW</td><td>This variable is site-specific. The recommended default values represent the total of the following produce-specific ingestion rates:

Ingestion Rate (kg/kg-day DW)
<table><tr><th>Plant Type</th><th>Farmer</th><th>Farmer Child</th><th>Resident</th><th>Res. Child</th><th>Fisher</th><th>Fisher Child</th></tr><tr><td>Exposed Aboveground Produce (Cr_{ag})</td><td>0.00047</td><td>0.00113</td><td>0.00032</td><td>0.00077</td><td>0.00032</td><td>0.00077</td></tr><tr><td>Protected Aboveground Produce (Cr_{pp})</td><td>0.00064</td><td>0.00157</td><td>0.00061</td><td>0.00150</td><td>0.00061</td><td>0.00150</td></tr><tr><td>Belowground Produce (Cr_{bg})</td><td>0.00017</td><td>0.00028</td><td>0.00014</td><td>0.00023</td><td>0.00014</td><td>0.00023</td></tr></table>
We derived ingestion rates from U.S. EPA (1997), Tables 13-61, 13-62, 13-63, 13-64, and 13-65. The ingestion rates listed in U.S. EPA (1997) are derived from the 1987-1988 USDA National Food Consumption Survey and may be used to assess exposure to contaminants in foods grown at a specific site. The ingestion rates were adjusted for cooking and preparation loss as recommended by U.S. EPA (1997). The amount of preparation and cooking loss varied depending on type of food consumed. We assumed that no preparation and cooking loss occurs with exposed fruits because we further assumed this type of fruit is eaten in the raw form. In addition, ingestion rates for the child receptor represent a time-weighted mean from the respective tables.

Uncertainty associated with this variable include the following:
The recommended ingestion rates are based on national average home produced consumption rates. Site-specific ingestion rates may be higher or lower than those recommended. Therefore, using the recommended ingestion rates may under- or overestimate I_{ag}.</td></tr>
<tr><td>F_{ag}</td><td>Fraction of produce that is contaminated</td><td>unitless</td><td>1.0
This variable is site-specific. We recommend using the default value in the absence of site-specific information, consistent with U.S. EPA (1997).

Only that portion of the diet produced at home (and therefore exposed to facility emissions) is of consequence in the risk assessment. As detailed above (in Section 6.2.2.2), the consumption rates we recommend represent only the home-produced portion of the diet. Therefore, by using consumption rates specific to home produced foods, it is reasonable to assume that 100% of those home produced foods are contaminated.

The following uncertainty is associated with this variable:
Using default values may overestimate F_{ag}.</td></tr>
</table>

TABLE C-1-2

COPC INTAKE FROM PRODUCE

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*. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

This document is cited as a source for *Br* values.

U.S. EPA 1990. *Exposure Factors Handbook.* Office of Health and Environmental Assessment, Exposure Assessment Group. Washington, D.C. March.

This is the document cited as the source of the fraction of produce that is contaminated (F_{ag}) the adult resident, child resident, and fisher. U.S. EPA assumes that F_{ag} for the fisher child is the same as for the fisher.

U.S. EPA 1992. *Technical Support Document for Land Application of Sewage Sludge.* Volumes I and II. Office of Water. Washington, D.C. EPA 822/R-93-001a.

This document is cited as a source for plant uptake response slope factors.

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

This document is cited as the source of the fraction of produce that is contaminated (F_{ag}) for the farmer (U.S. EPA assumes that F_{ag} for the farmer child is the same as for the farmer).

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document is the source for produce consumption rates.

TABLE C-1-3

COPC INTAKE FROM BEEF, MILK, PORK, POULTRY, AND EGGS

Description

This equation calculates the daily intake of COPCs from the ingestion of animal tissue (where the *i* in the equation refers to beef, milk, pork, poultry, or eggs). The consumption rate varies for children and adults and for the type of animal tissue (*j*). The concentration in the animal tissue will also vary with each scenario location.

Consumption rates were derived from the *Exposure Factors Handbook* (U.S. EPA 1997). U.S. EPA (1997) presents consumption rates based on body weight; therefore, body weight is not included as a variable in the calculation of I_i.

Uncertainties associated with this equation include the following:

(1) The amount of animal tissue intake is assumed to be constant and representative of the exposed population. This assumption may under- or overestimate I_i.
(2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_i.

Equation

$$I_i = A_i \cdot CR_i \cdot F_i$$

Variable	Description	Units	Value
I_i	Daily intake of COPC *i* from animal *j* tissue	mg/kg-day	
A_j	Concentration of COPC *i* in animal tissue *j*	mg/kg FW	**Varies** This variable is COPC- and site-specific, and is calculated using output from the equations in Tables B-3-10, B-3-11, B-3-12, B-3-13, and B-3-14. Uncertainties associated with this variable include the following: (1) Based on the information provided, A_{beef} and A_{pork} depend on estimated concentrations of COPCs in plant feeds and soil, and the biotransfer factors estimated for each constituent. To the extent the estimated concentrations and biotransfer factors do not reflect site-specific or local conditions, A_{beef} may be under- or overestimated. (2) Uptake of COPCs into chicken and eggs has typically been applied only to PCDDs and PCDFs but could possibly be used to calculate A_{chick} and A_{egg} resulting from other COPCs. (3) The assumption that 10 percent of a chicken's diet is soil may not represent site-specific or local conditions of chickens raised on farms. Stephens, Petreas, and Hayward (1992) and Stephens, Petreas, and Hayward (1995) suggest the percentage of soil in the diet of chickens raised under field conditions may be greater than 10 percent. Therefore, the concentration of COPCs in eggs, A_{egg}, and the concentration of COPCs in chicken, A_{chick}, may be underestimated.

TABLE C-1-3

COPC INTAKE FROM BEEF, MILK, PORK, POULTRY, AND EGGS

Variable	Description	Units	Value
CR_j	Consumption rate of animal tissue *j*	kg/kg-day FW	**Varies** This variable is site-specific. We derived our recommended ingestion rates of animal tissues (see the equation in Table C-1-4 for fish ingestion) from U.S. EPA (1997): Animal Tissue Ingestion Rates (kg/kg-day FW) Farmer / Farmer Child Homegrown Beef 0.00122 0.00075 Homegrown Milk 0.01367 0.02268 Homegrown Poultry 0.00066 0.00045 Homegrown Eggs 0.00075 0.00054 Homegrown Pork 0.00055 0.00042 Ingestion rates were based on data from U.S. EPA (1997) Tables 13-28, 13-36, 13-43, 43-54, and 13-55. The ingestion rates listed in U.S. EPA (1997) were derived from the 1987-1988 USDA National Food Consumption Survey and may be used to assess exposure to contaminants in foods raised at a specific site. Prior to the adjustment for cooking and preparation loss, the mean individual meat consumption rates were weighted by age group. The ingestion rates were then adjusted for cooking and preparation loss as recommended in U.S. EPA (1997). The total preparation and cooking loss was in the range of 45 to 54 percent for beef, pork, and poultry. In addition, ingestion rates for the child receptor represent a time-weighted mean from the respective tables. Where data for a specific age group was incomplete, the intake was extrapolated using data from the general population (Tables 11-11 and 11-13 of U.S. EPA 1997). See HHRAP Section 6.2.2.2 for a more detailed explanation of our recommended method for estimating age-appropriate consumption rates. U.S. EPA (1997) provides information for total home produced dairy (Table 13-28 of U.S. EPA 1997), but does not specify intake for fluid milk. For the metals mercury, selenium, and cadmium, the concentration in beef, milk, and pork, and the consumption rate are in kilograms dry weight per day. Wet-weight to dry-weight conversion information for beef, milk, and pork is presented in U.S. EPA (1997) The following uncertainty is associated with this variable: The recommended tissue-specific consumption rates may not accurately reflect site-specific local conditions. As a result, tissue-specific intakes may be under- or overestimated.

TABLE C-1-3

COPC INTAKE FROM BEEF, MILK, PORK, POULTRY, AND EGGS

Variable	Description	Units	Value
F_j	Fraction of animal tissue *j* that is contaminated	unitless	**1.0** This variable is site-specific. We recommend an F_j of 1.0 for all animal tissues consumed. This recommendation is consistent with NC DEHNR (1997). The following uncertainty is associated with this variable: The fraction of animal tissue that is contaminated is site-specific; therefore, any of the following may be under- or overestimated: variations in the proximity of the receptor to the contaminated source, size of the contaminated source, receptors of concern, mobility of receptors, and nature of exposure.

