4 SELECTION OF EXPOSURE SCENARIOS

This section discusses the pathways and scenarios that were selected for use when estimating potential exposures of human receptors to chemicals emitted from hazardous waste operations at the PCAPP. The selected pathways and scenarios are required to conform to the CDPHE exposure assessment requirements defined in the CHWRs. The requirements that relate to pathways and scenarios, presented in Section 1.9 along with other requirements for performing the MPHRA, are:

- providing an estimate of stack emissions
- performing air dispersion modeling for the estimated emissions
- defining assumptions and inputs to the dispersion model and risk calculations
- performing risk calculations using the results obtained from the air dispersion model
- examining exposure to adults and children, including the following exposure pathways:
  - direct inhalation
  - dermal exposure
  - exposure resulting from deposition of metallic and organic compounds in soil and surface water, and subsequent ingestion of local and homegrown foodstuffs or fish

The last item, examining exposure, involves estimating the magnitude, frequency, and duration for each identified pathway of exposure to a human receptor. The magnitude of an exposure is determined by estimating the amount of chemical available at the human receptor exchange boundaries (i.e., lungs, gastrointestinal tract, or skin) during a specified time period. The exposure setting is characterized and exposure pathways are identified by developing a conceptual site model.

Information presented in this section, specifically the exposure parameters, becomes inputs to the exposure equations presented in Sections D.8 and D.9 of Appendix D. The reader is referred to that appendix for a detailed discussion of the use of these parameters. Appendix E illustrates the use of the parameters by showing the step-by-step calculation process for a single chemical, vinyl chloride.

4.1 CONCEPTUAL SITE MODEL

A conceptual site model produces a framework for identifying the pathways by which human receptors may be exposed to emissions from hazardous waste operations at the PCAPP. This process makes it easier to evaluate risks using a consistent and comprehensive approach. The elements necessary to construct a complete conceptual site model are as follows:

- emission sources
- emission scenarios
- transport pathways
- exposure pathways and receptors

4.1.1 Emission Sources

As previously discussed in Sections 2.2 and 3.2.2, the following five emission source groups have been identified at the PCAPP:

- AFA stack
- 30-day hydrolysate storage tanks vent
- six BTA process stacks

- Brine Concentrator Feed Tanks vent
- BRS process stack

Emissions from these sources will be in the vapor phase and will be discharged to the atmosphere from the top of each stack. These emissions represent the only anticipated emissions to the environment from hazardous waste operations at the PCAPP. Liquid discharges are not anticipated, and residual solids will either be recycled or shipped off site for disposal.

4.1.2 Emission Scenarios

The MPHRA includes two release scenarios: long-term and short-term. Long-term emission rates produce concentrations for comparison with lifetime (chronic) effects and are based on maximum sustained emission rates from continuously emitting sources and annual average emission rates from intermittent sources during normal operations. Short-term emission rates produce concentrations that are higher than the long-term rates for comparison with hourly (acute) or other short-term effects and are based on maximum emission rates as well, but also include maximum short-term emission rates from some intermittent sources (for example, filling a feed or storage tank).

4.1.3 Transport Pathways

As required by the CHWRs, the primary emission transport pathway is air dispersion. Emissions from the facility stacks will be dispersed in the atmosphere by wind and other physical processes. Stack emissions released as vapors are expected to be more widely dispersed than particulate emissions. Once in the atmosphere, vapors may be available for a number of different transport pathways:

- dilution in the atmosphere
- absorption into soil and plants
- deposition or diffusion into a water body
- soil erosion by wind or surface water run-off
- consumption of contaminated media by livestock

