in Appendix B. Appendix A-2 explains how we recommend calculating COPC-specific *Bv* values for forage and silage (i.e. the same as they are calculated for aboveground produce).

5.4.2.1 Empirical Correction Factor for Forage and Silage (VG_{ag})

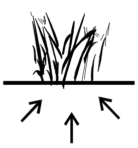
Please Section 5.3.2.1 for a detailed, general introduction to VG_{ag}. Using such a factor while estimating COPC concentrations specifically for forage and silage assumes that there is insignificant translocation of COPCs deposited on the surface of bulky silage to the inner parts of the vegetation. Applying a silage VG_{ag} would be relevant if the silage can't be characterized as leafy (e.g., if grain is used as silage). As a point of clarification, forage and silage are considered vegetative plant parts, and grains are considered reproductive plant parts.

U.S. EPA (1994m) didn't recommend a VG_{ag} value for silage. NC DEHNR (1997) recommended a VG_{ag} factor of 0.5 for bulky silage but didn't present a specific rationale for this value. U.S. EPA (1995b) noted that a volume ratio of outer whole surface area to volume of vegetation could be used to assign a silage VG_{ag} value, if one knew the proportions of each type of vegetation of which silage consisted. In the absence of specific data concerning the quantities of different silage material (e.g., hay and grain), U.S. EPA (1995b) recommended assuming a VG_{ag} of 0.5 for silage without rigorous justification.

We recommend using VG_{ag} values of 1.0 for forage and 0.5 for silage. As discussed, the primary uncertainty associated with this variable is the lack of specific information on the proportions of each vegetation type of which silage may consist, leading to the default assumption of 0.5.

Recommended Values for: **Empirical Correction Factor for Forage and Silage (VG_{ag})**
Forage = 1 Silage = 0.5

5.4.3 Forage, Silage, and Grain Concentrations Due to Root Uptake (*Pr*)



We recommend using Equations 5-20A and 5-20B (Section 5.3.3) to calculate the COPC concentration in aboveground and belowground produce resulting from root uptake. *Pr* is calculated for cattle forage, silage, and grain in the same way that it is calculated for aboveground produce, except that we recommend using forage/silage- and grain-specific bioconcentration factors (Br_{forage} and Br_{grain} respectively). Appendix A-2 explains how we recommend calculating COPC-specific *Br* values for forage and silage (i.e. exactly as it's calculated for aboveground produce). We provide a detailed discussion on how we recommend calculating *Pr* in Section 5.3.3. We further discuss the calculation of *Pr* in Appendix B.

5.4.4 Beef Concentration Resulting from Plant and Soil Ingestion (A_{beef})

As in U.S. EPA (1995h), we recommend using Equation 5-22 to calculate COPC concentration in beef tissue (A_{beef}). The equation was modified from an equation presented in U.S. EPA (1990c), U.S. EPA (1994r), U.S. EPA (1995b), and NC DEHNR (1996) by introducing a metabolism factor (MF). Equation 5-22 calculates the daily amount of a COPC that is consumed by cattle through the ingestion of contaminated feed items (plant) and soil. The equation includes biotransfer and metabolism factors to transform the daily animal intake of a COPC (mg/day) into an animal COPC tissue concentration (mg COPC/kg tissue). We further discuss using this equation in Appendix B, Table 3-10.

Recommended Equation for Calculating:
Concentration of COPC in Beef (A_{beef})

$$A_{beef} = \left(\sum (F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs\right) \cdot Ba_{beef} \cdot MF \qquad \text{Equation 5-22}$$

where

A_{beef}	=	Concentration of COPC in beef (mg COPC/kg FW tissue)
F_i	=	Fraction of plant type *i* grown on contaminated soil and ingested by the animal (cattle) (unitless)
Qp_i	=	Quantity of plant type *i* eaten by the animal (cattle) per day (kg DW plant/day)
P_i	=	Concentration of COPC in each plant type *i* eaten by the animal (cattle) (mg/kg DW)
Qs	=	Quantity of soil eaten by the animal (cattle) each day (kg/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
Bs	=	Soil bioavailability factor (unitless)
Ba_{beef}	=	COPC biotransfer factor for beef (day/kg FW tissue)
MF	=	Metabolism factor (unitless)

Sections 5.4.4.1 through 5.4.4.7 describe the parameters F_i, Qp_i, P_i, Qs, Cs, Bs, and MF, respectively. Appendix A-2 explains how we recommend calculating the COPC-specific parameter Ba_{beef}.

5.4.4.1 Fraction of Plant Type *i* Grown on Contaminated Soil and Eaten by the Animal (Cattle)(F_i)

As in U.S. EPA (1990e and 1994r), and NC DEHNR (1997), we recommend assuming that 100 percent of the plant materials eaten by cattle were grown on soil contaminated by the emission sources being evaluated. This assumption translates to a default value of 1.0 for F_i.

Recommended Value for: Fraction of Plant Type *i* Grown on Contaminated Soil and Eaten by the Animal (Cattle) (F_i)
1

5.4.4.2 Quantity of Plant Type *i* Eaten by the Animal (Cattle) Each Day (Qp_i)

The daily quantity of plants eaten by cattle can be estimated (kg DW/day) for each category of plant feed. U.S. EPA (1994r and 1998c) and NC DEHNR (1997) recommended including forage, silage, and grain feeds in this estimate.

