Appendix B

Methyl Bromide Exposure and Risk Evaluations

The exposure and risk evaluations for ARB's methyl bromide monitoring in Kern County are not completed.

Department of Pesticide Regulation

dpr

Paul E. Helliker
Director

MEMORANDUM

Gray Davis
Governor

Winston H. Hickox
*Secretary, California
Environmental
Protection Agency*

TO: Joseph Frank, Senior Toxicologist   **HSM-02008**
              Worker Health and Safety Branch

FROM: Sally Powell, Senior Environmental Research Scientist
              Worker Health and Safety Branch
              (916) 445-4248

DATE: April 2, 2002

SUBJECT: EXPOSURES TO METHYL BROMIDE IN MONTEREY AND SANTA CRUZ
                 COUNTIES BASED ON THE FALL 2001 MONITORING BY THE CALIFORNIA
                 AIR RESOURCES BOARD

This memorandum gives inhalation exposures as average concentrations of methyl bromide in air for 24-hour, 1-week and 8-week averaging periods, based on monitoring done by the California Air Resources Board in Monterey and Santa Cruz Counties in Fall 2001 (ARB, 2002).

Methods

Following the practice of the Worker Health and Safety (WHS) Branch, this memorandum reports arithmetic mean concentrations and tolerance limits estimated using lognormal methods. Lognormality is assumed for environmental contaminants in most cases. DPR's experience with many large environmental datasets has shown that they are usually well described by the lognormal distribution. In addition, WHS prefers to avoid the inconsistency of using different exposure statistics based on sample characteristics. WHS uses the arithmetic mean concentration because the concentration of interest for exposure assessment is the overall concentration in all of the air that a person could breathe during the averaging period. The arithmetic mean concentration is the best estimate of the average mass of residue per unit of environmental medium; it is equivalent to compositing all of the samples and measuring the concentration of the mixture (Parkhurst, 1998). This is true regardless of the shape of the underlying distribution.

No samples below the detection limit of 0.002 ppbv (7.2 ng/m^3) were reported. Twenty samples with flow-rate deviations greater than 25% were not used in the analysis. There were ten cases where a site had usable samples for only two days in a week. The data were not adjusted for background levels (average 0.45 ppbv or 1737 ng/m^3 in 4 samples at a background site) or recovery (range 122% to 156% in laboratory, trip and field spikes).

24-hr exposure

For each monitoring site separately, the maximum observed and the 95% tolerance limit for 24-hr concentrations are given. The 95% tolerance limit is the concentration that, with given probability, will be exceeded in 5% of future samples (Hahn and Meeker, 1991). It is calculated using lognormal distribution methods:

$$95\% \text{ tolerance limit} = \exp\{\text{arithmetic mean of log concentrations} + g_{(.90;95;\,n)} * (\text{sd of logs})\}.$$

The multiplier g for 90% probability is tabled in Hahn and Meeker (1991).

1-week exposure

For each monitoring site separately, the maximum and the 95% tolerance limit for weekly mean concentrations are given. Each weekly mean is calculated as the arithmetic mean of the 24-hr samples taken at a site during the week (i.e., nonmonitoring days are ignored). The 95% tolerance limit for weekly mean concentrations is calculated using normal distribution methods:

$$\text{95\% tolerance limit} = \text{arithmetic mean of week means} + g_{(.90;.95;\,n)}*(\text{sd of week means}).$$

Normal methods are used in this case because sample means from any distribution tend to be normally distributed.

8-week exposure

For each monitoring site separately, average exposure over the 8-week monitoring period is calculated as the arithmetic mean of the weekly means (calculated as above for 1-week exposure).

Results

Twenty-four-hour, 1-week and 8-week concentrations are presented in Table 1. Daily concentrations and intermediate calculations are shown in Tables 2 and 2a.

Table 1. Methyl bromide concentrations (ppbv) in Monterey and Santa Cruz Counties, 8 September – 7 November 2001, based on monitoring by the California Air Resources Board.

Site [a]	N days	Daily Maximum 24-hr	Daily 95% tolerance limit	1-week Maximum weekly[b] mean	1-week 95% tolerance limit	8-week Mean of weekly means
				ppbv		
CHU	29	1.84	2.08	1.16	1.40	0.56
LJE	32	14.49	21.72	8.99	11.29	2.82
MES	26	36.64	59.28	13.43	18.76	5.51
PMS	30	21.08	21.10	10.47	12.50	2.99
SAL	31	9.25	7.61	6.16	6.91	1.38
SES	30	5.31	7.53	2.54	3.32	1.22

a Monitoring sites described in ARB (2002).
b Each weekly mean is the arithmetic mean of the 24-hr samples (*n* ranged 2 - 4) in a calendar week.

Exposure appraisal

The average concentrations presented here are based on limited monitoring data and must be considered as having some degree of uncertainty. The representativeness of the six monitoring sites is unknown. Each site was monitored only 2 - 4 days per week for a relatively short (8-week) period. Weekend days were not monitored. It is unknown whether weekdays and weekends differ systematically in numbers of methyl bromide fumigations.

References

ARB. 2002. Ambient air monitoring for methyl bromide and 1,3-dichloropropene in Monterey and Santa Cruz Counties, Fall 2001. Report dated Mar. 29, Project No. P-01-004. Sacramento, CA: Quality Management Branch, Monitoring and Laboratory Division, Air Resources Board, California Environmental Protection Agency.

Hahn, G.J., and Meeker, W.Q. 1991. *Statistical Intervals: A Guide for Practitioners*. New York, John Wiley & Sons, Inc.

Parkhurst, D.F. 1998. Arithmetic versus geometric means for environmental concentration data. *Environmental Science and Technology News.* Feb. 1.

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    Lori Lim
    Randy Segawa

Table 2. Daily concentrations and intermediate calculations for Monterey/Santa Cruz County sites.

