Chapter 4
Exposure Scenario Identification

What's Covered in Chapter 4:

4.1 Characterizing the Exposure Setting

4.2 Recommended Exposure Scenarios
- Farmer
- Farmer Child
- Resident
- Resident Child
- Fisher
- Fisher Child
- Acute Receptor

4.3 Selecting Exposure Scenario Locations

The purpose of this chapter is to provide guidance on identifying "exposure scenarios" to evaluate in the risk assessment. Evaluating exposure scenarios will estimate the type and magnitude of human exposure to COPC emissions from hazardous waste combustors (including fugitive emissions). In this document, identifying exposure scenarios consists of :

- characterizing the exposure setting,
- identifying recommended exposure scenarios, and
- selecting exposure scenario locations.

Characterizing the exposure setting includes defining the dimensions of the assessment area (or "study area"). It also includes identifying the current and potential human activities and land uses within those boundaries. Within the context of the exposure setting, an exposure scenario is a combination of "exposure pathways" to which a "receptor" may be subjected.

> ***PLEASE NOTE***: for the purposes of this guidance, "we" refers to the U.S. EPA OSW.
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> The HHRAP is written for the benefit of a varied audience, including risk assessors, regulators, risk managers, and community relations personnel. However, the "you" to which we speak in this chapter is the performer of a risk assessment: the person (or persons) who will actually put the recommended methods into practice.

For this guidance, we define a receptor as a human being potentially exposed to COPCs emitted to the atmosphere from a hazardous waste combustion facility. An exposure "route" is the particular means of entry into the body. For the purposes of the HHRAP, receptors come into contact with COPCs via two primary exposure routes: either directly—via inhalation; or indirectly—via COPC deposition and subsequent ingestion of water, soil, vegetation, and animals that have been contaminated by COPCs through the food chain.

An exposure "pathway" is the course a chemical takes from its source to the person being exposed. An exposure pathway consists of four fundamental components:

1. a source and mechanism of COPC release (see Chapter 2);
2. a retention medium, or a transport mechanism and subsequent retention medium in cases involving media transfer of COPCs (see Chapter 3 for air transport of COPCs, and Chapter 5 for bioaccumulation of COPCs in the food chain);
3. a point of potential human contact with the contaminated medium; and
4. an exposure route.

Exposure to COPCs can occur via numerous exposure pathways, such as ingestion of diary products and home grown produce (see Section 4.2).

The HHRAP identifies a number of generic exposure scenarios (Farmer, Farmer Child; Fisher, Fisher Child; Resident, and Resident Child). Used as presented, these standardized scenarios should be reproducible across most sites and land use areas. We intend these scenarios to be appropriate for a broad range of situations, rather than to represent actual scenarios. We believe that the recommended exposure scenarios and associated assumptions are reasonable. They represent a scientifically sound approach that is protective of human health and the environment, while recognizing the uncertainties associated with evaluating real world exposures. For example, the scenarios are designed with a level of protectiveness intended to address potential receptors not directly evaluated, such as populations with somewhat higher exposures than the general public. At the same time, you can easily alter these scenarios to more closely reflect site-specific conditions. To be transparent, we recommend well-documenting, supporting and discussing any changes (i.e. deletions, additions, or modifications) to a recommended exposure scenario or scenario location with the appropriate parties (regulatory agency, facility, interested community members).

Selecting exposure scenario locations involves identifying the physical positions of the exposure scenarios within the study area. For example, you can position scenarios based on current or future human activities or land use. Alternatively, you can position scenarios artificially, as part of a screening assessment. You could, for example, locate all selected receptors at the area of greatest contaminant deposition, to maximize potential exposure. The HHRAP focuses on placement based on actual or potential activities and land use.

The following sections describe how we recommend

1. characterizing the exposure setting,
2. identifying which of the recommended exposure scenarios are appropriate for the risk assessment, and
3. selecting the exposure scenario locations.

4.1 CHARACTERIZING THE EXPOSURE SETTING

The purpose of characterizing the exposure setting is to identify the human receptors, their land uses and activities, which might be impacted by exposure to emissions from the facility being assessed. The exposure setting might include multiple sources (e.g., multiple stacks, fugitive emissions), as well as terrain both inside and outside the facility boundary (or "fenceline"). We believe both **current** and **reasonable potential** human activities or land uses are relevant, when determining which recommended exposure scenarios are appropriate for the risk assessment (see Section 4.2).

Experience has shown us that most significant deposition occurs within a 10 km radius, as measured from the centroid of a polygon centered on the stacks of the facility being assessed. Consequently, resources for characterizing the exposure setting might initially be focused within this area. Also, most recommended exposure scenarios appropriate for the assessment will likely be located within this area. It may be prudent, however, to also characterize the exposure setting beyond the 10 km radius, to determine if conditions exist which warrant additional exposure scenarios. Such conditions might include (but are not limited to) recommended exposure scenarios or special populations (see Section 4.1.3) not found within the 10 km area, or topographic features - such as hills - that tend to increase potential deposition. A 50 km radius is the recognized limit of the ISCST3 air dispersion model, and can be used as the outer boundary for characterizing additional exposure settings (See Chapter 3 for information on air modeling beyond a 50 km radius). All affected parties (i.e. regulators, facilities, interested community members) can then discuss if additional scenarios need to be assessed, and if so, their locations.

The study area might include land use and water bodies both inside and outside the facility fenceline. It's important to understand that some of the recommended scenarios might most appropriately be placed within facility boundaries. For example, some facilities located on substantial property rent portions of the property to the public for farming, ranching, or recreational purposes (e.g., fishing).

When characterizing the exposure setting, we highly recommend considering

- current and reasonable potential future land use,
- waterbodies and their associated watersheds, and
- special populations.

The following subsections provide information on these aspects.

