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FUMIGANT CONFINEMENT AND HALF-LOSS TIMES IN FOOD INDUSTRY STRUCTURES AND SHIPPING CONTAINERS

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ABSTRACT

Fumigant dosages are calculated using the formula concentration x exposure time = dosage (g.h m^{-3}) . Fumigant lost from the fumigation atmosphere ceases to contribute to the accumulating dosage. The rate of fumigant loss during the exposure is represented as Half-Loss Time (HLT) in hours. The more quickly fumigant escapes from the confined area, the shorter the HLT. Results from studies in which fumigant loss was monitored from a variety of food industry structures indicated that tape and seal confinement procedures achieved relatively short HLTs, generally less than 20 h, while tarping increased HLTs several fold. HLTs within untarped multi-story mills were not consistent across floors, the upper floors generally having shorter HLTs than the lower floors. HLTs also varied during the exposure time due to external environmental changes. A possible fumigation efficiency strategy in complex mills is to isolate floors, dosing each floor based on its HLT. Due to the apparent similarity in construction of shipping containers, fumigant confinement was predicted to be consistently high. Results of monitoring a series of containers fumigated with sulfuryl fluoride, however, revealed a wide range of HLTs from ~ 4 to >80 h, most likely due to differences in the gas permeation qualities of the wooden floors in the containers. To know, or predict HLT accurately is critical to fumigation cost effectiveness. Understanding sealing options and the associated costs and benefits allows the knowledgeable fumigator and customer to prepare the most appropriate fumigation management plan. Improving fumigant confinement makes economic sense when additional labor and material costs for sealing are less than the cost of using more fumigant.

INTRODUCTION

Cost effective use of fumigants is dependent on effectively confining the gas in the fumigated area. Striving for efficiency, the fumigator balances the cost of sealing the fumigated area against the cost of using additional fumigant to achieve the targeted dosage. This simple equation is fast becoming more complex, with the increasing costs of exposure mitigation procedures, regulatory limitations on the amount of fumigant permitted for use at a site, and product phase-outs. A new economic equation is driving the need for improved fumigant confinement.

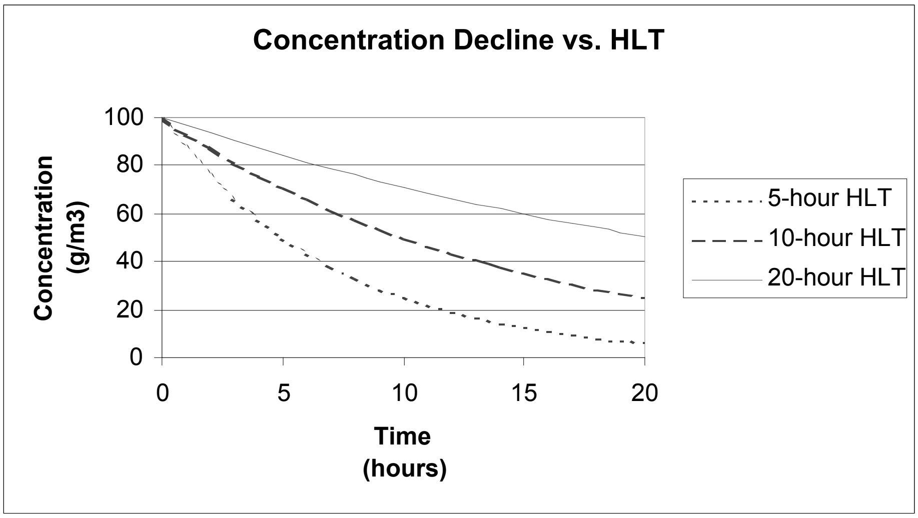

Fig. 1. Decline in fumigant concentration over time for three HLT scenarios: 5, 10 and 20 h.

IMPLICATIONS OF GAS LOSS AND DOSAGE ACCUMULATION

Fumigant dosages are calculated using the formula: Gas Concentration (C) x Exposure Time (t) = Dosage or Ct measured in $g \cdot h/m^3$ units. Fumigant lost from the fumigation atmosphere ceases to contribute to the accumulating dosage. The rate of fumigant loss during the exposure is represented as Half-Loss Time (HLT) in hours. The more quickly the gas escapes from the space being fumigated, the smaller the HLT value.

Fig. 1 depicts the decline in fumigant concentration over time for HLTs of 5, 10, and 20 h. Fig. 2 shows the relative accumulation of dosage in fumigations with these same HLTs. These graphs demonstrate some valuable lessons to incorporate into fumigation management plans.

Extending the exposure time in fumigations having short HLTs provides minimal benefit in accumulating dosage. Using the equation C x t = Ct to explain this, increasing t provides minimal additional accumulation of Ct when C is relatively small. Note: The 5-h HLT line in Fig. 2 plateaus after approximately 13 h.

