

WATER MOVEMENT AND CHEMICAL TRANSPORT IN A LOBLOLLY PINE FOREST

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INTRODUCTION

Chemical movement in the soil is usually assumed to be an advection-dispersion process. The advection is governed by the unsaturated version of Darcy's Law; the dispersion is controlled by properties of the porous matrix and the fluid. In a recent study, the pesticide Lindane was found to move more quickly and at higher concentrations to a depth of 30 cm at the base of Loblolly pine trees than in the open between trees (Dowd, *et al.*, in Press). This rapid flow may be caused by a non-Darcy flow process such as macropore or preferential flow due to animal burrowing, dead or living roots and subsurface cracks (Beven and Germann, 1982), or by soil loading at the base of the trees due to stem-flow (Voigt, 1960). This study is designed to distinguish between stemflow and macropore flow of water and tracer transport in a Loblolly pine stand.

Five tracers were used: Stable oxygen (^{18}O), deuterium, bromide, chloride, and potassium. Oxygen, deuterium, and bromide are the conservative tracers, and chloride and potassium are the non-conservative tracers.

The concentrations of the applied tracers are sufficiently different from the groundwater and precipitation so the different modes of water transport in the soil can be resolved. The conservative tracers will move with the water, while the non-conservative tracers will sorb onto soil and organic matter. The oxygen and deuterium serve as a check on the amount of evaporation occurring (Bengtsson *et al.*, 1987; Kennedy *et al.*, 1986; Sklash *et al.*, 1975). The bromide, chloride, and potassium were monitored for uptake by the trees through the root system. All five tracers were applied simultaneously.

MATERIALS & METHODS

Description of the Site

The study site is located in a Loblolly pine stand near Comer, Ga. It is adjacent to the site sprayed with Lindane, and it consists of two 10 m x 10 m square plots separated by about 30m. An irrigation system was constructed to water the plots and to apply the tracers. The soil is a Cecil soil with a shallow A horizon(0-20 cm), a thick B₁ horizon (20-80 cm), and a BC horizon that extends to below one meter.

Instrumentation and Analysis

The soil moisture of the plots was measured using time domain reflectometry (TDR)(Topp and Davis, 1985). Both horizontal and vertical spatial variability through the soil were measured. Depth integrated soil moisture was measured with

