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METHYL BROMIDE AS AN INSECT FUMIGANT--
A REVIEW OF THE LITERATURE THROUGH 1940

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Properties of Methyl Bromide

Methyl bromide (CH_3Br) as used in fumigation is a colorless gas with a slight sweetish odor similar to that of other low-molecular-weight alkyl halides. It has the following physical constants:

Molecular weight	-----	94.95
Boiling point	-----	3.56°C .
Melting point	-----	-93.66°C .
Specific gravity of liquid	-----	1.732 at 0°C .
Specific gravity of gas	-----	3.28 at 20°C . and 760 mm. compared with air under the same conditions

It is very slightly soluble in water and with cold water forms a white crystalline hydrate of the approximate formula $\text{CH}_3\text{Br} \cdot 20 \text{H}_2\text{O}$. It is soluble in the common organic solvents. It is noninflammable and in mixture with air can be exploded by a spark only within the narrow range of 13.5 to 14.5 percent by volume of methyl bromide.

This compound has been used for years by the chemical industry as a methylating agent in the preparation of dyes and antipyrine. It has been employed to some extent as a fire-extinguishing agent, either alone or mixed with other materials such as carbon tetrachloride. It has found limited use also as a refrigerating agent in mechanical refrigerators.

The insecticidal possibilities of methyl bromide were first reported by Le Goupil (63) in 1932. Since that time it has been tested extensively and is now widely used in the fumigation of nursery stock, fruits, seeds, bulbs, stored grain, and vegetables to destroy certain insects against which quarantines have been established. It has also been used to some extent as a general greenhouse fumigant. During 1940 probably 400,000 pounds of methyl bromide were used as an insecticidal fumigant in the United States. An important use also is as a rodenticide.

Methyl bromide possesses a number of advantages as a fumigant. It is highly toxic to many kinds of insects in all stages of development. It is stable chemically and in the concentrations used has no deleterious effect on most plant tissues. It imparts no objectionable taste or odor to foodstuffs fumigated with it and leaves no dangerous residue. It is convenient to handle, since it is readily liquefied and yet vaporizes at temperatures encountered in fumigating. It is the only common

fumigant which is a gas at room temperature and normal atmospheric pressure. It presents no fire or explosion hazard. Because of the great density of the gas, it is necessary to provide means for mixing it adequately with the air.

Like other fumigants highly toxic to insects, methyl bromide is also toxic to man, and adequate precautions must be taken in its use. Irish and coworkers (53) stated in 1940 that the literature records 42 definite cases of methyl bromide poisoning, of which 12 proved fatal. It was earlier believed that the toxic action was due to splitting of the methyl bromide in the body to form methanol and inorganic bromide, and that the methanol caused the poisoning. It now appears, however, that methyl bromide exerts a toxic action of its own. It is more toxic than any of the closely related halides, such as methyl chloride and ethyl bromide. It has a delayed effect, the symptoms often not appearing until hours, or even a day or more, after exposure. In mild cases the usual symptoms are disturbance of equilibrium, double vision, headache, and vertigo. In acute cases delirium, loss of consciousness, epileptiform convulsions and sometimes death occur. After recovery from severe poisoning there may be persistent neurasthenia for years.

Bibliography

The references on methyl bromide presented in this publication have been collected for the benefit of entomologists and others interested in the control of pests by chemical means. Only references to the insecticidal use of the compound and to its toxicity to man and animals have been included, except for a few patents or articles giving directions for the preparation of methyl bromide or for its determination in air or fumigated materials. They have been obtained mainly from the following abstract journals through 1940: Chemical Abstracts, Review of Applied Entomology (A), Biological Abstracts, Chemisches Zentralblatt, and Quarterly Cumulative Index Medicus.

ANONYMOUS.

(1)

Organic halogen compounds. [Gt. Brit.] Dept. Sci. and Indus. Res., Methods for the Detection of Toxic Gases in Industry, Leaflet 12, 6 pp. 1940.

Injuries from breathing industrial vapors containing a number of organic halogen compounds, including methyl bromide, are discussed, and the procedure for detecting them is described. The only simple method is the use of a halide detector lamp which burns pure ethyl alcohol and causes the decomposition of the various compounds. The halogen reacts with a small copper screw in the nozzle of the lamp to form copper halide, which imparts a green coloration to the flame; the degree of coloration depends upon the nature of the organic halide and upon its concentration in the air. Directions for handling the lamp, carrying out the tests, and interpreting the results are given. An experienced operator is needed, and he will have to get accustomed to the surroundings before he is certain of getting accurate results. The lamp cannot be used when inflammable gases are present.

- ADLER, H. J. (2)
Eine tödliche Brommethylvergiftung. Zentbl. f. Gewerbe Hyg. u.
Unfallverhütung (n.f.) 4: 161. 1927.

A fatal case of poisoning by methyl bromide is reported. About 16 hours intervened after the exposure before the onset of symptoms with convulsions.

- BACHEM, C. (3)
Beitrag zur Toxikologie der Halogenalkyle. Arch. f. Expt. Path.
u. Pharmacol. 122: 69-76. 1927.

Several reports of cases of methyl bromide poisoning are reviewed. Experiments are described in which mice were exposed to the vapors. A concentration of 0.001 mole per liter caused death in 75 minutes, and 0.000017 to 0.000136 mole per liter killed the mice within a few hours. In the narcosis the mice often reacted to strong tactile irritation (pinching); sporadically increased reflex excitability and indications of convulsions also occurred. A concentration of 0.000008 mole per liter in the course of many hours caused deep narcosis, which, however, was followed by rapid and lasting recovery.

- BERRY, C. E. (4)
Methyl bromide as a rodenticide. Calif. Dept. Agr., Monthly Bul.
27: 172-180. 1938.

Methyl bromide is effective in the control of rodents as well as the insects harbored by them. It can be used in wet or dry soils and at various temperatures. Although the cost is high, it can be used where follow-up or eradication methods are being carried on and around buildings where there is danger in using treated grain baits. It should be used only under proper supervision even by official agencies having a trained personnel, and should not be made available for general use until further safeguards have been developed.

- BEYNE and GOETT. (5)
Toxicité de certains extincteurs d'incendie et précautions qu'ils
comportent. Arch. de Méd. et de Pharm. Nav. 124: 409-427. 1934.

The toxicity of methyl bromide is briefly reviewed. Experiments with rabbits and dogs are described. A concentration of 36 mg. per liter for 25 minutes was fatal to a rabbit. Dogs died after exposure to 10 to 21 mg. per liter for 30 to 38 minutes.

- BING, D. (6)
[Methyl bromide poisoning.] Schweiz. Rundschau f. Med. 1910:
1167. [In German.]

Two nonfatal cases are reported in which residual symptoms continued for 6 and 7 months. The symptoms include tremor, dizziness, vomiting, and muscular debility, with some transitory psychic changes.

BOULIN, C., and SIMON, L. J.

(7)

Preparation of methyl chloride and methyl bromide from dimethyl sulfate. [Paris] Acad. des Sci. Compt. Rend. 170: 595-597. 1920. [In French.]

In the presence of hydrochloric acid, water hydrolyzes dimethyl sulfate to give, in part, methylsulfuric acid and methyl chloride. With 3 parts of hydrochloric acid (22° Bé.) and 1 part of water 90 percent or more of practically pure methyl chloride results. A saturated solution of sodium chloride works nearly as well, but the solution should be warmed to 60°-65° C. to start the reaction. Hydrobromic acid gives a similar reaction, but aqueous sodium bromide, slightly acidified with sulfuric acid, is preferred, giving (at 30°-35° C.) methyl bromide in 90 percent yield. Methyl bromide is very soluble in glacial acetic acid (42 gm. per 100 gm. of acetic acid at 24° C.). These methods are recommended for laboratory preparations.

BUSBY, R. L., and DRAKE, N. L.

(8)

Determination of small quantities of methyl bromide in air. Indus. and Engin. Chem., Analyt. Ed. 10: 390-392. 1938.

The method proposed is for determining the methyl bromide content of fumigated air. The sample of air is subjected to the saponifying effect of potassium hydroxide in alcohol, for which purpose a special apparatus has been devised. The alcohol is finally removed by distillation, the bromide oxidized to bromate by sodium hypochlorite, and the bromate determined iodometrically.

BYGDEN, A.

(9)

Preparation of methyl bromide. Jour. f. Prakt. Chem. 83: 421-424. 1911. [In German.]

Methyl bromide is obtained in 83-84 percent yield (as against 44.5 percent by the bromine and phosphorus method) by adding 450 gm. of methyl alcohol to 600 gm. of sulfuric acid, adding gradually 230 gm. of water and 300 gm. of powdered potassium bromide to the cold mixture, and heating until gas ceases to be evolved.

(10)

Preparation of methyl bromide. Jour. f. Prakt. Chem. 104: 285-288. 1922. [In German.]

Sulfuric acid (95 percent) is first diluted with water, the methyl alcohol is slowly added with cooling, followed by pulverized potassium bromide, and the flask with reflux condenser is slightly warmed. The evolved gases are passed through water or sodium hydroxide to remove hydrobromic acid and then through two bottles of concentrated sulfuric acid. Methyl bromide is then condensed in an ice-salt bath. The yield varied between 93.5 and 97.3 percent, depending on the proportion of methyl alcohol to the other reactants.

- CADE, A., and MAZEL, P. (11)
Intoxication par le bromure de méthyle. Soc. Méd. des Hôp. Paris,
Bul. et Mém. 47 (3): 722-727. 1923.

A rather severe nonfatal case of poisoning by methyl bromide is reported, in which symptoms persisted for 2 months. Another patient suffered from methyl bromide poisoning on four occasions in 27 years.

- CAIN, C. A. (12)
A methyl bromide dispenser for use in the fumigation of quarantined products. U. S. Bur. Ent. and Plant Quar. ET-156, 4 pp. 1940.
[Processed.]

A device is described for dispensing accurately measured small quantities of methyl bromide from a pressure cylinder.

- CAMERON, G. R., KARUNARATNE, W. A. E., and THOMAS, J. C. (13)
Massive necrosis (toxic infarction) of the liver following intra-portal administration of poisons. Jour. Path. and Bact. 44: 297-303. 1937.

Many organic poisons, including methyl bromide, when introduced directly into the portal circulation, produce strong local necrosis. The result is due, not to embolism or ischemia, but to the direct action of the poison on the liver cells. The condition may be designated as "toxic infarction."

- CHAO-LUN TSENG, and CHIA-SHU HOU. (14)
Preparation of alkyl bromides by the phosphorus bromide method. I. Chinese Chem. Soc. Jour. 2: 57-72. 1934.

