

Leaching of Nitrates and Herbicides under Low Pressure (High Volume) Irrigation

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ABSTRACT

The potential for contamination of groundwater by nitrates or pesticides from irrigated soils has not been fully evaluated. This project was initiated to monitor nitrate and herbicide leaching in a tile-drained field at SIDC in Outlook. Water samples were collected using suction lysimeters and analyzed for nitrate and four herbicides (2,4-D, dicamba, bromoxynil and diclofop). The concentrations of nitrates at depth were maintained by the downward movement of applied and mineralized N. Trace amounts of 2,4-D and diclofop were leached to 180 cm but bromoxynil and dicamba were not found below 60 cm depth. Dicamba and diclofop persisted longer in the soil than 2,4-D or bromoxynil but were only present in trace amounts at the end of August.

INTRODUCTION

Agrochemicals are used in crop production on most Saskatchewan farms. In an irrigation management system pesticide and fertilizer use are usually higher than under dryland management and there is more potential for the chemicals to move through the soil. If significant amounts of agrochemicals pass through the soil there may be groundwater contamination. Surface waters may be contaminated by effluent water from tile-drained fields.

Some Canadian aquifers are already contaminated with nitrates (Kohut et al. 1986). Although these nitrates were not solely agricultural in origin, the leaching of nitrate from agricultural soils has contributed to the problem. Nitrate leaching is common in areas where precipitation is high but may even occur under semi-arid conditions on the prairies (Campbell et al. 1991). The presence of pesticides in groundwater has been reported in Prince Edward Island (Priddle et al. 1988) and near Portage la Prairie, Manitoba (Krawchuk and Webster 1987). Trace amounts of herbicides have also been found in shallow groundwater in the Outlook Irrigation District (Maathuis et al. 1988).

To evaluate the potential environmental impact of agrochemicals under irrigation management in Saskatchewan, their behaviour in the unsaturated zone must be understood. This project was initiated to monitor the concentration of herbicides and nitrates in the soil solution in the unsaturated zone and to obtain data necessary to calibrate a computer model which will be used to assess the effect of management practice on chemical transport.

MATERIALS AND METHODS

The study was conducted on Field 11 at the Saskatchewan Irrigation Development Centre on Bradwell loam soils (Strushnoff and Acton 1987). The field was irrigated by a linear sprinkler system and tile drains had been installed. Salinity has been a problem on this field but the soils are being reclaimed by a fall leaching program. Basic soil properties were measured prior to seeding and are shown in Table 1.

Table 1. Soil properties on Field 11 prior to seeding.

Depth cm	Sand %	Clay %	Org C. %	E.C. mS/cm
0 - 30	42	17	1.4	0.56
30- 60	43	16	1.1	0.51
60- 90	42	18	0.9	0.58
90-150	39	21	0.7	1.28
150-180	35	25	0.7	1.43

Barley was seeded on the site on May 10th 1989. Ammonium phosphate fertilizer was applied with the seed at a rate of 27 kg P₂O₅ ha⁻¹. On June 5th the crop was sprayed with Hoe Grass II (diclofop and bromoxynil 23:8) at the recommended rate of 3.5 L ha⁻¹ (740 g ha⁻¹ diclofop and 250 g ha⁻¹ bromoxynil). Four days later, 850 mL ha⁻¹ (425 g ha⁻¹) 2,4-D and 230 mL ha⁻¹ (110 g ha⁻¹) Banvel (dicamba) were applied in the recommended tank mix. The plot was not irrigated until June 16th but 5.9 mm of rain fell between June 5th and June 16th.

Herbicides had been applied on Field 11 in each of the three years prior to this study (1986-1988) at the same rates as used this year. As a result herbicide residues detected in the lysimeters did not necessarily originate from herbicide applications made in 1989.

