

**Technical Support Document for the Second Tier Analysis
Sierra Pacific Industries
Increased Lumber Drying Capacity Project
Centralia, Washington
June 13, 2008**

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1. EXECUTIVE SUMMARY

Proposed acetaldehyde, acrolein, and formaldehyde from the Sierra Pacific Industries Increased Lumber Drying Capacity Project (Sierra Pacific) exceed a regulatory trigger level called an Acceptable Source Impact Level (ASIL). The project was therefore required to undergo a Second Tier analysis per Chapter 173-460 Washington Administrative Code (WAC).

On the basis of the Second Tier analysis described here and the modeled acetaldehyde, acrolein, and formaldehyde concentrations, the Washington State Department of Ecology (Ecology) has determined the health risks are within the range that Ecology may approve for proposed new sources of Toxic Air Pollutants (TAP) under Chapter 173-460 Washington Administrative Code (WAC).

This document describes the technical analysis performed by Ecology.

2. THE PROCESS

2.1 The Regulatory Process

The requirements for performing a toxics screening are established in Chapter 173-460 WAC. These rules require a review of any increase in toxic emissions for all new or modified stationary sources in the state of Washington.

2.1.1 The Three Tiers of Toxic Air Permitting

The objectives of Toxics Air Permitting are to establish the systematic control of new sources emitting toxic air pollutants in order to prevent air pollution, reduce emissions to the extent reasonably possible, and maintain such levels of air quality as will protect human health and safety.

There are three levels of review when processing a new or modified emissions unit emitting TAPs: (1) Tier One (toxic screening), (2) Tier Two (health impacts assessment), and (3) Tier Three (risk management decision).

All projects are required to undergo a toxic screening (Tier One analysis) as required by WAC 173-460-040. There are two ways to perform a Tier One analysis. If proposed emissions are below the Small Quantity Emission Rate (SQER) tables, no further analysis is required. If emissions are greater than the SQER table or no value exists in the SQER table, those emissions must be modeled and the resultant ambient concentration compared against the appropriate ASIL. If the ambient concentration is below the ASIL, then no further analysis is required.

A Second Tier analysis, promulgated in WAC 173-460-090, is a site-specific health impacts assessment. The objective of a Second Tier analysis is to quantify the increase in

lifetime cancer risk for persons exposed to the increased concentration of any Class A TAP and to quantify the increased health hazard from any Class B TAP in ambient air that would result from the proposed project. Once quantified, the cancer risk is compared to the maximum risk allowed by a Tier Two analysis, which is one in one hundred thousand, and the concentration of any Class B TAP that would result from the proposed project is compared to a Risk Based Concentration (RBC).

If the emissions of a toxic pollutant result in a cancer risk of greater than one in one hundred thousand, then an applicant may request Ecology perform a Tier Three analysis. A Tier Three is basically a risk management decision in which the director of Ecology makes a decision that the risk of the project is acceptable based on determination that emissions will be maximally reduced through available preventive measures, assessment of environmental benefit, disclosure of risk at a public hearing and related factors associated with the facility and the surrounding community.

Since Class B TAPs are not confirmed carcinogens, there is no Tier Three analysis performed. All risks are evaluated in the Tier Two analysis.

2.1.2 Processing Requirements

Ecology shall evaluate a source's Second Tier analysis only if:

- The authority (Southwest Clean Air Agency (SWCAA)) has advised Ecology that other conditions for processing the Air discharge Permit (ADP) have been met,
- Emission controls contained in the conditional ADP represent at least Best Available Control Technology for Toxics (T-BACT), and
- Ambient concentrations exceed acceptable source impact levels after using more refined emission quantification and air dispersion modeling techniques.

SWCAA submitted the three items listed above to Ecology on May 15, 2008.

2.2 T-BACT Verification

T-BACT is required for any new or modified emission unit that has an increase in emissions of toxic air pollutants.

2.2.1 Ambient Concentration of Toxic Air Pollutants

Ecology reviewed the application and verified the emission estimates. Emissions of acetaldehyde, acrolein, and formaldehyde exceed the ASILs and a Second Tier analysis must be performed.

3. THE PROJECT

3.1 Facility and Permitting History

- The Centralia Sawmill Company was issued its initial Air Discharge Permit (No. 06-2669) in March 2006.
- Sierra Pacific purchased the facility from the Centralia Sawmill Company in 2007.
- Sierra Pacific submitted an Air Discharge Permit application in May 2007 for the construction and operation of a wood-fired boiler and three lumber dry kilns.
- SWCAA issued a revised Air Discharge Permit (# 07-2753) in August 2007.
- The boiler and three kilns began operation in January 2008.

3.2 ADP Processing Timelines

SWCAA received the application on March 18, 2008. SWCAA provided a draft of the ADP to Ecology on May 15, 2008. Additional information was received by Ecology on May 22, 2008.

3.3 The Proposed Project

Sierra Pacific purchased the facility in 2007. At that time, lumber production was approximately 150 million board feet per year (MMbf/yr). In August 2007, they received an air discharge permit from SWCAA allowing three lumber kilns to be constructed. The three new lumber kilns allowed the facility to dry up to 135 MMbf/yr. Today Sierra Pacific is requesting to construct three more lumber kilns. SWCAA has required Sierra Pacific to combine the criteria pollutant and TAP evaluations and intends to treat the two projects as one project. The existing permit (07-2753) will be replaced to incorporate the two modifications. The facilities total lumber drying capacity will be limited to 300 MMbf/yr (165 MMbf/yr of which is expected to come from the six new lumber kilns). In addition, some minor operational changes to the boiler have been requested. Those changes include changing the oxides of nitrogen control system from urea to anhydrous ammonia; increase the oxides of nitrogen emission limit from 39 tons per year to 58.1 tons per year, increase anti-stain usage from 3,000 gallons per year to 5,000 gallons per year, and adding end curtains to the bin loading operation.