Parallel experiments with methyl and several other alcohols show that with theoretical amounts of phosphorus tribromide the yield of alkyl bromide is 10 percent higher than with theoretical amounts of red phosphorus plus bromine.

- CHAPMAN, P. J. (15)
Effect of methyl bromide on apple maggots in apples. (Scientific Note) Jour. Econ. Ent. 33: 817. 1940.

Picked and windfall Wealthy apples were fumigated with 1, 2, and 4 pounds of methyl bromide per 1,000 cubic feet for 1, 2, and 4 hours. The picked apples contained first and second instars and the dropped fruit contained mainly second and third instars of Rhagoletis pomonella (Walsh). All treatments gave complete kills except 1 pound of methyl bromide for 1 hour, which gave 91.2 percent control for picked fruit and 91.9 percent for dropped fruit. Injury to fruit occurred with the 2-pound dosage for 4 hours and with the 4-pound dosage for 2 and 4 hours.

CHRISTIE, F. R., and COBB, G. S.

(16)

The inefficacy of methyl bromide fumigation against the chrysanthemum foliar nematode [Aphelenchoides ritzemabosi (Schwartz 1911)]. Helminthol. Soc. Wash. Proc. 7: 62. 1940.

Fumigation with methyl bromide did not eliminate this nematode even when the chrysanthemum plants were treated under the most severe conditions that they were likely to tolerate, namely, fumigation with 3 pounds of methyl bromide per 1,000 cubic feet for 1.5 hours at 70° F. under 15 inches of sustained vacuum. It is likely that such treatment will also be ineffective against the strawberry bud nematode (Aphelenchoides fragariae Ritzema Bos, 1891).

DÉROBERT, L.

(17)

L'intoxication professionnelle par le bromure de méthyle. Gaz. Méd. de Strasbourg 99: 179-184. 1939.

A review giving sources of intoxication and literature on toxicity of methyl bromide.

DEUTSCHE GESELLSCHAFT FÜR SCHÄDLINGSBEKÄMPFUNG m. b. H.

(18)

Insecticides. French Patent 835,883, Jan. 5, 1939.

An insecticide is described consisting of a liquid of relatively high boiling point (e.g., alcohols, aromatic and aliphatic hydrocarbons, esters, and ketones) and an insecticidal substance of low boiling point (e.g., methyl bromide, chlorocyanide, ethylene oxide, dimethylamine, methyl mercaptan, and phosgene). The liquids may be absorbed in diatomite.

DONOHUE, H. C., JOHNSON, A. C., and BULGER, J. W.

(19)

Methyl bromide fumigation for Japanese beetle control. Jour. Econ. Ent. 33: 296-302. 1940.

Complete mortality of the adult beetles is obtained by doses of 2 pounds of methyl bromide per 1,000 cubic feet for 2 hours at 18.3°-32.2° C. One pound per 1,000 cubic feet suffices at 24.4°-32°, and 0.75 pound at 25°-30°. A method for treating refrigerator cars is described.

----- and JOHNSON, V. A.

(20)

The effect on plants of methyl bromide fumigation in Japanese beetle treatment tests; preliminary report. U. S. Bur. Ent. and Plant Quar. E-482, 14 pp. 1939. [Processed.]

Complete control of immature stages of the beetle in greenhouse and nursery stock was obtained by fumigating the plants with methyl bromide (2.5 pounds per 1,000 cubic feet, including the load) for 2.5 hours at a minimum soil and air temperature of 63° F. In tests of 187 genera of plants representing 503 horticultural varieties and unnamed entries, 6.6 percent showed injury or suspected injury sufficient to render the plants unsalable. Injury was most common (12 percent) among growing greenhouse plants. Among the dormant and semidormant plants only 3.2 percent were injured.

DOW CHEMICAL COMPANY.

(21)

Dow and Bear brand methyl bromide. Ed. 3, 23 pp. Midland, Mich. 1939.

This trade booklet sets forth the advantages of methyl bromide as a fumigant and discusses methods of application under various conditions.

DOZIER, H. L.

(22)

Studies of control measures for sweetpotato weevil in Louisiana. Jour. Econ. Ent. 32: 313-318. 1939.

Methyl bromide was the quickest acting and most effective fumigant tested for the control of Cylas formicarius elegantulus (Summers) in seed sweetpotatoes. A dosage of 5 cc. to 50 cubic feet gave complete kill of all stages in 12 hours at 88° F.

DUDLEY, H. C.

(23)

Bromide content of fruits and vegetables following fumigation with methyl bromide. Indus. and Engin. Chem., Analyt. Ed. 11: 259-261. 1939.

In samples of 50 to 100 gm. the methyl bromide is converted to potassium bromide by 1 percent alcoholic potassium hydroxide. This is ignited three times at 500° C. and extracted with hot water. A chromic acid solution is added, and the bromine liberated is aspirated into 10 percent potassium iodide. The liberated iodine is then titrated with standard 0.01 N sodium thiosulfate.

----- MILLER, J. W., NEAL, P. A., and SAYERS, R. R.

(24)

Studies on foodstuffs fumigated with methyl bromide. U. S. Pub. Health Serv. Rpts. 55: 2251-2282. 1940.

The amount of methyl bromide (determined as bromine) absorbed by fruits and vegetables during fumigation was found to be several times the normal bromide content. In most cases the fumigated material showed a drop in bromides after aeration. Dried fruits, fresh fruits, and vegetables absorbed minor quantities of the fumigant. The foodstuffs which absorb greater amounts of the fumigant include milled grains, cheese, nuts, and nut meats. The adsorptive capacity of milled grains is due primarily to their greater surface area, while the oily and fatty food absorb large quantities of methyl bromide because of its solubility in fats. Rats and rabbits were fed on diets consisting entirely of fumigated foodstuffs, all of which contained more methyl bromide than is found in similar foodstuffs fumigated by methods approximating commercial procedures. The results indicate that it is unlikely that the small amount of methyl bromide or bromide residues on commercially fumigated fresh vegetables and fruits, or on dried fruits, is harmful to the consumer. A bibliography lists 87 references to methyl bromide, a large part of them on its toxicology.

DUSTAN, G. G.

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STATE PLANT BOARD (25)

The effects of temperature and certain chemicals on cheese mites. Ent. Soc. Ontario, Ann. Rpt. 68: 60-67. 1938.

In experimental fumigation of cheese in an airtight room in

which an electric fan was kept running, a complete kill of Tyroglyphus farinae Deg., including the eggs, was obtained with a mixture of 6.8 percent of methyl bromide and 93.2 percent of carbon dioxide at rates from 8 to 20 pounds per 1,000 cubic feet and at temperatures from 58° to 63° F. An unpleasant taste, which extended to about 1/4 inch below unwaxed and exposed parts of the surface of the cheese, completely disappeared after exposure to the air for 36 to 48 hours. Animals were apparently not affected by feeding on cheese 24 hours after fumigation.

DUVOIR, M., FABRE, R., and LAYANI, F. (26)
Poisoning with methyl bromide. Soc. Méd. des Hôp. Paris, Bul.
et Mém. 53: 1540-1554. 1937. [In French.] (Also in Bul. Sci.
Pharmacol. 46: 15-26. 1939.)

Dogs kept in an atmosphere containing 35 to 48 mg. of methyl bromide per liter went into narcosis and died shortly after. The bromine could be detected in the organs, especially in those rich in lipoids. The pathologic picture points to a vasomotor crisis. Efforts to counteract this effect with vasoconstrictor substances, especially adrenaline, were not successful. Glutathione is suggested as a stabilizer of the vasomotor system.

EASTER, S. S. (27)
Fumigation of sweetpotatoes with methyl bromide for control of the sweetpotato weevil. Jour. Econ. Ent. 33: 921-926. 1940.

Methyl bromide is extremely toxic to Cylas formicarius elegantulus (Summers), killing the insects even when they are deeply imbedded in the sweetpotatoes. It produces a deleterious effect on the sweetpotatoes, which may result in considerable loss. Careful handling, partial curing, and postfumigation heating of the sweetpotatoes will partially avoid this loss.

FEIL, A. (28)
L'intoxication professionnelle par le bromure de méthyle. Semaine d' Hôp. Paris 6: 599-601. 1930.

The symptoms, diagnosis, and treatment of methyl bromide poisoning are discussed.

FISK, F. W., and SHEPARD, H. H. (29)
Laboratory studies of methyl bromide as an insect fumigant.
Jour. Econ. Ent. 31: 79-84. 1938.

Methyl bromide is a promising new fumigant with boiling point (4.5° C.) lower than that of other fumigants. Its toxicity to insects compares favorably with that of hydrocyanic acid gas, chloropicrin, and ethylene oxide. The granary weevil (Sitophilus granaria (L.)), the rice weevil (S. oryza (L.)), and the bean weevil (Acanthoscelides obtectus (Say)) are about equally susceptible to methyl bromide, the concentration for 50 percent mortality after 5 hours ranging from 4.0 to 6.1 mg. per liter. The adult confused flour beetle (Tribolium confusum Duv.) requires 10.2 mg. per liter for 50 percent mortality; its eggs are less resistant. Degree of absorption of the gases was determined by suspending a cage of test insects (Tribolium) above a 2-inch layer of whole-wheat flour in

the fumigation chamber. The ratio of the median lethal concentration (M.L.C.) with flour to that without flour equals the absorption ratio, which is 2. The M.L.C. of methyl bromide for Tribolium after 90 minutes' exposure at 25° in the presence of various food-stuffs and at various pressures follows: (1) Atmospheric pressure: empty flask 32.5, raisins 28.1, wheat 30.4, flour 50.0; (2) 240-mm. pressure: Empty flask 16.8, wheat 17.2, flour 34.0; (3) 30-mm. pressure: Empty flask 11.4, raisins 12.6, wheat 14.2, flour 26.0. The toxicity of methyl bromide is affected by temperature about as much as is that of carbon disulfide and less than that of chloropicrin. Methyl bromide is more effective on insects in the presence of moisture. The germination of corn, wheat, oats, barley, beans, and field pea seeds is not affected by fumigation with methyl bromide.

- FLORET. (30)
Klinischer Beitrag zur gewerblichen Brommethylvergiftung. Zentbl.
f. Gewerbe Hyg. und Unfallverhütung. 3: 146-149. 1915.

Three nonfatal cases of poisoning by methyl bromide are reported. A period of 4 to 6 weeks was required for recovery. Clinically, three stages were observed in the course of the illness: (1) Prodromal stage with dizziness, visual disturbances, disturbance of equilibrium, reeling gait; (2) stage of psychic excitement with delirium, delusions, convulsions, unconsciousness, coma; (3) appearance of nervous weakness (hypochondria, melancholia, hystero-neurasthenia), which may last for years.

