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MEMORANDUM

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HSM-03012

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SUBJECT: MITIGATION MEASURES FOR SEASONAL EXPOSURES OF
AGRICULTURAL WORKERS TO METHYL BROMIDE DURING SOIL
FUMIGATIONS

The Department of Pesticide Regulation (DPR) proposes the following mitigation measures to reduce seasonal exposures of agricultural workers during soil fumigations using products containing methyl bromide. This mitigation proposal is intended to reduce methyl bromide levels to or below the reference concentration, which is used as the regulatory target level, of 16 parts per billion (ppb) calculated as the 24-hour Time-Weighted-Average (TWA) concentration. The method employed for setting this target level is described in Lim (2003). In brief, Medical Toxicology staff recommended this target exposure level based on effects reported in a six-week study conducted in dogs. Based on an absence of proprioceptive placing response in beagles, the No-Observed-Effect Level (NOEL) was established at 5 parts per million (ppm). The human equivalent NOEL was determined to be 1.56 ppm (Lim, 2003). The reference concentration level of 16 ppb (for adults) was calculated by dividing the NOEL of 1.56 ppm by an uncertainty factor of 100. For a complete review of the available toxicity data, see Lim, 2003.

This mitigation proposal for methyl bromide employs information and data from several sources: (1) Daily methyl bromide exposures - HS-1659 (Thongsinthusak and Haskell, 2002), HSM-00014 (Gibbons and Thongsinthusak, 2000a), HSM-00015 (Gibbons and Thongsinthusak, 2000b), and HSM-97004 (Gibbons and Fong, 1997). (2) Protection factors for half-face and full-face respirators – NIOSH (1987) and HS-1612 (EAMP, 2003). (3) Definitions for acute (short-term) and intermediate-term (seasonal) exposures – HS-1612 (EAMP, 2003).



According to the California Pesticide Use Summaries Database from 1998 to 2000 (UC IPM, 2003), the high use period for methyl bromide in California occurs from August to October. During the highest portion of this high use "season", it is anticipated that agricultural workers may work five to seven days per week over approximately one month. This exposure scenario extends well beyond what would normally be considered short-term (acute) exposure (1 to 7 days) and is significantly less than what is typically considered annual (chronic) exposure (1 year). In this mitigation effort, we refer to this exposure scenario as intermediate-term exposure. Furthermore, we assume that intermediate-term exposure (sometimes referred to as seasonal exposure) is continuous. This one-month intermediate-term exposure was compared to sub-chronic toxicity data for consideration of potential toxicological impacts. For exposure periods beyond one month, it is assumed that the exposures would be intermittent rather than continuous. While the potential for adverse effects from intermittent exposure will not be directly addressed in the mitigation proposal, it is assumed that measures intended to mitigate intermediate-term continuous exposure will adequately mitigate intermediate-term intermittent exposures as well.

The Worker Health and Safety (WH&S) Branch of DPR, uses the arithmetic mean of exposures to represent exposures with durations longer than seven-days (EAMP, 2003). The average (mean) daily exposure is used because an upper bound exposure is considered unlikely to occur on a daily basis over an extended period of time. For exposure durations longer than short-term, a worker is expected to encounter a range of daily exposures with the average daily values assumed to be the best representation of a worker's typical daily exposure. Some of the conditions that would be expected to support this assumption include fluctuations in application rates, changes in environmental conditions such as temperature, wind speed and direction, different soil types, and different soil moisture content in treated fields.

The maximum work time for agricultural workers was determined by using the formula shown below.

Maximum work time (hours)/day = $16 \text{ ppb (regulatory target level)} \times 24 \text{ hours} / \text{Observed (measured) methyl bromide concentration (ppb; not the TWA concentration)}$.

A default protection factor of 90% is applied for a half-face respirator and 99% for a full-face respirator (EAMG, 2003). These default protection factors are consistent with the recommendation of National Institute for Occupational Safety and Health (NIOSH, 1987). When required, handlers of methyl bromide must wear NIOSH-certified respiratory protection specifically recommended by the manufacturer for use in atmospheres containing less than

5 ppm methyl bromide. Fumigation handlers must wear the required respiratory protection during the entire duration of the fumigation handling activity. NIOSH-approved air-supplying respiratory protection may be used in lieu of chemical cartridge respirators.