Suction lysimeters (Wagner 1962) were installed at depths of 30, 60, 90, 150 and 180 cm. There were 8 replicates at each depth. The tension in the lysimeters was adjusted manually to -33 kPa twice a day. Water samples were collected 5 times in 1989: June 19th and 26th, July 16th, and August 8th and 30th. The first samples were taken 3 days after the first irrigation. Between June 5th and August 30th, 445 mm of irrigation water were applied (205 mm of which was applied between August 16th and Aug 30th as part of the fall leaching) and 78 mm of rain fell. 4570 kg ha⁻¹ of barley were harvested on August 14th.

The water samples were analyzed for dissolved nitrogen and ammonia, total and ortho phosphate and electrical

conductivity at the Environment Canada Water Quality Laboratory in Saskatoon using standard methods (Environment Canada 1979). Herbicide analysis was conducted at the Agriculture Canada Research Station in Regina. The multi-residue technique described by Cessna et al. (1985) was modified to include analysis of diclofop. All water samples were stored at 4 °C until analysis.

Meteorological data including precipitation, maximum and minimum daily temperature, potential evaporation and sunshine hours were collected at the site by SIDC staff. SIDC staff also monitored flow from the tile drains and the level of the water table on a weekly basis.

An analysis of variance was performed for the residue data in a two-way classification using PROC GLM (SAS Institute 1985). Depth and time were used as the criteria for classification. Significant differences between means were detected using Fishers protected LSD (Steel and Torrie 1980).

RESULTS

The volume of outflow from the tile drain is shown in relation to precipitation and irrigation in Figure 1. Flows from the drain were very low in early May but increased as precipitation and irrigation increased. The water in the drains stopped flowing on July 6th due to crop uptake and evaporation. Flow resumed after the crop had been harvested and the fall irrigation started. Drainage rates by the end of August had risen to almost 5 mm d⁻¹.

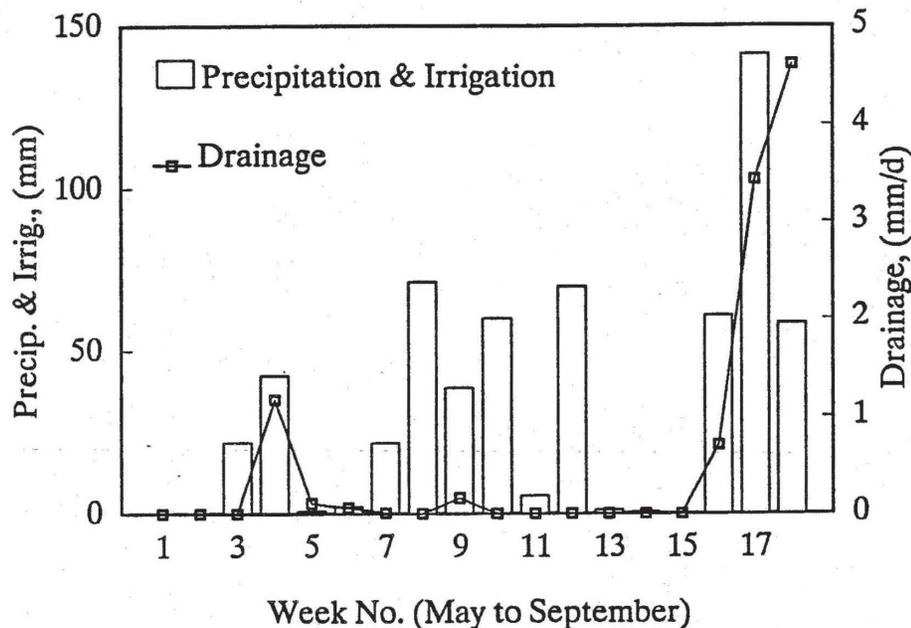


Figure 1. Precipitation, irrigation and drainage at the study site in 1989.

The distribution of nitrate in the soil solution with depth for the five sampling days is shown in Table 2. During the sampling period, organic N mineralization and plant uptake appear to have balanced as the concentration of nitrate in the soil solution at each depth remained relatively constant with time. There were no significant differences in nitrate concentration in the soil solution with time but there were significant differences between the concentrations at different depths in the soil. Nitrate concentration decreased significantly with depth: concentrations were greatest at the 30 cm depth, intermediate at 60 and 90 cm, lower at 150 cm and lowest at 180 cm.

