POTENTIAL PATHWAYS OF PESTICIDE TRANSPORT

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Being a conservative solute, bromide was used to trace potential pathways of pesticide transport under conservation tillage in sloping lands. The maximum concentration of bromide (30 ppm) was found at a depth of 40 cm at the top and back-slope positions compared to 20 ppm found at a depth of 80 cm at the toe-slope position after 360 days of simulation. Bromide at the toe-slope position moved deeper than at the top and back-slope positions. The potential of groundwater contamination beneath top-slope position is minimum due to lateral transport of the bromide at this slope position.

INTRODUCTION

The Missouri Flat Creek (MFC) watershed is a part of the Palouse region and an important watershed in the Pullman-Moscow area of Washington and Idaho states. It is characterized by hilly topography in the form of large dunes. Conservation tillage is practised at hill slope positions to prevent soil erosion and transport of pesticide with runoff. In response to the Clean Water Act, the Palouse Conservation District has questioned how farm management practices, such as conservation tillage, crop rotation, etc. may be used to prevent surface and groundwater contamination from agrochemicals.

Conservation tillage has proven very effective in reducing sediment generation and runoff. However, a more complicated relationship exists between tillage practices and the pollution from pesticides. Conservation tillage can increase germination of newly produced weed seeds and hence requires more use of herbicides for their control (Logan *et al.*, 1987). High herbicide application rates can increase the probability of herbicide leaching. Moreover, conservation tillage leaves more crop residue in the field which reduces runoff and the surface water pollution. Yet adsorption by organic matter decreases the mobility of applied herbicides which may provide less chance of leaching to groundwater. On the other hand, contouring, mulch tillage and higher surface coverage by crop residue all tend to increase infiltration and the risk of downward movement of herbicides. Because the interaction of tillage and pesticide parameters has not extensively been investigated, the end result is frequently difficult to predict. Computer models are becoming increasingly popular in analyzing complex interaction between pesticide, soil's physical and hydrologic characteristics and the climate of the area. Models help in decision making and understanding the potential pathways of pesticides transport without performing costly field experiments.

METHODOLOGY

A research site bout 23 km from the University of Idaho, Moscow, USA, with different soil conservation and crop management practices was selected. On the basis of soil conservation practices, the study area was divided into three slope positions; top-slope, back-slope and toe-slope. The top and back slopes were tilled with moldboard plow and the toe-slope with chisel plow. The effect of tillage on the soil physical parameters such as texture, bulk density and porosity was used to compute soil hydraulic properties and the surface roughness. To trace the potential pathways of pesticide transport, at each slope position, leaching plots of 10 x 10 m were sprayed on November 22, 1989 with KBr at 100 kg Br^- ha^{-1} as a bromide (Br) tracer. On December 20, 1989 and January 30, 1990, the leaching plots at all slope positions were sampled to a depth of 60 or 90 cm. On June 25, 1990 only the toe-slope plot was sampled. The soil samples were later used to determine the dispersivity of bromide under field conditions. The pathways of infiltrating water and the agrochemicals were studied with the help of two computer models; FEMWATER (Yeh, 1987) and HYDRUS (Kool & van Genuchten, 1989). FEMWATER is a two-dimensional flow model and was selected to estimate the lateral movement of bromide at the top-slope position. HYDRUS is a one-dimensional variably saturated flow and transport model. It was used to stimulate vertical leaching of bromide at the top, back and toe-slope positions of the MFC watershed. The soil hydraulic properties for the models were available from Johnson (1991).

RESULTS AND DISCUSSION

Leaching of bromide: Bromide is a conservative solute and was applied at each slope position to trace the possible pathways of pesticide movement. HYDRUS simulations for any solute require input of dispersivity of the solute, first-order decay coefficient, and partition coefficient (K_d). The values for dispersivity were obtained from unpublished work of Jeremy Dyson, former Research Associate, Department of Crop and Soil Science, Washington State University, Pullman. Using the transfer function technique, Dyson found that dispersivity of Br increased linearly with depth in the soil profile. A weighted average of dispersivity of about 49.0 cm was computed for all three slope positions. The decay coefficient was assumed to be zero for Br because it is a conservative solute. Very little adsorption of Br was expected because of its negative charge. A value of 0.01 mL g^{-1} was therefore assumed reasonable for Br partition coefficient (K_d).

