6.3.2 Exposure Assessment

A key component of conducting a risk-based screening evaluation is identification of potential exposures. An exposure assessment includes an evaluation of potential human and ecological receptors that may contact chemicals originating from the site, as well as routes, magnitude, frequency, and duration of exposure. An evaluation of all possible human and ecological exposures is necessary to identify receptors that currently are in contact with contaminants at the site or at off-site

locations affected by emissions, leaching, or runoff. The principal objective of the screening evaluation is to identify exposures that represent the maximally exposed individual (MEI) at the site. The MEI represents the maximum exposure for each receptor, based on maximum concentrations of COCs, maximum default exposure factors, and the assumption that all pathways are potentially complete, without regard to the likelihood that the pathway is complete. This standard differs from the reasonable maximum exposure (RME) commonly used in risk assessments (EPA 1989, 1992b). Use of the MEI provides an extremely conservative estimate of human and ecological risks, so that, if the risks and hazards calculated are within acceptable limits, no further investigation of the unit is required.

The concept of reasonable, as opposed to maximum, scenarios underlies the concept of RME developed by EPA. As defined by EPA (1989), the RME is the maximum exposure that is reasonably expected to occur at a site. It should be emphasized, however, that the RME exposure is for the same receptor as the MEI and that, before risks are calculated, it must be determined whether "it is likely that the same individual would consistently face the RME."

It is also important that intake parameters for each RME exposure pathway be "selected so that the combination of all intake variables results in an estimate of the reasonable maximum exposure for that pathway" (EPA 1989). In other words, the most conservative intake variables for each parameter for a given pathway are not used exclusively. A combination of average and upper-bound values should be used to estimate exposures that are meaningful and that represent the actual RME for the site.

To collect the information, the exposure assessment should consist of the following steps:

- Characterize the exposure setting and identify potential human and ecological receptors

- Identify pertinent exposure pathways and exposure routes

- Estimate exposure point concentrations

- Quantify chemical intake for exposures for specific pathways for each potential receptor

According to EPA guidance (1989), all complete exposure pathways should be selected for further evaluation unless it can be justified that:

- Exposure from the excluded pathway is much less than that from another pathway that involves the same medium at the same exposure point.

- The potential magnitude of exposure from a pathway is low.

- The probability that exposure will occur is very low, and the risks associated with the pathway are low.

In general, such judgments should be made only in a detailed risk evaluation in which relative risks, assumptions, and uncertainties are described fully.

Characterization of the exposure setting and identification of potential receptors is the first step in evaluating current or potential chemical exposures. The process includes an evaluation of the physical characteristics of the site, such as climate, vegetation, soil type, and hydrology of surface water and groundwater, that are pertinent to the risk assessment (EPA 1989). For ecological risk assessments, the evaluation also should include the presence of any threatened and endangered species.

Human receptors that may be exposed to chemicals released during combustion include on-site workers performing combustion operations and residential and recreational receptors in the vicinity of the site. Both direct and indirect exposure pathways are considered for workers on site, since direct contact with residues from combustion operations in soil and air may occur, and indirect exposure through deposition and storm water runoff also is possible.

Both direct and indirect exposure pathways are considered for residential and recreational receptors in the vicinity of the site. Direct exposures may occur via inhalation of vapors and particulates from the combustion source. Indirect contact with chemicals generated from combustion may occur through ingestion of produce, meat, dairy products, or fish that have been exposed to chemicals from the combustion unit through deposition to soil, surface water, and plants and through biological uptake. In addition, residents and recreational receptors in the area may contact indirectly with chemicals present in soil, air, groundwater, sediment, and surface water in which chemicals generated from combustion are present through wind suspension, deposition, storm-water runoff, infiltration, or percolation.

Once receptors and exposure scenarios have been identified, exposure pathways must be defined. According to EPA guidance (1989), an exposure pathway consists of four elements:

- A source and mechanism of chemical release
- A retention or transport medium (or media in cases involving transfer of chemicals)
- A point of potential contact with the contaminated medium (referred to as the exposure point)
- An exposure route (such as inhalation) at the contact point

Lacking any of the four elements, the exposure pathway is incomplete. Therefore, if no receptors exist that would contact the source or transport medium, the pathway is incomplete and need not be further evaluated.

