

Mortality of Forest Insect Pests by Methyl Iodide Tarpaulin Fumigation

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Abstract: Mortality tests were conducted using two new types of methyl iodide fumigant (MI) filled in pressurized gas cylinders (50% MI dissolved in 50% liquid carbon dioxide and 100% MI with pressurized air) to confirm complete mortality of *Xyleborus* sp. (all stages), *Platypus* sp. (all stages), Cerambycidae gen. et sp. (larva), *Monochamus alternatus* (larva), *Cryphalus fulvus* (all stages) and *Callidiellum rufipenne* (adult), and *Xyleborus perforans* (all stages). Fumigation was conducted at 60 g/m³, 80 g/m³ and 120 g/m³ for 24 hours at 7.9–10.6°C with 70–74% loading (v/v) under tarpaulin with a capacity of 5.4–6.0 m³. No difference was observed on gas diffusion between the two types of MI. Test insects were completely killed at 60 g/m³ for 24 hours at 10°C. MI would be a high potential fumigant for timbers infested with forest insect pests.

Key words: fumigation, methyl iodide, forest insect pests, mortality, tarpaulin

Introduction

In Japan, mortality tests for imported timbers infested with forest insect pests have been conducted with some fumigants of sulfuryl fluoride, phosphine, methyl isothiocyanate, methyl iodide (MI) and a mixture of these fumigants as alternatives to methyl bromide (MB), which was listed an ozone depleting substance (Mizobuchi *et al.*, 1996; Naito *et al.*, 1999, 2003; Oogita *et al.*, 1998; Soma *et al.*, 1996, 1997, 1999, 2004).

MI fumigation alone showed high efficacy against various species of forest insect pests among these fumigants. However MI fumigant left much room for improvement as it took a long time for dosing and gas diffusion because of its high boiling point of 42.5°C. Recently, two new types of MI filled in a pressurized gas cylinder with air or liquid carbon dioxide were developed to make up for the disadvantages of the conventional MI compound. These fumigants can be easily jetted from a high-pressurized gas cylinder.

Here we report results of the mortality of forest insect pests and gas diffusion under tarpaulin fumigation with these two types of MI fumigant.

Materials and Methods

1. Test Insects

The following imported and domestic logs infested with forest insect pests were provided for the test.

Xyleborus sp. (all stages), *Platypus* sp. (all stages) and Cerambycidae gen. et sp. (larva)

These insects and their stages were found in Malaysian logs (43–47 cm diameter × 2 m long with bark) imported to Niigata port in November 2005.

Xyleborus perforans (WALLASTON) (all stages)

Adults were collected from infesting broadleaf trees and reared on an artificial diet in small

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glass tubes. All stages were provided for the test.

***Cryphalus fulvus* NIIJIMA**

Adults were collected from infesting red pine in Iwate Prefecture in June 2005 and they were then allowed to oviposit on red pine logs (5 cm diameter $\times$ 50 cm long) and stored for 30 days. All stages of development were provided for the test.

***Callidiellum rufipenne* (MOTSUCHULSKY) (adult)**

Adults were collected in the Rokko mountain range in Hyogo Prefecture in April 2005 and they were then allowed to oviposit on Japanese cedar logs (10 cm diameter $\times$ 50 cm long) for 7 months. Adults were provided for the test.

***Monochamus alternatus* HOPE (larva)**

Larvae were collected from infesting red pine in Ibaraki Prefecture in June 2005. Emerged adults were allowed to oviposit on red pine logs (15 cm diameter $\times$ 1.5 m long) and stored for 3 months. Larvae were provided for the test.

2. Fumigation Standards

Fumigation standards in the test were established based on the mortality data conducted in 2003 and 2006. Naito *et al.* (2003) confirmed that complete mortality of many species of forest insects was achieved at 50 g/m³ of MI for at 15°C for 24 hours. Soma *et al.* (2006) suggested that MI fumigation standards for wood packing material infested with forest insect pests would be at 85 g/m³ at 10°C, 60 g/m³ at 15°C and 36 g/m³ at 25°C, respectively. Lower doses of 70 g/m³ at 10°C, 50 g/m³ at 15°C and 30 g/m³ at 25°C would be applied for logs under tarpaulin fumigation when calculated requirement doses by temperature based on gas absorption ratio of MI to logs were a lower ratio than that of wood packing material.

