Effect of soil type on atrazine and alachlor movement through the unsaturated zone. [DNR-062] 1989

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Madison, Wisconsin: Wisconsin Department of Natural Resources, 1989

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Wisconsin Groundwater Management Practice Monitoring Project No. 54

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Wisconsin Department of Natural Resources

Final Report on Project Entitled:

EFFECT OF SOIL TYPE ON ATRAZINE AND ALACHLOR MOVEMENT THROUGH THE UNSATURATED ZONE

FY89 Management Practice Monitoring Program

Submitted to:

Wisconsin Department of Natural Resources
Bureau of Water Resources Management
Groundwater Management Section

Submitted by:

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December 1989

I. Introduction

The initiative for this project arose when groundwater monitoring, adjacent to agricultural fields in the Central Sands and Lower Wisconsin River Valley (LWRV) areas of Wisconsin, showed conflicting detections of herbicides, despite similar cropping practices and what were believed to be similar soil types (Postle, 1988). Results from the monitoring program have found a much greater frequency of detects and higher concentrations of atrazine and alachlor in the LWRV compared to the Central Sands. The primary objective of this project was to compare the movement of two common herbicides (atrazine and alachlor) through exploratory soil columns representing each of these regions. A secondary objective was to examine the influence of an experimental polymer additive on herbicide movement.

Results from this study have been used to formulate a detailed research plan to study the uniqueness of herbicide movement at a field site in the LWRV.

II. Methods and Procedures

Five, 8-inch diam., intact soil columns (two 80-cm, three 40-cm) were extracted from a soil classified as Sparta sand located near the west edge of section 11, T8N-R4E, Iowa County. Three Plainfield sand columns (two 80-cm, one 40-cm) were collected from the Hancock Research Station, western Waushara County. The columns were placed in a greenhouse and instrumented to simulate field temperature and moisture regimes (Fig. 1; Fermanich et al., 1989). Except for a 6-year storm on day 20, water was applied according to an average rainfall pattern with respect to both amount and distribution of rain for 110 days (Fig. 2). Irrigation/supplemental water was applied following a pattern utilized by growers in the Lower Wisconsin River Valley (1.5 inches of total water per week). One corn plant was

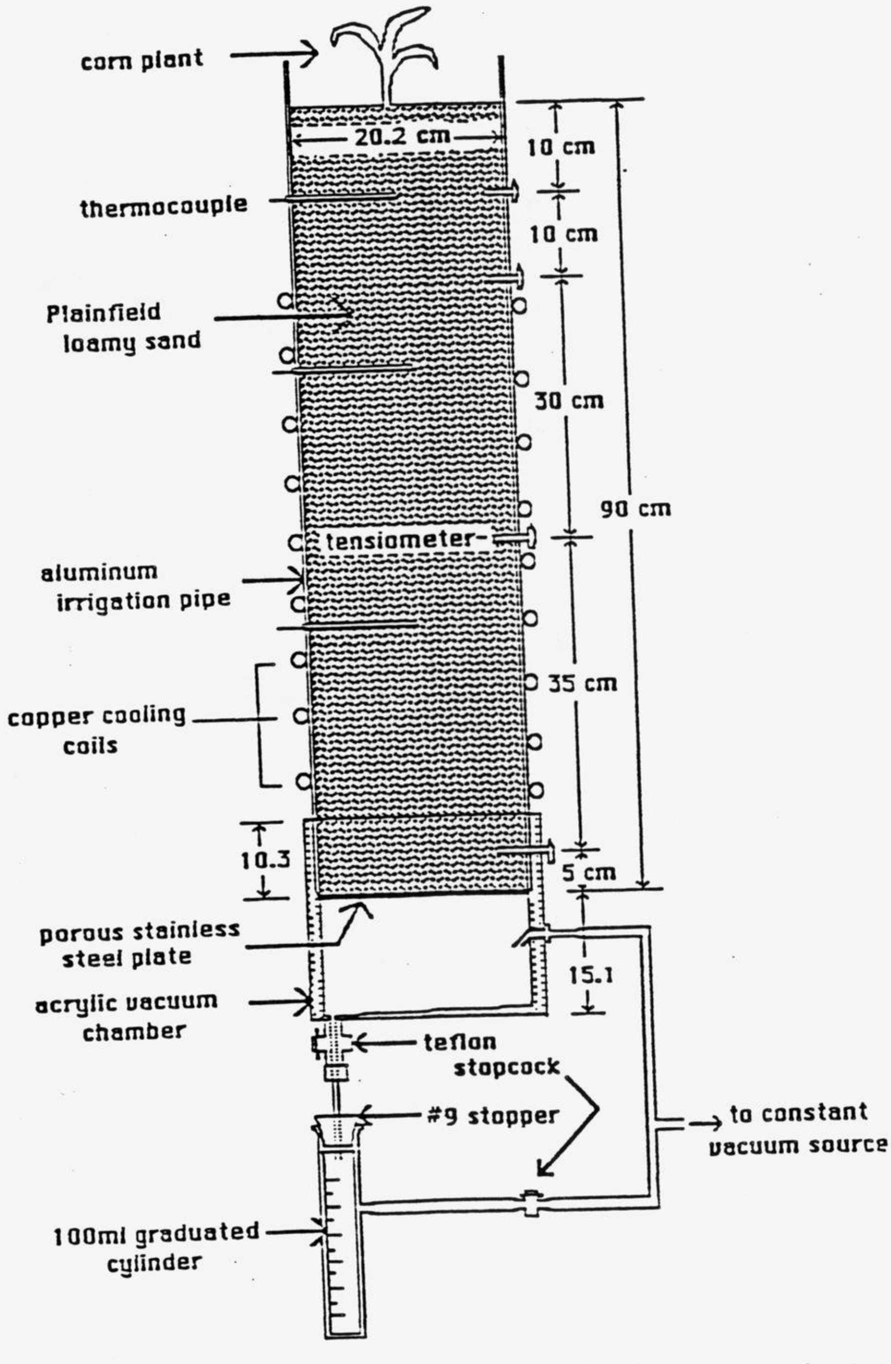

Figure 1. Schematic drawing of microlysimeter soil column experiments (from Fermanich et al., 1989).

