Composite Wood Product ATCM: A Risk Assessment Based on Daily Time-weighted Average (TWA) Formaldehyde (HCHO) Concentration

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Abbreviations

μg	microgram(s)
A	Inhalation absorption factor (OEHHA, 2003)
AT	Averaging time period (in days) (OEHHA, 2003)
C_{air}	(HCHO) Concentration in air (OEHHA, 2003)
C_{ind}	(HCHO) Concentration in indoor microenvironments
C_{inv}	(HCHO) Concentration in vehicles
C_{out}	(HCHO) Concentration in outdoor settings
CA	(State of) California
CARB	California Air Resources Board
DBR	Daily breathing rate (in liters/kg body weight-day) (OEHHA, 2003)
$Dose_{inh}$	Inhalation dose (in mg/kg-day) (OEHHA, 2003)
ED	Exposure duration (in years) (OEHHA, 2003)
EF	Exposure frequency (in days/year) (OEHHA, 2003)
HCHO	Formaldehyde
hr	Hour

kg	Kilogram
m^3	Cubic meter
mg	Milligram
OEHHA	Office of Environmental Health Hazard Assessment
RTI	Research Triangle Institute
T_{ind}	Time spent indoors (in hours)
T_{inv}	Time spent in vehicles (in hours)
T_{out}	Time spent outdoors (in hours)
TWA	Time-weighted average
USEPA	U.S. Environmental Protection Agency

I. Overview

Cancer risk from formaldehyde (HCHO) was evaluated in children and adults by calculating 9-year and 70-year inhalation doses, respectively, consistent with the standard health risk assessment procedures (i.e., "Hot Spots Program" methodology) developed by the Office of Environmental Health Hazard Assessment (OEHHA). Exposure to HCHO was estimated by calculating a daily time-weighted average (TWA) concentration, consistent with the U.S. Environmental Protection Agency's (USEPA) guidelines for scenario-based exposure assessments, which was used in the toxic air contaminant identification process for environmental tobacco smoke in California. Average and elevated daily TWA HCHO concentrations were used as inputs to estimate HCHO inhalation dose (mg HCHO/kg-day), from which cancer risk was estimated by applying the cancer potency factor for HCHO (2.1×10^{-2} kg-day/mg).

Estimates of daily TWA HCHO concentrations were developed by combining data on daily activity patterns (i.e., hours in a given microenvironment) and measured HCHO concentrations in the microenvironments from technical reports and the open literature. To calculate an individual's HCHO exposure (μg-hr/m^3) in a given microenvironment, an average or elevated HCHO concentration in the microenvironment was multiplied by the amount of time spent in the microenvironment. After summing the exposures experienced in indoor, outdoor, and in-vehicle microenvironments during a day, the total was divided by 24-hours to derive the TWA HCHO concentration used to calculate the chances per million of developing cancer in children and adults.

If approved by CARB, the proposed Phase 1 and 2 standards for hardwood plywood, particleboard, and medium density fiberboard, the estimated chances per million of developing cancer would reduce by 17% and 46%, respectively.

II. Methodology

To calculate potential cancer risk in adults and children, the Hot Spots Program equation (OEHHA, 2003) was used to determine an inhalation dose ($Dose_{inh}$) for HCHO:

$$Dose_{inh} = [(C_{air}) \times (DBR) \times (A) \times (EF) \times (ED) \times 10^{-6}] \div AT$$

Where:

$Dose_{inh}$	= Dose through inhalation (mg/kg body weight-day)
C_{air}	= HCHO concentration in air (µg/m^3)
DBR	= Daily breathing rate (liter/kg body weight-day)
A	= Inhalation absorption factor (dimensionless adjustment)
EF	= Exposure frequency (days/year)
ED	= Exposure duration (years)
10^{-6}	= Constant: (10^{-3} x 10^{-3}) for (µg to mg) and (liter to m^3), respectively
AT	= Averaging time period (70-years) in days (25,550 days)