NC DEHNR (1997) recommended plant ingestion rates for the cattle of either subsistence beef farmers or typical beef farmers. Subsistence beef farmers rely on a higher percentage of forage and silage to feed cattle, whereas typical beef farmers rely on greater amounts of grain to feed cattle. U.S. EPA (1990e) and U.S. EPA (1994r) identified plant ingestion rates only for subsistence farmers. The following daily quantities of forage, grain, and silage eaten by cattle were recommended by NC DEHNR (1997), U.S. EPA (1994r and 1990e), and Boone et al. (1981):

Source	Forage (kg DW/day)	Grain (kg DW/day)	Silage (kg DW/day)	References
NC DEHNR (1997) Subsistence Farmer Beef Cattle	8.8	0.47	2.5	Boone et al. (1981) NAS (1987)
NC DEHNR (1997) Typical Farmer Beef Cattle	3.8	3.8	1.0	Rice (1994)
U.S. EPA (1994r) Subsistence Farmer Beef Cattle	8.8	Not reported	Not reported	Boone et al. (1981) NAS (1987)
U.S. EPA (1990e) Subsistence Farmer Beef Cattle	8.8	0.47	2.5	Boone et al. (1981) McKone and Ryan (1989)
Boone et al. (1981)	8.87	1.9	2.5	Boone et al. (1981)

With the exception of a higher grain ingestion rate, Boone et al. (1981) rates are consistent with those recommended by U.S. EPA (1990e and 1994r), and NC DEHNR (1997). For typical farmer beef cattle, NC DEHNR (1997) cites Rice (1994) as a reference for the Qp_i variables and notes that the values include grain supplemented during the growing phase for beef cattle.

U.S. EPA (1990e) noted that McKone and Ryan (1989) reported an average total ingestion rate of 12 kg DW/day for the three plant feeds, which is consistent with the total recommended by U.S. EPA (1990e) and NC DEHNR (1997) (forage, grain, and silage total of 11.8 kg DW/day). U.S. EPA (1994r) and NC DEHNR (1997) also noted that NAS (1987) reported a daily dry matter intake that is 2 percent of an average beef cattle body weight of 590 kilograms. This results in a daily total intake rate of 11.8 kg DW/day. NAS (1987) reported that a nonlactating cow eats dry matter equivalent to 2 percent of its body weight.

We recommend using the following beef cattle ingestion rates of forage, silage, and grain. These values are based on the total daily intake rate of about 12 kg DW/day.

Recommended Values for: **Quantity of Plant Type *i* Eaten by the Animal (Cattle) Each Day (Qp_i)**
Forage = 8.8 kg DW/day
Silage = 2.5 kg DW/day
Grain = 0.47 kg DW/day

The principal uncertainty associated with Qp_i is the variability between forage, silage, and grain ingestion rates for cattle.

5.4.4.3 Concentration of COPC in Plant Type *i* Eaten by the Animal (Cattle) (P_i)

We generally recommend using Equation 5-23 to calculate the total COPC concentration in forage, silage, and grain. We recommend deriving values for *Pd*, *Pv*, and *Pr* for each type of feed by using Equations 5-14, 5-18, and 5-20, respectively.

Recommended Equation for Calculating:
Concentration of COPC in Plant Type *i* Eaten by the Animal (Cattle) (P_i)

$$P_i = \sum_i (Pd + Pv + Pr) \qquad \text{Equation 5-23}$$

where

P_i	=	Concentration of COPC in each plant type *i* eaten by the animal (mg COPC/kg DW)
Pd	=	Plant concentration due to direct deposition (mg COPC/kg DW)
Pv	=	Plant concentration due to air-to-plant transfer (mg COPC/kg DW)
Pr	=	Plant concentration due to root uptake (mg COPC/kg DW)

This equation is further described in Appendix B.

5.4.4.4 Quantity of Soil Eaten by the Animal (Cattle) Per Day (*Qs*)

Additional cattle contamination occurs through ingestion of soil.

NC DEHNR (1997) and U.S. EPA (1994r) recommended a soil ingestion rate for subsistence beef cattle of 0.5 kg/day. This rate is based on Fries (1994). U.S. EPA (1994r) and NC DEHNR (1997) noted that

Fries (1994) reported soil ingestion to be 4 percent of the total dry matter intake. NAS (1987) was also referenced. NAS (1987) cited an average beef cattle weight of 590 kg, and a daily dry matter intake rate (nonlactating cows) of 2 percent of body weight. This results in a daily dry matter intake rate of 11.8 kg DW/day and a daily soil ingestion rate of about 0.5 kg/day. U.S. EPA (1990e) reported a soil ingestion rate that is 3 percent of the forage intake rate of 8.8 kg DW/day, resulting in a daily soil ingestion rate of approximately 0.3 kg/day. Simmonds and Linsley (1981) and Thornton and Abrams (1983) were cited as the references for this assumption.

We recommend using 0.5 kg/day for the quantity of soil ingested by the animal (cattle).

Recommended Value for: **Quantity of Soil Ingested by the Animal (Cattle) Per Day (*Qs*)**
0.5 kg/day

5.4.4.5 Average Soil Concentration Over Exposure Duration (*Cs*)

We recommend using Equations 5-1C, 5-1D, and 5-1E to calculate the COPC concentration in soil as discussed in Section 5.2.1. Also, Appendix B further describes how we recommend calculating the soil concentration.

> ***Please Note:*** You might need to generate soil concentration estimates for grain separate from those for forage and silage. Currently, the HHRAP assumes that forage and silage are grown on untilled land, and grain is grown on tilled land. We highly recommend that your C_s calculations include the appropriate Z_s (1 for untilled land, 20 for tilled land).