Conversely, the benefit of achieving longer HLTs increases as exposure time is extended. Increasing t when C is relatively large does significantly increase dosage accumulation. Note: In Fig. 2, the Ct increases much more rapidly for the 20-h HLT, than for the shorter HLTs.

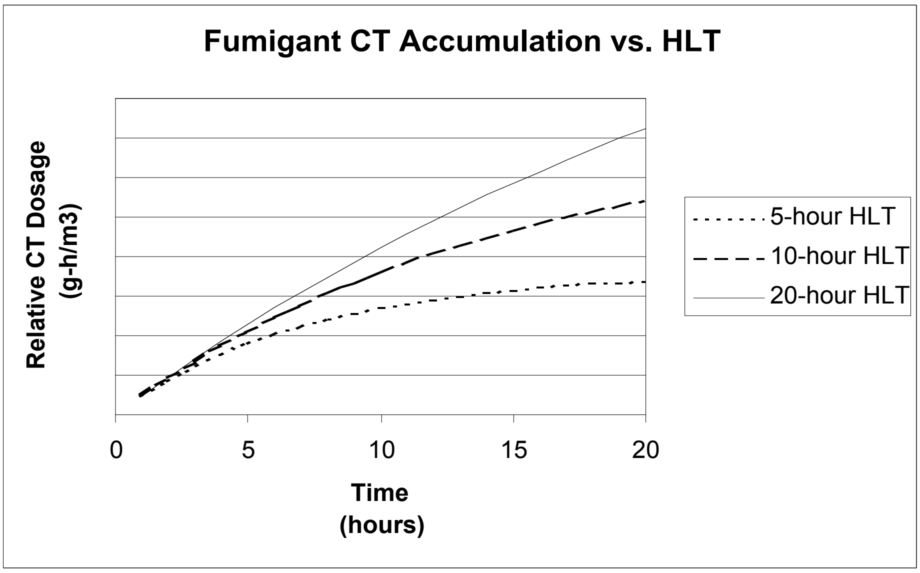

Fig. 2. Relative increase in fumigant Ct dosage for HLT scenarios: 5, 10, and 20 h.

Accurately predicting the HLT allows the fumigator to introduce the correct amount of fumigant to achieve the targeted Ct while also ending the fumigation with the minimal amount of fumigant to aerate. Note: The 10-h HLT line approximately meets the arbitrary target Ct (e.g., the center grid-line in Fig. 2), while the 5-h HLT does not reach the target (insects survive) and the 20-h HLT substantially exceeds it (excessive fumigant applied).

Conducting an efficient fumigation requires knowing or accurately predicting the HLT. This can be achieved by possessing a monitoring history for the structure, employing a HLT prediction tool such as the Fumiguide* system from Dow AgroSciences, or monitoring the fumigation. The HLT can then be incorporated into the fumigation management plan, controlling the concentration and exposure time to achieve a cost efficient fumigation.

FOOD INDUSTRY STRUCTURE HLTS

Food industry structures are generally sealed for fumigation with tape and polyethylene sheeting (tape-seal) rather than covering the structure with tarps as is typical for residential fumigations in the United States of America to control wood infesting insects. Figure 3 shows the HLTs for 13 methyl bromide and 11 sulfuryl fluoride food industry structure fumigations conducted in the USA and Europe by several different fumigation companies. The HLT values are for individual floors or sections of buildings, or entire structures such as mills or warehouses. All the structures were tape-sealed except for the one sulfuryl fluoride fumigation which had a 65 h HLT.

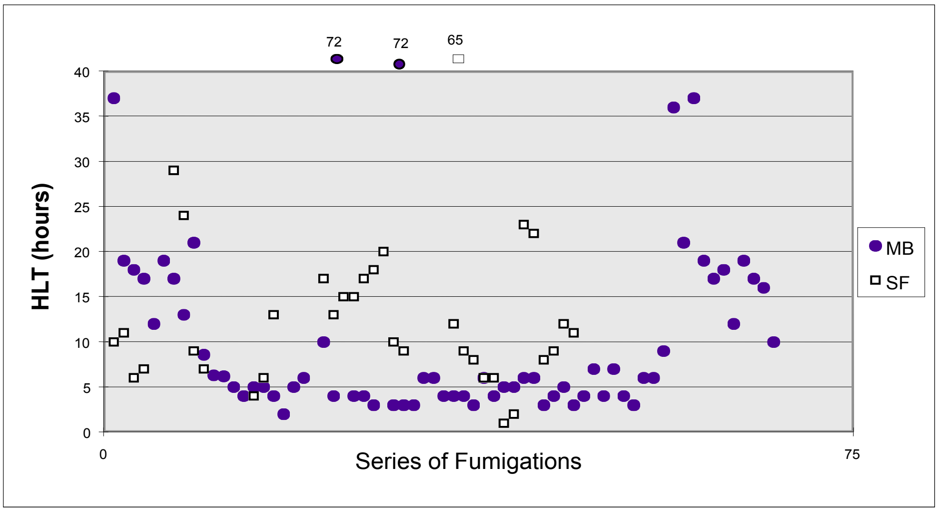

Fig. 3. Methyl bromide and sulfuryl fluoride half-loss times for areas within food industry structures.