4.1.1 Current and Reasonable Potential Future Land Use

Land use is an important factor in characterizing the exposure setting. When land use is overlaid with the air dispersion modeling results, the combination will demonstrate which recommended exposure scenarios (and their locations) are most relevant for the risk assessment. We recommend considering both current and reasonable potential future land use (i.e. "future land use"), because risk assessments typically evaluate the potential risks from facilities over long periods of time (greater than 30 years).

One can typically identify current land use, and indications of future land use, by reviewing hard copy and/or electronic versions of Land Use/Land Cover (LULC) maps, topographic maps, and aerial photographs. We list some sources below, and general information associated with several potential data and map resources. Also, as noted in Chapter 3, we recommend verifying that all mapping information you use is in the same Universal Transverse Mercator (UTM) coordinate system format (NAD27 or NAD83), to ensure consistency and prevent erroneous geo-referencing of locations and areas.

Land Use/Land Cover (LULC) Maps **-** you can download LULC maps directly from the United States Geological Survey (USGS) web site (http://mapping.usgs.gov/index.html), at a scale of 1:250,000, in the GIRAS file format. LULC maps are also available from the EPA web site (ftp://ftp.epa.gov/pub), at a scale of 1:250,000, in an Arc/Info export format. Within your study area, we recommend verifying the exact boundaries of polygons defining land use areas using available topographic maps and aerial photographs.

Topographic Maps **-** Topographic maps are readily available in both hard copy and electronic format directly from the USGS or numerous other vendors. These maps are commonly at a scale of 1:24,000, and in TIFF file format with a TIFF World File included for georeferencing.

Aerial Photographs **-** You can purchase hard copy aerial photographs directly from the USGS in a variety of scales and coverages. Electronic format aerial photographs or Digital Ortho Quarter Quads (DOQQs) are also available for purchase directly from the USGS, or from an increasing number of commercial sources.

Properly georeferenced DOQQs covering a 3-km or more radius of the assessment area, combined with overlays of the LULC map coverage and the ISCST3 modeled receptor grid node array, provide an excellent reference for identifying land use areas and justifying your choices of exposure scenario locations. The information above does not represent the universe of data available on human activities or land use. They are, however, readily available for little or no cost from a number of government sources, often via the Internet.

If feasible, we recommend verifying the accuracy of land use information with a site visit. Also, organizations exist that routinely collect and evaluate land use data (agricultural extension agencies, U.S. Department of Agriculture, natural resource and park agencies, and local governments). You may find discussions with these organizations helpful in updating current land use information or providing information regarding future land use. Local planning and zoning authorities are also potential sources of information on reasonable potential future land use. These authorities have information on the level of development allowed under current regulations, and what development may be expected in the future. The general public is another excellent source of information about land use in the area. Conducting a public workshop early in the data gathering process for the risk assessment can provide valuable information on land use, crops, special populations, etc. as well as starting a positive dialogue with the community. For example, by communicating with local tribes you might find that certain locations hold special significance for cultural or religious activities.

You can also use site-specific data on physiographic features (e.g., plant types, soil characteristics, land use, etc.) to verify the land uses identified using the resources listed above. You can readily determine the presence, type, and extent of physiographic features from the following sources:

- USGS topographic maps,

- Soil Conservation Service reports,
- county and local land use maps, and
- information from state departments of natural resources or similar agencies.

A study area might include multiple land uses, with differing current or potential human activity/land use characteristics. Your activity/land use analysis could identify multiple population centers (e.g., communities, residential developments, or rural residences), farms and ranches, or other land use types in the study area that would support recommended exposure scenarios. For example, if a study area includes a farm and a small residential community, you could consider both areas as possible exposure scenario locations (see Sections 4.2 and 4.3).

Once you've identified current land uses, we generally recommend also identifying areas with different reasonable potential ***future*** land use characteristics. For example, if a study area includes undeveloped property which could be converted to a residential community in the future, you might consider both of these land use types (i.e. undeveloped property, and residential community) in the risk assessment (see Sections 4.2 and 4.3). We recommend considering only potential future land uses which might reasonably be expected to occur. For example:

1. A rural area currently characterized as undeveloped open fields, could reasonably be expected to become farmland if it is able to support agricultural activities;
2. A rural area currently characterized by open fields and intermittent housing, could reasonably be expected to become a residential subdivision; and
3. An area currently characterized as a tidal swamp would **not** reasonably be expected to become farm land.

For transparency and clarity, we recommend describing any current or reasonably expected future land use in the risk assessment report. Of all the land use areas you identify, we generally recommend focusing on those areas that could be impacted by the COPC emissions you're evaluating in the risk assessment.

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- Identification and/or mapping of ***current*** land uses in the area, a description of the use, the area of the land described by the use, and the source of the information. You might choose to focus initially on those land use areas impacted by emissions of COPCs.
- Identification and/or mapping of the reasonable potential ***future*** land use areas, a description of the use, the source or rationale on which the description is based. You might choose to focus initially on those land use areas impacted by emissions of COPCs.

4.1.2 Water Bodies and Their Associated Watersheds

Surface water bodies and their associated watersheds are important factors in evaluating some of the recommended exposure scenarios. Specifically, water bodies can be important sources of fish for the fish ingestion pathway, or sources of water for the drinking water pathway (see Section 4.2). Your careful consideration is warranted when identifying which water bodies in the study area to assess. For the Fisher scenario, an appropriate water body (and/or its associated watershed) would receive deposition from the emission source, and be able to sustain a fish population harvested by humans. For the drinking water ingestion pathway, an appropriate waterbody (and/or its associated watershed) would receive deposition from the emission source, and be used as a direct drinking water source (i.e. not processed by a drinking water treatment facility). We recommend considering both current and potential human uses of water bodies found within the study area. In addition to identifying the human uses of water bodies, we recommend defining the surface areas and exact locations of the water bodies, and their associated watersheds. See Section 4.3 for a further discussion of selecting exposure scenario locations and their associated water bodies.