3.4 Site Description

The facility is located about three miles north-northwest of the center of Centralia, WA. The physical address is 3115 Kuper Road Centralia, Washington 98531 in Lewis County. The facility is located to the west of Interstate-5 and a small gravel pit lake. The Burlington-Northern Santa Fe (BNSF) railroad line runs along the western property boundary. The site is situated among undeveloped parcels owned by the port of Centralia. Residential properties are located to the west of the BNSF railroad tracks.



3.5 Emissions

Sierra Pacific has estimated its emissions from the project and they are compared to the Small Quantity Emission Rate Tables (SQER) below:

Pollutant	Class A or B Pollutant	Total Emissions from Boiler and six Kilns		SQER		Emissions Above SQER Yes or No?
		lb/hr	lb/yr	lb/hr	lb/yr	
Acetaldehyde	A	3.89	34,000	-	50	Yes
Acrolein	B	0.0577	487	0.02	175	Yes
Ammonia	B	6.27	52,300	2	17,500	Yes
Antimony	B	0.00213	17.7	0.02	175	No
Arsenic	A	0.000521	4.35	-	-	Yes
Benzene	A	0.0689	575	-	20	Yes
Beryllium	A	0.000144	1.2	-	-	Yes
Methyl bromide	B	0.00260	21.7	0.02	175	No
Cadmium	A	0.000269	2.25	-	-	Yes
Carbon tetrachloride	A	0.00421	35.2	-	20	Yes
Chlorobenzene	B	0.00308	25.7	0.02	175	No
Chloroform	A	0.00255	21.3	-	10	Yes
Chlorophenols	A	0.00000313	0.0261	-	50	No
Chromium, hexavalent	A	0.0000163	0.136	-	-	Yes
Chromium (III)	B	0.000143	1.19	0.02	175	No
Cobalt	B	0.0000116	0.0968	0.02	175	No
Copper	B	0.000691	5.76	0.02	175	No
1,2-Dichloroethane	A	0.00271	22.6	-	10	Yes
Dichloromethane	A	0.0266	222	-	50	Yes
1,2-Dichloropropane	A	0.00308	25.8	-	-	Yes
Ethyl benzene	B	0.00291	24.2	5	43,748	No
Formaldehyde	B	0.202	1,700	-	20	Yes
Hydrogen chloride	B	0.325	2,710	0.02	175	Yes
Lead	A	0.00459	38.3	-	50	No
Manganese dust	B	0.00911	76.0	0.02	175	No
Mercury	B	0.0000386	0.322	0.02	175	No
Methyl alcohol	B	2.89	25,200	5	43,748	No
Napthalene	B	0.00878	73.2	2.6	22,750	No
Nickel	A	0.000234	1.96	-	0.5	Yes
Nitric oxide	B	13.9	116,000	2	17,500	Yes
Pentachlorophenol	A	0.00000211	0.0176	-	50	No
Phenol	B	0.00116	9.71	1.2	10,500	No
PAH	A	0.00000167	0.0140	-	-	Yes
Selenium	B	0.000162	1.35	0.02	175	No
Sulfuric acid	B	0.196	1,630	0.02	175	Yes
2,3,7,8-Tetrachlorodibenzo-p-dioxin	A	0.000000019	0.000158	-	-	Yes
Turpentine	B	11.0	96,000	5	43,748	Yes
Perchloroethylene	A	0.00355	29.6	-	500	No
Tin	B	0.000615	5.13	0.02	175	No
Toluene	B	0.00197	16.5	5	43,748	No
1,1,2-Trichloroethane	B	0.00285	23.8	2.6	22,750	No
Trichloroethylene	A	0.00281	23.5	-	50	No
Trichlorofluoromethane	B	0.00376	31.4	5	43,748	No
2,4,6-Trichlorophenol	A	0.00000105	0.00879	-	50	No
Vanadium	B	0.000126	1.05	0.02	175	No
Vinyl chloride	A	0.00171	14.2	-	10	Yes
Xylenes	B	0.00227	19.0	5	43,748	No

Emissions of acetaldehyde, acrolein, ammonia, arsenic, benzene, beryllium, cadmium, carbon tetrachloride, chloroform, chromium hexavalent, 1,2-dichloroethane, dichloromethane, 1,2-dichloropropane, formaldehyde, hydrogen chloride, nickel, nitric oxide, Polynuclear Aromatic Hydrocarbons (PAH), sulfuric acid, 2,3,7,8-tetrachlorodibenzo-p-dioxin, turpentine, and vinyl chloride exceed the values listed in SQER tables. The applicant then modeled these TAPs and compared them to their respective ASILs as shown in Section 3.5.1.1.

3.5.1 Point of Compliance

Assessment of potential health risks from the project were based on the maximum modeled concentration of acetaldehyde, acrolein, ammonia, arsenic, benzene, beryllium, cadmium, carbon tetrachloride, chloroform, chromium hexavalent, 1,2-dichloroethane, dichloromethane, 1,2-dichloropropane, formaldehyde, hydrogen chloride, nickel, nitric oxide, PAH, sulfuric acid, 2,3,7,8-tetrachlorodibenzo-p-dioxin, turpentine, and vinyl chloride at an assumed point of public exposure (nearest point of ambient air) the property fence line. The maximum concentration is assumed to be at the property fence line and the distance to the nearest residence.

3.5.1.1 Emissions Concentrations

Below is the modeling results of the pollutants that exceeded the SQERs compared to the ASILs.