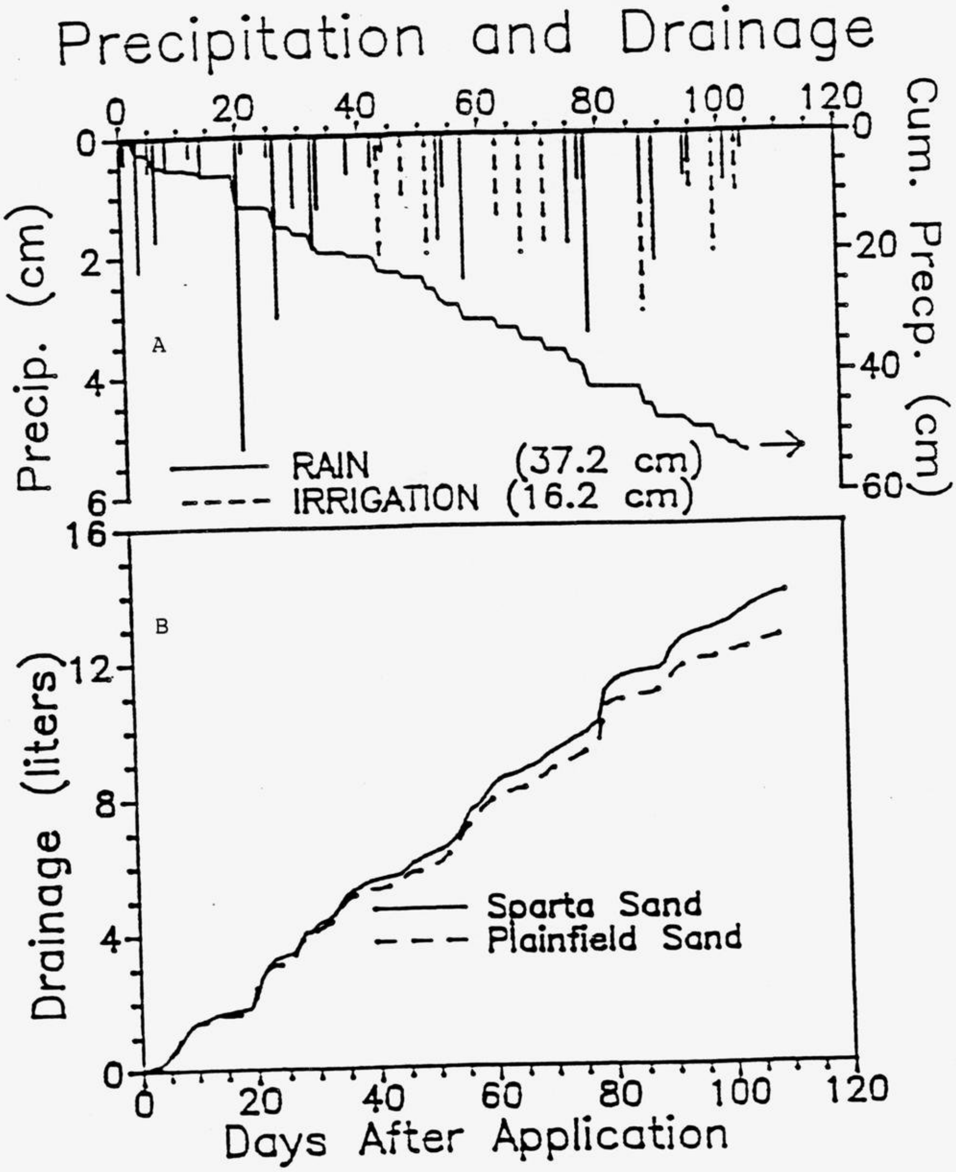

Figure 2. Precipitation distribution and cumulative precipitation (A) and drainage (B) for Sparta and Plainfield 80-cm columns. Drainage data are means of duplicate columns.

grown in each column to provide plant uptake and evapotranspiration. Evapotranspiration was determined by weighing the columns each day and recording all water applications and drainage.

Atrazine (^{14}C-labeled) was applied to all columns at a rate of 1.3 kg ha^{-1} and alachlor was applied at 1.6 kg ha^{-1} (Table 1). Two of the 40-cm Sparta columns received the polymer (2% by volume) along with the regular herbicide application solution. In addition to the herbicide applications, bromide in the form of KBr was applied to all columns as a non-adsorbed, conservative tracer of water movement.

Leachate was collected daily, pooled (approximately every 3 days) and analyzed for ^{14}C, parent atrazine, and alachlor. At the completion of the experiment (110 days), each soil column was sectioned into six or eight depth increments (0-2.5, 2.5-5, 5-10, 10-20, 20-30, 30-40, 40-60, and 60-80 cm) and the soil and plants were analyzed for ^{14}C and the herbicides. Total ^{14}C-atrazine residues in the leachate were determined by liquid scintillation counting (LSC). Parent atrazine and alachlor in water and soil were determined after extraction by gas chromatography. Total ^{14}C in soil and plants was determined by combusting all ^{14}C-atrazine residues to $^{14}CO_2$ followed by LSC. Bromide concentration in leachate was determined using a specific ion electrode.

Soil samples were taken in the field at selected depths adjacent to the area where the columns were obtained and characterized with respect to particle size distribution, pH, hydraulic conductivity, organic carbon content, and atrazine adsorption. A portion of these data was obtained from a separate but closely related study being conducted in this laboratory by Brian Girard.

Table 1. Experimental design for microlysimeter soil columns.

Soil type	Column length	Treatment†	Replication
	cm		
Sparta sand	80	Regular	Two
Sparta sand	40	Regular	One
Sparta sand	40	w/Polymer	Two
Plainfield sand	80	Regular	Two
Plainfield sand	40	Regular	One

† Regular treatment received 1.3 and 1.6 kg ha^{-1} active ingredient of ^{14}C-atrazine and alachlor, respectively. Polymer treatment included the addition of a polyacrylate to the regular application solution.

III. Results

Water Balance

All columns received the same amount of simulated rain and irrigation, totaling 53.4 cm. Table 2 gives total drainage, evapotranspiration, as well as rain and irrigation for all treatments. There was less drainage from Plainfield columns compared to Sparta (Table 2 and Fig. 2B). Drainage differences may be due to a slightly greater water holding capacity of the Plainfield sand and in turn greater evapotranspiration (ET). Because of the size of the columns and poor plant growth, ET for the 110 days is about one-half of what may be expected in the field--and about one-half of that measured in a previous column study. Nonetheless comparisons in solute movement between the two soils can still be made.

