USE OF BIOREACTORS TO REMOVE METHYL BROMIDE FOLLOWING CONTAINED FUMIGATIONS

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Use of methyl bromide (MB) as a quarantine, commodity and structural fumigant is under scrutiny because its release to the atmosphere contributes to depletion of stratospheric ozone. No single alternative to the use of MB as a fumigant has been identified. In contained fumigations, high levels of MB (4,000 to 25,000 ppm) are directly vented to the atmosphere following several hours to days of exposure of structures or of commodities. Although presently exempt, future regulation of the amount of MB released by quarantine and commodity fumigations is likely. Also, there is renewed interest in the ability of MB to kill spores of *Bacillus anthracis* (1) which may result in greater use of MB for this purpose (R. Scheffrahn, pers. comm.). Hence, if MB use is to continue, it is imperative to lower the amount released to the atmosphere by collecting the gas following fumigation for eventual recycling or destruction.

Several strategies have been proposed for capturing MB from the waste stream of commodity fumigations. Among these, adsorption of MB on zeolite or on activated charcoal has received considerable attention (2). Recovery of MB adsorbed on zeolite is possible, however no working system for recycling the captured MB has been reported. Recovery of MB adsorbed on activated charcoal has been demonstrated and the cost is reasonable (3). More than 90% of the added MB may be recovered using a single bed or cartridge of activated charcoal adsorber, however emission of 200 to 500 ppm MB may still result from this practice. Stricter environmental controls in the future will likely require lower emissions, necessitating a second adsorbing bed in series with the first, or further strategies for removing MB.

Biodegradation offers another solution to removal of MB from the waste stream of contained fumigations. Several newly identified species of a-Proteobacteria (including strain IMB-1) can directly oxidize and grow on methyl halides. Elevated levels of MB are toxic to many organisms, however, strain IMB-1 can oxidize and grow on pulsed additions of relatively high concentrations (2,500 to 10,000 ppm) of MB. In this study, we report on the oxidation of MB during growth of strain IMB-1 using pulsed additions of up to 4,000 ppm MB in a closed-system bioreactor (Fig. 1) and during growth on a continuous supply of 5,000 ppm MB in an open-system bioreactor. Limitations arising from exposure of strain IMB-1 to higher concentrations of MB (up to 60,000 ppm) are considered.

Oxidation of MB by employing these microorganisms can provide a practical solution to removing MB from contaminated air if the concentration of MB can be controlled to fall within the optimal physiological range. Bioreactors of various types employ bacterially mediated reactions to remove contaminants from large quantities of water or air effluent. Advantages of bioreactors include their high efficiency and low cost of operation. Scaling a bioreactor process from laboratory bench to field scale is often a matter of overcoming engineering challenges. In the case of MB, an additional challenge is posed by the toxicity of the compound to the organisms comprising the bioreactor. This challenge can be met by dampening the load of fumigant, for instance by adsorption onto a solid surface such as activated charcoal, followed by release and controlled introduction into the bioreactor.

This presentation describes the design and operation of two bioreactors that can remove high concentrations of MB from the waste stream of contained fumigations. A closed-system bioreactor consisting of 0.5 L of growing culture of strain IMB-1 removed MB (2,500 to 4,000 ppm) from re-circulating air. Strain IMB-1 grew to high cell densities in the bioreactor using pulsed additions of MB as its sole carbon and energy source (Fig. 2). Concentrations of CH_4 added at the start remained constant, suggesting that the reactor was free of leaks. Bacterial oxidation of MB produced CO_2 and hydrobromic acid (HBr) which required continuous neutralization with NaOH for the system to operate efficiently. Strain IMB-1 was capable of sustained oxidation of large amounts of MB (170 mmol in 46 days). In an open-system bioreactor (10-L fermenter), strain IMB-1 oxidized a continuous supply of MB (5,000 ppm in air). Growth was continuous and 0.5 mol (46 g) of MB was removed from the air supply in 14 days.

Bioreactors can be used alone or in series following a fixed-bed adsorber to obtain the desired remediation depending on conditions (e.g. high concentrations of MeBr) or requirements (e.g. high removal rate for perishables). Bioreactors may be especially useful in reclaiming MeBr previously adsorbed on activated charcoal or zeolite, where MeBr can be sequestered and later removed by heating and/or flushing with air. This practice of load dampening lends itself to controlled introduction of MeBr into the bioreactor.