5.4.4.6 Soil Bioavailability Factor (*Bs*)

The efficiency of transfer from soil may differ from the efficiency of transfer from plant material for some COPCs. If the transfer efficiency is lower for soils, then the ratio would be less than 1.0. If it is equal to or greater than that of vegetation, the *Bs* value would be equal to or greater than 1.0.

Until more COPC-specific data becomes available for this parameter, we recommend a default value of 1 for *Bs*.

Recommended Values for: Soil Bioavailability Factor (*Bs*)
1.0

5.4.4.7 Metabolism Factor (*MF*)

The metabolism factor (*MF*) estimates the amount of COPC that remains in fat and muscle. Based on a study by Ikeda et al. (1980), U.S. EPA (1995h) used a COPC-specific *MF* to account for metabolism in animals and humans. Evidence indicates BEHP is more readily metabolized and excreted by mammalian species than other contaminants (ATSDR 1987). As in U.S. EPA (1995h), we recommend a *MF* of 0.01 for bis(2-ethylhexyl)phthalate (BEHP). Lacking data to support derivation of other chemical-specific *MF*s, we recommend using a *MF* of 1.0 for all chemicals other than BEHP. Using the recommended values for this variable, *MF* has no quantitative effect on A_{beef} (with the exception of BEHP).

Recommended Values for: Metabolism Factor (*MF*)
bis(2-ethylhexyl)phthalate (BEHP) = 0.01 All other COPCs = 1.0

The *MF* presented above for BEHP applies only to mammalian species, including beef cattle, dairy cattle, and pigs. It does not relate to metabolism in produce, chicken, or fish. In addition, since exposures evaluated in this guidance are intake driven, using an MF applies only to estimating COPC concentrations in food sources used in evaluating indirect human exposure, including ingestion of beef, milk, and pork. In summary, an *MF* is not applicable for direct exposures to air, soil, or water, or to ingestion of produce, chicken, or fish.

5.4.5 COPC Concentration In Milk Due to Plant and Soil Ingestion (A_{milk})

We recommend modifying Equation 5-22 (Section 5.4.4) to calculate COPC milk concentrations (A_{milk}), as follows:

Recommended Equation for Calculating:
Concentration of COPC in Milk (A_{milk})

$$A_{milk} = \left(\sum (F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs\right) \cdot Ba_{milk} \cdot MF \qquad \text{Equation 5-24}$$

where

A_{milk}	=	Concentration of COPC in milk (mg COPC/kg milk)
F_i	=	Fraction of plant type *i* grown on contaminated soil and ingested by the animal (dairy cattle) (unitless)
Qp_i	=	Quantity of plant type *i* eaten by the animal (dairy cattle) each day (kg DW plant/day)
P_i	=	Concentration of COPC in plant type *i* eaten by the animal (dairy cattle) (mg/kg DW)
Qs	=	Quantity of soil eaten by the animal (dairy cattle) each day (kg soil/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
Bs	=	Soil bioavailability factor (unitless)
Ba_{milk}	=	COPC biotransfer factor for milk (day/kg WW tissue)
MF	=	Metabolism factor (unitless)

Appendix A-2 explains how we recommend calculating the COPC-specific parameter Ba_{milk}. The discussion in Section 5.4.4 of the variables F_i, Qp_i, P_i, Qs, Cs, and MF for beef cattle generally applies to the corresponding variables for dairy cattle. However, there are some differences in assumptions made for dairy cattle; these differences are summarized in the following subsections.

We recommend using Equation 5-24 to estimate A_{milk}. Using Equation 5-24 is described further in Appendix B, Table B-3-11.

5.4.5.1 Fraction of Plant Type *i* Grown on Contaminated Soil and Eaten by the Animal (Dairy Cattle) (F_i)

The calculation of F_i for dairy cattle is identical to that for beef cattle (Section 5.4.4.1).

5.4.5.2 Quantity of Plant Type *i* Eaten by the Animal (Dairy Cattle) Per Day (Qp_i)

As discussed in Section 5.4.4.2, the daily quantity of forage, silage, and grain feed consumed by cattle is estimated for each category of feed material. However, daily ingestion rates for dairy cattle are estimated differently than for beef cattle. We generally recommend estimating the daily quantity of feed consumed by cattle on a dry weight basis for each category of plant feed.

NC DEHNR (1997) recommended using plant ingestion rates for either subsistence dairy farmer or typical dairy farmer cattle. In addition, subsistence dairy farmers rely on a higher percentage of forage and silage to feed cattle, whereas typical dairy farmers rely on greater amounts of grain to feed cattle. U.S. EPA (1990e and 1994r) identified plant ingestion rates only for subsistence farmers.

The following daily quantities of forage, grain, and silage eaten by dairy cattle were recommended by NC DEHNR (1997), U.S. EPA (1994r), U.S. EPA (1990e), and Boone et al. (1981):

Source	Forage (kg/day DW)	Grain (kg/day DW)	Silage (kg/day DW)	References
NC DEHNR (1997) Subsistence Dairy Farmer Cattle	13.2	3.0	4.1	Boone et al. (1981) NAS (1987)
NC DEHNR (1997) Typical Dairy Farmer Cattle	6.2	12.2	1.9	Rice (1994)
U.S. EPA (1994r) Subsistence Dairy Farmer Cattle	13.2	Not reported	Not reported	Boone et al. (1981) NAS (1987)
U.S. EPA (1990e) Subsistence Dairy Farmer Cattle	11.0	2.6	3.3	Boone et al. (1981) McKone and Ryan (1989)
Boone et al. (1981)	11.0	2.6	3.3	Boone et al. (1981)

U.S. EPA (1990e) noted that McKone and Ryan (1989) reports an average total ingestion rate of 17 kg/day DW for the three plant feeds, which is consistent with the total ingestion rate recommended by U.S. EPA (1990e). U.S. EPA (1994r) and NC DEHNR (1997) noted that NAS (1987) reports a daily dry matter intake that is 3.2 percent of an average dairy cattle body weight of 630 kilograms. This results in a daily total intake rate of approximately 20 kg/day DW, which is consistent with the average total ingestion rates for the three plant feeds recommended by U.S. EPA (1994r) and NC DEHNR (1997) . NAS (1987) reported that dairy cows eat dry matter equivalent to 3.2 percent of their body weight; the

630-kilogram average dairy cow body weight was not confirmed. U.S. EPA (1995b) also cited a feed ingestion rate of 20 kg/day DW, citing U.S. EPA (1993c).