Table 2. Variations in nitrate concentrations ($\mu\text{g g}^{-1}$) in the soil solution with depth and over time.

Depth	19/6	26/6	16/7	8/8	30/8
30	-	27.8	17.9	-	-
60	16.9	18.6	16.1	10.5	-
90	20.1	16.7	13.3	15.3	16.4
150	14.1	14.2	10.2	14.1	14.4
180	6.3	7.7	7.1	7.4	7.3

Neither dicamba nor 2,4-D were present in more than trace amounts in the soil solution (Figure 2). The concentration of dicamba was significantly greater at the 30 cm depth than at 90 cm and deeper. Below 60 cm depth concentrations of dicamba were below 0.010 ppb. The concentrations at all depths decreased slightly with time but the effect was not significant. 2,4-D decreased significantly with depth and time. On June 19th the concentration of 2,4-D in solution was relatively constant throughout the profile ranging between 0.040 and 0.050 ppb. By June 26th the concentration had dropped to around 0.030 ppb and was still fairly uniform through the profile. After June 26th virtually no 2,4-D was detected at the 150 and 180 cm depths but at 30, 60 and 90 cm the concentrations continued to decrease with time.

Bromoxynil concentration in the soil solution decreased with depth and time (Figure 2) but the variability between lysimeters was high and the differences were not statistically significant. The greatest concentrations of bromoxynil were found in the 60 cm lysimeters. On June 19th two of the 60 cm lysimeters had bromoxynil concentrations greater than 2 ppb but all of the other samples were less than 0.05 ppb.

The concentration of diclofop in solution varied significantly with both depth and time (Figure 2). On June 19th the concentration of diclofop in solution was greater than at any other sampling time but there were no other

