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COMPARISON OF A ONE-DIMENSIONAL,STEADY-STATE HYDRAULIC MODEL WITH A TWO-DIMENSIONAL, TRANSIENT HYDRAULIC MODEL FOR ALDICARB TRANSPORT THROUGH SOIL

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ABSTRACT

Both models adequately projected chemical transport velocity and concentration through the vertical soil profile at the relatively homogeneous field site evaluated. The two-dimensional solution also projects the transport through the ground water and was able to describe three successive years of application.

INTRODUCTION

Aldicarb (Temik) has been found in ground waters of Long Island, NY (USA) (ref. (Fig. 1). Long Island, NY, is approximately 180 km long and 25 km wide on the Atlantic Coast of the USA. The soil is a glacially deposited sandy to gravelly loam with little horizon development. To evaluate the potential adverse effects from agronomic use, models are needed that evaluate the spatial and temporal distribution of the chemical. Two generalized models are compared with field data. Advantages and disadvantages of each approach are discussed.

The field sampled was slightly less than 3 ha. Soil samples were examined at two locations within the field (Fig. 2) with samples obtained from the surface to ground water. Three clusters of ground-water sampling wells were also installed and sampled around the site.

RESULTS

One-dimensional steady state approach

Recharge was approximated in the area based on climatic data from the closest reporting station and estimates of evapotranspiration based on pan evaporation using methods described by Jensen (ref. 2). The volumetric water content was

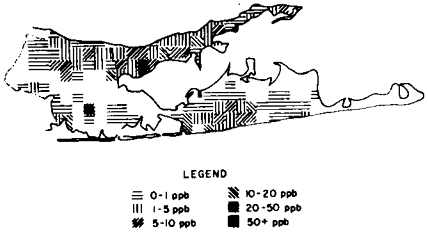

Fig. 1. Aldicarb distribution in Eastern Long Island, NY (USA) (ref. 1)

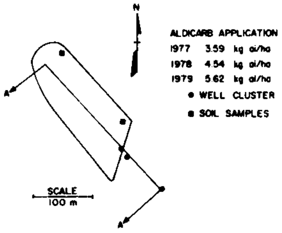

Fig. 2. Study field showing selected sampling points and history of application.

estimated at 300 cm H_2O from soil texture measurements at the site based on empirical relationships of Clapp and Hornberger (ref. 3). The spatial and temporal distribution of the chemical was estimated by solving the equation

$$\frac{\partial C}{\partial t} = D\,\frac{\partial^2 C}{\partial t^2} - V\,\frac{\partial C}{\partial x} - \frac{\rho}{\Theta}\;\frac{\partial s}{\partial t} \qquad (1)$$

where: C is the solution concentration in mg/l; t is the time in hrs.; D is the dispersion coefficient in $cm^2/hr.$ which was approximated as $0.002\ D_o \exp(10\ \Theta) + 2.93V^{1.11}$ (ref. 4); D_o is the diffusion coefficient in water; V is the interstitial water velocity which is equal to recharge/Θ; x is the distance along flow path in cm; ρ is the bulk density of soil estimated at 1.55 g/cm^3; Θ is the volumetric water content.

The sink/source term (s) is described by the equation

$$s(t) = K_d C + \int_o^t k\ C\ dt \qquad (2)$$

where: K_d is the soil partition coefficient approximated by $(3.64 - 0.55 \log C_o)$ $(\frac{\%\ oc}{100})$ (ref. 5); C_o is the water solubility of the chemical (mg/l); oc is the organic carbon in the soil; the dissipation constant for the chemical is k.

The solution used in the evaluation is

$$\frac{C}{C_t} = \frac{1}{2}\left[\operatorname{erf}\ \frac{x + x_o + V_p t}{2\left(\frac{D}{R}\,t\right)^{\frac{1}{2}}} - \operatorname{erf}\ \frac{x - V_p t}{2\left(\frac{D}{R}\,t\right)^{\frac{1}{2}}}\right] \qquad (3)$$

where: x_o is the equivalent length of the slug calculated from the solubility of the chemical and the amount of chemical applied.

$$V_p = V/(1 + \frac{\rho}{\Theta} K_d) \qquad (4)$$

$$R = V_p/V \qquad (5)$$

$$C_t = C_o \exp\ (- \frac{\rho}{0}\ \frac{t}{R}\ k) \qquad (6)$$

Aldicarb was applied to the soil in 1977, 1978, and 1979. The one-dimensional model is limited to projection in unsaturated soil. Model projections for 1977 and 1978 indicate that both applications should have reached the water table before the sampling date of December 1979. The results presented for the one-dimensional model are only for 1979. Figure 3 shows good agreement between observed field data and model projections.