REFERENCE AND DISCUSSIONS

Stephens, R.D., M.X. Petreas, and D.G. Hayward. 1992. "Biotransfer and Bioaccumulation of Dioxins and Dibenzofurans from Soil." Hazardous Materials Laboratory, California Department of Health Services. Berkeley, California. Presented at the 12th International Symposium on Dioxins and Related Compounds. August 24 through 28. University of Tampere, Tampere, Finland.

This document is cited as the source of the assumption that free-range chickens ingest soil as 10 percent of their diet and as the source of the dioxin and furan congeners-specific *BCF*s recommended by NC DEHNR (1997). However this document does not clearly reference or document the assumption that soil represents 10 percent of a free-range chicken's diet. The document appears to cite two other documents as supporting its assumption: (1) Chang, Hayward, Goldman, Harnly, Flattery and Stephens (1989) and (2) Petreas, Goldman, Hayward, Chang, Flattery, Wiesmuller, Stephens, Fry, and Rappe (1992).

Also, this document presents dioxin and furan congener-specific *BCF*s (thigh) for the low- exposure group after 80 days of a 178-day total exposure period. The chickens in the low-dose group were fed a diet containing 10 percent soil with a PCDD/PCDF concentration of 42 ppt I-TEQ. Chickens in the high-dose group were fed a diet containing 10 percent soil with a PCDD/PCDF concentration of 458 ppt I-TEQ; *BCF* results were not presented from the high-dose group.

Stephens, R.D., M.X. Petreas, and D.G. Hayward. 1995. "Biotransfer and Bioaccumulation of Dioxins and Furans from Soil: Chickens as a Model for Foraging Animals." *The Science of the Total Environment.* Volume 175: 253-273.

This document is an expansion of the results originally presented in Stephens, Petreas, and Hayward (1992). In particular, this document suggests that the percentage of soil in the diet of chickens raised under field conditions is likely to be greater than 10 percent, the value that was used in the experimental study presented in this document.

Also, this document presents dioxin and furan congener-specific *BCF*s (thigh) under two exposure schemes; low exposure and high exposure. The white leghorn (Babcock D 300) chickens in the low group were fed a diet containing 10 percent soil with a PCDD/PCDF concentrations of 42 ppt I-TEQ. Chickens in the high group were fed a diet containing 10 percent soil with a PCDD/PCDF concentration of 460 ppt I-TEQ (some congeners were fortified by spiking).

The *BCF*s presented for low- and high-dose groups both represent averages of results from Day-80 and Day-164 of a total 178-day exposure period.

TABLE C-1-3

COPC INTAKE FROM BEEF, MILK, PORK, POULTRY, AND EGGS

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document is the source for home produced beef, milk, pork, poultry, and egg consumption rates.

TABLE C-1-4

COPC INTAKE FROM FISH

Description

This equation calculates the daily intake of COPCs from the ingestion of fish. Consumption rates were derived from the *Exposure Factors Handbook* (U.S. EPA 1997). U.S. EPA (1997) presents consumption rates based on body weight; therefore, body weight is not included as a variable in the calculation of I_{fish}.

The limitations and uncertainty introduced in calculating this value include the following:

(1) The amount of fish intake is assumed to be constant and representative of the exposed population. This assumption may under- or overestimate I_{fish}.
(2) The standard assumptions regarding period exposed may not be representative of any actual exposure situation. This assumption may under- or overestimate I_{fish}.

Equation

$$I_{fish} = C_{fish} \cdot CR_{fish} \cdot F_{fish}$$

Variable	Description	Units	Value
I_{fish}	Daily intake of COPC from fish	mg/kg-day	
C_{fish}	Concentration in fish	mg/kg	**Varies** This variable is COPC- and site-specific, and is calculated using output from the equations in Tables B-4-26 through B-4-28; the fish concentration will vary for each water body. The following uncertainty is associated with this variable: The methodology does not account for concentration variations across fish species. Different species may accumulate COPCs to different extents depending, for example, on their feeding habits and fat content. This may cause C_{fish} to be under- or overestimated.

TABLE C-1-4

COPC INTAKE FROM FISH

Variable	Description	Units	Value
CR_{fish}	Consumption rate of fish	kg/kg-day FW	**Varies** The consumption rate varies for the receptor considered. The following home produced or caught ingestion rates for fish were derived from U.S. EPA (1997): Receptor — Ingestion Rate (kg/kg-day FW) Fisher — 0.00125 Fisher Child — 0.00088 We derived ingestion rates using data from U.S. EPA (1997) Table 13-23. The ingestion rates listed in U.S. EPA (1997) were derived from the 1987-1988 USDA National Food Consumption Survey and may be used to assess exposure to contaminants in foods grown, raised, or caught at a specific site. Prior to the adjustment for cooking and preparation loss, the mean individual fish consumption rates were weighted by age group. The ingestion rates were then adjusted for cooking and preparation loss as recommended in U.S. EPA (1997). The total preparation and cooking loss for fish was 41 percent. In addition, the ingestion rates for the child receptor represents a time-weighted mean. Where data for a specific age group was incomplete, the intake was extrapolated using data from the general population (Table 10-46 of U.S. EPA 1997). See HHRAP Section 6.2.2.2 for a more detailed explanation of our recommended method for estimating age-appropriate consumption rates. Uncertainties introduced by assumptions made to calculate this value include the following: (1) Our recommended intake rates don't necessarily take into account the types of fish that will be present in the water body. Separate intake rates are needed for freshwater and estuarine fish and shellfish, depending on the nature of the local surface water body. This assumption can overestimate or underestimate CR_{fish}. (2) These intake rates do not represent long behavior patterns, which is the focus of the exposure assessments used to support chronic health effects. This introduces uncertainty into the estimates of medians and other percentiles. This assumption can overestimate or underestimate CR_{fish}. (3) The intake rates represent total intake rates of home-caught fish. Where use of site-specific information would reveal the amount of fish consumed from waters within the study area, this information should be used. This assumption can overestimate or underestimate CR_{fish}.
F_{fish}	Fraction of fish that is contaminated	unitless	**1.0** We recommend using this default value if site-specific information is not available. The contaminated fraction will vary with each exposure scenario; however, NC DEHNR (1997) and U.S. EPA (1994) assume that this value equals 1.0 for the fisher. The following uncertainty is associated with this variable: Using 1.0 as a default value for fraction of fish that is contaminated assumes that receptors consume only contaminated fish; this assumption may overestimate F_{fish}.

TABLE C-1-4

COPC INTAKE FROM FISH

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 source documents for the equation in Table C-1-4.

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 one of the reference source documents for the equation in Table C-1-4.

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document is the source for home-caught fish consumption rates.

TABLE C-1-5

COPC INTAKE FROM DRINKING WATER

Description

This equation calculates the daily intake of COPC from drinking water. COPC intake from drinking water is calculated from the concentration of COPC dissolved in the water column of each surface water body or watershed identified as a drinking water source. The dissolved concentration is used to estimate COPC intake from drinking water because it is assumed the water is filtered prior to human consumption. The COPC concentration will vary for each water body. The consumption rate varies for children and adults.

Uncertainties associated with this equation include the following:

(1) The amount of drinking water intake is assumed to be constant and representative of the exposed population. This assumption may under- or overestimate I_{dw}.

(2) The standard assumptions regarding period exposed may not be representative of any actual exposure situation. This assumption may under- or overestimate I_{dw}.

Equation

$$I_{dw} = \frac{C_{dw} \cdot CR_{dw} \cdot F_{dw}}{BW}$$

Variable	Description	Units	Value
I_{dw}	Daily intake of COPC from drinking water	mg/kg-day	
C_{dw}	Dissolved phase water concentration	mg/L	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table B-4-24. Uncertainties associated with this variable include the following: All of the variables in the equation in Table B-4-24 are COPC- and site-specific. Therefore, using default values rather than site-specific values, for any or all of these variables, will contribute to the under- or overestimating C_{wt}. We expect the degree of uncertainty associated with the variables d_w and d_b to be minimal because information for estimating d_w is generally available and the probable range for d_b is narrow. The uncertainty associated with the variables F_{water} 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.