- FLURY, F., and ZANGGER, H. (31)
Lehrbuch der Toxikologie für Studium und Praxis, 500 pp.
Berlin. 1928.

Symptoms of methyl bromide poisoning are briefly reviewed. There is a typical interval of several hours or days before the onset of severe symptoms (p. 206).

- and ZERNIK, F. (32)
Schädliche Gase, Dämpfe, Nebel, Rauch-und Staubarten. 637 pp.
Berlin. 1931.

The action of methyl bromide as a nerve poison is probably due to decomposition to form methyl alcohol or formaldehyde (pp. 309-310).

- FRANCOLINI, J. DE. (33)
L'emploi du bromure de méthyle pour le traitement des graines de
semence. Rev. de Path. Veg. et d'Ent. Agr. de France 22: 1-8.
1935.

In experiments in Morocco in February 1934, 100 percent mortality of all stages of Sitophilus oryza (L.) and of a small number of S. granaria (L.) infesting wheat was obtained by exposure to methyl bromide at the rate of 2 ounces per 100 cubic feet at 19.5° C. At first the weevils became very active, but activity gradually diminished until after about 6 hours all movement ceased. In further tests 100 percent mortality of the adults of S. oryza was obtained with the same amount of fumigant by exposing them 2 hours in glass tubes closed with muslin under bell jars at 22° C.,

though some of the weevils did not die until the next day. All larvae within the grains were killed by 24 hours' exposure to 1 ounce per 100 cubic feet at 21° C. Even at the rate of 5 1/2 ounces to 100 cubic feet for 24 hours, methyl bromide only slightly reduced the germinating power of wheat and other cereals.

----- (34)
Action sur les produits végétaux du bromure de méthyle en fumigation sous vide partiel. Rev. de Path. Veg. et d'Ent. Agr. de France 22: 9-12. 1935.

Tests were carried out in Morocco to determine the action of methyl bromide on various fruits, vegetables, and plants exposed to 6-7 ounces per 100 cubic feet for an hour at 22°-26° C. A partial vacuum was maintained for 20 minutes, after which the pressure was brought back to normal, and the products were ventilated for 10 minutes after fumigation. Bananas became soft and blackened, pears became soft without showing outward change, and potatoes became brown and slightly soft, but none of the other fruits or vegetables were affected. Of 25 plants the only ones injured were Fuchsia, Iresine, and Zantedeschia, the leaves of which withered and dropped 48 hours after exposure. Susceptibility to methyl bromide appears to be related to the water content of the plant or fruit. A series of tests showed that the hydrobromic acid given off by methyl bromide in a saturated atmosphere does not exceed 2 parts per 1,000 if the fumigation is of normal duration.

FRIEMANN, W. (35)
Berufliche, tödliche Brommethyl-Vergiftung. Samml. Vergiftungsfällen 8: 31-32. 1937.

A further report is made on a case of methyl bromide poisoning first reported by Opperman (see reference 95), in which there were repeated epileptiform attacks for 2 years, and even after 4 years there was some nystagmus and feeling of discomfort. Two new cases are reported, of which one was fatal. Both men were exposed at the same time, but the one who died had been exposed repeatedly previously.

GERBALDI, C. (36)
Methyl bromide as an insecticide. Rev. Fruttic. 3: 281-283. 1939. [In Italian.]

All the larvae of (Cydia) Grapholitha molesta (Busck) and Carpocapsa pomonella (L.) in pears exposed to 15 gm. of methyl bromide per cubic meter for 18 hours were killed. No injury to the fruit from methyl bromide was observed. In French crab apples, however, the type of injury described by Phillips and coworkers (100) was found.

GLASER, E. (37)
Zur Kenntnis der gewerblichen Brommethylvergiftungen. Deut. Ztschr. f. die Gesam. Gerichtl. Med. 12: 470-474. 1928.

A fatal case of methyl bromide poisoning is reported. There was an interval after exposure before the onset of any symptoms.

The patient then soon lost consciousness and died within a few hours. The concentration of methyl bromide in the air to which workers are exposed should not exceed 1.9 mg. in 100 liters.

----- and FRISCH, S.

(38)

The effect of technically and hygienically important gases and vapors upon the organism. Brominated hydrocarbons of the aliphatic series. Arch. f. Hyg. 101: 48-64. 1929. [In German.]

Subcutaneous injection showed that tetrabromoethane is six times, dibromomethane four times, and methyl bromide seven times as toxic as ethyl bromide. The toxic action of the vapors of dibromoethane and methyl bromide is eight times greater than that of ethyl bromide vapor. The inhalation of tetrabromoethane vapor is without toxic result. Because of its greater volatility, the danger attending the use of ethyl bromide is more than twice as great as that attending the use of the more toxic dibromoethane. Methyl bromide is still more dangerous, and great caution should be observed in its use. The inhalation of subnarcotic doses of dibromoethane and methyl bromide may eventually result in death. The animals appear to tolerate large concentrations of the compounds for a short time better than lower concentrations for longer periods.

GOLDSCHMID, E., and KUHN, E.

(39)

Brommethylvergiftung mit tödlichem Ausgang. Zentbl. f. Gewerbe Hyg. u. Unfallverhütung 8: 28-36. 1920.

Nine cases of poisoning occurred in a dye factory following the bursting of a large vessel containing methyl bromide. There were three deaths, and these cases all followed the same general course—a short period of feeling unwell followed by sudden epileptiform convulsions, loss of consciousness, disturbances of breathing and, in a few hours, death. The six other cases complained consistently of vertigo, headache, general weakness, and disturbance of equilibrium.

GRONOW, W. E.

(40)

Die Anwendung chemischer Sonder-Nassfeuerlöscher in den gewerblichen Betrieben unter dem Gesichtspunkte ihrer Einwirkung auf die Benutzer. Zentbl. f. Gewerbe. Hyg. u. Unfallverhütung (n.f.) 4: 161-166. 1927.

When used as a fire-extinguisher liquid, methyl bromide shows less tendency than carbon tetrachloride to form harmful decomposition products. As yet, only hydrobromic acid has been observed, which irritates the respiratory organs but possesses no toxic properties.

GUEFFROY, W., and EHRHARDT, W.

(41)

The halogenated hydrocarbons of the fatty series as solvents and their significance to the medical practice. Zentbl. f. Gewerbe Hyg. u. Unfallverhütung 25: 224-230. 1938. [In German.]

These solvents as a class are capable of producing acute poisoning and occasionally blood changes. The lungs are the chief

portal of entry into the body. Absorption through the skin is possible. Frequently, on long exposures the chloride and neutral sulfur content of the urine increases, as does the acidity. Danger from fire and explosions frequently exists. The specific properties and actions of a number of these compounds, including methyl bromide, are discussed in detail. No specific medical prophylaxis for chronic poisoning by this class of compounds is known.

HAMILTON, C. C.

(42)

Methyl bromide used successfully to fumigate plants in soil beds. Hort. Topics 3 (6): 11. 1939.

Experiments have shown that emulsions made by adding 50 cc. of methyl bromide to 250 cc. of wood alcohol and diluting in 3 gallons of water will kill grubs of Anomala orientalis Waterh. in azalea beds both in the greenhouse and outdoors. Examination made 7 days after treatment revealed that all the larvae were either dead or disabled, but the azalea plants were not injured.

(43)

Methyl bromide fumigation for control of asiatic beetle grubs attacking azalea plants. Jour. Econ. Ent. 33: 486-490. 1940.

Fumigation of soil and azalea plants in raised benches and floor benches by confining methyl bromide under a fumigating box at the rate of 1 cc. per square foot caused no injury to plants in spring tests and only slight leaf burn to one variety in fall tests. Soil temperature ranged from 54° to 81° F. A complete kill of grubs of Anomala orientalis Waterh. was obtained in all tests except those conducted when the soil temperature was 54° at a depth of 8 inches and 58° at 4 inches.

Fumigation of soil by injecting at 6-inch intervals methyl bromide and methyl or ethyl alcohol (1:15) at a rate of 0.5 cc. of methyl bromide killed most of the grubs and caused little or no injury to plants. By diluting this solution with water and sprinkling over the area to be treated, a nearly complete kill of the grubs could be obtained without injury to plants, when 1 cc. of methyl bromide per square foot was used; 0.5 or 0.75 cc. gave less than 50 percent kill.

HAWKINS, L. A.

(44)

Fumigation of dormant deciduous nursery stock for the oriental fruit moth with methyl bromide. U. S. Bur. Ent. and Plant Quar. E-458, 3 pp. 1933. [Processed.]

Control of the immature stages of Grapholitha molesta (Busck) on bare-root stock was obtained by fumigation at the rate of 3.5 pounds per 1,000 cubic feet for 4 hours at 70° F.

(45)

The use of methyl bromide for the treatment of quarantined plant products. U. S. Bur. Ent. and Plant Quar. E-484, 6 pp. 1939. [Processed.]

Results are given of experiments for the control of various insects in green vegetables, sweetpotatoes, bulbs, potted plants, greenhouse stock, nursery stock, and other plant products.

(46)

Fumigation of vetch seed to control the vetch bruchid. U. S. Bur.
Ent. and Plant Quar. E-492, 2 pp. 1939. [Processed.]

Bruchus brachialis Fahr. in infested seed can
be killed by fumigation at a dosage of 3 pounds per 1,000 cubic
feet for 4 hours, at 70° F. There was no appreciable lowering
of the viability of the seed by this treatment.

HELLHOFF, E.

(47)

[Cases of methyl bromide toxication.] Inaug.-Diss. Berlin. 1924.
Reference in article by L. Merzbach, Ztschr. f. die Gesam. Expt.
Med. 63: 383-392. 1928.

HENDERSON, Y., and HAGGARD, H. W.

(48)

Noxious gases and the principles of respiration influencing their
action. 220 pp. New York, 1927. (Amer. Chem. Soc. Monograph
No. 35.).

The monohalogen compounds of methane—methyl bromide, methyl
iodide, and methyl chloride—are reactive gases, for after absorp-
tion by the body they are decomposed into methanol, which is nearly
nonreactive, and the halogen acid. The acid then combines with the
sodium of the blood to form the sodium halide. The marked cumu-
lative effect of methanol and its destructive action upon the ner-
vous system render these three methyl halides particularly poison-
ous. They do not themselves accumulate in the body and reach an
equilibrium preventing further absorption, as in the case of non-
reactive gases, but they are decomposed with the production of
methanol. Consequently, methanol continues to accumulate in the
body as long as the exposure persists. Thus severe poisoning by
methanol results after prolonged exposure to concentrations of a
methyl monohalide too small to exhibit the anesthetic action of
the undecomposed substance. The symptoms are those of methanol
poisoning. Their development may be slow and recovery delayed;
there is usually intense excitement and even epileptiform con-
vulsions. Gastric and intestinal disturbances, vomiting, diarrhea,
and pain may also occur (pp. 159-160).

