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 the PCAPP and EDS, i.e., the conceptual site model. 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 contact
  - ingestion of surface water and locally grown foodstuffs and fish

The last item, examining exposure, is the subject of this section and involves estimating the magnitude, frequency, and duration for each identified pathway of exposure to a human receptor. Information presented in this section, specifically the exposure parameters, becomes inputs to the exposure equations presented in Sections D.8 (direct inhalation exposure) and D.9 (indirect exposure) 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

The conceptual site model for this screening level MPHRA provides the basis for identifying and evaluating the potential risks to human health. Development of a conceptual model facilitates consistent and comprehensive evaluation of risks by producing a framework for identifying the pathways by which human receptors may be exposed to emissions from the PCAPP and EDS. The elements necessary to construct a complete conceptual site model include identification of the following items:

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

4.1.1 Emission Sources

As previously discussed in Section 3.2.2.6, the following seven emission source groups have been identified at the PCAPP and EDS:

- AFA stack
- 30-day Storage Tanks vent
- Four BTS OTS stacks
- WRS BC feed tank OTS
- BRS OTS stack
- Two AFS stacks for EDS1
- Two AFS stacks for EDS2

COPC emissions from these sources will be in the vapor and particle phases and will be discharged to the atmosphere from the top of each stack/vent. These emissions represent the only anticipated emissions to the environment from CHWR-regulated operations at the PCAPP and EDS. Residual solids and liquids will either be recycled or shipped off site for treatment and/or 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 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). These emission rates are used to calculate ambient concentrations over short time periods (i.e., 1 hour).

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, which were assumed to be equal in density to air, will not settle gravimetrically and thus are expected to be more widely dispersed than particulate emissions. Once in the atmosphere, vapors and particulates may be transported by various mechanisms and subsequently become available for inhalation or ingestion. For example, particulates may settle to the ground where they may degrade and become incorporated into soil and plants. Particulates may also deposit onto the surface of a water body, while vapors may diffuse into the water body. Vapors may also be absorbed directly into soil and plants. Soil impacted by emissions may be transported by wind or surface water run-off. Impacted air and plants may be inhaled or consumed by both humans and livestock. In summary, once in the environment, COPCs may be transported by a number of different 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

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 other EPA documents. 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. Chronic (long-term) exposure calculations are performed using the chronic emission rates and toxicity values at the point of maximum off-site impact of annual average concentrations. This RME individual is assumed to breathe air only at this one location over the entire PCAPP and EDS operating periods (5 years) and to eat homegrown foodstuffs (fruit, vegetables, and meat) only 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. Tables 4-1 through 4-3 present a summary of exposure pathways, parameters, and human receptors evaluated in this MPHRA. The ingestion rates in Tables 4-1 through 4-3 were obtained from the *Exposure Factors Handbook* (USEPA, 2011).

The human receptors selected for the chronic exposure scenarios include the following:

- resident
- subsistence fisher
- subsistence farmer
- worker

Specific exposure media and pathways associated with each of these human receptors are described below. Note that ingestion of drinking water from a surface water source is not considered a potential exposure pathway for any human receptor at this time and is not evaluated further. Incidental ingestion of surface water is considered an exposure pathway for human receptors as indicated in Table 4-1. Intentional consumption of surface water is not considered in this analysis.

The subsistence farmer scenario is based on the assumption that the receptor is physically located at the RME individual location continuously for up to 40 years during which he/she receives direct inhalation exposure for the initial 5 years (1 year for the infant receptor) as a result of treatment operations. During the exposure duration, 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 40 percent of the fish consumed by the subsistence farmer is locally caught. The subsistence farmer also is exposed via dermal contact to both soil and surface water during the exposure duration.

The resident scenario is based on the assumption that the receptor is physically located at the RME individual location continuously for up to 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 (1 year for the infant receptor) as a result of treatment operations. These exposure pathways are the same as those evaluated for the subsistence farmer, but the fraction of consumed foodstuff assumed to be contaminated is lower--i.e., the resident consumes 40 percent contaminated foodstuffs, while the subsistence farmer consumes 100 percent contaminated foodstuffs.

