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MEMORANDUM

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SUBJECT: REVIEW OF CHLOROPICRIN AIR MONITORING DATA IN REGISTRATION DATA PACKAGE 230168

I reviewed indoor and outdoor chloropicrin air monitoring data from Registration Data Package 230168, which was submitted to the California Department of Pesticide Regulation (DPR) by Dow AgroSciences, LLC. This data package contains data collected during and following structural fumigations with sulfuryl fluoride (SF), with chloropicrin used as a warning agent (Barnekow and Byrne, 2006). Chloropicrin monitoring data are summarized in this memo, and concentrations to be used in the chloropicrin exposure assessment are calculated.

Study Design

The purpose of the study was to determine the adequacy of a proposed change in aeration methods, in which exhaust fans are operated remotely to minimize worker exposure when initiating aeration. Four houses in California were each fumigated twice by professional fumigators, for a total of eight replicates with monitoring of both SF and chloropicrin. Table 1 summarizes replicate details. Temperature ranges during fumigation and aeration are summarized in Appendix 1.

Replicates 1 and 2 were conducted at a one-story 32,000-ft^3 house (fumigation volume estimated from amount of chloropicrin used, 3.2 ounces in both replicates, and from the reported use rate of 1 oz per 10,000-ft^3) in Ojai in November 2004. Replicates 3 and 4 were conducted at an L-shaped, 53,000-ft^3 house (one-story, other than an attached garage beneath a game room) in Homeland in November 2004. Replicates 5 and 6 were conducted at a one-story 25,000-ft^3 house in Reedley in December 2004 (estimated from chloropicrin amounts of 2.6 and 2.4 ounces, respectively). Replicates 7 and 8 were conducted at a two-story, approximately 40,000-ft^3 house in Reedley in February 2005; the amount of chloropicrin used was 3.6 and 4.1 ounces, respectively. No explanation was given for the fact that about 14% more chloropicrin was used in Replicate 8 than in Replicate 7, such as whether house was tarped to include more area in Replicate 8 than in Replicate 7. The amount of SF reportedly used in Replicate 8 was also 14% greater than that used in Replicate 7, suggesting the possibility that the fumigation volume was greater. However, no dimensions were provided for any of the houses.

Following 20-hour fumigations, each house was aerated for 12 hours (replicates 1 through 6) or 24 hours (replicates 7 and 8). At the end of this aeration period, SF concentrations in all eight replicates were less than 5 ppm (the concentration requiring respiratory protection at that time), as noted on page 25 of the study report: "The structures were clear of SF - no additional aeration period was needed."

Table 1. Details of Fumigation Replicates [a]

House	Location	Replicate	Dates	Amount of Chloropicrin (oz) [b]	Estimated Fumigation Volume (ft^3) [c]
1	Ojai	1	November 8 – 11, 2004	3.2	32,000
		2	November 11 – 14, 2004	3.2	32,000
2	Homeland	3	November 15 – 18, 2004	5.3	53,000
		4	November 18 – 21, 2004	5.3	53,000
3	Reedley	5	December 13 – 16, 2004	2.6	25,000
		6	December 16 – 19, 2004	2.4	25,000
4	Reedley	7	February 14 – 17, 2005	3.6	40,000
		8	February 17 – 20, 2005	4.1	40,000

[a] Data from Barnekow and Byrne (2006), Tables 1 – 4.
[b] Amount in ounces (1 ounce = 0.015 liters).
[c] Estimated from amount of chloropicrin used and from the reported use rate of 1 oz per 10,000-ft^3. Volume of the fourth house is estimated to one significant figure.

During fumigation and aeration, chloropicrin concentrations were monitored at 32 samplers positioned at various distances from all four sides and corners of each house. Samples were collected at about 5 ft above ground. At two houses (used for replicates 1, 2, 7, and 8), six samplers were positioned at a series of distances of approximate 5, 10, 25, 50, 75, and 100 ft from each side, with two samplers positioned 5 and 10 ft from the corners, and at the other two houses (used for replicates 3 – 6), the opposite configuration was used with six samplers at each corner and two at 5 and 10 ft from each side. During fumigation, outdoor samples were collected at one 4-hour followed by two 8-hour intervals (Intervals 1 – 3). During aeration, outdoor samples were collected at four 1-hour followed by two 4-hour intervals (Intervals 4 – 9). Following clearance, four indoor samplers were used to monitor chloropicrin concentrations in the attic, crawlspace, utility area and either the living room or a bedroom for four 1-hour intervals, followed by four 8-hour intervals (Intervals 10 – 17).

All houses were tarped prior to fumigant introduction, and tarps were removed following aeration. Clearance testing was done after tarp removal. All tarps were stated to be "of fair to excellent condition," except for a tarp used during Replicate 3 to cover "the southeastern portion of the house from the roof to the ground of the two story section (outside porch, game room and garage)." Once the structure was cleared, the central air handling systems were turned on "in accordance with the recommended procedures." However, Barnekow and Byrne noted that the damper was not opened in Replicate 5, "significantly reducing air flow. Therefore, measured

concentrations inside the Replicate 5 home could conceivable represent a 'worst case' situation since activity that would promote structural aeration beyond those measures normally used was minimized."

Chloropicrin was measured with air sampling tubes containing 600 mg (400 mg in front section, 200 mg in back section) of XAD-4 sorbent connected to air pumps calibrated at 100 ml per minute. Flow rates were calibrated at the start and end of each monitoring interval with a flowmeter. Samples were placed in a freezer immediately after each sampling interval, and shipped frozen to the laboratory once both replicates at each site were completed. Due to a shipping delay, samples from Replicates 5 and 6 thawed during shipment, and were at ambient temperature when they reached the laboratory. The potential effect thawing might have on the results, if any, is unknown, as the study did not determine storage stability data for chloropicrin.

Analytical Method and Quality Assurance

Sorbent in the front and selected back sections of the air sampling tubes was extracted with ethyl acetate, and the amount of chloropicrin in each sorbent section was determined using gas chromatography with an electron capture detector. The limit of detection (LOD) and limit of quantification (LOQ) were determined statistically from the standard deviation of recovery from 94 samples spiked at 0.1 µg chloropicrin per tube. The mean $\pm$ standard deviation (SD) was 0.0831 $\pm$ 0.0153 µg. The SD was multiplied by 3 to get an LOD of 0.046 µg chloropicrin per section and multiplied by 10 to get an LOQ of 0.153 µg chloropicrin per section. Barnekow and Byrne (2006) reported "ND" for "not detected" for any sample with chloropicrin below the LOD; they reported results between the LOD and LOQ, but identified them with parentheses. In accordance with DPR practice for data used to estimate exposure, in this memorandum ½ LOQ (i.e., 0.076 µg/tube) is substituted for any sample in which chloropicrin was below the LOQ.