Pollutant	Class A or Class B TAP?	Highest Modeled Concentration ($\mu\text{g}/\text{m}^3$)	ASIL ($\mu\text{g}/\text{m}^3$)	Emissions Above ASIL Yes or No?
Acetaldehyde	A	15.8	0.4500000 (annual average)	Yes
Acrolein	B	0.602	0.02 (24-hr average)	Yes
Ammonia	B	0.18	100 (24-hr average)	No
Arsenic	A	6.5E-05	0.0002300 (annual average)	No
Benzene	A	0.0089	0.1200000 (annual average)	No
Beryllium	A	1.8E-05	0.0004200 (annual average)	No
Cadmium	A	3.4E-05	0.0005600 (annual average)	No
Carbon tetrachloride	A	0.00052	0.0670000 (annual average)	No
Chloroform	A	0.00032	0.0430000 (annual average)	No

Pollutant	Class A or Class B TAP?	Highest Modeled Concentration ($\mu\text{g}/\text{m}^3$)	ASIL ($\mu\text{g}/\text{m}^3$)	Emissions Above ASIL Yes or No?
Chromium, hexavalent	A	2.0E-06	0.0000830 (annual average)	No
1,2-Dichloroethane	A	0.00034	0.0380000 (annual average)	No
Dichloromethane	A	0.0033	0.5600000 (annual average)	No
1,2-Dichloropropane	A	0.00039	4.0 (24-hr average)	No
Formaldehyde	B	0.17	0.0770000 (annual average)	Yes
Hydrogen chloride	B	0.041	0.0021000 (annual average)	No
Nickel	A	2.9E-05	0.0021000	No
Nitric oxide	B	1.7	100 (24-hr average)	No
PAH	A	2.1E-07	0.00048 (annual average)	No
Sulfuric acid	B	0.045	3.3 (24-hr average)	No
2,3,7,8-Tetrachlorodibenzo-p-dioxin	A	2.4E-09	0.00000003 (annual average)	No
Turpentine	B	121	1900 (24-hr average)	No
Vinyl chloride	A	0.00021	0.0120000 (annual average)	No

3.5.2 Pollutants Subject to Second Tier Analysis

Emissions of ammonia, arsenic, benzene, beryllium, cadmium, carbon tetrachloride, chloroform, hexavalent, chromium, 1,2-dichloroethane, dichloromethane, 1,2-dichloropropane, hydrogen chloride, nickel, nitric oxide, PAH, sulfuric acid, 2,3,7,8-tetrachlorodibenzo-p-dioxin, turpentine, and vinyl chloride are below the ASIL after being modeled. Acetaldehyde, acrolein, and formaldehyde are subject to review under this Second Tier analysis.

3.5.2.1 Background Emissions

Acetaldehyde, acrolein, and formaldehyde are produced during combustion. As a result, these pollutants can be measured in ambient air. Higher levels of these pollutants are

found immediately downwind of combustion sources, especially near heavy traffic in urban atmospheres.

Acetaldehyde is ubiquitous in the ambient environment as it is produced naturally by plants. It is also a product of incomplete wood combustion in fireplaces and wood stoves, coffee roasting, burning of tobacco, and vehicle exhaust fumes. Residential fireplaces and wood stoves are the two highest sources of acetaldehyde emissions to ambient air.

Acrolein can be formed from the breakdown of other pollutants found in ambient air. Combustion of fuels represents the major source of emissions of acrolein to the atmosphere. Acrolein may also be released while cooking foods, especially while using cooking oils.

Formaldehyde is released into the atmosphere during combustion. Although formaldehyde is found in ambient air, higher levels of formaldehyde are expected in indoor air, where it is released from building materials and furniture.

Estimates of average acetaldehyde, acrolein, and formaldehyde levels in the census tract relevant to Sierra Pacific's proposed lumber kiln are available from EPA's 1999 National Air Toxics Assessment (NATA). For comparison, estimates from a more urban environment (Seattle) are presented along with monitoring results from 2007. Generally, estimated pollutant levels are 2 to 10 times lower in the tract associated with the project compared to Beacon Hill. Mobile on-road sources (cars and trucks) are the main contributors of estimated pollutant impacts.

Pollutant	NATA 1999		2000-2007 Monitored Average Concentration
	Tract 53041970300 (Northwest of Centralia)	Tract 53033010000 (Beacon Hill – Seattle)	Beacon Hill (Seattle)
Acetaldehyde	0.74	2.9	1.4
Acrolein	0.023	0.21	0.45
Formaldehyde	0.78	3.1	1.6

3.5.3 T-BACT

T-BACT is contained in the proposed ADP No. 08-2799, and consists of the use of process temperature limits and vertical dispersion of exhaust gases to meet the requirements of T-BACT for the new dry kilns. Many of the conditions in the proposed decision are BACT/T-BACT for a particular activity. Ecology concurs with the SWCAA T-BACT determination.

3.5.4 Air Dispersion Modeling

The air quality dispersion model used for this project was EPA's AERMOD model, with EPA's PRIME algorithm for building downwash. Meteorological data from April 1, 1994 through March 31, 1995 from the Chehalis Generation Facility were combined with National Weather Services upper air data from Quileute, Washington. Only one year of meteorological data was used because the data came from a source that was adjacent to the proposed facility. Data included hourly wind speed and wind direction data, the standard deviation of the horizontal component of the wind speed and air temperature at three levels (10 m, 30 m, and 65 m).

4. GENERIC HEALTH IMPACTS ASSESSMENT PROCESS

A health impacts assessment was prepared by the applicant and it was reviewed and approved by Ecology. Ecology has put together a project team consisting of an engineer, a toxicologist, and a modeler.

Below are descriptions of the content of each part of the Health Impacts Assessment.

4.1 Hazard Identification

Hazard identification involves gathering and evaluating toxicity data on the types of health injury or disease that may be produced by a chemical and on the conditions of exposure under which injury or disease is produced. It may also involve characterization of the behavior of a chemical within the body and the interactions it undergoes with organs, cells, or even parts of cells. This information may be of value in determining whether the forms of toxicity known to be produced by a chemical agent in one population group or in experimental settings are also likely to be produced in human population groups of interest. Note that risk is not assessed at this stage; hazard identification is conducted to determine whether and to what degree it is scientifically correct to infer that toxic effects observed in one setting will occur in other settings (e.g., are chemicals found to be carcinogenic or teratogenic in experimental animals also likely to be so in adequately exposed humans?).

4.2 Exposure Assessment

This step involves describing the nature and size of the various populations exposed to a chemical agent in the vicinity of the proposed project. The evaluation could include past exposures, current exposures, or exposures expected in the future.