Sample Start Date	Week	CHU (ng/m3)	(pptv)	LJE (ng/m3)	(pptv)	MES (ng/m3)	(pptv)	PMS (ng/m3)	(pptv)	SAL (ng/m3)	(pptv)	SES (ng/m3)	(pptv)
8-Sep-01	1	1293	333	2143	552	256	66	1514	390	1843	475	494	127
9-Sep-01	1	3638	938	24132	6219	14710	3791	16274	4194	3831	987	6000	1546
10-Sep-01	1	2881	742	18744	4830					16739	4314		
11-Sep-01	1			20895	5385								
	1 Average	2604	671	16478	4246	7483	1928	8894	2292	7471	1925	3247	837
17-Sep-01	2	935	241	1198	309	4123	1063	4145	1068	624	161	4388	1131
18-Sep-01	2	793	204	941	243	2959	763	2890	745	811	209	3893	1003
	2 Average	864	223	1070	276	3541	913	3517	906	717	185	4140	1067
22-Sep-01	3	1857	478	4629	1193	3911	1008	6650	1714	2133	550	10980	2830
23-Sep-01	3	974	251	2033	524	2697	695	4408	1136	1259	325	4021	1036
24-Sep-01	3	1283	331	2963	764	25511	6574	9946	2563	1786	460	6005	1548
25-Sep-01	3	5526	1424	2694	694	73909	19046	51028	13150	4698	1211	1936	499
26-Sep-01	3	1852	477	1016	262	41809	10774	12611	3250	1068	275	8998	2319
27-Sep-01	3	1885	486	870	224	72565	18700	50866	13108	1193	307	4388	1131
	3 Average	2229	575	2368	610	36734	9466	22585	5820	2023	521	6055	1560
3-Oct-01	4	1297	334	1632	420	1417	365	2158	556	1277	329	1646	424
4-Oct-01	4			655	169	7364	1898	3103	800	469	121	3000	773
5-Oct-01	4	942	243	1251	322	8306	2140	6262	1614	1176	303	4215	1086
6-Oct-01	4	2816	726	1515	390	142190	36642	11366	2929	9400	2422	1237	319
	4 Average	1685	434	1263	326	39819	10261	5722	1475	3080	794	2524	651
11-Oct-01	5	3735	963	5526	1424	86617	22321	10979	2829	9151	2358	5301	1366
12-Oct-01	5	4583	1181	11240	2897			81818	21084	34582	8912	16357	4215
13-Oct-01	5	7123	1836	28732	7404			38822	10004	35899	9251	15562	4010
14-Oct-01	5	2579	665	24962	6433	17600	4536	30832	7945	16062	4139	2260	582
	5 Average	4505	1161	17615	4539	52109	13428	40613	10466	23923	6165	9870	2544
19-Oct-01	6	3120	804	10049	2590	9933	2560	7803	2011	4803	1238	7891	2034
20-Oct-01	6			1683	434	1345	347	1462	377	1387	357	948	244
21-Oct-01	6	974	251	534	138	6638	1711	1463	377	552	142	2215	571
22-Oct-01	6	3921	1010	35847	9238	29689	7651	7994	2060	3156	813	20621	5314
	6 Average	2671	688	12028	3100	11901	3067	4680	1206	2475	638	7918	2041

Continued

Table 2. Continued.

27-Oct-01	7	2228	574	15531	4002	17007	4383	9457	2437	3909	1007	1310	338
28-Oct-01	7	2779	716	51795	13348	12121	3124	2063	532	2254	581	1434	369
29-Oct-01	7	2240	577	56236	14492	15002	3866	6036	1555	2221	572	1871	482
30-Oct-01	7	1080	278	16007	4125			1334	344	1879	484	274	71
	7 Average	2082	536	34892	8992	14710	3791	4722	1217	2566	661	1222	315
4-Nov-01	8	1115	287	3076	793			586	151	1182	305	442	114
5-Nov-01	8	409	105	1357	350	3681	948	1372	353	607	156	736	190
6-Nov-01	8	392	101	1478	381	9614	2477	4628	1193	370	95	3498	901
7-Nov-01	8	1040	268	1342	346	1013	261	1591	410	672	173	7200	1856
	8 Average	739	190	1814	467	4769	1229	2044	527	708	182	2969	765
Mean of week means		2172	560	10941	2819	21383	5510	11597	2989	5370	1384	4743	1222
SD of week means		1189	306	11940	3077	18676	4813	13396	3452	7789	2007	2956	762
Max of week means		4505	1161	34892	8992	52109	13428	40613	10466	23923	6165	9870	2544
n weeks		8	8	8	8	8	8	8	8	8	8	8	8
95th %ile of week means		4425	1140	33562	8649	56767	14629	36976	9529	20128	5187	10343	2665
90% tol limit on 95th%		5446	1404	43824	11293	72817	18765	48489	12496	26822	6912	12884	3320
Max of days		7123	1836	56236	14492	142190	36642	81818	21084	35899	9251	20621	5314

Table 2a. Natural logarithms of daily concentrations and intermediate calculations for Monterey/Santa Cruz County sites.

In values

	CHU		LJE		MES		PMS		SAL		SES	
	(ng/m3)	*(pptv)	(ng/m3)	*(pptv)	(ng/m3)	*(pptv)	(ng/m3)	*(pptv)	(ng/m3)	*(pptv)	(ng/m3)	*(pptv)
8-Sep-01	7.165	5.809	7.670	6.314	5.544	4.188	7.322	5.966	7.519	6.163	6.203	4.847
9-Sep-01	8.199	6.843	10.091	8.735	9.596	8.240	9.697	8.341	8.251	6.895	8.700	7.344
10-Sep-01	7.966	6.610	9.839	8.483					9.725	8.370		
11-Sep-01			9.947	8.591								
17-Sep-01	6.841	5.485	7.088	5.732	8.324	6.968	8.330	6.974	6.436	5.080	8.387	7.031
18-Sep-01	6.676	5.320	6.847	5.491	7.993	6.637	7.969	6.613	6.698	5.342	8.267	6.911
22-Sep-01	7.526	6.170	8.440	7.084	8.272	6.916	8.802	7.446	7.665	6.309	9.304	7.948
23-Sep-01	6.881	5.525	7.617	6.262	7.900	6.544	8.391	7.035	7.138	5.782	8.299	6.943
24-Sep-01	7.157	5.801	7.994	6.638	10.147	8.791	9.205	7.849	7.488	6.132	8.700	7.344
25-Sep-01	8.617	7.261	7.899	6.543	11.211	9.855	10.840	9.484	8.455	7.099	7.568	6.213
26-Sep-01	7.524	6.168	6.923	5.567	10.641	9.285	9.442	8.086	6.973	5.617	9.105	7.749
27-Sep-01	7.541	6.186	6.768	5.412	11.192	9.836	10.837	9.481	7.084	5.728	8.387	7.031
3-Oct-01	7.167	5.811	7.397	6.041	7.256	5.900	7.677	6.321	7.152	5.796	7.406	6.050
4-Oct-01			6.485	5.129	8.904	7.548	8.040	6.684	6.150	4.794	8.006	6.650
5-Oct-01	6.848	5.492	7.132	5.776	9.025	7.669	8.742	7.386	7.070	5.714	8.346	6.990
6-Oct-01	7.943	6.587	7.323	5.967	11.865	10.509	9.338	7.982	9.148	7.792	7.120	5.764
11-Oct-01	8.226	6.870	8.617	7.261	11.369	10.013	9.304	7.948	9.122	7.766	8.576	7.220
12-Oct-01	8.430	7.074	9.327	7.971			11.312	9.956	10.451	9.095	9.702	8.346
13-Oct-01	8.871	7.515	10.266	8.910			10.567	9.211	10.488	9.132	9.653	8.297
14-Oct-01	7.855	6.499	10.125	8.769	9.776	8.420	10.336	8.980	9.684	8.328	7.723	6.367
19-Oct-01	8.046	6.690	9.215	7.859	9.204	7.848	8.962	7.606	8.477	7.121	8.973	7.618
20-Oct-01			7.429	6.073	7.204	5.848	7.287	5.931	7.235	5.879	6.854	5.498
21-Oct-01	6.881	5.525	6.280	4.924	8.801	7.445	7.288	5.932	6.314	4.958	7.703	6.347
22-Oct-01	8.274	6.918	10.487	9.131	10.299	8.943	8.986	7.631	8.057	6.701	9.934	8.578