Quality assurance samples consisted of unfortified control samples (blanks), laboratory spikes, travel spikes, and field spikes. Blanks and spikes were handled as follows: travel blanks and spikes were carried to the site and kept in the sample freezer until their return to the laboratory for analysis; laboratory blanks and spikes were stored in the laboratory until analysis; and field blanks and spikes were carried to the background site, connected to sampling pumps for 8 hours before fumigation, and handled and stored with samples. Ten sets of 12 travel blanks and spikes and ten sets of 12 field blanks and spikes were used. Each set of 12 tubes contained three blanks, three tubes spiked at 1 µg, three tubes spiked at 50 µg, and three tubes spiked at 200 µg. All blanks had results below the LOQ.

Table 2 summarizes field spike recoveries. However, reported results had not been corrected for site-specific field spike recoveries, which is DPR's usual practice for data used to estimate exposure. A total of 138 spikes were analyzed in the study, and mean $\pm$ SD recovery of all spikes was 86.7% $\pm$ 15.5%. This mean "study recovery" was used by Barnekow and Byrne (2006) to correct all samples results at or above the LOQ. DPR practice is in general agreement with U.S.

Environmental Protection Agency (U.S. EPA) policy, in which individual samples are corrected for site-specific and fortification-level specific field spike recoveries below 90% (U.S. EPA, 1992; U.S. EPA, 1998).

Table 2. Summary of Field Spike Recoveries for Chloropicrin [a]

Replicate	Level [b]	No. Samples [c]	Mean Recovery (%) [d]	SD [e]	CV [f]
Replicate 1	1	41	45.2	34.5	76
	50	0	91.6	15.3	17
	200	0	127	12.8	10
Replicate 2	1	55	62.7	1.02	1.6
	50	3	95.7	7.99	8.4
	200	0	131	3.33	2.6
Replicate 3	1	68	99.5	1.56	1.6
	50	11	81.3	4.60	5.7
	200	0	118	2.26	1.9
Replicate 4	1	58	95.4	1.50	1.6
	50	8	81.7	3.31	4.1
	200	0	104	2.75	2.7
Replicate 5	1	23	85.6	1.00	1.2
	50	17	107	22.4	21
	200	0	117	29.3	25
Replicate 6	1	39	81.4	2.16	2.7
	50	4	111	5.29	4.8
	200	0	106	52.4	50
Replicate 7	1	56	76.0	1.38	1.8
	50	1	100	12.4	12
	200	0	124	11.6	9.3
Replicate 8	1	44	82.0	0.115	0.14
	50	0	91.9	9.21	10
	200	0	120	12.1	10

[a] Data from Barnekow and Byrne (2006), Tables 32 – 39.
[b] Fortification level in µg/tube.
[c] Number of samples with results in this range (i.e., LOQ – 10 µg/tube, 10.1 – 100 µg/tube, or > 100 µg/tube); samples below the limit of quantification (LOQ) were not corrected. Barnekow and Byrne (2006) corrected all samples above the LOQ for 86.7% recovery.
[d] Mean of three samples, except for 1-µg and 50-µg levels of Replicate 1, which are means of two samples.
[e] Standard deviation.
[f] Coefficient of Variation. Calculated as follows: CV = 100% x (SD/mean).

Uncorrected data were not provided by Barnekow and Byrne (2006); to correct data for recovery from specific spike levels at individual sites it was necessary to first calculate uncorrected values

by multiplying by 86.7%. Results were then corrected by dividing by the mean recoveries of the appropriate spike level for individual replicates, as summarized in Table 3.

One 1-µg field spike from Replicate 1 had a recovery of 963%. The other 1-µg field spikes in that set had recoveries of 69.6% and 67.3%, and the high spike was omitted as an outlier. One 50-µg field spike from Replicate 1 was omitted (no recovery reported), without explanation.

Table 3. Field Spike Recovery Correction Factors for Samples [a]

Replicate	Level [b]	No. Samples [c]	Mean Recovery (%) [d]	Residue Range for Correction (µg/tube)	DPR Correction Factor [e]
Replicate 1	1	41	45.2	LOQ – 10	0.452
Replicate 2	1	55	62.7	LOQ – 10	0.627
	50	3	95.7	10.1 – 100	1.00
Replicate 3	1	68	99.5	LOQ – 10	1.00
	50	11	81.3	10.1 – 100	0.813
Replicate 4	1	58	95.4	LOQ – 10	1.00
	50	8	81.7	10.1 – 100	0.817
Replicate 5	1	23	85.6	LOQ – 10	0.856
	50	17	107	10.1 – 100	1.00
Replicate 6	1	39	81.4	LOQ – 10	0.814
	50	4	111	10.1 – 100	1.00
Replicate 7	1	56	76.0	LOQ – 10	0.760
	50	1	100	10.1 – 100	1.00
Replicate 8	1	44	82.0	LOQ – 10	0.820

[a] Barnekow and Byrne (2006) corrected all samples for 86.7% recovery before reporting.
[b] Fortification level in µg/tube. Only field spike recoveries used to correct samples are included.
[c] Number of samples subjected to this correction. Samples below the limit of quantification (LOQ) were not corrected, and are not included in this table.
[d] Mean of three samples, except for Replicate 1, which is the mean of two samples.
[f] Department of Pesticide Regulation (DPR) practice is to adjust residues for samples with corresponding field spike recoveries of less than 90%.

Breakthrough (quantifiable chloropicrin residues recovered from back sorbent section as well as front section) did not occur at a level sufficient to cause concern. To determine breakthrough, Barnekow and Byrne (2006) analyzed the back section of 10% of the field and travel spikes, and of any samples in which the amount of chloropicrin recovered from the front section exceeded approximately 0.4 µg. Breakthrough results are summarized in Table 4. Huey and Materna (2002) defined breakthrough in air sampling tubes as “a condition in which the mass of a collected gas or vapor in the backup section is greater than 10% of the mass in the front section." If a chemically significant amount of analyte passes through the front section of a tube, this is an indication that the tube did not quantitatively capture the analyte. Breakthrough is a concern in

exposure monitoring because it could result in underestimating chloropicrin concentrations to which individuals may be exposed. However, in this study the highest breakthrough was 9.9%, below the level of concern, and nearly 90% of samples tested did not have quantifiable residues in the back section.

Table 4. Breakthrough in Chloropicrin Field Spikes and Samples [a]

Replicate	Type [b]	Number of Tubes Tested	Number with Breakthrough > LOQ [c]	Percent Tested Tubes with Breakthrough [d]	Highest Breakthrough (%) [e]
Replicate 1	Spikes	23	5	21.7	0.97
	Samples	27	0	0	NA
Replicate 2	Spikes	24	10	41.7	3.8
	Samples	37	0	0	NA
Replicate 3	Spikes	24	6	25.0	0.57
	Samples	56	9	16.1	9.9
Replicate 4	Spikes	21	0	0	NA
	Samples	34	0	0	NA
Replicate 5	Spikes	0	NA	NA	NA
	Samples	27	8	29.6	4.5
Replicate 6	Spikes	0	NA	NA	NA
	Samples	31	0	0	NA
Replicate 7	Spikes	0	NA	NA	NA
	Samples	27	0	0	NA
Replicate 8	Spikes	0	NA	NA	NA
	Samples	24	0	0	NA
Overall	Spikes	92	21	22.8	3.8
	Samples	263	17	6.5	9.9
	Combined	355	38	10.7	9.9

[a] Data from Appendix C, Table 11, in Barnekow and Byrne (2006), where amounts recovered from front and back sections are reported separately. Only tubes in which back sections were analyzed are included here.
[b] Spikes include both travel and field spikes. Samples include both indoor and outdoor samples, during intervals 1 through 17 (fumigation through post-clearance).
[c] The limit of quantification (LOQ) is 0.153 µg/tube. NA: Back section not analyzed.
[d] Percent of tubes in which the back section was analyzed with quantifiable residues in the back section.
[e] Breakthrough as percent of combined amount in front and back sections.