4.3 Dose-Response Assessment

Dose-response assessment is the process of characterizing the relationship between exposure to a chemical and incidence of an adverse health effect in exposed populations. This step involves the identification of the toxicological profiles of all toxic air pollutants that exceed the ASIL. It includes a discussion of the toxicological effects of hazardous

substances, chemicals, and compounds. Each profile includes an examination, summary, and interpretation of available toxicological and epidemiological data evaluations on the hazardous substance.

4.4 Risk Characterization

This step involves the integration of data analyses from each step of the health impact assessment to determine the likelihood that the human population of interest will experience any of the various forms of toxicity associated with a chemical under its known or anticipated conditions of exposure.

4.5 Uncertainty Characterization

In almost all risk assessments undertaken in support of regulatory decisions, especially concerning chronic hazards, risk assessors are required to go beyond available data and make inferences about risks expected for conditions of exposure under which direct evidence of risk cannot now be collected. When scientific uncertainty is encountered in a risk assessment, the integration of any assumptions is required to fill information gaps. The following are examples of components that constitute gaps in the scientific basis for assessing human cancer risk:

- How relevant is the data to humans?
- How relevant to humans are results from animal studies using a different route of exposure?
- How relevant are results from studies using an exposure regimen (in terms of frequency and duration) that differs from the human situation?
- Which species/strains of animals are most appropriate for dose-response assessment in humans?
- How should risk estimates be developed?
- Using most sensitive species/strain/sex.
- Combining incidents of benign and malignant tumors.
- Using pooled tumor incidence (tumor bearing animals)?
- Can results of an animal study that does not extend over a lifetime be extrapolated to lifetime?
- How does the dose-response relation relate to the unobservable dose-response relation in the dose region of concern for the human population under study?
- How should low-dose risk be modeled?
- Do agents operate by threshold or non-threshold mechanisms?

5. HEALTH IMPACTS ASSESSMENT

5.1 Introduction

The Second Tier analysis described below was conducted according to the requirements promulgated in Chapter 173-460 WAC. It addressed the public health risk associated

with exposure to acetaldehyde, formaldehyde, and acrolein emissions from lumber kiln operations in the health impacts assessment prepared by the consultant (Geomatrix) for Sierra Pacific Industries.

5.2 Hazard Identification

There are three TAPs being evaluated in this analysis. They are acetaldehyde, formaldehyde, and acrolein.

- Acetaldehyde is a colorless liquid that volatilizes at room temperature. It has a pungent odor at high concentrations and a pleasant fruity odor at low concentrations.
- Formaldehyde is a colorless gas with a pungent, suffocating odor at room temperature. Formaldehyde is readily soluble in water at room temperature.
- Acrolein is a colorless to yellowish flammable liquid at room temperature with a disagreeable, choking odor. It is extremely acrid and irritating to mucous membranes.

5.2.1 Acute Effect

5.2.1.1 Acetaldehyde

Humans exposed to acetaldehyde in air can experience irritation of the eyes, skin, and respiratory tract. Relative to the two other pollutants being evaluated for this project (i.e., acrolein and formaldehyde), acetaldehyde requires much higher concentrations to cause these effects in humans.¹

In animals, acute inhalation caused an increase in blood pressure and a decrease in respiratory rate. Acetaldehyde's acute toxicity is considered to be low based on the high concentration ($> 20,000 \text{ mg/m}^3$) required to cause death in at least 50 percent of exposed animals.

5.2.1.2 Formaldehyde

Low levels of formaldehyde can cause irritation of the eyes, nose, throat, and skin. It is possible that people with asthma will be more sensitive to the effects of inhaled formaldehyde. At concentrations that typically occur in ambient air, effects occur in tissues where formaldehyde enters the body (i.e., nose or mouth). At higher levels, coughing, wheezing, and bronchitis may occur.

5.2.1.3 Acrolein

Acrolein is a potent irritant to skin and mucous membranes. Effects of acrolein typically occur at the point of exposure (i.e., nasal passages, eyes). Short-term exposure to

¹ http://www.arb.ca.gov/toxics/id/summary/acetaldehyde_b.pdf

acrolein can cause eye and nasal irritation at relatively low concentrations (< 1ppm [2.3 mg/m³]) in air. Higher concentrations may also irritate the entire respiratory tract. Accidental exposures to extremely high levels of acrolein result in high fever, dyspnea, coughing, foam expectoration, cyanosis, pulmonary edema, and death.²

Animals exposed to higher concentrations showed signs of lesions in the respiratory tract and respiratory distress. These effects became more severe with increasing concentrations. At higher levels, respiratory distress resulted in death.

5.2.2 Chronic Effects

5.2.2.1 Acetaldehyde

There is little information regarding health outcomes in humans related to long-term exposure to acetaldehyde. In animals, chronic inhalation exposure to acetaldehyde has produced changes in the mucus membranes of the nose and trachea, growth retardation, slight anemia, and increased kidney weight. EPA derived a reference concentration based on the degeneration of a layer of cells lining the tissue responsible for smell in the noses (olfactory epithelium) of rats.³

5.2.2.2 Formaldehyde

Chronic exposure to formaldehyde by inhalation in humans has been associated with respiratory symptoms and eye, nose, and throat irritation. Animal studies have reported effects on the nasal respiratory epithelium and lesions in the respiratory system from chronic inhalation exposure to formaldehyde.

5.2.2.3 Acrolein

No chronic human exposure studies are available. Longer-term studies in laboratory animals at higher concentrations have demonstrated severe nasal lesions as well as pronounced adverse effects on lung function leading to lethality. Studies indicated that rats were most sensitive species.

5.2.3 Carcinogenicity

5.2.3.1 Acetaldehyde

There is currently insufficient human data regarding the carcinogenic effects of acetaldehyde. Animal studies involving inhalation of acetaldehyde have shown an increased rate of nasal tumors in rats and laryngeal (pertaining to the larynx) tumors in hamsters. EPA has classified acetaldehyde as a Group B2, probable human carcinogen.