Continued

Table 2a. Continued.

27-Oct-01	7.709	6.353	9.651	8.295	9.741	8.385	9.154	7.798	8.271	6.915	7.178	5.822
28-Oct-01	7.930	6.574	10.855	9.499	9.403	8.047	7.632	6.276	7.721	6.365	7.268	5.912
29-Oct-01	7.714	6.358	10.937	9.581	9.616	8.260	8.705	7.350	7.706	6.350	7.534	6.178
30-Oct-01	6.985	5.629	9.681	8.325			7.196	5.840	7.538	6.182	5.612	4.256
4-Nov-01	7.017	5.661	8.032	6.676			6.374	5.018	7.075	5.719	6.091	4.735
5-Nov-01	6.014	4.658	7.213	5.857	8.211	6.855	7.224	5.868	6.408	5.052	6.601	5.245
6-Nov-01	5.971	4.616	7.299	5.943	9.171	7.815	8.440	7.084	5.913	4.557	8.160	6.804
7-Nov-01	6.946	5.591	7.202	5.846	6.920	5.565	7.372	6.016	6.510	5.154	8.882	7.526
Overall mean of days	7.48	6.12	8.38	7.02	9.14	7.78	8.69	7.34	7.74	6.38	8.01	6.65
Overall SD of days	0.72	0.72	1.43	1.43	1.51	1.51	1.26	1.26	1.23	1.23	1.09	1.09
n days	29	29	32	32	26	26	30	30	31	31	30	30
95th %ile of days	6081	1567	48725	12556	123345	31786	50677	13060	18459	4757	19269	4966
90% tol limit on 95th	8054	2076	84282	21719	230039	59281	81887	21102	29532	7610	29225	7531

dpr
Department of Pesticide Regulation

MEMORANDUM

TO: Joseph Frank, Senior Toxicologist   HSM-02012
Worker Health and Safety Branch

FROM: Sally Powell, Senior Environmental Research Scientist
Worker Health and Safety Branch
(916) 445-4248

DATE: April 9, 2002

SUBJECT: REVISED EXPOSURES TO METHYL BROMIDE BASED ON THE FINAL
REPORT ON THE 2001 MONITORING IN OXNARD/CAMARILLO AND
SANTA MARIA BY THE ALLIANCE OF THE METHYL BROMIDE
INDUSTRY

Exposures to methyl bromide in Oxnard/Camarillo and Santa Maria, based on the draft report by
the Alliance of the Methyl Bromide Industry (AMBI, 2002a), were reported previously (Powell,
2002). In the final AMBI report (AMBI, 2002b), minor corrections to three data points from
Oxnard/ Camarillo have been made. There were no changes to the Santa Maria data. This
memo gives revised exposures based on the corrected data. All exposure calculations were as
described in Powell (2002). Exposures are expressed as concentrations of methyl bromide in air
for 24-hour, 1-week and 8-week averaging periods (Table 1). Daily concentrations and
intermediate calculations are shown in Tables 2 and 3.

**Table 1. Methyl bromide concentrations (ppbv) in Oxnard/Camarillo and Santa Maria,
2001, based on monitoring by the Alliance of the Methyl Bromide Industry.**

Site[a]	n days	Daily Maximum 24-hr	Daily 95% tolerance limit	1-week Maximum weekly[b] mean	1-week 95% tolerance limit	8-week Mean of weekly means
Oxnard/Camarillo (15 Aug – 10 Oct, 2001)				ppbv		
PVW	31[c]	3.17	2.56[d]	2.01	2.59	0.56
UWC	19	4.35	8.77	2.08	3.48	0.82
SHA	29	2.94[e]	2.43[f]	2.30[g]	2.55[h]	0.50[i]
ABD	21	0.44[j]	0.44	0.44[j]	0.58	0.18
Santa Maria (23 Aug – 9 Oct, 2001)				ppbv		
BLO	31	4.55	4.85	1.89	2.25	0.73
AGCCRS	28	1.16	1.28	0.85	1.00	0.28
EDW	30	11.15	10.57	6.49	7.10	1.32
PNT	24	2.69	4.62	1.75	2.26	0.93

a Monitoring sites described in AMBI (2002b).
b Each weekly mean is the arithmetic mean of the 24-hr samples (*n* ranged 1 - 5) in a calendar week.
c Changed from 30 days in draft version.
d Changed from 2.68 ppbv in draft version.
e Changed from 3.38 ppbv in draft version.
f Changed from 2.41 ppbv in draft version.
g Changed from 2.47 ppbv in draft version.
h Changed from 2.73 ppbv in draft version.
i Changed from 0.51 ppbv in draft version.
j Measured in a week with only one 24-hr sample.

References

AMBI. 2002a. Draft preliminary report: Methyl bromide ambient air monitoring in
    Oxnard/Camarillo and Santa Maria, August-October, 2001. Draft dated Feb. 15.
    Sacramento, CA: Alliance of the Methyl Bromide Industry.