With the above physico-chemical parameters for Br, the movement of Br was simulated at the top-, back-, and toe-slope positions. The concentration of Br in soil solution (flux averaged concentration) is shown in Figures a, b and c after 30, 60, 90 and 360 days of simulation. At the top-slope position (Figure a), Br moved deeper after 360 days of simulation. The concentration (20 ppm) of Br was maximum at a depth of about 40 cm after 360 days of simulation. After about a year, a noticeable concentration of Br (10 ppm) had moved to a depth of 140 cm indicating a potential pathway for a conservative solute. After 30 and 360 days at a depth of 20 cm, the concentration of Br was about 70 ppm and 20 ppm, respectively. The observed concentration of bromide at the top-slope position, after 40 days of its application, was maximum (60 ppm) in a depth range of 40 to 60 cm. The observed and simulated concentrations of Br are comparable indicating that HYDRUS may

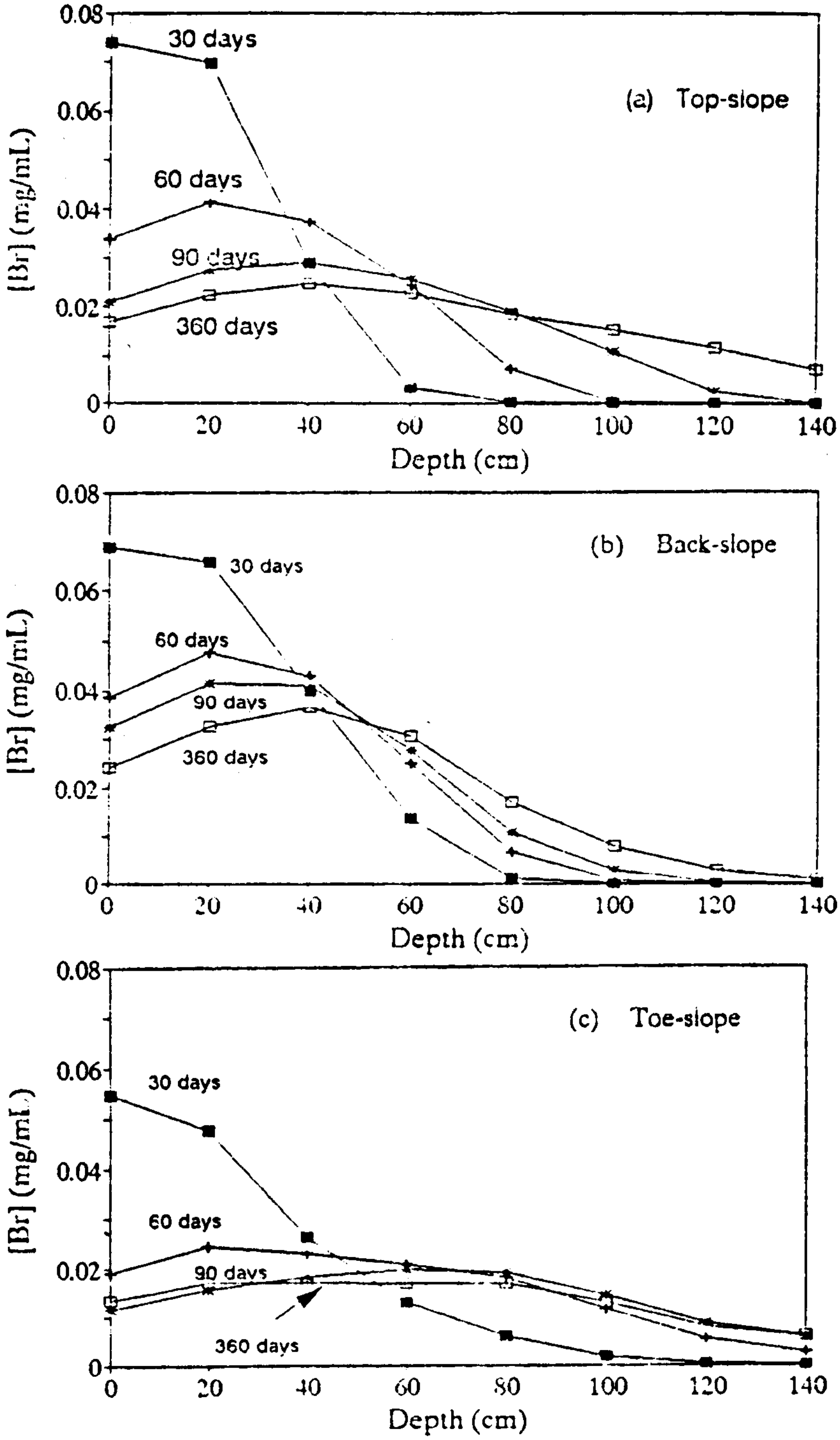

Fig. Concentration of bromide at different slope positions at different times.

be used to predict the behaviour of pesticides with variable success.

At the back-slope position, the maximum concentration (35 ppm) of Br was also found at about 40 cm as noted at the top-slope position after 360 days. In contrast, the concentration of Br at a depth of 140 cm was almost zero for any time of simulation. Patterns of Br concentration (Fig. b) are similar to those at the top-slope position. For given simulation periods, Br concentration within the top 40 cm of soil was about 25% higher than at the top-slope position. Br concentration at the 20 cm depth was about 35 ppm compared to 20 ppm at the top-slope position after 360 days of simulation.

Bromide at the toe-slope position (Fig. c) has moved deeper than at the top or back-slope positions. A uniform concentration of about 10 ppm up to 80 cm was noted after 360 days of simulation mainly because of higher water recharge. At a depth of 140 cm, the Br concentration of about 7 ppm can be of concern. It is interesting to note that Br concentration in the whole profile of 140 cm did not change significantly after the first 60 days of simulation. This may be due to a change in