To confirm reliability of MI fumigation standards under tarpaulin fumigation, mortality tests were conducted at doses of 60, 80 and 120 g/m³ at 10°C as the representation of three doses and temperatures as the standard.

3. MI Fumigants

MI filled in a gas cylinder with high pressured air (MI with air) was jetted through a siphon and sprayed like fog through a special designed stainless steel nozzle on the load of timbers. Doses of 60 and 120 g/m³ were used for the test. A 50% MI dissolved in 50% liquid carbon dioxide in a gas cylinder (MI with carbon dioxide) were also jetted through a siphon and sprayed through a stainless steel pipe on the load of timbers. Doses of 60 and 80 g/m³ were used for the test.

Diffusion and penetration of these fumigants are accelerated by high-pressurized air from gas cylinders.

4. Fumigation

Fumigation was conducted at the designated disinfestation timber yard by the Plant Protection Station, the Ministry of Agriculture, Forestry and Fisheries at Niigata port in November 2005.

The aforementioned infested logs (two Malaysian logs, 10 Japanese cedar logs and 10 red pine logs) and 70–80 larch logs as filler logs (10–15 cm diameter $\times$ 2 m long with bark) per fumigation were prepared for the mortality test. Fumigation was conducted with log volumes of 3.8–4.2 m³ under tarpaulin with a capacity of 5.4–6.0 m³. Each fumigation lot was covered with two different types of sheets of plain semitransparent polyethylene of 0.2 mm thick for “MI with air” and of high-density plain semitransparent film of 0.1 mm thick for “MI with carbon dioxide.”

Water pipes (20 cm diameter) were placed on the tarpaulin hem for prevention of gas leakage. Each fumigation was conducted for 24 hours at 10°C with a 70% loading of timbers.

5. Monitoring of Gas Concentration, Temperature and Calculation of Residual Gas Ratio and CT Product

MI was dosed through a stainless steel pipe placed on the top of the load. Gas concentrations at two places (30 cm down from the top of the lot and 30 cm above the ground) of the load were monitored with gas chromatograph (FID) at time intervals of 1, 2, 4, 12, and 24 hours after commencement of fumigation. An automatic temperature recorder also monitored temperatures inside and outside of the tarpaulin during the fumigation.

The residual gas ratio was calculated with the following formula;

$$\text{Residual gas ratio (\%)} = 100 \times \frac{\text{gas concentration (mg/l) after 24 hour fumigation}}{\text{applied dose (g/m}^3\text{)}}$$

The CT product was calculated with the following formula;

$$\text{CT product (mg} \cdot \text{h/l)} = 1.5C_1 + 1.5C_2 + 11C_4 + 10C_{24}$$

(where C_x is the gas concentration after x -hour of fumigation)

6. Evaluation of Mortality

Treated and untreated control infested logs were placed in a plastic box with 300 mesh sheets for 7–10 days at an ambient temperature of 10°C in the warehouse. Confirmation of the survival of the test insects in all stages were carried out through barking, chopping or dissecting logs after storing at 20–25°C in the room. Mortality of egg stages were confirmed as hatched larvae after storing at 25°C for 7 days.

Results and Discussion

1. Temperatures

Figure. 1 shows temperatures inside and outside of the tarpaulin during fumigation. MI was dosed at 12 : 00 when temperatures inside of the tarpaulin were 8.0–10.6°C. Temperatures outside the tarpaulin gradually dropped from 10.3°C at 12 : 00 to 5.5°C at midnight. Average temperature inside the tarpaulin was at 8.8°C during fumigation for 24 hours.

