Appendix G. Summary of Ecotoxicity Data

Efficacy Studies on Methyl Bromide

Organism	Dose/Exposure	Response	Reference
Microorganisms			
*Fusarium oxysporum, Pythium, Rhizoctoia (*Fungal pathogens*)*	Methyl bromide (2 lb/100ft^2) applied to nine chrysanthemum varieties	No Fusarium detected in soil. Although not completely controlled. Good control of Pythium, Rhizoctonia. No phytotoxicity observed to any chrysanthemum variety.	MRID 00010245 (Crane and Mellinger 1974)
Armillairia mella (causes oak root fungus)	Field study in vineyard. Applied at 300 and 400 lb/A under tarp.	Nearly total control of *A. mellea* at 300 lb/A. Total control of *A. mellea* at 400 lb/A.	MRID 00013029 (Kissler *et al.* 1973)
Fanleaf virus	Field study applying methyl bromide at 400-800 lb/A under tarp.	Good control over fanleaf virus.	MRID 00013030 (Raski and Schmitt 1972)
Armillaria mellea (fungus)	Infected roots treated with methyl bromide in air at exposures ranging from 500 to 2200 ppm for 1-16 days.	Increase in control of fungal populations with increasing dose and time of exposure	MRID 00013163 (Munneeke *et al.* 1970)
Armillaria mellea and Trichoderma sp.	Laboratory study of fungal infections on roots. Methyl bromide exposure ranged from 5-67 mLa.i./2L air for 4 days.	*Armillaria mellea* was more senstivie than *Trichoderma*. Both populations were significantly decreased from the methyl bromide application.	MRID 00013174 (Ohr *et al*. 1973)
Insects			
Several Insects	Review	Use of methyl	MRID 00114033

Organism	Dose/Exposure	Response	Reference
	No data reported in this paper.	bromide as a space fumigant is effective in controlling confused flour beetle, granary weevil, German cockroaches, cheeses skippers, cheese mites, corn borer, rice weevils, red flour beetle, lesser grain borer, Indian-meal moth, Kharpa beetle, tobacco moth and several wood boring insects.	(Dow Chemical Company 1974)
Cornstock mealy bug	Field Study applying methyl bromide at 2.5 lb/1000ft^3 for 2 and 2.5 hours.	Methyl bromide effective at killing eggs.	MRID 00116551 (Vettek 1971)
Callosobruchus chinensis (cow pea or black weevil)	24 hour exposure to methyl bromide in sealed flasks. Dose range and formulation was not specified.	Reported LC_{50} Values Eggs: 0.851 mg/L Larva: 2.2mg/L Pupa: 0.891 mg/L Adults: 1.67 mg/l	Adu and Muthi 1985
12 strains of 7 beetle species	Laboratory space fumigation study at 15º and 25º C. Methyl bromide concentrations range from 0.6-3.0 mg/L at 15º C and 1.3-4.0 at 25º C for various exposure periods.	Methyl bromide more effective at 25 ºC than 15ºC for all strains.	Bell 1988
Cadelle beetle	Laboratory fumigation study. Methyl bromide exposures include 10, 16 and 23 mg/L for 5 hours.	Insects with a high respiratory rate were more susceptible to methyl bromide than insects with a low respiratory rate.	Bond 1956
Acarus siro (cheese infecting mite)	Laboratory fumigation study.	Reported LC_{50} values:	

Organism	Dose/Exposure	Response	Reference
	Exposure to various concentration of metyl bromide for 4, 8, 16 and 24 hours.	4 hour LC50 = 9.13 mg/L 8 hour LC50= 4.61 mg/L 16 hour LC50=2.47 mg/L 24 hour LC50=1.69 mg/L	
Codling moth eggs	Mechanism of action study. Eggs exposed to 48 g/m^3 a.i. for 2 hours.	One hour after exposure, cell division stopped. Cells of surviving eggs showed general characteristics of neoplastic cells. Methyl bromide appears to act as a general cell toxin.	Cheetham 1990
Codling moth larvae	Mechanism of action study. Laboratory fumigation of larvae to 3.6-9.6 g/m^3 methyl bromide for 2 hours.	Examination of changes in ventral nerve cord and ganglia. Changes observed in perineural glial cells such as membrane disruption, dilation of endoplasmic reticulum, vacuolization of cytoplasm. Mechanism of action appears to be through disruption of normal neuronal function.	Cheetum 1992
Cydia pomonella (codling moth)	Space fumigation, recirculating method, over 2 hours.	Effects examined on freshly laid eggs and diapausing 5^{th} instars. Mortality observed for both eggs and 5^{th} instars, with eggs more tolerant.	Dentener *et al.*1998
Plodia	Fumigation flour	Decrease in moth	Doud and Philips