You can typically identify the use, area, and location of water bodies and their associated watersheds by reviewing the same hard copy and /or electronic versions of LULC maps, topographic maps, and aerial photographs used to identify land uses. We present sources and general information associated with each of these data types or maps in Section 4.1.1.

You might also get information on water body use from local authorities (e.g., state environmental agencies, fish and wildlife agencies, or local water control districts). This might include information about viability to support fish populations and drinking water sources. Surface water bodies that are used

As drinking water sources in the assessment area are generally evaluated in the risk assessment. While water bodies closest to the facility will generally have higher deposition rates, risk estimates are also affected by other physical parameters (e.g. the size of the water body and the associated watershed) and by the properties of the COPCs being emitted.

Once you've selected a water body, we recommend identifying the area extent (defined by UTM coordinates) of its watershed. Watershed runoff can be a significant contributor to overall water body COPC loadings. Media concentration equations use the extent of pervious and impervious areas in the watershed, as well as COPC concentrations in watershed soil, to calculate the water body COPC concentrations (see Chapter 5 and Appendix B). We therefore recommend clearly identifying and discussing the area extent of the watershed with the interested parties (both permitting authority and facility).

You generally define the area extent of a watershed by identifying topographic highs that result in downslope drainage into the water body. We recommend ensuring that the watershed and it's contribution to the water body are defined relative to the exposure scenario location associated with the water body (e.g. location on the water body of the drinking water intake, fishing pier, etc.), and subsequent risk estimates. Please keep in mind that the total watershed area can be very extensive relative to the area that is impacted from facility emissions.

For example, if facility emissions principally impact an area of land which drains into a specific tributary of a large river system and immediately upstream of a private drinking water intake point, you may wish to consider evaluating an "effective" watershed area rather than the entire watershed area of the large river system. For such a large river system, the watershed area can be on the order of thousands of square kilometers and can include numerous tributaries draining into the river at points that would have no net impact on the drinking water intake or on the water body COPC concentration at the exposure point of interest.

To use the HHRAP as recommended, you will need the following water body and watershed parameters (on an average annual basis):

- Water body surface area
- Watershed surface area
- Impervious watershed area

- Average water body volumetric flow rate
- Water body current velocity
- Depth of water column
- Total suspended solids (TSS)
- Universal Soil Loss Equation (USLE) rainfall/erosivity factor

The impervious watershed area is generally a function of urbanization within the watershed, and is typically presented as a percentage of the total watershed area. Volumetric flow rate and water body current velocity are typically annual average values. State or local geologic surveys often keep records on flow rate and current velocity of larger water bodies. You can calculate the volumetric flow rates for smaller streams or lakes by multiplying the watershed area by one-half of the local average annual surface runoff. Lacking site-specific data, you can calculate current velocities by dividing the volumetric flow rate by the cross-sectional area (***NOTE***: current velocities are not used in the equations for lakes). State or local sources sometimes have information on the depths of water bodies available. Discussions on determining the USLE rainfall/erosivity factor are included in Chapter 5 and Appendix B.

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- Identification and/or mapping of water bodies and associated watersheds potentially impacted by facility emissions of COPCs, including surface area of the water body and area extent of the contributing watershed, defined by UTM coordinates
- Rationale for selecting or excluding water bodies within the assessment area from evaluation
- Information on water body use that may justify including or excluding the water body from evaluation
- Documentation of water body area, watershed area, impervious area, volumetric flow rate, current velocity, depth of water column, total suspended solids (TSS), and the USLE rainfall/erosivity factor
- Description of assumptions made to limit the watershed area to an “effective” area
- Copies of all maps, photographs, or figures used to define water body and watershed characteristics

4.1.3 Special Population Characteristics

Special populations are human receptors or segments of the population that may be at higher risk due to increased sensitivity and/or increased exposure to COPCs. Fetuses, infants and children, and the elderly are examples of human life stages (i.e. populations) which might be more sensitive to COPC exposure. You might consider some tribal groups a special population because their ingestion of fish at rates higher than the general public increases their exposure to chemicals that bioaccumulate. Subsistence residents are also likely to have higher exposures from ingestion of meat (locally harvested game), produce (wild berries and onions, for example), and soil. There may be special locations where cultural activities are conducted, or that are sacred to the tribes, and we encourage evaluating exposures at these locations.

We've developed the assumptions specified in this guidance – such as the protective nature of the recommended exposure scenarios (see Section 4.2), and the use of RfDs which have been developed to account for toxicity to sensitive receptors – to also protect the health of special populations. However, you may also need to specifically address populations that are located in impacted areas because of unique characteristics of the exposure setting or to address particular community concerns. For example, a day care center or hospital may be located in an area that is directly impacted by the facility stack emissions. Receptors at these locations may be especially sensitive to the adverse effects and/or the exposure setting is particularly conducive to exposure. Consequently, due to site-specific exposure characteristics, exposure to children at the day care center, or to the sick in the hospital, might need to be specifically evaluated. Section 4.2 provides additional discussion on evaluating potential exposure of special populations, as part of evaluating recommended exposure scenarios. Additionally, the Agency has a stated policy focused on consistently and explicitly evaluating environmental health risks to infants and children in all risk assessments (U.S. EPA 1995j).

Concerns about special populations can arise at any time in the permitting process. We therefore recommend identifying special populations as part of characterizing the exposure setting. You can identify special populations in the assessment area based on the location of schools, hospitals, nursing homes, day care centers, parks, community activity centers, etc. If available information indicates that there are children exhibiting pica behavior (defined for risk assessment purposes as "an abnormally high soil ingestion rate") in the assessment area, these children could also represent a special population (see Section 6.2.3.1).