2. Gas Concentrations and CT Products

Figure. 2 shows progressive gas concentrations in the cases of fumigation at 60 g/m³ for both MI fumigants. High concentrations of 83–85 mg/l were confirmed with almost the same concentration at the upper and lower positions in 1-hour fumigation for “MI with carbon dioxide” and gas concentrations reduced gradually to 19 mg/l which was an equivalent dose to 32% of

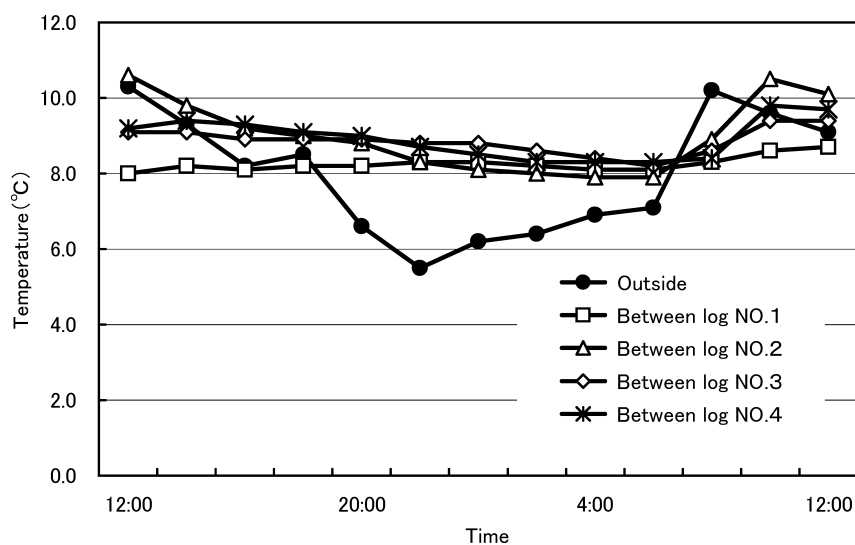


Fig. 1. Change of temperatures inside and outside of the tarpaulin during methyl iodide fumigation.

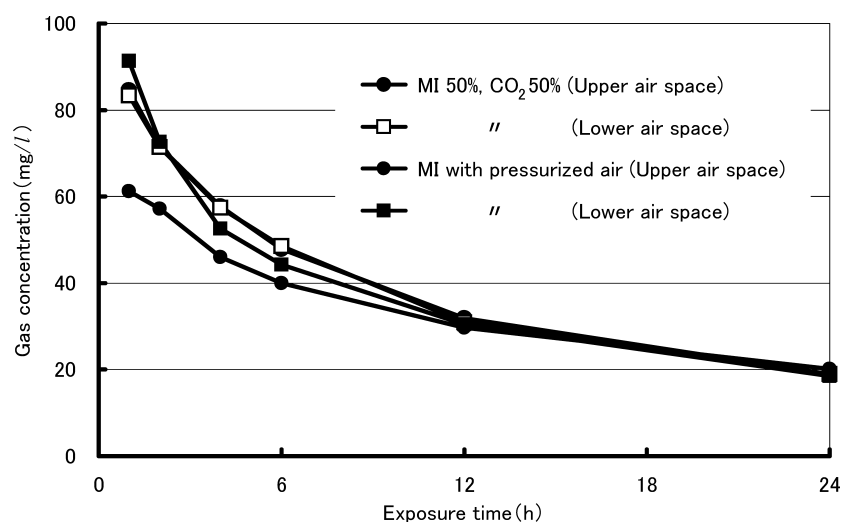


Fig. 2. Progressive gas concentrations during tarpaulin fumigation at 60 g/m³ of two types of methyl iodide (MI 50%, CO₂ 50% and MI with pressurized air) for 24 hours at 10°C with 70% loading.

Table 1. Residual gas concentration, residual gas ratio and CT product for logs fumigated with methyl iodide for 24 hours under tarpaulin sheet.