TABLE C-1-5

COPC INTAKE FROM DRINKING WATER

Variable	Description	Units	Value
CR_{dw}	Rate of consumption of drinking water	L/day	**0.67 or 1.4** This variable is site-specific. We recommend using default values of 0.67 (child) and 1.4 (adult) in the absence of site-specific data. Our recommended average adult consumption rate of drinking water is based on information cited in U.S. EPA (1997). For the child receptor, U.S. EPA (1997) provides recommended drinking water intake rates for various age groups in Table 3-30. The child default drinking water intake was derived using a time-weighted average for the age groups 0 to 6 years of age. The following uncertainty is associated with this variable: The average consumption rate of drinking water is based on the average intake observed from five studies. The number of studies conduct may underestimate or underestimate CR_{dw}.
F_{dw}	Fraction of drinking water that is contaminated	unitless	**1.0** This variable is site-specific. Consistent with U.S. EPA (1994), we recommend assuming 1.0 for the fraction of drinking water that is contaminated. The following uncertainty is associated with this variable: Some receptors may consume a fraction of their drinking water from sources unimpacted by facility emissions. Therefore, this assumption will likely overestimate F_{dw}.
BW	Body weight	kg	**15 or 70** This variable is site-specific. We recommend using default values of 15 (children) or 70 (adults) in the absence of site-specific information. These default values are consistent with U.S. EPA (1991; 1994). Uncertainties associated with this variable include: These body weights represent the average weight of an adult and child. However, depending on the receptor, the body weights may be higher or lower. These default values may overestimate or underestimate actual body weights. However, the degree of under- or overestimation is not expected to be significant.

TABLE C-1-5

COPC INTAKE FROM DRINKING WATER

REFERENCES AND DISCUSSION

U.S. EPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C. March 21.

This document is cited as the reference source document of the exposure frequency and body weight variables.

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.

This document was cited as the source of the fraction of drinking water that is contaminated.

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document is the source for the drinking water consumption rates.

TABLE C-1-6

TOTAL DAILY INTAKE

(Page 1 of 3)

Description

This equation calculates the daily intake of COPC via all indirect exposure pathways. As discussed in Chapter 4 and Table 4-1, the indirect exposure pathways considered in the calculation of the total daily intake of COPCs are specific to the recommended exposure scenario evaluated and the representative exposure setting. Daily intake values from exposure pathways which are not evaluated in a respective exposure scenario may be assumed to be zero when calculating the total daily intake of COPC (*I*).

Uncertainties associated with this equation include the following:

(1) The uncertainties associated with estimates of total intake are those associated with each of the medium- or tissue-specific intakes.

(2) To the extent that medium- or tissue-specific intakes do not accurately represent site-specific local conditions, *I* may be under- or overestimated.

Equation

$$I = I_{soil} + I_{ag} + I_{beef} + I_{milk} + I_{fish} + I_{pork} + I_{poultry} + I_{eggs} + I_{dw}$$

Variable	Description	Units	Value
I	Total daily intake of COPC	mg/kg-day	
I_{soil}	Daily intake of COPC from soil	mg/kg-day	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-1. The value for this variable will vary for each receptor and each exposure scenario location. Uncertainties associated with this variable include the following: (1) We assume the amount of soil intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{soil}. (2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_{soil}.

TABLE C-1-6

TOTAL DAILY INTAKE

Variable	Description	Units	Value
I_{ag}	Daily intake of COPC from aboveground produce	mg/kg-day DW	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-2. The value for this variable will vary for each receptor and each exposure scenario location. Uncertainties associated with this variable include the following: (1) We assume the amount of produce intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{ag}. (2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_{ag}.
I_{beef}; I_{milk}; I_{pork}; $I_{poultry}$; I_{eggs}	Daily intake of COPC from beef, milk, pork, poultry, and eggs	mg/kg-day FW	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-3. The value for this variable will vary for each receptor and each exposure scenario location. Uncertainties associated with this variable include the following: (1) We assume the amount of animal tissue intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{beef}, I_{milk}, I_{pork}, $I_{poultry}$, and I_{eggs}. (2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_{beef}, I_{milk}, I_{pork}, $I_{poultry}$, and I_{eggs}.
I_{fish}	Daily intake of COPC from fish	mg/kg-day FW	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-4. The value for this variable will vary for each water body evaluated. Uncertainties associated with this variable include the following: (1) We assume the amount of fish intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{fish}. (2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_{fish}.

TABLE C-1-6

TOTAL DAILY INTAKE

(Page 3 of 3)

Variable	Description	Units	Value
I_{dw}	Daily intake of COPC from drinking water	mg/kg-day	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-5. The value for this variable will vary for each water body evaluated. Uncertainties associated with this variable include the following: (1) We assume the amount of drinking water intake is constant and representative of the exposed population. This assumption may under- or overestimate I_{dw}. (2) The standard assumptions regarding period exposed may not be representative of an actual exposure situation. This assumption may under- or overestimate I_{dw}.

TABLE C-1-7

INDIVIDUAL CANCER RISK: CARCINOGENS

Description

This equation calculates the individual cancer risk from indirect exposure to carcinogenic COPCs. The exposure duration varies for different scenarios. Uncertainties associated with this equation include the following:

(1) Default factors for exposure frequency and exposure duration are assumed to represent the highest exposure that is reasonably expected to occur at a site and, in practice, is estimated by combining upper-bound (90th to 95th percentile) values for these exposure parameters, but not all parameters. This assumption may over- or underestimate the *Cancer Risk*$_i$.

(2) Slope factors are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a COPC, and are accompanied by the weight of evidence classification to indicate the strength of the evidence that the agent is a human carcinogen. This classification potentially over- or underestimates *Cancer Risk*$_i$.

(3) Risk at low exposure levels is difficult to measure directly, either by animal experiments or by epidemiological studies. The development of a cancer slope factor generally entails applying a model to the available data set and using the model to extrapolate from the relatively high doses administered to experimental animals (or the exposures noted in epidemiological studies) to lower exposure levels expected for human contact in the environment. This approach may under- or overestimate *Oral CSF*.

Equation

$$Cancer\ Risk_i = \frac{I \cdot ED \cdot EF \cdot CSF}{AT \cdot 365}$$

Variable	Description	Units	Value
Cancer Risk$_i$	Individual lifetime cancer risk through indirect exposure to COPC carcinogen *i*	unitless	
I_i	Daily intake of COPC *i* from animal tissue *j*	mg COPC/kg BW-day	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-6. The value for this variable will vary for each exposure pathway and each exposure scenario location. The following uncertainty is associated with this variable: This variable is COPC- and site-specific. See the equation in Table C-1-6 regarding the calculation of and uncertainties associated with this variable.

TABLE C-1-7

INDIVIDUAL CANCER RISK: CARCINOGENS

Variable	Description	Units	Value
ED	Exposure duration	yr	**6, 30, or 40** This variable is exposure scenario-specific: Exposure Scenario — ED Farmer — 40 (U.S. EPA 1994) Farmer Child — 6 (U.S. EPA 1989) Adult Resident — 30 (U.S. EPA 1989) Child Resident — 6 (U.S. EPA 1989) Fisher — 30 (U.S. EPA 1994) Fisher Child — 6 (U.S. EPA 1989) The following uncertainty is associated with this variable: This exposure duration is a single value that represents the highest exposure that is reasonably expected to occur at a site. This assumption may overestimate *ED*.
EF	Exposure frequency	days/yr	**350** This variable is site-specific. We recommend using this default value in the absence of site-specific information, consistent with U.S. EPA (1991). The following uncertainty is associated with this variable: This exposure frequency is a single value that represents the most frequent exposure that is reasonably expected to occur at a site, assuming 2 weeks of vacation or travel. This assumption may overestimate *EF*.
AT	Averaging time	yr	**70** This variable is site-specific. We recommend using this default value in the absence of site-specific information, consistent with U.S. EPA (1989). The following uncertainty is associated with this variable: The recommendation for averaging time may not accurately represent site-specific time; specifically, this single value may under- or overestimate the length of time of exposure.
365	Units conversion factor	day/yr	

TABLE C-1-7

INDIVIDUAL CANCER RISK: CARCINOGENS

Variable	Description	Units	Value
Oral CSF	Oral Cancer Slope Factor	$(mg/kg\text{-}day)^{-1}$	**Varies** This variable is COPC-specific. We recommend using the companion database to the HHRAP as an initial source for this parameter. We also recommend checking the recommended hierarchy of sources of health benchmark values (discussed in Appendix A-2) to make sure the database values are still valid, especially if using database values result in risk estimates of concern. Uncertainties associated with this variable include the following: (1) Slope factors are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a COPC; and are accompanied by the weight of evidence classification to indicate the strength of the evidence that the agent is a human carcinogen. (2) Risk at low exposure levels is difficult to measure directly either by animal experiments or by epidemiological studies. Developing a cancer slope factor generally entails applying a model to the available data set and using the model to extrapolate from the relatively high doses administered to experimental animals (or the exposures noted in epidemiological studies) to the lower exposure levels expected for human contact in the environment. This approach may under- or overestimate *Oral CSF*.

