

A laboratory lysimeter for pesticide transport with controlled boundary conditions

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Abstract

The widespread use of various pesticides in agriculture is resulting in growing concern about contamination of soil, water and wider environment. This paper describes a laboratory lysimeter facility that allows undisturbed soil columns to be used with controlled boundary conditions to quantify the transport of pesticides through the soil. The Br⁻ breakthrough results to date indicated that the laboratory lysimeters are suitable for pesticide transport studies through the soils over a range of soil types, environmental conditions and hydraulic or soil water conditions and can provide valuable data to aid in improved transport risk assessment.

Key Words

Pesticide transport, undisturbed soil column, breakthrough curve

Introduction

Water is a solvent capable of carrying significant quantities of dissolved pesticides and other agro-chemicals. Pesticides can be found in surface and groundwaters due to runoff and/or leaching (Goss 1992; Holvoet *et al.* 2007). The transport of pesticides through soil is a function of water movement mechanisms, the chemical properties of the soil and the properties of the pesticide itself (degradation rate and adsorption / desorption characteristics). The physics of soil water and solute movement can be used to determine the fate of pesticide compounds, although the physico-chemical interactions of the solute with the soil particles will vary depending on the nature of the solute as well as the solid (Leeds-Harrison 1995). In many pesticide studies these interactions are characterized by pesticide specific sorption isotherms that are related to soil properties such as organic carbon content, soil texture, pH and cation exchange capacity (Gao *et al.* 1998; Wauchope *et al.* 2002; Picton and Farenhorst 2004). Several studies have been published that used either disturbed or undisturbed soil columns (Köhne *et al.* 2006; Dousset *et al.* 2007) to understand the transport of a given pesticide in the soil system. When disturbed soil is used, the focus of the study is on the role of soil constituents and pesticide interaction while undisturbed soil permits consideration of the role of pore structures on transport kinetics. Studying undisturbed soil also permits evaluation of the role of soil water status on transport, but systematically controlling soil water status can be quite difficult.

Pesticide transport studies can be conducted in the field (Højber *et al.* 2005), in field lysimeters (Winton and Weber 1996) or in laboratory lysimeters (Köhne *et al.* 2006). Field scale studies have the advantage of revealing the consequences of interaction with the natural climate and environment, but are complicated by the fact that it becomes difficult to control the consequences of variable temperature effects on degradation rates. Studies to understand pesticide kinetics in soils require laboratory experiments in order to have a controlled environment as one of the variables / treatments. This paper describes a laboratory lysimeter facility that was designed to permit: (i) undisturbed soil columns to be studied; (ii) controlled boundary conditions to be used to evaluate the role of different pores sizes in pesticide transport ; and (iii) control of soil water status to evaluate which soil pores function in pesticide transport under various conditions. Preliminary evaluation of the system was undertaken with a Bromide tracer to determine the main physical transport characteristics of selected soils before undertaking pesticide transport studies.

Methods

Lysimeter design

The lysimeter system (Figure 1) was designed to enable examination of saturated and unsaturated transport of agrochemicals through undisturbed soils. The system is operated in an air conditioned lab (ambient temperature of 20 °C ± 2). At its centre is a soil column 10 cm i.d. x 20 cm long. This is contained between thin layers of sand held in place by mesh and clamped by end-plates and steel rods. The sample is prepared

such that there is a clean surface top and bottom that are tightly held against the sand to ensure hydraulic continuity throughout the system. The end caps are sealed in place using molten paraffin wax. Above the soil column are two reservoirs, one containing a Br⁻ solution and one containing the agro-chemical of interest for the study. Below the soil column is an effluent trap, a pressure regulator and a vacuum pump. Alternatively a peristaltic pump can be installed above the soil column. When using pressure heads to drive transport, the system can be set up to permit transport with small hydraulic heads by gravity or with larger heads by the vacuum pump. Alternatively transport can be forced at a constant flux by using the peristaltic pump. A range of soil water status conditions can thus be established ranging from a wetting cycle, through saturated flow to a drying cycle. For evaluating a particular agrochemical, the soil column is first saturated with a Br⁻ solution at known constant hydraulic head. Once the system is in equilibrium, or at the desired condition, the agrochemical is introduced by changing the source of transporting solution. The agrochemical can be injected by either a step or pulse method.

