Appendix F

Basis for Estimating Reductions in
Daily Time-weighted Average Formaldehyde Concentration

An estimate of the maximum potential HCHO emission reductions was prepared as a basis for calculating the changes in HCHO emissions that would result from HWPW, PB, and MDF meeting the proposed Phase 1 and Phase 2 standards. Using the emission factors in Appendix D and the amounts of wood products in Appendix E, the following estimates of maximum potential HCHO emissions were determined.

A. Calculation of Maximum Potential HCHO Emissions (µg/hr)

A.1. Home Plan 9802 (Dream House Source, Not Dated)

Table F-1. Maximum Potential HCHO Emissions from Uncoated HWPW, PB, and MDF in a Site-built 800 ft^2 Home: Comparison among 2002 Production-weighted Average, Phase 1, and Phase 2 Compliant Materials[1]

Product	Amount (m^2)	----- HCHO Emissions (µg/hr) -----		
		2002	Phase 1	Phase 2
⅝" PB	2.7	700	594	297
¾" PB	35.8	9,459	8,026	4,013
¼" HWPW	9.7	1,265	956	599
⅝" HWPW	4.2	548	414	260
¾" HWPW	9.0	1,179	891	558
¼" MDF	14.0	5,138	3,668	1,918
½" MDF	3.1	1,131	807	422
Door – PB	9.8	108	92	51
Oak	11.9	59	59	59
Total	-----	19,589	15,509	8,177
Difference	-----	-----	4,080	11,412
% Reduction	-----	-----	21%	58%

(1) HCHO Emission Rates (µg/m^2-hr) for HWPW: 2002 = 131, Phase 1 = 99, and Phase 2 = 62.
HCHO Emission Rates (µg/m^2-hr) for PB: 2002 = 264, Phase 1 = 224, and Phase 2 = 112.
HCHO Emission Rates (µg/m^2-hr) for MDF: 2002 = 367, Phase 1 = 262, and Phase 2 = 137.
HCHO Emission Rates (µg/m^2-hr) for Door-PB: 2002 = 11, Phase 1 = 9.4, and Phase 2 = 5.2.
HCHO Emission Rates (µg/m^2-hr) for Oak: 2002 = 5, Phase 1 = 5, and Phase 2 = 5.

A.2. Home Plan 18401 (Dream House Source, Not Dated)

Table F-2. Maximum Potential HCHO Emissions from Uncoated HWPW, PB, and MDF in a Site-built 2,000 ft^2 Home: Comparison among 2002 Production-weighted Average, Phase 1, and Phase 2 Compliant Materials[1]

Product	Amount (m^2)	----- HCHO Emissions (µg/hr) -----		
		2002	Phase 1	Phase 2
⅝" PB	5.9	1,567	1,329	665
¾" PB	53.4	14,092	11,956	5,978
¼" HWPW	17.9	2,342	1,770	1,108
⅝" HWPW	6.9	898	679	425
¾" HWPW	23.3	3,048	2,304	1,443
¼" MDF	25.2	9,232	6,591	3,446
½" MDF	6.6	2,431	1,735	907
Door – PB	21.3	234	199	110
Oak	19.4	97	97	97
Maple	1.1	5	5	5
Total	-----	33,946	22,665	14,185
Difference	-----	-----	7,281	19,761
% Reduction	-----	-----	22%	58%

(1) HCHO Emission Rates (µg/m^2-hr) for HWPW: 2002 = 131, Phase 1 = 99, and Phase 2 = 62.
HCHO Emission Rates (µg/m^2-hr) for PB: 2002 = 264, Phase 1 = 224, and Phase 2 = 112.
HCHO Emission Rates (µg/m^2-hr) for MDF: 2002 = 367, Phase 1 = 262, and Phase 2 = 137.
HCHO Emission Rates (µg/m^2-hr) for Door-PB: 2002 = 11, Phase 1 = 9.4, and Phase 2 = 5.2.
HCHO Emission Rates (µg/m^2-hr) for Oak/Maple: 2002 = 5, Phase 1 = 5, and Phase 2 = 5.

B. Estimated Maximum Potential HCHO Concentration

To calculate the maximum potential HCHO concentration in a home, the following equation was applied:

$$\text{Max } (\mu g/m^3) = \{[\text{Total emissions } (\mu g/hr)] \div [\text{Volume } (m^3) \times \text{Ventilation } (hr^{-1})]\}$$

Where "total emissions" refers to the values in Tables F-1 and F-2, "volume" refers to the effective volume of the home (Hodgson et al., 2002), and "ventilation" refers to the number of air changes per hour. Concentrations of HCHO in homes are reported to range from < 9 to 285 µg/m^3 (CARB, 2005).