HOWARD, F. L.

(49)

Chloropicrin, steam, carbon disulfide and other treatments for
injurious soil microorganisms. Veg. Growers' Assoc. Amer. Ann.
Rpt. 1939: 115-130.

Methyl bromide is a powerful insecticide which it appears can
be developed into an efficient soil fumigant for growing plants.

I. G. FARBENINDUSTRIE A.-G.

(50)

Alkyl halides. German Patent 478,126, June 20, 1929. [In German.]

Alkyl halides are prepared by passing a mixture of an aliphatic
alcohol vapor with a hydrogen halide at an elevated temperature
over a catalyst comprising active carbon and phosphoric acid.
The examples describe the preparation of methyl chloride, methyl
bromide, and propyl chloride.

(51)

Alkyl halides. British Patent 375,199, June 23, 1932.

Alkyl chlorides and bromides are obtained by action, in the liquid phase at temperatures exceeding 100° C., of concentrated hydrochloric or hydrobromic acid on the corresponding alcohol. The preparation of methyl bromide from methanol and 40 percent hydrobromic acid is given as an example.

INTERNATIONAL LABOUR OFFICE.

(52)

Occupation and health. v. 2. Geneva. 1934.

The chemistry, toxic action, pathology, and prophylaxis of methyl bromide are briefly reviewed (pp. 238-240).

IRISH, D. D., ADAMS, E. M., SPENCER, H. C., and ROWE, V. K.

(53)

The response attending exposure of laboratory animals to vapors of methyl bromide. Jour. Indus. Hyg. and Toxicol. 22: 218-230. 1940.

Animals tolerate large doses for short periods of time. After long exposures severe lung irritation is observed. Animals succumb to single exposures of 12 to 24 hours at a concentration of 0.85 mg. per liter. Rats survived for a variable period (1 to 3 weeks to 5 months or more) repeated exposures of 7 1/2 to 8 hours daily to 0.42 mg. per liter, but they showed definite intoxication and poor growth. Guinea pigs were more resistant, a majority surviving a full 6 months with nearly normal growth. Rabbits were more susceptible. When the concentration was lowered to 0.25 mg., it was tolerated by both rats and guinea pigs in repeated exposures for 6 months. Monkeys tolerated 0.25 mg. for 5 weeks or more. When the concentration was 0.13 mg., rats, guinea pigs, and monkeys survived repeated exposures for 6 months without gross symptoms of histopathological changes. Rabbits survived repeated exposures to 0.065 mg. for 6 months.

Animals tolerated for a long period a daily 8-hour exposure to a concentration not far below the maximum tolerated for a single exposure of 8 hours. Rats and guinea pigs tolerated for 6 months approximately one quarter the maximum concentration when exposed for a single 8-hour period daily. This indicates the ability to destroy rapidly or excrete methyl bromide and recover quickly from each exposure. Animals exposed to concentrations and for periods sufficient to cause a definite paralysis were able to recover completely if removed from the chamber. Recovered animals showed no functional or physiological abnormality.

JAQUET, A.

(54)

Ueber Brommethylvergiftung. Deut. Arch. f. Klin. Med. 71: 379-386. 1901.

Two cases, neither fatal, of poisoning by methyl bromide are reported. The first symptoms were weakness and vertigo, visual disturbances, and dyspnea. In slight poisoning these seem to be the only symptoms. In more severe poisoning or in especially predisposed persons there may follow psychic disturbances, even reaching delirium. It is notable that the severe symptoms may

appear only after several days. Some residual neurasthenia was observed. A few experiments with animals are described.

JOACHIMOGLU, G.

(55)

Toxikologische Betrachtungen über einige moderne Feuerlöschmittel.
Deut. Med. Wchnschr. 56: 785-787. 1930.

Methyl bromide is much more toxic than carbon tetrachloride. Concentrations as low as 0.00009 mole per liter were fatal to dogs upon prolonged exposure. The animals displayed lung edema and finally died after severe dyspnea.

JOHNSON, A. C.

(56)

A low-cost water seal fumigator. U. S. Bur. Ent. and Plant Quar.
ET-154, 2 pp., illus. 1940. [Processed.]

Directions are given for the construction of a water-sealed fumigator from a 50-gallon oil drum. Carbon disulfide and methyl bromide have been used in this fumigator.

JOHNSON, V. A.

(57)

Fumigating with hydrocyanic acid and methyl bromide. U. S. Patent
2,147,947, Feb. 21, 1939.

For destroying living organisms such as Japanese beetles, 1 ounce of hydrogen cyanide and 8 ounces of methyl bromide are used per 1,000 cubic feet of space. Such a mixture has a mutual synergistic action.

JONES, R. M.

(58)

Toxicity of methyl formate, ethylene oxide and methyl bromide, in admixture with carbon dioxide, to the rust-red flour beetle.
Iowa State Col. Jour. Sci. 13: 73-74. 1938.

The maximum insecticidal effects of methyl formate, ethylene oxide, and methyl bromide against Tribolium castaneum (Hbst.) were obtained with concentrations of 40, 60, and 20 percent, respectively, of carbon dioxide. Increase of carbon dioxide may decrease the effectiveness.

(59)

Toxicity of fumigant-carbon dioxide mixtures to the red flour beetle. Jour. Econ. Ent. 31: 298-309. 1938.

The toxicity of methyl formate, methyl bromide, and ethylene oxide, alone and in mixture with various concentrations of carbon dioxide, was studied with Tribolium castaneum (Hbst.) as test insect. The toxicity of these fumigants may be markedly increased by the addition of certain percentages of carbon dioxide. The stimulative effect of carbon dioxide is considerably more pronounced with methyl formate and ethylene oxide than with methyl bromide. Maximum efficiency of methyl formate, ethylene oxide, and methyl bromide is obtained with approximately 40, 20 and 10 percent of carbon dioxide, respectively.

KOHN-ABREST, E.

(60)

Précis de toxicologie, 388 pp., illus. Paris. 1934.

Methyl bromide is four times as toxic as carbon tetrachloride (p. 83).

LANGE, W. H., Jr.

(61)

Tests with methyl bromide as a fumigant for larvae of the artichoke plume moth. Jour. Econ. Ent. 32: 66-69. 1940.

Platyptilia carduidactyla (Riley) is controlled with minimum plant injury by a dosage in vacuo of 1 pound per 1,000 cubic feet. The temperature should be 22.2° to 24.4° C. and the exposure 2 to 2.5 hours. Treatment at atmospheric pressure increases plant injury.

LATTA, R.

(62)

Methyl bromide fumigation for destruction of pod-borer larvae. Jour. Econ. Ent. 33: 176-179. 1940.

Doses as low as 0.5 pound per 1,000 cubic feet produced complete mortality of Maruca testulalis Geyer, in 2 hours at temperatures above 21° C. at atmospheric pressure, or in 90 minutes at a 15-inch vacuum. Low temperatures required higher doses. For commercial atmospheric fumigation 1.5 pounds per 1,000 cubic feet for 2 hours is advised (temperature 21°). Green lima beans, string beans, and pigeon peas are not injured by doses necessary to kill the larvae of this insect.

LE GOUPIL.

(63)

Les propriétés insecticides du bromure de méthyle. Rev. de Path. Vég. et d'Ent. Agr. de France. 19: 169-172. 1932.

In studies of vacuum fumigation with various substances, methyl bromide, which was originally used in combination with inflammable liquid fumigants to reduce the danger of fire, was found to possess a much higher specific toxicity than the fumigants with which it was mixed. Further tests were carried out with methyl bromide alone and diluted in a liquid possessing slight insecticidal properties, such as carbon tetrachloride. Sitophilus granaria (L.) was chosen as the test insect on account of its resistance to insecticides. A few other species, notably Tribolium, were also used. The time of exposure was 1 1/2 hours in every case, but the dose ranged from 2 to 13.5 ounces per 100 cubic feet. The insects were treated both isolated in vitro and buried in various types of commodities, in dry atmospheres as well as in varying degrees of moisture, in the presence of rags soaked in oil, and at temperatures from 15° to 26° C. With doses below 3.5 ounces some insects were still alive when they were withdrawn from the autoclave, but all succumbed within a few hours. Larvae, pupae, and adults still inside unsplit grains were reached just as effectively as those developing between the grains, and it is probable that the eggs were also destroyed. Methyl bromide is toxic to man only in very large doses, and since it is very volatile and soluble in water, it is easily eliminated from fumigated commodities. It is uninflammable under all conditions and can be used to reduce the danger of

fire with such substances as ethylene oxide. Although its price is high, the small quantities required render the cost of using it reasonable. It does not appear to affect the germinating power of cereals, but tests have not been carried far enough in this direction to be conclusive.

LEPESME, P.

(64)

The efficacy of methyl bromide in the disinfection of vegetables under partial vacuum. Acad. d'Agr. de France Compt. Rend. 24: 783-787. 1938. [In French.]

Ninety-minute exposure to 40 gm. per cubic meter of methyl bromide under a partial vacuum of 50 mm. of mercury will completely destroy Sitophilus granaria (L.), S. oryza (L.), Rhizopertha dominica (F.), Tribolium castaneum (Hbst.), Gnathocerus cornutus (F.), Oryzaephilus surinamensis (L.), Laemophloeus spp., Bruchus signaticornis Gyll., and Ephestia kuehniella Zell. This dose can be lowered to 30 gm. in some cases.

LEPIGRE, A.

(65)

The disinfection of grains with mixtures of ethylene oxide and carbon dioxide. Soc. d'Encouragement pour Indus. Nat. Bul. 135: 385-462. 1936. [In French.]

The use of methyl bromide as a fumigant for grain is discussed. Its properties are given and its action on man and higher animals is discussed, chiefly from the literature. The danger of its decomposition into hydrobromic acid in treated goods is thought to be considerable. Little is known of its effect on wheat for milling, but its effect on the germination of the grain is considered serious if a dosage of 6 ounces per 100 cubic feet of air is used.

LINDGREN, D. L.

(66)

Methyl bromide fumigation of codling-moth larvae. Jour. Econ. Ent. 29: 1174-1175. 1936. (Correction in Jour. Econ. Ent. 30: 381. 1937.)

Five pounds of a mixture containing 3.4 percent by volume of methyl bromide and 96.6 percent of carbon dioxide per 100 cubic feet killed all the larvae buried in sacks. Methyl bromide is much more toxic to these larvae than hydrogen cyanide or carbon disulfide.

