Identifying Soil and Transport Properties Using a Model of Infiltration-Redistribution Flow and Transport in the Unsaturated Zone

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Abstract

Reactive transport properties under unsteady unsaturated flow conditions are estimated from field-measured transport data. The data is from a recent field experiment (Dror et al. 1999a,b) in which herbicides (Bromacil, Atrazine, and Terbuthylazine) applied at the soil surface were transported by a few cycles of intermittent irrigation, and concentrations were measured to a depth of 1.2 m by gas chromatography. An analytic stochastic model of flow and reactive transport accounting for multiple infiltration-redistribution cycles is applied in an inverse mode to identify soil and chemical transport properties and measurement uncertainty. Transport, measured at the end of water redistribution, is more sensitive to residual water in the field and less sensitive to the hydraulic conductivity and maximum saturated moisture content. Sorption in the field is found to be less than laboratory-based predictions. The degradation-rate coefficients agree with laboratory measurements.

1 Introduction

Predicting and controlling the behavior of organic chemicals in the field is a difficult and complex problem due to the large number of processes that affect contaminant propagation. In some field tests, organic chemicals leach to groundwater with unexpected rapidity (Flury 1996), while in others they remain in the field for exceptionally long periods (Bowmer 1991). A large body of literature is devoted to improving our understanding of chemical behavior at field scale and to relating field behavior to quantifiable transport processes.
In this chapter we present an attempt to quantify some simple measures of behavior (linear equilibrium sorption coefficient $K_d$ and first-order decay rate $\lambda$) of three common herbicides – Atrazine (ATR), Bromacil (BRM), and Terbuthylazine (TBA) – under natural field conditions. Field data from transport experiments at the Volcani Agricultural Research Institute (Bet Dagan, Israel) are interpreted using a model developed by Indelman et al. (1998) which is extended to account for multiple infiltration-redistribution cycles and to compute confidence intervals for estimates of $K_d$ and $\lambda$. Results are compared to laboratory measurements made at Bet Dagan and to transport properties reported in the literature.

Biological, chemical, and transport properties of the soil at Bet Dagan are reported in numerous studies. Parameters controlling water flow were measured by Russo and Bressler (1981), Russo and Bouton (1992), and Russo et al. (1997). Chemical characterization and transport studies were carried out by Tauber-Yasur et al. (1999) and Dror et al. (1999a,b). Shapir and Mandelbaum (1997) measured biological characteristics of Bet Dagan soil and also studied degradation of Atrazine in soil cultures in the laboratory.

2 Brief Description of the Field Experiment

Data for this study are from the reactive transport experiments of Dror et al. (1999a,b), and a detailed description of the experiment and collected data are presented there. Herein we provide a brief description of the field experiment and information needed for our analysis. Transport experiments were conducted on a noncultivated 6 by 20 m plot in the coastal area of Israel. The soil was classified as a Hamra Red Mediterranean sandy loam. Before the experiment, the plot was disk-tilled to a depth of 15 cm and, during the experiment, the soil surface was kept bare.

During the 1996 summer, three chemicals, ATR (0.5 g m$^{-2}$), BRM (1.2 g m$^{-2}$), and TBA (0.5 g m$^{-2}$) were applied together in a 1:75 water dilution as a pulse input onto the soil surface using a mechanical handsprayer. The spatial distribution of the chemical application on the field surface was measured by collecting deposited material in 5-cm diameter glass dishes. The mean mass of tracer that reached the field was 0.94 g m$^{-2}$ for BRM and 0.38 g m$^{-2}$ for TBA and ATR. The coefficient of variation of application rate was 0.2 for each chemical. Immediately after application of the chemicals, the field was irrigated with 5 mm of water to enhance incorporation of the chemicals into the soil and to prevent losses at the soil surface.

After chemical application, the field was irrigated ten times at 7-day intervals using a minisprinkler irrigation system. In each irrigation event, 50 mm of water was applied over $t_\text{irr} = 6$-h period. The spatial distribution of the leaching water on the field surface was determined by collecting water in tin cans randomly distributed on the soil surface. The distribution of water applied on the field