In calculating the amount of chloropicrin recovered from a sampler in which both front and back sections were analyzed, residues in the back section above the LOQ were added to those in the front section. If residues in the back section were below the LOQ, then this was taken as evidence that breakthrough did not occur and concentrations were calculated from residues recovered from the front section alone.

Results

Outdoor samples were collected during fumigation (Intervals 1 – 3) and during aeration (Intervals 4 – 9). During many sample intervals at each site, no quantifiable chloropicrin occurred at any of the 32 outdoor samplers. Indoor samples were collected following aeration and clearance, and spanned Intervals 10 – 17.

Chloropicrin concentrations in $\mu g/m^3$ were calculated by dividing the residue of chloropicrin recovered from the sampler in micrograms (µg) by the volume sampled in cubic meters (m^3). Chloropicrin concentrations reported in $\mu g/m^3$ were converted to equivalent concentrations in parts per billion (ppb), expressed as ratio of volume of chloropicrin to volume of air, using the ideal gas law. At 1 atmosphere of pressure and a temperature of 25°C, the concentration in ppb is equal to the concentration in $\mu g/m^3$, multiplied by 24.45 liter-atm/mole and divided by the molecular weight of 164.38 g/mole. As 24.45/164.38 = 0.1487, this value was multiplied by the concentration in $\mu g/m^3$ to obtain the concentration in ppb.

<u>Outdoor Concentrations</u>
Samples were collected at a total of 32 outdoor samplers at each of eight houses for nine sampling intervals, for a total of 2,304 samples. However, three samples were lost during field collection (one each at Replicates, 3, 4, and 7), and one sample from Replicate 7 was lost during analysis. Thus, a total of 2,300 samples were analyzed. Of these, 197 (8.6%) contained chloropicrin above the LOQ.

Table 5 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 1. Chloropicrin was below the LOQ in all samplers in all but Intervals 2 and 3. For intervals when all samples were below the LOQ, the highest concentration was calculated by dividing ½ LOQ by volume monitored and thus correlates with lowest volume monitored rather than with wind speed and direction.

The highest outdoor concentration in Replicate 1 was 30.5 $\mu g/m^3$ (4.53 ppb). This concentration occurred at Sampler 2B (5 ft south of the structure) during Interval 3, during the last 8 hours of fumigation. Quantifiable chloropicrin occurred during Interval 2 at samplers 5 – 10 ft east, northeast, southeast, and south of the house (Samplers 1A, 2A, 4A, 1B, 2B, 4B, 1C, 2C, and 3C). During Interval 3, quantifiable chloropicrin was occurred at samplers 5 – 10 ft east, northeast, southeast, south, southwest, and west of the house (Samplers 1A, 2A, 4A, 1B, 2B, and 4B). No quantifiable chloropicrin occurred at any sampler during Interval 1 or during the 12-hour aeration (Intervals 4 – 9).

Table 5. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 1 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	6	*3.64*	*1.90*	*1C*	*NA* [f]	*NA*	0.086	291	(NW)
2	6	21.9	3.26	1B	SE	5	0.013	38.8	(NE)
3	8	30.5	4.53	2B	S	5	0.049	21.7	(N)
4	1	*10.9*	*1.62*	*7C*	*NA*	*NA*	0.057	86.9	(E)
5	1	*13.7*	*1.94*	*2D*	*NA*	*NA*	0.421	47.8	(NE)
6	1	*13.7*	*2.03*	*7A*	*NA*	*NA*	0.106	335	(NW)
7	1	*13.2*	*1.96*	*7A*	*NA*	*NA*	0.129	320	(NW)
8	4	*3.27*	*0.486*	*5B*	*NA*	*NA*	0.277	169	(S)
9	4	*3.45*	*0.512*	*3A*	*NA*	*NA*	0.114	222	(SW)

[a] Data from Barnekow and Byrne (2006): Table 13, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 6 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 2. In five sampling intervals (all but Intervals 2, 3, 7, and 8), chloropicrin was below the LOQ in all samplers. Conversely, the highest concentration occurred during Replicate 7, midway through the 12-hour active aeration (i.e., the aeration fan is started at the beginning of Interval 4 and continued through the end of Interval 9, at which point tarps are removed). The highest concentration in Replicate 2 was 244 μg/m^3 (36.2 ppb). This concentration occurred at Sampler 2C (5 ft west of the house) during Interval 7; it is also the highest outdoor concentration in the study.

Higher chloropicrin concentrations were measured in Replicate 2 in Intervals 7 – 8 than earlier in the aeration (Intervals 4 – 6). The difference could be due at least in part to increased vertical mixing; the samplers were 5 ft above the ground, and during aeration chloropicrin was venting from an opening that was at least twice that high. In addition to 2C, three other samplers had quantifiable chloropicrin during Interval 7: Samplers 8A (100 ft northeast), 5B (25 ft southeast), and 4D (10 ft north). During Interval 8, three samplers other than 6A had quantifiable chloropicrin: 1A (5 ft northeast), 8B (100 ft southeast), and 5C (25 ft southwest).

Table 6. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 2 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	6	*3.38*	*0.503*	*4A*	*NA* [f]	*NA*	0.153	205	(SW)
2	7	41.2	6.12	1B	SE	5	0.044	339	(NW)
3	8	39.1	5.82	1B	SE	5	0.122	353	(N)
4	1	*11.8*	*1.76*	*6A*	*NA*	*NA*	0.121	8.32	(N)
5	1	*13.4*	*2.00*	*2B*	*NA*	*NA*	0.166	342	(N)
6	1	*13.8*	*2.05*	*7A*	*NA*	*NA*	0.209	343	(N)
7	1	244	36.3	2C	W	5	0.185	116	(SE)
8	4	64.6	9.61	6A	NE	50	0.169	178	(S)
9	4	*3.40*	*0.505*	*8D*	*NA*	*NA*	0.162	252	(W)

[a] Data from Barnekow and Byrne (2006): Table 14, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 7 summarizes the highest chloropicrin concentration at an outdoor sampler in each interval in Replicate 3. Quantifiable chloropicrin occurred during Interval 1 in samplers 5 – 10 ft north, northeast, east, and west of the house (Samplers 2A, 4A, 1B, 2B, 3B, 4B, 2D, and 4D); the wind direction was predominantly from the northeast, but it was variable during the interval. During Interval 2, chloropicrin was above the LOQ at 16 of the 32 samplers, including most of the ones 5 and 10 ft from the house and up to 50 ft away (i.e., 6C located 50 ft southeast of the house). During Interval 3, chloropicrin above the LOQ was measured at 23 samplers, including all that were within 25 ft of the house, and all samplers up to 75 ft from its southwest corner. In all six sampling intervals during aeration (i.e., Intervals 4 – 9), chloropicrin was below the LOQ in all samplers.