(67)

Methyl iodide as a fumigant. Jour. Econ. Ent. 31: 320. 1938.

Tests with methyl iodide on scale insects (Coccidae), lady beetles (Coccinellidae), confused flour beetles (Tribolium confusum Duv.), codling moth larvae (Carpocapsa pomonella (L.)), and some other insects indicate that this compound has possibilities as a fumigant. In tests on citrus seedlings concentrations above those lethal to the insects were not toxic to the plants.

LIVINGSTONE, E. M.

(68)

Fumigation of bulk soil with methyl bromide for the white-fringed beetle in New Orleans. U. S. Bur. Ent. and Plant Quar. E-512, 4 pp. 1940. [Processed.]

Experimental work with methyl bromide as a fumigant for potting soil and five additional types of soil showed that larval infestations of Pantomorus leucoloma (Boh.) in bulk quantities of these soils were destroyed by treatment with 38.3 cc. per cubic yard for 48 hours, at 42°-88° F. No harmful effect on plants from the use of soil fumigated with methyl bromide has been noted by commercial users.

(69)

Methyl bromide fumigation of the white-fringed beetle larva in small flowerpots in New Orleans. U. S. Bur. Ent. and Plant Quar. E-513, 4 pp. 1940. [Processed.]

Fumigation of the larva of Pantomorus leucoloma (Boh.) in New Orleans with methyl bromide at the rate of 1 pound to each 1,000 cubic feet of chamber space for 4 hours at about 85° F. destroyed infestations in the soil about the roots of plants growing in 3-inch or smaller flowerpots, but not in 4-inch pots. The volume of the 4-inch pot is 2.3 times that of the 3-inch pot. The treatment has been used successfully in quarantine work in New Orleans and is tolerated by approximately 90 percent of the plant species and varieties.

-----, EASTER, S. S., and SWANK, G. R.

(70)

Methyl bromide in aqueous solution to control Pantomorus leucoloma [Boh.] and P. peregrinus [Buch.]. Jour. Econ. Ent. 33: 531-533. 1940.

An aqueous solution containing 0.3 percent of methyl bromide and 0.6 percent of ethyl alcohol destroyed larvae of both species about the roots of balled nursery stock. The application of 40 gallons per 100 square feet of soil surface gave complete mortality of the larvae in 18 hours or less.

LÖFFLER, W., and RÜTIMEYER, W.

(71)

Ueber Vergiftung mit Brommethyl und Nachweis der Substanz in Blut und Organen vergifteter Tiere. Vrtljschr. Gerichtl. Med. 60: 60-67. 1920.

A fatal case of methyl bromide poisoning is described. This acute seizure had been preceded by subacute intoxication during periods when the patient had worked in an enclosed space where there was some exposure to methyl bromide, with apparent remission of all symptoms during periods when he worked in the open.

LOS ANGELES COUNTY AGRICULTURAL COMMISSIONER.

(72)

Codling moth. Los Angeles Co., Calif., Agr. Comm., Ann. Rpt.
1940: 7.

Packers of pears and apples equipped themselves with fumigation apparatus to take advantage of a change in the standardization law, which allowed 5 percent of visible worms and 5 percent of invisible worms in the packed fruit provided methyl bromide fumigation was used.

LOUNSKY, J.

(73)

Note sur la resistance des azalées à la fumigation au bromure de méthyle. Inst. Agron. et des Stas. de Rech. de Gembloux Bul. 8: 126-131. 1939. [Summaries in Dutch, German, and English.]

In continued investigations 34 varieties of azalea plants were treated in winter, without being removed from their packing (wicker baskets or wooden packing cases), by vacuum fumigation with methyl bromide at the rate of 40 or 80 gm. per cubic meter for 2 hours. On the whole, the treatments had no injurious effects on the plants.

----- and VANDERWALLE, R.

(74)

Observations sur le comportement de plantes d'azalées dans divers essais de traitement de désinsectisation. Inst. Agron. et des Stas. de Rech. de Gembloux Bul. 8: 52-58. 1939.

Fumigation with methyl bromide caused no injury to azalea plants when used at 40 gm. per cubic meter for 1, 2, or 3 hours at reduced or atmospheric pressure, but gave irregular results at higher dosages, sometimes causing injury that was found to be due chiefly to impurities and which was always more severe at the bottom of the fumigating chamber.

MACKIE, D. B.

(75)

Entomological service. Calif. Dept. Agr. (Ann. Rpt. 1936) Bul. 25: 455-481, illus. 1937.

Methyl bromide was used extensively as a fumigant during 1936.

(76)

Entomological service. Calif. Dept. Agr. (Ann. Rpt. 1937) Bul. 26: 418-438. 1938.

Fumigation with methyl bromide gas proved very satisfactory for destroying Keiferia lycopersicella (Busck) in harvested tomatoes, and was also used against Listroderes obliquus Klug in celery. In cold weather, however, this fumigant was less effective than hydrocyanic acid gas except at much higher dosages, which sometimes caused injury to plants, especially those with a noticeable oil content.

(77)

Methyl bromide—its expectancy as a fumigant. Jour. Econ. Ent.
31: 70-79. 1938.

Methyl bromide is toxic to a large group of insects and other animals. Many plants in the active or dormant stage can accommodate themselves to its vapors at concentrations and exposure periods which are lethal to animals. The vapors are noninflammable and stable at temperatures, pressures, and moisture conditions met in practice. Lack of a distinctive odor at toxic vapor concentrations presents a hazard to humans which will necessitate the use of a warning compound (lachrymating gas). The equipment necessary in using this fumigant presents no great mechanical difficulty.

(78)

Entomological service. Calif. Dept. Agr. (Ann. Rpt. 1938) Bul.
27: 645-668. 1939.

As the second generation of Carpocapsa pomonella (L.) hatched at the time of the first picking of pears, newly hatched larvae, which were difficult to detect at the time of picking, were numerous in the fruit. Fumigation of the packed and wrapped fruit in the trucks ready for shipment with 2 pounds of methyl bromide per 1,000 cubic feet was found to destroy all larvae in 2 to 3 hours.

(79)

Modern fumigation for pest control. Pests 7 (4): 6-8. 1939.

The amount and type of material fumigated greatly affect the concentration of gas in the air. Hydrocyanic acid gas and ethylene oxide, being water-soluble, are greatly affected by moisture, whereas carbon disulfide, methyl bromide, carbon tetrachloride, and ethylene dichloride, being fat-soluble, are less affected. In vacuum fumigation holding the vacuum throughout the exposure is more effective than dissipating the vacuum as soon as the fumigant is introduced. The control of termites by fumigants is worth further investigation. The author is testing tri- and tetra-chloro-ethylene and methyl bromide.

(80)

----- and CARTER, W. B.
Methyl bromide as a fumigant. A preliminary report. Calif. Dept.
Agr., Bul. 26: 153-162. 1937.

This fumigant possesses certain properties which permit its use against a number of forms of insect life not possible hitherto because of injury to the host. Data relative to its toxicity to human subjects are inconclusive. The gas has about the same insecticidal value as ethylene oxide. Methyl bromide was used at the rate of 2.5 pounds per 1,000 cubic feet for 90 minutes in the fumigation of potatoes for Gnoringoschema operculella (Zell.) with 100 percent kill. In one season 220 cars of potatoes were fumigated without injury to vegetables or to personnel. The tomato pinworm is easily destroyed by the same dosage. Preliminary tests on citrus trees showed complete control, without injury to the tree,

of resistant California red scale. The gas may be used in vacuum fumigators and mixed with carbon dioxide. Insects which apparently survive the fumigation become comatose and die after several days. This fumigant is less injurious than hydrogen cyanide to certain plants and tissues, including coleus, begonias, ferns, and other succulent plants.

----- and CARTER, W. B. (81)
Observations on Hypera brunneipennis and its destruction in baled hay by fumigation. Calif. Dept. Agr., Bul. 28: 387-392. 1939.

Adults of H. brunneipennis in cages of perforated copper tubing were buried in bales of tightly compressed alfalfa hay in ordinary freight and refrigerator cars loaded to full capacity. Ordinary freight cars were found to be unsuitable for fumigation, but complete mortality in refrigerator cars was obtained with a dosage of 1.1 pounds of methyl bromide per 1,000 cubic feet in the baled hay and also in bags of flax seed, the periods of exposure ranging from 6 to 24 hours for the hay and 12 to 24 for the seed. Complete mortality was also obtained in 12 hours when bales of alfalfa hay were fumigated at 1 pound per 1,000 cubic feet under a gas-proof tarpaulin.

----- and CARTER, W. B. (82)
Destruction of alfalfa weevil Hypera variabilis by fumigation and other means. Calif. Dept. Agr., Bul. 28: 466-470. 1939.

Penetration by methyl bromide was slower in timothy than in alfalfa hay. When 26 adults were placed in the center of a bale of each in a refrigerator car filled with timothy hay and fumigated for 10 hours at a dosage of 1.2 pounds of methyl bromide per 1,000 cubic feet, all those in the alfalfa were dead 3 hours after treatment, whereas 5 of those in timothy were active 5 days afterward. Complete mortality was obtained in baled timothy hay in refrigerator cars by fumigation at dosages of 1.2 and 2.4 pounds per 1,000 cubic feet for 24 and 6 hours, respectively. The bromine residues 72 hours after treatment for 24 hours at these dosages were 19.8 and 34.9 p.p.m. compared with 5.8 p.p.m. for untreated hay. When bales of alfalfa hay were fumigated at 2 pounds per 1,000 cubic feet under a gas-proof tarpaulin, all the adults were dead immediately after treatment for 12 hours, and 4 hours after treatment for 6 hours, but heavy concentrations of bromide remained. When the dosage was halved, all the adults were dead 3 hours after fumigation for 6 or 12 hours.

----- and CARTER, W. B. (83)
Fumigation of fresh fruit with methyl bromide under industrial conditions. Calif. Dept. Agr., Bul. 29: 78-86. 1940.

Packers during the 1939 season fumigated 1956 carloads of California Bartlett pears to destroy codling moth larvae. The work was done in refrigerator cars, refrigerator trucks, or under gastight tarpaulins. Fumigation should not be done below 65° or above 95° F. in the car. The dosage is not less than 4 or

more than 5 pounds per car, with an exposure of 2 hours. Twenty cars of mixed fruit (pears, plums, and peaches) were also treated without injury, as were 5,000 boxes of apples consigned to Hawaii. The same method was used in treating 5,310 boxes of winter pears to destroy the mealybug Pseudococcus maritimus (Ehrh.).

MALLET, M.

(84)

Insecticides for agricultural products. French Patent 747,798, June 23, 1933.