Fumigant	Methyl iodide dose g/m ³	Average temperature °C	Residual gas concentration mg/l	Ratio of residual gas ¹⁾ %	CT product ²⁾ mg·h/l
Methyl iodide with pressurized air	60	8.8	20.9	34.8	789
	120	8.9	34.3	28.5	1,276
Methyl iodide 50%, CO ₂ 50%	60	8.3	19.0	31.6	853
	80	9.0	35.4	44.3	1,348

¹⁾ $100 \times \text{gas concentration after 24 hrs fumigation (mg/l)} / \text{applied dose (g/m}^3\text{)}$.

²⁾ $0.5C_1 + 1.5C_2 + 2C_4 + 4C_6 + 9C_{12} + 6C_{24}$ (C_x : gas concentration after x hours).

the applied dose at the end of fumigation for 24 hours. This is because carbon dioxide accelerated diffusion and penetration of MI gas while in the case of “MI with air”, a small difference between the upper and lower position in 1-hour fumigation was confirmed and the difference was reduced by 5.0 mg/l in the 4-hour fumigation, because MI is 4.9 times heavier than air and deposited on the ground just after dosing at a low fumigation temperature. Almost the same pattern in gas reduction curves were confirmed on fumigation from several hours after dosing to the end of fumigation. Also, no difference was confirmed on air tightness of polyethylene and high-density film because almost the same residual gas concentrations at the end of fumigation was apparent.

Table 1 shows gas concentrations, residual gas ratios and CT products from fumigation with two MI fumigants. Residual gas concentrations were 19.0–20.9 mg/l and residual gas ratios were 31.6–34.8%. CT products were 789–853 mg·h/l at 60 g/m³ at 8°C. Residual gas ratios in these tests with logs were extremely higher than those (14.8% at 84 g/m³ at 10°C) in the previous test with wood packing material (Soma *et al.*, 2006). The difference was caused mainly by the difference in gas absorption ratios of logs and wood packing material.

3. Mortality

Table 2 shows mortality data for forest insect pests. All stages of the pest, such as *Xyleborus* sp. (all stages), *Platypus* sp. (all stages) and Cerambycidae gen. et sp. (larvae) in Malaysian logs, *Xyleborus perforans* (all stages on an artificial diet), *Monochamus alternatus* (larvae in red pine logs) and *Callidellum rufipenne* (larvae in red pine logs) and *Cryphalus fulvus* (all stages under bark of red pine logs) were killed completely at 60 g/m³ at 8.0–10.6°C for 24 hours of fumigation with 70–74% loading.

Table 2. Mortality of forest insect pests fumigated with methyl iodide under tarpaulin sheet.¹⁾

Species	Stage	Control		Methyl iodide with pressurized air				Methyl iodide 50%, CO ₂ 50%			
				MI 60 g/m ³		MI 120 g/m ³		MI 60 g/m ³		MI 80 g/m ³	
		<i>n</i>	Mortality %	<i>n</i>	Mortality ²⁾ %	<i>n</i>	Mortality ²⁾ %	<i>n</i>	Mortality ²⁾ %	<i>n</i>	Mortality ²⁾ %
<i>Xyleborus</i> sp. ³⁾	egg	34	0	79	100	11	100	63	100	74	100
	larva	97	18.6	349	100	178	100	266	100	352	100
	pupa	33	15.2	184	100	80	100	104	100	136	100
	adult	11	45.5	67	100	36	100	81	100	105	100
	total	175	16.0	679	100	305	100	514	100	667	100
<i>Platypus</i> sp. ³⁾	egg	3	0	11	100	0	—	21	100	3	100
	larva	4	0	38	100	12	100	18	100	51	100
	pupa	3	0	15	100	1	100	1	100	2	100
	adult	3	33.3	4	100	7	100	6	100	11	100
	total	13	7.7	68	100	20	100	46	100	67	100
Cerambycidae ³⁾ (Gen et sp.)	larva	4	0	12	100	5	100	3	100	11	100
<i>Xyleborus perforans</i>	egg	195	0	0	—	87	100	0	—	68	100
	larva	148	0	13	100	134	100	5	100	175	100
	pupa	60	0	39	100	19	100	23	100	89	100
	adult	123	8.1	98	100	173	100	563	100	117	100
	total	526	1.9	150	100	413	100	591	100	449	100
<i>Cryphalus fulvus</i>	egg	0	—	2	100	0	—	10	100	0	—
	larva	67	0	38	100	51	100	33	100	0	—
	pupa	0	—	6	100	0	—	9	100	0	—
	adult	1	0	9	100	38	100	31	100	34	100
	total	68	0	55	100	89	100	83	100	34	100
<i>Monochamus alternatus</i>	larva	14	0	24	100	42	100	35	100	53	100
<i>Callidiellum rufipenne</i>	adult	52	0	172	100	240	100	209	100	206	100