RECOMMENDED INFORMATION FOR THE RISK ASSESSMENT REPORT

- Identification and/or mapping of the locations of special populations at potentially higher risk from exposure to facility sources (anticipated to be located in areas impacted by facility emissions); focusing on the characteristics of the exposure setting to ensure that selected exposure scenario locations are protective of the special populations.

4.2 RECOMMENDED EXPOSURE SCENARIOS

We recommend evaluating the following exposure scenarios when they are consistent with site-specific exposure settings (also see Table 4-1):

- Farmer
- Farmer Child
- Resident
- Resident Child
- Fisher
- Fisher Child
- Acute Receptor
- Nursing Infant (Covered as exposure pathway under adult exposure scenarios)

These are the same exposure scenarios recommended by earlier OSW guidance, with the exception of the Farmer Child, Fisher Child, and acute receptor. The Farmer Child scenario was introduced into the indirect screening process in the risk assessment completed to support the proposed Hazardous Waste Combustion Rule and by NC DEHNR (1997). We include the Fisher Child scenario in order to be consistent with the adult/child pairings we recommend for the Resident and Farmer scenarios. We include the acute receptor scenario to ensure that the assessment evaluates all receptors that may be significantly exposed to emissions from facility sources.

In addition to the recommended exposure scenarios listed above, we recommend evaluating, where appropriate, special populations (as defined in Section 4.1.3) and communities of concern. Do this by identifying their locations, and determining whether they are located in areas with exposure setting characteristics that are particularly conducive to COPC impacts from facility emissions. Examples of additional exposure scenarios include hunters, trespassers, workers (see below), recreational fishers, etc.

You could evaluate some populations using a combination of a recommended exposure scenario expected to overestimate exposure compared to the populations, and maximum modeled air parameter values specific to the location (see Section 4.3). If this initial evaluation suggests that the receptors are protected, then no additional assessment is necessary. If, on the other hand, this evaluation estimates levels of risk which are of concern, a refined evaluation may be needed. The refined exposure scenario would evaluate the specific exposure pathways appropriate to the special population.

Take, for example, a children's school or day care center located in an area receiving deposition of facility emissions. You could evaluate potential exposure of children at this location using the Resident Child scenario at the location of the school or day care center. In most cases, evaluating this scenario at the school location will over-estimate exposure. This is because the Resident Child scenario includes an exposure pathway (ingestion of homegrown produce) which is most likely not occurring at that location. Also, the residential scenario assumes that a child breaths the air 24 hours/day, ingests 100 mg of soil/day; and is exposed for 6 years - when the child is probably only at day care 5 days/week and up to 10 hours/day. If this generates risk estimates of concern, you could conduct a more refined evaluation that adjusts the exposure assumptions to be more representative of the site.

We don't routinely recommend assessing workers at a facility that burns hazardous waste in the risk assessment, because we assume that those workers are protected by regulation and guidance of the U.S. Occupational Safety and Health Administration (OSHA). There are, however, some instances where workers impacted by exposure to facility emissions are not covered by the appropriate OSHA regulations. For example, workers located at a nearby but separate facility or commercial area, whose duties are independent of combustor operations, are not necessarily covered by the appropriate OSHA regulations. Also, on a site with multiple on-site activities (e.g., manufacturing, hazardous waste combustion, and military operations) the OSHA regulations would address the worker at the manufacturing operations with respect to those operations and not the emissions from the separate hazardous waste combustion operations. Considering such instances in the risk assessment may be appropriate.

We no longer refer to our recommended farmer and fisher exposure scenarios as "subsistence" scenarios. The associated daily consumption amounts (see Table 4-2, as well as Appendix C) are more comparable to reasonable (versus subsistence) amounts.

As mentioned above, an exposure scenario is defined as a combination of exposure pathways to which a receptor is subjected at a particular location. Table 4-1 presents the exposure pathways we recommend evaluating for each of the exposure scenarios. Food-related ingestion pathways could represent significant potential exposure to COPCs released from combustion sources (U.S. EPA 1994l; 1994g; 1998c; NC DEHNR 1997), due primarily to the potential for COPCs to bioaccumulate up the food chain.

TABLE 4-1

RECOMMENDED EXPOSURE SCENARIOS FOR A HUMAN HEALTH RISK ASSESSMENT

Exposure Pathways	Recommended Exposure Scenarios[a]						
	Farmer	Farmer Child	Resident	Resident Child	Fisher	Fisher Child	Acute Receptor[b]
Inhalation of Vapors and Particulates	•	•	•	•	•	•	•
Incidental Ingestion of Soil	•	•	•	•	•	•	--
Ingestion of Drinking Water from Surface Water Sources	•	•	•	•	•	•	--
Ingestion of Homegrown Produce	•	•	•	•	•	•	--
Ingestion of Homegrown Beef	•	•	--	--	--	--	--
Ingestion of Milk from Homegrown Cows	•	•	--	--	--	--	--
Ingestion of Homegrown Chicken	•	•	d	d	d	d	--
Ingestion of Eggs from Homegrown Chickens	•	•	d	d	d	d	--
Ingestion of Homegrown Pork	•	•	--	--	--	--	--
Ingestion of Fish	d	d	d	d	•	•	--
Ingestion of Breast Milk	c	--	c	--	c	--	--

Notes:

• Pathway is included in exposure scenario.

-- Pathway is not included in exposure scenario.

[a] Exposure scenarios are defined as a combination of exposure pathways evaluated for a receptor at a specific location.

[b] The acute receptor scenario evaluates short-term 1-hour maximum COPC air concentrations (see Chapter 3) at any land use area that would support the other recommended exposure scenarios, as well as commercial and industrial land use areas (excluding workers at the facility being directly evaluated in the risk assessment).

[c] Infant exposure to PCDDs, PCDFs, and dioxin-like PCBs via the ingestion of their mother's breast milk is evaluated as an additional exposure pathway, separately from the recommended exposure scenarios identified in this table (see Chapter 2).