AMBI. 2002b. Final report: Methyl bromide ambient air monitoring in Oxnard/Camarillo and
    Santa Maria, August-October, 2001. Report dated April 4. Sacramento, CA: Alliance of
    the Methyl Bromide Industry.

Powell, S. 2002. Exposures to methyl bromide based on the report on the 2001 monitoring in
    Oxnard/Camarillo and Santa Maria by the Alliance of the Methyl Bromide Industry.
    HSM-02007. Sacramento, CA: Worker Health and Safety Branch, Department of Pesticide
    Regulation, California Environmental Protection Agency.

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    Randy Segawa

Table 2. Daily concentrations and intermediate calculations for Oxnard/Camarillo.

ppbv

DATE	Week	PVW	UWC	SHA	ABD
15-Aug-01	1	1.82	2.58	0.69	
16-Aug-01	1	1.05	1.85	0.17	
17-Aug-01	1	3.17	1.80	0.18	
18-Aug-01	1				
19-Aug-01	1				
1 Average		2.01	2.08	0.35	
20-Aug-01	2				
21-Aug-01	2	0.50	1.53		
22-Aug-01	2	1.91	0.45		
23-Aug-01	2	2.49	4.35	2.94	
24-Aug-01	2		2.01	2.86	
25-Aug-01	2	0.81	0.25	1.09	
26-Aug-01	2				
2 Average		1.43	1.72	2.30	
27-Aug-01	3				
28-Aug-01	3	0.12	0.21	1.09	
29-Aug-01	3	0.15	0.10	0.07	
30-Aug-01	3	0.28	0.35	0.56	0.44
31-Aug-01	3	0.15	0.18		
1-Sep-01	3				
2-Sep-01	3				
3 Average		0.18	0.21	0.57	0.436
3-Sep-01	4				
4-Sep-01	4				
5-Sep-01	4				
6-Sep-01	4	0.20		0.04	0.05
7-Sep-01	4	0.10		0.03	0.13
8-Sep-01	4	0.07		0.05	0.13
9-Sep-01	4	0.16		0.23	0.39
4 Average		0.13		0.09	0.18
10-Sep-01	5				
11-Sep-01	5				
12-Sep-01	5				
13-Sep-01	5	0.17		0.38	0.07
14-Sep-01	5	0.15		0.07	0.10
15-Sep-01	5	0.20		0.13	0.15
16-Sep-01	5	0.29		0.11	0.11
5 Average		0.20		0.17	0.11
17-Sep-01	6	0.35		0.13	0.14
18-Sep-01	6				
19-Sep-01	6	0.18	0.18	0.10	0.10
20-Sep-01	6	0.59	0.30	0.58	0.11
21-Sep-01	6				
22-Sep-01	6				
23-Sep-01	6				
6 Average		0.37	0.24	0.27	0.116

ln(ppbv)

	DATE	Week	PVW	UWC	SHA	ABD
Wed	15-Aug-01	1	0.60	0.95	-0.37	
Thur	16-Aug-01	1	0.05	0.61	-1.77	
Fri	17-Aug-01	1	1.15	0.59	-1.73	
	18-Aug-01	1				
	19-Aug-01	1				
	20-Aug-01	2				
Tue	21-Aug-01	2	-0.70	0.42		
Wed	22-Aug-01	2	0.65	-0.79		
Thur	23-Aug-01	2	0.91	1.47	1.08	
Fri	24-Aug-01	2		0.70	1.05	
Sat	25-Aug-01	2	-0.21	-1.40	0.09	
	26-Aug-01	2				
	27-Aug-01	3				
Tue	28-Aug-01	3	-2.11	-1.54	0.08	
Wed	29-Aug-01	3	-1.90	-2.29	-2.70	
Thur	30-Aug-01	3	-1.29	-1.05	-0.58	-0.83
Fri	31-Aug-01	3	-1.87	-1.74		
	1-Sep-01	3				
	2-Sep-01	3				
	3-Sep-01	4				
	4-Sep-01	4				
	5-Sep-01	4				
Thur	6-Sep-01	4	-1.61		-3.27	-2.96
Fri	7-Sep-01	4	-2.30		-3.41	-2.03
Sat	8-Sep-01	4	-2.67		-3.02	-2.08
Sun	9-Sep-01	4	-1.85		-1.47	-0.93
	10-Sep-01	5				
	11-Sep-01	5				
	12-Sep-01	5				
Thur	13-Sep-01	5	-1.80		-0.98	-2.67
Fri	14-Sep-01	5	-1.93		-2.69	-2.27
Sat	15-Sep-01	5	-1.61		-2.04	-1.92
Sun	16-Sep-01	5	-1.25		-2.17	-2.17
Mon	17-Sep-01	6	-1.05		-2.02	-2.00
	18-Sep-01	6				
Wed	19-Sep-01	6	-1.71	-1.71	-2.32	-2.28
Thur	20-Sep-01	6	-0.53	-1.19	-0.54	-2.21
	21-Sep-01	6				
	22-Sep-01	6				
	23-Sep-01	6				

continued

Table 2. Continued.

		ppbv						ln(ppbv)					
DATE	Week	PVW	UWC	SHA	ABD			DATE	Week	PVW	UWC	SHA	ABD
24-Sep-01	7							24-Sep-01	7				
25-Sep-01	7							25-Sep-01	7				
26-Sep-01	7	0.17	0.60	0.45	0.25	Wed		26-Sep-01	7	-1.79	-0.52	-0.81	-1.37
27-Sep-01	7	0.08		0.09	0.12	Thur		27-Sep-01	7	-2.48		-2.38	-2.10
28-Sep-01	7	0.08		0.10	0.15	Fri		28-Sep-01	7	-2.48		-2.32	-1.88
29-Sep-01	7	0.11		0.19	0.19	Sat		29-Sep-01	7	-2.20		-1.67	-1.64
30-Sep-01	7	0.15		0.07	0.06	Sun		30-Sep-01	7	-1.93		-2.65	-2.87
	7 Average	0.12	0.60	0.18	0.16								
1-Oct-01	8							1-Oct-01	8				
2-Oct-01	8							2-Oct-01	8				
3-Oct-01	8							3-Oct-01	8				
4-Oct-01	8							4-Oct-01	8				
5-Oct-01	8							5-Oct-01	8				
6-Oct-01	8							6-Oct-01	8				
	8 Average												
7-Oct-01	9	0.06	0.07	0.10	0.04	Sun		7-Oct-01	9	-2.80	-2.73	-2.34	-3.17
8-Oct-01	9	0.05	0.05	0.05	0.06	Mon		8-Oct-01	9	-3.04	-2.91	-3.02	-2.75
9-Oct-01	9	0.09	0.07	0.07	0.10	Tue		9-Oct-01	9	-2.44	-2.73	-2.73	-2.27
10-Oct-01	9	0.10	0.07	0.11	0.11	Wed		10-Oct-01	9	-2.29	-2.70	-2.24	-2.20
	9 Average	0.07	0.06	0.08	0.08								