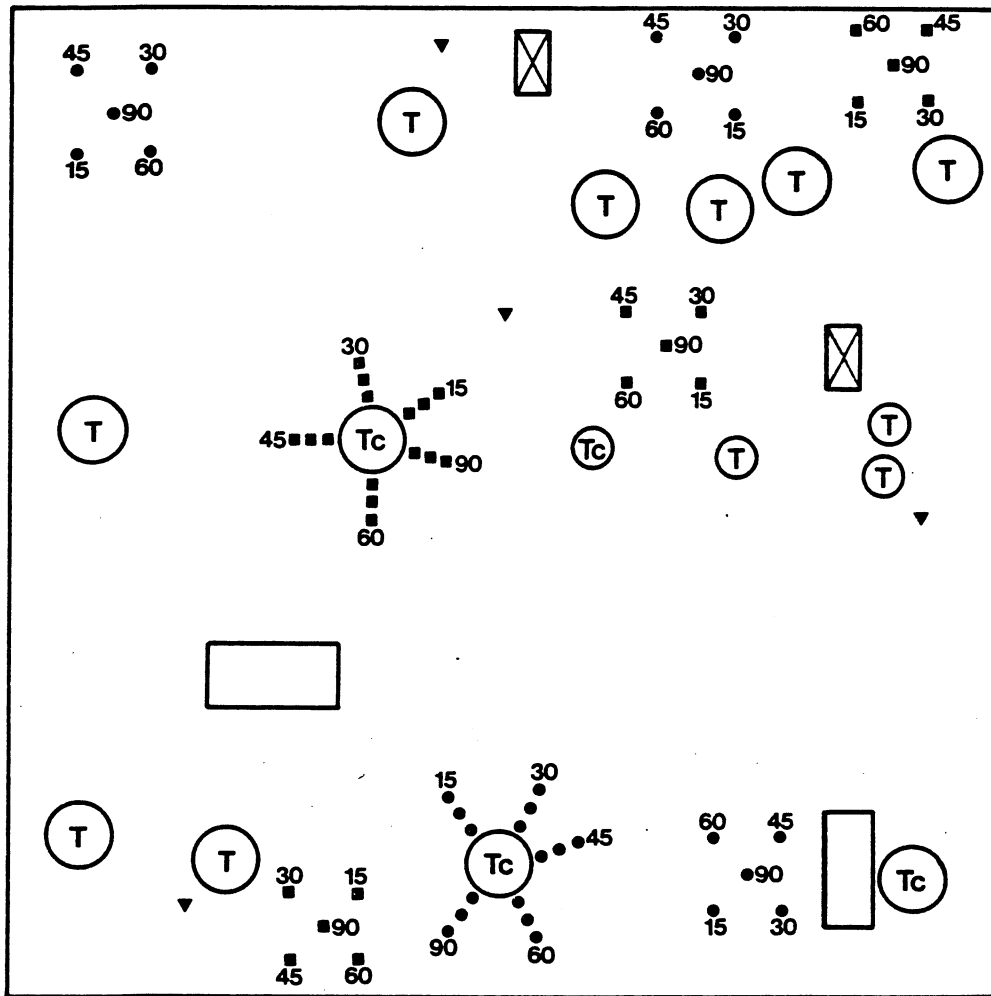
25 and 50 cm vertical rods. Vertical profiles were measured using rod pairs installed in the walls of four pits at seven depths: 7.5, 15, 30, 45, 60, 75, and 90 cm. For each pit at each depth, six replicates were established. In each plot one pit was in the open and one pit was adjacent to a tree. Soil suction was measured with tensiometers using mercury manometers. Soil water was sampled with one bar, high flow cup lysimeters installed adjacent to trees using a radiating, ring pattern, and in the open using five lysimeters in a nested pattern. Initial concentrations of the tracers were taken at the surface of the forest floor using plastic cups, and again just below the forest litter with zero-tension lysimeters (Figure 1). The water was sampled on a daily basis for the first three weeks, and then every three to four days thereafter.

The water samples taken from the one bar, high flow lysimeters and zero-tension lysimeters were analyzed for the five tracers described above. Three milliliters of each sample were equilibrated with CO_2 , and analyzed using mass spectrometry. The deuterium will be extracted using a uranium-furnace method.

The bromide and chloride concentrations are determined by ion chromatography. Pine needles will also be analyzed for bromide, chloride, and potassium after making aqueous extracts. The potassium concentration will be determined using atomic adsorption spectrophotometry.

Description of the Experiment

The experiment was conducted in several phases. First, the plots were irrigated with water, to bring them as close to field capacity as possible, simulating winter rainfall. Pond water was applied at approximately one inch increments to prevent surface saturation and overland flow. This was repeated until the plots were near field capacity to a depth of 90 cm. After the plots were wet, the tracers were applied by the sprinkler system. The oxygen-18 and deuterium enriched water came from a swimming pool which has been allowed to evaporate for the majority of a year. The chloride was added periodically to the pool during the year. Bromide and potassium were added to the water in holding tanks prior to tracer application. The first experiment was conducted with stemflow collars fixed to trees to eliminate that process. After completion of the first experiment, the plots were flushed with pond water until the concentrations return to normal or near-normal conditions. The stemflow collars were then removed and the experiment repeated to determine the effects of stemflow loading on the hydrologic processes.



LEGEND

● Lysimeter - depth in centimeters	■ Tensiometer - depth in centimeters
▼ Zero-tension Lysimeter	▭ Horizontal TDR Plot
⊙ Tree	⊗ Vertical TDR Plot
⊙ Tc Tree with Collar	

Each horizontal TDR plot contains 6 pairs of rods at the following depths:
7.5cm., 15cm., 30 cm., 45cm., 60cm., 75 cm., 90 cm.

Figure 1: SCHEMATIC LAYOUT OF PLOT ONE

DISCUSSION

Figure 2 shows moisture values content for four depths in an open area. Each plotted value represents the average of six measurements taken horizontally over a 50 cm length using TDR. The increasing soil moisture with depth reflects a depth related change in soil texture. The percent clay increases from less than 20 percent near the surface to more than 50 percent at one meter.