The highest concentration in Replicate 3 was 50.3 μg/m^3 (7.48 ppb). This concentration occurred at Sampler 2B (5 ft east of the house) in Interval 2, during fumigation.

Table 7. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 3 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]
		(μg/m^3)	ppb	Name	Location	Distance		
1	2	31.4	4.67	2B	E	5	0.429	46.6 (NE)
2	7	50.3	7.48	2B	E	5	0.978	23.5 (NE)
3	8	35.6	5.29	2A	N	5	0.712	91.3 (E)
4	1	*11.5*	*1.71*	*2C*	*NA* [f]	*NA*	0.403	80.5 (E)
5	1	*13.3*	*1.98*	*5B*	*NA*	*NA*	0.358	68.0 (NE)
6	1	*13.2*	*1.96*	*7C*	*NA*	*NA*	1.72	88.6 (E)
7	1	*13.1*	*1.94*	*5A*	*NA*	*NA*	2.19	82.7 (E)
8	4	*3.27*	*0.486*	*many*	*NA*	*NA*	0.616	67.8 (NE)
9	4	*3.31*	*0.492*	*7B*	*NA*	*NA*	0.553	286 (W)

[a] Data from Barnekow and Byrne (2006): Table 15, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 8 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 4. In four sampling intervals (Intervals 5 – 8), chloropicrin was below the LOQ in all samplers. Conversely, the highest concentrations occurred during Replicate 9, at the end of the 12-hour active aeration; the highest concentration associated with the replicate (129 μg/m^3; 7.86 ppb) was measured during this interval.

During Interval 9, quantifiable chloropicrin concentrations were measured at eleven samplers (1C, 2C, 4C, 5C, 8C, 1D, 2D, 4D, 5D, 6D, 8D), all to the southeast, south, southwest, or west of the tarped structure. Barnekow and Byrne considered these concentrations to be "anomalous," noting that chloropicrin during earlier intervals was below the LOQ at all samplers, and that during Interval 9 quantifiable chloropicrin did not occur at other samplers to the southeast or southwest (specifically, 3C, 6C, 7C, 3D, and 7D). However, the appearance of quantifiable chloropicrin in an aeration interval following intervals during which all samples were below the LOQ also occurred in Replicate 2. Furthermore, because it is typical for a volatilized chemical from a point source to move downwind in a meandering plume, it is possible for some samplers to be "skipped" by the plume and to measure no quantifiable chloropicrin. Increased vertical mixing might account for the fact that chloropicrin was quantifiable in Interval 9 but not in previous intervals, as the aeration vent was located approximately 10 ft above ground, and samplers were 5 ft high. But the wind during Interval 9 was on average out of the south, and

during each 5-minute interval in the sampling period the wind was either from the south, the southeast, or the southwest. The wind direction suggests that the chloropicrin in samplers south of the structure might not have come from the structure, but no definite conclusion can be drawn from the available information.

Table 8. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 4 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	4	11.7	1.74	2B	E	5	1.10	290	(W)
2	8	12.4	1.85	2B	E	5	0.101	333	(NW)
3	8	19.2	2.86	2B	E	5	0.631	88.5	(E)
4	1	30.5	4.53	4D	W	10	1.69	85.3	(E)
5	1	*13.2*	*1.96*	*4D*	*NA* [f]	*NA*	1.57	102	(E)
6	1	*13.4*	*2.00*	*4A*	*NA*	*NA*	1.36	111	(E)
7	1	*13.4*	*2.00*	*4B*	*NA*	*NA*	0.817	122	(SE)
8	4	*3.36*	*0.499*	*5C*	*NA*	*NA*	0.852	183	(S)
9	4	129	19.2	2D	*NA*	*NA*	1.03	187	(S)

[a] Data from Barnekow and Byrne (2006): Table 16, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 9 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 5. In all but Intervals 2, 3, and 8, chloropicrin was below the LOQ at all samplers. Quantifiable chloropicrin occurred in 8-hour time-weighted average (TWA) samples collected during Interval 2 at samplers 5 – 10 ft north and west of the house (Samplers 2C, 2D, and 4D); the wind direction was predominantly from the south. During Interval 3, the dominant wind direction was from the northeast, and quantifiable chloropicrin was measured at samplers 5 – 10 ft south, west, and north of the house (Samplers 2B, 2C, 4C, 2D, and 4D). The highest concentration in Replicate 5 was 21.4 μg/m^3 (3.19 ppb). This concentration occurred during Interval 8, midway through the aeration period, at sampler 4D, which was north of the house. During Interval 8 chloropicrin above the LOQ was also measured at all four of the samplers 5 – 10 ft north and northwest of the house (Samplers 1D, 2D, 3D, and 4D); the wind direction was predominantly from the northeast.

Table 9. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 5 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	6	*3.30*	*0.491*	*8D*	*NA* [f]	*NA*	0.205	68.7	(NE)
2	7	8.16	1.21	2D	N	5	0.025	170	(S)
3	8	7.26	1.08	2C	W	5	0.088	64.7	(NE)
4	1	*11.5*	*1.71*	*7D*	*NA*	*NA*	0.046	73.7	(E)
5	1	*14.2*	*2.11*	*8A*	*NA*	*NA*	0.015	324	(NW)
6	1	*13.1*	*1.94*	*2A*	*NA*	*NA*	0.017	45.8	(NE)
7	1	*13.1*	*1.94*	*3D*	*NA*	*NA*	0.000	270	(W)
8	4	21.4	3.19	4D	N	10	0.636	54.2	(NE)
9	4	*3.40*	*0.505*	*7B*	*NA*	*NA*	0.396	23.6	(N)

[a] Data from Barnekow and Byrne (2006): Table 17, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 10 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 6. In all but Intervals 2, 3, and 8, chloropicrin was below the LOQ in all samplers. The highest concentration of 16.4 μg/m^3 (2.44 ppb) occurred during Interval 2, at Sampler 4B, 10 ft south of the house.

During Interval 2, quantifiable chloropicrin concentrations were measured at eleven samplers (1A, 2A, 4A, 1B, 2B, 3B, 4B, 5B, 1C, 2C, 2D), radiating from the tarped structure in all directions except northwest; the wind was predominantly out of the west. During Interval 3 quantifiable chloropicrin was measured at a single sampler (1C), located 5 ft southwest of the house. And during Interval 9, chloropicrin was above the LOQ at two samplers (2A and 4A), 5 and 10 ft east of the house.