Organism	Dose/Exposure	Response	Reference
interpunctella (Indian meal moth)	mill. Application rate not specified.	population at various locations around the mill.	2000
Corcyra cephalonica (rice moth)	Lab study. Space fumigation in sealed glass bottles. Metyl bromide concentrations ranging from 0.63 to 4.051 mg/L for 5 hours.	Conclusions: 1. Adult diet did not affect susceptibility of eggs. 2. 3 day old eggs were more susceptible than 1 day old eggs. 3. Diet did not affect susceptibility of 1st larvae instars. 4. Addition of yeast and casein to diet decreased susceptibility of 3rd and last larval instars. 5. Wheat bran diet increased susceptibility of 3rd and last instars. 6. Larger larvae are more resistant. 7. Diet may slightly affect susceptibility of 3 day old pupae	El-Buzz *et al.* 1974

Organism	Dose/Exposure	Response	Reference
7 species of beetles, all growth stages	Laboratory experiment in fumigation chamber. Methyl bromide concentration in chamber was approximately 4.0 mg/L. Exposure time ranged from 4-48 hours depending on species.	In all species, egg and pupal stages were more tolerant than larval and adult stages. Large variability in susceptibility between species.	Hole 1981.
Ostrinia nubilali and Chilo agramemnon (overwintering corn borer)	Field study. Methyl bromide ampoules (no formulation specified) applied to piles of corn stalks at 16, 20, 24 and 28g/m^3 for 8, 16 and 24 hours. Stacks covered with plastic tarps.	Similar results for both species. For 8 and 16 hour exposures, dose-dependent mortality observed. At 24 hour exposure, there was 100% mortality.	Isa *et al.* 1970
Oryzaephilus Mercator (merchant grain beetle)	Laboratory fumigation study. 0.5 to 2 hour exposure at 0.2g/L.	Methyl bromide effective in killing larvae and adults. 1005 of adults and larvae killed after 1 and 2 hour exposure.	Joshi 1974
Tribolium confusum (flour beetle)	Laboratory fumigation study conducted at 3 temperatures (40, 60 and 80 ºC) and 3 exposure periods (2, 5 and 16 hours).	Methyl bromide effectiveness increased with increasing exposure time and increasing temperature.	Kenaga 1960
Acarus siro (mite)	Space fumigation study on eggs. Methyl bromide exposure of 40 g/m^3 for 24 hours. Mechanism study.	Exposure of 0,1,2,3, 4 and 5 day old eggs. Integument of eggs became sticky, non-elastic and soft. Changes in	Klag and Komorowska 1975

Organism	Dose/Exposure	Response	Reference
		developing nervous system were observed. Deformity of embryos observed.	
Several peanut pests: almond moth, Indian meal moth, red flour beetle, merchant grain beetle	Methyl bromide applied to bags of peanuts at a dose of 32 mg/L over 24 hours.	Controlled insect infestations.	Leesch *et al.* 1974
Cydia pomenlla (codling moth)	Space fumigation study on plums at exposure of 22.5 and 48 g/m^3	Eggs on plants were controlled by doses of 22.5 and 48g/m^3.	Leesch *et al.* 1999
Incisitermes minor (Western drywood termite)	Space fumigation study with CO2-synergized methyl bromide at 1.4kg/177.8 m^3	Termite mortality was 100% after 3 days of treatment.	Lewis and Havery 1996
Pea leafminer	Laboratory study. Fumigation of insects with methyl bromide in sealed chambers at approximately 13.5 mg/L)	LD_{50} values: Eggs: 23.3 mg/L*h Larvae: 15.5 mg/L*h in less than 7 days. Larvae: 14.4 mg/L*h at time periods of more than 7 days.	MacDonald and Mitchell 1996
Graphognathus keucoloma (white fringed beetle)	Laboratory fumigation study. Exposure of 1^{st} instar larvae to methyl bromide for 24 hours. Concentrations not specified.	Efficacy of methyl bromide on the soil dwelling 1^{st} instar white fringed beetle resulted in dose-related increase in mortality of larvae.	Mathiessen *et al.* 1996
Ephestia kuehniella (Mediterranean flour moth), *Sitotroga cerealella* (Angoumois grain moth), *Tribolium castaneum* (Red	Laboratory fumigation study. Exposure to methyl bromide for 5, 6, or 7 hours at concentrations of 1.2-2.4 mg/L for	Examined susceptibility of 1, 2 and 3 day old eggs. Older eggs were more susceptible. Effectiveness increased with	Mostafa and Kamel 1972

