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MODELING TRANSPORT OF METRIBUZIN IN SLOPING LANDS

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The differences is soil hydraulic properties in sloping landscapes are believed to control the rate and movement of infiltrated water which influence the transport of herbicides. The impact of slope positions on transport of metribuzin was simulated using one-dimensional computer kodel "HYDRUS". Model simulations showed that metribuzin moved deeper at the top and back-slope positions than at the toe-slope position. After 360 days of simulation, the solution concentration of metribuzin below 40 cm was almost zero at all slope positions. Metribuzin did not seem to be sensitive to dispersivity.

INTRODUCTION

The protection and utilization of groundwater represents a significant concern for water resources management in the world. The contamination of groundwater by herbicides may endanger the interests of a number of users, especially the local population and the agriculture of the area. Metribuzin is an effective pre-emergence herbicide for controlling annual grass and numerous broad leaf weeds in the crop of wheat. Its molecular formula is $C_8H_{14}N_4OS$. The molecular weight of the metribuzin is 214.3 g with specific gravity of 1.28. The solubility in water being 122 mg 100 g^{-1} (1200 ppm) at 20°C is greater than in any other organic solvent.

Very little is known about the movement of metribuzin in the soil and water environment. It is generally known that metribuzin fate and movement depend upon adsorption, degradation, leaching, volatilization and plant uptake processes. Adsorption is the dominant factor that controls herbicide mobility for a given leaching regime. Soil factors that control adsorption include organic carbon content, pH and texture. Water solubility and vapour pressure of an herbicide also affect the potential for adsorption of an herbicide.

Differential rates of erosion on steep slopes of the hilly area and different management practices change the soil factors at different slope positions. The physical properties and the biological conditions of soil vary with depth and also with slope positions. As a result of differences in erosion across the landscape, landscape position controls many soil properties including texture, hydraulic conductivity, organic matter content and crop productivity. These differences in soil characteristics at different slope positions and depths very much control the rate and direction of movement of infiltrated water and hence the transport of herbicides. The question as to how these factors affect the movement of an herbicide to groundwater at different slope positions and soil conservation practices may be answered with the help of a computer model. The model can handle varied soil types, physical and hyrologic characteristics and climatological differences in the area.

MODELING METHODOLOGY

To investigate the impact of different slope positions on the movement of metribuzin, a study with a south-facing slope and an elevation gain of 34 m over a distance of about 280 m was selected near the University of Idaho, Moscow Campus. The study area was divided into three slope positions: top-slope, back-slope and toe-slope. This deviation of site by slope position was according to the current farming practices which usually follow hillslope contours.

Finite element models are popular in water flow and solute transport problems because of their verstality in simulating irregular boundaries as in sloping lands and better handling of the variably saturated and heterogeneity in material properties. Several two and three dimensional models dealing both with saturated and unsaturated flow and solute transport have been compared by Mangold and Tsang (1991). The documentation, code availability and the field application to sloping lands were the major crierion in the selection of a particular model for this study. With the above criteria in mind, the one dimensional flow and transport model "HYDRUS" (Kool and van Genuchten, 1989) was selected.

The governing equation used in HYDRUS for vertical flow through porous medium is:

$$C \frac{\partial h}{\partial t} = \frac{\partial}{\partial Z} [K_S \frac{\partial h}{\partial Z} - K_S] - S(z, t) \quad (1)$$

where h is the pressure head (L); $C = d\Theta/dh$ is the soil water capacity (L^3/L^4), Θ (L^3/L^3) the volumetric water content; K_s is the hydraulic conductivity (L/T), S (Z, t) represents the volumetric root water uptake (L/T); Z is soil depth which is taken positive downward and t is time. The initial conditions can be defined in terms of pressure head, or in terms of water content. Transport of miscible components of herbicide is described by the advection-dispersion equation:

$$\frac{\partial}{\partial Z} [\theta D \frac{\partial C}{\partial Z}] - q \frac{\partial C}{\partial Z} - \lambda_1 \theta C - \lambda_2 \rho_b S = \theta \frac{\partial C}{\partial t} + \rho_b \frac{\partial S}{\partial t} \quad (2)$$

where C is the solute concentration (M/L^3), S is adsorbed concentration (M/M), D is the dispersion coefficient (L^2/T), q is the Darcy velocity (L/T), and λ_1 and λ_2 are first-order decay coefficients (1/T) for the dissolved and adsorbed phase, respectively.

RESULTS AND DISCUSSION

Mallawatantri (1990) examined the effects of soil depth and different slope-positions on adsorption of metribuzin. The effect of slope positions and depth on a linear partition coefficient K_d (ml/g) for the site is shown in Table 1.