4.1.4 Chronic Exposure Pathways and Receptors

Exposure pathways to consider were selected based on guidance from the CDPHE and procedures presented in the USEPA's HHRAP (USEPA, 2005a). In all cases, the most recent guidance is used and is supplemented, when necessary, with guidance provided in older documents. Tables 4-1 through 4-3 present a summary of exposure pathways, parameters, and human receptors evaluated in this MPHRA. As described in Section 3.2.3, the RME individual is located at the point of maximum calculated impacts determined by the air dispersion model. Thus, all chronic exposure calculations occur at the point of maximum off-site concentrations. This RME individual is assumed to breathe air only at this one location over the entire PCAPP operating period (5 years) and to eat homegrown foodstuffs (fruit, vegetables, and meat) from the 10,000 square meters (m^2) (2.5 acres) of land at the point of maximum impact for up to 40 years. Additionally, because this MPHRA is a screening level tool, upper percentile (95^{th}) ingestion rates were used for home-produced foodstuffs. The ingestion rates in Tables 4-1 through 4-3 were obtained from the *Exposure Factors Handbook* (USEPA, 1997), *Child-Specific Exposure Factors Handbook* (USEPA, 2002a), and *Estimated Per Capita Fish Consumption in the United States* (USEPA, 2002b).

Table 4-1. PCAPP Scenario-specific Adult Exposure Parameters[a]

Parameter	Adult Resident	Adult Subsistence Fisher	Adult Subsistence Farmer	Adult Worker
Body weight (kg)	70	70	70	70
Exposure duration for indirect pathways (yr)	30	30	40	25[c]
Exposure duration for direct pathways (yr)	5	5	5	5
Exposure frequency (day/yr)	350	350	350	250[c]
Exposure time (hr/day)	24	24	24	8[c]
Averaging time for carcinogenic effects (yr)	70	70	70	70
Averaging time for noncarcinogenic direct pathways (yr)	5	5	5	5
Averaging time for noncarcinogenic indirect pathways (yr)	30	30	40	25[c]
Ingestion rate:				
soil (kg/day)	0.0001	0.0001	0.0001	0.00005[c]
exposed fruit (kg/day)	0.425	0.425	0.425	n/a
protected fruit (kg/day)	0.470	0.470	0.470	n/a
exposed vegetables (kg/day)	0.316	0.316	0.316	n/a
protected vegetables (kg/day)	0.115	0.115	0.115	n/a
below-ground vegetables (kg/day)	0.282	0.282	0.282	n/a
Beef (kg/day)	0.163	0.163	0.163	n/a
Pork (kg/day)	0.080	0.080	0.080	n/a
poultry (kg/day)	0.142	0.142	0.142	n/a
eggs (kg/day)	0.100	0.100	0.100	n/a
Milk (kg/day)	0.836	0.836	0.836	n/a
fish (kg/day)	0.256	0.256	0.256	n/a
incidental surface water (mℓ/hr)	50[c]	50[c]	50[c]	n/a
Inhalation rate (m^3/hr)	0.83	0.83	0.83	0.83
Soil fraction contaminated	1	1	1	1
Produce fraction contaminated	0.4[b]	0.4[b]	1	n/a[d]
Beef fraction contaminated	0.4[b]	0.4[b]	1	n/a
Pork fraction contaminated	0.4[b]	0.4[b]	1	n/a
Poultry fraction contaminated	0.4[b]	0.4[b]	1	n/a
Milk fraction contaminated	0.4[b]	0.4[b]	1	n/a
Fish fraction contaminated	0.4[b]	1	0.4[b]	n/a

a. USEPA, 1997, *Exposure Factors Handbook*. National Center for Environmental Assessment (NCEA), Office of Research and Development, Washington, DC.
b. As a conservative assumption in this MPHRA, this human receptor will obtain 40 percent of his or her produce, beef, pork, poultry, and milk from local subsistence farmers and 40 percent of his or her fish from local sources.
c. USEPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*. Office of Emergency and Remedial Response.
d. n/a = Pathway not evaluated for this human receptor.