Handlers of methyl bromide can follow one of the two options of mitigation measures depending on their actual workdays in a period of time.

Option 1. Require a half-face or a full-face respirator.

Seasonal exposure estimates for handlers of methyl bromide and daily maximum work time (hours) for workers performing various work tasks are shown in Table 1. Factors and formula used in the calculation of the maximum work time are shown above. Daily allowable work hours for handlers not wearing a respirator range from 0.4 to 3 hours. In general, most of these restricted daily work hours are considered impractical for handlers of methyl bromide. When these handlers wear an appropriate half-face respirator, daily work hours can be extended, except for a few work tasks as shown in Table 1. An employee may perform fumigation-handling activities without the work hour limitations specified in Table 1 if an appropriate full-face respirator is worn during the entire duration of the activity.

Option 2. Limit maximum workdays to less than three days per calendar month.

As previously indicated, exposure durations of seven-days or fewer are considered short-term (or acute). When workdays for handlers are limited to no more than three-days per calendar month, we assume that intermediate-term exposure and its potential toxicological impact can be avoided. By allowing workers to work any three-days in a single calendar month, a maximum of six-days over a period approximating one month could result; i.e., when back to back three-days per month exposures occur. Under these conditions, we assume that the toxicologic impact would be in response to short-term exposure. Therefore, when handlers follow these workday limitations, they need only follow short-term exposure mitigation measures; i.e., they will not be required to wear respiratory protection provided they follow daily work hour limitations as specified in Table 2. To qualify for this option, handlers must not have work related exposures to methyl bromide for 30-days prior to initiation of this option. Furthermore, they must not be exposed to methyl bromide from performing other work tasks. Adequate records must be kept to confirm these requirements. This option may be time consuming regarding the record keeping and verification processes, however, it will allow less stringent mitigation efforts for occasional users of methyl bromide.

The acceptable fumigation methods for methyl bromide and requirements for each of these methods under options 1 and 2 are shown in Appendix A.

References:

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- Exposure Assessment and Mitigation Program (EAMP). 2003. Guidance for the preparation of human pesticide exposure assessment documents (Draft). Worker Health and Safety Branch, Department of Pesticide Regulation. HS-1612.
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- Lim, L. 2003. Methyl bromide: Risk characterization document - Inhalation exposure. Addendum to Volume I (RCD 2002-03). Medical Toxicology Branch, Department of Pesticide Regulation.
- National Institute for Occupational Safety and Health (NIOSH). 1987. NIOSH respirator decision logic. U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer. May.
- Thongsinthusak, T., and Haskell, D. 2002. Estimation of exposure of persons in California to methyl bromide during and/or after agricultural and nonagricultural uses. Worker Health and Safety Branch, Department of Pesticide Regulation. HS-1659.
- University of California, Statewide Integrated Pest Management Program (UC IPM). 2003. Methyl bromide use in California (1998-2000). (<http://www.ipm.ucdavis.edu/PUSE/puse1.html>).

Table 1. Mitigation Measures for Seasonal Exposures of Agricultural Workers to Methyl Bromide (MB).

Application method	Reference	Work task ^a	Replicate	Without a half-face respirator		With a half-face respirator	
				Mean MB (ppb) (not the TWA)	Maximum work time (hours) ^b	Mean MB (ppb) (not the TWA)	Maximum work time (hours) ^b
(1). Nontarp/ Shallow/Bed	HSM-00014	Applicator	4	416	1	41.6	9
		Cultipacker Driver	1	327	1	32.7	12
(2a). Nontarp/Deep/ Broadcast	HS-1659 (B.6)	Applicator	2	635			
		Cultipacker Driver	1	410			
(2b). Nontarp/Deep/ Broadcast	HS-1659 (B.6)	Applicator	1	240			
		Cultipacker Driver	1	290			
(2c). Nontarp/Deep/ Broadcast	HS-1659 (B.7)	Applicator	1	360			
(2d). Nontarp/Deep/ Broadcast	HS-1659 (B.7)	Applicator	2	388			
		Cultipacker Driver	2	141			
		Supervisor	1	280			
(2e). Nontarp/Deep/ Broadcast	HS-1659 (B.8)	Applicator	1	30			
		Cultipacker Driver	1	30			
(2). Nontarp/Deep/ Broadcast	<u>Weighted- mean MB</u> (from B.6-B.8)	Applicator	7	382	1	38.2	10
		Cultipacker Driver	5	202	2	20.2	19
		Supervisor	1	280	1	28.0	14
(3). Tarp/Shallow/ Broadcast	HS-1659 (B.1)	Applicator	8	459	1	45.9	8
	HS-1659 (B.2)	Copilot	7	926	0.4	92.6	4
	HS-1659 (B.3)	Shoveler	10	609	1	60.9	6
	HS-1659 (B.12)	Tarp cutter ^c	3	326	1	32.6	12
	HS-1659 (B.12)	Tarp remover ^c	12	131	3	13.1	29

