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EXTENSION

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Soil Fumigation with Methyl Bromide: Environmental Quality and Worker Safety [1]

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Methyl bromide (MB) is a restricted use agricultural pesticide, available for retail sale and use only by certified pesticide applicators or persons under their direct supervision. It is currently registered with EPA as an insecticide, fungicide, nematicide, and herbicide for many fruit and vegetable crops, and as a structural and commodity fumigant. For pest control purposes, MB is commonly mixed in various proportions with Chloropicrin (CP). In low concentrations, CP is used primarily as an odorant for detection of MB which is odorless. At higher concentrations (upwards of 50%), CP is used primarily as a fungicide.

Methyl bromide is commonly used under plastic mulch in Florida as a preplant soil fumigant, allowing increased production for many fruit and vegetable crops. Preplant application of methyl bromide to soils controls a wide variety of pests at a much lower cost than use of many specific pesticides. In some instances, pesticides are not available to effectively manage a specific pest problem, e.g., *Fusarium oxysporum*, thus necessitating the use of methyl bromide for economic crop production. For subtropical agricultural production systems, use of methyl bromide is cost effective for most high value crops. It controls a wider spectrum of pests, thus reducing overall use of pesticides required to produce a given crop, and in turn may reduce field worker exposure to pesticides.

Method of Application

Methyl bromide and Chloropicrin are premixed and sold in compressed gas cylinders. The mixture is shank-injected into the soil 6 to 8 inches deep using a positive pressure closed system (pressurized with nitrogen gas). Rates of application commonly vary from 100 to over 400 lbs active ingredient per acre. A polyethylene tarp may be laid down over the soil immediately behind the shanks of the injection equipment. In most cases however, fertilizers are frequently top dressed (banded) onto the bed surface following injection as a separate field operation before the plastic is installed. The tarp, although not impervious to MB/CP gases, reduces the dissipation rate of gases into the air which lessens the hazards to farm workers and increases the overall efficacy of the treatment by subjecting soil pests to greater cumulative levels of MB. Use of equipment capable of MB injection, fertilization and tarp laying in a single operation, thereby avoiding lengthy tarping

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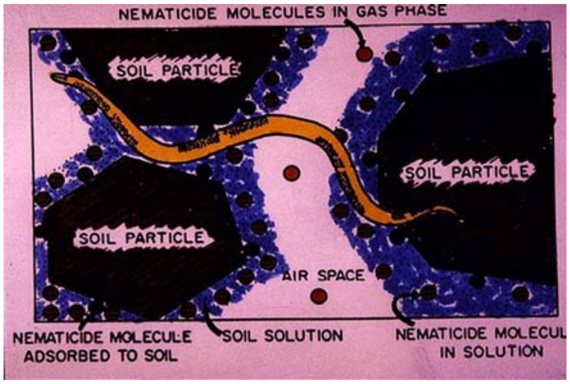
delays, is preferred for its risk reduction to farm workers. Reducing the width of fumigated beds, currently promoted by water conservationists, would also significantly reduce per acre use rates for MB, and reduce worker exposure.

Once injected into soil and at temperatures above 40°F, MB vaporizes rapidly into a gas and diffuses through open soil pore space. Since diffusion is greater in air above the soil surface, upward mass flow and diffusion is usually greater than downward movement and much of the gas escapes the soil and enters the atmosphere. Soil moisture content is important in this regard, primarily as it relates to the availability of continuous pore space. Soils which are too moist inhibit extensive diffusion through soil. Soils which are too dry promote the rapid escape of gases from soil into the atmosphere. Soil temperature is also important as it relates to soil moisture, since it directly influences the vaporization rate of methyl bromide in soil. As temperatures increase the vaporization rate increases. The importance of soil moisture and temperature to product efficacy and worker safety cannot be overemphasized. For example, when MB was applied to a dry, sandy soil, under conditions of high air and soil temperatures, and there is a 20 minute delay between fumigation and covering, a 40% loss of MB from the soil was observed. It is important therefore, that appropriate soil conditions and land preparations be performed prior to fumigation to enhance soil retention and minimize potential worker exposure to MB.



open soil pore space.