Based on more recent references (NAS 1987; U.S. EPA 1993c) which recommend a feed ingestion rate of 20 kg/day DW, we recommend a default total ingestion rate of 20 kg DW/day for dairy cattle.

Recommended Values for: Quantity of Plant Type *i* Eaten by the Animal (Dairy Cattle) Per Day (Qp_i)
Forage = 13.2 kg DW/day
Silage = 4.1 kg DW/day
Grain = 3.0 kg DW/day

Uncertainties associated with estimating Qp_i include estimating forage, grain, and silage ingestion rates, which will vary from site to site. Assuming uniform contamination of plant materials consumed by cattle also introduces uncertainty.

5.4.5.3 Concentration of COPC in Plant Type *i* Eaten by the Animal (Dairy Cattle) (P_i)

The estimation of P_i for dairy cattle is identical to that for beef cattle (Section 5.4.4.3).

5.4.5.4 Quantity of Soil Eaten by the Animal (Dairy Cattle) Per Day (*Qs*)

As discussed in Section 5.4.4.4, contamination of dairy cattle also results from the ingestion of soil. We generally recommend the following soil ingestion rate for dairy cattle:

Recommended Values for: Quantity of Soil Eaten by the Animal (Dairy Cattle) Per Day (*Qs*)
0.4 kg/day

U.S. EPA (1994r) and NC DEHNR (1997) recommended a soil ingestion rate of 0.4 kg/day for dairy cattle, based on Fries (1994). U.S. EPA (1994r) and NC DEHNR (1997) noted that Fries (1994) reported soil ingestion rates as 2 percent of the total dry matter intake. NAS (1987) was also referenced, which reported an average dairy cattle weight of 630 kilograms and a daily dry matter intake rate (nonlactating cows) of 3.2 percent of body weight. This resulted in a daily dry matter intake rate of 20 kg/day DW, and a daily soil ingestion rate of approximately 0.4 kg/day. NC DEHNR (1997) recommended a soil ingestion rate of 0.2 kg/day for the cattle of typical dairy farmers, citing Rice (1994). U.S. EPA (1990e) reported soil ingestion rates as 3 percent of the forage intake rate. U.S. EPA (1990e) assumed that the more protective forage intake rate of 13.2 kg/day DW results in a daily soil ingestion rate of about 0.4 kg/day. Simmonds and Linsley (1981) and Thornton and Abrams (1983) were cited as the references for this assumption.

Uncertainties associated with *Qs* include the lack of current empirical data to support soil ingestion rates for dairy cattle. Assuming uniform contamination of soil ingested by cattle also adds uncertainty.

5.4.5.5 Average Soil Concentration Over Exposure Duration (*Cs*)

The calculation of *Cs* for dairy cattle is the same as for beef cattle (Section 5.4.4.5).

> ***Please Note:*** You might need to generate soil concentration estimates for grain separate from those for forage and silage. Currently, the HHRAP assumes that forage and silage are grown on untilled land, and grain is grown on tilled land. We highly recommend making sure that your C_s calculations include the appropriate Z_s (2 for untilled land, 20 for tilled land).

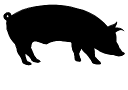
5.4.5.6 Soil Bioavailability Factor (*Bs*)

The calculation of *Bs* for dairy cattle is the same as for beef cattle (Section 5.4.4.6).

5.4.5.7 Metabolism Factor (*MF*)

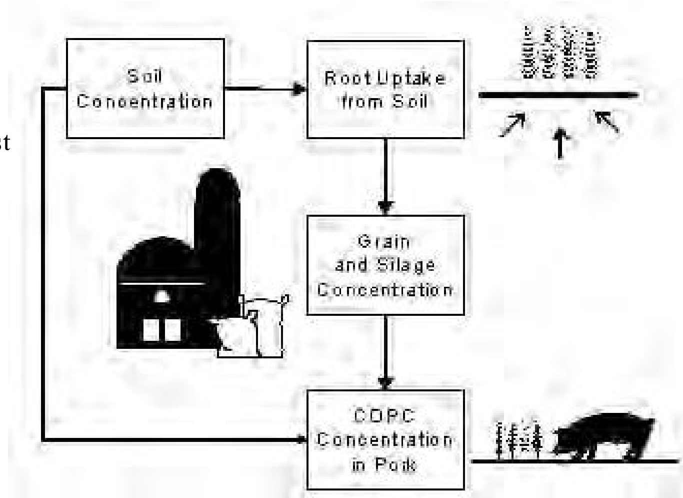
The recommended values for *MF* are identical to those we recommend for beef cattle (Section 5.4.4.7).

5.5 CALCULATING COPC CONCENTRATIONS IN PORK



Under the approach recommended in this guidance, COPC concentrations in pork tissue are estimated on the basis of the amount of COPCs that swine consume through a diet consisting of silage and grain. Additional COPC contamination of pork tissue may occur through their ingestion of soil.