B.1. Home Plan 9802 (Dream House Source, Not Dated)

Calculation Inputs

- 2002-based HCHO emissions = 19,589 µg/hr
- Phase 1-based HCHO emissions = 15,509 µg/hr
- Phase 2- based HCHO emissions = 8,177 µg/hr
- Volume = 170 m^3 (= 95% total volume of 179 m^3)
- Ventilation = 0.5 hr^{-1}

Max 2002-based HCHO (µg/m^3) = [(19,589 µg/hr) ÷ (170 m^3 x 0.5 hr^{-1})]
= [(19,589 µg/hr) ÷ (85 m^3/hr)]
= 230 µg/m^3

Max Phase 1-based HCHO (µg/m^3) = [(15,509 µg/hr) ÷ (170 m^3 x 0.5 hr^{-1})]
= [(15,509 µg/hr) ÷ (85 m^3/hr)]
= 182 µg/m^3

Max Phase 2-based HCHO (µg/m^3) = [(8,177 µg/hr) ÷ (170 m^3 x 0.5 hr^{-1})]
= [(8,177 µg/hr) ÷ (85 m^3/hr)]
= 96 µg/m^3

The maximum potential reduction in HCHO concentration from Phase 1 and Phase 2 is about 21% and 58%, respectively, in consideration of the mix of composite wood products found in a comparable site-built home.

B.2. Home Plan 18401 (Dream House Source, Not Dated)

Calculation Inputs

- 2002-based HCHO emissions = 33,946 µg/hr
- Phase 1-based HCHO emissions = 26,665 µg/hr
- Phase 2- based HCHO emissions = 14,185 µg/hr
- Volume = 425 m^3 (= 95% total volume of 448 m^3)
- Ventilation = 0.5 hr^{-1}

Max 2002-based HCHO (µg/m^3) = [(33,946 µg/hr) ÷ (425 m^3 x 0.5 hr^{-1})]
= [(33,946 µg/hr) ÷ (212.5 m^3/hr)]
= 160 µg/m^3

Max Phase 1-based HCHO (µg/m^3) = [(26,665 µg/hr) ÷ (425 m^3 x 0.5 hr^{-1})]
= [(26,665 µg/hr) ÷ (212.5 m^3/hr)]
= 125 µg/m^3

Max Phase 2-based HCHO (µg/m^3) = [(14,185 µg/hr) ÷ (425 m^3 x 0.5 hr^{-1})]
= [(14,185 µg/hr) ÷ (212.5 m^3/hr)]
= 67 µg/m^3

As for the 800 ft^2 house, the maximum potential reduction in HCHO concentration from Phase 1 and Phase 2 is about 21% and 58%, respectively, in consideration of the mix of composite wood products found in a site-built home.

C. Change in Daily Time-weighted Average HCHO Concentration

It was assumed that after Phase 1 and Phase 2, the use of compliant products would bring about 21% and 58% decreases, respectively, in combined HWPW, PB, and MDF emissions of HCHO in a home. Assuming that HCHO emissions from HWPW, PB, and MDF account for 75% of the measured concentration in a home, the Phase 1 and Phase 2 standards would effectively reduce HCHO concentrations by 16% and 44%, respectively.

Phase 1 Concentration Reduction = [(0.21 x 0.75) x 100%]
= [(0.16) x 100%]
= 16%

Phase 2 Concentration Reduction = [(0.58 x 0.75) x 100%]
= [(0.44) x 100%]
= 44%

Therefore, the estimated in-home Phase 1 and Phase 2 HCHO concentrations would be 84% and 56% of the mean and elevated concentrations used to calculate a typical and worst-case exposures.

C.1. Child Exposure

A daily time-weighted average HCHO concentration was calculated for mean and elevated exposure scenarios. Daily exposure was divided into time spent indoors, in-vehicles', and outdoors using the average child activity pattern in Table VII-3. Exposures to HCHO in each microenvironment were calculated by multiplying the time spent in the microenvironment (hr) by the mean or elevated HCHO concentration for the microenvironment (Table F-3). A daily time-weighted average (TWA) exposure concentration was calculated by totaling the three exposure fractions in "µg HCHO/m^3 x hr" and dividing by 24-hours.