Leachate Loss

Figure 3A and 3B show average bromide concentration-time breakthrough curves for the 40- and 80-cm columns, respectively. Peak concentration in the leachate for 40-cm columns occurred rather quickly, approximately 11 days after application. Time to peak in the 80-cm columns (approximately 21 days) was about twice as long compared to the 40-cm columns. There was little difference between soil types with respect to transport of the conservative tracer bromide. Comparing the transport of the nonreactive bromide ion (Fig. 3) to atrazine (Fig. 4) and alachlor (Fig. 5), there is a delay in the time required to reach peak leachate concentration. Peak concentration transport time for atrazine and alachlor was three to four times longer than that of bromide.

Results indicate a substantial difference in movement of both herbicides between the two soil types. Parent atrazine leachate concentration was up to 100 times greater from the Sparta (LWRV) columns compared to the

Table 2. Water balance after 110 days of simulated field conditions for Sparta sand (LWRV) and Plainfield sand (Central Sands) columns.†

Soil type	Treatment	Drainage	ET	Rain	Irrigation
		-------------	cm	---------------	
Sparta	40 cm	46.0	8.5	37.2	16.2
Sparta	40 cm w/poly	44.8	10.1	37.2	16.2
Sparta	80 cm	44.5	11.7	37.2	16.2
Plainfield	40 cm	39.9	13.3	37.2	16.2
Plainfield	80 cm	40.3	14.9	37.2	16.2

† Data for 80-cm and Sparta w/poly columns are means of duplicate columns.

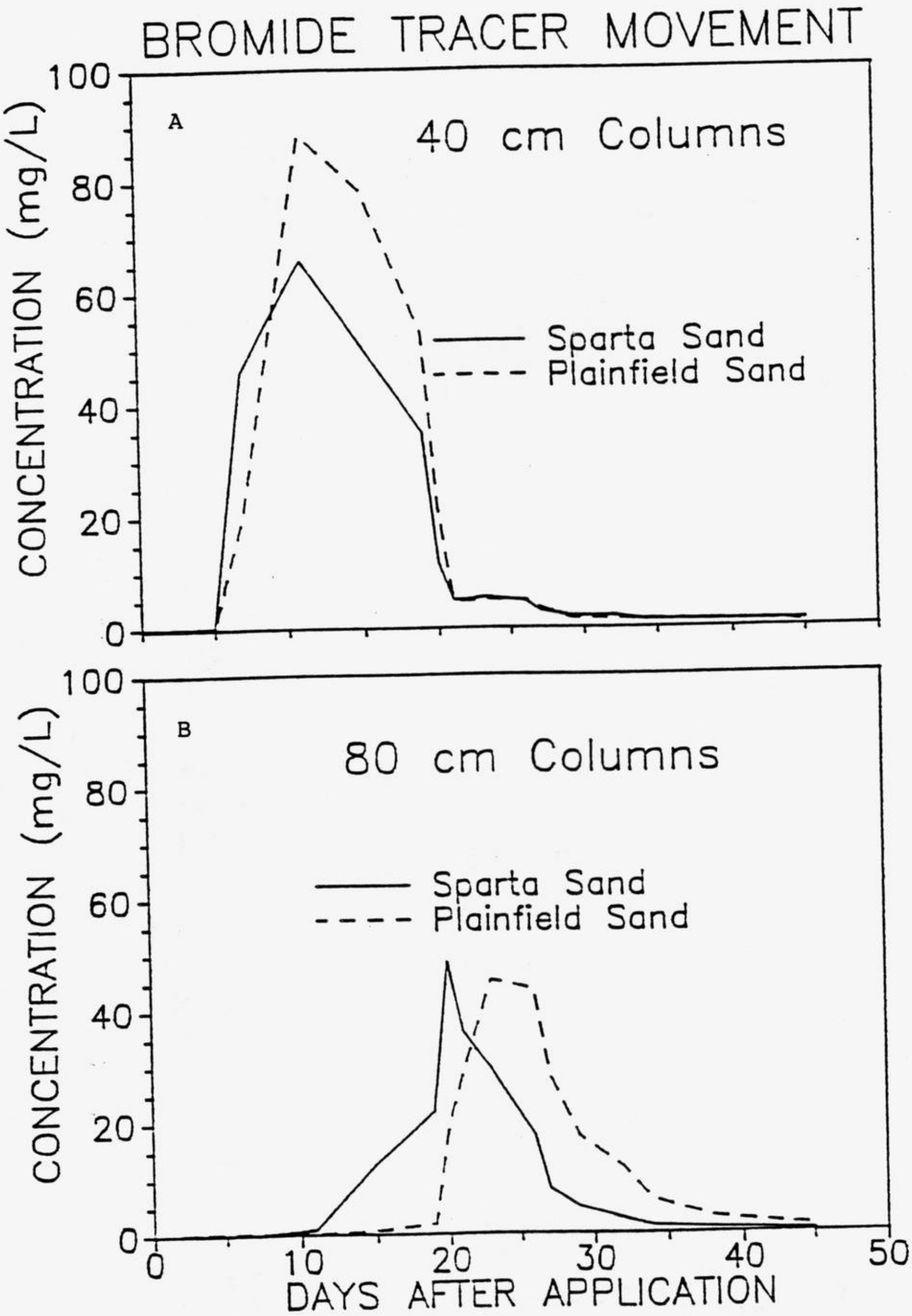

Figure 3. Average bromide concentration-time breakthrough curves for 40- (A) and 80-cm (B) Sparta and Plainfield soil columns.