FIGURE 5-5
COPC CONCENTRATION IN PORK



Equation 5-22 (Section 5.4.4) describes how we recommend calculating COPC concentration in beef cattle (A_{beef}). We suggest modifying Equation 5-22 to calculate COPC concentrations in swine (A_{pork}), as follows:

Recommended Equation for Calculating:
Concentration of COPC in Pork (A_{pork})

$$A_{pork} = \left(\Sigma(F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs\right) \cdot Ba_{pork} \cdot MF$$ Equation 5-25

where

A_{pork}	=	Concentration of COPC in pork (mg COPC/kg FW tissue)
F_i	=	Fraction of plant type *i* grown on contaminated soil and ingested by the animal (swine)(unitless)
Qp_i	=	Quantity of plant type *i* eaten by the animal (swine) each day (kg DW plant/day)
P_i	=	Concentration of COPC in plant type *i* eaten by the animal (swine) (mg/kg DW)
Qs	=	Quantity of soil eaten by the animal (swine) (kg/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
Bs	=	Soil bioavailability factor (unitless)
Ba_{pork}	=	COPC biotransfer factor for pork (day/kg FW tissue)
MF	=	Metabolism factor (unitless)

Appendix A-2 explains how we recommend calculating the COPC-specific parameter Ba_{pork}. The discussions in Section 5.4.5 of the variables F_i, Qp_i, P_i, Qs, Cs and MF for beef cattle generally apply to the corresponding variables for pork. However, some different assumptions are made for pork. These differences are summarized in the following subsections.

We generally recommend using Equation 5-25 to calculate COPC pork concentrations (A_{pork}). This equation is further described in Appendix B, Table B-3-12.

5.5.1 Fraction of Plant Type *i* Grown on Contaminated Soil and Eaten by the Animal (Swine) (F_i)

The calculation of F_i for pork is identical to that for beef cattle (Section 5.4.4.1).

5.5.2 Quantity of Plant Type *i* Eaten by the Animal (Swine) Each Day (Qp_i)

Section 5.4.4.2 discusses estimating the daily quantity of forage, silage, and grain feed consumed by beef cattle for each feed category. However, daily ingestion rates for pork are estimated differently than for beef cattle. U.S. EPA (1994r and 1998c), and NC DEHNR (1997) recommended only including silage and grain feeds to estimate daily plant quantity eaten by swine. Because swine are not grazing animals, they are assumed not to eat forage (U.S. EPA 1998c). We therefore generally recommend estimating the daily quantity of plant feeds (kilograms of DW) consumed by swine for each category of plant feed.

U.S. EPA (1990e) and NC DEHNR (1997) recommended grain and silage ingestion rates for swine of 3.0 and 1.3 kg DW/day, respectively. NC DEHNR (1997) references U.S. EPA (1990e) as the source of these ingestion rates. U.S. EPA (1990e) reported total dry matter ingestion rates for hogs and lactating sows as 3.4 and 5.2 kg DW/day, respectively. U.S. EPA (1990e) cites Boone et al. (1981) as the source of the ingestion rate for hogs, and NAS (1987) as the source of the ingestion rate for a lactating sow. Boone et al. (1981) reported a grain ingestion rate of 3.4 kg DW/day for a hog. NAS (1987) reported an average ingestion rate of 5.2 kg DW/day for a lactating sow. U.S. EPA (1990e) recommended using the average of these two rates (4.3 kg DW/day).

U.S. EPA (1990e) assumed that 70 percent of the swine diet is grain and 30 percent silage to obtain the grain ingestion rate of 3.0 kg DW/day and the silage ingestion rate of 1.3 kg DW/day. U.S. EPA (1990e) cited U.S. EPA (1982b) as the source of the grain and silage dietary fractions. U.S. EPA (1995b) recommended an ingestion rate of 4.7 kg DW/day for a swine, referencing NAS (1987). NAS (1987) reported an average daily intake of 4.36 kg DW/day for a gilt (young sow) and a average daily intake of 5.17 kg DW/day for a sow, which averages out to 4.7 kg/DW/day. Assuming the 70 percent grain to 30 percent silage diet noted above, estimated ingestion rates of 3.3 kg DW/day (grain) and 1.4 kg DW/day (silage) are derived.

Recommended Values for: Quantity of Plant Type *i* Eaten by the Animal (Swine) Each Day (Qp_i)
Grain = 3.3 kg DW/day
Silage = 1.4 kg DW/day

Uncertainties associated with this variable include the variability of actual grain and silage ingestion rates from site to site. You could use site-specific data to mitigate this uncertainty. In addition, assuming uniform contamination of the plant materials consumed by swine produces some uncertainty.

5.5.3 Concentration of COPC in Plant Type *i* Eaten by the Animal (Swine) (P_i)

The suggested calculation of P_i for pork is identical to that for beef cattle (Section 5.4.4.3).

5.5.4 Quantity of Soil Eaten by the Animal (Swine) Each Day (Q_s)

As discussed in Section 5.4.4.4, additional contamination of swine results from ingestion of soil. The following Q_s values were recommended by earlier guidance:

Guidance	Quantity of Soil Eaten by Swine Each Day (Q_s)
U.S. EPA (1990e)	Stated that sufficient data are not available to estimate swine soil ingestion rates.
NC DEHNR (1997)	0.37 kg/day Estimated by assuming a soil intake that is 8% of the plant ingestion rate of 4.3 kg DW/day). U.S. EPA (1993f) was cited as the reference for the soil ingestion rate of 8 percent of dry matter intake.
U.S. EPA (1998c)	Cites a companion "Parameters Guidance Document" for detailed recommendations on Q. The "Parameters" document has not been published.