Potential Risks to Human Health

MB has come under close scrutiny in recent years due to an increased incidence of occupationally related cases of overexposure and accidental deaths. Most occupational injuries from exposure to methyl bromide have not involved agricultural uses. For example, in California from 1975 to 1986, there were on average 32 worker exposure cases per year involving methyl bromide, most of which were related to structural and commodity fumigation. Cases of MB overexposure are known to occur in Florida, however, summary statistics are not available.

Methyl bromide is a colorless, tasteless, nonflammable gas which is odorless except at extremely high concentrations. Because MB is a gas at room temperature, respiratory problems through inhalation are the most common and serious injury. MB is poorly absorbed through the skin, although contact with MB can cause skin blisters and diffuse through the skin to enter the circulatory system. In the body, it may cause severe lung irritation and cumulative damage to the heart, kidneys, and nervous systems. Accidental overexposure to MB may result in acute (short term) or chronic (long term) poisoning. Relatively high MB concentrations in an estimated range of 8600 to 60,000 ppm have generally resulted in fatal poisoning of man, as have 2000 ppm for one hour. Non-fatal poisoning have resulted from prolonged exposure to concentrations in the estimated range of 100 to 500 ppm. In the United States the Threshold Limit Value (TLV), which sets a guideline for acute exposure level for MB in air, is 5 ppm. Although superseded by the TLV, the permissible exposure limit (PEL), based on exposure to MB five days a week for eight hours a day, is 20 ppm. Exposure to these amounts of MB do not result in the appearance of toxic symptoms. Currently there is no conclusive evidence linking methyl bromide exposure to cancer or reproductive abnormalities in humans.

Chloropicrin is a colorless oily liquid whose PEL and TLV is 0.1 ppm. The reported odor threshold is 0.3 to 1.1 ppm which exceeds the respiratory guidelines established for CP. However, concentrations of 0.3 ppm result in painful irritation to the eyes in three to 30 seconds. Since chloropicrin causes so much irritation of the eyes and upper respiratory tract, exposed individuals are unlikely to inhale a quantity of fumigant capable of damaging the lungs. MB is not so irritating to the nose, eyes, throat, and bronchi, but causes serious injury to the cells lining the fine air sacs of the lung. The onset of symptoms of MB poisoning may be delayed several hours or days following exposure. Thus, it is more likely than other fumigants to induce pulmonary edema (fluids in lungs), a major cause of death from MB overexposure. Mixtures with chloropicrin should therefore be used to minimize the insidious effects of Methyl bromide. Currently MB and CP are not recommended by the Florida Cooperative Extension Service unless a chloropicrin content of at least 2% is present in the mixture.

Worker Exposure During Fumigation

Concentrations of MB and CP measured within the breathing zone of drivers and coworkers on injection equipment, and shovelers in the field have been monitored during preplant soil fumigations in California. The results from these studies indicate that workers on injection equipment are subject to the highest risk of MB and CP exposure. Lowest exposure levels were always observed with shovelers. In the majority of cases, worker exposure levels during application were well within acceptable limits and did not pose a known health hazard to workers. However, in some cases for drivers and coworkers on application equipment, concentrations did exceed the EPA established acute TLV for MB of 5 ppm and for CP of 0.1 ppm. Concentrations ranged from nondetectable levels to 8.3 ppm for MB and 1.5 ppm for CP. Extrapolation of these results to Florida conditions, where sandy soils predominate, suggests that potential worker inhalation exposure may be greater under conditions of high application rate, low soil clay content, low soil moisture and high soil temperature. Wind conditions are also of paramount importance due to dilution effects. Wind speeds of at least 1 mph have recently been proposed in California as a threshold guideline for soil fumigation.