Table 4-2. PCAPP Scenario-specific Child Exposure Parameters[a]

Parameter	Child Resident	Child Subsistence Fisher	Child Subsistence Farmer
Body weight (kg)	15	15	15
Exposure duration for indirect pathways (yr)	5	5	5
Exposure duration for direct pathways (yr)	5	5	5
Exposure frequency (day/yr)	350	350	350
Exposure time (hr/day)	24	24	24
Averaging time for carcinogenic effects (yr)	70	70	70
Averaging time for noncarcinogenic direct pathways (yr)	5	5	5
Averaging time for noncarcinogenic indirect pathways (yr)	5	5	5
Ingestion rate:			
soil (kg/day)	0.0002	0.0002	0.0002
exposed fruit (kg/day)	0.434[c]	0.434[c]	0.434[c]
protected fruit (kg/day)	0.299[c]	0.299[c]	0.299[c]
exposed vegetables(kg/day)	0.109[c]	0.109[c]	0.109[c]
protected vegetables (kg/day)	0.091[c]	0.091[c]	0.091[c]
root vegetables (kg/day)	0.114[c]	0.114[c]	0.114[c]
beef (kg/day)	0.054	0.054	0.054
pork (kg/day)	0.037	0.037	0.037
poultry (kg/day)	0.057	0.057	0.057
eggs (kg/day)	0.061[c]	0.061[c]	0.061[c]
cow milk (kg/day)	0.728	0.728	0.728
fish (kg/day)	0.134[d]	0.134 [d]	0.134 [d]
incidental surface water (mℓ/hr)	50[e]	50[e]	50[e]
Inhalation rate (m^3/hr)	0.5	0.5	0.5
Soil fraction contaminated	1	1	1
Produce fraction contaminated	0.4[b]	0.4[b]	1
Beef fraction contaminated	0.4[b]	0.4[b]	1
Pork fraction contaminated	0.4[b]	0.4[b]	1
Poultry fraction contaminated	0.4[b]	0.4[b]	1
Milk fraction contaminated	0.4[b]	0.4[b]	1
Fish fraction contaminated	0.4[b]	1	0.4[b]

a. USEPA, 1997, *Exposure Factors Handbook*. NCEA, Office of Research and Development, Washington, DC.
b. As a conservative assumption in this MPHRA, this human receptor will obtain 40 percent of his or her produce, beef, pork, poultry, and milk from local subsistence farmers and 40 percent of his or her fish from local sources.
c. USEPA, 2002a. *Child-Specific Exposure Factors Handbook*.
d. USEPA, 2002b. *Estimated Per Capita Fish Consumption in the United States*.
e. USEPA, 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*. Office of Emergency and Remedial Response.

Table 4-3. PCAPP Scenario-specific Infant Exposure Parameters[a]

Parameter	Infant Resident	Infant Subsistence Fisher	Infant Subsistence Farmer
Body weight (kg)	10	10	10
Exposure duration for indirect pathways (yr)	1	1	1
Exposure duration for direct pathways (yr)	1	1	1
Exposure frequency (day/yr)	350	350	350
Exposure time (hr/day)	24	24	24
Averaging time for carcinogenic effects (yr)	70	70	70
Averaging time for noncarcinogenic direct pathways (yr)	1	1	1
Averaging time for noncarcinogenic indirect pathways (yr)	1	1	1
Ingestion rate:			
soil (kg/day)	0.0002	0.0002	0.0002
exposed fruit (kg/day)	0.388 [c]	0.388 [c]	0.388 [c]
protected fruit (kg/day)	0.083 [c]	0.083 [c]	0.083 [c]
exposed vegetables(kg/day)	0.074 [c]	0.074 [c]	0.074 [c]
protected vegetables (kg/day)	0.078 [c]	0.078 [c]	0.078 [c]
root vegetables (kg/day)	0.096 [c]	0.096 [c]	0.096 [c]
beef (kg/day)	0.032	0.032	0.032
pork (kg/day)	0.017	0.017	0.017
poultry (kg/day)	0.035	0.035	0.035
eggs (kg/day)	0.033 [c]	0.033 [c]	0.033 [c]
breast milk (kg/day)	0.980 [c]	0.980 [c]	0.980 [c]
cow milk (kg/day)	1.709	1.709	1.709
fish (kg/day)	0.134 [d]	0.134 [d]	0.134 [d]
Inhalation rate (m^3/hr)	0.1875	0.1875	0.1875
Soil fraction contaminated	1	1	1
Produce fraction contaminated	0.4[b]	0.4[b]	1
Beef fraction contaminated	0.4[b]	0.4[b]	1
Pork fraction contaminated	0.4[b]	0.4[b]	1
Poultry fraction contaminated	0.4[b]	0.4[b]	1
Milk fraction contaminated	0.4[b]	0.4[b]	1
Fish fraction contaminated	0.4[b]	1	0.4[b]