In the risk-based screening evaluation, all potentially complete exposure pathways are considered and evaluated. In fact, EPA Regions 3, 6, and 9 have developed risk-based concentrations that include exposure to soil, water, and air through a combination of pathways for residential and occupational receptors. Those values can be used

Default Exposure Scenarios Recommended by the HHRAP (EPA, 1998a)

- Adult and Child Resident
- Subsistence Farmer and Child
- Subsistence Fisher and Child
- Acute Risk

to screen sites if the pathways are representative of on- and off-site exposures in the vicinity of the combustion unit. However, additional site-specific information is used in the detailed risk assessment to identify exposure pathways that are most likely complete.

It should be noted that the exposure pathways described above may not be complete at all facilities. In general, a permit writer should decide whether the screening level and detailed assessments include all relevant exposure pathways, and if any pathway has been excluded, that exclusion is justified. The permit writer should consider the following concerns when making such a determination:

Screening Level Evaluation:

- Do occupational receptors have direct contact with the combustion unit?
- Are work areas located within the emission plume from the unit?
- Are there off-site residential areas within the emission plume from the unit?
- Are agricultural activities conducted in areas within the emission plume from the unit?
- Is groundwater used as a potable or domestic water supply? As an agricultural water supply?
- Are surface water bodies located within the emission plume from the unit? If so, is such surface water used for recreational purposes? For occupational purposes? As a water supply? Could rainwater runoff from the unit enter a surface water body (as indicated by distance, annual rainfall, and gradient)?

Detailed Risk Evaluation:

For every receptor and exposure pathway considered potentially complete, the following issues should be addressed:

- Do the exposure parameters reflect reasonable assumptions about the site? If not, what are reasonable exposure parameters for the site and why?

- Were exposure point concentrations appropriately determined (that is, using the 95 percent UCL)?

- Which pathways seem least likely to be complete (for example, homegrown produce or dairy products for an off-site resident)? Are these pathways currently complete? Should they outweigh calculated risks or hazards related other pathways?

After complete exposure pathways have been identified in either the detailed or the screening level approach, chemical intakes for exposures through each pathway for each potential receptor should be quantified. Chemical intake rates should be estimated for all complete exposure pathways, on the basis of the exposure point concentrations and the estimated magnitude of exposure to contaminated media.

Exposure is based on "intake," which is defined as the mass of a substance taken into the body per unit of body weight per unit of time. Intake from a contaminated medium is determined by the amount of the chemical in the medium, the frequency and duration of exposure, the body weight of the receptor, contact rate, and the averaging time. Below is a generic equation that is used to calculate chemical intake:

CDI = (C x CR x EF x ED)/(BW x AT)

where:

CDI = chronic daily intake (milligram per kilogram body weight - day, [mg/kg-day])

C = chemical concentration (mg/kg or milligram per liter [mg/L])

CR = contact rate or ingestion rate (milligrams soil per day or liters per day)

EF = exposure frequency; how often exposure occurs (days per year)
ED = exposure duration; how long exposure occurs (years)
BW = body weight (kilogram, [kg])
AT = averaging time; period over which exposure is averaged

Chemical intake by ingestion and inhalation is quantified as an administered dose. Contaminant intake from dermal exposure is estimated as an absorbed dose. Equations for estimating dermal contact include additional exposure parameters of adherence and absorption factors or permeability constants. Adherence factors indicate the amount of soil that adheres to the skin. Absorption factors reflect the desorption of the chemical from soil and absorption of the chemical across the skin. Permeability constants represent the rate at which a chemical in water penetrates the skin.

Two approaches to an ecological assessment that may be used for the screening exposure assessment are direct and indirect assessment. Exposure to ecological receptors may be assessed directly by comparing maximum concentrations of chemicals on site to protective ecological benchmark concentrations for appropriate media. Field data collected during combustion testing, screening level data from MSDS sheets, or other sources may be used for the initial screening. Maximum detected concentrations of chemicals on site should be compared with ecological benchmark concentrations to eliminate chemicals that are not likely to pose an ecological risk. EPA publications are the preferred source for ecological benchmarks. Some EPA regions, including Region 4 (EPA, 1999b), have established ecological benchmarks for various media. EPA water quality criteria (EPA 1986) may be used as screening benchmarks for aquatic ecosystems. The National Oceanic and Atmospheric Administration (NOAA) has developed benchmark concentrations for chemicals in sediment (NOAA 1991). Soil screening benchmarks are available through the Oak Ridge National Laboratory (Will and Suter 1995). A statistical background comparison for inorganic

chemicals also should be conducted to eliminate naturally occurring chemicals or those not related to the site from further consideration. Concentrations of chemicals that exceed ecological benchmark concentrations and background levels are considered to pose a potential ecological risk and should be further evaluated in the detailed ecological risk assessment. Ecological benchmark concentrations may not be available for all chemicals detected at a site or for all media. Chemicals for which benchmark values are not available should not be eliminated from further consideration. Their potential effects instead must be discussed qualitatively.