	PVW	UWC	SHA	ABD			PVW	UWC	SHA	ABD
Mean of week means	0.564	0.817	0.500	0.179	Overall mean of days		-1.43	-0.98	-1.69	-2.12
SD of week means	0.736	0.862	0.743	0.131	Overall SD of days		1.14	1.41	1.23	0.60
Max of week means	2.014	2.077	2.297	0.436	n days		31	19	29	21
n weeks	8	6	8	6						
95th %ile of week means	1.96	2.55	1.91	0.44						
90% tol limit on 95th %ile	2.59	3.48	2.55	0.58						
Max of days	3.17	4.35	2.94	0.44	95th %ile of days		1.65	4.37	1.51	0.34
					90% tol limit on 95th		2.56	8.77	2.43	0.44

Table 3. Daily concentrations and intermediate calculations for Santa Maria.

| | ppbv | | | | | | | ln(ppbv) | | | | | |
DATE	Week	BLO	AGC	EDW	PNT		DATE	Week	BLO	AGC	EDW	PNT
23-Aug-01	2	0.04	0.03	0.02		Thur	23-Aug-01	2	-3.12	-3.47	-4.07	
24-Aug-01	2	0.03	0.13	1.02		Fri	24-Aug-01	2	-3.44	-2.01	0.02	
25-Aug-01	2	0.68	0.11	0.69		Sat	25-Aug-01	2	-0.39	-2.23	-0.38	
26-Aug-01	2	3.46	0.13	1.33	0.34	Sun	26-Aug-01	2	1.24	-2.02	0.29	-1.08
	2 Average	1.05	0.10	0.76	0.34							
27-Aug-01	3	2.09	0.14	0.98	0.68	Mon	27-Aug-01	3	0.74	-2.00	-0.02	-0.38
28-Aug-01	3	0.19	0.06	0.44	0.10	Tue	28-Aug-01	3	-1.67	-2.88	-0.81	-2.28
29-Aug-01	3	0.34	0.02	0.32	1.29	Wed	29-Aug-01	3	-1.08	-3.73	-1.14	0.25
30-Aug-01	3	0.30	0.06	0.58	1.68	Thur	30-Aug-01	3	-1.19	-2.78	-0.54	0.52
31-Aug-01	3						31-Aug-01	3				
1-Sep-01	3						1-Sep-01	3				
2-Sep-01	3						2-Sep-01	3				
	3 Average	0.73	0.07	0.58	0.94							
3-Sep-01	4						3-Sep-01	4				
4-Sep-01	4	0.07	0.05	0.30	0.22	Tue	4-Sep-01	4	-2.70	-3.10	-1.22	-1.51
5-Sep-01	4	0.17	0.05	0.09	0.43	Wed	5-Sep-01	4	-1.80	-3.08	-2.42	-0.85
6-Sep-01	4	0.21	0.13	0.59	0.51	Thur	6-Sep-01	4	-1.55	-2.01	-0.52	-0.67
7-Sep-01	4	0.11		0.20		Fri	7-Sep-01	4	-2.19		-1.59	
8-Sep-01	4						8-Sep-01	4				
9-Sep-01	4						9-Sep-01	4				
	4 Average	0.14	0.07517	0.30	0.39							
10-Sep-01	5						10-Sep-01	5				
11-Sep-01	5	1.47	0.15	1.30	1.81	Tue	11-Sep-01	5	0.38	-1.90	0.26	0.59
12-Sep-01	5		0.21	0.68	0.78	Wed	12-Sep-01	5		-1.57	-0.39	-0.25
13-Sep-01	5	0.40	0.21	0.64	0.59	Thur	13-Sep-01	5	-0.91	-1.57	-0.44	-0.54
14-Sep-01	5	0.51	0.20	1.01	1.07	Fri	14-Sep-01	5	-0.67	-1.63	0.01	0.07
15-Sep-01	5						15-Sep-01	5				
16-Sep-01	5	0.78					16-Sep-01	5	-0.25			
	5 Average	0.79	*0.19*	*0.91*	*1.06*							
17-Sep-01	6	0.31	0.14	0.54	0.57	Mon	17-Sep-01	6	-1.18	-1.94	-0.62	-0.57
18-Sep-01	6	0.33	0.37	0.83		Tue	18-Sep-01	6	-1.12	-1.01	-0.19	
19-Sep-01	6	0.42	0.30	0.49		Wed	19-Sep-01	6	-0.87	-1.22	-0.72	
20-Sep-01	6						20-Sep-01	6				
21-Sep-01	6						21-Sep-01	6				
22-Sep-01	6						22-Sep-01	6				
23-Sep-01	6						23-Sep-01	6				
	6 Average	0.35	0.27	0.62	0.57							

continued

Table 3. Continued.

ppbv

DATE	Week	BLO	AGC	EDW	PNT	
24-Sep-01	7	2.22	0.20	4.09	1.24	Mon
25-Sep-01	7	1.12		7.08		Tue
26-Sep-01	7	0.34	0.42	11.15	0.55	Wed
27-Sep-01	7	1.20	0.72	4.05	0.83	Thur
28-Sep-01	7					
29-Sep-01	7					
30-Sep-01	7	4.55		6.08	2.69	Sun
	7 Average	1.89	0.45	6.49	1.33	
1-Oct-01	8	0.24	0.90	0.38	1.98	Mon
2-Oct-01	8	0.52	1.16	0.68	1.85	Tue
3-Oct-01	8	0.24	0.48	0.22	1.43	Wed
4-Oct-01	8					
5-Oct-01	8					
	8 Average	0.33	0.85	0.42	1.75	
6-Oct-01	9	0.58	0.08	0.36	0.82	Sat
7-Oct-01	9	0.52	0.21		0.93	Sun
8-Oct-01	9	0.21	0.17	0.26	0.21	Mon
9-Oct-01	9	1.04	0.39	0.82	2.26	Tue
	9 Average	0.59	0.21	0.48	1.06	