Note: HS-1659 (B.6) means MB data were from the exposure document, HS-1659, Table B.6 (Thongsinthusak and Haskell, 2002).

HSM-00014 means MB data were from HSM-00014 (Gibbons and Thongsinthusak, 2000a).

Nontarp/shallow/bed means MB is injected into bedded soil using shallow shanks. Bed is not covered with tarpaulin.

^a Cultipacker driver is synonymous with tractor equipment driver.

^b Determined based on the target exposure level of 16 ppb.

^c A different study employing application method 3 (Tarpaulin/Shallow/Broadcast) is used.

Table 1 (cont.). Mitigation Measures for Seasonal Exposures of Agricultural Workers to Methyl Bromide (MB).

Application method	Reference	Work task	Replicate	Without a half-face respirator		With a half-face respirator	
				Mean MB (ppb) (not the TWA)	Maximum work time (hours) ^a	Mean MB (ppb) (not the TWA)	Maximum work time (hours) ^a
(4a). Tarp/Shallow/ Bed	HS-1659 (B.9)	Applicator	1	330			
		Copilot	2	432			
(4b). Tarp/Shallow/ Bed	HS-1659 (B.9)	Applicator	1	180			
		Copilot	2	690			
(4c). Tarp/Shallow/ Bed	HS-1659 (B.10)	Driver 1(applicator)	1	120			
		Applicator 1	1	180			
		Drip tape layer	1	270			
		Driver 2 (tarp)	1	20			
		Copilot (tarp)	2	142			
(4). Tarp/Shallow/ Bed	<u>Weighted- mean MB</u> (from B.9-B.10)	Applicator	4	203	2	20	19
		Copilot	5	503	1	50	8
		Tarp cutter ^c	Use work time in method (3)				
		Tarp remover ^c	Use work time in method (3)				
(5). Tarp/Deep/ Broadcast ^b	HS-1659 (B.1)	Applicator	8	459	1	45.9	8
		Copilot	7	926	0.4	92.6	4
	HS-1659 (B.2)	Shoveler	10	609	1	60.9	6
		Tarp cutter ^c	Use work time in method (3)				
	HS-1659 (B.3)	Tarp remover ^c	Use work time in method (3)				
(6). Drip System - Hot Gas	Gibbons & Fong (1997)	Applicator	15	793	0.5	79.3	5
		Tarp cutter ^c	Use work time in method (3)				
		Tarp remover ^c	Use work time in method (3)				

^a Determined based on the target exposure level of 16 ppb.

^b No monitoring data for this method, but the application method is considered to be comparable to "Tarpaulin/Shallow/Broadcast (method 3)."

^c A different study employing application method 3 (Tarpaulin/Shallow/Broadcast) is used.

Table 2. Maximum Work Hours in a Maximum 3 Workdays per Calendar Month.

Fumigation Method/Activities	Maximum Application Rate	Maximum Work Hours in a 24-Hour Period (without the use of respirators)
Nontarpaulin/Shallow/Bed: Tractor Equipment Driving	200 lbs.	4*
Nontarpaulin/Deep/Broadcast: Tractor Equipment Driving	400 lbs.	4*
Tarpaulin/Shallow/Broadcast: Tractor Equipment Driving Shoveling, Copiloting Tarpaulin Cutting Tarpaulin Removal	400 lbs.	4* 3* 4 7
Tarpaulin/Shallow/Bed: Tractor Equipment Driving Shoveling, Copiloting Tarpaulin Cutting Tarpaulin Removal	250 lbs.	4* 4* 4 7
Tarpaulin/Deep/Broadcast: Tractor Equipment Driving Shoveling, Copiloting Tarpaulin Cutting Tarpaulin Removal	400 lbs.	4* 3* 4 7
Drip System – Hot Gas: Applicators Tarpaulin Cutting Tarpaulin Removal	225 lbs.	2* 4 7