Organism	Dose/Exposure	Response	Reference
flour beetle), *and Sitophilus oryzae* (Rice weevil)	moths and 3.5-8.0 mg/L for beetles.	increasing exposure period.	
Brown dog tick	Laboratory study with doses of 32-144 mg/L for methyl bromide.	Almost 1005 mortality at all doses. Efficacy reduced at temperatures below 10ºC.	Roth 1973
Anthonomus grandis (boll weevil, Ebony Pearl strain)	Laboratory fumigation study. Exposure to methyl bromide concentrations ranging from 16-96 mg/L for 1-16 hours at temperatures ranging from 0.6-35ºC.	100% mortality or nearly 100% under all experimental conditions.	Roth and Kennedy 1972
Plodia interpunctella (Indian meal moth)	Laboratory study. Space fumigation in vials using methyl bromide doses ranging from 6.0-18.04 mg/L for 1 hour.	Diapausing (hibernating) insects are less susceptible than non-diapausing insects.	Sardesai 1972
10 species of Neartic termite	Laboratory fumigation study. Exposure to methyl bromide for 20 hours at 27ºC. Concentration range not specified.	All species of termites were susceptible to methyl bromide. There was a wide range of susceptibility observed between species.	Scheffrahn and Su 1992
Trogoderma variable (warehouse beetle)	Laboratory study. Exposure to methyl bromide for 2-24 hours at temperatures of 15.6 21.1 and 26.7 ºC. Concentrations ranged from 8-40 mg/L.	Observed eggs and post-embryonic growth stages. Effectiveness increased as exposure time and temperature increased. Very little difference between growth	Vincent and Lindgren 1975

Organism	Dose/Exposure	Response	Reference
		stages regarding sensitivity.	
Maconellicoccus hirsutus (pink hibiscus mealybug)		Dose response study. All stages tested including eggs, crawlers, early nymphs and adults. Based on LD_{50} values, eggs were the most sensitive. LD_{50} values: eggs: 7.1 mg/L crawlers: 25.1 mg/L early nymphs: 26.5 mg/L Methyl bromide was effective at controlling pink hibiscus mealybug. All stages were completely controlled following exposure to 48 mg/L for 2 hours.	Zettler *et al.* 2002
Trichhodorus, Belonolaimu, rootknot *and Hemicycliophora*	Field study. Methyl bromide applied by soil injection to plots of tomatoes. Rate was not specified.	Decrease in soil populations of all nematodes. Decrease in wilt of tomato plants.	MRID 00010152 (Walters 1974)
Xiphinema index (dagger nematode)	Field study. Methyl bromide was applied at 400-800 lb/A under tarp.	Nearly total eradication of nematodes.	MRID 00013030 (Raski and Schmitt 1972) Data also reported in Soil Chemical Corp. 1972, MRID 00118839)
Nematodes	Field study. Vineyards treated with methyl bromide. (cannot read rate on	Good control over nematodes in soil.	MRID 00013031 (Schmitt 1972)

Organism	Dose/Exposure	Response	Reference
	microfiche).		
Nematodes	Greenhouse study. 24 hour exposure to methyl bromide in the soil at concentrations ranging from 200 to 800 ppm. Different concentrations were used on different species.	*Xiphinema index* 24 h LC_{50} = 200-250ppm *Heloidogyne incognita* 100% mortality at 600-650 ppm *Heterdera schachtil* 100% mortality at 750-800 ppm	MRID 00013032 (Lear 1972)
Four plant parasitic nematodes: *Paratylenhcus spp.; Heterodera schachtii; Meloidogyne incognita; and Xiphinema index*	Fumigation of nematode infested soil in cans. Exposure to methyl bromide for 1-21 days at concentrations in the soil ranging from 20-2500 ppm.	Toxicity varied with species in order of of increased sensitibity: *Paratylenhcus spp.; Heterdera schachtii; Meloidogyne incognita*; and *Xiphinema index*. Toxicity increased with increased temperature, exposure time and dose.	Abdalla and Lear 1975
Hoplolarimus Columbus and Pratylenchus brachyurus (nematodes infecting cotton)	Greenhouse study. Soil treated with methyl bromide (454 g/16 pots; pot size: 40 cm) then planted with cotton.	Marked reduction in soil content of nematodes.	Birds *et al*. 1974
Root knot nematode	Field study (white clover plots). Methyl bromide applied at 1 lb/100 ft^2 with four applications.	Methyl bromide provided good control over nematode population for up to 3 years after initial treatment.	Chen *et al.* 1962
Nematodes	Field study. Methyl bromide with chloropicrin (2%) 871 lb/A applied to celery seed beds	Significant reduction in nematode population up to 150 days after treatment.	Darby *et al*. 1962

