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F.A.S.T. (FUMIGATION ABATEMENT AND DESTRUCTION) SYSTEM

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ABSTRACT

The F.A.S.T. System scrubber accompanies a fumigation chamber/area by functioning to capture and destroy fumigant gases such as methyl bromide, sulfuryl fluoride, methyl iodide and any other alkyl halides. The F.A.S.T. system contains a depository holding scrubbing material that causes a substantially complete chemical breakdown of the fumigant introduced. The solution is non-carbon based and is mostly aqueous containing chemical degradation properties. Any alkyl halide such as methyl bromide or sulfuryl fluoride agitated through the depository can be broken down through the scrubbing solution by a SN2 chemical reaction. By-products of the reaction are retained in the scrubber depository leaving only ambient air to be released into the atmosphere.

INTRODUCTION

Many native and non-native species of moths, beetles, borers, parasites, nematodes, other microorganisms, and rodents have the ability to damage a wide range of agricultural and non-agricultural commodities and stored products. Such items can include grain, seed, flour, processed foods, cut wood, logs and a wide variety of other perishable and non-perishable goods and products. Fumigation using specialized gases with lethal properties to a broad spectrum of pests, especially insects, rodents, and pest microorganisms, are a fast and effective eradication method to prevent damage to stored commodities (Mueller, 2010). Fumigations can take place in any gas/air tight chamber, building or structure to eliminate infestations. Sealed containers, trailers, boxcars, import and export shipments, grain bins, homes and other free standing structures, where fumigant gas can be introduced and held for a long enough periods of time to, make for desirable fumigation areas and permit eradication. Other more unique situations where fumigations may take place include libraries, restaurants, ship holds, museums, and rare and/or high value artifacts.

For many years, methyl bromide (MeBr) has been widely used as a pesticide fumigant. However, because bromine released from methyl bromide has been found to contribute to depletion of the ozone layer in the troposphere, its use is being eliminated under both U.S. laws and international treaties. Nevertheless, until such time as those fully take effect, methyl bromide is still being used as a fumigant, particularly in the U.S. for quarantine and pre-shipment purposes (Mueller, 2010). From an environmental standpoint, there is therefore a strong incentive to develop systems that will ensure that fumigations performed with methyl bromide will not result in its escape into ambient atmosphere.

Because of the ozone-depleting drawbacks associated with the use of methyl bromide as a fumigant, efforts have been made to find and/or develop non-ozone depleting substitute pesticide fumigants. One such substitute is sulfuryl fluoride (SF). Although not an ozone depletor, SF is a colorless and odorless gas which is toxic if inhaled (MeBr gas is also toxic if inhaled). SF is therefore a hazardous gas, and it is necessary to take stringent safety precautions and perform fumigations using only properly trained personnel using proper safety techniques.

Most fumigant systems in present use offer little, if any, control of the spent fumigant gas, even those involving the use of toxic and/or ozone depleting substances like MeBr and SF. Frequently, all that is done is to maintain a safety perimeter (about 15 m) around the location so that any persons in the area will be at a safe inhalation distance when the spent fumigant is simply exhausted to the atmosphere (Swords et al., 2011). Other systems offer some recovery of the spent fumigant; however, these systems use carbon absorption techniques that require activated carbon based filters and/or beds to capture the fumigant (Swords et al., 2011). The activated carbon does not destroy the fumigant but instead only holds the fumigant for a short time, eventually allowing it to be let back into the atmosphere. Moreover, carbon based systems are only able to be used with MeBr and are ineffective when the fumigant is SF. Thus, there is a need for improvement in this field.

MATERIALS AND METHODS

The scrubber functions to capture and destroy any harmful fumigant gas by a nucleophilic-substitution reaction. The F.A.S.T. system removes fumigant from a variety of fumigation situations including agricultural and non-agricultural commodities and/or stored products, structures and articles of value. The system includes a fumigation chamber enclosing in a substantially gastight manner an area containing an object to be fumigated therein. A fumigant gas having environmentally hazardous and/or toxic-to-humans properties is provided for introduction into the chamber. A fumigant gas scrubber containing fumigant destruction properties is also provided. A delivery system is employed for delivering the fumigant gas into the fumigation chamber and for delivering spent fumigant gas under pressure to the fumigant gas scrubber after the object has been fumigated. The scrubber functions to capture and destroy any harmful fumigant gas, such as for example methyl bromide or sulfuryl fluoride, which might otherwise be released to the atmosphere after fumigations (Swords et al., 2011). The system can be used with pallets, shipping containers, fumigation chambers, trailers and is able to fumigate small buildings and bins from a truck-based mobile system. Methyl bromide (MeBr) or sulfuryl fluoride (SF) is drawn out of the area fumigated by a regenerative air blower that forces contact with the scrubbing liquid through a multi-prong filter head. The spent fumigant gas is agitated through the solution causing a chemical breakdown of the fumigant gas into liquid and other non-hazardous by-products (Swords et al., 2011).