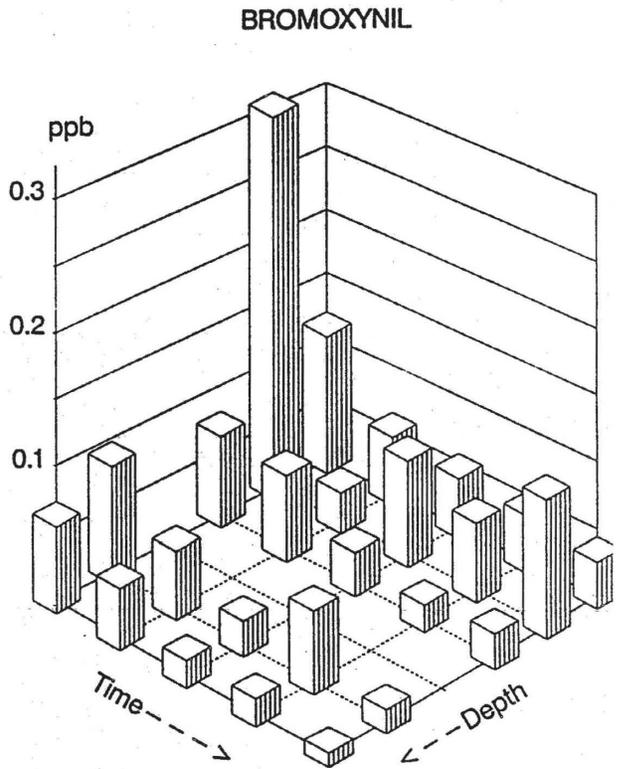
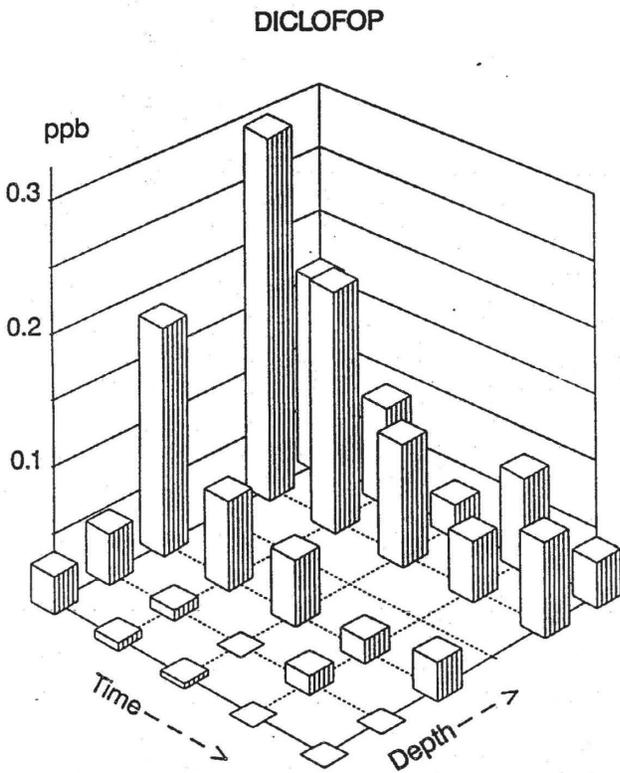
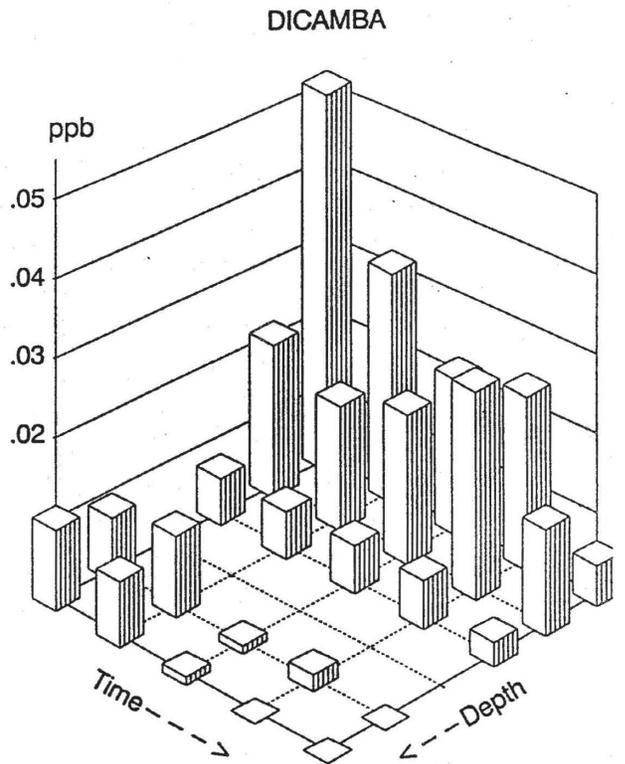
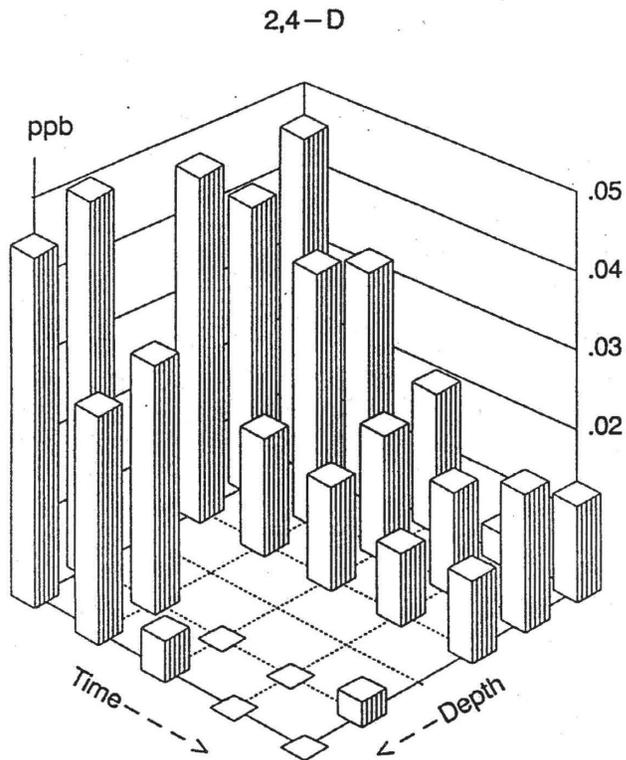