² <http://www.atsdr.cdc.gov/toxprofiles/tp124.html>

³ <http://www.epa.gov/ncea/iris/subst/0290.htm>

5.2.3.2 Formaldehyde

Some studies of people exposed to formaldehyde in workplace air found more cases of cancer of the nose and throat than expected, but these workers may have been exposed to multiple different chemicals, so it is not clear if formaldehyde was the chemical that caused this increased rate. In animal studies, rats exposed to high levels of formaldehyde in air developed cancer in a type of epithelial cell in the nose (nasal squamous cell carcinoma). The United States Department of Health and Human Services has determined that formaldehyde may reasonably be anticipated to be a carcinogen. EPA has classified formaldehyde as a Group B1, probable human carcinogen.

5.2.3.3 Acrolein

The potential carcinogenicity of acrolein cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or the inhalation route of exposure.

5.2.4 Reproductive/Developmental Effects

No information is available on the reproductive or developmental effects of acetaldehyde in humans. In animals, acetaldehyde has been shown to cross the placenta to the fetus. Developmental effects were noted in studies where animals were injected with acetaldehyde.

A review of animal studies suggests that formaldehyde will not cause birth defects in humans.

No studies were located regarding developmental effects in humans or animals after inhalation exposure to acrolein.

5.2.5 Terrestrial Fate

Acetaldehyde will volatilize rapidly in near surface and surface soils. Acrolein in soil can be mobile, but a large portion is expected to volatilize or be broken down by microorganisms or other reactive processes.

5.2.6 Aquatic Fate

Acetaldehyde mixes with water, but will not reside long in surface water as it either will volatilize or be broken down by microbes.

Formaldehyde dissolves easily in water, but it does not reside long in water and is not commonly found in drinking water supplies.

Acrolein dissolves readily in water but levels are reduced through volatilization, aerobic biodegradation, and hydration to other compounds that subsequently biodegrade. Half-lives of <1–3 days for small amounts of acrolein in surface water have been observed.

5.2.7 Atmospheric Fate

Generally, acetaldehyde, formaldehyde, and acrolein are not persistent in air. They react with other chemicals in air (mainly sunlight-derived radicals). The estimated half-life for the reaction of acetaldehyde with hydroxyl produced by ultra violet light is 6.2 hours.

Most formaldehyde in the air also breaks down during the day. The breakdown products of formaldehyde in air include formic acid and carbon monoxide.

When released into air, acrolein is broken down by chemicals generated in sunlight producing carbon monoxide, formaldehyde, and glycolaldehyde. Acrolein also reacts with nitrogen oxides to form peroxyxynitrate and nitric acid.

5.3 Exposure Assessment

In order for pollutants to cause harm, people first must be exposed. To assess exposure, it is important to identify locations where people might be exposed, estimate the concentration of pollutants at places where people might be exposed, and estimate how much time and how long they might be at a location. In the case of Sierra Pacific's lumber kiln emissions, inhalation and dermal exposure are the routes of exposure evaluated because acetaldehyde, formaldehyde, and acrolein emission from the project are not likely to build up in food, soil, and water.

5.3.1 Estimating Concentration

Air modeling as described in Section 3.5.4 was used to estimate maximum 1-hr, 24-hr, and annual average concentrations of acetaldehyde, acrolein, and formaldehyde in air near Sierra Pacific.

5.3.2 Identification of Exposed Populations

Current aerial photographs and land use designations are useful for identifying potentially exposed populations. The table below shows the distances to the sensitive receptors, businesses, and residences.

#	Facility	Direction from Lumber Kiln	Estimated Distance in Feet	Estimated Distance in Meters
F1	Unoccupied	South	200	60
F2	Unoccupied	South	200	60
R1	Residence	South	800	240
R2	Residence	Northwest	1,700	520

5.3.3 Discussion of TAP Exposure Concentrations

Air modeling was used to estimate pollutant concentrations at the point of highest concentration (i.e., the fence line) and residences near the facility. Maximum 1-hr and 24-hr concentrations and annual average concentrations are presented at two most impacted residences and fence line points in the following table.

#	Maximum 1-hr Concentration ($\mu\text{g}/\text{m}^3$)			Maximum 24-hr Concentration ($\mu\text{g}/\text{m}^3$)			Annual Concentration ($\mu\text{g}/\text{m}^3$)		
	Acetaldehyde	Acrolein	Formaldehyde	Acetaldehyde	Acrolein	Formaldehyde	Acetaldehyde	Acrolein	Formaldehyde
F1	167	2.4	1.8	43	0.60	0.50	15.8	0.22	0.18
F2	220	3.1	2.4	40	0.56	0.44	11.9	0.17	0.13
R1	82	1.2	0.9	6.6	0.09	0.14	2.2	0.03	0.04
R2	158	2.2	1.7	9.3	0.13	0.10	1.3	0.02	0.02

5.3.4 Discussion of Exposure Duration

Exposure duration has implications with regard to health risk that a chemical poses on human health. In most cases, a person continuously exposed to a chemical cannot tolerate as high of concentrations as a person that is exposed for only a short time. Having identified potentially exposed populations, it is also important to consider the amount of time a person might be exposed. People who work at commercial or industrial locations near Sierra Pacific are likely only to be exposed for up to the duration of their workday (e.g., 8 hours per day). Residents living near Sierra Pacific have the potential to be exposed for a longer period (e.g., 24 hours per day). Residents and occupants of commercial properties both have the opportunity to be exposed for short-term durations (e.g., 1-hr).

5.4 Dose-Response Assessment

Dose-response assessment describes the quantitative relationship between the amounts of exposure to a substance (the dose) and the incidence or occurrence of injury (the response). The process often involves establishing a toxicity value or criterion to use in assessing potential health risk.