[d] Site-specific exposure setting characteristics (e.g., presence of ponds on farms, or presence of ponds or small livestock within semi-rural residential areas) may warrant the permitting authority consider adding this exposure pathway to the scenario (see Section 4.2).

As indicated in Table 4-1, some exposure setting characteristics may warrant you consider including additional exposure pathways when evaluating a particular exposure scenario. For example, the recommended Farmer exposure scenario doesn't typically include the fish ingestion exposure pathway. However, in some areas of the country it's common for farms to have stock ponds that are fished on a regular basis for the farm family's consumption. Since the ingestion rates we recommend for those food pathways already considered in the evaluation are not significant enough to preclude the Farmer also ingesting the fish caught from the local pond, the fish ingestion exposure pathway may also be relevant in such locations. You could use the same rationale for residential scenarios where residents are located in semi-rural areas which allow small livestock (e.g., free range poultry for eggs), and/or residents located by small ponds suitable for fishing, or wetlands that support crawfish harvest.

We also recommend evaluating infant exposure to PCDDs and PCDFs via the ingestion of their mother's breast milk as an additional exposure pathway at all recommended adult exposure scenario locations. Chapter 2 and Appendix C further describe the ingestion of breast milk exposure pathway.

In addition, although some risk assessments conducted by U.S. EPA (1996b) have discounted the direct inhalation risks to all receptors except the adult Resident (nonfarmer) and Resident Child (nonfarmer), we generally recommend evaluating the direct inhalation exposure pathway for all receptors.

We don't typically recommend evaluating the following exposure pathways as part of an exposure scenario:

> ***Ingestion of Ground Water*** - U.S. EPA (1998c) found that ground water is an insignificant exposure pathway for combustion emissions; in addition, U.S. EPA (1994k) noted that uptake from ground water into food crops and livestock is minimal because of the hydrophobic nature of dioxin-like compounds. We anticipate potential exposure to COPCs through ingestion of drinking water from surface water bodies to be much more significant. Ingestion of ground water is further discussed in Section 6.2.4.2.
>
> ***Inhalation of Resuspended Dust*** - U.S. EPA (1990e) found that risk estimates from inhalation of resuspended dust was insignificant. We anticipate exposure through direct inhalation of vapor and particle phase COPCs and incidental ingestion of soil to be much more significant. Inhalation of resuspended dust is further discussed in Section 6.2.3.3.
>
> ***Dermal Exposure to Surface Water, Soil, or Air*** - Available data indicate that the contribution of dermal exposure to soils to overall risk is typically small (U.S. EPA 1996g; 1995h). For example, the risk assessment conducted for the Waste Technologies Industries, Inc., hazardous waste incinerator in East Liverpool, Ohio, indicated that—for an adult farmer in a subarea with high exposures—the risk resulting from soil ingestion and dermal contact was 50-fold less than

the risk from any other exposure pathway and 300-fold less than the total estimated risk (U.S. EPA 1996g; 1995h). Also, there are significant uncertainties associated with estimating potential COPC exposure via the dermal exposure pathway. The most significant of these uncertainties are associated with determining the impact of soil characteristics and the extent of exposure (e.g., the amount of soil on the skin and the length of exposure) on estimating compound-specific absorption fractions (ABS).

We don't generally recommend evaluating the dermal exposure to soil pathway as part of the recommended exposure scenarios. However, if either a facility or a permitting authority feel that site-specific conditions indicate dermal exposure to soil may contribute significantly to total soil-related exposures, we recommend following the relevant methods described in U.S. EPA NCEA document, *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* (U.S. EPA 1998c). Dermal exposure is further discussed in Section 6.2.3.2 of this guidance.

Inhalation of COPCs and Ingestion of Water by Animals - We don't recommend these animal exposure pathways in calculating animal tissue concentration because we expect their contributions to total risk to be negligible compared to the contributions of the recommended animal exposure pathways. However, you might need to evaluate these exposure pathways on a case-by-case basis considering site-specific exposure setting characteristics.

Our recommended exposure scenarios are further discussed in the following subsections.

4.2.1 Farmer

The Farmer exposure scenario is made up of the exposure pathways through which an adult member of a farming or ranching family could be exposed. We recommend including this scenario when farming or ranching takes place, or may reasonably take place some time in the future, in the study area. As indicated in Table 4-1, we recommend assuming the Farmer is exposed to COPCs emitted from the facility through the following exposure pathways:

- Direct inhalation of vapors and particles
- Incidental ingestion of soil
- Ingestion of drinking water from surface water sources
- Ingestion of homegrown produce (i.e. fruits and vegetables)
- Ingestion of homegrown beef
- Ingestion of milk from homegrown cows
- Ingestion of homegrown chicken
- Ingestion of eggs from homegrown chickens
- Ingestion of homegrown pork
- Ingestion of breast milk (evaluated separately, for an infant of the Farmer; see Chapter 2)

While on the farm property, the Farmer inhales air containing COPC-impacted vapors and suspended particles. Through daily activities, the Farmer ingests incidental amounts of soil. If site characterization suggests that impacted surface waterbodies are used as direct drinking water sources (see Section 4.1.2), the farm family receives its water from a surface waterbody. The farm family raises and consumes beef and milk cattle, pigs, and free-range chickens (including eggs). Cattle ingest soil while foraging on a grazing field, as well as being fed silage and grain grown on the farm. Pigs are contained within a yard or small field, where they are assumed not to forage, but ingest soil while being fed a combination of silage and grain grown on the farm. Free-range chickens are contained within a yard or field, where they ingest soil while being fed grain grown on the farm. The Farmer grows enough fruits and vegetables to supply the family with produce.