C.2. Adult Exposure

A daily TWA HCHO concentration was calculated for mean and elevated exposure scenarios as for a child, except for using the average adult activity pattern in Table VII-3. Exposures to HCHO in each microenvironment were calculated by multiplying the time spent in the microenvironment (hr) by the mean or elevated HCHO concentration for the microenvironment (Table F-4).

Table F-3. Daily Time-weighted Average (TWA) HCHO Exposure Concentration for a Child[1]

A. Mean Exposure Scenario -- Child

Place	Time	---------- HCHO (µg/m^3) ----------			----- Exposure (µg/m^3 x hr) -----		
		Mean	Mean P1	Mean P2	Mean	Mean P1	Mean P2
Indoor	20.65	17.2	14.5	9.7	355.2	299.2	200.7
In-vehicle	1.25	9.6	9.6	9.5	12.0	11.9	11.9
Outdoor	2.10	3.7	3.7	3.7	7.8	7.8	7.7
Total	24	-----	-----	-----	375.0	318.9	220.3
TWA	-----	-----	-----	-----	15.6 µg/m^3	13.3 µg/m^3	9.2 µg/m^3

B. Elevated Exposure Scenario -- Child

Place	Time	---------- HCHO (µg/m^3) ----------			----- Exposure (µg/m^3 x hr) -----		
		Elev	Elev P1	Elev P2	Elev	Elev P1	Elev P2
Indoor	20.65	46.7	39.3	26.4	964.4	812.5	544.9
In-vehicle	1.25	12	11.9	11.9	15.0	14.9	14.9
Outdoor	2.10	15	14.9	14.9	31.5	31.3	31.2
Total	24	-----	-----	-----	1,010.9	858.7	591.0
TWA	-----	-----	-----	-----	42.1 µg/m^3	35.8 µg/m^3	24.6 µg/m^3

(1) Indoor P1 and P2 concentrations are 84% and 56% of the Mean or Elev concentrations, respectively. In-vehicle and Outdoor concentrations are 99.5% of the Mean or Elev concentrations. TWA = total (µg/m^3 x hr) ÷ 24-hr.

Table F-4. Daily Time-weighted Average (TWA) HCHO Exposure Concentration for an Adult[1]

A. Mean Exposure Scenario -- Adult

Place	Time	---------- HCHO (µg/m^3) ----------			----- Exposure (µg/m^3 x hr) -----		
		Mean	Mean P1	Mean P2	Mean	Mean P1	Mean P2
Indoor	20.82	17.2	14.5	9.7	358.1	301.7	202.3
In-vehicle	1.71	9.6	9.6	9.5	16.4	16.3	16.3
Outdoor	1.47	3.7	3.7	3.7	5.4	5.4	5.4
Total	24	-----	-----	-----	379.9	323.4	224.0
TWA	-----	-----	-----	-----	15.8 µg/m^3	13.5 µg/m^3	9.3 µg/m^3

B. Elevated Exposure Scenario -- Adult

Place	Time	---------- HCHO (µg/m^3) ----------			----- Exposure (µg/m^3 x hr) -----		
		Elev	Elev P1	Elev P2	Elev	Elev P1	Elev P2
Indoor	20.82	46.7	39.3	26.4	972.3	819.2	549.4
In-vehicle	1.71	12	11.9	11.9	20.5	20.4	20.3
Outdoor	1.47	15	14.9	14.9	22.1	21.9	21.8
Total	24	-----	-----	-----	1,014.9	861.5	591.5
TWA	-----	-----	-----	-----	42.3 µg/m^3	35.9 µg/m^3	24.6 µg/m^3

(1) Indoor P1 and P2 concentrations are 84% and 56% of the Mean or Elev concentrations, respectively. In-vehicle and Outdoor concentrations are 99.5% of the Mean or Elev concentrations. TWA = total (µg/m^3 x hr) ÷ 24-hr.

D. References

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

Dream House Source. Not Dated. Home Plan 9802. Accessed: 20 July 2006. From: http://www.dreamhomesource.com/Plan.asp?PlanID=980

Dream House Source. Not Dated. Home Plan 18401. Accessed: 20 July 2006. From: http://www.dreamhomesource.com/Plan.asp?PlanID=18401

Hodgson AT, D Beal, and JER McIlvaine. 2002. Sources of formaldehyde, other aldehydes and terpenes in a new manufactured house. Indoor Air, 12: 235-242.