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*If the actual methyl bromide application rate is less than the maximum application rate shown in the table above for the particular fumigation method used, the maximum work hours may be increased in accordance with the following formula:

$$\left(\frac{\text{maximum application rate for method}}{\text{actual application rate}} \right) \times \frac{\text{maximum work hours in a 24-hour period}}{\text{revised maximum work hours in a 24-hour period}} =$$

Appendix A
Methods of Fumigation for Methyl Bromide

The fumigation shall be made only in accordance with the following restrictions:

(1) Nontarpaulin/Shallow/Bed

- (A) Application rate shall not exceed 200 pounds of methyl bromide per acre.
- (B) The application tractor shall be equipped with an air fan dilution system.
- (C) Rearward-curved (swept-back) chisels shall be used with:
 - 1. closing shoes and bed-shaper, or closing shoes and compaction roller; and
 - 2. chisel injection points positioned beneath and ahead of the closing shoes.
- (D) Injection depth shall be between 10 and 15 inches. The injection depth to preformed beds must not be below the bed furrow.
- (E) Injection spacing shall be 40 inches or less.
- (F) The soil shall not be disturbed for at least three days (72 hours) following completion of injection to the application block.
- (G) The application block restricted-entry interval shall be three days.

(2) Nontarpaulin/Deep/Broadcast

- (A) Application rate shall not exceed 400 pounds of methyl bromide per acre.
- (B) Forward-curved chisel shall be used with:
 - 1. An application tractor equipped with an air fan dilution system, and the injection depth shall be at least 20 inches; or
 - 2. Closing shoes and compaction roller and the injection depth shall be at least 24 inches.
- (C) Injection spacing shall be 68 inches or less.
- (D) The soil shall not be disturbed for at least four days (96 hours) following completion of injection to the application block.
- (E) The application block restricted-entry interval shall be four days.

(3) Tarpaulin/Shallow/Broadcast

- (A) Application rate shall not exceed 400 pounds of methyl bromide per acre.
- (B) Application shall be made using either:
 - 1. An application tractor equipped with an air fan dilution system, and with a plow consisting of horizontal v-shaped blades mounted by a vertical arm to the tool bar. The fumigant shall be injected laterally beneath the soil surface; or
 - 2. Rearward-curved (swept-back) chisels, closing shoes, and compaction roller shall be used.
- (C) Injection depth shall be between 10 and 15 inches.
- (D) Injection spacing shall be 12 inches or less.
- (E) The tarpaulin shall be laid down simultaneously (with fumigant injection) by tarpaulin-laying equipment mounted on the application tractor.

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- (F) The tarpaulin shall not be cut until a minimum of five days (120 hours) following completion of injection to the application block.
- (G) Tarpaulin removal shall begin no sooner than 24 hours after tarpaulin cutting has been completed.
- (H) The application block restricted-entry interval shall end at completion of tarpaulin removal, and shall be at least six days.

(4) Tarpaulin/Shallow/Bed

- (A) Application rate shall not exceed 250 pounds of methyl bromide per acre.
- (B) Rearward-curved (swept-back) chisels shall be used with either:
 - 1. Closing shoes and compaction roller. The closing shoes shall cover the chisel marks with soil just ahead of the compaction roller, and the tarpaulin shall be laid down simultaneously (with fumigant injection) by tarpaulin-laying equipment mounted on the application tractor; or
 - 2. Bed shaper. The chisels shall be placed with the injection point under the bed shaper, and the tarpaulin shall be laid down simultaneously (with fumigant injection) by tarpaulin-laying equipment mounted on the application tractor; or
 - 3. Combination bed former and bed shaper. The chisels shall be placed between the bed former and the bed shaper. The tractor with the tarpaulin-laying equipment shall immediately follow the application tractor.
- (C) Injection depth shall be between 6 and 15 inches. The injection depth to preformed beds must not be below the bed furrow.
- (D) Injection spacing shall be 12 inches or less.
- (E) The tarpaulin shall not be cut until at least five days (120 hours) following completion of injection to the application block.
- (F) If tarpaulins are removed before planting, tarpaulin removal shall begin no sooner than 24 hours after tarpaulin cutting has been completed. The application block restricted-entry interval shall end at completion of tarpaulin removal, and shall be at least six days.
- (G) If tarpaulins are not to be removed before planting, the application block restricted-entry interval shall either:
 - 1. consist of the five-day period described in subsection (E) plus an additional 48 hours after holes have been cut for planting, or
 - 2. be at least 14 days. If this option is chosen, the methyl bromide air concentration underneath the tarpaulin must test less than five parts per million before planting begins.