As in NC DEHNR (1997), we recommend the following soil ingestion rate for swine:

Recommended Value for: **Quantity of Soil Eaten by the Animal (Swine) Each Day (*Q_s*)**
0.37 kg DW/day

Uncertainties associated with this variable include the lack of current empirical data to support soil ingestion rates for swine, and assuming uniform contamination of the soil ingested by swine.

5.5.5 Average Soil Concentration Over Exposure Duration (*Cs*)

Our suggested calculation of *Cs* for pork is the same as for beef cattle (Section 5.4.4.5).

> ***Please Note:*** You might need to generate soil concentration estimates for grain separate from those for silage. We recommend assuming that silage is grown on untilled land, and grain is grown on tilled land. We highly recommend that you make sure that your C_s calculations include the appropriate Z_s (2 for untilled land, 20 for tilled land).

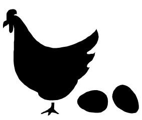
5.5.6 Soil Bioavailability Factor (*Bs*)

Our suggested calculation of *Bs* for pork is the same as for beef cattle (Section 5.4.4.6)

5.5.7 Metabolism Factor (*MF*)

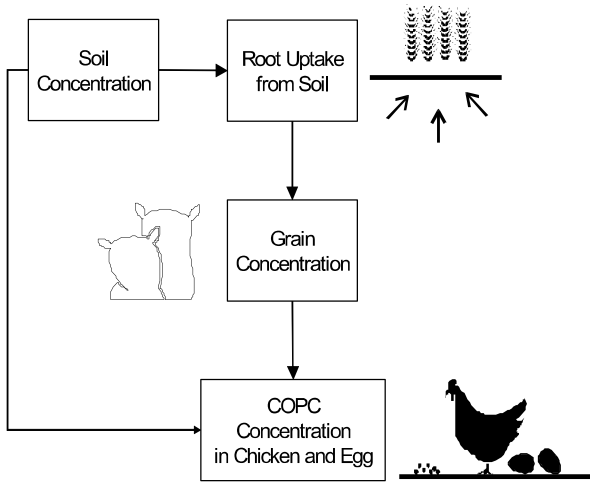
Our recommended values for MF are identical to those we recommended for beef cattle (Section 5.4.4.7).

5.6 CALCULATING COPC CONCENTRATIONS IN CHICKEN AND EGGS



Under the approach outlined in this guidance document, estimates of the COPC concentrations in chicken and eggs are based on the amount of COPCs that chickens consume through ingestion of grain and soil. We recommend assuming that the uptake of COPCs via inhalation and via ingestion of water are insignificant relative to other pathways. The HHRAP assumes that chickens are housed in a typical manner that allows contact with soil. Because of this, chickens are assumed to consume 10 percent of their diet as soil. Assuming 10 percent is consistent with the study from which the biotransfer factors were obtained (Stephens et al. 1995). We recommend assuming that the remainder of the diet (90 percent) consists of grain grown at the exposure scenario location. Therefore, it's appropriate to assume 100 percent of the grain consumed is contaminated. The equations don't account for the uptake of COPCs via ingestion of contaminated insects and other organisms (e.g., worms, etc.), which may also contribute to the ingestion of COPCs. This may be a limitation, depending on the site-specific conditions under which the chickens are raised.

FIGURE 5-6
COPC CONCENTRATION IN CHICKEN & EGGS



We generally recommend using the algorithm for aboveground produce described in Section 5.3 to estimate the COPC concentration in grain. Grain is considered to be protected from direct deposition of particles, and vapor transfer. This approach considers only contamination due to root uptake of COPCs in calculating COPC concentrations in grain. Our recommended equations for calculating concentrations in chicken and eggs are presented in Appendix B. The method we used to derive biotransfer factors, and the COPC-specific values for chicken and eggs are presented in Appendix A-2.

As in NC DEHNR (1997), we recommend using Equation 5-26 to calculate COPC concentrations in chicken and eggs (Stephens et al. 1995). We generally recommend calculating COPC concentrations in chicken and eggs separately. Parameters and variables in Equation 5-26 are further described in Appendix B, Tables B-3-13 and B-3-14.

Recommended Equation for Calculating:
Concentration of COPC in Chicken and Eggs ($A_{chicken}$ or A_{egg})

$$A_{chicken} \text{ or } A_{egg} = (\Sigma[F_i \cdot Qp_i \cdot Pi] + Qs \cdot Cs \cdot Bs) \cdot (Ba_{egg} \text{ or } Ba_{chicken}) \qquad \text{Equation 5-26}$$

where

$A_{chicken}$	=	Concentration of COPC in chicken (mg COPC/kg FW tissue)
A_{egg}	=	Concentration of COPC in eggs (mg COPC/kg FW tissue)
F_i	=	Fraction of plant type *i* (grain) grown on contaminated soil and ingested by the animal (chicken)(unitless)
Qp_i	=	Quantity of plant type *i* (grain) eaten by the animal (chicken) each day (kg DW plant/day)
P_i	=	Concentration of COPC in plant type *i* (grain) eaten by the animal (chicken) (mg/kg DW)
Qs	=	Quantity of soil eaten by the animal (chicken) (kg/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
Bs	=	Soil bioavailability factor (unitless)
$Ba_{chicken}$	=	COPC biotransfer factor for chicken (day/kg FW tissue)
Ba_{egg}	=	COPC biotransfer factor for eggs (day/kg FW tissue)

Appendix A-2 explains how we recommend determining the COPC-specific parameters $Ba_{chicken}$ and Ba_{egg}. The remaining parameters are discussed in Appendix B and in the following subsections.