The scenario assumes that a portion of the Farmer's diet comes from each homegrown food type listed above (see Table 6-1 and Appendix C for consumption rates). All of these portions are impacted by emissions from the facility being assessed. The recommended consumption rates don't represent the Farmer's entire intake of each food type, but rather only the homegrown portion of the Farmer's diet. It is therefore reasonable to assume that 100% of this subset of each food type (i.e. the homegrown portion) is contaminated. Also, because the portions represent only the homegrown portion of the Farmer diet, assuming ingestion of all meat groups by the Farmer does not grossly overestimate the total amount of meat a farmer or rancher could reasonably consume. Breaking out consumption by food type is an important step in estimating the relative contributions to COPC-specific risk from ingestion of each food type.

Previous Agency guidance (for example, U.S. EPA 1993f and U.S. EPA 1994f) didn't include the ingestion of chicken and eggs exposure pathways. NC DEHNR (1997) considers chicken and egg ingestion pathways only for exposure to dioxins and furans, because biotransfer factors were only available for dioxins and furans when that guidance was published. U.S. EPA (1998c) includes ingestion of both poultry and eggs. Currently, biotransfer factors can be derived from literature data for other organic compounds and metals. Therefore, we generally recommend including the chicken and egg ingestion exposure pathways for all COPCs with available biotransfer factors. Further discussion of these exposure pathways, including numeric equations, parameters values, and COPC-specific inputs, can be found in Chapter 5 and Appendices A, B, and C.

When evaluating the ingestion of drinking water from surface water for the Farmer scenario, we generally recommend also considering the potential for ingestion of cistern water at farm or ranch locations, in addition to surface water sources. If site-specific information (e.g. interviews with local health departments) suggests that cistern water is likely used, or could be used for a drinking water source, you could evaluate ingestion of cistern water in a manner similar to that used to evaluate ingestion of water from a surface water body (see Chapter 5 and Appendix B). Site-specific information (e.g. do cisterns in the study area tend to be covered or uncovered?) can educate decision makers as to appropriate equations and parameter values to use in assessing the ingestion of drinking water from cisterns.

We don't usually recommend the ingestion of fish exposure pathway for the Farmer exposure scenario. However, as indicated in the notes to Table 4-1, we do recommend that you consider evaluating the fish ingestion pathway if regional or site-specific exposure setting characteristics (e.g., presence of ponds on farms or ranches that support fish for human consumption) are identified that warrant consideration. You can use the applicable estimating media concentration equations for ingestion of fish as presented in Chapter 5 and Appendix B. Also, evaluating the Fisher and Fisher Child exposure scenarios (see Sections 4.2.5 and 4.2.6) at farm or ranch locations may be appropriate where on-site ponds are used as sources of fish for human consumption.

We recommend evaluating the exposure of an infant to PCDDs, PCDFs, and dioxin-like PCBs via the ingestion of breast milk as an additional exposure pathway, separately from this exposure scenario (see Chapter 2).

If site-specific information is available indicating that farmers in the study area don't raise a type of livestock, nor is raising that type of livestock likely to occur in the future, then you could reasonably consider eliminating the related exposure pathway (or pathways, in the case of chicken and egg ingestion). However, if one meat source is not used, its place in the diet is often taken by one or more of the remaining exposure pathways. Take care, therefore, to consider the intake rates of the remaining exposure pathways, to ensure that the total amount consumed (summed fraction from each food group) is representative. See Chapter 6 (Quantifying Exposure) for further discussion of the implications of modifying our recommended exposure pathways.

4.2.2 Farmer Child

The Farmer Child exposure scenario is made up of the exposure pathways through which a child member of a farming or ranching family may reasonably be expected to be exposed. Agency policy recommends consistently and explicitly evaluating environmental health risks to infants and children in all risk assessments (U.S. EPA 1995j). As indicated in Table 4-1, the scenario assumes the Farmer Child is exposed to COPCs emitted from the facility through the same exposure pathways as the Farmer. The primary differences between the Farmer and Farmer Child are in exposure duration (6 years for the child vs . 40 years for the adult), and consumption rates (e.g. 1.4 homegrown produce servings per week for child vs. 2.8 homegrown produce servings per week for adult, see Table 6-1).

4.2.3 Resident

The Resident exposure scenario is made up of the exposure pathways through which an adult receptor may be exposed in an urban or nonfarm rural setting. We recommend including the adult Resident scenario, because potential exposure to COPCs through ingesting homegrown produce has been shown to be potentially significant. This exposure scenario equates with the "Home Gardener" scenario recommended by U.S. EPA (1994g) and NC DEHNR (1997). As indicated in Table 4-1, the scenario assumes the adult Resident is exposed to COPCs from the emission source through the following exposure pathways:

- Direct inhalation of vapors and particles
- Incidental ingestion of soil
- Ingestion of drinking water from surface water sources
- Ingestion of homegrown produce
- Ingestion of breast milk (evaluated separately, for an infant of the Resident; see Chapter 2)

While on their property, the Resident inhales air containing COPC-impacted vapors and suspended particles. Through daily activities, the Resident ingests incidental amounts of soil. If site characterization suggests that impacted surface waterbodies are used as direct drinking water sources (see Section 4.1.2), the resident family receives its water from a surface waterbody. The Resident grows fruits and vegetables for home consumption (NC DEHNR 1997). Breaking out consumption by exposure pathway is an important step in estimating the relative contributions to COPC-specific risk from ingestion of each food type. Further discussion of these exposure pathways, including equations, parameter values, and COPC-specific inputs, can be found in Chapter 5 and Appendices A, B, and C.

We don't usually recommend evaluating the ingestion of fish exposure pathway for the Resident exposure scenario. However, as indicated in the notes to Table 4-1, we do recommend that you consider evaluating the fish ingestion pathway if exposure setting characteristics (e.g., presence of ponds within semi-rural residential areas that support fish for human consumption) are identified that warrant consideration. It may be appropriate to evaluate the Fisher and Fisher Child exposure scenarios (see Sections 4.2.5 and 4.2.6) at residential locations where ponds or surface water bodies are used as a potential source of fish for human consumption.