The subsistence fisher scenario is based on the assumption that the receptor is physically located at the RME individual location continuously for up to 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 (1 year for the infant receptor) as a result of treatment operations. These exposure pathways are the same as those evaluated for the subsistence farmer, but the fraction of consumed foodstuff assumed to be contaminated is lower--i.e., the subsistence fisher consumes 40 percent contaminated foodstuffs, while the subsistence farmer consumes 100 percent contaminated foodstuffs. In addition, the subsistence fisher obtains fish for consumption from a local water body that has been impacted by PCAPP and EDS emissions for the operational life of the facility. This exposure scenario assumes that 100 percent of the fish consumed by the subsistence fisher was locally caught.

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

Parameter	Adult Resident	Adult Subsistence Fisher	Adult Subsistence Farmer	Adult Worker
Body weight (kg)	80	80	80	80
Exposure duration for indirect pathways (yr)	30	30	40	25[b]
Exposure duration for direct pathways (yr)	5	5	5	5
Exposure frequency (day/yr)	350	350	350	250[b]
Exposure time (hr/day)	24	24	24	8[b]
Averaging time for carcinogenic effects (yr)	78	78	78	78
Averaging time for noncarcinogenic direct pathways (yr)	5	5	5	5
Averaging time for noncarcinogenic indirect pathways (yr)	30	30	40	25
Ingestion rate:				
soil (kg/day)	0.0001	0.0001	0.0001	0.0001[b]
exposed fruit (kg/day)	0.560	0.560	0.560	n/a
protected fruit (kg/day)	0.648	0.648	0.648	n/a
exposed vegetables (kg/day)	0.352	0.352	0.352	n/a
protected vegetables (kg/day)	0.248	0.248	0.248	n/a
below-ground vegetables (kg/day)	0.328	0.328	0.328	n/a
beef (kg/day)	0.157	0.157	0.157	n/a
pork (kg/day)	0.073	0.073	0.073	n/a
poultry (kg/day)	0.124	0.124	0.124	n/a
eggs (kg/day)	0.070	0.070	0.070	n/a
milk (kg/day)	0.993	0.993	0.993	n/a
fish (kg/day)	0.168	0.168	0.168	n/a
incidental surface water (ml/hr)	71[a]	71[a]	71[a]	n/a
Inhalation Rate (m^3/hour)	0.83	0.83	0.83	0.83
Soil Fraction Contaminated	1	1	1	1
Produce Fraction Contaminated	0.4[c]	0.4[c]	1	n/a
Beef Fraction Contaminated	0.4[c]	0.4[c]	1	n/a
Pork Fraction Contaminated	0.4[c]	0.4[c]	1	n/a
Poultry Fraction Contaminated	0.4[c]	0.4[c]	1	n/a
Milk Fraction Contaminated	0.4[c]	0.4[c]	1	n/a
Fish Fraction Contaminated	0.4[c]	1	0.4[c]	n/a

a. US Environmental Protection Agency, 2011, Exposure Factors Handbook: 2011 Edition. National Center for Environmental Assessment, Office of Research and Development, Washington, DC.
b. US Environmental Protection Agency, 2004, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Office of Superfund Remediation and Technology Innovation, Washington, DC. EPA/540/R/99/005.
c. As a conservative assumption in this MPHRA, residents will obtain 40 percent of their produce, beef, milk and pork from local subsistence farmers and 40 percent of their fish from local sources.
n/a Pathways not evaluated for this human receptor.

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

Parameter	Child Resident	Child Subsistence Fisher	Child Subsistence Farmer
Body weight (kg)	16.2	16.2	16.2
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)	78	78	78
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)	0.469	0.469	0.469
protected fruit (kg/day)	0.324	0.324	0.324
exposed vegetables(kg/day)	0.118	0.118	0.118
protected vegetables (kg/day)	0.098	0.098	0.098
below-ground vegetables (kg/day)	0.123	0.123	0.123
beef (kg/day)	0.052	0.052	0.052
pork (kg/day)	0.024	0.024	0.024
poultry (kg/day)	0.047	0.047	0.047
eggs (kg/day)	0.032	0.032	0.032
cow milk (kg/day)	1.052	1.052	1.052
fish (kg/day)	0.067	0.067	0.067
incidental surface water (ml/hr)	120[a]	120[a]	120[a]
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. US Environmental Protection Agency, 2011, Exposure Factors Handbook: 2011 Edition. National Center for Environmental Assessment, Office of Research and Development, Washington, DC.
b. As a conservative assumption in this MPHRA, residents will obtain 40 percent of their produce, beef, milk and pork from local subsistence farmers and 40 percent of their fish from local sources.