An indirect evaluation of ecological exposure involves selection of a key species from each guild, on the basis of information collected during the site reconnaissance; characteristics of the chemicals that were identified in the benchmark screening; and the physiological, behavioral, and ecological factors related to potentially exposed species. Exposure should be assessed for key species that are susceptible through one of the three exposure pathways: inhalation, ingestion, or dermal contact.

More information is generally available to quantify exposure levels for terrestrial animals through ingestion pathways than for dermal and inhalation exposures. Although the results for exposure routes other than ingestion may be less certain, for the preliminary screening, all complete routes should be evaluated, with conservative assumptions applied. For example, conservative assumptions for parameters such as exposure duration, extent of contact, and surface area.

Conservative assumptions (such as maximum chemical concentrations and upper-bound exposure parameters) are made in evaluating exposures for each receptor. All potentially complete pathways are included, without regard for the likelihood that the pathway is complete. Assuming maximum exposure for the preliminary screening requires less site-specific information, thereby expediting the combustion permitting process for both permit writers and reviewers. It also provides an extremely

conservative estimate of ecological risks. Therefore, if calculated HIs are below 1.0, no further unit investigation is required.

As with human risk assessments, exposure for ecological risk assessment is based on "intake." Intake from a contaminated medium is determined by the amount of the chemical in the medium, the contact rate, and body weight. Following is a generic equation that is used to calculate chemical intake:

$$I = C \times IR \times 1/BW$$

where:

I = Intake (mg/kg-day)
C = Chemical concentration (mg/kg or mg/L)
IR = intake rate (mg/day soil or food or L/day)
BW = body weight (kg)

Additional site-specific exposure parameters -- for example, proportion of diet that is contaminated, area use factor, bioavailability, dermal adherence, dermal absorption, permeability constants, and other factors should be incorporated into the generic algorithm, as appropriate.

Bioconcentration and bioaccumulation are the two primary mechanisms that must be considered in estimating chemical uptake by aquatic species (Maughan 1993). Simplified aquatic exposure models that account for both bioaccumulation and bioconcentration may be used for the preliminary screening (Maughan 1993). Exposure pathways of concern for aquatic species include direct contact with water and ingestion of sediment and contaminated food.

According to the EPA's ecological risk assessment guidance (EPA 1994 and 1999c), the maximum concentration of a chemical in each medium should be used to calculate the preliminary exposure estimate, using conservative assumptions in the absence of site-specific information. For air risk

assessments, such as those for incinerators, it is common to use the maximum concentration as the exposure point concentration for air or soil and model concentrations for off-site locations. That approach generally is recommended for most screening level evaluations because those concentrations are identified easily and represent conservative assumptions regarding exposure point concentrations. EPA guidance (EPA 1990) presents detailed information about estimating exposure point concentrations in plants and animals on the basis of air-dispersed chemicals.

If a detailed risk assessment is conducted, the exposure concentration may be refined to reflect more realistic exposure conditions, rather than a maximum concentration. As in the detailed human health risk assessment, the recommended concentration for use in the ecological risk assessment is the 95 percent UCL, which is an upper bound of the average concentration. If the 95 percent UCL concentration exceeds the maximum measured concentration for the site, the maximum measured concentration should be used. The 95 percent UCL concentration can be used to calculate off-site modeled exposure and uptake concentrations.

The exposure assessment in the detailed ecological evaluation uses information from the detailed site investigation and problem formulation (EPA 1994), including:

- Ecological setting of the site
- Inventory of contaminants that are or may be present at the site
- Extent and magnitude of the contamination present, along with the spatial and temporal variability of that contamination
- Environmental fate and transport of contaminants

In the detailed ecological exposure assessment, the most critical exposure pathways are identified and

evaluated in detail, and pathways determined to be insignificant or unlikely to be complete can be ignored. Justification must be provided, however, for the exclusion of pathways. Complex mathematical models may be applied to estimate concentrations of chemicals in environmental media, and a combination of average and upper-bound species-specific exposure parameters obtained from literature and additional field investigation may be used to determine the extent of exposure. In addition, trophic webs should be developed to identify primary routes of energy flow and identify organisms that have the potential of exposure at the site (Maughan 1993).