In Florida average wind conditions are difficult to generalize considering the number of lakes and large bodies of water which through differential heating and cooling, influence wind velocity and direction. In general however, wind speeds are lowest (less than 10 MPH) at daybreak and increase rapidly, after maximum heating, to an average maximum of 10 to 15 mph during late afternoon (4 to 6 PM). Average wind velocities then decrease rapidly after sunset to the generally still conditions which exist at daybreak. Land and sea breezes may modify average wind speeds considerably, although the basic pattern of mid-late afternoon maximum wind velocities remain the same.

The majority of agricultural overexposure injuries caused by MB during soil fumigation are skin, eye, and respiratory injuries due to uncoupling or breakage of hoses under pressure, improper application techniques, and changing of MB cylinders. These injuries could have in all probability been avoided had equipment been properly maintained, preapplication inspections performed, armored MB delivery tubes installed, and in the case of eye injuries, had victims been wearing proper eye protection as directed by the product label. New product label restrictions requiring 10 gallons of potable water and a self-contained breathing apparatus on the tractor or in a nearby service vehicle will help to minimize serious health hazards in the event of a field accident. Minimizing tarping delays, precision placement (8-12 inches), and elevating rear inspection seats or platforms above the soil surface, away from zones where MB is known to accumulate, will also serve to reduce accidental exposures.

Worker Exposure After Fumigation

Workers who remain close to and sometimes sit on recently fumigated beds, subject themselves to potentially harmful and unnecessary respiratory and dermal exposure risks. As indicated previously, plastic mulches impede rapid gas escape and are not completely impervious to MB. Since MB is a very dense gas (three times heavier than air), it may concentrate to unhealthful levels near the soil surface in the absence of turbulent wind currents. It is important that persons using MB take the proper precautions to protect themselves from exposure, allowing common sense to prevail in many situations. This would include maintaining themselves in an upwind position or preferably exiting the field immediately following fumigation. In those reported cases where accidental overexposure to MB have occurred, premature removal of tarps from the treated field has been the primary causal factor. In Florida, label requirements for prohibiting worker reentry into fumigated fields for a period of 48 hr, thus serve to reduce the risk of exposures following fumigation.

dermal exposure.

Worker Exposure Downwind of Fumigation Site

Atmospheric monitoring studies for concentrations of MB and CP in air downwind from field application sites have been conducted in a number of locations within California during and after shallow preplant soil fumigations. In general, MB and CP concentrations were shown to fluctuate diurnally, with highest concentrations occurring during morning hours when wind velocities were lowest and unfavorable for turbulent mixing. In these studies, concentrations of MB ranged from below the detectable limit (1.1 to 3.0 ppb) up to 900 ppb. Extensive field monitoring studies generally show levels of downwind worker exposure to methyl bromide to be less than 1 ppm, which is 1/20 of the current OSHA workplace standard and 1/5 of what the Environmental Protection Agency permits. Concentrations of chloropicrin ranged from below the detectable limit (1 ppb) up to 81 ppb. In general, agricultural uses of methyl bromide and chloropicrin should not pose acute health hazards to people living and/or working around the fumigated fields under normal conditions.

Food Residues

Although many agricultural crops, as consumed, contain no detectable residues of methyl bromide, MB residues (inorganic bromides) are known to accumulate in many plants, primarily in leaf tissues and stalks, rather than roots or fruit. Bromine uptake by plants depends largely upon soil texture and organic matter content, temperature, amount of leaching which has occurred as well as to plant species. Food tolerances for MB residues have been established in or on a wide variety of agricultural commodities, ranging from 25 ppm to 300 ppm, with the majority at 60 ppm or less. Dietary consumption of bromine residues is not well understood so a maximum average daily intake (ADI) of 1 mg bromine /kg body weight for humans has been established.