REFERENCES AND DISCUSSION

U.S. EPA. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A).* Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002. December.

This document is cited as the reference source document of the exposure duration for adult and child residents. This document is also cited as the reference source document for the averaging time for carcinogens.

U.S. EPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C.

This document is cited as the reference source document of the exposure frequency.

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.

This document is cited as the reference source document of the exposure duration for the fisher and farmer.

TABLE C-1-8

HAZARD QUOTIENT: NONCARCINOGENS

Description

This equation calculates the hazard quotient for indirect exposure to noncarcinogenic COPCs. The following uncertainty is associated with this equation.

A chronic *RfD* is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic *RfDs* are specifically developed to be protective for long-term exposure (from 7 years to a lifetime) to a compound. COPC-specific reference doses (*RfD*) are unlikely to underestimate a chemical potential for causing adverse effects.

Equation

$$HQ = \frac{I \cdot ED \cdot EF}{RfD \cdot AT \cdot 365}$$

Variable	Description	Units	Value
HQ	Hazard quotient	unitless	
I_i	Daily intake of COPC *i* from animal tissue *j*	mg COPC/ kg-day	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-6. The value for this variable will vary for each exposure pathway and each exposure scenario location. Uncertainties associated with this variable are site-specific.
ED	Exposure duration	yr	**6, 30, or 40** Consistent with U.S. EPA (1994b) and NC DEHNR (1997), we recommend using the following default values: Exposure Scenario — *ED* Farmer — 40 (U.S. EPA 1994a) Farmer Child — 6 (U.S. EPA 1989) Adult Resident — 30 (U.S. EPA 1989) Child Resident — 6 (U.S. EPA 1989) Fisher — 30 (U.S. EPA 1994a) Fisher Child — 6 (U.S. EPA 1989) Uncertainty associated with this variable includes: These exposure durations are single values that represent the highest exposure that is reasonably expected to occur at a site. These values may overestimate *ED* for some individuals.

TABLE C-1-8

HAZARD QUOTIENT: NONCARCINOGENS

Variable	Description	Units	Value
EF	Exposure frequency	days/yr	**350** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This value is based on U.S. EPA (1991) and is consistent with U.S. EPA (1994b). Uncertainty associated with this variable includes: This exposure frequency is a single value that represents the most frequent exposure that is reasonably expected to occur at a site with two weeks of vacation or travel. This recommended value may overestimate *EF* for individuals who are away from their home for more than two weeks each year. On the other hand, some individuals (such as farmers) may remain at their home (or farm) for more than 350 days per year. In either case, the degree of over- or underestimation is not expected to be significant in most cases.
RfD	Reference Dose	mg/kg-day	**Varies** This variable is COPC-specific. We recommend using the companion database to the HHRAP as an initial source for this parameter. We also recommend checking the recommended hierarchy of sources of health benchmark values (discussed in Appendix A-2) to make sure the database values are still valid, especially if using database values result in risk estimates of concern. The following uncertainty is associated with this variable: A chronic *RfD* is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic *RfDs* are specifically developed to be protective for long-term exposure (from 7 years to a lifetime) to a compound. COPC-specific *RfDs* are unlikely to underestimate a COPC's potential for causing adverse health effects.
365	Units conversion factor	day/yr	
AT	Averaging time	yr	**6, 30, or 40** This variable is site-specific and related to *ED*. Specifically, the *AT* for noncarcinogens is numerically the same as ED. This default value is consistent with U.S. EPA (1989), U.S. EPA (1991), and U.S. EPA (1994a). Uncertainty associated with this variable includes: Our recommended averaging time may not accurately represent site-specific time; specifically this single value may under- or overestimate the length of an average adult lifetime.

TABLE C-1-8

HAZARD QUOTIENT: NONCARCINOGENS

(Page 3 of 3)

REFERENCES AND DISCUSSION

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

U.S. EPA. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A).* Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002. December.

This document is cited as the reference source document of the exposure duration for adult and child residents. U.S. EPA OSW assumes that the recommended exposure duration for the child resident may also reasonably be applied to the farmer child and to the fisher child.

U.S. EPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C.

This document is cited as a source document for exposure frequency and averaging time.

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

This document is cited by U.S. EPA (1994b) as the same document for the recommended default exposure duration (*ED*) values for the farmer and fisher. The *ED* value of 40 years recommended for both the farmer and the fisher is based on the assumption that "farmers live in one location longer than the general population".

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 the following:

- An exposure frequency of 350 days per year
- Receptor-specific exposure duration values as presented in U.S. EPA (1994a)— fisher (40 years) and farmer (40 years) and U.S. EPA (1989)—adult resident (30 years) and child resident (6 years)
- Adult and child body weights of 70 kg and 15 kg, respectively

TABLE C-1-9

TOTAL CANCER RISK: CARCINOGENS

Description

For carcinogens, cancer risks are added across all carcinogenic COPCs. See Appendix A for identification of carcinogens. Uncertainty associated with this equation includes the following:

Total Cancer Risk assumes that different carcinogens affect the same target organ to produce a cancer response, ignoring potential antagonistic or synergistic effects or disparate effects on different target organs.

Equation

$$Total\ Cancer\ Risk = \sum_{i} Cancer\ Risk_i$$

Variable	Description	Units	Value
Total Cancer Risk	Individual lifetime cancer risk through indirect exposure to all COPC carcinogens	unitless	
Cancer Risk$_i$	Individual lifetime cancer risk through indirect exposure to COPC carcinogen *i*	unitless	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-7. The value for this variable will vary for each exposure pathway. Uncertainties associated with this variable include the following: (1) We assume that the default values for exposure frequency and exposure duration represent the highest exposure that is reasonably expected to occur at a site. In practice, intakes are estimated by combining upper-bound (90th to 95th percentile) values for these exposure variables, but not for other parameters. This assumption is likely to overestimate intakes and the *Cancer Risk*$_i$. (2) Slope factors are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen; and are accompanied by the weight of evidence classification to indicate the strength of the evidence that the agent is a human carcinogen. This classification potentially over- or underestimates risk. (3) Risk at low exposure levels is difficult to measure directly either by animal experiments or by epidemiological studies. Developing a cancer slope factor generally entails applying a model to the available data set and using the model to extrapolate from the relatively high doses administered to experimental animals (or the exposures noted in epidemiological studies) to lower exposure levels expected for human contact in the environment. This approach is likely to overestimate *CSF*.

TABLE C-1-10

TOTAL HAZARD INDEX: NONCARCINOGENS

Description

For non-cancer health effects, hazard quotient for all COPCs, regardless of target organs, are summed to calculate a total *hazard index*. Uncertainties associated with this equation include the following:

(1) Assuming that different COPCs affect the same target organ to produce an adverse health effect, while ignoring potential antagonistic or synergistic effects or disparate effects on different target organs, may overestimate the total hazard index.
(2) Total hazard index assumes that a single individual in the exposure scenario is exposed to site-related contaminants at estimated exposure concentrations by all pathways that make up the scenario. It is unlikely, however, that a single individual will be exposed by each pathway in the exposure media. This assumption may overestimate the total hazard index.

Equation

$$Total\ Hazard\ Index = \Sigma_j\ HI_j$$

$$HI = \Sigma_i\ HQ_i$$

Variable	Description	Units	Value
Total Hazard Index	Total individual hazard index for all COPCs across all exposure pathways	unitless	
HI_j	Hazard Index for exposure pathway *j*	unitless	**Varies** This variable is COPC- and site-specific. The value for this variable will vary for each exposure pathway. Uncertainties associated with this variable are site-specific.
HQ_i	Hazard Quotient for COPC *i*	unitless	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-8. The value for this variable will vary for each exposure pathway. Uncertainties associated with this variable are site-specific.