5.6.1 Fraction of Plant Type *i* Grown on Contaminated Soil and Eaten by the Animal (Chicken)(F_i)

The calculation of F_i for chicken is identical to that for beef cattle (Section 5.4.4.1).

5.6.2 Quantity of Plant Type *i* Eaten by the Animal (Chicken) Each Day (Qp_i)

Section 5.4.4.2 discusses estimating the daily quantity of forage, silage, and grain feed consumed by beef cattle for each feed category. However, daily ingestion rates for chicken are estimated differently than for beef cattle. NC DEHNR (1997) recommended that only grain feeds be included in this estimate. Because chickens are not grazing animals, they are assumed not to eat forage (U.S. EPA 1998c). Chickens are similarly assumed not to consume any silage. We recommend only estimating the daily quantity of plant feeds (kilograms of DW) consumed by chicken (*Qp*) for grain feed.

As in Ensminger (1980), Fries (1982), and NAS (1987), we recommend using the following ingestion rate:

Recommended Value for: **Quantity of Plant Type *i* Eaten by the Animal (Chicken) Each Day (Qp_i)**
Grain = 0.2 kg DW/day

Uncertainties associated with this variable include the variability of actual grain ingestion rates from site to site. In addition, assuming uniform contamination of plant materials consumed by chicken produces some uncertainty.

5.6.3 Concentration of COPC in Plant Type *i* Eaten by the Animal (Chicken) (P_i)

The total COPC concentration is the COPC concentration in grain. We recommend using Equation 5-27 to calculate P_i. This equation is further described in Appendix B.

Recommended Equation for Calculating:
Concentration of COPC in Plant Type *i* Eaten by the Animal (Chicken) (P_i)

$$P_i = \sum_i (Pr) \qquad \text{Equation 5-27}$$

where

P_i	=	Concentration of COPC in each plant type *i* eaten by the animal (mg COPC/kg DW)
Pr	=	Plant concentration due to root uptake (mg COPC/kg DW)

We generally recommend calculating plant concentration due to root uptake (Pr) using Equation 5-20, as discussed in Section 5.3.3.

5.6.4 Quantity of Soil Eaten by the Animal (Chicken) Each Day (Qs)

COPC concentration in chickens also results from intake of soil. As discussed earlier, The HHRAP assumes that chickens consume 10 percent of their total diet as soil, a percentage that is consistent with the study from Stephens et al. (1995). We recommend the following soil ingestion rate for chicken:

Recommended Value for: Quantity of Soil Eaten by the Animal (Chicken) Each Day (*Qs*)
0.022 kg DW/day

Uncertainties associated with this variable include the lack of current empirical data to support soil ingestion rates for chicken, and assuming uniform contamination of soil ingested by chicken.

5.6.5 Average Soil Concentration Over Exposure Duration (*Cs*)

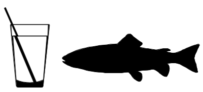
The calculation of *Cs* for chicken is the same as for beef cattle (Section 5.4.4.5).

> ***Please Note:*** We recommend assuming that forage and silage are grown on untilled land, and grain is grown on tilled land. We highly recommend making sure that your C_s calculations include the appropriate Z_s (20 for tilled land).

5.6.6 Soil Bioavailability Factor (*Bs*)

The calculation of *Bs* for chicken is the same as for beef cattle (Section 5.4.4.6)

5.7 CALCULATING COPC CONCENTRATIONS IN DRINKING WATER AND FISH

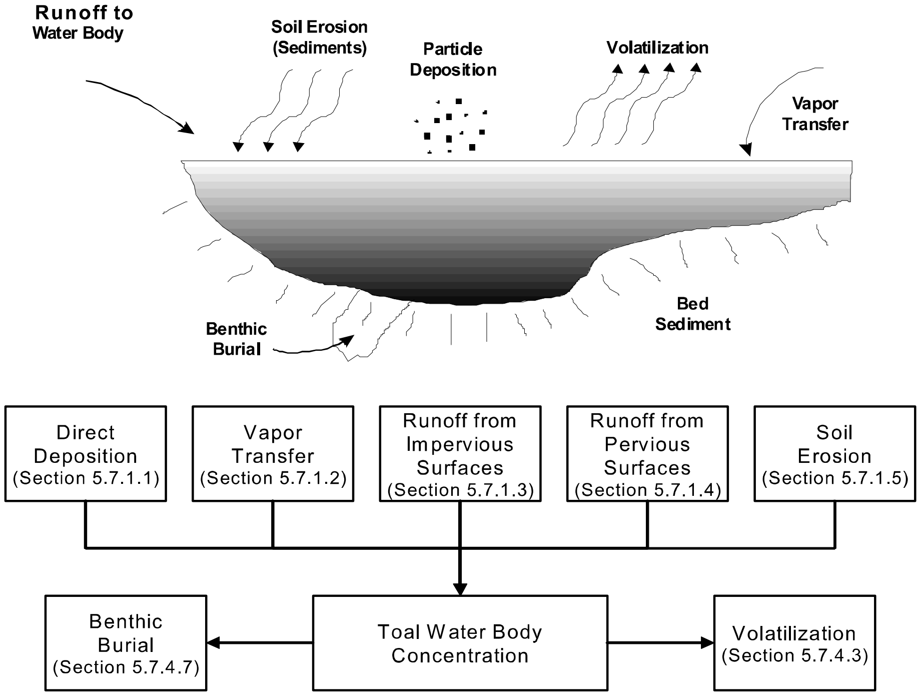


We generally recommend calculating COPC concentrations in surface water for all water bodies you selected to evaluate in the risk assessment. Specifically, those waterbodies selected as potential sources for the drinking water and/or fish ingestion exposure pathways. Mechanisms we suggest considering in determining COPC loading of the water column include:

- Direct deposition,
- Runoff from impervious surfaces within the watershed,
- Runoff from pervious surfaces within the watershed,
- Soil erosion over the total watershed,
- Direct diffusion of vapor phase COPCs into the surface water, and
- Internal transformation of compounds chemically or biologically.