SN2 Substitution Reaction

The destruction process proceeds by the SN2 substitution reaction. This can be explained as a reaction of an electron pair donor, which would be a nucleophile (Nu), with an electron pair acceptor, which is the electrophile. The key to this reaction is that the electrophile must have a leaving group in order for the reaction to take place. In this case it is the halide (X) shown in Fig. 1. The halides in fumigants are bromide (Br) and fluoride (F) in methyl bromide and sulfuryl fluoride. The nucleophile that causes the breakdown is within the scrubbing solution.

The electron pair from the nucleophilic scrubbing solution attacks the electrophile which can be methyl bromide, sulfuryl fluoride or any other alkyl halide. This nucleophilic attack takes place at the carbon or sulfur molecule at the center forming a new bond, while the leaving group, Br or F, departs with an electron pair.

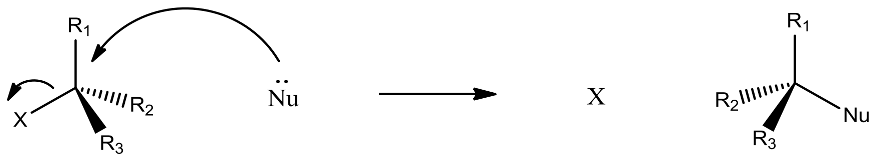

Fig. 1- Reaction of an electron pair donor, a nucleophile (Nu), and an electron pair acceptor, which is the electrophile and a leaving group halide (X).

System Workings

Following fumigation, the system is switched on from a 110 or 220 volt power source providing the necessary energy to run the system. The system employs a regenerative air blower that operates to draw out fumigant through a network of 4 and 2 inch piping to be delivered under pressure scrubbing solution depository. Once the air blower is running, the spent fumigant gas is drawn into the scrubber system inlet and travels through flexible tubing. At the other end of the flexible tubing, a reducer reduces the diameter of the inlet opening. At this point, the fumigant gas flows through piping and into the blower inlet. At the air blower inlet, the fumigant gas then moves through the regenerative air blower building pressure and then is forced through the blower outlet.

Moving from the blower outlet, the spent fumigant gas then travels through piping into the scrubber inlet in the depository and through an agitator having a filter head positioned inside and towards the bottom of the depository. The depository, containing the special scrubbing liquid, may be a wide variety of volumes (currently the largest is 950 L [250 gal]). The filter head, which is multi-pronged, is designed so that on each prong contains small apertures that allow the spent fumigant to bubble through (Swords et al., 2011). Size of apertures may vary to provide the optimum range of bubbling size and/or agitation action so that the fumigant gas can be broken down chemically much easier as it travels through the scrubbing solution from the multi-prong filter head. Spent fumigant gas bubbles through the scrubbing solution creating agitation and complete chemical breakdown of the gas introduced. Ambient air is allowed to travel up and through the exhaust and non-toxic and environmentally non hazardous or ozone depleting by products are contained within the depository (Swords et al., 2011). Gas concentrations can be monitored throughout the entire scrubbing process. The monitoring equipment provides readings of how much fumigant is left in the fumigation chamber, when the reading from the equipment within the chamber reads 0-0.0353 g m^{-3} (0-1 g/ft^3), the process has been completed and sealing may be removed. Two other locations are monitored for fumigant concentration including the exhaust from the scrubbing system and another monitoring line measuring ambient air surrounding the chamber and system. Overall, the system within 10-15 minutes can completely remove fumigant from 28.3 m^3 (1000ft^3) but is subject to change with up scaling and further testing. Our most common 950 L (250 gal) system allows more than 4 air exchanges per hour on land/sea containers or trailers and runs at a minimum of 6 m^3/min (215 ft^3/min).