(5) Tarpaulin/Deep/Broadcast

- (A) Application rate shall not exceed 400 pounds of methyl bromide per acre.
- (B) Forward-curved chisels shall be used with either:
 - 1. An air fan dilution system on the application tractor; or
 - 2. Closing shoes and compaction roller.

- (C) Injection depth shall be at least 20 inches.
- (D) Injection spacing shall be 66 inches or less.
- (E) The tarpaulin shall be laid down simultaneously (with fumigant injection) by tarpaulin-laying equipment mounted on the application tractor.
- (F) The tarpaulin shall not be cut until at least five days (120 hours) following completion of injection to the application block.
- (G) Tarpaulin removal shall begin no sooner than 24 hours after tarpaulin cutting has been completed.
- (H) The application block restricted entry interval shall end at completion of tarpaulin removal, and shall be at least six days.

(6) Drip System - Hot Gas

A hot gas application through a subsurface drip irrigation system to tarpaulin-covered beds may be used if all of the following criteria are met:

- (A) Application rate shall not exceed 225 pounds of methyl bromide per acre.
- (B) The fumigant shall be injected beneath the soil surface at a minimum depth of one inch.
- (C) The portion of the drip system used in the fumigation shall be physically disconnected from the main water supply during the fumigation to prevent possible contamination of the water supply.
- (D) All fittings and emitters underneath the tarpaulin shall be buried in the soil to a minimum depth of one inch.
- (E) Prior to the start of the fumigation, all drip tubing shall be checked for blockage, and the irrigation system connections and fittings checked for blockage and leaks using pressurized air and/or water. The end of each drip tubing shall be placed under the tarpaulin prior to introduction of fumigant.
- (F) The tarpaulin shall be placed and inspected for tears, holes, or improperly secured edges prior to fumigating. Repairs and adjustments shall be made before the fumigation begins.
- (G) Prior to the start of the fumigation, all fittings above ground and outside of the tarpaulin shall be pressure-tested with compressed air, water, or nitrogen gas to a maximum pressure of 50 pounds per square inch. A soap solution shall be used to check the fittings for leaks if using air or nitrogen. All apparent leaks shall be eliminated prior to the fumigation. All drip tubing with emitters connected to the distribution manifold not covered by the tarpaulin shall be sealed to prevent fumigant loss through the emitters.
- (H) Prior to introducing the fumigant, the drip system shall be purged of water by means of pressurized gas, such as CO₂ or nitrogen.
- (I) The drip system shall be purged prior to disconnecting any line containing the fumigant.
- (J) After purging, drip tubing shall be pinched off and then disconnected from the distribution manifold. All disconnected tubing leading into the treated field shall be secured to prevent gas from escaping.

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- (K) All fittings used for connecting or disconnecting the heat exchanger to the irrigation system manifold shall be of a positive shut-off design.
- (L) All persons shall wear the eye protection specified on the label when working with a manifold system or tubing containing the fumigant under pressure.
- (M) The entire fumigation system (heater, valves, and manifold) shall be purged of the fumigant at the end of each day's fumigation.
- (N) The tarpaulin shall not be cut until at least five days (120 hours) following completion of injection to the application block.
- (O) If tarpaulins are removed before planting, tarpaulin removal shall begin no sooner than 24 hours after tarpaulin cutting has been completed. The application block restricted-entry interval shall end at completion of tarpaulin removal and shall be at least six days.
- (P) If tarpaulins are not to be removed before planting, the application block restricted-entry interval shall either:
 1. consist of the five-day period described in subsection (N) plus an additional 48 hours after holes have been cut for planting, or
 2. be at least 14 days. If this option is chosen, the methyl bromide air concentration underneath the tarpaulin must test less than five parts per million before planting begins.