a. USEPA, 1997, *Exposure Factors Handbook*. NCEA, Office of Research and Development, Washington, DC.
b. As a conservative assumption in this MPHRA, this human receptor will obtain 40 percent of his or her produce, beef, pork, poultry, and milk from local subsistence farmers and 40 percent of his or her fish from local sources.
c. USEPA, 2002a. *Child-Specific Exposure Factors Handbook*.
d. USEPA, 2002b. *Estimated Per Capita Fish Consumption in the United States*. No value given for infant fish ingestion, child value used as conservative estimate.

The human receptor chronic exposure scenarios include the following:

- adult subsistence farmer
- adult resident
- adult subsistence fisher
- adult worker
- child of a subsistence farmer
- child resident
- child of a subsistence fisher
- infant of a subsistence farmer
- infant resident
- infant of a subsistence fisher

Specific exposure media and pathways associated with each human receptor are described below. Table 4-4 summarizes the exposure pathways evaluated for each receptor. Ingestion of drinking water from a surface water source is not a potential exposure pathway for any human receptor, as discussed in Section 1.4.2.

The adult subsistence farmer scenario is based on the assumption that an adult is physically located at the RME individual location continuously for 40 years during which he/she receives direct inhalation exposure for the initial 5-years as a result of PCAPP operations. During the 40 years, 100 percent of his/her foodstuffs, except for fish, (fruit, vegetables, meat, milk, and eggs) are produced on the 10,000 m^2 (2.5 acres) of land with the highest deposition. This exposure scenario assumes that only 40 percent of the fish consumed by the farmer is locally caught. The farmer is also exposed dermally to both soil and surface water during the 40-year exposure duration.

The adult resident scenario is based on the assumption that an adult is physically located at the RME individual location continuously for 30 years during which he/she consumes foodstuffs (fruit, vegetables, meat, milk, and eggs) produced on the 10,000 m^2 (2.5 acres) of land with the highest deposition rate and receives direct inhalation exposure for the initial 5-years as a result of PCAPP operations. These exposure pathways are the same as those evaluated for the adult subsistence farmer, but the fraction of consumed foodstuff assumed to be contaminated is lower--i.e., the adult resident consumes 40 percent contaminated foodstuffs, while the adult subsistence farmer consumes 100 percent contaminated foodstuffs.

The adult subsistence fisher scenario is based on the assumption that an adult fishes at a water body that has been impacted by PCAPP emissions for the operational life of the facility and consumes the locally caught fish for 30 years. The exposure pathways are the same as those evaluated for the adult subsistence farmer; however, it is assumed that all fish consumed by the subsistence fisher was locally caught, while a lower fraction of all other foodstuff is consumed (i.e., the adult subsistence fisher consumes 40 percent contaminated foodstuffs other than fish.)

The adult worker scenario is based on the assumption that an adult works 8 hours per day, 250 days per year at the RME individual location for the duration of the PCAPP emissions. The exposure pathways are the same as those evaluated for the adult resident except the adult worker does not consume any home-grown produce, meat, fish, milk, or eggs. The worker is exposed dermally to soil, but not to surface water.