EPA, California's Office of Environmental Health Hazard Assessment (OEHHA), and the Agency for Toxic Substances and Diseases Registry (ATSDR) have developed toxicological values for some of the chemicals of concern. These toxicological values are used for quantifying health risk or establishing risk based concentrations. Toxicological values derived for cancer and non-cancer effects are shown below.

Chemical	Agency	Type	Value	Animal or Human	Critical Effect	UF	Date
Acetaldehyde	EPA	Chronic RfC	9 ug/m ³	Rats	Degeneration olfactory epithelium	1000	10/91
		URF	2.2x10 ⁻⁶ per ug/m ³	Rats Hamsters	Nasal, Laryngeal Tumors	NA	10/91
	OEHHA	Chronic REL	9 ug/m ³	Rats	Degeneration olfactory epithelium	1000	5/93
		URF	2.7x10 ⁻⁶ per ug/m ³	Rats	Nasal tumors	NA	4/99
Acrolein	EPA	RfC	0.02 ug/m ³	Rats	Nasal lesions	1000	6/2003
	OEHHA	Acute REL	0.19 ug/m ³	Human	Eye irritation	60	4/99
		Chronic REL	0.06 ug/m ³	Rats	Histological lesions upper airway	300	1/2001
	ATSDR	Acute MRL	6.9 ug/m ³	Human	Nasal and throat irritation Decreased respiratory rate	100	8/2007
		Intermediate MRL	0.09 ug/m ³	Rats	Nasal epithelial metaplasia Bronchial inflammation	300	8/2007
Formaldehyde	EPA	URF	1.3 x 10 ⁻⁵ per ug/m ³	Rats	Nasal squamous Cell carcinomas	NA	5/91
	OEHHA	Acute REL	94 ug/m ³	Human	Eye irritation	10	4/99
		Chronic REL	3 ug/m ³	Human occupational	Nasal and eye irritation, nasal obstruction, and lower airway discomfort; histopathological nasal lesions including rhinitis, squamous metaplasia, and dysplasia	10	2/2000
		URF	6.6 x 10 ⁻⁶ per ug/m ³	Rats	Nasal squamous Cell carcinomas	NA	3/92
	ATSDR	Acute MRL	49 ug/m ³	Human	Nasal and eye irritation	9	7/99
		Intermediate MRL	37 ug/m ³	Monkey	Nasopharyngeal irritation (hoarseness and	30	7/99

Chemical	Agency	Type	Value	Animal or Human	Critical Effect	UF	Date
					nasal congestion and discharge) and lesions in the nasal epithelium		
		Chronic MRL	9.8 ug/m ³	Human occupational	Mild irritation of the eyes and upper respiratory tract and mild damage to the nasal epithelium	30	7/99

UF – uncertainty factor

5.4.1 Risk Based Concentrations for Exposed Populations (non-cancer effects)

To evaluate possible non-cancer effects from exposure to acetaldehyde, acrolein, and formaldehyde from Sierra Pacific’s lumber kiln emissions, modeled concentrations were compared to their respective non-cancer comparison value [EPA inhalation reference concentration (RfC), OEHHA reference exposure level (REL) or ATSDR chronic minimal risk level (MRL)]. The MRL and RfC are concentrations in air below which non-cancer health effects are not expected.

RfCs and MRLs are set well below toxic effect levels in order to provide an added measure of safety. The higher the chemical concentration is above the RfC, REL, or MRL, the closer it will be to an actual toxic effect level.

Because chronic RfCs, RELs, and MRLs are based on a continuous exposure, an adjustment was made to account for the fact that people working at commercial properties are typically exposed for only eight hours per day, five days per week. This adjustment is shown below:

$$\text{Chronic RBCs} = \frac{\text{AT} \times \text{Chronic RfC, REL, or MRL}}{\text{EF (days per year)} \times \text{EF (hours per 24-hr day)} \times \text{ED}}$$

Scenario	Pollutant	Value	Source	EF (days /yr)	EF (hrs / 24-hr)	ED (yr)	AT	Chronic Risk Based Concentration
Commercial/ Industrial Worker	Acetaldehyde	9	EPA, OEHHA	250	8 /24	1	365	39.4
	Formaldehyde	3	OEHHA					13.1
	Acrolein	0.02	EPA					0.09
		0.06	OEHHA					0.27
Residential	Acetaldehyde	9	EPA, OEHHA	365	24/24	1	365	9
	Formaldehyde	3	OEHHA					3
	Acrolein	0.02	EPA					0.02
		0.06	OEHHA					0.06

The resulting risk based concentrations for non-cancer health effects are concentrations at or below which health adverse effects are not likely to occur. Risk based concentrations should reflect the exposure characteristics of the various receptors. In this case, the two types of receptors are residential and commercial/industrial workers. The acute MRLs or RELs are the RBCs for both receptor types, but because workers are not likely to spend as much time in the area as residents, adjusted chronic (long-term) risk based concentrations were calculated.

The following table shows the non-cancer risk based concentrations derived for exposure to acetaldehyde, acrolein, and formaldehyde for acute and chronic exposures at residential and commercial settings.

Scenario	Averaging Time	RBC ($\mu\text{g}/\text{m}^3$)			Source
		Acetaldehyde	Acrolein	Formaldehyde	
Residential	1-hr	NA	6.9	49	ATSDR Acute MRL
	24-hr	NA	6.9	49	ATSDR Acute MRL
	annual	9	0.02 to 0.06	3	EPA RfC and OEHHA chronic REL
Workers at Commercial/Industrial Properties	1-hr	NA	6.9	49	OEHHA Acute REL
	annual	39.4	0.09 to 0.27	13.1	EPA RfC and OEHHA chronic REL adjusted for exposure frequency

5.4.2 Quantifying Cancer Risk

Some chemicals have the ability to cause cancer. Cancer risk is estimated by determining the concentration of acetaldehyde and formaldehyde at each receptor point and multiplying it by its respective unit risk factor (URF). Some unit risk factors are derived from human population data. Others are derived from laboratory animal studies

involving doses much higher than are encountered in the environment. Use of animal data requires extrapolation of the cancer potency obtained from these high dose studies down to real-world exposures. This process involves much uncertainty.