RESULTS FROM SCRUBBING PROCESS

Table 1. F.A.S.T. System removing MeBr from 90 m^3 trailer

Time (min)	Conc. Trailer ($g\ m^{-3}$)	Conc. Exhaust ($g\ m^{-3}$)	Conc. Air ($g\ m^{-3}$)	Corrected Conc. ($g\ m^{-3}$)
0	128	0	0	0
5	67	2	2	0
10	28	3	2	1
15	27	1	2	0
20	24	2	1	1
25	20	1	1	0
30	14	1	1	0
35	7	1	1	0
40	5	1	1	0
45	2	1	1	0
50	1	1	1	0

<u>Example 1</u>: F.A.S.T. System removing MeBr from 90 m^3 (3200 ft^3) trailer.
Date: 6/14/2011 Start Time: 4:00 pm
MeBr: 6.8 kg (15 lb) Trailer: 90 m^3 (3200 ft^3)
Note: Concentration measured in units of g m^3 (oz/1000 ft^3)
Filter: Multi-head Filter

Table 2. F.A.S.T. System removing MeBr from 28 m^3 fumigation chamber

Time (min)	Conc. Chamber ($g\ m^{-3}$)	Conc. Exhaust ($g\ m^{-3}$)	Conc. Air ($g\ m^{-3}$)	Corrected Conc. ($g\ m^{-3}$)
0	111	0	0	0
5	30	0	0	0
10	7	0	0	0
15	0	0	0	0

<u>Example 2</u>: F.A.S.T. System removing MeBr from 28 m^3 (1000 ft^3) fumigation chamber.
Date: 8/17/2011 Start Time: 3:45 pm
MeBr: 0.7 kg (1.5 lb) Chamber: 28 m^3 (1000 ft^3)
Note: Concentration measured in units of g m^{-3} (oz/1000 ft^3)
Filter: Multi-head Filter

Table 3. F.A.S.T. System removing MeBr from 90 m^3 fumigation trailer

Time (min)	Conc. Trailer (g m^{-3})	Conc. Exhaust (g m^{-3})	Conc. Air (g m^{-3})	Corrected Conc. (g m^{-3})
0	30	0	0	0
5	18	1	2	0
10	12	2	1	1
15	11	2	1	1
20	9	1	0	1
25	8	1	1	0
30	7	0	0	0
35	3	2	1	1
40	3	1	0	1
45	1	1	1	0

Example 3: F.A.S.T. System removing SF from a 90 m^3 (3200 ft^3)trailer.
Date: 6/14/2011 Start Time: 5:25 pm
SF: 6.4 kg (14 lb) Trailer: 90 m^3 (3200 ft^3)
Note: Concentration measured in units of g m^{-3} (oz/1000 ft^3)
Filter: Multi-head Filter

Table 4. F.A.S.T. System removing MeBr from 28 m^3 fumigation trailer

Time (min.)	Conc. Chamber (g m^{-3})	Conc. Exhaust (g m^{-3})	Conc. Air (g m^{-3})	Corrected Conc. (g m^{-3})
0	70	0	0	0
5	20	2	2	0
10	5	2	2	0
15	3	0	0	0
20	1	0	0	0

Example 4: F.A.S.T. System removing SF from 28 m^3 (1000 ft^3)trailer.
Date: 7/1/2011 Start Time: 2:00 pm
SF: 0.7 kg (1.5 lb) Chamber: 28 m^3 (1000 ft^3)
Note: Concentration measured in units of g m^{-3} (oz/1000 ft^3)
Filter: Multi-head Filter

Example 5: Gas chromatograph analysis of F.A.S.T. System exhaust (small scale).

Fig. 3 represents the concentration of methyl bromide from the exhaust as a function of time. This study was done on small scale within the lab hood using gas chromatograph analysis to determine the concentration of methyl bromide by peak area after gas has been scrubbed and allowed to flow through the exhaust.

As can be seen in the above graph 100% methyl bromide has a concentration / peak area of over 1,000,000 units. After scrubbing, the gas/air flow from exhaust is analyzed showing miniscule amounts of methyl bromide present.

Fig. 2- Recent F.A.S.T. System Scrubber installed at Chicago O'Hare International Airport.

Example 6: Gas chromatograph (GC) analysis of scrubber exhaust from 794 L system (210 gal).
Fig. 4 shows the results of GC analysis for the scrubber exhaust of the large scale 794 L system (210 gal) F.A.S.T. system. The grey trace represents concentrated methyl bromide with overlays of the scrubber exhaust (the dotted line) and ambient air surrounding the system (solid black line). The results show no indications of methyl bromide present from the F.A.S.T. System exhaust as well as the surrounding ambient air.