¹⁾ Fumigation was conducted at 8.0–10.6°C for 24 hours with 70–74% loading (v/v).²⁾ Mortality was evaluated for 7–10 days after fumigation.³⁾ Mature infesting pests were found in imported Malaysian log.**Table 3.** Methyl iodide tarpaulin fumigation standards for logs infested with the forest the insect pests.

Temperature (°C)	Time (h)	Dose (g/m ³)	Minimum gas concentration after 24 hours (mg/l)	Minimum CT product ¹⁾ (mg·h/l)
10–14.9	24	70	13	450
15–24.9	24	50	11	400
25 or above	24	30	8	300

¹⁾ SOMA *et al.* (2006).

MI has shows a high potential fumigant for imported logs infested with various species of forest insect pests.

4. Proposed Tarpaulin Fumigation Standards

Residual gas ratios (31.6–34.3% at 60 g/m³ at 8°C) for log fumigation in this test were considerably higher than those (14.8% at 84 g/m³ at 10°C) for wood packing material in previous tests (Soma *et al.*, 2006). This was because of the lower gas absorption ratio of logs compared to wood

packing material. Complete mortality against the pest was achieved at 10°C at 60 g/m³ for 24 hours under tarpaulin fumigation.

Table 3 shows proposed MI tarpaulin fumigation standards by dose and temperature. Minimum gas concentration at the end of fumigation were determined by both progressive gas concentrations and estimated minimum CT products for complete mortality of many species of forest insect pests. Complete mortality of forest insect pests could be achieved if minimum gas concentrations in the schedule of 70 g/m³ at 10°C, 50 g/m³ at 15°C and 30 g/m³ at 25°C are maintained under tarpaulin fumigation.

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和 文 摘 要

ヨウ化メチルによる木材天幕くん蒸試験

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輸入木材害虫を対象にヨウ化メチルくん蒸剤の実用化を図るため、ポンベに充填した2種類のヨウ化メチル製剤（50%，w/wで二酸化炭素と混合充填したもの及び空気で加圧圧縮したもの）を用い、天幕くん蒸による殺虫効果を調査した。木材天幕は、コンクリート製の土場に供試材（マレーシア材、杉材、赤松材）とカラマツ材（充填材）を積み上げ、ビニールシート又はEVO

シートを被覆して作成した（5.4～6.0 m³）。ヨウ化メチルの薬量は、二酸化炭素製剤では60及び80 g/m³、圧縮充填剤では60及び120 g/m³、くん蒸時間は24時間で実施し、くん蒸温度は7.9～10.6°C（材間温度）であった。試験の結果、マレーシア材に寄生した *Xyleborus* sp.（全態合計2,165頭）、*Platypus* sp.（全態合計201頭）、カミキリムシ科の一種（幼虫合計31頭）、

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赤松材に寄生したマツノマダラカミキリ（木部内幼虫合計 154 頭）、キイロコキクイムシ（全態合計 261 頭）、杉材に寄生したヒメスギカミキリ（木部内成虫合計 827 頭）及び人工飼料中のフィリピンザイノキクイムシ（全

態合計 1,603 頭）は、いずれも完全殺虫され、2 種類のヨウ化メチル製剤を用いた天幕くん蒸による木材害虫の殺虫処理は、ヨウ化メチル 60 g/m^3 、24 時間、 10°C の条件で可能であることが明らかとなった。