Table 4-4. Exposure Pathway/Human Receptor Combinations Evaluated

Receptor	Exposure Pathway								
	Inhalation	Dermal Contact with Surface Water	Dermal Contact with Soil	Incidental Ingestion of Soil	Incidental Ingestion of Surface Water	Ingestion of Produce[a]	Ingestion of Terrestrial Animal Products[b]	Ingestion of Fish	Ingestion of Breast Milk
Adult resident	X	X	X	X	X	X	X	X	n/a[c]
Adult fisher	X	X	X	X	X	X	X	X	n/a
Adult farmer	X	X	X	X	X	X	X	X	n/a
Adult worker	X	n/a	X	X	n/a	n/a	n/a	n/a	n/a
Child of adult resident	X	X	X	X	X	X	X	X	n/a
Child of adult fisher	X	X	X	X	X	X	X	X	n/a
Child of adult farmer	X	X	X	X	X	X	X	X	n/a
Infant of adult resident	X	n/a	X	X	n/a	X	X	X	X
Infant of adult fisher	X	n/a	X	X	n/a	X	X	X	X
Infant of adult farmer	X	n/a	X	X	n/a	X	X	X	X

a. Produce includes above-ground exposed fruits and vegetables, above-ground protected fruits and vegetables, and below-ground vegetables.
b. Terrestrial animal products include beef, pork, chicken, eggs, and milk.
c. n/a = Pathway not evaluated for this human receptor.

The child exposure scenarios are based on the assumption that a child is physically located at the RME individual location continuously from the second through the sixth year of life. This 5-year exposure scenario is assumed to coincide exactly with the 5-year operational period of the PCAPP. During this time, the child is exposed to the same pathways and contaminated foodstuff fractions as the corresponding scenario-specific adult (i.e., the subsistence fisher child is exposed via the same routes as the adult subsistence fisher) but with different ingestion and inhalation rates.

The infant exposure scenarios are based on the assumption that an infant is physically located at the RME individual location continuously for the first year of life. The infant exposure scenarios are assumed to occur during the 5-year operational period. During this time, the infant obtains some nourishment through breast feeding. In addition to ingestion of breast milk, the inhalation pathway and consumption of home-produced foodstuffs pathways are evaluated for the infant scenario. Infants are exposed dermally to soil, but not to surface water.

For the purposes of this MPHRA, the subsistence farmer scenarios are expected to represent the maximum exposure scenarios. Exposure parameters specified in Tables 4-1, 4-2, and 4-3 for the subsistence farmer scenarios are equal to or greater than all other exposure scenarios in all categories except fish consumption. Because fishing is possible in a pond near the PCAPP, inclusion of the fisher scenario supplements the farmer scenario and/or the resident in areas where emissions can be deposited into the fishing pond.

4.1.5 Acute Exposure Pathways and Receptors

Acute exposure pathways and receptors were selected based on guidance from the CDPHE. The acute exposure pathway was developed to represent an on-site PCD worker. As described in Section 3.2.3, the PCD worker is located at the point of maximum calculated on-site impacts determined by the air dispersion model. The PCD worker is assumed to inhale the COPC air concentrations at the maximum on-site impact location over the entire acute exposure event.

4.2 CUMULATIVE LIFETIME EXPOSURE SCENARIO

The cumulative lifetime exposure scenario is calculated for three different human receptors:

- resident
- fisher
- farmer

Because the PCAPP will operate only for a 5-year period, and the exposure period due to consumption of local foodstuffs is either 30 or 40 years (depending on the receptor), the cumulative lifetime exposure is calculated as a combination of several different exposure scenarios. Lifetime exposure for these receptors, therefore, consists of the cumulative exposure from the following pathways:

- 1 year of inhalation exposure as an infant, plus
- 4 years of inhalation exposure as a child, plus
- 1 year of indirect exposure as an infant, plus
- 5 years of indirect exposure as a child, plus
- 24 (resident and fisher) or 34 (farmer) years of indirect exposure as an adult

The cumulative lifetime exposure scenario also is assessed as if PCAPP operations commenced at the start of the childhood exposure period (i.e., the exposure period consists of 5 years of direct and indirect exposure as a child plus 25 or 35 years of indirect exposure as an adult).

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