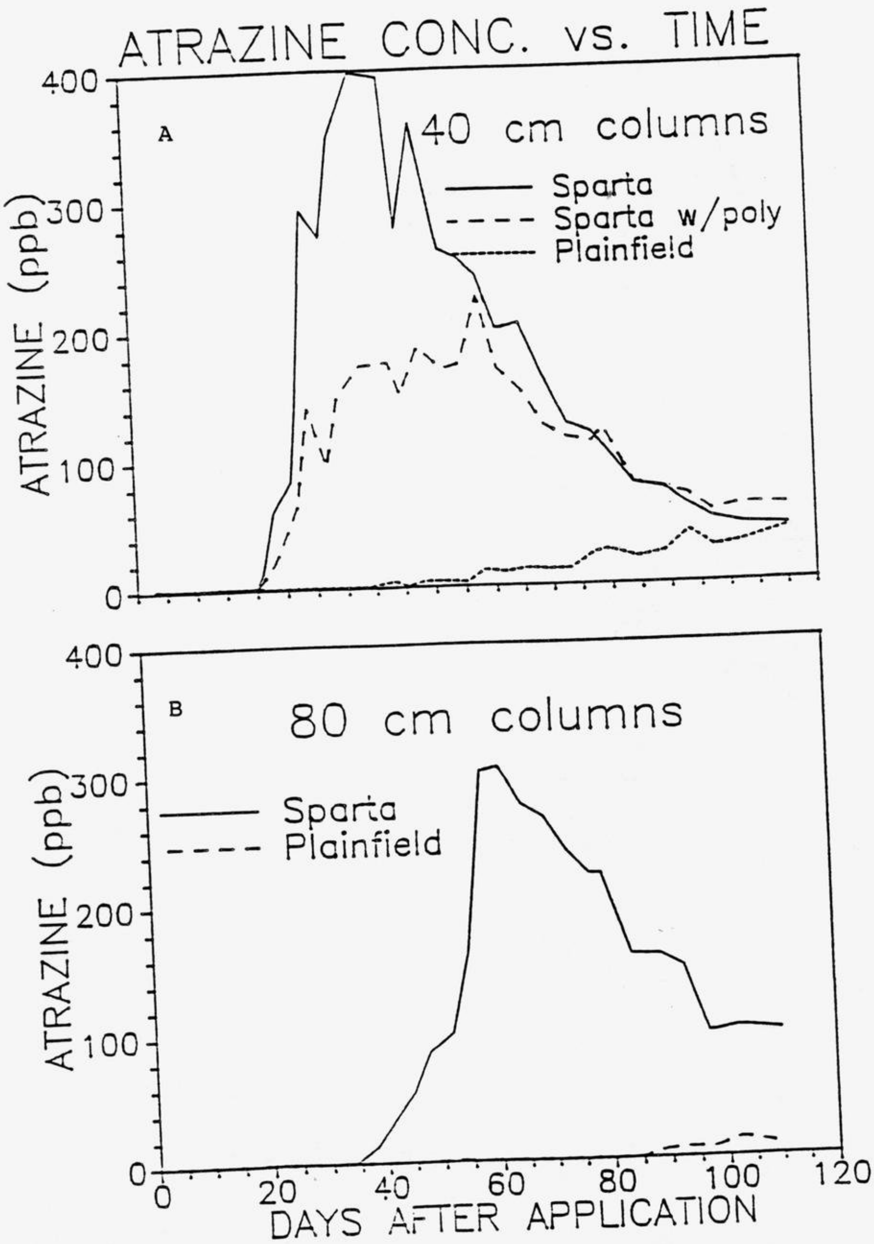

Figure 4. Atrazine concentration in leachate for Sparta (w/poly = polyacrylate added) and Plainfield 40- (A) and 80-cm (B) soil columns. Data for 80-cm and Sparta w/poly columns are means of duplicate columns.

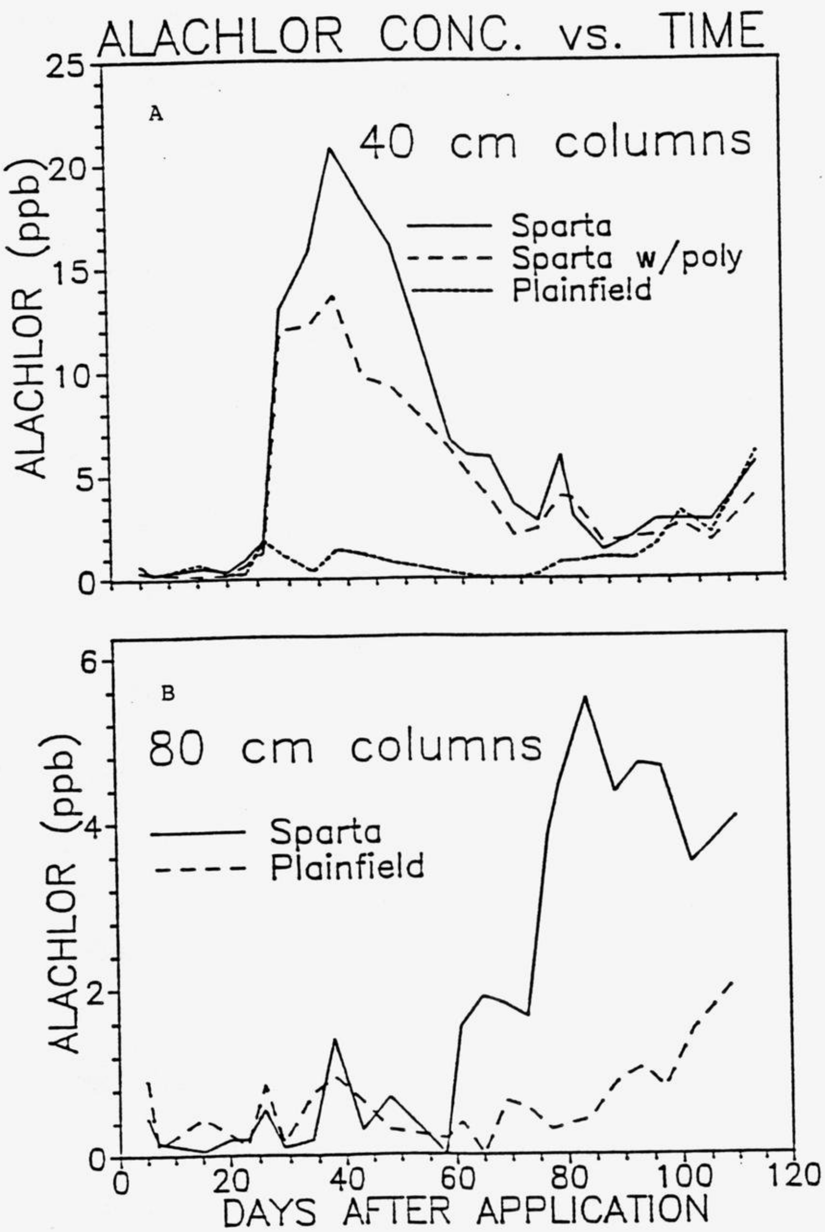

Figure 5. Alachlor concentration in leachate for Sparta (w/poly = polyacrylate added) and Plainfield 40- (A) and 80-cm (B) soil columns. Data for 80-cm and Sparta w/poly are means of duplicate columns.