Current regulatory practice assumes that there is no “safe dose” of a carcinogen and that a very small dose of a carcinogen will give a very small cancer risk. Cancer risk estimates are, therefore, not yes/no answers but measures of chance (probability). Such measures, however uncertain, are useful in determining the magnitude of a cancer threat because any level of a carcinogenic contaminant carries an associated risk. The validity of the “no safe dose” assumption for all cancer-causing chemicals is not clear. Some evidence suggests that certain chemicals considered carcinogenic must exceed a threshold of tolerance before initiating cancer. For such chemicals, risk estimates are not appropriate. More recent guidelines on cancer risk from EPA reflect the potential that thresholds for some carcinogenesis exist. However, EPA still assumes no threshold unless sufficient data indicate otherwise.⁴

5.5 Risk Characterization

In this step, modeled pollutant concentrations are used to quantify non-cancer hazards and cancer risk to determine if possible health threats exist.

5.5.1 Hazard Quotient

Hazard quotients were calculated for different scenarios and averaging periods depending on land use and varying durations of exposure. A hazard quotient (HQ) is the ratio of the potential exposure to a substance compared to the exposure level that is considered “safe” (e.g., risk based concentration).

$$\text{HQ} = \frac{\text{maximum 1-hr, 24-hr, or annual average concentration (ug/m}^3\text{)}}{\text{Corresponding 1-hr, 24-hr, or annual RBC (ug/m}^3\text{)}}$$

An HQ of one or less indicates that adverse health effects are not expected to result from exposure to emissions of that substance. As the HQ increases above one, the probability of human health effects increases by an undefined amount. However, it should be noted that a hazard quotient above one is not necessarily indicative of health impacts due to the application of uncertainty factors in deriving toxicological reference values (e.g., RfC, MRL, and REL)

The following table shows modeled concentrations, RBCs, and HQs at each receptor point. In most cases, hazard quotients are less than one, and therefore of no concern for non-cancer effects. The chronic hazard quotients for acrolein exposure exceed one at residential and fence line receptors.

⁴ U.S. Environmental Protection Agency. Guidelines for Carcinogen Risk Assessment (Review Draft). NCEA-F-0644 July 1999. Web address: Available at <http://www.epa.gov/NCEA/raf/cancer.htm>

	Maximum Impacted Residential			Maximum Impacted Point (fence line)		
	Acetaldehyde	Formaldehyde	Acrolein	Acetaldehyde	Formaldehyde	Acrolein
1- hr concentration	158	1.7	2.2	220	2.4	3.1
1-hr RBC	NA	49	6.9	NA	49	6.9
1-hr HQ	NA	0.03	0.32	NA	0.05	0.45
24- hr concentration	9.3	0.10	0.13	43	0.50	0.60
24-hr RBC	NA	49	6.9	NA	NA	NA
24-hr HQ	NA	<0.01	0.01	NA	NA	NA
Annual concentration	2.2	0.04	0.03	15.8	0.18	0.22
annual RBC	9	3	0.02	39.4	13.1	0.09
annual HQ	0.24	0.01	1.5	0.40	0.01	2.4

5.5.2 Discussion of Hazard Quotients that Exceed One

Hazard quotients related to chronic exposure to acrolein exceed one (1.5 at residential receptor, and 2.4 at the fence line). As shown previously in the table in Section 5.4 of this document, acrolein has two chronic toxicity values available (EPA's RfC of 0.02 mg/m³ and OEHHA's REL of 0.06 mg/m³). The same studies were used as the basis for developing the toxicity values. EPA chose to apply a higher uncertainty factor. Contrarily, if OEHHA's chronic REL were used to derive the RBC, the chronic hazard quotients for acrolein would be less than one.

It should be noted that had other toxicological values been used to derive acute RBCs for acrolein, 1-hr hazard quotients would have exceeded one. In addition to ATSDR's acute MRL (the basis for the acute RBC), other public agencies have established toxicological values for acute exposure to acrolein. Most recently, Minnesota Department of Health established an acute health based value (HBV) for acrolein in air⁵ at 2 ug/m³. California's OEHHA developed an acute REL of (0.19 ug/m³) based on mild eye irritation in human volunteers exposed to acrolein.

ATSDR's MRL was chosen to derive the acute acrolein RBCs. MRLs are defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (noncarcinogenic) over a specified duration of exposure. The specified duration of exposure for acute MRLs is 14 days or less. In the study that is the basis for the acute MRL, subjects were exposed for 1-hr duration; therefore, the MRL may appropriately be applied to 1-hr exposure duration. ATSDR's MRL (6.9 ug/m³) was derived using the LOAEL of 0.3 ppm (688 ug/m³) for nasal and throat irritation and decreased respiratory rate in humans. The LOAEL of 0.3 ppm was divided by an uncertainty factor of 100 (10 for using a LOAEL and 10 for human variability).

⁵ <http://www.health.state.mn.us/divs/eh/risk/guidance/acroleinmemo.html>

ATSDR's MRL was chosen as the RBC because it was more recent than OEHHA's REL. Although Minnesota's HBV is more recent than the MRL, AQP normally chooses toxicological reference values from three sources (EPA, OEHHA, and ATSDR). In the case, the severity of end point could be a consideration when determining if an exposure is acceptable or unacceptable. In the case of acrolein, mild eye irritation is the critical effect used in deriving both OEHHA's REL and Minnesota's HBV. Mild nose and throat irritation was the basis for ATSDR's MRL. To put things into context of what has been measured in ambient air, OEHHA's 1-hr REL (0.19 ug/m³) is lower than the average concentration measured in Seattle (0.46 ug/m³).