	BLO	AGC	EDW	PNT
Mean of week means	0.73	0.28	1.32	0.93
SD of week means	0.55	0.26	2.10	0.48
Max of week means	1.89	0.85	6.49	1.75
n weeks	8	8	8	8
95th %ile of week means	1.77	0.77	5.29	1.85
90% tol limit on 95th %ile	2.25	1.00	7.10	2.26
Max of days	4.55	1.16	11.15	2.69

ln(ppbv)

DATE	Week	BLO	AGC	EDW	PNT
24-Sep-01	7	0.80	-1.62	1.41	0.22
25-Sep-01	7	0.11		1.96	
26-Sep-01	7	-1.09	-0.87	2.41	-0.60
27-Sep-01	7	0.18	-0.33	1.40	-0.19
28-Sep-01	7				
29-Sep-01	7				
30-Sep-01	7	1.52		1.81	0.99
1-Oct-01	8	-1.44	-0.11	-0.98	0.68
2-Oct-01	8	-0.65	0.15	-0.39	0.62
3-Oct-01	8	-1.45	-0.74	-1.52	0.36
4-Oct-01	8				
5-Oct-01	8				
6-Oct-01	9	-0.54	-2.58	-1.03	-0.20
7-Oct-01	9	-0.66	-1.56		-0.07
8-Oct-01	9	-1.57	-1.79	-1.34	-1.57
9-Oct-01	9	0.04	-0.95	-0.20	0.82

	BLO	AGC	EDW	PNT
Overall mean of days	-0.86	-1.80	-0.37	-0.24
Overall SD of days	1.17	0.98	1.31	0.82
n days	31	28	30	24
95th %ile of days	3.10	0.87	6.42	3.24
90% tol limit on 95th	4.85	1.28	10.57	4.62

Department of Pesticide Regulation

Paul E. Helliker
Director

MEMORANDUM

TO: Gary Patterson, Ph.D., Chief
Medical Toxicology Branch

FROM: Nu-may Reed, Ph.D. Staff Toxicologist
Medical Toxicology Branch
(916) 324-3508

DATE: April 11, 2002

SUBJECT: Risk of methyl bromide exposure in Monterey and Santa Cruz counties based on
California Air Resources Board monitoring in Fall 2001

This memorandum contains the estimation of risk associated with the air concentration of methyl
bromide detected in Monterey and Santa Cruz counties by the California Air Resources Board
(ARB) during the Fall (September 8 - November 7) of 2001 (ARB, 2002). In addition, a
comparison is made between the risk estimates of year 2000 and 2001.

The risk is expressed as the margin of exposure (MOE), the ratio of the toxicity threshold No-
Observed-Effect Level (NOEL) to the exposure:

$$MOE = \frac{NOEL}{Exposure} \qquad \text{(Equation 1)}$$

The current assessment uses the same critical NOELs from animal toxicity studies as used in
previous assessments (Lim, 2001). These NOELs were converted into human equivalence
through accounting for the differences in breathing rates and exposure durations between
laboratory animals and humans. The human equivalent NOELs are: 21 ppm and 25 ppm,
respectively, for adult and children acute exposures; 12 ppm and 7 ppm, respectively, for adult
and children 1-week exposures; and 0.2 ppm and 0.1 ppm, respectively, for adult and children 6-
week exposures (Lim, 2001).

Year 2001 monitoring

The air concentrations for three exposure scenarios are calculated by the Worker Health and
Safety Branch (Powell, 2002) based on the ARB sampling taken in the Fall of 2001 (ARB,
2002). Three sets of ambient air concentrations are available for the six monitoring sites: the 24-
hour daily maximum and 95% tolerance limit, the maximum weekly average and 95% tolerance
limit, and the 8-week average (Powell, 2002). The corresponding MOEs are presented in Table
1 for children and Table 2 for adults. A MOE of 100 is generally considered adequate for the
protection of human health. This 100-fold factor takes into account the potential 10-fold higher
sensitivity of humans than animals on a dose per body weight basis, and a 10-fold inter-
individual variation in sensitivity among humans.

Conclusion: The MOEs for both the 24-hour and the 1-week exceed the benchmark of 100. Based on the highest daily and the 95% tolerance limit of concentrations, the MOEs for a 24-hour exposure ranged 422 - 13,587 for children and 354 - 11,413 for adults. Based on the highest weekly average and the 95% tolerance limit of concentrations, the MOEs for a 1-week exposure ranged 373 - 6,034 for children and 640 - 10,345 for adults. The children's 8-week MOEs are below 100 (ranged 18 - 82) for 5 of the 6 sites, with the exception of MOE of 179 for the CHU (Chualar school) site. The adults' 8-week MOEs are below 100 (ranged 36 - 71) for 3 sites (LJE, La Joya Elementary School; MES, MacQuiddy Elementary School; PMS, Pajaro Middle School), and above 100 (ranged 145 - 357) for the remaining 3 sites (CHU; SAL, MBUAPCD Ambient Monitoring Station; SES, Salsepuedes Elementary School). The uncertainties in the calculated exposure concentrations are discussed in Powell (2002) regarding the limited and unknown representativeness of the monitoring data. The uncertainties in the toxicity data are discussed in Lim (2001) regarding the necessity of extrapolating from animal data and from the Lowest-Observed-Effect Level (LOEL) to the NOEL.

Table 1. Children MOEs for methyl bromide exposure in Monterey and Santa Cruz Counties in 2001[a]

Site [a]	Monitored days (N)	Daily		1-Week		8-Week
		Maximum 24-hr	95% tolerance limit	Maximum weekly mean	95% tolerance limit	Mean of weekly means
CHU	29	13,587	12,019	6,034	5,000	179
LJE	32	1,725	1,151	779	620	35
MES	26	682	422	521	373	18
PMS	30	1,186	1,185	669	560	33
SAL	31	2,703	3,285	1,136	1,013	72
SES	30	4,708	3,320	2,756	2,108	82

a/ Based on the air concentrations calculated from the ARB monitoring during September 8 - November 7, 2001 (Powell, 2002). The monitoring sites were described in the ARB report (ARB, 2002). The MOE was the ratio of the NOEL to the exposure. The human-equivalent NOELs of 25 ppm, 7 ppm, and 0.1 ppm were used for calculating the 24-hour, 1 week, and 8-week MOEs (Lim, 2001).