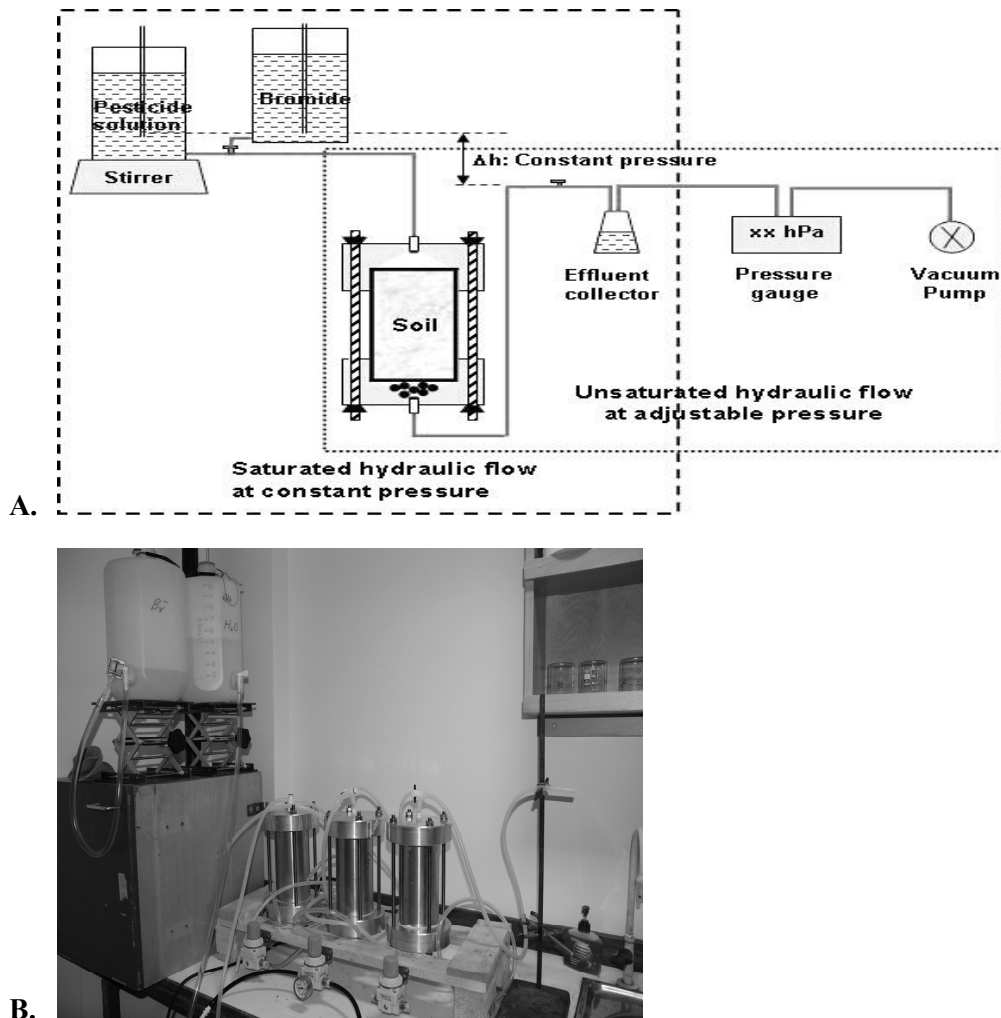


Figure 1. Soil column apparatus used in transport experiment: A: Schematic. B: Photograph

Soil sampling

Soils are sampled by driving stainless steel soil columns (10 cm i.d., 20 cm long) into the soil. For very stony soils, a plinth of soil can be isolated, the steel ring placed around it and the cavity filled with molten paraffin wax. Once filled with soil, the columns are excavated and sealed in air- and water-tight plastic bags. The ends of the columns are supported to ensure there is as little transport disturbance as possible.