Plainfield (Central Sands) columns (Fig. 4). The highest atrazine concentration measured from a Sparta 80-cm column was 435 ug L^{-1} compared to 14 ug L^{-1} for a Plainfield 80-cm column. Alachlor concentration in the leachate of the Sparta columns was also greater than that in the leachate of the Plainfield columns (Fig. 5). However, the concentration of alachlor in the leachate for all columns was considerably less than that of atrazine.

Over 45% of the applied atrazine leached through the 40-cm column of Sparta sand, compared to just over 3% for the Plainfield sand (Fig. 6A). The 80-cm columns showed (Fig. 6B) the Sparta and Plainfield losing 36 and 0.4% of the applied atrazine, respectively. Total ^{14}C-residues (parent plus metabolites) leached from 40-cm Sparta and Plainfield columns was 66 and 9% of the applied, respectively (Fig. 6A and Table 3). Twenty-five times less total ^{14}C-residues were leached from the 80-cm Plainfield columns compared to the 80-cm Sparta columns (Fig. 6B and Table 3).

Alachlor leachate loss showed similar trends to atrazine between soil types (Fig. 7). The greatest loss was less than 2% of the applied (Sparta 40-cm column).

Soil Herbicide Distribution

Soil atrazine and alachlor concentration after 110 days is shown in Figs. 8A and 8B. The highest concentration of atrazine in the Sparta columns was found below 40-cm (Fig. 8A), whereas the highest concentration of atrazine was found in the 10- to 30-cm increment of Plainfield columns, illustrating less susceptibility to leaching. There was less difference between soil types for soil concentrations of alachlor (Fig. 8B).

^{14}C-atrazine Residue Distribution

Table 3 and Fig. 9 show the distribution of ^{14}C-atrazine residues after 110 days of simulated field conditions for Sparta (LWRV) and Plain-

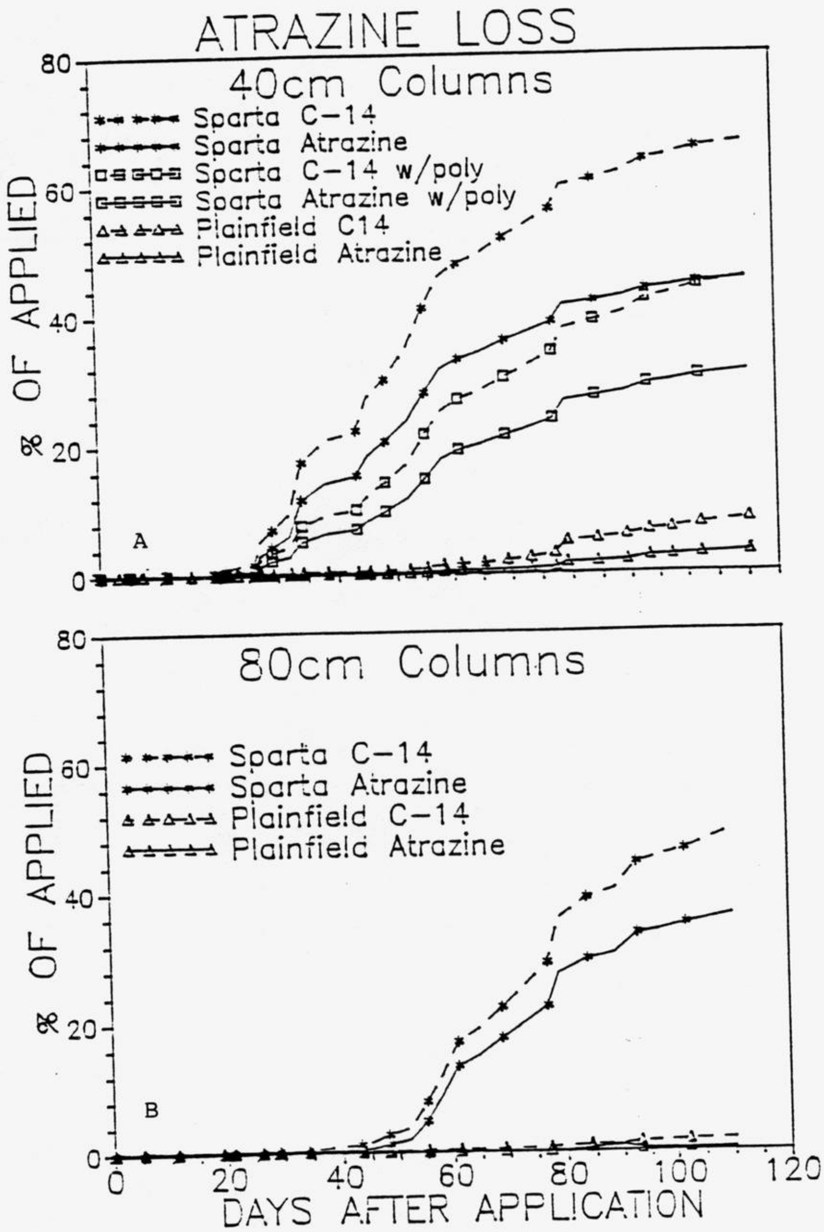

Figure 6. Cumulative percent of applied ^{14}C (dashed) and parent atrazine (solid) in leachate for Sparta (w/poly = poly-acrylate added) and Plainfield 40- (A) and 80-cm (B) columns receiving ^{14}C-atrazine. Data for 80-cm and Sparta w/poly are means of duplicate columns.

Table 3. ^{14}C distribution after 110 days of simulated field conditions for Sparta sand (LWRV) and Plainfield sand (Central Sands) columns receiving ^{14}C-labeled atrazine.†

Soil type	Treatment	Leachate	Soil	Plant	Total recovered
		% of applied ^{14}C			
Sparta	40 cm	66.3	23.5	0.04	89.8
Sparta	40 cm w/poly	45.4	37.6	0.11	83.1
Sparta	80 cm	49.0	46.4	0.13	95.5
Plainfield	40 cm	8.9	66.0	0.75	75.7
Plainfield	80 cm	1.8	70.8	0.65	73.3

† Results are based on liquid scintillation counting (LSC) of water samples for ^{14}C and oxidation-$^{14}CO_2$ trapping followed by LSC of soil and plant samples. Data represent all ^{14}C-atrazine residues, not just parent atrazine.