Agricultural fumigants contain a considerable amount of methyl bromide, which is not only toxic to insects but has fireproofing properties, permitting the addition of inflammable products to the liquid with safety. Carbon tetrachloride may be added to lower the vapor pressure.

McLAINE, L. S., and MUNRO, H. A. U.

(85)

Developments in vacuum fumigation at the port of Montreal. Ent. Soc. Ontario, Ann. Rpt. 67: 15-17. 1936.

A proprietary fumigant containing approximately 7 percent of methyl bromide and 93 percent of carbon dioxide killed European corn borer larvae when used at the rate of 40 pounds per 1,000 cubic feet for 90 minutes. A 2-hour exposure at the same rate gave complete mortality of apple maggots and codling moth larvae in the centers of infested apples. Analysis of vegetables and fruits fumigated with the mixture under experimental conditions showed that to a very limited extent the methyl bromide reacted with the plant material to give a water-soluble bromine compound.

MEIXNER, K.

(86)

Vergiftung durch Dämpfe des Feuerlöschmittels Polcin (Methylbromid). Beitr. z. Gerichtl. Med. 8: 10-17. 1928.

A workman employed in filling fire extinguishers with this liquid was fatally poisoned by the fumes. Convulsions and marked cyanosis preceded death. Autopsy showed lung edema and an early stage of brain edema.

MERZBACH, L.

(87)

Zur Pharmakologie des Brommethyls und einiger seiner Verwandten. Ztschr. f. die Gesam. Expt. Med. 63: 383-392. 1928.

Dogs were killed by exposure to 0.00009-0.00054 mole of methyl bromide per liter. Marked edema of the lungs was produced. A concentration of 0.000036 mole per liter was not fatal. Exposure of carp [Moorkarpfen] to 2.139 gm. of methyl bromide in 1,000 cc. of water caused narcosis in 18 minutes, but 1.8373 gm. caused no narcosis after 20 minutes. Exposure of isolated frog hearts to 6.5115 gm. in 1,000 cc. of Ringer solution produced a diastolic stoppage, although the heart recovered spontaneously; with 5.7975 gm. in 1,000 cc. there was no stoppage, but the amplitude was less and the frequency reduced.

METCALF, C. L., and FLINT, W. P.

(88)

Destructive and useful insects. 981 pp. New York and London.
1939.

The physical properties of methyl bromide are described. "It is about as toxic to many insects as chloropicrin and is used at dosages from 1 to 2 1/2 lbs. per 1,000 cubic feet for 12 to 16 hours in buildings. It is not narcotic to the insects and kills very slowly. It is recommended for use in ordinary atmospheric fumigation, as in mills and greenhouses, and in vacuum chambers, and also for such stored products as fresh fruits and green vegetables, dried fruits and other stored food products, household goods, nursery stock and ornamental flowers, and for rodent control. It does not injure the germination of seeds if they are dry. High temperature and humidity increase the effectiveness of this gas." It appears to be a very promising fumigant, but much is still to be learned about it (pp. 288-289).

For the control of bedbugs in congested places, individual rooms or apartments can safely be fumigated with commercial gases containing methyl bromide (p. 888).

MINISTERSTWO SPRAW WOJSKOWYCH.

(89)

Preparation of methyl bromide. Polish Patent 24,777, May 25, 1937.

Sulfur dioxide and bromine react in the presence of water to form hydrobromic acid and sulfuric acid. To this are added, dropwise, methyl alcohol and excess sulfuric acid, and the methyl bromide obtained is distilled off.

MUNRO, H. A. U.

(90)

Some observations on the use of methyl bromide as a fumigant. Ent. Soc. Ontario, Ann. Rpt. 68: 72. 1938.

This is a brief summary of studies in Quebec on the use of methyl bromide as a fumigant for apples. It was highly toxic to apple insects when applied at the rate of 2 pounds per 1,000 cubic feet at 80° F. In each test an initial vacuum of 3 inches absolute pressure was dropped to 27 inches after introduction of the fumigant, the vault temperatures being maintained at 80° by fan circulation. In several varieties of apples exposures of 90 and 60 minutes killed larvae of Carpocapsa pomonella (L.) and Rhagoletis pomonella (Walsh), respectively. Eggs of Rhagoletis in the fruits were killed in 30 minutes, but 60 minutes were necessary for eggs of Carpocapsa. In some experiments, however, it appeared that methyl bromide caused injury to apples.

(91)

Some fumigation methods employed in the United States to prevent the spread of the Japanese beetle (Popillia japonica Newm.). Ent. Soc. Ontario, Ann. Rpt. 70: 80-83. 1939.

Methods of fumigating fruits, vegetables, potted plants, and nursery stock with methyl bromide are described.

NATIONAL INSTITUTE OF HEALTH.

(92)

Preliminary recommendations to fumigators using methyl bromide or mixtures containing methyl bromide as a fumigant. U. S. Pub. Health Serv., Natl. Inst. Health. May 16, 1938, 1 p.
[Processed.]

- (1) Avoid breathing air containing methyl bromide.
- (2) On completion of fumigation, provide thorough ventilation for cars, rooms, or buildings before entering.
- (3) When necessary to enter spaces containing methyl bromide, use a gas mask provided with a canister giving protection against organic vapors, or a positive pressure hose mask.
- (4) Avoid spilling methyl bromide. Get to fresh air immediately in case of spillage. Remove any clothing in contact with skin which has become impregnated with the liquid.
- (5) Post warning signs notifying that methyl bromide is being used and that the gas is toxic.
- (6) Store containers of methyl bromide in a cool, well-ventilated place, outside inhabited buildings. Avoid leakage by seeing that valves on cylinders are tightly closed.

NUCKOLLS, A. H.

(93)

Comparative life, fire and explosion hazards of common refrigerants. Underwriters Laboratories, Misc. Hazards No. 2375, 118 pp. 1933.

Methyl bromide was among the materials investigated. Toxicity was determined with concentrations of 0.5-1.0 percent and 2-2.5 percent by volume (with higher concentration in some cases) by exposing guinea pigs for periods of 5 minutes to 2 hours. The effect of decomposition of the gas mixtures by heat from gas and oil flames and electric heating units was also determined, and analyses were made of the decomposition products. Investigation of fire and explosion hazards included determination of ignition temperature, limits of flammability or explosibility, explosion pressure, as well as time tests and speed-of-flame-propagation tests. The apparatus used and results of tests applied are described in detail.

OETTINGEN, W. F. von

(94)

The halogenated hydrocarbons: Their toxicity and potential dangers. Jour. Indus. Hyg. and Toxicol. 19: 349-448. 1937.

The literature on the toxicity of methyl bromide is reviewed.

OPPERMANN, K.

(95)

Methylbromid-Vergiftungen, berufliche. Samml. Vergiftungsfallen 4 (Abt. A): 157-160. 1933.

Two nonfatal cases of methyl bromide poisoning are described in which there were long symptom-free intervals. Brain irritation persisted for a long period in one case, and psychic debility in the other.

- PERELIS, W. J. (96)
Bromination of saturated aliphatic hydrocarbon gases. Indus. and Engin. Chem., Indus. Ed. 25: 1160-1161. 1933.

The method described uses a low bromine concentration in the presence of iron powder at 290°-370° C. Methyl bromide was obtained by this means from methane.

- PETERS, G. (97)
The biological-chemical evaluation of gaseous insecticides. Anz. f. Schädlingsk. 14: 116-122. 1938. [In German.]

Data on the boiling point, specific heat, heat of vaporization, and saturation limit at 20° C. are given for a number of gaseous insecticides, including methyl bromide. The vapor density, molecular weight, and explosion limits are also given. The most important factors in fumigation are gas concentration and time.

- PETRI, E. (98)
Pathologische Anatomie und Histologie der Vergiftungen. In Henke, F., and Lubarsch, O. Handbuch der Speziellen pathologischen Anatomie und Histologie. v. 10, pp. 272-273. Berlin. 1930.

The symptoms and pathology of methyl bromide poisoning are reviewed from various literature sources.

- PHILLIPS, W. R., and MUNRO, H. A. U. (99)
Methyl bromide injury to apples. Jour. Econ. Ent. 32: 344. 1939.

Although fumigation with methyl bromide was previously reported as injuring apples, later investigations gave different results. With a dose of 2.5 pounds per 1,000 cubic feet for 90 minutes in a vacuum vault and 80° F., only two of seven apple varieties were injured.

- MUNRO, H. A. U., and ALLEN, C. E. (100)
Some observations on the fumigation of apples with methyl bromide. Sci. Agr. 19: 7-20. 1938.

The standard treatment was found to be lethal to insects feeding internally in apples. The residue of bromide was so slight as to be harmless to human beings. Under certain conditions, however, methyl bromide caused both internal and external injury to the apples. No injury resulted, however, when the apples were picked at the proper stage of maturity and stored for 6 weeks at 32° or 39° F., and standard treatment was used. The damage, therefore, appears to be physiological rather than mechanical.

- PIPER, W. R., Jr., and DAVIDSON, R. H. (101)
Methyl bromide vapor against five species of stored product insects. Jour. Econ. Ent. 31: 460-461. 1938.

Fumigation tests at atmospheric pressure and various room temperatures, concentrations and exposure periods were made on adults of Sitophilus granaria (L.) and Acanthoscelides obtectus (Say), larvae of Trogoderma versicolor Creutz., larvae and adults

of Cathartus quadricollis (Guer.) (Silvanus gemellatus Duv.), and larvae of Tenebrio obscurus F., both exposed and covered to a depth of 6 inches by wheat. It was estimated that 1 pound of methyl bromide per 1,000 cubic feet should kill all these insects in 12 hours at 58°-70° F. Lower dosages may be sufficient or higher ones required in practical fumigation according to the species concerned and the quantity and nature of the infested material. Sitophilus was the most susceptible, the species being increasingly resistant in the order named. Under conditions in which all the insects were killed, the germinating powers of wheat, oats, corn, and beans were not affected. Immersion in liquid methyl bromide and exposure to its vapor did not affect any of nine common metals or change the color of seven wallpapers or nine samples of dyed cotton goods. No ill effects were experienced by the operators, and the fumigant was found to be noninflammable and easy to handle.

QUAYLE, H. J. (102)

The development of resistance to hydrocyanic acid in certain scale insects. Hilgardia 11: 183-210. 1938.

Preliminary experiments indicated that forms of Aonidiella aurantii (Mask.) which are resistant and nonresistant to hydrocyanic acid gas differ in their reaction to methyl bromide.

RICHARDSON, B. W. (103)

Some further additions to therapeutics. I. Organic bromides. Practitioner 6: 337-345. 1871.

Methyl bromide is mentioned as a general anesthetic.

----- (104)

Methyl-bromide. Asclepiad 8: 239-240. 1891.