Figure 3 shows moisture content values for the same depths at the base of a tree. Unlike the open area results, the moisture content at 7.5, 15, and 30 cm depths were similar. This is probably due to an increase in the effective soil porosity due to roots in the A and A/B transition horizons. This increase in the soil porosity suggests that the soil beneath a tree will respond more rapidly to water or tracer additions.

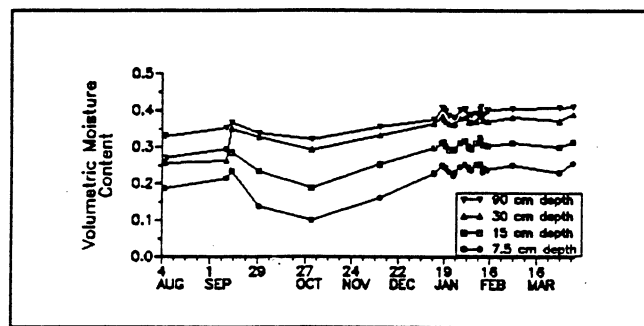


Figure 2. Moisture content values in the open.

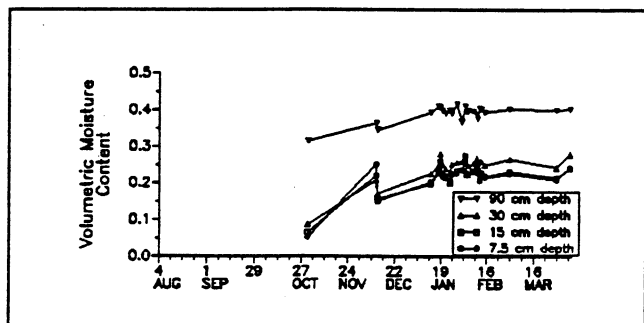


Figure 3. Moisture content values below a tree.

Figure 4 illustrates bromide concentrations for three depths in the open and beneath a tree. The similarity of the curves for the 15 cm depths indicates that the two sites behave alike in the A horizon. Both sites yielded low but measurable concentrations one day after the application of the tracers, (February 2). The 45 cm depths also behaved similarly, although more bromide was transported to that depth beneath the trees. This pattern was broken when the data from the 90 cm depths were plotted. Beneath the tree, some of the tracer arrived almost immediately; the concentrations were low but measurable. In the open, the concentrations of the tracer at 90 cm were below the minimum detection limit of 1 mg/l for the entire study period. Because bromide behaves as a conservative tracer, the shallow lysimeter results indicate that flow is similar in the two areas to the top of the clay-rich B₁ horizon. Flow through the B₁ horizon is enhanced, however, by the presence of the root system at the base of the trees. The high flow rate in the upper horizons suggests that macropore flow occurred at both sites. The residence time of

the bromide in the soil profile is consistent with flow through the finer pore fractions. Therefore, a small portion of a conservative chemical will move rapidly through the soil in the macropores while the remainder will move more slowly through the soil mass.

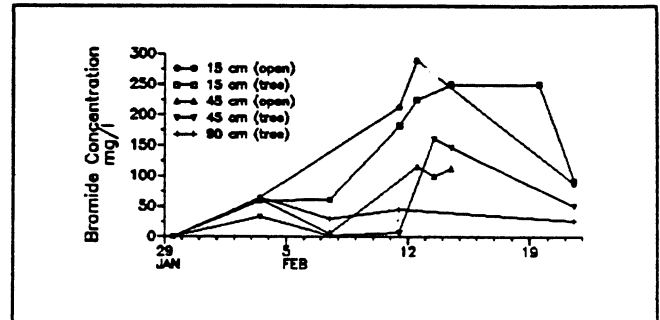


Figure 4. Bromide concentrations for several depths.

Preliminary oxygen and deuterium data indicate that evaporation plays a significant role in the amount of water present in the mineral soil. Summertime conditions can be expected to enhance this process, and evaporation in the shallow horizons of the mineral soil can be expected to affect those contaminants that have a gas phase component, such as many organic pesticides.

These results indicate that water and chemicals can move rapidly through a forest soil. The macropore pathway may allow more rapid transport of contaminants that adsorb on soil surfaces than is generally assumed. This could result in contamination of water resources by sources previously thought to be immobile in the soil column and thus non-pollutants.

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