Table 10. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 6 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	4	*3.31*	*0.493*	*7B*	*NA* [f]	*NA*	0.334	254	(W)
2	8	16.4	2.44	4B	S	10	0.413	289	(W)
3	8	9.37	1.39	1C	SW	5	0.165	60.5	(NE)
4	1	*11.2*	*1.67*	*1D*	*NA*	*NA*	0.133	66.4	(NE)
5	1	*13.0*	*1.93*	*8C*	*NA*	*NA*	0.080	76.7	(E)
6	1	*13.4*	*2.00*	*3C*	*NA*	*NA*	0.016	90.7	(E)
7	1	*13.4*	*2.00*	*8D*	*NA*	*NA*	0.049	272	(W)
8	4	*3.27*	*0.486*	*many*	*NA*	*NA*	0.316	233	(SW)
9	4	8.27	1.23	4A	E	10	0.753	271	(W)

[a] Data from Barnekow and Byrne (2006): Table 18, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 11 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 7. In Intervals 5 – 9, chloropicrin was below the LOQ in all samplers. The highest concentration of 54.7 μg/m^3 (8.13 ppb) occurred during Interval 4, which spanned the first hour of the aeration period. During Interval 1, quantifiable chloropicrin was measured at Sampler 1B, 5 ft east of the house. The wind was predominantly from the southwest in Interval 2, and chloropicrin was above the LOQ at twelve samplers (1A, 3A, 1B, 2B, 3B, 1C, 2C, 3C, 1D, 2D, 3D, 5D), located on all but the northeast corner of the house. Chloropicrin was above the LOQ in eight samplers during Interval 3 (1A, 3A, 1B, 1C, 3C, 1D, 3D, 5D), located on the north, east, south, and west sides. During Interval 4 chloropicrin above the LOQ was measured at all six of the samplers that were west of the house (1D, 3D, 5D, 6D, 7D and 8D); the wind direction was predominantly from the northeast.

Table 11. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 7 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	6	7.66	1.14	1B	E	5	0.459	216	(SW)
2	7	26.0	3.86	1B	E	5	0.206	232	(SW)
3	8	22.7	3.37	1B	E	5	0.179	123	(SE)
4	1	54.7	8.13	8D	W	100	0.159	67.6	(NE)
5	1	*13.4*	*2.00*	*5B*	*NA* [f]	*NA*	0.418	179	(S)
6	2	*6.71*	*0.998*	*8A*	*NA*	*NA*	0.746	188	(S)
7	4	*4.59*	*0.683*	*8B*	*NA*	*NA*	0.173	71.2	(E)
8	8	*1.77*	*0.263*	*2D*	*NA*	*NA*	0.495	279	(W)
9	8	*1.96*	*0.292*	*7B*	*NA*	*NA*	0.185	302	(NW)

[a] Data from Barnekow and Byrne (2006): Table 19, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Table 12 summarizes the highest chloropicrin concentration at an outdoor sampler in each sampling interval in Replicate 8. In all but Intervals 2, 3, and 5, chloropicrin was below the LOQ in all samplers. During Interval 2, chloropicrin was above the LOQ at samplers 5 – 10 ft to the west of the house. During Interval 3, quantifiable chloropicrin was measured at eight samplers (1A, 3A, 1B, 3B, 1C, 3C, 5C, 1D), located on the north, east, south, and west sides. The highest concentration of 33.5 μg/m^3 (4.98 ppb) occurred at Sampler 1D (5 ft west) during Interval 5, in the aeration period; chloropicrin was also above the LOQ at two other samplers (2C and 3D), on the southwest corner and west side of the house.

Table 12. Highest Outdoor Chloropicrin Concentration in Each Interval in Replicate 8 [a]

Interval	Hours	Highest Concentration [b]		Sampler [c]			Mean Wind Speed (m/s) [d]	Mean Wind Direction [e]	
		(μg/m^3)	ppb	Name	Location	Distance			
1	4	*3.36*	*0.499*	*many*	*NA* [f]	*NA*	0.677	251	(W)
2	4	9.59	1.43	1D	S	5	0.174	86.5	(E)
3	8	12.4	1.85	1B	E	5	0.368	253	(W)
4	1.75	*11.6*	*1.72*	*1D*	*NA*	*NA*	0.241	307	(NW)
5	1.75	33.5	4.98	1D	W	5	0.495	25.4	(NE)
6	2	*7.08*	*1.05*	*5D*	*NA*	*NA*	0.304	111	(E)
7	4	*3.56*	*0.529*	*2C*	*NA*	*NA*	0.835	133	(SE)
8	7	*1.86*	*0.276*	*5B*	*NA*	*NA*	0.251	99.9	(E)
9	8	*1.68*	*0.250*	*1C*	*NA*	*NA*	0.210	73.3	(E)

[a] Data from Barnekow and Byrne (2006): Table 20, Table B-2 in Appendix B and Table 11 in Appendix C.
[b] Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For intervals when all samples were <LOQ, the highest concentration was calculated by dividing ½ LOQ by the smallest sample volume.
[c] Sampler where highest concentration in interval occurred. Location and distance are with respect to the house; distance is in feet from house. Multiply values by 0.305 to get distance in meters.
[d] Wind speed measured in 5-minute increments and averaged over each sample interval. Reported value is resultant mean wind speed. Multiply value by 2.24 to express result as miles/hour.
[e] Resultant mean wind direction. Wind is from the north at 0 degrees, from the east at 90 degrees, from the south at 180 degrees, and from the west at 270 degrees.
[f] NA: Not applicable. All samplers were <LOQ in this interval, and the sampler with the highest concentration is based on volume sampled (See Footnote b). For this reason, the sampler location is irrelevant.

Indoor Concentrations

Post-clearance indoor chloropicrin concentrations were measured at four indoor samplers in each of eight houses for eight sampling intervals, for a total of 256 samples. However, one sample from Replicate 4 was lost during analysis. Thus, a total of 255 samples were analyzed. Of these, 231 (90.6%) contained chloropicrin above the LOQ.

Table 13 summarizes indoor air concentrations in Replicate 1. Chloropicrin was above the LOQ during all sampling intervals in the bedroom and utility area. Concentrations in the bedroom ranged from 79.7 μg/m^3 (11.8 ppb) to 550 μg/m^3 (81.8 ppb). Concentrations in the utility area ranged 14.8 – 505 μg/m^3 (2.20 – 75.1 ppb). In the attic, chloropicrin concentrations were below the LOQ during the first and fourth 8-hour intervals (Intervals 14 and 17); however, the study report notes that the measurement during Interval 14 is erroneous (and the concentration underestimated) because the sample tube was put in backwards, which caused the back-up section to absorb chloropicrin. The error was not caught prior to analysis, and because no chloropicrin was detected in the front section the back-up section was not analyzed. In the crawl space, chloropicrin was below the LOQ during the four 1-hour intervals (Intervals 10 – 13), and ranged 18.1 – 57.9 μg/m^3 (2.69 – 8.62 ppb) during the first three 8-hour intervals.