Several deaths have occurred from the use of methyl bromide as a general anesthetic.

RICHERT, P. H. (105)

Apparatus for dispensing methyl bromide. U. S. Patent 2,156,869, May 2, 1939, to Dow Chemical Co.

Various details of valve construction, etc. are given.

ROHRER, F.

Ueber Brommethylvergiftung. Ein Beitrag zur Frage der Spätwirkungen von Giftstoffen. Vrtljrschr. f. Gerichtl. Med. 60: 51-59. 1920.

A fatal case of poisoning by methyl bromide is reported. The patient was exposed while making repairs on a pipe carrying the material in a plant for the manufacture of antipyrine. There was a symptom-free interval of about 24 hours between exposure and the onset of epileptiform seizures, coma, and death.

SAYERS, R. R., YAUT, W. P., THOMAS, B. G. H., and BERGER, L. B. (107)
Physiological response attending exposure to vapors of methyl bromide, methyl chloride, ethyl bromide, and ethyl chloride. U. S. Pub. Health Serv. Bul. 185: 1-56. 1929.

The purpose was to determine the effects of these vapors escaping in refrigeration plants. Guinea pigs were used. Short exposure to high concentration of the vapors produced similar symptoms, anesthetic in character, excitement, rapid loss of equilibrium, struggling and running motion of the legs, followed by rapid recovery of those animals which had not died in the chamber. With low concentration of vapor and long exposure, the symptoms were similar-- weakness, rapid pulse; convulsive, rapid respiration, with rales; and in some cases a frothy, bloody exudate from the nostrils; followed usually by death in 1 to 4 days. Ethyl chloride was the least toxic and methyl bromide the most. Addition of chemical agents to these refrigerants to serve as a warning of their escape is suggested.

SCHRÖTER, G. (108)
Methyl bromide. German Patent 330,642, Nov. 25, 1917.

Methane or methane-containing gas mixtures are passed with bromine over catalysts, particularly iron, at temperatures above 200° C.

SCHULER. (109)
Vergiftung durch Brommethyl? Deut. Vrtljrschr. f. Öffentl. Gsndhtspflege. 31: 696-704. 1899.

Three cases of poisoning by methyl bromide are reported, one of which was fatal. These men worked with apparatus in which methyl bromide was made from methyl sulfate and sodium bromide. Experiments on rabbits, guinea pigs, and mice are described. All the animals were killed by the concentrations of methyl bromide ranging from 1 to 8 percent by volume. Symptoms observed in the animals were somnolence, running of nose, slowness of pulse, and cyanosis.

SCHWARTZ, F. (110)
Brommethyl in der Schädlingsbekämpfung. Ärztl. Sächverstandigenztg. 42: 258-259. 1936.

The insecticidal use and the toxicology of methyl bromide are briefly discussed.

SHEPARD, H. H., and BUZICKY, A. W. (111)
Further studies of methyl bromide as an insect fumigant. Jour. Econ. Ent. 32: 854-859. 1939.

Laboratory tests were continued in 1938 (see Fisk and Shepard 29) with common insects that occur in houses or infest stored products. Their susceptibility to methyl bromide and its effectiveness in comparison with that of other fumigants are shown in a table. With 5 hours' exposure at 25° C. the median lethal concentrations of methyl bromide, chloropicrin, ethylene oxide, carbon

disulfide, and ethylene dichloride to the larvae of Attagenus piceus (Oliv.), and of the first two compounds to the adults, were 17.5, 5, 17, 88, 195, 9.5, and 1.3, mg. per liter, respectively, and those of methyl bromide were 5 and 3.1 mg. to larvae and adults of Flodia interpunctella (Hbn.), 13 and 7 to larvae of Tenebrio obscurus F. and Tineola bisselliella (Hum.), 4.2 and 4.7 to male and female adults of Zabrotes subfasciatus Boh., and 6.5 and 5.4 to adults of Stegobium paniceum (L.) and Rhizopertha dominica (F.). The insect material used was as nearly uniform as possible, most of the larvae being almost full-grown and most of the adults fairly young.

Differences in the speed of action of various fumigants against adults of Tribolium confusum Duv. are shown on graphs. Those exposed to methyl bromide at higher concentrations than that necessary for complete mortality seemed normally active immediately after the exposure but died within 48 hours. An added lethal effect of the low temperature appeared to depend on the cold resistance of the particular species concerned. The dose required to kill adult Tribolium increased down to about 8°-9° C. and then decreased, whereas that necessary to kill adults of Sitophilus granaria (L.) increased down to nearly 0° C. The temperature appeared to have no effect on the flour-absorption ratio.

Baking tests showed no detectable injury to flour fumigated for 5 hours at 2 pounds per 1,000 cubic feet.

STAHL.

(112)

Die Anwendung chemischer Sonder-nassfeuerlöscher in den gewerblichen Betrieben unter dem Gesichtspunkte ihrer Einwirkung auf die Benutzer. Zentbl. f. Gewerbe Hyg. u. Unfallverhütung (n.f.) 5: 78-80. 1928.

The author takes issue with the recommendation of methyl bromide as a fire extinguisher liquid by Von Gronow (40) and quotes several authorities to show that its use is dangerous.

STEIGER, O.

(113)

Ueber Brommethylvergiftung. München. Med. Wchnschr. 65: 753-755. 1918.

A nonfatal case of methyl bromide poisoning is reported. The usual symptoms of dizziness, vertigo, paralysis of the extremities, disturbances of vision, etc., appeared, followed after several days by hallucinations and strong motor unrest. The blood contained methemoglobin, and blood was excreted through the kidneys. After 2 months there was a decrease in skin sensitivity in the region of the radial nerve in the right hand, with a feeling of "fuzziness," and a similar sensation in the right leg.

STEINKOPF, W., and FROMMEL, W. (114)

Ueber die Darstellung von Brommethyl. Deut. Chem. Gesell. Ber.

38: 1865-1868. 1905.

Methyl bromide is prepared by adding bromine slowly to a mixture of methyl alcohol and red phosphorus.

----- and SCHWEN, G. (115)

Preparation of methyl bromide. Jour. f. Prakt. Chem. 102:

363-364. 1921. [In German.]

The authors increased the yield from 44.5 percent to 77 percent of the theory (calculated from the bromine) by using methyl alcohol (110 gm.), bromine (110 gm.), and phosphorus (22 gm.). To avoid the formation of an explosive mixture, they kept the methyl alcohol-phosphorus mixture slowly boiling before and during the addition of bromine.

STENGER, V. A., SHRADER, S. A., and BESHGETOOR, A. W. (116)

Analytical methods for methyl bromide. Indus. and Engin. Chem.,

Analyt. Ed. 11: 121-124. 1939.

Since the vapors of methyl bromide are toxic, it is important to have a simple procedure for the rapid detection of the gas in air. The literature is reviewed and the results of 2 years' experience at the plant of the Dow Chemical Company in Michigan are summarized. The well-known Beilstein test, which can be made quickly with the Frigidaire halide leak detector, can serve for the approximate determination of 50 to 500 p.p.m. The procedure of Kolthoff-Yutzy (Indus. and Engin. Chem., Analyt. Ed. 9: 75-76. 1937) is, however, more accurate for these concentrations. For the analysis of fumigated products, this procedure can be applied after ashing with potassium hydroxide in alcohol and in the presence of sodium chloride. Recoveries of 96 percent were obtained with 1 mg. of methyl bromide in 10 gm. of flour, nuts, dried fruits, or tobacco. For larger quantities the Volhard titration is recommended.

STEWART, M. A. and MACKIE, D. B. (117)

The control of sylvatic plague vectors. Amer. Jour. Hyg. 28:

469-480. 1938.

The control of fleas in rodent burrows, as well as the rodents themselves, necessary in the suppression of sylvatic plague, may be accomplished by fumigation with methyl bromide. All stages of fleas are susceptible to this fumigant, but the adults are the most easily killed. It appears from field tests that the dosage of liquid methyl bromide, approximately 10 cc. per burrow opening, ordinarily used to kill ground squirrels is also sufficient to kill all stages of the fleas. It is believed that the spread of bubonic plague occurring through the transportation of plague-flea-infested grains, cereals, etc., may be checked by fumigating these cargoes with methyl bromide, and that the materials so treated will not in any way be rendered unfit for human consumption.

STORER, T. I.

(118)

Control of injurious rodents in California. Calif. Agr. Col. Ext. Cir. 79, rev., 62 pp. 1938.

In 1936 methyl bromide was tested experimentally as a means of ground squirrel control. The results were encouraging, and further studies are planned, especially as to practical means for handling the gas. If suitable methods are developed, its use will be limited, for a time, to follow-up operations, since the cost of methyl bromide is as yet too high to permit its use in regular control work.

TAYLOR, A. L., and McBETH, C. W.

(119)

Preliminary tests of methyl bromide as a nematocide. Helminthol. Soc. Wash. Proc. 7: 94-96. 1940.

Methyl bromide appears to be an effective soil nematocide for use against the root-knot and free-living nematodes. Satisfactory results were obtained in preliminary trials with 80 cc. to treat a layer of soil 15 cm. thick in a fumigation box of 1 cu. m. capacity. Fair results were obtained with 1.5 pounds to treat 225 square feet of soil, when the chemical was applied through hollow-tile lines buried 18 inches under the soil and 18 inches apart. There was some evidence that methyl bromide also controls fungi and bacteria in the soil, but an attempt to eliminate root-knot nematodes from tomato plants was unsuccessful. Nematodes in the larger galls were not killed, and most of the plants were killed or severely injured.

TIETZE, A.

(120)

Clinical observations on intoxication by methyl bromide and carbon tetrachloride. Arch. f. Gewerbepath. u. Gewerbehyg. 4: 733-739. 1933. [In German.]

These chemicals are very soluble in lipoids, and thus constitute poisons for the organism and particularly for the nervous system. The disturbances which they cause in the organism are described.

UNITED STATES BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE.

(121)

Dried-fruit insects. U. S. Bur. Ent. and Plant Quar. Ann. Rpt. 1936: 6-7.

Fumigation of packed raisins with methyl bromide at the rate of 4 cc. per 25-pound box gave complete control of Ephestia figulilella Greg. and Plodia interpunctella (Hbn.).

(122)

Methyl bromide as a fumigant. U. S. Bur. Ent. and Plant Quar. Ann. Rpt. 1937: 79.

Fumigation with methyl bromide was effective in killing Japanese beetles in green beans packed in hampers and in killing larvae of the beetle infesting strawberry plants packed, with soil on their roots, in crates. It also gave promise of being a good greenhouse fumigant, giving nearly complete kills of three varieties of

aphids, the common red spider, one species of thrips, two species of mealybugs, and immature stages of the southern armyworm. Concentrations sufficient to kill Japanese beetles were tested on a variety of plants without injury. Special apparatus has been devised for introducing this and other fumigants into refrigerator cars.