The numerical values of the components in the above equation were chosen based on OEHHA (2003), except for the calculation of C_{air}. For this component, a daily time-weighted average (TWA) HCHO concentration was calculated, consistent with the scenario-based guidelines for exposure assessment developed by USEPA (Federal Register, 1992). A daily TWA HCHO concentration was calculated separately for adults and children. In general terms, daily TWA HCHO concentration is:

$$\text{Daily TWA} = [(T_{ind} \times C_{ind}) + (T_{out} \times C_{out}) + (T_{inv} \times C_{inv})] \div 24$$

Where:

Daily TWA	= Daily time-weighted average HCHO concentration (µg/m^3)
T_{ind}	= Time spent indoors (hr)
C_{ind}	= Indoor HCHO concentration (µg/m^3)
T_{out}	= Time spent outdoors (hr)
C_{out}	= Outdoor HCHO concentration (µg/m^3)
T_{inv}	= Time spent in-vehicles (hr)
C_{inv}	= In-vehicle HCHO concentration (µg/m^3)
24	= Constant (24 hr/day)

III. Selection of Input Values for Calculating Inhalation Dose

The following paragraphs describe the basis for the numerical values of the parameters in the inhalation dose equation used in this analysis. Table 1 lists the

numerical values of the inputs used to calculate inhalation dose and chances per million of developing cancer in children and adults.

Table 1. Numerical Values of the Inhalation Dose Parameters[1]

Parameter	Numerical Value(s)	Applicable to:
Daily Breathing Rate (DBR)	581 liter/kg-day 271 liter/kg-day	Children Adults
Inhalation Absorption Factor (A)	1	Both
Exposure Frequency (EF)	350 days/year	Both
Exposure Duration (ED)	9 years 70 years	Children Adults
Averaging Time Period (AT)	25,550 days	Both

(1) Source: OEHHA (2003).

III.A. Inhalation Dose ($Dose_{inh}$)

III.A.1. Formaldehyde Concentration (C_{air}): In this analysis, we calculated a daily TWA HCHO concentration as an input to C_{air} for calculating an average and elevated HCHO exposure in adults and children. For adults, subsequent risk analyses were based on a 70-year lifetime exposure, whereas risk analyses for children were based on a 9-year exposure. Detailed information concerning the calculation of Daily TWA is provided in section III.B.

III.A.2. Daily Breathing Rate (DBR): For adults, the mean value for a 70-year exposure is 271 liter/kg-day (OEHHA, 2003). In this case, we opted to use the average breathing rate instead of the high-end DBR value of 393 liter/kg-day, in consideration of uncertainties with respect to the decay in HCHO emissions from composite wood products over time. For children, however, we used the high-end DBR of 581 liter/kg-day (vs. the average DBR value of 452 liter/kg-day) due to the shorter duration of the exposure period (9 vs. 70-years).

III.A.3. Inhalation Absorption Factor (A): Currently, for analyses of all substances in the Hot Spots Program, A = 1 (OEHHA, 2003).

III.A.4. Exposure Frequency (EF): The recommended value is 350 days/year (OEHHA, 2003). This parameter was held constant in the calculations for both adults and children. While exposures to HCHO are more likely to be experienced 365 days/year, we used the standard EF value given uncertainties in the rate of decay in HCHO emissions from composite wood products over time.

III.A.5. Exposure Duration (ED): Potential lifetime cancer risk was calculated on a 9-year or 70-year exposure basis, the standard "Hot Spots Program" durations for children and adults, respectively (OEHHA, 2003).

III.A.6. Averaging Time (AT): For adults and children, chances per million of developing cancer was calculated on a 70-year exposure basis (i.e., 25,550 days), the standard "Hot Spots Program" averaging time for health risk assessments (OEHHA, 2003).

