A NEW METHOD FOR ESTIMATING THE PERMEABILITY OF PLASTIC FILMS TO FUMIGANT VAPORS

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When greenhouse and field soils are fumigated, the soil surface is often covered with a plastic tarp to reduce loss of the chemical via volatilization. Low- or high-density polyethylene tarps (LDPE or HDPE) are commonly used; however, these films have been reported to have significant permeability to methyl bromide (MeBr) and other soil fumigants. Plastic films that have reduced permeability to soil fumigants, particularly MeBr, have been developed in response to the call for management practices that reduce emissions and maintain or increase the efficacy of soil fumigants. To assist in the development of these management practices, a rapid, accurate method to measure the permeability of plastic films to soil fumigants is needed.

The permeability of plastic films to gaseous solutes is due to diffusion and is thought to occur by the solute dissolving into the surface of the film, followed by the diffusion through the film and evaporation from the opposite film surface. This paper describes a new method for estimating the mass transfer coefficient of gases diffusing through plastic films. Unlike currently-used methods, which use a flow-through chamber under steady state conditions, the transfer of fumigant across a film was determined in a static chamber. This method was used to measure the permeability of HDPE to MeBr, 1,3-dichloropropene (1,3-D), and chloropicrin.

Permeability cells were fabricated from stainless steel cylindrical stock of 12 cm ID. Cells were constructed in two halves, each approximately 4 cm long, sealed on one end by soldering a stainless steel plate to the column. Additional cells for the testing of low-permeability films were 12 cm ID × 1 cm (each half). A piece of the plastic film to be tested was placed between the two cell halves and the cell halves sealed together to provide a gas tight system. Sampling ports were constructed from brass fittings and were installed at the midpoint of each cell half.

Vapor was spiked on one side of the film (source chamber), and the gas-phase concentration on each side of the film was monitored until concentrations in the source chamber and receiving chamber were equal. MeBr, 1,3-D, and chloropicrin were spiked to separate cells (3 replicates per fumigant). Gas-tight syringes were used to collect vapor samples from each chamber at various times throughout the course of the experiment. Samples were placed in headspace vials and analyzed using headspace GC-ECD.

The diffusion of a gaseous solute is described by Fick's first law: $J=-h(C_{source}-C_{receiving})$, where J is the flux density and C is gas-phase concentration. The mass transfer coefficient, h, is a measure of the resistance to diffusion. For permeable films such as HDPE, h is high, while lower values of h indicate a more effective barrier to diffusion.

The mass transfer coefficient was determined from the experimental data by nonlinear regression using a model which relies on a mass balance approach (see curve fits in Figure 1). The flux of fumigant leaving the source chamber is balanced by an increase in concentration in the receiving chamber with time. Because of these changing concentrations, the flux is always changing in these systems; however, the mass transfer coefficient remains constant. Agricultural films have significant sorption capacity, necessitating the inclusion of a sorption term in the model. Sorption is indicated in the permeability columns by (i) an initial rapid decrease in the source concentration that is not accompanied by a corresponding increase in the receiving chamber and (ii) an equilibrium concentration ratio <0.5, because some of the mass is held on the film (Figure 1). The cells were gas-tight for the duration of the experiment, as indicated for the conservation of mass in the columns after sorption is complete.

Mass transfer coefficients for the fumigants MeBr, 1,3-D, and chloropicrin were determined for 1.0-mil HDPE at 40EC. Results demonstrate that HDPE is much more permeable to 1,3-D than to chloropicrin and MeBr (Figure 2). Preliminary results indicate that the mass transfer coefficient decreases with decreasing temperature; thicker HDPE films and barrier films demonstrate decreased mass transfer coefficients relative to HDPE.

This approach holds promise for use as a relatively rapid and reliable method to determine the permeability of plastic films to fumigant compounds. Because the mass transfer coefficient is independent of the concentration gradient, this property of the film can be compared under different application conditions and management practices, while the methods currently used to determine film permeability measure flux through the film at a constant concentration gradient. This method, which requires a minimum of equipment, is especially useful as a screening tool in the development of new agricultural films or soil fumigants.