Table 13. Indoor Chloropicrin Concentrations in Replicate 1 [a]

Interval	Hours	Attic (1E)		Bedroom (2E)		Utility Area (3E)		Crawl Space (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	502	74.6	550	81.8	315	46.8	*12.1*	*1.79*
11	1	439	65.3	515	76.5	276	41.0	*13.0*	*1.93*
12	1	389	57.8	447	66.5	164	24.4	*11.0*	*1.63*
13	1	296	44.0	339	50.4	505	75.1	*11.0*	*1.63*
14	8	*1.62* [b]	*0.240*	206	30.7	64.1	9.53	18.1	2.69
15	8	152	22.6	136	20.2	42.8	6.36	57.9	8.62
16	8	179	26.6	180	26.8	63.8	9.49	50.6	7.53
17	8	*1.64*	*0.243*	79.7	11.8	14.8	2.20	*1.64*	*0.245*

[a] Data from Barnekow and Byrne (2006): Table 73 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.
[b] Sample tube was placed in pump backwards, and only the front section was analyzed.

Table 14 summarizes indoor air concentrations in Replicate 2. Chloropicrin was above the LOQ during all sampling intervals in the attic, bedroom, and utility area. Concentrations in the attic ranged 146 – 657 μg/m^3 (21.7 – 97.7 ppb). In the bedroom chloropicrin concentrations ranged 142 – 636 μg/m^3 (21.1 – 94.6 ppb), and in the utility area they ranged 13.9 – 165 μg/m^3 (2.06 – 24.5 ppb). Chloropicrin concentrations in the crawl space were above LOQ only during Intervals 14 – 16, when they ranged 12.3 – 59.0 μg/m^3 (1.82 – 8.78 ppb).

Table 14. Indoor Chloropicrin Concentrations in Replicate 2 [a]

Interval	Hours	Attic (1E)		Bedroom (2E)		Utility Area (3E)		Crawl Space (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	429	63.7	488	72.6	165	24.5	*11.8*	*1.75*
11	1	373	55.5	479	71.3	65.4	9.73	*12.8*	*1.90*
12	1	472	70.3	551	81.9	114	17.0	*12.4*	*1.85*
13	1	657	97.7	636	94.6	110	16.3	*12.8*	*1.90*
14	8	215	32.0	226	33.6	48.4	7.20	12.3	1.82
15	8	237	35.2	191	28.4	69.1	10.3	59.0	8.78
16	8	248	36.8	284	42.2	56.0	8.33	27.5	4.10
17	8	146	21.7	142	21.1	13.9	2.06	*1.60*	*0.238*

[a] Data from Barnekow and Byrne (2006): Table 73 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.

Table 15 summarizes indoor air concentrations in Replicate 3. All indoor samplers measured chloropicrin above the LOQ during all sampling intervals. Concentrations in the attic ranged 142 – 536 μg/m^3 (21.2 – 79.7 ppb). The highest concentrations were measured in the bedroom,

ranging 281 – 698 μg/m^3 (41.7 – 104. ppb). In the utility area concentrations ranged 39.7 – 201 μg/m^3 (5.91 – 29.9 ppb), and in the crawl space they ranged 240 – 541 μg/m^3 (35.7 – 80.4 ppb).

Table 15. Indoor Chloropicrin Concentrations in Replicate 3 [a]

Interval	Hours	Attic (1E)		Bedroom (2E)		Utility Area (3E)		Crawl Space (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	397	59.1	462	68.7	134	20.0	288	42.8
11	1	426	63.4	578	86.0	201	29.9	323	48.1
12	1	481	71.6	588	87.4	191	28.4	402	59.7
13	1	536	79.7	698	104	140	20.8	541	80.4
14	8	307	45.6	401	59.6	87.2	13.0	349	51.9
15	8	283	42.1	362	53.8	82.2	12.2	321	47.7
16	8	284	42.3	300	44.5	57.2	8.51	304	45.3
17	8	142	21.2	281	41.7	39.7	5.91	240	35.7

[a] Data from Barnekow and Byrne (2006): Table 74 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures.

Table 16 summarizes indoor air concentrations in Replicate 4. The highest indoor concentration in the study, 3,060 μg/m^3 (456 ppb), occurred in this replicate, in the crawl space during the second hour post-clearance (Interval 11); the second highest concentration, 3,010 μg/m^3 (448 ppb), occurred in the bedroom during the first post-clearance hour (Interval 10). Chloropicrin was above the LOQ during all sampling intervals in the attic and bedroom, ranging 6.43 – 2,270 μg/m^3 (0.956 – 337 ppb) and 4.69 – 3,010 μg/m^3 (0.697 – 448 ppb), respectively. The bedroom sample collected during the last monitoring interval was reported to have been lost during analysis. Concentrations in the crawl space were above the LOQ in all but the last sampling interval, ranging 2.73 – 3,060 μg/m^3 (0.406 – 456 ppb). In the utility area, concentrations were above the LOQ during all but Interval 13, ranging 10.8 – 38.0 μg/m^3 (1.61 – 5.65 ppb).

Table 16. Indoor Chloropicrin Concentrations in Replicate 4 [a]

Interval	Hours	Attic (1E)		Bedroom (2E)		Utility Area (3E)		Crawl Space (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	2,270	337	3,010	448	29.2	4.34	2,960	440
11	1	2,000	297	2,880	429	38.0	5.65	3,060	456
12	1	669	99.5	2,000	297	28.5	4.23	2,020	300
13	1	357	53.1	1,020	152	*12.5*	*1.86*	1,060	158
14	8	12.9	1.92	7.33	1.09	13.0	1.93	7.46	1.11
15	8	6.95	1.03	4.69	0.697	26.4	3.92	3.12	0.465
16	8	6.94	1.03	6.81	1.01	10.8	1.61	2.73	0.406
17	6	6.43	0.956	LS [b]	LS	14.6	2.17	*2.08*	*0.309*

[a] Data from Barnekow and Byrne (2006): Table 74 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.
[b] LS = Lost sample. The sample was lost during analysis.

Table 17 summarizes indoor air concentrations in Replicate 5. Chloropicrin was above the LOQ during all sampling intervals in the attic and utility area, ranging 214 – 1,510 μg/m^3 (31.8 – 225 ppb) and 565 – 1,880 μg/m^3 (84.1 – 279 ppb), respectively. Concentrations in the living room were above the LOQ in all but the second post-clearance interval (Interval 11), ranging 547 – 2,040 μg/m^3 (81.3 – 303 ppb). It is unclear why chloropicrin was below the LOQ during the second hour post-clearance, given that concentrations exceeded 1,000 μg/m^3 during the first hour (Interval 10) and in the 26 hours following that sample (Intervals 12 – 15). In the crawl space, concentrations were above the LOQ during the first two hours post-clearance and in the first three 8-hour samples, ranging 17.7 – 50.8 μg/m^3 (2.63 – 7.56 ppb).