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

Parameter	Infant Resident	Infant Subsistence Fisher	Infant Subsistence Farmer
Body weight (kg)	7.8	7.8	7.8
Exposure duration for indirect pathways (yr)	1	1	1
Exposure duration for direct pathways (yr)	1	1	1
Exposure frequency (day/yr)[b]	350	350	350
Exposure time (hr/day)	24	24	24
Averaging time for carcinogenic effects (yr)	78	78	78
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)	0.303	0.303	0.303
protected fruit (kg/day)	0.065	0.065	0.065
exposed vegetables(kg/day)	0.058	0.058	0.058
protected vegetables (kg/day)	0.061	0.061	0.061
below-ground vegetables (kg/day)	0.075	0.075	0.075
beef (kg/day)	0.014	0.014	0.014
pork (kg/day)	0.005	0.005	0.005
poultry (kg/day)	0.023	0.023	0.023
eggs (kg/day)	0.010	0.010	0.010
breast milk (kg/day)	1.160	1.160	1.160
cow milk (kg/day)	0.380	0.380	0.380
fish (kg/day)	0.023	0.023	0.023
Soil Fraction Contaminated	1	1	1
Produce Fraction Contaminated	0.4[c]	0.4[c]	1
Beef Fraction Contaminated	0.4[c]	0.4[c]	1
Pork Fraction Contaminated	0.4[c]	0.4[c]	1
Poultry Fraction Contaminated	0.4[c]	0.4[c]	1
Milk Fraction Contaminated	0.4[c]	0.4[c]	1
Fish Fraction Contaminated	0.4[c]	1	0.4[c]

a. US Environmental Protection Agency, 2011, Exposure Factors Handbook: 2011 Edition. National Center for Environmental Assessment, Office of Research and Development, Washington, DC.
b. Exposure Frequency is 350 days per year, except when calculating additional risk due to early-life exposures to vinyl chloride. In this case, EF may not be prorated and must be 365 days per year.
c. As a conservative assumption in this MPHRA, residents will obtain 40 percent of their produce, beef, milk and pork from local subsistence farmers and 40 percent of their fish from local sources.

The 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 a total of 25 years with the initial 5 years coinciding exactly with the 5-year operational period of the PCAPP and EDS. The exposure pathways are the same as those evaluated for an 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.

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 worker at PCAPP or EDS and an off-site resident located at the RME location. The worker and resident are located at the points of maximum calculated on-site and off-site (fence line) impacts, respectively, determined by the air dispersion model. The acute exposure receptors are assumed to inhale the COPC air concentrations at the maximum impact locations over the entire acute exposure event.

4.2 EXPOSURE SCENARIOS

Chronic exposures were evaluated for a total of five exposure scenarios for each of the human receptors selected for this MPHRA. Acute exposures were evaluated only for the inhalation pathway, and because the exposure criteria are concentrations defined to protect the most sensitive populations, the acute assessment does not differentiate between adult, child, or infant. The only differentiation is between on-site (assumed to be an adult worker) and off-site (assumed to be a resident along the PCD fenceline) receptors. The five chronic exposure scenarios evaluated for the subsistence farmer, resident, and subsistence fisher receptors are:

- individual adult
- individual child
- individual infant
- composite lifetime (I)
- composite lifetime (II)

The adult exposure scenarios are based on the assumption that an adult is physically located at the RME individual location continuously for the entire exposure duration (40 years for a subsistence farmer, 30 years for a resident and subsistence fisher, and 25 years for a worker). During the initial 5 years of exposure, he/she receives direct exposure through inhalation of emissions that result from the PCAPP and EDS operations. During the entire exposure duration, he/she receives indirect exposure through ingestion of contaminated foodstuffs and dermal contact with soil and water based on the scenario-specific pathways and receptors as described above and illustrated in Table 4-4. Table 4-1 presents the adult exposure parameters for the scenario-specific pathways and receptors described above.