Organism	Dose/Exposure	Response	Reference
Meloidogyne javanica (root knot nematodes)	Field study. Methyl bromide applied at 70 g/m2 one month before planting tomato and melon plants.	Dramatic reduction in soil nematode populations and increased plant yield. Re-colonization observed during the second year after treatment, with decreased plant yields.	Eddaoudi and Bourijate 1998
Steinerema carpocapsae (entomopathogenic nematode)	Laboratory study. 0.45 kg methyl bromide gas in a sealed container for 2 days.	Nematode infectivity of wax moth larvae decreased for up to 25 days.	Gibb and Buhler 1998
Pratylenchus brachyurus	Laboratory study. Space fumigation of peanut shells and whole peanut pods in one-liter flasks for 24 hours at 25° C. Methyl bromide concentrations ranged from 17.3 to 50.9 mg/L. Formulation was not specified.	At 17.3 mg/L, nearly complete eradication of nematodes. At doses larger than 24.5 mg/L, complete eradication of nematodes.	Minton and Gillenwater 1973
Three species of parasites (Tylenchodorus sp., Trichodorus sp., and Pratylenchus zeae)	Field study. Methyl bromide (98% with 2% chloropicrin) applied to soil at an application rate of 2 lb/100ft^2. Tarped prior to planting corn.	Complete eradication of nematodes 2 weeks after treatment. Population started to recover after 3 months, but did not reach untreated levels.	Oakes *et al.* 1956
Tylenchulus semipenetrans (citrusnematode)	Field study. Pre-plant soil fumigation with 49 and 98 g/m^2 methyl bromide in a replant area of citrus trees.	No nematodes detected 2 years after fumigation. Populations began to recover after 3 years, but did not reach pre-treatment levels after 7 years.	Roux *et al.* 1998

Organism	Dose/Exposure	Response	Reference
Meloidogyne (Root knot nematodes)	Field study. Chisel application of methyl bromide: 100, 150 and 200 lb/A	Dose-dependent decrease in number of nematodes in soil.	Sher *et al.* 1958
Nematodes (species not specified)	Field study. Methyl bromide containing 2% chloropicrin applied to 3 pepper cultivars. The application rate was not specified.	High control over nematode infestations.	Thies and Fery 1997
Root knot nematodes	Field study. Methyl bromide injected into soil at 200 and 300 lb/A. Samples covered with tarps.	Nematode populations were "controlled".	Thompson 1959
Heterodera rostoshiensis (potato cyst nematode)	Field study. Methyl bromide (98%) and chloropicrin (2%) applied to a sandy clay soil and covered with polyethylene tarp.	Decrease in number of larvae invading roots. Increase in number of cysts and eggs in the soil. Increase in potato yield.	Whitehead *et al.* 1972
Meloidogyne incognita, Xiphinema index, Dorylaimus sp.	Laboratory study. Nematodes in soil with tomato plants were exposed to "flowing" 600 ppm methyl bromide for up to 132 hours.	*Meloidogyne incognita* became progressively immobile over 38 hours. Infection of tomato plants deceased after 30 hours. Results indicate gradual "narcotization" of nematodes. No evidence of "Narcotization" in Xiphinema index. "Narcotization" effect on *Dorylaimus spp*. was intermediate.	Van Gundy *et al* 1972
Nematodes (species	Laboratory/Field	Following	Yeates *et al* 1991

Organism	Dose/Exposure	Response	Reference
not identified)	study. Core soil samples fumigated in the laboratory with methyl bromide at a concentration of 48 mg/m^3. Samples were then returned to the field and monitored at 1, 5, 12, 26, 54,110 and 166 days.	treatment, no nematodes in the soil were observed until the day 26 sampling. At 166 days after treatment, the population was recovering, but was still significantly below untreated samples.	