Table 17. Indoor Chloropicrin Concentrations in Replicate 5 [a]

Interval	Hours	Attic (1E)		Living Room (2E)		Crawl Space (3E)		Utility Area (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	753	112	1,340	199	46.1	6.85	1,120	167
11	1	839	125	*13.0*	*1.93*	50.8	7.56	1,880	279
12	1	1,430	212	2,040	303	*13.0*	*1.93*	1,610	240
13	1	1,510	225	1,750	260	*12.5*	*1.86*	1,880	279
14	8	921	137	1,230	183	18.9	2.82	1,060	157
15	8	748	111	1,040	155	21.6	3.21	1,180	175
16	8	333	49.5	824	123	17.7	2.63	751	112
17	8	214	31.8	547	81.3	*1.60*	*0.238*	565	84.1

[a] Data from Barnekow and Byrne (2006): Table 75 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.

Table 18 summarizes indoor air concentrations in Replicate 6. Chloropicrin was above the LOQ during all sampling intervals in the attic, ranging 89.4 – 503 μg/m^3 (13.3 – 74.8 ppb). Concentrations in the living room, crawl space, and utility area were above the LOQ in all but the last sampling interval, ranging 79.0 – 294 μg/m^3 (11.7 – 43.7 ppb), 57.8 – 1,090 μg/m^3 (8.60 – 162 ppb), and 54.9 – 289 μg/m^3 (8.17 – 43.0 ppb), respectively.

Table 18. Indoor Chloropicrin Concentrations in Replicate 6 [a]

Interval	Hours	Attic (1E)		Living Room (2E)		Crawl Space (3E)		Utility Area (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	503	74.8	294	43.7	492	73.2	289	43.0
11	1	254	37.8	190	28.2	1,090	162	132	19.6
12	1	279	41.4	286	42.5	452	67.2	111	16.4
13	1	199	29.6	181	26.9	431	64.1	71.2	10.6
14	8	165	24.6	189	28.1	264	39.2	84.9	12.6
15	8	89.4	13.3	79.0	11.7	121	18.0	54.9	8.17
16	8	94.4	14.0	211	31.4	57.8	8.60	194	28.8
17	6	261	38.8	*1.49*	*0.221*	*1.50*	*0.223*	*1.49*	*0.222*

[a] Data from Barnekow and Byrne (2006): Table 75 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.

Table 19 summarizes indoor air concentrations in Replicate 7. Concentrations in the attic, living room, and utility area were above the LOQ in all sampling intervals, ranging 21.5 – 92.2 μg/m^3 (3.19 – 13.7 ppb), 82.0 – 292 μg/m^3 (12.2 – 43.4 ppb), and 25.0 – 264 μg/m^3 (3.71 – 39.2 ppb), respectively. Concentrations in the crawl space were above the LOQ in all but the first post-clearance and next-to-last sampling intervals, ranging 12.5 – 141 μg/m^3 (1.86 – 20.9 ppb).

Table 19. Indoor Chloropicrin Concentrations in Replicate 7 [a]

Interval	Hours	Attic (1E)		Living Room (2E)		Crawl Space (3E)		Utility Area (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	81.6	12.1	115	17.1	*12.8*	*1.90*	119	17.6
11	1	84.4	12.6	132	19.6	55.6	8.27	122	18.2
12	1	69.6	10.4	219	32.5	62.6	9.32	117	17.3
13	1	57.7	8.58	204	30.3	86.9	12.9	141	21.0
14	8	35.1	5.22	292	43.4	141	20.9	264	39.2
15	8	92.2	13.7	195	29.0	59.5	8.84	170	25.3
16	8	56.6	8.41	82.0	12.2	*1.59*	*0.237*	25.0	3.71
17	8	21.5	3.19	82.2	12.2	12.5	1.86	52.7	7.84

[a] Data from Barnekow and Byrne (2006): Table 76 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.

Table 20 summarizes indoor air concentrations in Replicate 8. Chloropicrin was above the LOQ at all samplers through the end of the monitoring intervals, except for the crawl space sampler in the first hour post-clearance. The highest concentrations were measured in the utility area and living room, ranging 50.5 – 116 μg/m^3 (7.51 – 17.3 ppb) and 39.5 – 103 μg/m^3 (5.88 – 15.3 ppb), respectively. Concentrations in the attic ranged 23.1 – 87.1 μg/m^3 (3.44 – 13.0 ppb). Chloropicrin was above the LOQ in the crawl space during all samples except the first hour post-clearance, ranging 24.2 – 94.3 μg/m^3 (3.60 – 14.0 ppb), respectively.

Table 20. Indoor Chloropicrin Concentrations in Replicate 8 [a]

Interval	Hours	Attic (1E)		Living Room (2E)		Crawl Space (3E)		Utility Area (4E)	
		(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)	(μg/m^3)	(ppb)
10	1	57.8	8.59	50.9	7.57	*13.9*	*2.06*	116	17.3
11	1	87.1	13.0	85.3	12.7	94.3	14.0	110	16.3
12	1	69.6	10.4	101	15.0	76.6	11.4	68.4	10.2
13	1	57.4	8.54	103	15.3	82.4	12.3	64.3	9.56
14	8	58.2	8.65	39.5	5.88	75.5	11.2	85.1	12.7
15	8	50.9	7.57	80.7	12.0	63.0	9.37	67.2	9.99
16	8	46.9	6.98	82.8	12.3	24.2	3.60	50.5	7.51
17	6	23.1	3.44	61.3	9.11	70.3	10.5	89.6	13.3

[a] Data from Barnekow and Byrne (2006): Table 76 and Table B-2 in Appendix B. Concentrations in micrograms per cubic meter and parts per billion (ppb), rounded to three significant figures. Italicized results are from samples below the limit of quantification (LOQ). For samples <LOQ, the concentration was calculated by dividing ½ LOQ by the sample volume.

Exposure Estimates from Study

Outdoor chloropicrin concentrations measured in this study can be used to estimate chloropicrin exposures of bystanders to structural fumigation, and indoor concentrations can be used to estimate exposures of individuals entering treated structures following fumigation and clearance.

Outdoor Concentrations

The highest outdoor concentration during a 1-hour interval occurred in Replicate 2 and was **244 μg/m^3 (36.2 ppb)**. This concentration was measured at Sampler 2C (5 ft west of the house) during Interval 7, the fourth hour of aeration. As the highest offsite concentration for a 1-hour interval associated with structural fumigation, this concentration will be used to estimate 1-hour exposure of bystanders to chloropicrin.

The highest outdoor concentration measured during an interval longer than an hour also occurred in Replicate 2; it was 41.2 μg/m^3 (6.12 ppb). This was a 7-hour sample, collected during Interval 2, during fumigation.