TABLE C-1-11

SEGREGATED HAZARD INDEX FOR SPECIFIC ORGAN EFFECTS: NONCARCINOGENS

Description

For non-cancer health effects, hazard quotients are added across COPCs when they target the same organ to calculate a segregated *hazard index*. See Appendix A-2 for identification of noncarcinogens and their associated target organ. Since segregation by critical effect requires the identification of all major effects, information in Appendix A-2 may not always represent the most current and complete information on COPC-specific major effects. Therefore, Appendix A-2 may require supplemental information about COPC-specific major effects. Uncertainties associated with this equation include the following:

(1) Target organ segregation is dependent upon the critical effect. Segregation by critical effect requires the identification of all major effects, not just those seen at higher doses. The segregation process may over- or underestimate the *hazard index*.

Equation

$$HI_j = \sum_i HQ_i$$

Variable	Description	Units	Value
HI_j	Hazard index for exposure pathway *j*	unitless	
HQ_i	Hazard quotient for COPC *i*	unitless	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-1-8. The value for this variable will vary for each exposure pathway. The following uncertainty is associated with this variable: (1) We assume that the default values for exposure frequency and exposure duration represent the highest exposure that is reasonably expected to occur as a site. In practice, intakes are estimated by combining upper-bound (90th to 95th percentile) values for these exposure variables, but not for other parameters. This equation is likely to overestimate intakes and HI_j. (2) Adverse health effects at low exposure levels are difficult to either directly either by animal experiments or by epidemiological studies. The development of *RfD*s generally entails applying uncertainty factors to extrapolate from the results of studies using high exposure doses to lower exposure doses expected for human contact in the environment. This approach is unlikely to underestimate and likely overestimate HI_j. The uncertainties associated with this variable are COPC- and site-specific and will vary for each exposure pathway.

TABLE C-2-1

INHALATION CANCER RISK FOR INDIVIDUAL CHEMICALS: CARCINOGENS

Description

This equation calculates the excess lifetime individual cancer risk from the average daily intake via inhalation of a COPC carcinogen. Uncertainties associated with this equation include:

(1) COPC-specific *URF* values are unlikely to underestimate, and may overestimate, the carcinogenic potential of a COPC because of the choice of mathematical models and the use of uncertainty factors in the estimation of these values.
(2) The uncertainty associated with the variable C_a are largely site-specific.

Equation

$$Cancer\ Risk_{inh(i)} = EC \cdot URF_{(i)}$$

$$EC = \frac{C_a \cdot EF \cdot ED}{AT \cdot 365\ days/year}$$

Variable	Description	Units	Value
$Cancer\ Risk_{inh(i)}$	Individual lifetime cancer risk through direct inhalation of COPC carcinogen *i*	unitless	
EC	Exposure concentration	µg/m^3	

TABLE C-2-1

INHALATION CANCER RISK FOR INDIVIDUAL CHEMICALS: CARCINOGENS

Variable	Description	Units	Value
URF	Inhalation Unit Risk Factor	$(\mu g/m^3)^{-1}$	**Varies** This variable is COPC-specific. We recommend using the companion database to the HHRAP as an initial source for this parameter. We also recommend checking the recommended hierarchy of sources of health benchmark values (discussed in Appendix A-2) if using database values results in risk estimates of concern. The following general uncertainty is associated with this variable: COPC-specific inhalation unit risk factors (*URF*s) are generally estimated by fitting the results of studies conducted on laboratory animals with a mathematical model. The model generally recommended by U.S. EPA is the linearized multistage (LMS) model. U.S. EPA's position on assessing carcinogenic potential was updated (U.S. EPA 1996b) and should be considered along with recommended toxicological benchmarks and information (U.S. EPA 1995; 1996a). The LMS model assumes that there is no "safe dose" or threshold below which a COPC causing cancer at higher doses will no longer cause cancer in expected individuals. In other words, any exposure to a carcinogen may, through a series of stages, cause cancer in an exposed individual. Also, a series of uncertainty factors are applied to the results before the results are fitted with the LMS model. Applying uncertainty factors follows the underlying assumption that humans are, or may be, as sensitive or more sensitive to the carcinogenic effects of COPCs than the laboratory animals that were tested. As a result of the choice of models and the use of uncertainty factors, COPC-specific *URF*s are unlikely to underestimate a COPC's potential for causing cancer.
C_a	Total COPC air concentration	$\mu g/m^3$	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table B-5-1. Uncertainty associated with this variable includes: Calculated assuming a default S_T value for background plus local sources, rather than a S_T value for urban sources. If a specific site is located in an urban area, using 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 the S_T value 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.

TABLE C-2-1

INHALATION CANCER RISK FOR INDIVIDUAL CHEMICALS: CARCINOGENS

Variable	Description	Units	Value
EF	Exposure frequency	days/yr	**350** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This value is based on U.S. EPA (1991) and is consistent with U.S. EPA (1994b). Uncertainties associated with this variable include: This exposure frequency is a single value that represents the most frequent exposure that is reasonably expected to occur at a site, with two weeks of vacation. This recommended value may overestimate EF for individuals who are away from their home for more than two weeks each year. On the other hand, individuals such as subsistence farmers may remain at their home (or farm) for more than 350 days per year. In either case, we don't expect a significant degree of over- or underestimation in most cases.
ED	Exposure duration	yr	**6, 30, or 40** We recommend reasonable maximum exposure (RME) values for T_2: Exposure Duration — RME — Reference Child Resident, Farmer Child, Fisher Child — 6 years — U.S. EPA (1997b) Adult Resident and Fisher — 30 years — U.S. EPA (1997b) Farmer — 40 years — U.S. EPA (1994b) U.S. EPA (1994c) recommended the following unreferenced values: Exposure Duration — Years Subsistence Farmer — 40 Adult Resident — 30 Subsistence Fisher — 30 Child Resident — 9 Uncertainties associated with this variable include the following: (1) Exposure duration rates are based on historical mobility rates and may not remain constant. This assumption may overestimate or underestimate *Cs* and Cs_{tD}. (2) Mobility studies indicate that most receptors that move remain in the vicinity of the emission sources. However, it is impossible to accurately predict the likelihood that these short-distance moves will influence exposure, based on factors such as atmospheric transport of pollutants. This assumption may overestimate or underestimate *Cs* and Cs_{tD}.

TABLE C-2-1

INHALATION CANCER RISK FOR INDIVIDUAL CHEMICALS: CARCINOGENS

Variable	Description	Units	Value
AT	Averaging time	yr	**70** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This default value is consistent with U.S. EPA (1989), U.S. EPA (1991), and U.S. EPA (1994b). Uncertainties associated with this variable include: The recommendation for averaging time may not accurately represent site-specific time; specifically this single value may under- or overestimate the length of an average adult lifetime.

REFERENCES AND DISCUSSION

U.S. EPA. 1995. *Health Effects Assessment Summary Tables. Annual Update.* OHEA-ECAO-CIN-909. Environmental Criteria and Assessment Office, Office of Research and Development Cincinnati, Ohio.

This document represent U.S. EPA's secondary source of *Inhalation CSF* values.

U.S. EPA. 1996a. "Integrated Risk Information System (IRIS)". *Database on Toxicity Information Network (TOXNET).*

This reference represents U.S. EPA's primary source of *Inhalation CSF* values and other toxicity factors. This reference is updated periodically and should be reviewed prior to preparing a risk assessment.

U.S. EPA. 1996b. "Proposed Guidelines for Carcinogenic Risk Assessment." *Federal Register.* 61 FR 31667. Volume 61. Number 120. June 20.

This document proposes new guidelines for assessing the carcinogenicity of COPCs.

TABLE C-2-2

INHALATION HAZARD QUOTIENT FOR COPCS: NONCARCINOGENS

Description

This equation calculates the *HQ* for inhalation exposures to COPCs that have noncancer health effects. Uncertainties associated with this equation include the following:

(1) COPC-specific reference concentrations (*RfC*) are unlikely to underestimate a COPC's potential for causing adverse health effects.
(2) Most of the uncertainties associated with the variables in the equation in Table B-5-1 (used to calculate C_a), specifically those associated with the variables *Q, Cyv*, and *Cyp*, are site-specific.