Risk to Environment

MB is a simple compound (CH_3Br) composed of carbon, hydrogen and bromine which places it within the family of halogenated compounds. Bromine, the major constituent of methyl bromide, is a common element in sea water (65 ppm), potassium salts, and has also been detected in some fresh water systems (10 to 89 ppm). Many different natural and manmade sources are now known to contribute to atmospheric concentrations of bromine and of methyl bromide. For example, marine algae and spray from ocean waves have been estimated to contribute about 70-80% of the bromine in air. Three major manmade sources of atmoshperic methyl bromide have been identified: agricultural usage (soil and commodity fumigation), biomass burning, and potentially the exhaust from automobiles using leaded gasolines. Although estimated with considerable uncertainty, as much as 30-60% of the methyl bromide applied to soil is thought to escape the plant bed. It is not clear how methyl bromide finds its way into the upper atmosphere or how global atmospheric mixing occurs, since methyl bromide by molecular weight is three times heavier than air.

The emission of methyl bromide into the atmosphere is of critical importance because the most recent environmental assessments by geophysical and atmospheric scientists have concluded that chlorine and bromine appear to be the chemical compounds largely responsible for global ozone depletion in our upper atmosphere. These same scientific assessments have also implicated methyl bromide as a significant contributor to stratospheric ozone depletion.

Increased ultraviolet radiation is thought to be the major consequence and health concern related to atmospheric ozone depletion. An increase in ultraviolet radiation is expected to have many undesirable affects on man, animals, plants, and materials. The potential adverse impacts include suppression of the human immune system contributing to an increase in the incidence or severity of infectious disease, cataracts, non-melanoma skin cancers, as well as reduced growth and photosynthesis of land and aquatic plants, and increased degradation of wood and plastic products leading to discoloration and loss of strength.

Final degradation products in soil and air include carbon dioxide (CO_2), water (H_2O), and inorganic bromine (-Br). When methyl bromide is degraded in soil, the halogen (Br) may combine with other negatively charged ions. Although inorganic bromine accumulation in soil is of concern to the Environmental Protection Agency, it is not believed to present an environmental hazard since many soils have a normal concentration of bromine in the range of 1 to 5 ppm. Irrigations following methyl bromide fumigation are used to leach ion residues from plant root zones where accumulations do occur. Extensive groundwater testing, in numerous locations within Collier and West Palm Beach counties, has failed to detect residues of MB in Florida groundwater under areas where MB has been used extensively. MB is not expected to run off fields to surface water because of application methods under plastic tarps.

Conclusions

Worker Safety

Under normal conditions, available evidence seems to indicate that worker exposure to methyl bromide does not represent any unreasonable human health risks. Downwind drift exposure to workers in adjacent fields should not constitute a significant threat either, particularly if chloropicrin formulations and plastic mulches are used, under appropriate soil conditions and land preparations. However, careless use of agrichemicals has plagued the continued availability of agricultural pesticides in general. Growers should recognize that carelessness, as it relates to MB use and worker safety will not be tolerated by state and federal officials. To avoid field accidents and to guarantee the continued availability of MB, farm workers must become knowledgeable of safety precautions and technical procedures for soil fumigation. Growers must accept this responsibility in addition to providing a safe working environment. This includes the preparation and conditioning of soil to maximize MB retention, routine inspection and maintenance of application equipment, and to delay planting to allow for sufficient aeration. New MB application manuals, pesticide safety seminars, and pesticide certification requirements for workers and equipment, developed jointly by chemical manufacturers/distributors and government agencies will also aid in this regard.

Environmental

As indicated previously, methyl bromide is now viewed as a significant ozone-depleting compound. Because of expected adverse environmental impacts, the Environmental Protection Agency (EPA) will enforce the Clean Air Act of 1990, which mandates a complete phaseout of methyl bromide use in the United States by January 1, 2005. With the impending loss of MB, new environmentally-compatible strategies for soil pest control must be developed, in a relatively short time to avoid significant losses in crop productivity due to a broadcomplex of soilborne plant pests and pathogens.