Table 1. The effect of soil depth and slope positions on linear partition coefficient K_d (ml/g) of metribuzin

Depth (cm)	K_d Top-slope	K_d Toe-slope
0-30	0.64	1.10
30-60	0.27	0.44
60-100	0.15	0.17

The herbicide adsorption varies significantly with depth. For example, surface soils (0-15 cm) adsorb about 5 times more metribuzin than the subsurface soils (60-100 cm) and about 2.4 times more metribuzin than soil from a depth of 30-60 cm. The potential mobility of pesticides is much higher

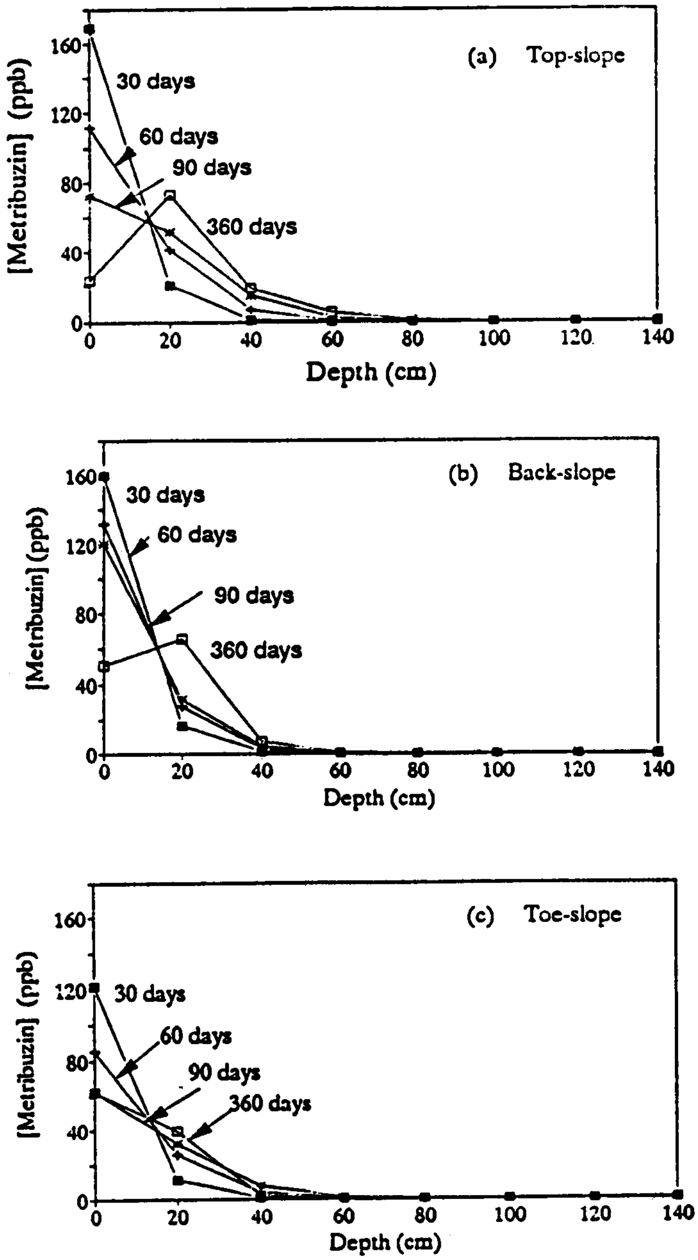

Figure 1. Concentration of metribuzin at different slope positions at different times.

in the subsurface soil than in the surface soil. Consequently, if a pesticide leaches beyond the surface soil where it is strongly adsorbed, its mobility increases due to decrease in adsorption and organic matter content in subsurface soils.

Movement of metribuzin: Vertical movement of metribuzin in soils at the top, back and toe-slope positions is given in Figure 1. These simulations used dispersivity as 5 cm, half life equal to 37 days and the partition coefficient (K_d) as given in Table 1. The value of K_d was both depth and slope dependent. Metribuzin was applied on November 22, 1989 at the rate of 0.28 kg ha^{-1} (ai).

In general, computer simulations showed that metribuzin did not move very deep at any slope position. Almost no metribuzin moved below 40 cm at all slope positions. At the top and back-slope positions (Figures 1 a and 1 b), the maximum concentration of metribuzin in soil water (65 ppb) was found at about 20 cm after 360 days. Metribuzin at the toe-slope position (Figure 1 c) remained shallower than at other two slope positions. This is due to the fact that metribuzin is strongly adsorbed by organic matter content which was about 30% higher (Mallawatantri, 1990) at the toe-slope position than at the top-slope position at all depths. The maximum concentration of about 60 ppb was found at the soil surface after 360 days of simulation which was about 50% of the concentration noted after the first 30 days of simulation.

The lateral movement of metribuzin was estimated as about 9 and 17 m at the top and back-slope positions using FEMWATER (Tahir, 1992). The distance that metribuzin may move laterally is significantly greater than the downward movement. Surface ponding and shallow water table at the lower slope positions along with lateral movement of metribuzin from upper slope positions may increase the potential of surface and groundwater contamination at the lower slope positions.