Table 2. Adults MOEs for methyl bromide exposure in Monterey and Santa Cruz Counties in
2001[a]

Site [a]	Monitored days (N)	Daily		1-Week		8-Week
		Maximum 24-hr	95% tolerance limit	Maximum weekly mean	95% tolerance limit	Mean of weekly means
CHU	29	11,413	10,096	10,345	8,571	357
LJE	32	1,449	967	1,335	1,063	71
MES	26	573	354	894	640	36
PMS	30	996	995	1,146	960	67
SAL	31	2,270	2,760	1,948	1,737	145
SES	30	3,955	2,789	4,724	3,614	164

a/   Based on the air concentrations calculated from the ARB monitoring during September 8 -
November 7, 2001 (Powell, 2002). The monitoring sites were described in the ARB report
(ARB, 2002). The MOE was the ratio of the NOEL to the exposure. The human equivalent
NOELs of 21 ppm, 12 ppm, and 0.2 ppm were used for calculating the 24-hour, 1 week, and
8-week MOEs (Lim, 2001).

Year 2000 and 2001 comparison

Air concentrations for 5 of the 6 sites were also monitored in year 2000 (ARB, 2001). The
corresponding MOEs were calculated (Lim, 2001) based on the exposure concentrations
similarly estimated by Powell (2001). The year to year comparison of risk is expressed as the
"2001/2000" ratio of MOEs. A less than one ratio (i.e., "2001/2000" < 1) indicates lower MOE
for the year 2001, corresponding to a higher air concentration. The comparison reflects the
difference in air concentrations for the two year's monitoring, regardless whether the ratio is
derived from the corresponding sets of children's or adults' MOEs. The "2001/2000" ratio from
children's MOEs are presented for the 24-hour exposure (Table 3), 1-week exposure (Table 4),
and 7 - 8 -week exposure (Table 5).

Conclusion: The "2001/2000" ratio varies from site to site, ranging from 0.8 to 3.1 for a 24-hour
exposure, indicating a generally similar or lower air concentration at most sites during year 2001
monitoring. The "2001/2000" ratio varies from 0.5 to 3.3 for a 1-week exposure, with 2-fold
higher 1-week exposure at the SAL site (MBUAPCD Ambient Monitoring Station) and 2.2- to
3.3-fold lower exposure at the SES site (Salsepuedes Elementary School). Overall, these 24-

hour and 1-week MOEs for both years exceed the benchmark of 100 for all monitoring sites (Table 3, 4). The "2001/2000" ratios for a 7- to 8-week period are above one (ranged from 1.2 to 2.5) for 4 of the 5 sites in the comparison (except SAL site), also reflecting lower air concentrations in year 2001 as monitored. The ratio of 0.9 at SAL reflects a 10% higher year 2001 air concentrations for the 7- to 8- week period. Except CHU (Chualar school) and OAS (Oak Avenue school) sites, the children MOEs for both years for all other sites are below the benchmark of 100 considered as adequate for the protection of health.

Table 3. Comparison of the 24-hour MOEs for year 2000 and 2001[a]

Sites	Maximum 24 hours			95% upper limit		
	2001	2000	2001/2000	2001	2000	2001/2000
CHU	13,587	10,373	1.3	12,019	11062	1.1
LJE	1,725	1,042	1.7	1,151	1351	0.9
MES	682	-	-	422	-	-
PMS	1,186	812	1.5	1,185	828	1.4
SAL	2,703	3,161	0.9	3,285	4,052	0.8
SES	4,708	1,524	3.1	3,320	2,049	1.6
OAS	-	13,587	-	-	20,661	-

[a] The MOEs for year 2001 is taken from Table 1. The MOEs for year 2000 are taken from the risk calculation by Lim (2001). Values represent the MOEs for children.

Table 4. Comparison of the 1-week MOEs for year 2000 and 2001[a]

Sites	Maximum weekly mean			95% upper limit		
	2001	2000	2001/2000	2001	2000	2001/2000
CHU	6,034	4,348	1.4	5,000	4,294	1.2
LJE	779	667	1.2	620	631	1.0
MES	521	-	-	373	-	-
PMS	669	452	1.5	560	409	1.4
SAL	1,136	2,326	0.5	1,013	2,229	0.5
SES	2,756	843	3.3	2,108	940	2.2
OAS	-	6,931	-	-	7,625	-

[a] The MOEs for year 2001 is taken from Table 1. The MOEs for year 2000 are taken from the risk calculation by Lim (2001). Values represent the MOEs for children

Table 5. Comparison of the 7- to 8-week MOEs for year 2000 and 2001[a]

Sites	Mean of weekly means		
	2001	2000	2001/2000
CHU	179	155	1.2
LJE	35	26	1.3
MES	18	-	-
PMS	33	13	2.5
SAL	72	78	0.9
SES	82	38	2.2
OAS	-	258	-

[a] The MOEs for year 2001 is taken from Table 1. The MOEs for year 2000 are taken from the risk calculation by Lim (2001). Values represent the MOEs for children.

References

ARB. 2002. Ambient air monitoring for methyl bromide and 1,3-dichloropropene in Monterey and Santa Cruz Counties, Fall 2001. Report dated Mar. 29, Project No. P-01-004. Sacramento, CA: Quality Management Branch, Monitoring and Laboratory Division, Air Resources Board, California Environmental Protection Agency.

ARB, 2001. Final report from the 2000 methyl bromide and 1,3-dichloropropene air monitoring in Monterey and Santa Cruz counties. Air Resources Board, California Environmental Protection Agency, Sacramento, CA.

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Powell, S. 2002. Exposures to methyl bromide in Monterey and Santa Cruz counties based on the Fall 2001 monitoring by the California Air Resources Board. Memorandum to J. Frank on April 2, 2002.

Powell, S. 2001. Exposures to methyl bromide based on ARB 2000 monitoring in Monterery/Santa Cruz and Kern Counties. Memorandum J. Frank on February 9, 2001.