The sealing techniques and effort, as well as structural conditions varied substantially across these fumigations. No structure was fumigated with both fumigants. Thus, the impact of the fumigant used on HLT cannot be inferred from this data. These results, however, do indicate a trend of relatively short HLT and significant variability in HLT among food industry structure fumigations. Assuming exposure times of 24 h to 36 h, improving HLTs beyond the observed median of 6 h for methyl bromide and 10 h for sulfuryl fluoride through better sealing, would significantly reduce the amount of fumigant necessary to reach the targeted Cts.

SHIPPING CONTAINER HLTS

Cargo containers are commonly fumigated in or near the major shipping ports of the world for quarantine purposes. These fumigations are generally not monitored to determine the HLT unless monitoring is required by applicable regulations.

Sulfuryl fluoride gas concentrations were monitored during 24 h fumigations of 19 shipping containers outgoing from United States of America port cities. Professional fumigators conducted the fumigations according to standard practice. Twelve containers were 6.1 m long ("20 foot" containers) and seven were 12.2 m long ("40 ft" containers). During four of the fumigations, the container was covered with a tarpaulin ('tarped') to confine the fumigant. In 15 fumigations, the container was sealed only by closing the door and taping the small air circulation vents on the sides of the containers ('taped'). Two containers were fumigated a second time with the air vents left open to investigate the impact of open vents on HLT.

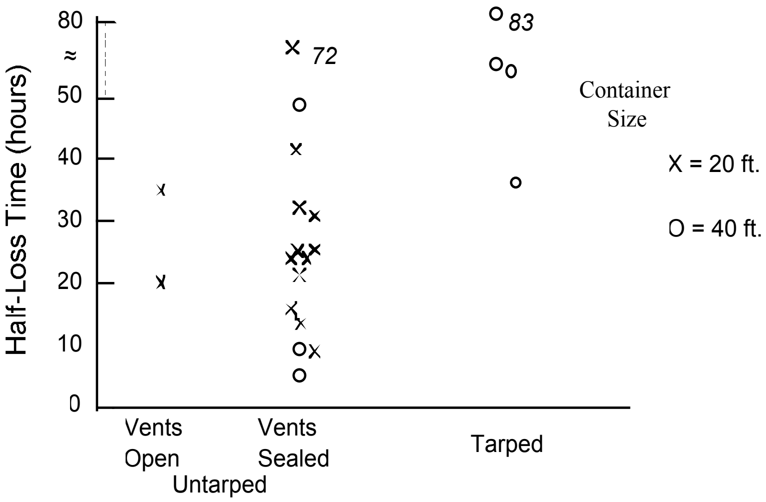

Fig. 4. Half loss time of sulfuryl fluoride from shipping containers under three different sealing techniques: tarpaulin covering entire container, no tarp - air vents sealed, no tarp - air vents open.

Figure 4 shows the HLT recorded for each of the container fumigations. Monitoring of gas concentrations during the 24 h exposure periods showed that fumigant HLTs from untarped containers varied from 4.5 h to 72 h, with a median of about 21-24 h. Tape-sealing the container air vents improved HLT values from 60%

(20 h improved to 32 h) to over 100% (35 h improved to 72 h). Tarped containers achieved generally long HLTs, from 35 h to 83 h.

Visual inspection of the containers was not a reliable technique for predicting HLT. We speculate that the HLT is most influenced by the gas permeability of the flooring. Floors are commonly wood, but are difficult to thoroughly inspect when the container is loaded.

The initial concentration target and minimum exposure time for shipping container fumigations is generally set by quarantine regulation, while maximum exposure time is limited by the shipping company's schedule. The Australian Quarantine and Inspection Service (AQIS) manual on Cargo Containers – Quarantine Aspects and Procedures (2000), specifies that, "A standard of 30% or more of the original fumigant concentration is required when measured after 24 hours" which is approximately a 14 h HLT. Knowing the HLT for containers being fumigated could provide options for meeting regulatory requirements and reducing fumigant consumption while increasing the probability of 100% control of quarantine pests.

CONCLUSIONS

Knowing or accurately predicting HLTs is critical to the economical use of fumigants and is an integral part of good stewardship. Inaccurate HLT prediction results in insufficient or excessive use of the fumigant. For any particular fumigation, this leads to higher fumigant costs or increased risk of control failure. Long term, utilizing accurate HLTs to determine optimal exposure times and concentrations to achieve the targeted dosage demonstrates good stewardship and may help sustain the availability of fumigants for insect pest control.

ACKNOWLEDGEMENTS

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REFERENCE

Anon. (2000) The Australian Quarantine and Inspection Service (AQIS) manual on Cargo Containers – Quarantine Aspects and Procedures.