(123)

Fumigation of potatoes by methyl bromide as a condition of certification of potatoes moving by refrigerator car from the area listed in regulation 5 of quarantine No. 48. U. S. Dept. Agr., B.E.P.Q. 473, 1 p. 1938.

The following treatment was authorized as a basis for certification of potatoes moving to points outside the Japanese beetle quarantine areas between June 15 and October 15: "Fumigation of potatoes in dry refrigerator cars with methyl bromide at a dosage of 2 pounds per 1,000 cubic feet of space, including the space occupied by the potatoes and bunkers of the cars, for a period of 2 hours during which time the car shall remain tightly closed with the plugs in place in the ventilator hatches. The temperature within the car when fumigated shall not be less than 70° F. Provision shall be made for circulating the mixture of air and fumigant in the car for as long a time as is deemed necessary by the inspector. At the end of the fumigation period the hatches shall be opened, the plugs removed, screens placed in the hatch openings, and the car shipped under standard ventilation."

(124)

Fumigation of onions by methyl bromide as a condition of certification of onions moving by refrigerator car from the area listed in regulation 5 of quarantine No. 48. U. S. Dept. Agr., B.E.P.Q. 475, 1 p. 1938.

The same treatment for onions as that described for potatoes in the previous reference (B.E.P.Q. 473) is authorized.

(125)

Fumigation of tomatoes by methyl bromide as a condition of certification of tomatoes moving by refrigerator car from the area listed in regulation 5 of quarantine No. 48. U. S. Dept. Agr., B.E.P.Q. 480, 1 p. 1938.

The same treatment for tomatoes as that described for potatoes in B.E.P.Q. 473 is authorized.

(126)

Administrative instructions to inspectors on the treatment of nursery products, fruits, vegetables, and soil, for the Japanese beetle (Sec. 301.48a). U. S. Dept. Agr., B.E.P.Q. 499, 20 pp. 1939.

The use of methyl bromide is authorized for treatment in a fumigation chamber of plants with or without soil, using 2 1/2 pounds of gas per 1,000 cubic feet (including space occupied by the load) at a temperature of not less than 63° F. for 2 1/2 hours.

For fumigation of strawberry plants in shipping crates of field-packed baskets, 3 pounds should be used per 1,000 cubic feet for 4 hours at a temperature of at least 60° F. For the treatment of fruits and vegetables in refrigerator cars, 2 pounds per 1,000 cubic feet (5 pounds per car) should be used for 2 hours at a temperature of at least 70° F.

B.E.P.Q. 499, Sup. 1, 1 p. 1939.

(127)

The instructions in B.E.P.Q. 499 are modified to state that the method is to be applied only to plants with bare roots or in 12-inch pots or smaller, or in soil balls not larger than 12 inches in diameter or thicker than 12 inches when not spherical. The soil should not be puddled or saturated, and the balls should not be jammed tightly together.

B.E.P.Q. 499, Sup. 1, rev., 2 pp. 1940.

(128)

The minimum temperatures in the dosage schedule provided in B.E.P.Q. 499 for fumigation of plants with or without soil are changed to the following: 63° F. for an exposure of 2 1/2 hours, 54° F. for 4 hours, and 50° for 4 1/2 hours.

B.E.P.Q. 499, Sup. 1, rev. 2, 2 pp. 1940.

(129)

An approved fumigation chamber equipped with vaporizing, air-circulating, and ventilating systems must be provided. The air within the chamber must be kept in circulation during the fumigation. At the completion of the treatment, the chamber must be well ventilated before it is entered and the plants are removed. The temperature of soil and air for each type of treatment must remain throughout the period of treatment at least that specified as follows: For dosage of 2 pounds per 1,000 cubic feet, 70° F. for 2 1/2 hours; for 2 1/2 pounds per 1,000 cubic feet, 63° for 2 1/2 hours, 54° for 4 hours, and 50° for 4 1/2 hours.

B.E.P.Q. 499, Sup. 2, 2 pp. 1940.

(130)

The following dosages are specified for fumigation of refrigerator cars: 1.6 pounds per 1,000 cubic feet (4 pounds per car) at a temperature of at least 80° F., or 2 pounds per 1,000 cubic feet (5 pounds per car) at a temperature of at least 70° F.

Administrative instructions modifying the restrictions of the white-fringed beetle quarantine by authorizing treatment by methyl bromide solution of balled nursery stock not larger than six (6) inches in thickness (or of specified thickness) (Sec. 301.72-5c). U. S. Dept. Agr. B.E.P.Q. 503, 2 pp. 1939.

(131)

The soil balls must be buried in sand and plunged in boxes or trays approximately 1 foot deep, which are watertight. A 2-inch

space filled with sand shall be provided between the balls. The balls shall be treated with a solution of 0.3 percent of methyl bromide and 0.6 percent of denatured alcohol by volume in water, applied evenly over the surface of the sand at the rate of 40 gallons per 100 square feet. The soil balls shall remain embedded thereafter for 24 hours. The temperature of the balls during treatment shall be not lower than 70° F.

(132)

B.E.P.Q. 503, rev., 1 p. 1940.

As a result of more recent investigations, the instructions are revised to provide that soil balls 7 inches in diameter may be so exposed for 8 hours at a minimum temperature of 65° F. The modification is restricted, however, to treatment for larvae of Pantomorus leucoloma Boh. The former specifications remain in effect for treatment of larvae of P. peregrinus Buch.

(133)

Administrative instructions; conditions governing the entry of cipollini from Morocco (Sec. 319.56-2f). U. S. Dept. Agr. B.E.P.Q. 504, 1 p. 1939.

Fumigation with methyl bromide is made a condition of entry for all shipments of cipollini from Morocco in order to eliminate any infestation of Exosoma lusitanica (L.) which might be present.

(134)

Administrative instructions amending authorization of the shipment of fruits and vegetables from Hawaii to the mainland subject to fumigation with methyl bromide under supervision. U. S. Dept. Agr. B.E.P.Q. 510, 2 pp. 1940.

Provision is made for the certification of guavas, papayas, bell peppers, bitter melons, cucumbers, summer squash, string beans, and tomatoes for movement into the United States, when prescribed fumigation with methyl bromide is applied in Hawaii. The commodity must be fumigated in a gastight chamber for 3 1/2 hours with 2 pounds of methyl bromide per 1,000 cubic feet at a temperature of not less than 80° F.

(135)

Methyl bromide fumigation. Construction details for an approved fumigation chamber. U. S. Bur Ent. and Plant Quar. 32 pp. 1940. [Processed.]

Construction details are given for a box-type fumigation chamber, suitable for chambers of 50 and 100 cubic feet.

VAYSSIÈRE, P.

(136)

Les stations de désinfection des végétaux sous vide partiel.
Soc. d'Encouragement pour Indus. Nat. Bu. 1934: 295-308.

Methyl bromide kills all stages of insects at doses of 30 to 50 gm. per cubic meter (3 to 5 oz. per 100 cubic feet), and its action is comparable to that of ethylene oxide. Its vapors are

not readily soluble, and it breaks up slowly in the presence of humidity, forming hydrogen bromide. Its use in the fumigation of vegetable substances with an appreciable humidity content but not a continuous cuticle is therefore inadvisable. Excellent results, however, have been secured in the treatment of pears, the color and consistency of which remain unaffected, and for which ethylene oxide is unsuitable.

(137)

La désinfection des châtaignes. Rev. de Path. Veg. et d'Ent.
Agr. de France 25: 277-293. 1938.

(Balaninus) Curculio elephas Gyll. and (Laspeyresia) Cydia splendana Hbn. are serious pests of chestnuts in France. Fumigation with methyl bromide at the rate of 2 to 3 ounces per 50 cubic feet for 3 hours at an initial vacuum of 700 mm. and subsequent vacuum of 20 mm. gave a complete kill.

VOSS.

(138)

New syntheses in the solvent industry. Kunststoffe 17: 79-80, 132-134, 205-207. 1927.

Recent patents are reviewed on processes dealing with the generation of methyl alcohol from water gas, direct oxidation of methane to methyl alcohol, manufacture of methyl chloride and bromide from methane, and the oxidation of these to methyl alcohol and the manufacture of methyl alcohol from carbon monoxide.

WEBSTER, R. W.

(139)

Legal medicine and toxicology. 862 pp. Philadelphia. 1930.

Early symptoms of methyl bromide poisoning are headache, weakness, vertigo, vomiting, and some disturbances of vision. The gait may be staggering, and slight pain in the extremities and neuritic symptoms may be noted. After several hours or even days, severe symptoms may appear in the form of strong contractions of different groups of muscles, clonic spasms of the entire body, double vision, pareses of the extremities, sleepiness, and polyneuritis. Convulsive type of respiration may be noted, and in the fatal cases reported epileptiform attacks are merged into a terminal coma. Physical signs of pneumonia may be noted. Convalescence is slow.

WIESMANN, R.

(140)

Untersuchungen über die Biologie und Bekämpfung der Erdbeermilbe, Tarsonemus fragariae, H. Zimmermann. Landw. Jahrb. der Schweiz. 51: 335-348. 1937.

Tests were made on the control of Tarsonemus pallidus Banks (T. fragariae Zimm.) with a number of fumigants, including a Swiss preparation called S-gas. This is supplied in a liquid form in ampules, its active constituent being methyl bromide. Methyl bromide is a rather violent respiratory poison, but is easy to apply with safety to strawberry runners, which can be fumigated in any tightly closed metal box in which the ampule is broken. A strength of 2 percent by volume killed all the mites and eggs in

6 hours at 15° C. Fumigation would not be effective at lower temperatures. At 18° the time could be reduced to 4 hours, but no harm was done to the plants by fumigating for 6 hours. All stages except the eggs were killed in 6 hours with 0.75 percent at 18°. Atmospheric humidity did not affect S-gas, which acted perfectly in fully saturated air. No injury to the plants occurred, even with a strength of 2.4 percent.

WILMOT, R. J.

(141)

Fumigation of horticultural products. Fla. Agr. Expt. Sta. Ann.
Rpt. 1938: 106. 1939.

It was found that the green pods of cowpea could be fumigated safely with methyl bromide, and that fumigation with half the basal dosage [2.5 lbs. per 1,000 cu. ft. for 90 minutes] gave complete control of larvae and adults of the cowpea pod borer. It also controlled larvae of the tomato pinworm without injury to the plants.

INDEX TO INSECTS AGAINST WHICH METHYL BROMIDE HAS BEEN TESTED

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