Considering other potential mechanisms may be appropriate, due to site-specific conditions (e.g., tidal influences). Typically, though, we assume that contributions from other potential mechanisms are negligible compared to those evaluated in the HHRAP.

FIGURE 5-7
COPC LOADING TO THE WATER BODY



The total concentration of each COPC partitions between the sediment and the water column. Partitioning between water and sediment varies with the COPC. The HHRAP uses the Universal Soil Loss Equation (USLE) and a sediment delivery ratio to estimate the rate of soil erosion from the watershed. The equations we recommend for estimating surface water concentrations include a sediment mass balance, in which the amount of sediment assumed to be buried and lost from the water body is equal to the difference between the amount of soil introduced to the water body by erosion and the amount of suspended solids lost in downstream flow. As a result, we typically assume that sediments do not accumulate in the water body over time, and an equilibrium is maintained between the surficial layer of sediments and the water column. The total water column COPC concentration is the sum of the COPC concentration dissolved in water and the COPC concentration associated with suspended solids. Appendix B-4 presents the equations we recommend using to estimate surface water concentrations.

To evaluate the COPC loading to a water body from its associated watershed, we generally recommend calculating watershed soil-specific COPC concentrations. The equation in Section 5.2 for estimating COPC concentration in soil includes a loss term that considers the loss of contaminants from the soil after deposition. These loss mechanisms all lower the soil concentration associated with a specific deposition rate. Appendix B (Tables B-4-1 through B-4-28) provides the equations we recommend for calculating COPC concentrations in watershed soils and in the water body.

The equations presented in Appendix B for modeling COPC loading to a water body represent a simple steady-state model to solve for a water column in equilibrium with the upper sediment layer. These equations (Appendix B) predict the steady-state mass of contaminants in the water column and underlying sediments, and don't address the dynamic exchange of contaminants between the water body and the sediments following changes in external loadings. While appropriate for calculating risk under long-term average conditions, evaluating complex water bodies or shorter term loading scenarios might be improved by using a dynamic modeling framework [e.g., Exposure Analysis Modeling System (EXAMS), or Water Quality Analysis Simulation Program (WASP), both of which can be downloaded from the EPA Center for Exposure Assessment Modeling]. Although typically more resource intensive, such analysis may be able to refine modeling of contaminant loading to a water body. Also, the computations may better represent the exposure scenario you are evaluating.

For example, EXAMS allows performing computations for each defined segment or compartment of a water body or stream. These compartments are considered physically homogeneous and are connected via advective and dispersive fluxes. Compartments can be defined as littoral, epilimnion, hypolimnion, or benthic. Such resolution also makes it possible to assign receptor locations specific to certain portions of a water body where evaluating exposure is of greatest interest.

The following are some considerations regarding the selection and use of a dynamic modeling framework or simulation model to evaluate water bodies:

- Will a complex surface water modeling effort provide enhanced results over the use of the more simplistic steady-state equations presented in Appendix B?
- Are the resources needed to conduct, as well as review, a more complex modeling effort justified compared to the more refined results?
- Has the model been used previously for regulatory purposes, and therefore, already has available documentation to support such uses?

- Can the model conduct steady-state and dynamic analysis? and
- Does the model require calibration with field data, and if so, are there sufficient quantity and quality of site-specific data available to support calibration?

As mentioned previously in Chapter 2 (Section 2.3.5.3 - "Mercury"), the SERAFM model offers a dynamic modeling framework for mercury that enables the user to model specific water body mercury transformation processes in lieu of applying default speciation assumptions.

5.7.1 Total COPC Load to the Water Body (L_T)

As in U.S. EPA (1994r) and NC DEHNR (1997), we recommend using Equation 5-28 to calculate the total COPC load to a water body (L_T). This equation is described in detail in Appendix B, Table B-4-7.

Recommended Equation for Calculating:
Total COPC Load to the Water Body (L_T)

$$L_T = L_{DEP} + L_{dif} + L_{RI} + L_R + L_E + L_I$$ Equation 5-28

where

L_T	=	Total COPC load to the water body (including deposition, runoff, and erosion) (g/yr)
L_{DEP}	=	Total (wet and dry) particle phase and vapor phase COPC direct deposition load to water body (g/yr)
L_{dif}	=	Vapor phase COPC diffusion load to water body (g/yr)
L_{RI}	=	Runoff load from impervious surfaces (g/yr)
L_R	=	Runoff load from pervious surfaces (g/yr)
L_E	=	Soil erosion load (g/yr)
L_I	=	Internal transfer (g/yr)

Due to the limited data and uncertainty associated with the chemical or biological internal transfer, L_I, of compounds into degradation products, we generally recommend a default value for this variable of zero. However, if a permitting authority determines that site-specific conditions indicate calculating internal transfer may need to be considered, we recommend following the methods described in U.S. EPA (1998c). The remaining variables (L_{DEP}, L_{dif}, L_{RI}, L_R, and L_E) are discussed in the following subsections.