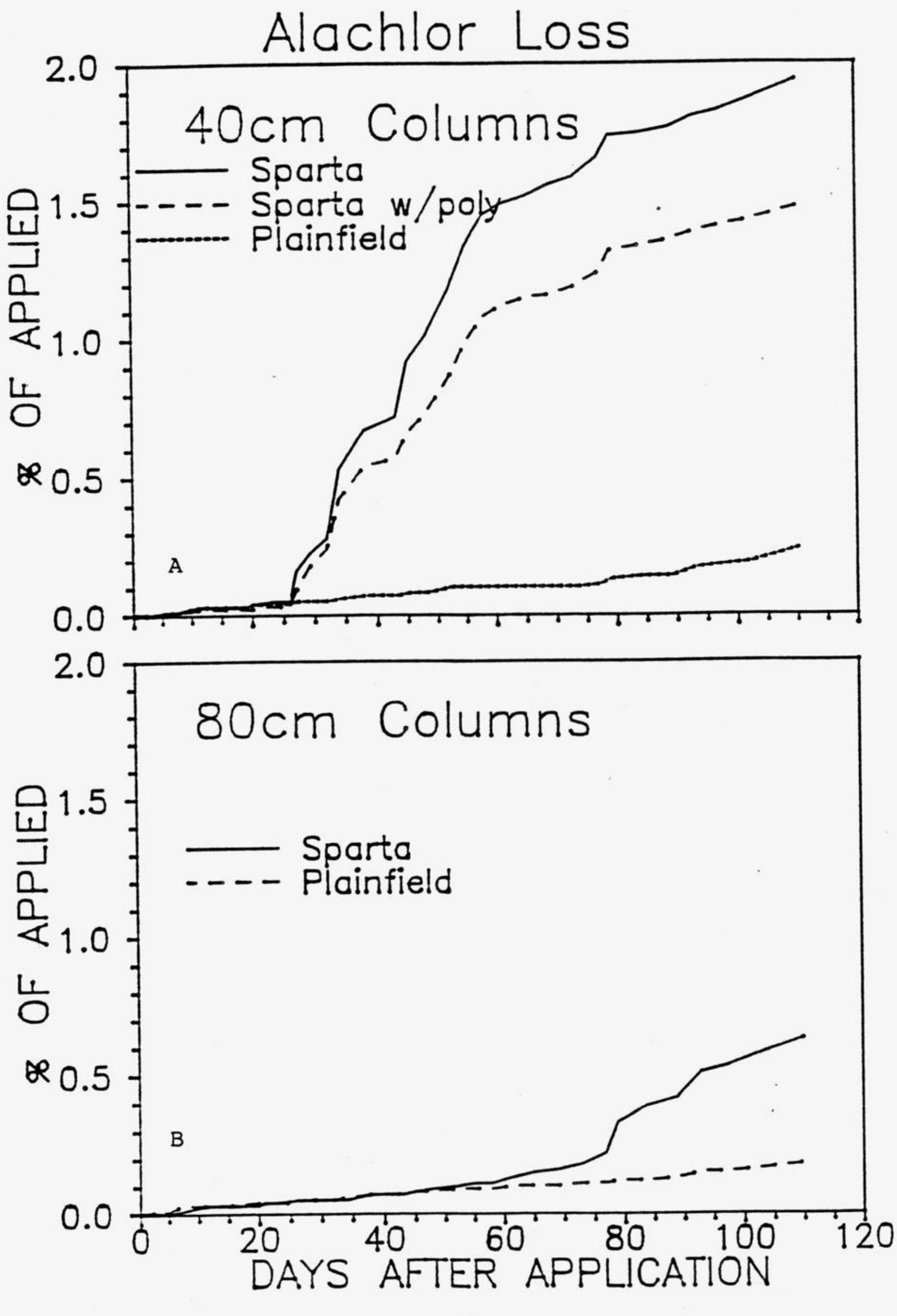

Figure 7. Cumulative percent of applied alachlor in leachate for Sparta (w/poly = polyacrylate added) and Plainfield 40- (A) and 80-cm (B) soil columns.