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 and EDS. Therefore, he/she receives direct exposure through inhalation of emissions that result from the PCAPP and EDS operations for the entire childhood exposure duration. During this time, the child also receives indirect exposure to the same pathways and contaminated foodstuff fractions based on the scenario-specific pathways and receptors described above and illustrated in Table 4-4. Table 4-2 presents the child exposure parameters for the scenario-specific pathways and receptors described above.

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	√[c]	√	√	√	√	√	√	√	n/a[d]
Adult subsistence fisher	√	√	√	√	√	√	√	√	n/a
Adult subsistence farmer	√	√	√	√	√	√	√	√	n/a
Adult worker	√	n/a	√	√	n/a	n/a	n/a	n/a	n/a
Child resident	√	√	√	√	√	√	√	√	n/a
Child subsistence fisher	√	√	√	√	√	√	√	√	n/a
Child subsistence farmer	√	√	√	√	√	√	√	√	n/a
Infant resident	√	n/a	√	√	n/a	√	√	√	√
Infant subsistence fisher	√	n/a	√	√	n/a	√	√	√	√
Infant subsistence farmer	√	n/a	√	√	n/a	√	√	√	√

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, poultry, eggs, and milk.
c. √ - indicates this pathway was assessed for this receptor.
d. n/a - pathway not evaluated for this human receptor.

The infant exposure scenarios, illustrated in Table 4-4, 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 any 1 year of the 5-year operational period of the PCAPP and EDS. 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. Table 4-3 presents the infant exposure parameters for the scenario-specific pathways and receptors described above.

Because the PCAPP and EDS 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), two composite lifetime exposure scenarios (lifetime (I) and lifetime (II)) were evaluated to combine exposure periods for several different receptors. The lifetime (I) exposure scenario assumes that the human receptor is born at the start of the 5-year operational period of the PCAPP and EDS, is directly and indirectly exposed to emissions for the first 5 years of life, and indirectly exposed for the remainder of the scenario-specific exposure duration. This exposure scenario, therefore, consists of the cumulative exposure to carcinogenic COPCs and the duration-weighted average exposure to noncarcinogenic COPCs 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 subsistence fisher) or 34 (subsistence farmer) years of indirect exposure as an adult

The lifetime (II) exposure scenario assumes that the human receptor is a child (i.e., 1 year old) at the start of the 5-year operational period, is directly and indirectly exposed to the PCAPP and EDS emissions as a child (ages 1 through 6), and indirectly exposed as an adult for the remainder of the scenario-specific exposure duration. Like the lifetime (I) exposure scenario, the lifetime (II) exposure scenario, therefore, consists of the cumulative exposure to carcinogenic COPCs and the duration-weighted average exposure to noncarcinogenic COPCs from the following pathways:

- 5 years of inhalation exposure as a child, plus
- 5 years of indirect exposure as a child, plus
- 25 (resident and subsistence fisher) or 35 (subsistence farmer) years of indirect exposure as an adult

For the purposes of this MPHRA, receptors included within the subsistence farmer and fisher scenarios would be expected to represent the maximum exposure scenarios. Exposure parameter values specified in Tables 4-1, 4-2, and 4-3 for the subsistence farmer receptors are equal to or greater than those for receptors in all other exposure scenarios for all parameters except fish consumption, which is highest for the subsistence fisher receptors. Therefore, the subsistence farmer scenarios would be expected to result in the highest risk and hazard due to higher ingestion rates of contaminated produce and terrestrial animal products (via a contaminated fraction of 1 for the subsistence farmer as compared to 0.4 for the subsistence fisher and resident). However, the higher ingestion rates of contaminated fish for the subsistence fisher, compared to the subsistence farmer and resident, could yield higher risks and hazards for the subsistence fisher if concentrations of the risk driving chemicals are significantly higher in fish than in produce and terrestrial animal products.

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