Equation

$$HQ_{inh(i)} = \frac{EC * 0.001}{RfC}$$

$$EC = \frac{C_a \cdot EF \cdot ED}{AT \cdot 365\ days/year}$$

Variable	Description	Units	Value
$HQ_{inh(i)}$	Hazard quotient for direct inhalation of COPC noncarcinogen *i*	unitless	
EC	Exposure concentration	µg/m^3	
0.001	Units conversion factor	mg/µg	

TABLE C-2-2

INHALATION HAZARD QUOTIENT FOR COPCS: NONCARCINOGENS

Variable	Description	Units	Value
RfC	Reference concentration	mg/m^3	**Varies** This variable is COPC-specific, and values can be found in the HHRAP companion database. The following uncertainty is associated with this variable: COPC *RfC*s are generally estimated by applying a series of uncertainty factors to the results of studies conducted on laboratory animals. The application of uncertainty factors follows the underlying assumption that humans are, or may be, as sensitive or more sensitive to the harmful effects of COPCs than the laboratory animals that were tested. *RfC*s are designed to ensure that the general public, including sensitive subpopulations, will not experience adverse health effects as a result of exposure to a COPC at its *RfC*. As a result, COPC-specific *RfC*s are unlikely to underestimate a COPC's potential for causing adverse health effects.
C_a	Total COPC air concentration	$\mu g/m^3$	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table B-5-1.
EF	Exposure frequency	days/yr	**350** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This value is based on U.S. EPA (1991) and is consistent with U.S. EPA (1994b). Uncertainties associated with this variable include: This exposure frequency is a single value that represents the most frequent exposure that is reasonably expected to occur at a site, with two weeks of vacation. This recommended value may overestimate EF for individuals who are away from their home for more than two weeks each year. On the other had, individuals such as subsistence farmers may remain at their home (or farm) for more than 350 days per year. In either case, we don't expect a significant degree of over- or underestimation in most cases.

TABLE C-2-2

INHALATION HAZARD QUOTIENT FOR COPCS: NONCARCINOGENS

Variable	Description	Units	Value
ED	Exposure duration	yr	**6, 30, or 40** We recommend reasonable maximum exposure (RME) values for T_2: Exposure Duration — RME — Reference Child Resident, Farmer Child, Fisher Child — 6 years — U.S. EPA (1997b) Adult Resident and Fisher — 30 years — U.S. EPA (1997b) Farmer — 40 years — U.S. EPA (1994b) U.S. EPA (1994c) recommended the following unreferenced values: Exposure Duration — Years Subsistence Farmer — 40 Adult Resident — 30 Subsistence Fisher — 30 Child Resident — 9 Uncertainties associated with this variable include the following: (1) Exposure duration rates are based on historical mobility rates and may not remain constant. This assumption may overestimate or underestimate *Cs* and Cs_{tD}. (2) Mobility studies indicate that most receptors that move remain in the vicinity of the emission sources. However, it is impossible to accurately predict the likelihood that these short-distance moves will influence exposure, based on factors such as atmospheric transport of pollutants. This assumption may overestimate or underestimate *Cs* and Cs_{tD}.
AT	Averaging time	yr	**6, 30, or 40** This variable is site-specific and related to *ED*. Specifically, the *AT* for noncarcinogens is numerically the same as ED. This default value is consistent with U.S. EPA (1989; 1991; 1994a). Uncertainty associated with this variable includes: Our recommended averaging time may not accurately represent site-specific time; specifically this single value may under- or overestimate the length of an average adult lifetime.

TABLE C-2-3

TOTAL INHALATION CANCER RISK: CARCINOGENS

Description

Cancer risk to the individual via inhalation are added across all COPCs that are carcinogenic via the direct inhalation route of exposure.

Uncertainties associated with this equation include the following:

(1) *Total Cancer Risk* assumes that different carcinogens affect the same target organ to produce a cancer response, ignoring potential antagonistic or synergistic effects or disparate effects on different target organs. This assumption may overestimate *Total Cancer Risk*.

(2) The summation of cancer risks across multiple COPCs means that the uncertainties associated with estimating cancer risk for each COPC are also summed. This means *Total Cancer Risk*, as defined below, is unlikely to be overestimated.

Equation

$$Total\ Cancer\ Risk_{inh} = \sum_{i} Cancer\ Risk_{inh(i)}$$

Variable	Description	Units	Value
$Total\ Cancer\ Risk_{inh}$	Total individual lifetime cancer risk through direct inhalation of all COPC carcinogens	unitless	
$Cancer\ Risk_{inh(i)}$	Individual lifetime cancer risk through direct inhalation for COPC carcinogen *i*	unitless	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-2-1. Uncertainties associated with this variable include the following: (1) COPC-specific *URF* values are unlikely to underestimate, and may overestimate, the carcinogenic potential of COPCs because of the mathematical models and the use of uncertainty factors in the estimation of these values. (2) Most of the uncertainties associated with the variables used to calculate C_a, specifically *Q, Cyv*, and *Cyp*, are site-specific.

TABLE C-2-4

HAZARD INDEX FOR INHALATION: NONCARCINOGENS

Description

For non-cancer health effects, *HQs* for inhalation exposures are added across COPCs when they target the same organ to obtain an *HI* for the target organ. See Appendix A-2 for target organs and Appendix A-3 for COPC-specific inhalation *RfC*s and for identification of COPCs that cause noncarcinogenic effects via the inhalation route of exposure and their associated target organs. Uncertainties associated with this equation include the following:

(1) The summation of noncarcinogenic hazards across multiple COPCs means that the uncertainties associated with estimating hazards for each COPC (see *HQ* below) are also summed. This means that the total noncarcinogenic hazard, as defined below, is unlikely to be overestimated.
(2) As defined below, the *HI* sums the *HQ*s for all COPCs to which a receptor is potentially exposed. Ideally, *HQs* should be summed only for COPCs that affect the same target organs and systems. To the extent that COPCs affect different target organs, summing their associated *HQs* will overestimate the actual *HI*.

Equation

$$HI_{inh} = \sum_{i} HQ_i$$

Variable	Description	Units	Value
$HI_{inh(j)}$	Hazard index for target organ effect *j* through direct inhalation of all COPCs	unitless	
$HQ_{inh(i)}$	Hazard quotient for direct inhalation of COPC *i*	unitless	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-2-2. Uncertainties associated with this variable include the following: (1) COPC-specific *RfCs* are unlikely to underestimate a COPC's potential for causing adverse health effects. (2) Most of the uncertainties associated with the variables used to calculate C_a, specifically *Q, Cyv*, and *Cyp*, are site-specific.

TABLE C-3-1

CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK

Description

This equation calculates the concentration of dioxins and dioxin-like PCBs in milkfat of breast milk. Uncertainties associated with this equation include the following:

(1) The most significant uncertainties associated with this equation are those associated with the variable *m*. Because *m* is calculated as the sum of numerous potential intakes, estimates of *m* incorporate uncertainties associated with each exposure pathway. Therefore, *m* may be under- or overestimated. Every effort should be made to limit and characterize the uncertainties associated with this variable.

(2) This equation assumes that the concentration of dioxinand dioxin-like PCBs in breast milkfat is the same as in maternal fat. To the extent that this is not the case, uncertainty is introduced.

Equation

$$C_{milkfat} = \frac{m \cdot 1\times10^{9} \cdot h \cdot f_1}{0.693 \cdot f_2}$$

The average maternal intake of dioxin for each adult exposure scenario (*m*) is equal to the total daily intake of dioxin and dioxin-like PCBs (*I*) from inhalation [calculated as the average daily COPC intake via inhalation (*ADI*) using the equation provided below] and all indirect pathways [which is calculated using the equation in Table C-1-6 and based on the highest annual average soil concentration (Cs_{td})] for each adult exposure scenario concentration.

$$ADI = \frac{C_a \cdot IR \cdot ET \cdot EF \cdot ED \cdot 0.001\ mg/\mu g}{BW \cdot AT \cdot 365\ day/yr}$$

Variable	Description	Units	Value
$C_{milkfat}$	Concentration of dioxin and dioxin-like PCBs in milk fat of breast milk for a specific exposure scenario	pg COPC/kg milk fat	