We recommend evaluating exposure of an infant to PCDDs, PCDFs, and dioxin-like PCBs via the ingestion of breast milk as an additional exposure pathway, separately from this exposure scenario (see Chapter 2).

4.2.4 Resident Child

The Resident Child exposure scenario is made up of the exposure pathways through which a child receptor may be exposed in an urban or nonfarm rural setting. This exposure scenario equates with the "Child of the Home Gardener" scenario recommended by U.S. EPA (1994g) and NC DEHNR (1997). Agency policy recommends consistently and explicitly evaluating environmental health risks to infants and children in all risk assessments (U.S. EPA 1995j). As indicated in Table 4-1, the scenario assumes the Resident Child is exposed to COPCs emitted from the facility through the same exposure pathways as the Resident adult. The primary differences between the Resident and Resident Child are in exposure duration (6 years for the child vs . 30 years for the adult), and consumption rates (e.g. 1.2 homegrown produce servings per week for the child vs. 2.3 homegrown produce servings per week for the adult, see Table 6-1).

4.2.5 Fisher

The Fisher exposure scenario is made up of the exposure pathways through which an adult receptor may be exposed in an urban or nonfarm rural setting where fish is the main source of protein in the receptor diet. We recommend including the Fisher scenario, because food-related ingestion routes may represent significant potential exposure to COPCs released from combustion sources (U.S. EPA 1994l; 1994g; 1998c; NC DEHNR 1997). The potential exposure is due primarily to the potential for COPCs to bioaccumulate up the food chain. Breaking out consumption by exposure pathway is an important step in estimating the relative contributions to COPC-specific risk from ingestion of each food type. As indicated in Table 4-1, the scenario assumes the Fisher is exposed to COPCs emitted from the facility through the following exposure pathways:

- Direct inhalation of vapors and particles
- Incidental ingestion of soil
- Ingestion of drinking water from surface water sources
- Ingestion of homegrown produce
- Ingestion of fish
- Ingestion of breast milk (evaluated separately, for an infant of the Fisher; see Chapter 2)

While on their property (i.e. where they reside), the Fisher inhales air containing COPC-impacted vapors and suspended particles. Through daily activities, the Fisher ingests incidental amounts of soil. If site characterization suggests that impacted surface waterbodies are used as direct drinking water sources (see Section 4.1.2), the fisher family receives its water from a surface waterbody. The Fisher grows fruits and vegetables for home consumption (NC DEHNR 1997). The Fisher harvests enough fish from waterbodies in the study area impacted by facility emissions to supply the family with a significant portion of their protein. Further discussion of these exposure pathways, including numeric equations, parameters values, and COPC specific inputs, can be found in Chapter 5 and Appendices A, B, and C.

We recommend evaluating the exposure of an infant to PCDDs, PCDFs, and dioxin-like PCBs via the ingestion of breast milk as an additional exposure pathway, separately from this exposure scenario (see Chapter 2).

4.2.6 Fisher Child

The Fisher Child exposure scenario is made up of the exposure pathways through which a child receptor may be exposed in an urban or nonfarm rural setting where fish is the main source of protein in the receptor diet. Evaluating this exposure scenario is the same as the adult/child pairings recommended for the Farmer and Resident scenarios. In addition, Agency policy recommends consistently and explicitly evaluating environmental health risks to infants and children in all risk assessments (U.S. EPA 1995j). As indicated in Table 4-1, the scenario assumes the Fisher Child is exposed to COPCs emitted from the facility through the same exposure pathways as the Fisher. The primary differences between the Fisher and Fisher Child are in exposure duration (6 years for child vs. 30 years for the adult), and consumption rates (e.g. 1.2 homegrown produce servings per week for the child vs. 2.3 homegrown produce servings per week for the adult, see Table 6-1).

4.2.7 Acute Receptor Scenario

In addition to long-term chronic effects evaluated in the other recommended exposure scenarios, we generally recommend evaluating the acute exposure scenario. The acute receptor scenario accounts for short-term effects of exposure to maximum 1-hour concentrations of COPCs in emissions from the facility (see Chapter 3) through direct inhalation of vapors and particles (see Table 4-1 and Chapter 7). A receptor could be exposed in an urban or rural setting where human activity or land use supports any of the recommended exposure scenarios. The receptor could also be exposed in commercial and industrial land use areas (excluding workers from the facility) not typically covered by the other recommended exposure scenarios. As mentioned in Section 4.2 above, we assume that workers from the facility being assessed in the risk assessment are protected by OSHA programs, and therefore aren't generally included in hazardous waste combustion risk assessments.

We discuss further this recommended exposure scenario and associated exposure pathway, including numeric equations, parameters values, and COPC-specific inputs, in Chapter 7 and Appendices A, B, and C.

4.3 SELECTING EXPOSURE SCENARIO LOCATIONS

Exposure scenario locations are the physical places within the study area selected for evaluating one or more of the recommended exposure scenarios. We generally recommend choosing exposure scenario locations based on COPC air concentrations and deposition rates from ISCST3 (see Chapter 3) specific to land use areas defined during exposure setting characterization (see Section 4.1). Location-specific air concentrations and deposition rates are then used as inputs to the equations which estimate media concentrations.

We would like to emphasize that the method and resulting selection of exposure scenario locations is one of the most critical steps of the risk assessment process, with huge impacts on standardization across all facilities evaluated, and reproducibility of results. This is, at least partly, because ISCST3-modeled air parameter values (and the resulting media concentration estimates) can vary significantly, even within individual land use areas.