III.B. Daily Time-weighted Average HCHO Concentration (Daily TWA)

While it is recognized that individual HCHO exposures vary across California, the average and elevated exposures presented here are based on mid-range HCHO concentrations that are reported to occur across the state. Several mitigating factors were considered relative to selecting the HCHO concentrations used herein, such as the duration of the exposure (9 or 70 years), reports of maximum concentrations up to four-fold higher than the mid-range values used, and the decay in HCHO emissions from composite wood products over time.

To calculate total daily exposure to HCHO requires data on activity patterns (i.e., time spent in different microenvironments; Table 2) and typical HCHO concentrations ($\mu g/m^3$) in the selected microenvironments. A daily TWA was calculated for an average and elevated exposure for adults and children (i.e., four scenarios – current-average and current-elevated for children and adults).

Table 2. Age-group Specific and Average Child and Adult Activity Patterns[1]

Age	T_{ind} (hr)	T_{out} (hr)	T_{inv} (hr)	T_{total} (hr)
0-2	21.43	1.57	1.01	24.00
3-5	20.47	2.38	1.15	23.99
6-8	20.34	2.83	0.83	24.00
9-11	19.69	3.28	1.03	24.01
12-17	21.23	1.00	1.78	23.99
18-24	20.55	1.23	2.22	24.01
25-34	20.98	1.21	1.83	23.99
35-44	20.65	1.36	1.98	23.96
45-54	20.95	0.98	2.03	23.96
55-64	20.64	1.73	1.63	23.99
65^+	21.57	1.15	1.3	24.02
Child – Average	20.55	2.45	1.00	24.00
Adult – Average	20.82	1.47	1.71	24.00

(1) Sources: University of California, Berkeley, 1991a and 1991b. T_{ind} = time spent indoors; T_{out} = time spent outdoors, T_{inv} = time spent in-vehicles, and T_{total} = (T_{ind} + T_{out} + T_{inv}). Averages for children and adults are the average from age 0-9 and 0-70 years, respectively.

III.B.1. Time Spent -- indoors (T_{ind}), outdoors (T_{out}), and in-vehicles (T_{inv}): Summary data in two technical reports were used to calculate the average time spent indoors, outdoors, or in a vehicle (University of California, Berkeley, 1991a; 1991b). For children from age 0-11, average time spent was calculated as the mean for boys and girls for age groups 0-2, 3-5, 6-8, and 9-11 (University of California, Berkeley, 1991b). Activity patterns for adolescents and adults were calculated as the mean for men and women for age groups 12-17, 18-24, 25-34, 35-44, 45-54, 55-64, and 65^+ (University of California, Berkeley, 1991a). Over a conceptual 70-year lifetime, the standard exposure duration for health risk assessments (OEHHA, 2003), T_{ind} ranged from 19.69 to 21.57 hr/day, T_{out} from 0.98 to 3.28 hr/day, and T_{inv} from 0.83 to 2.22 hr/day (Table 2).

III.B.2. HCHO Concentration – indoors (C_{ind}), outdoors (C_{out}), and in-vehicles (C_{inv}): Average and elevated HCHO concentration data were primarily obtained from CARB (2005), a report prepared for the Legislature on indoor air pollution in California. In Appendix III of CARB (2005), average and maximum HCHO concentrations in selected indoor and outdoor microenvironments were estimated (Table 3) and served as the principal basis for calculating daily TWA. For conventional homes, the elevated concentration represents the average concentration measured in newly built homes (Sherman and Hodgson, 2002). The average and elevated HCHO concentrations for time spent in vehicles were estimated from the data in Research Triangle Institute (1998).

Table 3. Average and Elevated HCHO Concentrations ($\mu g/m^3$) in Selected Indoor and Outdoor Microenvironments[1]

Microenvironment	Average ($\mu g/m^3$)	Elevated ($\mu g/m^3$)
Conventional Home	17.2	46.7
In-vehicle	9.6	12.0
Outdoors	3.7	15.0

(1) Sources: CARB (2005); Research Triangle Institute (1998); Sherman and Hodgson (2002).