For the preliminary evaluation of the system, two soils (Elton (E) and Clonroche (CL) series) that are typical of arable soils in Ireland were sampled. In addition to the undisturbed soil columns, samples were taken in triplicate for bulk densities at 0-10 cm and 10-20 cm depths, and a composite disturbed soil sample (0-15 cm) was taken for physico-chemical analysis. The loose soil was air-dried and ground to pass through a 2 mm sieve before analysis. Soil columns were stored in the dark at 4°C until use.

Results

The soils differed in bulk density, but other properties were very similar, reflecting their typical use as arable soils (Table 1).

Table 1. Physio-chemical characteristics of soils used.

Depth (cm)	Soil type	clay (%)	silt (%)	sand (%)	pH (in CaCl ₂)	Cation Exchange Capacity (Cmol/kg)	Bulk density (g/cm ³)
0-10	E	29	65	6	6.3	23.4	1.15
10-20							1.26
0-10	CL	30	68	2	6.3	19.9	1.03
10-20							1.00

We saw that the soils had very high hydraulic conductivity, which reflected the loose, aggregated topsoil structure that contained many large pores (Figure 2). The Br⁻ breakthrough provides a useful comparison for agrochemicals. If the breakthrough of a pesticide is slower than Br⁻, then there is potentially a significant soil interaction and retention of the active ingredient.

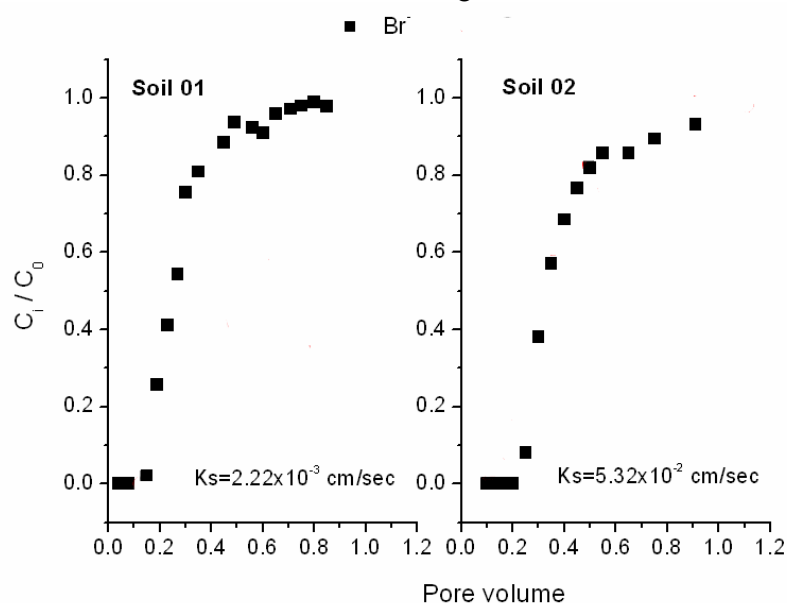


Figure 2. Br⁻ breakthrough curves for two Irish soils under saturated conditions with step input of Br⁻.

Preliminary work with the system indicated that it would provide valuable data on agrochemical transport through undisturbed soils over a range of soil types (unlimited as even stony soils can be sampled), environmental conditions (from very low temperatures to tropical conditions as controlled by constant temperature laboratory settings) and hydraulic or soil water status conditions (wetting, saturated, drying, step input, pulse input, constant flow).

Prior to full experimentation with the system, work will be conducted on the effects of pesticide degradation rates within the system to evaluate the role of time in data analysis (Blumhorst 1996). We expect quite different results between soils and chemicals. For example mobility studies on chlorothalonil suggest that it is immobile or moderately mobile in soils due to its high sorption (Ngan *et al.* 2005). We will be able to evaluate whether boundary conditions and soil water status influence its transport and fate.

Conclusion

The Br⁻ breakthrough results to date indicate that the laboratory lysimeter system will be suitable for pesticide transport studies and will provide valuable data to aid in improved transport risk assessment.

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