TABLE C-3-1

CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK

Variable	Description	Units	Value
m	Average maternal intake of dioxin and dioxin-like PCBs for each adult exposure scenario	mg COPC/kg BW-day	**Varies** This variable is COPC- and site-specific and is equal to the total daily intake of dioxin and dioxin-like PCBs (I) from inhalation [calculated as the average daily COPC intake via inhalation (ADI) using the equation provided above] and all indirect pathways [which is calculated using the equation in Table C-1-6 and based on the highest annual average soil concentration (Cs_{td})] for each adult exposure scenario concentration. The following uncertainty is associated with this variable: (1) The uncertainty associated with this variable may be significant, because this uncertainty represents the sum of all uncertainties associated with each of the potential exposure pathways. To gauge the potential magnitude of the uncertainty associated with this variable, compare estimated m values to values reported in the literature.
1×10^9	Units conversion factor	pg/mg	
h	Half-life of dioxin in adults	days	**2,555** This variable is COPC- and site-specific. We recommend using this default value, consistent with U.S. EPA (1994a) and U.S. EPA (1994b). The following uncertainty is associated with this variable: As discussed in U.S. EPA (1994a), the half-life may vary from about 5 to 7 years for 2,3,7,8-TCDD. Using the upper end of the range is conservative. Based on the work of Schecter (1991), and Schlatter (1991), as discussed in U.S. EPA (1994a), the value of h may vary by almost one order of magnitude (1.1 to 50) for different dioxin and furan congeners around the value of 7 proposed for 2,3,7,8-TCDD. The differences are largely the result of differences in absorption. However, if the average material intake of dioxin is calculated in terms of *TEQ*s, we assume using a single h value based on 2,3,7,8-TCDD is reasonable.
f_1	Fraction of ingested dioxin and dioxin-like PCBs that is stored in fat	unitless	**0.9** This variable is COPC- and site-specific. We recommend using this default value, consistent with U.S. EPA (1994b). The source of this value is U.S. EPA (1994a).
f_2	Fraction of mother's weight that is fat	unitless	**0.3** This variable is COPC-specific. We recommend using this default value, consistent with U.S. EPA (1994a) and U.S. EPA (1994b). The source of this value is U.S. EPA (1994a). The following uncertainty is associated with this variable: Although this single value clearly does not adequately represent all potentially exposed women of childbearing age, we assume the average uncertainty associated with this value to be minimal.

TABLE C-3-1

CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK

Variable	Description	Units	Value
ADI	Average daily COPC intake via inhalation	mg COPC/ kg-day	
C_a	Total COPC air concentration	µg/m^3	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table B-5-1. Uncertainty associated with this variable includes: Calculated assuming a default S_T value for background plus local sources, rather than a S_T value for urban sources. If a specific site is located in an urban area, using 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 the S_T value 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.
IR	Inhalation rate	m^3/hr	**adult: 0.83** We recommend using default values of 0.83 in the absence of site-specific information. The recommended adult value is consistent with values used in U.S. EPA (1991; 1994b; 1996a), and consistent with average of values provided in U.S. EPA (1997) when considering adult age brackets for both male and female inhalation rates for indoor and outdoor activities in a residential setting. Uncertainty associated with this variable includes: The recommended inhalation rates do not consider individual respiratory or activity differences. Therefore, based on the individual and the activities that individual is engaged in, the recommended inhalation rates may under-or overestimate the actual rates. However, we don't expect the degree of under-or overestimation to be significant.
ET	Exposure time	hrs/day	**24** This variable is site-specific. We recommend using this default value in the absence of site-specific data. Uncertainty associated with this variable includes: The recommended *ET* value assumes that an individual remains at a specific location 24 hours per day. In reality this is likely to be true only for a minority of the population including young children, their caregivers, and elderly or individuals who are sick. Therefore, the recommended value contributes to a degree of overestimation for much of the population. However, it must be noted that though an individual may not always be at a single location, that individual may continue to be exposed to emissions at an alternate location.

TABLE C-3-1

CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK

Variable	Description	Units	Value
EF	Exposure frequency	days/yr	**350** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This value is based on U.S. EPA (1991) and is consistent with U.S. EPA (1994b). Uncertainties associated with this variable include: This exposure frequency is a single value that represents the most frequent exposure that is reasonably expected to occur at a site with two weeks of vacation. This recommended value may overestimate *EF* for individuals who are away from their home for more than two weeks each year. On the other hand, some individuals (such as farmers) may remain at their home (or farm) for more than 350 days per year. In either case, we don't expect the degree of over- or underestimation to be significant in most cases.
ED	Exposure duration	yr	**30, or 40** This variable is site-specific. Consistent with U.S. EPA (1994b), we recommend using the following default values: Exposure Scenario — *ED* Farmer — 40 (U.S. EPA 1994a) Adult Resident — 30 (U.S. EPA 1989) Fisher — 30 (U.S. EPA 1994a) Uncertainties associated with this variable include: These exposure durations are single values that represent the highest exposure that is reasonably expected to occur at a site. These values may overestimate *ED* for some individuals.
BW	Body weight	kg	**70** This variable is site-specific. We recommend using default value of 70 (adults) in the absence of site-specific information. These default values are consistent with U.S. EPA (1991; 1994b). Uncertainties associated with this variable include: This body weight represents the average weight of an adult. However, depending on the site, the body weights may be higher or lower. This default value may overestimate or underestimate actual body weights. However, we don't expect the degree of under- or overestimation to be significant.

TABLE C-3-1

CONCENTRATION OF DIOXINS AND DIOXIN-LIKE PCBs IN BREAST MILK

Variable	Description	Units	Value
AT	Averaging time	yr	**70** This variable is site-specific. We recommend using this default value in the absence of site-specific data. This default value is consistent with U.S. EPA (1989), U.S. EPA (1991), and U.S. EPA (1994b). Uncertainties associated with this variable include: The recommended averaging time may not accurately represent site-specific time; specifically this single value may under- or overestimate the length of an average adult lifetime.
0.001	Units conversion factor	mg/μg	
365	Units conversion factor	days/yr	

REFERENCES AND DISCUSSION

Schecter, A. 1991. "Dioxins and Related Chemicals in Humans and in the Environment." In: *Biological Basis for Risk Assessment of Dioxins and Related Compounds*: Gallo, M.; Schenplein, R; Van Der Heijden, K. Eds; Banbury Report 35, Cold Spring Harbor Laboratory Press.

This document is cited by U.S. EPA (1994a) as the source of information related to the metabolism of dioxin and related compounds, in addition to concentrations of various congeners in adipose tissue.

Schlatter, C., 1991. "Data on Kinetics of PCDDs and PCDFs as a Prerequisite for Human Risk Assessment." In: *Biological Basis for Risk Assessment of Dioxins and Related Compounds*; Gallo, M; Schenplein, R; Van Der Heijder, K., eds. Banbury Report 35, Cold Spring Harbor Laboratory press.

This document is cited by U.S. EPA (1994a) as a source of a method of estimating the half-life of dioxin-related compounds, based on uptake data relative to 2,3,7,8-TCDD. U.S. EPA (1994a) proposed the following equation, based on this document:

$$C_{TCDD} = \frac{D_{TCDD} \cdot t_{1/2,\ TCDD} \cdot V}{\ln 2}$$

where

C_{TCDD} = Concentration of TCDD in body
D_{TCDD} = Daily intake of TCDD
$t_{1/2}$, *TCDD* = Half-life of TCDD in body
V = Volume of body compartment

Smith, A.H. 1987. "Infant Exposure Assessment for Breast Milk Dioxins and Furans Derived from Waste Incineration Emissions." *Risk Analysis.* 7(3) 347-353.

This document is cited by U.S. EPA (1994a) as the source of the equation in Table C-3-1 and the recommended values for h (2,555 days), f_1 (0.9), and f_2 (0.3). This document assumes that the concentration of dioxins in breast milkfat is the same as in maternal fat.

U.S. EPA. 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A).* Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002. December.

This document is cited as the reference source document of the exposure duration for adult residents. This document is also cited as reference source document for the averaging time for carcinogens.

U.S. EPA. 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.* Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-03. Washington, D.C. March 21.

This document is cited as the reference source document of the exposure frequency, body weight, and adult inhalation rate variables.

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. EPA/600/6-88/0055Cb. Washington, D.C. June.

This document cites Smith (1987) as the source for half of the recommended values for the life of dioxin for adults (*h)*, proportion of ingested dioxin that is stored in fat (f_1), and proportion of mother's milk that is fat (f_2).

This document is cited by U.S. EPA (1994b) as the same document for the recommended default exposure duration (*ED*) values for the farmer and fisher. The *ED* value of 40 years recommended for both the farmer and the fisher is based on the assumption that "farmers live in one location longer than the general population".