the direction of flow (from recharge to discharge). The observed concentration of Br at a depth of 20 cm after 30, 70 and 190 days of application, was 55, 20 and 10 ppm, respectively. The observed concentration of 10 ppm after 190 days compares closely with the simulated concentration of about 15 ppm throughout the profile depth of 100 cm.

Lateral movement of bromide: Maximum lateral movement of Br at the top- and back-slope positions was estimated using lateral flux values of FEMWATER simulations for 1991-92 rainfall season. The results indicate that Br may move laterally to a distance of about 26 and 59 m at the top- and back-slope positions, respectively. The estimated lateral movement is considerably greater than vertical movement of Br (140 cm), indicating that a high concentration of non-conservative solute in both surface and subsurface waters may occur at the lower positions. At the top-slope position, the maximum lateral movement of Br after 40 days of application was observed as 80 ppm at a distance of about 16 m from the centre of the study plot. The maximum lateral movement occurred at a depth of 22.5 cm. At the toe-slope position, after 40 days of application, Br moved laterally to a distance of about 16 m but the concentration was only 30 ppm at a depth of 42.5 cm.

Conclusions: The observed and simulated profiles of Br transport lead to the following conclusions:

1. The maximum concentration of Br (25 to 30 ppm) was found at a depth of 40 cm at the top- and back-slope positions after 360 days of simulation. The potential of groundwater contamination beneath this slope position is minimum mainly due to lateral transport of the solute.
2. At the top-slope position, a mobile solute may move laterally up o a distance of 8 to 12 m from the point of application as indicated by field observation and the lateral transport estimate for Br.
3. At the toe-slope position,·the potential of groundwater contamination exists as the vertical leaching is dominant at this slope position. Simulated profiles of Br were in better agreement with the observed at the toe-slope position. Very little lateral movement of Br was observed at this slope position.

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