To ensure consistent and reproducible risk assessments, we recommend using the following procedures to select your exposure scenario locations. These procedures also reduce the chances that the location(s) you select to evaluate a land use area overlook locations within that same land use area that would result in higher risk estimates. This can be important given the complexity of multiple modeled air parameters and phases per location, possibly multiple facility emission sources, each with multiple source-specific COPCs. This approach also provides a more complete risk evaluation of areas surrounding the facility. This information often becomes relevant later in the permitting process and in risk communication to the surrounding public.

As detailed in Chapter 3, ISCST3 estimates COPC concentrations in the air above, and deposition rates onto, specific locations (i.e. receptor grid nodes) around a central point (e.g. combustor facility stack). If all the locations modeled by ISCST3 are viewed as a group, they form a grid of horizontal and vertical lines on a map, with each location a node, or intersection between vertical and horizontal lines; hence the name "grid nodes" for modeled locations. Also, Section 4.1 of this chapter explained the steps and issues involved in characterizing the various uses of the land in the study area. Figure 4-1 is a graphic representation of these two sets of information, and demonstrates some of the relationship between them. For example, a single land use area can have multiple grid nodes associated with it, each node with its own air concentration and deposition levels. Choosing exposure scenario location(s) for a land use area is a matter of choosing which grid node(s) will provide the data used to generate media concentrations used in the exposure scenario. We recommend the following steps:

FIGURE 4-1

ISCST3 GRID NODES AND LAND USE DESIGNATIONS

***Step 1: Define Land Use Areas To Evaluate* -** To avoid confusion and misidentification, land use areas, water bodies, and watersheds identified during the exposure setting characterization step, are best defined and mapped using UTM coordinates in a format consistent with that used to define locations of facility emission sources and the ISCST3 receptor grid nodes. Formats include NAD27 or NAD83 UTM.

Step 2: Identify Receptor Grid Node(s) Within Each Defined Land Use Area* -** For each defined land use area, identify the receptor grid nodes within or on the boundary of that area (defined in Step 1) that represent the location of highest ***yearly average concentration for each ISCST3 air parameter output (i.e., air concentration, dry deposition, wet deposition) for each phase (i.e., vapor, particle, particle-bound). We recommend choosing concentrations specific to each facility emission source (e.g., stacks, fugitives), as well as all emission sources at the facility combined. This results in selecting one or more receptor grid nodes (and therefore the exposure scenario locations for that land use area), with the following attributes:

- Highest vapor phase air concentration
- Highest vapor phase dry deposition rate

- Highest vapor phase wet deposition rate
- Highest particle phase air concentration
- Highest particle phase wet deposition rate
- Highest particle phase dry deposition rate
- Highest particle-bound phase air concentration
- Highest particle-bound phase wet deposition rate
- Highest particle-bound phase dry deposition rate

With the exception of water bodies and watersheds (discussed in Step 4 below), we recommend using only air parameters for a single receptor grid node as inputs into the media equations for each exposure scenario location. We also recommend using actual parameter values, without averaging or other statistical manipulation. However, based generally on the number and location of facility emission sources, you might select multiple exposure scenario locations for a specific land use area.

U.S. EPA Region 6 applied these criteria to actual sites, using actual modeled air parameters, and found that only 1 to 3 receptor grid nodes were typically selected per land use area. This was because, in most cases, the highest air concentration and deposition rate occurred at the same receptor grid node.

> ***Please note:*** while these criteria tend to minimize the chances of overlooking maximum risk within a land use area, they do not preclude you from selecting additional exposure scenario locations within that same land use area based on site-specific risk considerations (see Step 3 below).

***Step 3: Identify Receptor Grid Nodes For Acute Risk and Site-Specific Risk Considerations* -** In addition to the receptor grid nodes selected in Steps 1 and 2 above, you might consider additional receptor grid nodes to evaluate acute risk or site-specific risk considerations (e.g., special populations).

To evaluate a land use area (including commercial and industrial land use areas) for acute risk, choose location(s) from receptor grid nodes with the highest modeled ***hourly*** vapor phase air concentration and highest ***hourly*** particle phase air concentration (see Chapter 3) specific to each emission source, as well as all emission sources combined. For site-specific risk considerations, we recommend considering the receptor grid node closest to the exposure point being evaluated (e.g. school, hospital). However, in some cases, a more protective approach might select the closest receptor grid node or nodes with the highest modeled air parameter values.

***Step 4: Identify Receptor Grid Nodes For Water Bodies and Watersheds* -** For recommended exposure scenarios that include evaluating water bodies and their associated watersheds, we recommend considering the receptor grid nodes within their area extent or "effective" areas (defined and mapped in Step 1). For water bodies, you could select the receptor grid node with the highest modeled air parameter values. You could also average the air parameter values for all receptor grid nodes within the area of the water body. For watersheds, you could average the modeled air parameter values of all receptor grid nodes within the drainage basin (excluding the area of the water body). Media concentration equations for water bodies and watersheds need the same air parameter values as found in Step 2 above; yearly averages for each ISCST3 modeled air parameter (e.g., air concentration, dry deposition, wet deposition) for each phase (e.g., vapor, particle, particle-bound); specific to each emission source (e.g., stacks, fugitives) as well as all emission sources at the facility combined.

For evaluating potential exposure routes other than ingestion of fish, we consider it reasonable to assume that the Fisher and Fisher Child reside at the same exposure scenario locations as the Resident scenario. You can similarly assume that the Fisher and Fisher Child exposure scenarios are exposed through ingestion of fish from the water body with the highest modeled combined deposition, that can or does support fish populations. As a result of some site specific conditions, it may be appropriate to evaluate the Fisher and Fisher Child assuming exposure through ingestion of fish calculated using COPC water concentrations from one water body, and exposure from ingestion of drinking water calculated using COPC water concentrations from a different water body.

To reiterate, we recommend initially evaluating current and reasonable potential future land use areas defined during the exposure setting characterization, using the most representative recommended exposure scenario(s), at actual receptor grid nodes selected using the four-step process explained above.