However, higher concentrations occurred during Intervals 4 – 8 in Replicate 2, which together span 8 hours. The rolling time-weighted average concentration from these samplers will be used

to estimate occupational bystander exposure (the 1-hour multiples are omitted from the equation below, and only the 4-hour multiplier is shown explicitly):
[11.8 + 13.4 + 13.8 + 244 + (4 x 64.6)]/8 = **67.7 µg/m^3 (10.1 ppb).**

The longest sampling interval in this study was 8 hours. Although no 24-hour samples were collected, 24-hour concentrations for residential bystander exposure can be estimated as rolling time-weighted averages. The highest concentration estimated this way is from Intervals 2 – 8 in Replicate 2, which span 23 hours (as above, 1-hour multipliers are omitted from the equation):
[(7 x 41.2) + (8 x 39.1) + 11.8 + 13.4 + 13.8 + 244 + (4 x 64.6)]/23 = **49.7 µg/m^3 (7.39 ppb).**

Indoor Concentrations
The highest indoor concentration during a 1-hour interval occurred in Replicate 4 and was **3,060 µg/m^3 (456 ppb).** Although this concentration was measured in the crawl space, an area not normally occupied in a house, it is only slightly higher than a 1-hour concentration of 3,010 µg/m^3 (448 ppb) measured in the bedroom of the same replicate. Furthermore, in other replicates (including Replicate 3, which used the same house as Replicate 4), the highest concentrations occurred in areas other than the crawl space, suggesting that crawl space concentrations do not generally overestimate concentrations elsewhere in the house. Additionally, there is no reason to exclude the crawl space as a non-representative location; for example, it could represent an occupied basement. Underground rooms are becoming common in parts of California where zoning laws limit expansion upward or outward (Sims, 2001). Finally, only four samplers were placed inside each house, and a compelling reason would be needed to exclude data from any one of them. Thus, this concentration is considered representative of reentry exposure associated with structural fumigation, and will be used to estimate 1-hour reentry exposure to chloropicrin.

The highest indoor concentration during an 8-hour interval (needed for occupational reentry exposure) was measured in the living room in Replicate 5 and was **1,230 µg/m^3 (183 ppb)**. Unlike the 1-hour concentration, it comes from an area in the house that is likely to be occupied. This concentration will be used to estimate 8-hour occupational reentry exposure to chloropicrin.

Although no 24-hour indoor samples were collected for residential reentry exposure estimates, 24-hour concentrations can be estimated as rolling time-weighted averages spanning intervals that approximate 24 hours. The highest concentration estimated this way is from Intervals 10 – 15 in the living room of Replicate 5, which span 20 hours:
[1,340 + 13.0 + 2,040 + 1,750 + (8 x 1,230) + (8 x 1,040)]/20 = **1,160 µg/m^3 (172 ppb).**

Table 21 summarizes bystander and residential reentry (indoor) exposures estimated from this study that will be used in the exposure assessment.

Table 21. Chloropicrin Exposure Estimates for Bystander and Reentry Scenarios

	Bystanders		Reentry	
	(µg/m^3)	(ppb)	(µg/m^3)	(ppb)
1- hour	244	36.2	3,060	456
8-hour	67.7	10.1	1,230	183
24-hour	49.7	7.39	1,160	172

Comments for Exposure Appraisal

To decrease the likelihood of underestimating exposures, results in this memo were corrected for field spike recoveries. This practice is recommended by U.S. EPA for data used to estimate exposure (U.S. EPA, 1992); DPR is in accordance with U.S. EPA policy to correct only for field spike recoveries below 90% (U.S. EPA, 1998). Corrections for field spike recoveries are intended to compensate for loss of analyte during the sampling period and subsequent transportation and storage, as well as incomplete recovery in the analysis; the correction assumes that both sample and spiked tubes are subjected to the same factors at similar intensities. Rather than correct for field spike recoveries, Barnekow and Byrne (2006) corrected results for pooled laboratory and field spike recoveries. Laboratory spikes are intended to account for differences between analytical batches in factors such as extraction, reagents, and equipment calibration, and do not account for conditions in the field during sample collection and processing. As sampling intervals were quite long in some cases (as long as 8 hours), and as conditions differed substantially between some sites, DPR believes that correction for field spike recoveries is appropriate for these samples.

Nominally, the use rate for chloropicrin was the same in all eight replicates, suggesting that results can be pooled across replicates without adjustment for application rates. Although the amount of chloropicrin used during each fumigation was reported (to two significant figures), the fumigation volume was not reported. Insufficient information was provided to verify application rates were the same between the four houses; however, as shown in Table 1, different amounts of chloropicrin were reported between replicates in the third and fourth houses. It is possible that the houses were tarped differently, or that there was another factor causing a difference in fumigation volume between the first and second fumigations of these houses. Alternately, perhaps the chloropicrin was not measured with the same precision in those houses as in the first two houses. Regardless of the reason for the difference in chloropicrin amounts used, as all fumigations were conducted by commercial fumigators they are considered to reflect realistic conditions. Concentrations were not adjusted for possible differences in application rates.

Outdoor concentrations were measured only during fumigation and aeration. Once the aeration was considered complete (and sulfuryl concentrations were below 5 ppm, the concentration requiring respiratory protection at that time), only indoor samples were collected. However, the indoor samples suggest that substantial chloropicrin was present indoors, particularly in

Replicates 3, 4, and 5. Bystanders could potentially continue to be exposed to chloropicrin following clearance.

The study reviewed here was conducted in 2004 and 2005. Since then, SF product labels have been changed. Current product labels require respiratory protection at concentrations exceeding 1 ppm, and unprotected persons are prohibited from entering fumigated structures until SF concentrations are at or below 1 ppm. Reported post-clearance SF concentrations were consistently below 1 ppm (4,200 $\mu g/m^3$) in Replicates 1, 2, 3, 6, 7, and 8. In Replicates 4 and 5, post-clearance concentrations were below 1 ppm within 20 hours of clearance. Post-clearance chloropicrin concentrations in this study suggest that even with an additional day for aeration, individuals entering post-clearance could be exposed to chloropicrin.

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APPENDIX 1. TEMPERATURE RANGES DURING FUMIGATION AND AERATION.

Table A1. Outdoor Temperatures Reported During Fumigation and Aeration [a]

House	Location	Replicate	Event [b]	Temperature Range (°C)		Temperature Range (°F)	
				Minimum	Maximum	Minimum	Maximum
1	Ojai	1	Fumigation	7.4	12.0	45.3	53.6
			Aeration	8.5	18.1	47.3	64.6
	Ojai	2	Fumigation	5.1	17.3	41.2	63.1
			Aeration	4.7	22.5	40.5	72.5
2	Homeland	3	Fumigation	6.7	22.2	44.1	72.0
			Aeration	7.1	21.5	44.8	70.7
	Homeland	4	Fumigation	6.7	21.9	44.1	71.4
			Aeration	10.2	19.9	50.4	67.8
3	Reedley	5	Fumigation	8.8	10.3	47.8	50.5
			Aeration	8.7	10.0	47.7	50.0
	Reedley	6	Fumigation	-0.7	13.8	30.7	56.8
			Aeration	-1.7	14.0	28.9	57.2
4	Reedley	7	Fumigation	10.7	18.4	51.3	65.1
			Aeration	10.9	13.5	51.6	56.3
	Reedley	8	Fumigation	7.4	12.0	45.3	53.6
			Aeration	8.5	18.1	47.3	64.6

[a] Temperatures were 5-minute averages; minimum and maximum temperatures from Barnekow and Byrne (2006), Tables 13 – 20.
[b] Fumigation spans Intervals 1 – 3 and aeration spans Intervals 4 - 9.

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