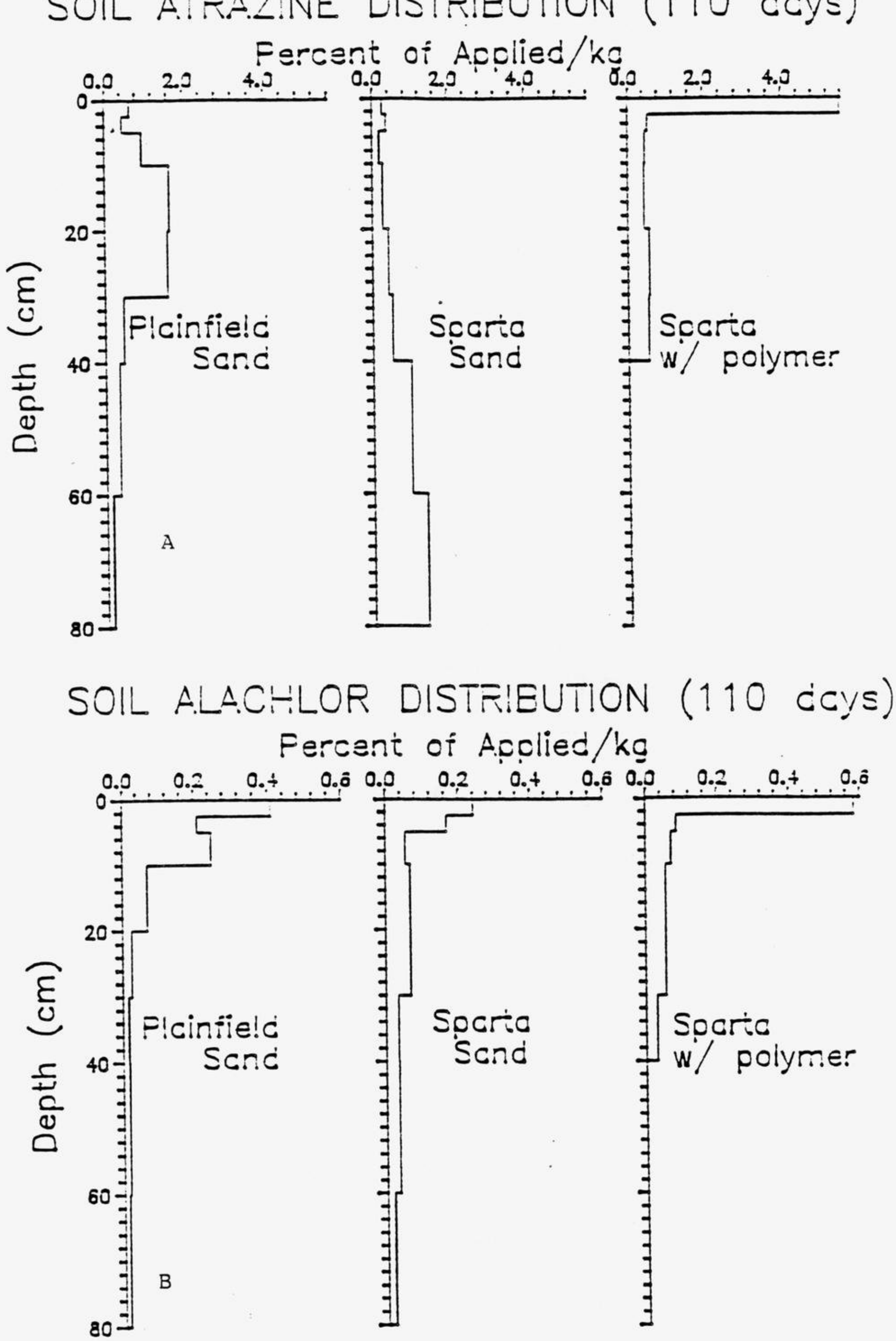

Figure 8. Average atrazine (A) and alachlor (B) concentration distribution in Sparta (w/poly = polyacrylate added) and Plainfield soil columns after 110 days of field simulated conditions. Sparta w/polymer are for duplicate 40-cm columns only.

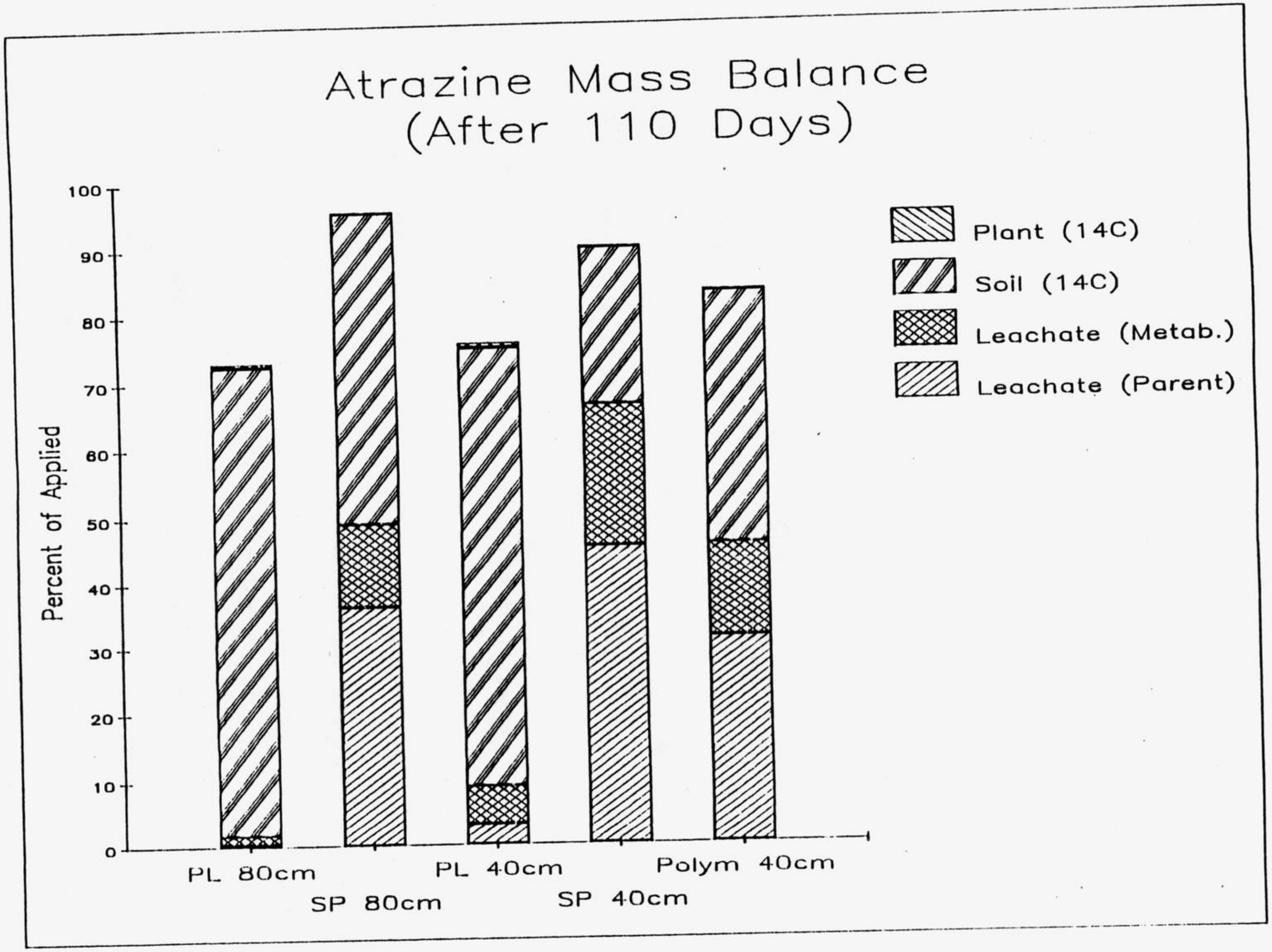

Figure 9. Cumulative ^{14}C-atrazine residue distribution after 110 days of simulated field conditions for Sparta sand (LWRV) and Plainfield sand (Central Sands) columns. PL = Plainfield sand; SP = Sparta sand; Metab. = ^{14}C-atrazine metabolites (residues) other than parent atrazine.

field (Central Sands) sand. The majority of ^{14}C recovered from Sparta columns was in the leachate, whereas the majority of ^{14}C-residues recovered from Plainfield columns remained in the soil. The greater plant uptake (Table 3) of ^{14}C-atrazine residues in Plainfield columns compared to Sparta columns is consistent with the reduced leaching and greater ET measured for the Plainfield columns (Table 2). The major portion (70%) of ^{14}C-atrazine residues leached from the Sparta 40- and 80-cm columns was in the form of parent atrazine (Fig. 9). On the other hand, the total ^{14}C-atrazine residues recovered in the leachate of Plainfield columns was mostly comprised of ^{14}C-atrazine metabolites rather than parent atrazine. Total recovery of ^{14}C-atrazine residues was 10 to 20% less for Plainfield columns compared to Sparta columns (Table 3 and Fig. 9). These results may partially be due to the fact that more herbicide remained in the soil portion, particularly in the upper profile, of the Plainfield microlysimeter columns, increasing the opportunity for chemical and biological breakdown.