IV. Discussion

IV.A. Estimated Cancer Risk in Children

For children, estimated chances per million of developing cancer ranged from 22 to 62 based on a 9-year exposure to HCHO at the current-average and current-elevated TWA HCHO concentrations (Table 4). Upon adoption of the proposed Phase 1 and 2 standards for hardwood plywood, particleboard, and medium density fiberboard, chances per million of developing cancer would be reduced

by 17% and 46%, respectively, in the both the average and elevated exposure scenarios.

Table 4. Estimated Cancer Risk in Children: 9-year Exposure to Average and Elevated Time-weighted Average (TWA) HCHO Concentrations (μg/m^3)

Exposure Scenario[1]	TWA HCHO Concentration	9-year Cancer Risk (Chances per Million)
Current-average	15.5	22
• Post Phase 1	13.0	19
• Post Phase 2	8.3	12
Current-elevated	42.0	62
• Post Phase 1	35.2	52
• Post Phase 2	22.4	33

(1) Assumes a 22% and 65% decrease in HCHO emissions in homes following the Phase 1 and 2 standards, respectively. Cancer potency factor for HCHO = 2.1 x 10^{-2} (mg/kg-day)$^{-1}$ (OEHHA, 2005).

IV.B. Estimated Cancer Risk in Adults

For adults, estimated chances per million of developing cancer ranged from 86 to 231 based on a 70-year exposure to HCHO at the current-average and current-elevated TWA HCHO concentrations (Table 5). Upon adoption of the proposed Phase 1 and Phase 2 standards for hardwood plywood, particleboard, and medium density fiberboard, chances per million of developing cancer would be reduced by 17% and 46%, respectively, in the both the average and elevated exposure scenarios.

Table 5. Estimated Cancer Risk in Adults: 70-year Exposure to Average and Elevated Time-weighted Average (TWA) HCHO Concentrations (μg/m^3)

Exposure Scenario	TWA HCHO Concentration	70-year Cancer Risk (Chances per Million)
Current-average	15.8	86
• Post Phase 1	13.3	73
• Post Phase 2	8.5	46
Current-elevated	42.3	231
• Post Phase 1	35.4	193
• Post Phase 2	22.4	122

(1) Assumes a 22% and 65% decrease in HCHO emissions in homes following the Phase 1 and 2 standards, respectively. Cancer potency factor for HCHO = 2.1×10^{-2} $(mg/kg\text{-}day)^{-1}$ (OEHHA, 2005).

V. References

CARB. 2005. Indoor Air Pollution in California. Report to the Legislature, Pursuant to Health & Safety Code §39930. Research Division, Sacramento, CA. 248 pp.

Federal Register. 1992. Notices: Part VI., U.S. Environmental Protection Agency, Guidelines for Exposure Assessment. Vol. 57(104), pp. 22888-22938. May 29, 1992.

Office of Environmental Health Hazard Assessment (OEHHA). 2003. The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. Appendix I: Calculation Examples for Estimating Potential Health Impacts. OEHHA, Oakland, CA. 11 pp.

OEHHA. 2005. Part II: Technical Support Document for Describing Available Cancer Potency Factors. Appendix A: Hot Spots Unit Risk and Cancer Potency Values. Air Toxicology and Epidemiology Section, Oakland, CA. 5 pp.

Research Triangle Institute (RTI). 1998. Concentrations of Selected Air Pollutants Inside California Vehicles. Final Report, CARB Contract No. 95-339, Research Division, Sacramento, CA. 155 pp.

Sherman MH and AT Hodgson. 2002. Formaldehyde as a basis for residential ventilation rates. Manuscript No. LBNL-49577, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, Berkeley, CA. 17 pp.

University of California, Berkeley (UCB). 1991a. Activity Patterns of California Residents. Final Report, CARB Contract No. A6-177-33, Research Division, Sacramento, CA. 63 pp.

UCB. 1991b. Study of Children's Activity Patterns. Final Report, CARB Contract No. A733-149, Research Division, Sacramento, CA. 83 pp.