Attachment:　　Powell, 2002
　　　　　　　　 Lim, 2001

cc: Lori Lim
　　 Keith Pfeifer

Paul E. Helliker
Director

MEMORANDUM

Gray Davis
Governor

Winston H. Hickox
*Secretary, California
Environmental
Protection Agency*

TO: Gary Patterson, Ph.D., Chief
          Medical Toxicology Branch

FROM: Lori O. Lim, Ph.D. Staff Toxicologist
          Medical Toxicology Branch
          (916) 324-3515

DATE: April 11, 2002

SUBJECT: Risk of methyl bromide exposure in Oxnard/Camarillo and Santa Maria based on
          the Alliance of the Methyl Bromide Industry monitoring in Fall 2001

This memorandum contains the estimation of risk associated with methyl bromide air concentrations detected in Oxnard/Camarillo and Santa Maria areas by the Alliance of the Methyl Bromide Industry (AMBI) (AMBI, 2002a and b). Monitoring was performed from August 15 to October 10, 2001 in the Oxnard/Camarillo sites, and from August 23 to October 9, 2001 in Santa Maria sites.

The risk is expressed as the margin of exposure (MOE), the ratio of the toxicity threshold No-Observed-Effect Level (NOEL) to the exposure:

$$MOE = \frac{NOEL}{Exposure} \qquad \text{(Equation 1)}$$

The current assessment uses the same critical NOELs from animal toxicity studies as used in previous assessments (Lim, 2001). These NOELs were converted into human equivalence through accounting for the differences in breathing rates and exposure durations between laboratory animals and humans. The human equivalent NOELs are: 21 ppm and 25 ppm, respectively, for adult and children acute exposures; 12 ppm and 7 ppm, respectively, for adult and children 1-week exposures; and 0.2 ppm and 0.1 ppm, respectively, for adult and children 6-week exposures (Lim, 2001).

Year 2001 monitoring

The air concentrations were calculated by the Worker Health and Safety Branch (Powell, 2002a and b) based on the AMBI sampling taken in the Fall of 2001. The MOEs were calculated based on the revised ambient air concentrations in the final AMBI report (AMBI, 2002b) for the eight monitoring sites: the 24-hour daily maximum and 95% tolerance limit, the maximum weekly average and 95% tolerance limit, and the 8-week average (Powell, 2002b). The corresponding MOEs are presented in Table 1 for children and Table 2 for adults. A MOE of 100 is generally considered adequate for the protection of human health. This 100-fold factor takes into account the potential 10-fold higher sensitivity of humans than animals on a dose per body weight basis, and a 10-fold inter-individual variation in sensitivity among humans.

Conclusion: The MOEs for both the 24-hour and the 1-week methyl bromide air concentrations from all sites exceeded the benchmark of 100. Based on the highest daily and the 95% tolerance limit of concentrations, the MOEs for a 24-hour exposure ranged 2,242 to 56,818 for children and 1,883 to 47,727 for adults. Based on the highest weekly average and the 95% tolerance limit of concentrations, the MOEs for a 1-week exposure ranged 986 to 15,909 for children and 1,690 to 27,273 for adults. For the 8-week mean methyl bromide air concentrations, the children 8-week MOEs exceeded 100 (ranged 108 to 556) for 7 of the 8 sites, with the exception of MOE of 76 for the EDW (United Water Cons. District #2) site. The adults' 8-week MOEs exceeded the benchmark and ranged from 152 to 1,111. The uncertainties in the calculated exposure concentrations were discussed in Powell (2002a) regarding the limited and unknown representativeness of the monitoring data. In addition, Powell (2002a) noted that the timing and location of nearby methyl bromide applications were not yet known for the monitoring period. Monitoring at the Oxnard UWC site was intentionally skipped during two weeks when fumigation were occurring nearby. The uncertainties in the toxicity data are discussed in Lim (2001) regarding the necessity of extrapolating from animal data and from the Lowest-Observed-Effect Level (LOEL) to the NOEL.

Table 1. Children MOEs for methyl bromide exposure in Oxnard/Camarillo and Santa Maria areas in 2001[a]

Site [a]	Monitored days (N)	Daily		1-Week		8-Week
		Maximum 24-hr	95% tolerance limit	Maximum weekly mean	95% tolerance limit	Mean of weekly means
Oxnard/Camarillo sites (August 15 to October 10, 2001)						
PVW	31	7,886	9,766	3,483	2,703	179
UWC	19	5,747	2,851	3,365	2,011	122
SHA	29	8,503	10,288	3,043	2,745	200
ABC	21	56,818	56,818	15,909	12,069	556
Santa Maria sites (August 23 to October 9, 2001)						
BLO	31	5,495	5,155	3,704	3,111	137
AGCCRS	28	21,552	19,531	8,235	7,000	357
EDW	30	2,242	2,365	1,079	986	76
PNT	24	9,294	5,411	4,000	3,097	108

a/ Based on the air concentrations calculated from the AMBI monitoring during the Fall of 2001 (Powell, 2002b). The monitoring sites were described in the final AMBI report (AMBI, 2002b). The MOE was the ratio of the NOEL to the exposure. The human-equivalent NOELs of 25 ppm, 7 ppm, and 0.1 ppm were used for calculating the 24-hour, 1 week, and 8-week MOEs (Lim, 2001).

Gary Patterson
April 11, 2002
Page 3

Table 2. Adults MOEs for methyl bromide exposure in Oxnard/Camarillo and Santa Maria areas in 2001[a]

Site [a]	Monitored days (N)	Daily		1-Week		8-Week
		Maximum 24-hr	95% tolerance limit	Maximum weekly mean	95% tolerance limit	Mean of weekly means
Oxnard/Camarillo sites (August 15 to October 10, 2001)						
PVW	31	6,625	8,203	5,970	4,633	357
UWC	19	4,828	2,395	5,769	3,448	244
SHA	29	7,143	8,642	5,217	4,706	400
ABC	21	47,727	47,727	27,273	20,690	1,111
Santa Maria sites (August 23 to October 9, 2001)						
BLO	31	4,615	4,330	6,349	5,333	274
AGCCRS	28	18,103	16,406	14,118	12,000	714
EDW	30	1,883	1,987	1,849	1,690	152
PNT	24	7,807	4,545	6,857	5,310	215

a/ Based on the air concentrations calculated from the AMBI monitoring during the Fall of 2001 (Powell, 2002b). The monitoring sites were described in the final AMBI report (AMBI, 2002b). The MOE was the ratio of the NOEL to the exposure. The human equivalent NOELs of 21 ppm, 12 ppm, and 0.2 ppm were used for calculating the 24-hour, 1 week, and 8-week MOEs (Lim, 2001).

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Attachments: Powell, 2002a and b
              Lim, 2001

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