Polymer Results

Addition of the polymer to the herbicide application solutions showed a reduction in the concentration (Fig. 4A and 5A) and amount (Fig. 6A and 7A) of herbicides leached through the 40-cm Sparta columns. In the 110 days, the duplicate polymer columns lost an average of 31% of the applied atrazine, compared to the 45% leached from the Sparta column not receiving the polymer (Fig. 6A). In analyzing the soil that remained in the columns at the end of the experiment, the data showed (Fig. 8A and 8B) that the columns receiving the polymer had a significant amount of the herbicides remaining at the surface of the soil, compared to those receiving the regular application.

Soil Properties

Particle size distribution data (Table 4) show the Sparta sand to be made up of primarily medium and fine sand with very little (<3%) clay. The Plainfield soil consists of less sand in the upper horizon, contains 2% more clay and a greater amount of silt than Sparta. Plainfield is a coarser textured sand. The small difference in clay and silt content is probably quite important with respect to water holding capacity and retention of solutes. Table 5 gives data from another study in our laboratory focusing on atrazine adsorption coefficients. In the upper 20-cm, the hydraulic conductivity of saturated Sparta sand is five times greater than that of Plainfield. The higher clay and organic carbon content of Plainfield sand (0 to 20-cm) gives rise to a Kd (adsorption distribution coefficient) that is 1.7 times greater than Sparta sand. Both soils have very low absorptive capacity for atrazine in the 50- to 80-cm layer. It has also been reported that atrazine is adsorbed to a greater extent (Weber, 1970) and is less mobile (Helling, 1970) at acid pH. Table 4 shows a slightly (0.5 pH units) higher pH for the Sparta soil compared to the Plainfield, thus pH may also contribute to the adsorption differences. The combination of increased hydraulic conductivity, reduced water holding capacity, and less adsorptive capacity of Sparta sand probably all contribute to the increased mobility of atrazine and alachlor, relative to Plainfield sand.

IV. Summary

The results of this project indicate that significant differences in herbicide movement can exist on sandy soils previously considered to be characteristically similar. The Sparta soil (LWRV) has very little ability to retain atrazine in the top 80-cm compared to the Plainfield sand of the

Table 4. Particle size distribution and pH of Sparta sand (LWRV) and Plainfield sand (Central Sands).†

Depth	Coarse sand	Medium sand	Fine sand	Total sand ‡	Silt	Clay	pH
cm	----------	----------	----------	%	----------	----------	
			Sparta				
0- 5	5.2	62.1	27.9	95.8	2.2	2.0	6.6
5-10	4.7	63.6	26.6	95.5	2.3	2.2	6.7
10-20	5.1	63.7	25.8	94.9	2.6	2.5	6.8
20-30	5.3	64.8	23.5	93.9	3.3	2.8	6.8
30-40	5.8	67.2	21.1	44.3	2.9	2.8	6.5
40-60	5.5	66.7	22.4	94.7	2.7	2.6	6.1
60-80	5.2	71.4	22.1	98.0	0.9	1.1	5.5
			Plainfield				
0- 5	31.9	43.2	12.4	87.8	8.1	4.2	6.1
5-10	31.0	43.4	12.4	87.9	7.9	4.2	6.2
10-20	31.8	43.4	12.8	87.9	7.8	4.2	6.0
20-30	30.3	42.8	14.6	88.1	7.5	4.5	5.8
30-40	29.7	42.3	17.4	89.9	5.8	4.3	5.6
40-60	32.0	43.2	17.3	93.0	3.8	3.2	5.3
60-80	33.8	41.9	17.4	93.7	3.6	2.7	5.5

† Samples taken directly adjacent to soil columns. Data are means of three samples.

‡ Sand fractions may not add up to total sand due to loss during fractionation.

Central Sands. This preliminary column experiment also indicates that alachlor is likely to be more mobile in Sparta sand than in Plainfield sand. The utilization of the experimental polymer in the herbicide application solution may be beneficial in reducing movement of herbicides through the soil profile.

This cursory study has led to a more comprehensive column study looking at atrazine, alachlor, and metolachlor movement in Sparta and Plainfield sand. There are three irrigation treatments (ET, ET+ 25%, and no irrigation) within the Sparta soil treatment, as well as a polymer treatment. Plainfield columns are being irrigated at ET. All treatments are replicated three times and consist of 80-cm columns. The cursory study has also given rise to a field study in the LWRV looking at herbicide movement under several irrigation and management schemes.

V. References

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Helling, C.S. 1970. Movement of s-triazine herbicides in soils. Residue Rev. 32:175-210.

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Weber, J.B. 1970. Adsorption of s-triazines by montmorillonite as a function of pH and molecular structure. Soil Sci. Soc. Am. Proc. 34:401-404.

Table 5. Selected properties of Sparta sand (LWRV) and Plainfield sand (Central Sands).†

Soil‡	Depth	Saturated hydraulic conductivity	Sand	Silt	Clay	pH	Organic carbon	Kd§ atrazine
	cm	cm s^{-1}		%			%	
Sparta	0-20	0.0120	94.9	3.2	1.9	6.5	0.37	0.287
	50-80	0.0100	95.7	2.0	2.3	5.7	0.15	0.070
Plainfield	0-20	0.0023	86.3	9.2	4.5	6.4	0.46	0.492
	50-80	0.0110	94.7	3.1	2.2	5.9	0.07	0.065

† Data collected by Brian Girard (Research Assistant, UW-Soil Science) for atrazine adsorption studies.

‡ Samples collected in the same area (within 100 feet) where soil columns were obtained.

§ Atrazine batch adsorption coefficient. Data are means of four concentrations and four equilibration times. Larger number equals greater adsorption.

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