1) Kolb, R.W., Schneiter, R. J. Bact. **1950**, 59, 401-412**.**
2) Leesch, J.G., Knapp, G.F., Mackey, B.E. J. Stored Prod. Res., **2000,** 36, 65-74.
3) Snyder, J.D., Leesch, J.G. Ind. Eng. Chem. Res. **2001**, 40, 2925-2933

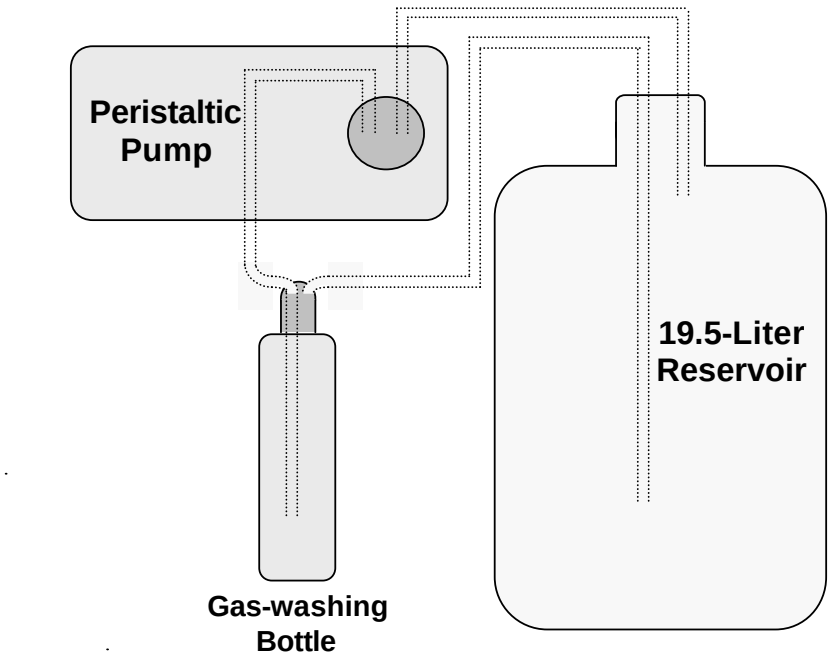

Figure 1. Schematic drawing of the closed-system bioreactor (not to scale).

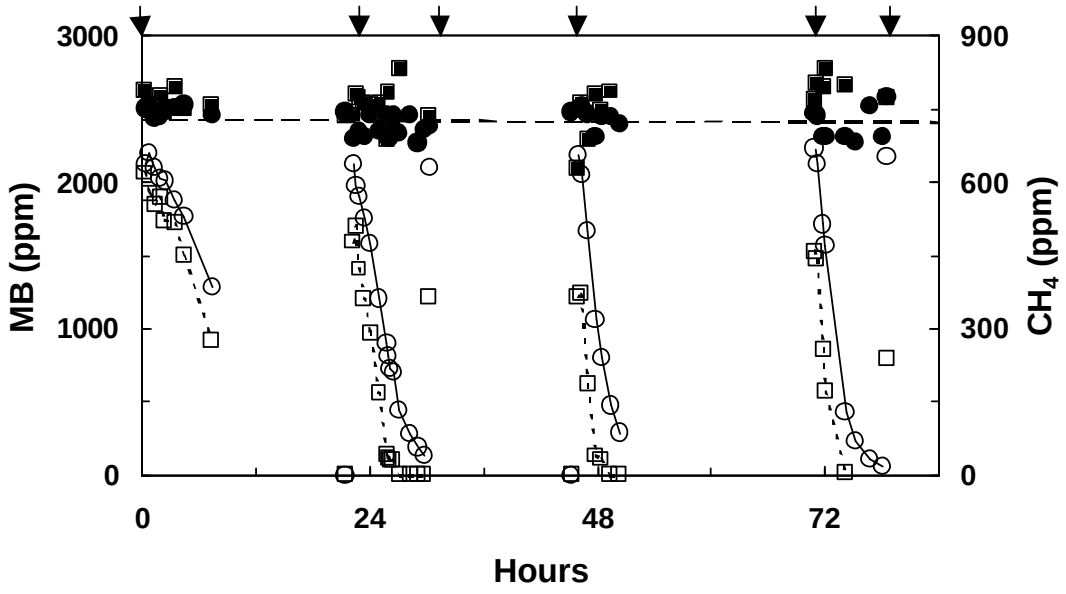

Figure 2. First 4-days of operation of the closed-system bioreactor- Concentration of MB (open symbols) and CH_4 (closed symbols) in air entering the gas-washing bottle (circles) and exiting the gas-washing bottle (squares). Arrows indicate the time of addition of MB. Concentrations of MB were lowered by passage through the gas-washing bottle. Removal of MB from the headspace was more rapid as cells grew in the bioreactor.