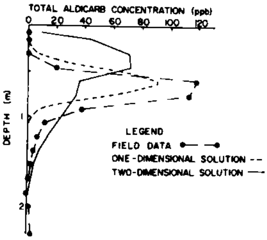

Fig. 3. Comparison of one-dimensional and two-dimensional projections for the 1979 application assuming average recharge 0.00386 cm/hr and dissipation of 0.00019 hr^{-1} (ref. 6) versus the field data for the east sampling point.

Two-dimensional transient approach

Recharge in the area was approximated in the same manner as the one-dimensional steady state approach although the model was capable of analyzing transient flow. Water flux through the profile was calculated from the two-dimensional equation

$$\frac{d\Theta}{d\Psi}\frac{\partial\Psi}{\partial t} = \frac{\partial}{\partial x}\left[K(\Psi)\frac{\partial\Psi}{\partial x}\right] + \frac{\partial}{\partial y}\left[K(\Psi)\frac{\partial\Psi}{\partial y}\right] - \frac{\partial K(\Psi)}{\partial y} \qquad (7)$$

where: $\Theta = \Theta_s\ (\Psi_s/\Psi)^{1/b}$, for $\Psi<\Psi_s$; $\Theta = \Theta_s$, for $\Psi\geq\Psi_s$

$K = K_s\ (\Psi_s/\Psi)^{2+(\gamma+2)b}$, for $\Psi<\Psi_s$; $K = K_s$, for $\Psi\geq\Psi_s$

Θ_s is the porosity of the soil; Ψ_s is the air entry matric potential in cm H_2O; Ψ is matric potential; b and γ are empirically determined parameters (ref. 3). The spatial and temporal distribution of the chemical is given by the equation

$$\frac{\partial(C)}{\partial t} = -\frac{\partial}{\partial x}(q_xC) - \frac{\partial}{\partial y}(q_yC) - \frac{\rho}{\Theta}\frac{\partial s}{\partial t} \qquad (8)$$

where: q_x is the water flux in x direction and q_y is the water flux in y direction. Dispersion, which was included in Eq. 1, is ignored. Numerical dispersion does occur, in the four-step finite element analysis performed (ref. 7), allowing the result to appear dispersed. Dispersion was not considered essential to include in the numerical solution.

Figure 4 shows the calculated water flux for the two-dimensional solution. Figure 5 shows the projected and measured chemical distribution in the solution phase. Figure 3 shows the total concentration in the soil.

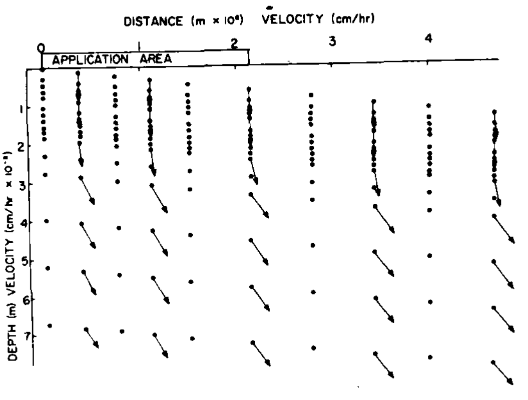

Fig. 4. Nodal pattern for two-dimensional calculations and selected water flux vectors.

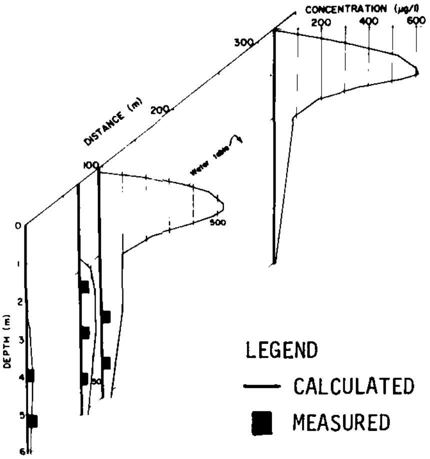

Fig. 5. Calculated and measured solution concentration (Section A-A, Fig. 2) for a three year projection assuming k = 0.0019 above water table and k = 0.0 below water table with average recharge = 0.00732.

Comparison of the two approaches

The one-dimensional approach is computationally efficient and requires minimal input data, while the two-dimensional approach requires complex input data to utilize its ability to describe the natural system hydrogeologically, biologically, and chemically. The two-dimensional approach is computationally inefficient and expensive to run on a computer. The one-dimensional approach is limited to relatively homogeneous systems while the two-dimensional numerical approach permits describing nonhomogeneous (layered) systems. The one-dimensional approach does not evaluate transient hydraulics and assumes constant water content and flux while the two-dimensional system describes the transient water flow and calculates water content and water flux as a function of time and space. The one-dimensional model does not calculate transport within ground water while the two-dimensional model does. Either model can evaluate adverse effects but model limitations should be considered.

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