U.S. EPA. 1994b. *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 using the equation in Table C-3-1 and values for the variables in this equation: h (2,555 days), f_1 (0.9), and f_2 (0.3).

This document also recommends the following:

- An adult inhalation rate of 20 m^3/day (0.83 m^3/hr)
- An exposure frequency of 350 days per year
- Receptor-specific exposure duration values as presented in U.S. EPA (1994a)—fisher (40 years) and farmer (40 years) and U.S. EPA (1989)—adult resident (30 years)
- Adult body weight of 70 kg
- An averaging time, AT, of 70 years

U.S. EPA. 1997. *Exposure Factors Handbook.* Office of Research and Development. EPA/600/P-95/002F. August.

This document recommends an adult inhalation rate value of 20.5 m^3/day (0.85 m^3/hr) if considering indoor and outdoor activities.

TABLE C-3-2

AVERAGE DAILY DOSE TO THE EXPOSED INFANT

Description

This equation calculates the average daily dose for an infant exposed to contaminated breast milk. Uncertainty associated with this equation includes the following:

The most significant uncertainty associated with this equation is the selection of a value for averaging time (*AT*). As stated in U.S. EPA (1994a), "Little agreement exists regarding the appropriate choice of an averaging time for less than lifetime exposures. This is especially true for cases where exposure is occurring in a particularly sensitive developmental period."

An averaging time (*AT*) of 1 year is appropriate for assessing noncarcinogenic effects. However, using this value may overestimate a lifetime average appropriate for assessing carcinogenic risk by almost two orders of magnitude (70/1).

Equation

$$ADD_{infant} = \frac{C_{milkfat} \cdot f_3 \cdot f_4 \cdot IR_{milk} \cdot ED}{BW_{infant} \cdot AT}$$

Variable	Description	Units	Value
ADD_{infant}	Average daily dose for infant exposed to contaminated breast milk	pg COPC/kg BW-day	
$C_{milkfat}$	Concentration of COPC in milk fat of breast milk for a specific exposure scenario	pg COPC/kg milkfat	**Varies** This variable is COPC- and site-specific, and is calculated using the equation in Table C-3-1. The following uncertainty is associated with this variable: The most significant uncertainties associated with the calculation of this variable are those associated with the variable *m* and the estimate of $C_{milkfat}$. Uncertainties associated with *m* represent a sum of the various uncertainties associated with each of the potential exposure pathways (see the equation in Table C-1-6).
f_3	Fraction of mother's breast milk that is fat	unitless	**0.04** This variable is COPC- and site-specific. We recommend using this default value, consistent with U.S. EPA (1994a; 1994b; 2002). As cited in U.S. EPA (1994a), the source of this variable value is Smith (1987). We assume the uncertainty associated with this value is minimal.

TABLE C-3-2

AVERAGE DAILY DOSE TO THE EXPOSED INFANT

Variable	Description	Units	Value
f_4	Fraction of ingested COPC that is absorbed	unitless	**0.9** This variable is COPC- and site-specific. We recommend using this default value, as do U.S. EPA (1994a; 1994b). As cited in U.S. EPA (1994a), the source of this variable value is Smith (1987). We assume the uncertainty associated with this value is minimal.
IR_{milk}	Ingestion rate of breast milk by the infant	kg/day	**0.688** This variable is COPC- and site-specific. We recommend using this default value, from Table 2-10 in U.S. EPA (2002). The following uncertainty is associated with this variable: U.S. EPA (2002) reports a 12-month time weighted average of 688 mL/day. Assuming a density of breast milk of slightly more than 1.0, the recommended value is converted from milliliters per day to kilograms per day. We don't anticipate significant site-specific variation from this value.
ED	Exposure duration	yr	**1.0** This variable is COPC- and site-specific. We recommend using this default value, as do U.S. EPA (1994a; 1994b). The following uncertainty is associated with this variable: Some infants may nurse for more or less than the recommended 1 year. However, we don't expect the average uncertainty associated with this variable value to be large.
BW_{infant}	Body weight of infant	kg	**9.4** As cited in U.S. EPA (2002), this value is estimated using using data from NHANES III, which was conducted from 1988 to 1994. The following uncertainty is associated with this variable: As reported in U.S. EPA (2002), NHANES III collected body weight data for approximately 15,000 children between the ages of 2 months and 17 years. U.S. EPA (2002) reported a range of body weights for 7-12 month-old infants of 9.1 to 9.7 kilograms, with a mean body weight of 9.4 kilograms. Based on this information and an assumed 1-year *ED*, we expect the uncertainty associated with this variable value to be minimal.

TABLE C-3-2

AVERAGE DAILY DOSE TO THE EXPOSED INFANT

Variable	Description	Units	Value
AT	Averaging time	yr	**1** This variable is COPC- and site-specific. We recommend using this default value, as do U.S. EPA (1994a; 1994b). The following uncertainty is associated with this variable: The uncertainty associated with this variable value is significant, as stated in U.S. EPA (1994a): "Little agreement exists regarding the appropriate choice of an averaging time for less than lifetime exposures. This is especially true for cases where exposure is occurring in a particularly sensitive developmental period." An averaging time of 1 year is appropriate for assessing noncarcinogenic effects. However, using this value may overestimate a lifetime average, appropriate for assessing carcinogenic risk, by almost two orders of magnitude (70/1).

REFERENCES AND DISCUSSION

National Center for Health Statistics. 1987.

Cited in U.S. EPA (1994a) as the source of the recommended BW_{infant} value of 10 kilograms. However, that document does not provide a complete reference for this document.

Smith., A.H. 1987. "Infant Exposure Assessment for Breast Milk Dioxins and Furans Derived from Waste Incineration Emissions." *Risk Analysis*. 7(3) 347-353.

This document is cited by U.S. EPA (1994a) as the source of the recommended values for the variables in the equation in Table C-3-2.

U.S. EPA. 1994a. *Estimating Exposure to Dioxin-Like Compounds. Review Draft.* Office of Research and Development. EPA/600/6-88/0055Cc. Washington ,D.C. June.

This document is cited as the original source of the fraction of fat in breast milk, fraction of ingested COPC that is absorbed, and exposure duration.

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 using the equation in Table C-3-2 and values for the variables in this equation: f_3 (0.04), f_4 (0.9), *ED* (1 year), and *AT* (1 year).

U.S. EPA. 2002. *Child-Specific Exposure Factors Handbook*. EPA-600-P-00-002B. National Center for Environmental Assessment (Washington Office) and U.S. EPA ORD. September.

This document recommends values for the variables f_3 (0.04), IR_{milk} (0.688 kg/day), and BW_{infant} (9.4 kg).

TABLE C-4-1

ACUTE HAZARD QUOTIENT

(Page 1 of 1)

Description

This equation calculates the acute hazard quotient *AHQ* for short term inhalation exposures to COPCs. Uncertainties associated with this equation include the following:

(1) Uncertainties may be associated with development components of COPC-specific acute inhalation exposure criteria (AIECs), including exposure group protected, exposure duration, and toxicity endpoint. Uncertainties are specific to each COPC's AIEC, and may under or overestimate the potential for causing adverse health effects.
(2) Most of the uncertainties associated with the variables in the equation in Table B-6-1 (used to calculate C_{acute}), specifically those associated with the variables *Q, Chv*, and *Chp*, are site-specific.

Equation

$$AHQ_{inh(i)} = \frac{C_{acute} \cdot 0.001}{AIEC}$$

Variable	Description	Units	Value
$AHQ_{inh(i)}$	Acute hazard quotient for inhalation of COPCs	unitless	
C_{acute}	Acute air concentration	µg/m^3	**Varies** This variable is COPC- and site-specific, and is calculated by using the equation in Table B-6-1.
AIEC	COPC acute inhalation exposure criteria	mg/m^3	**Varies** This variable is COPC-specific (see the companion database to the HHRAP) and determined following a hierarchal approach as discussed in Chapter 7 of the HHRAP. The following uncertainty is associated with this variable: Uncertainties may be associated with development components of COPC-specific acute inhalation exposure criteria (AIECs), including exposure group protected, exposure duration, and toxicity endpoint. Uncertainties are specific to each COPC's AIEC, and may under or overestimate the potential for causing adverse health effects.
0.001	Conversion factor	mg/µg	