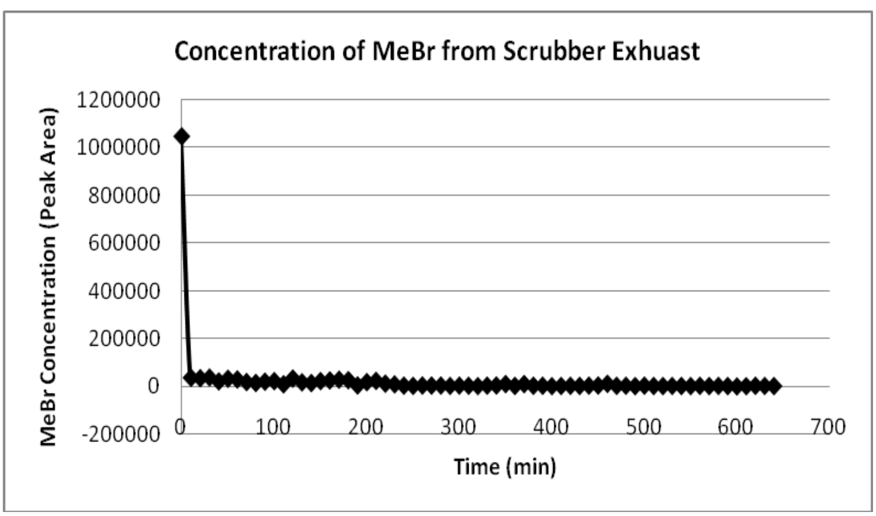

Fig. 3- Gas chromatograph analysis of F.A.S.T. system exhausts showing concentration of methyl bromide as a function of time.

Scrubbing Solution Quenching:
After repeated use the scrubbing solution depletes and needs to be replaced. This is the saturation point of the solution which is directly dependent on the molar ratio of fumigant to scrubbing material. Our 946 L system (250 gal) system will destroy approximately 363 – 454 kg (800 - 1000 lb) of methyl bromide or sulfuryl fluoride; however this is subject to change depending on the size of the system which can be customized to be more or less. Upon reaching the saturation point, an over the counter – food grade neutralizing product is used as an additive to quench the scrubbing solution before disposal. This quenching process lowers the pH of the solution making the scrubbing solution neutral. The spent solution then has a low neutral pH and has a flash point of greater than 82.2°C (180°F) making it extremely non-flammable and non hazardous. Saturated material can be disposed of at a local waste management facility for a low, economical cost of less than $40 per 208 L (55 gal) drum.

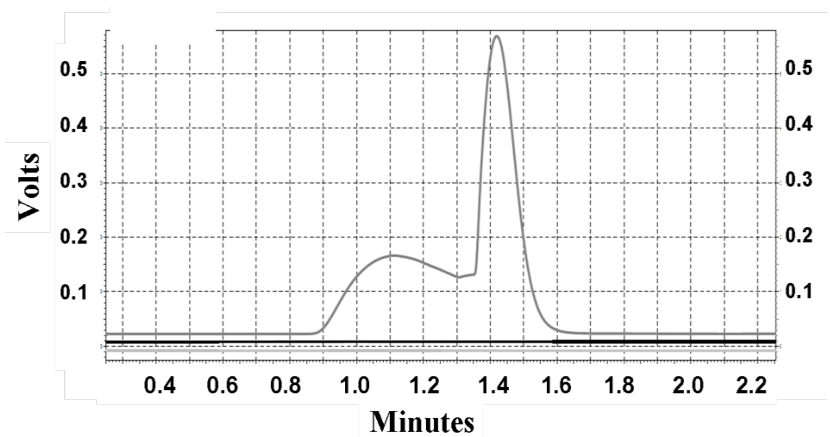

Fig. 4- Gas chromatograph analysis and comparison of scrubber exhaust, ambient air and concentrated methyl bromide. The darker grey trace represents the peaks created from concentrated methyl bromide with overlays of the scrubber exhaust (solid black line) and ambient air surrounding the system (solid light grey line).

REFERENCES

Mueller DK (2010). Reducing Customer Complaints in Stored Products. Carmel, Indiana: UN Communications.

Swords P, VanRyckeghem A, Mueller D (2011) Current Methyl Bromide Recapture Technologies and Uses. MBAO Conference. San Diego, California, October 2011.