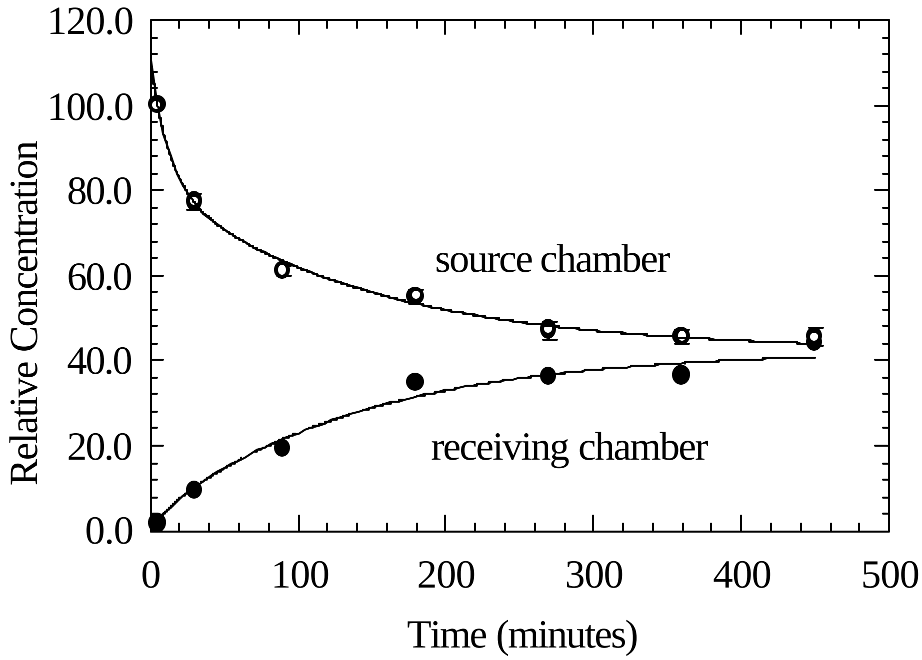

Figure 1. Methyl bromide concentrations in permeability cells containing 1-mil HDPE and incubated at 40EC. Each data point is the mean concentration in three replicate cells.

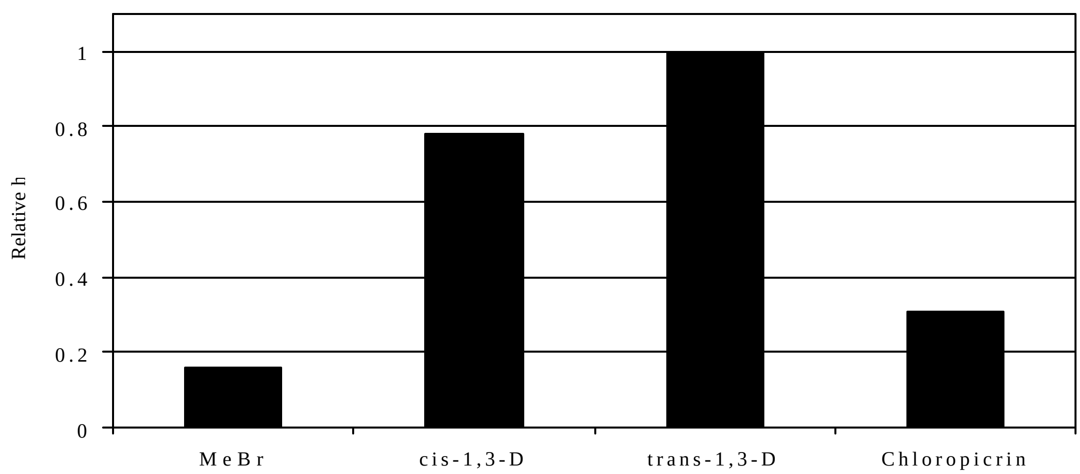

Figure 2. Mass transfer coefficients (relative to trans-1,3-D) for fumigant compounds diffusing through 1-mil HDPE at 40EC.