Sensitivity of metribuzin to dispersivity: Sensitivity of metribuzin to dispersivity for different slope positions is given in Figure 2. Two dispersivity values, 5 and 10 cm were used to study sensitivity of herbicide in question for 60 days of simulation. At all three slope positions, the concentration of metribuzin at any depth did not show any significant sensitivity to the change in dispersivity. At a depth of 20 cm, the solution concentration of metribuzin at the top-slope position is about 1.5 times higher (40 ppb) than at the back and toe-slopes (25 ppb). This observation indicates that metribuzin is more strongly adsorbed at the lower slope positions than at the top-slope. With both dispersivities, metribuzin did not move beyond a depth of 60 cm. Higher concentrations near the soil surface suggest that the adsorption is more dominant than dispersivity at all slope positions.

Conclusions: A one-dimensional simulation with HYDRUS on transport of metribuzin showed the following:

1. Simulation of metribuzin indicated metribuzin to remain near the soil surface. The solution concentration of metribuzin at a depth of 20 cm was 6, 4.5 and 4% of that applied at the top, back and toe-slope positions, respectively. These results indicated that adsorption in these soils is significant and greatly reduces the potential for contamination of groundwater by pesticides.
2. At the toe-slope position, the concentration of metribuzin in soil solution was small compared to upper slope positions where organic matter contents and herbicide adsorption are lower. The lateral movement of metribuzin at the back-slope position was about twice to that of the top-slope position.

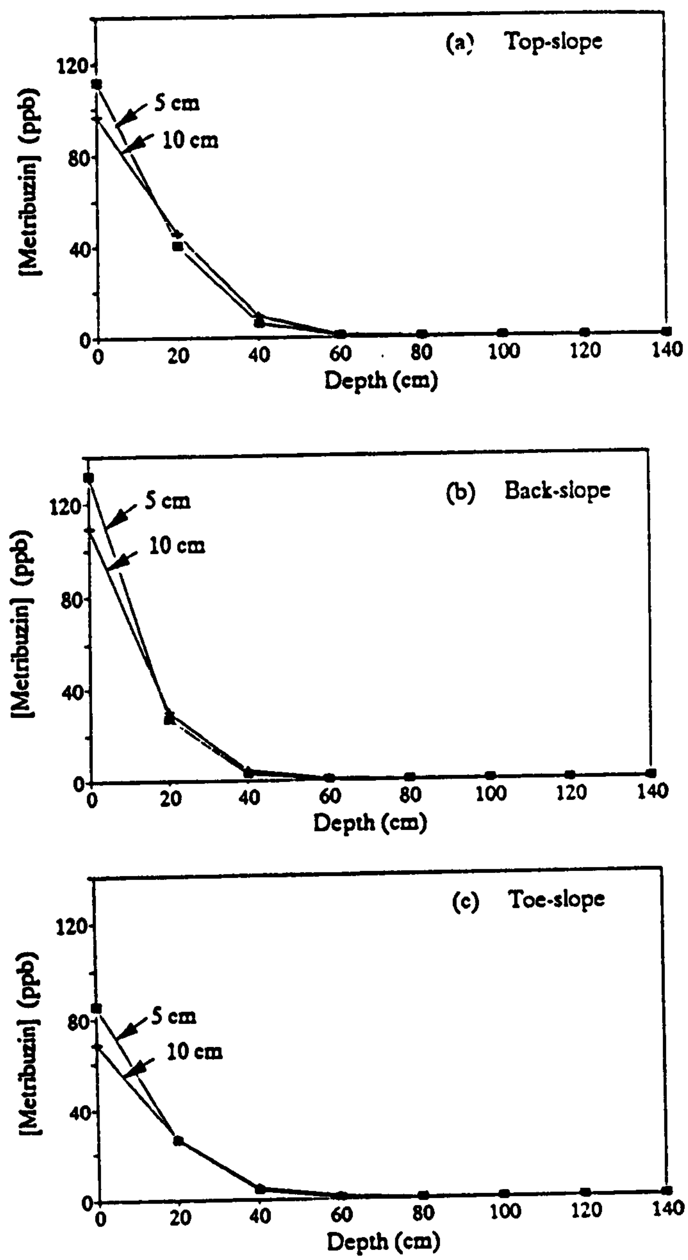

Figure 2. Sensitivity of metribuzin concentration to dispersivity at different slope positions after 60 days of simulation.

3. Metribuzin did not show any significant sensitivity to dispersivity at any slope position. The herbicide mostly remained adsorbed within the top 40 cm of the soil profile.

REFERENCES

Kool, J.B. and M. Th. van Genuchten. 1989. HYDRUS: One dimensional variably saturated flow and transport model, including hysteresis and root water uptake. Version 3.2. Hydrogeologic Inc., Virginia, USA.

Mallawatantri, A.P. 1990. Effects of long-term management, slope position and depth on pesticide transport parameters. M.S. Thesis, Washington State Univ., Pullman, USA.

Mangold, D.C. and C.F. Tsang. 1991. A summary of subsurface hydrological and hydrochemical models. Rev. Geophysics, 29 (1): 51-79.

Tahir, A.R. 1992. Computer simulation of flow and transport processes at different slope positions of Missouri Flat Creek Watershed. Ph.D. Thesis, Univ. of Idaho, Moscow, USA.