Figure 2. Variation in herbicide concentration with depth and time. (Note that the depth axis is reversed for diclofop).

significant differences in concentration with time. In contrast to the other herbicides, the concentration of diclofop was significantly lower at 30 cm than at the other depths. The greatest concentration of diclofop was generally found at the 150 cm depth but concentrations at 90 and 180 cm were also high. After June 19th only negligible amounts of diclofop were found at 30 and 60 cm depth.

DISCUSSION

The nitrate distribution was very stable through time. There was no evidence of the concentration of nitrate at depth increasing through time although water was flowing from the field drains. Providing the drainage water did not contain nitrate concentrations greater than those found at 180 cm (around $7 \mu\text{g l}^{-1}$ which is just below the standard for drinking water of $10 \mu\text{g l}^{-1}$), nitrate leaching was within acceptable limits in 1989. Water draining from irrigated fields should be monitored to ensure that nitrate reaching the water supply remains at acceptable levels. Appropriate management of fertilizer additions and irrigation water applications may reduce the nitrate loading in the tile drain effluent.

The differences in the distributions of the four herbicides through time and with depth result partly from their chemical properties. Values for degradation rates (half-life in soil), Koc (organic carbon adsorption coefficient) and solubility are shown in Table 3.

Table 3. Chemical properties for the herbicides used in this study.

Herbicide	Half-life days	Koc l kg^{-1}	Solubility mg l^{-1}
2,4-D	4 **	30 ¶¶	9×10^2 *
Bromoxynil	3 ¶	300 §§	1.3×10^2 *
Dicamba	17 **	3 ¶¶	4.5×10^3 *
Diclofop	20 §	53 §§	2.3×10^1 φ

* WSSA (1983)

** Altom and Stritzke (1973)

¶ Smith (1984)

§ Smith (1977)

¶¶ Grover and Smith (1974)

§§ calculated by method of Kenga and Goring (1978)

φ personal communication - Hoechst Canada, Regina

Diclofop appeared to be the most persistent chemical applied at the site. The half-life of diclofop in soil was the longest of the herbicides studied and as a result the herbicide was still present in the profile on August 30th.

Although dicamba was present at lower concentrations than diclofop, it also has a long half-life and was slow to dissipate. The rapid dissipation of the other chemicals was a reflection of their short half-lives.

2,4-D was found at all depths on the first sampling day. Either the chemical penetrated rapidly to 180 cm, or residues from previous applications were present at depth. The short half-life of 2,4-D and the rapid dissipation observed in this study suggest that the residues detected at the shallower depths were from chemical applied in 1989. Since diclofop is more persistent in soil than 2,4-D, the relatively high concentrations of diclofop found at 150 cm may reflect an accumulation of the chemical over time. However the presence of residues at 180 cm depth indicate that diclofop is capable of leaching through soil. The other herbicides were not found in significant quantities below 90 cm.

None of the herbicides studied appear to present a threat to the water supply. Trace amounts of diclofop and 2,4-D were found at depth in the soil but the concentrations at 180 cm were too low to have a significant effect on the quality of water in the environment.

CONCLUSIONS

Some nitrate appeared to be leached from the study site but the concentrations at 180 cm depth did not exceed drinking water quality guidelines. Nonetheless, applications of irrigation water and fertilizer must be prudently managed to ensure that water quality is maintained.

Trace amounts of 2,4-D and diclofop were detected at 180 cm. The quantities of herbicide leached were too small to cause any harm to the environment but should not be disregarded. The differing leaching characteristics of the four herbicides illustrate the importance of understanding how an applied chemical and its degradation products will behave in soil.

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