5.5.3 Cancer Risk

In this document, cancer risks are reported using scientific notation to quantify the increased cancer risk of an exposed person, or the number of excess cancers that might result in an exposed population. For example, a cancer risk of 1 x 10⁻⁶ means that if 1,000,000 people were exposed, one excess cancer might occur, or a person's chance of getting cancer in their life increases by 0.0001 percent. The reader should note that these estimates are for excess cancers that might result in addition to those normally expected in an unexposed population. Cancer risks quantified in this document are an upper-bound theoretical estimate. Actual risks are likely to be much lower.

The formula for determining cancer risk is as follows:

$$\text{Risk} = \frac{C_{\text{Air}} \times \text{URF} \times \text{EF} \times \text{ED}}{\text{AT}}$$

Where:

C_{Air} = Concentration in air at the receptor (ug/m³)

URF = Unit Risk Factor (ug/m³)⁻¹

EF1 = Exposure Frequency (days per year)

EF2 = Exposure Frequency (hours per day)

ED = Exposure Duration (years)

AT = Averaging Time (days)

As shown in the following table, estimated cancer risks for residential and worker/commercial property scenarios are less than 1 x 10⁻⁵.

Location	Pollutant	Annual C _{air}	URF	EF1 (days /yr)	EF2 (hrs / 24-hr)	ED (yr)	AT (days)	Risk
Maximum Concentration Fenceline	Acetaldehyde	15.8	2.2x10 ⁻⁶ to 2.7x10 ⁻⁶	250	8 /24	25	25550	2.8x10 ⁻⁶ to 3.5x10 ⁻⁶
	Formaldehyde	0.18	6.6x10 ⁻⁶ to 1.3x10 ⁻⁵					9.7x10 ⁻⁸ to 1.9x10 ⁻⁷
	Total							2.9x10 ⁻⁶ to 3.7x10 ⁻⁶

Location	Pollutant	Annual Cair	URF	EF1 (days /yr)	EF2 (hrs / 24-hr)	ED (yr)	AT (days)	Risk
Maximum Impacted Residence	Acetaldehyde	2.2	2.2x10 ⁻⁶ to 2.7x10 ⁻⁶	365	24/24	70	25550	4.8x10 ⁻⁶ to 5.9x10 ⁻⁶
	Formaldehyde	0.04	6.6x10 ⁻⁶ to 1.3x10 ⁻⁵					2.6x10 ⁻⁷ to 5.2x10 ⁻⁷
	Total							5.1x10 ⁻⁶ to 6.4x10 ⁻⁶

5.6 Uncertainty Characterization

To the extent that an individual will be exposed to emissions of acetaldehyde, acrolein, and formaldehyde from this proposed project, the applicant submitted the following uncertainty analysis:

- One of the largest sources of uncertainty in any risk evaluation is associated with the scientific community's limited understanding of the toxicity of most chemicals in humans following exposure to the low concentrations generally encountered in the environment. There is much toxicological uncertainty with regard to establishing toxicological reference values for acrolein. Both acute and chronic duration reference values varied between public agencies.
- An air dispersion model was used to predict the off-site concentrations of formaldehyde emission increases expected to result from the proposed project. Site specific or site-representative inputs were used in the model where appropriate and defaults that are generally conservative were incorporated when such information was not available. The modeling methodology was also consistent with that presented in the ADP application submitted to SWCAA.
- The focus of the evaluation was on potential exposure at the maximum fence line location, which is protective of actual receptors located farther from the facility.
- TAP emission rates for the proposed project have been estimated using an approach consistent with that used in the ADP application submitted to SWCAA for the dried lumber production capacity increase. These emission factors are averages of the results of relatively few tests conducted on laboratory-scale lumber drying equipment, and, in some cases, the range of results being averaged is considerable. Although the facility dries both western hemlock and Douglas fir, the western hemlock emission factors represent the worst-case emission factor for all TAPs under consideration, so the entire kiln throughput was assumed western hemlock for a conservative analysis.

- Exposure assumptions for receptors are highly conservative as they assume a person is at one location for 24 hours per day, 365 days per year for 70 years. These assumptions overestimate the actual exposure and risk.

6. CONCLUSION

The project will not have a significant adverse impact on air quality. The Washington State Department of Ecology finds that the applicant, Sierra Pacific Industries, has satisfied all requirements for Second Tier analysis.

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7. LIST OF ABBREVIATIONS

AERMOD	Air dispersion model
ADP	Air Discharge Permit (which is similar to a Notice of Construction as defined in Chapters 173-400 & 460 WAC)
AOP	Air Operating Permit as described in Chapter-173-401 WAC
AQP	Air Quality Program
AT	Averaging Time (days)
ATSDR	Agency for Toxic Substance Disease Registry
ASIL	Acceptable Source Impact Level
ATSDR	Agency for Toxic Substances and Diseases Registry
BACT	Best Available Control Technology
C	Celsius
Cair	Concentration in air
CAS	Chemical Abstracts Service
CNS	Central Nervous system
deg	Degrees
ED	Exposure Duration (years)
EF	Exposure Frequency
EF1	Exposure Frequency (days per year)
EF2	Exposure Frequency (hours per day)
Ecology	Washington State Department of Ecology, Headquarters Office
EPA	United States Environmental Protection Agency
HBV	Health Based Value
HIA	Health Impacts Assessment
HQ	Hazard Quotient
hr	Hour
IARC	International Agency for Research on Cancer
IRIS	Integrated Risk Information System
LOAEL	Lowest Observable Adverse Effect Level
MRL	ATSDR Minimal Risk Level
m/sec	Meters per Second
mg/m ³	Milligrams per Cubic Meter
NATA	National Air Toxics Assessment
OEHHA	California's Office of Environmental Health Hazard
NO	Nitric Oxide
REL	OEHHA Reference Exposure Level
RBC	Risk Based Concentration
RfC	Reference Concentration
RfD	Reference Dose
SQER	Small Quaintly Emission Rate
TAP	Toxic Air Pollutants
T-BACT	Best Available Control Technology for Toxics
TWA	Time Weighted Average
WAC	Washington Administrative Code
UF	Uncertainty Factor
URF	Unit Risk Factor
ug/m ³	Micrograms per Cubic Meter