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MANAGEMENT PERSPECTIVE

This work evaluates the dissipation rates and losses of atrazine and metolachlor under controlled drainage/subirrigation and natural conditions. The evaluations are based on data measured in two field plots and an agricultural watershed with two different soil types, a poorly drained Brookston clay loam with low organic carbon fraction and a well drained Guelph loam with high organic carbon fraction.

The dissipation rates and losses of atrazine and metolachlor are affected by organic carbon fractions of the soil types, but not by the magnitude of the spatial area.

The field data presented in this report are useful for validation of pesticide transport models. The controlled drainage/subirrigation technology is a viable tool for minimizing the migration of agricultural pollutants into groundwater.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Ce travail évalue les taux de dissipation et les pertes d'atrazine et de metolachlore dans des conditions naturelles et dans des conditions réglées de drainage/sous-irrigation. Ces évaluations sont basées sur des données mesurées dans deux parcelles et un bassin versant agricole avec deux types de sol, un loam argileux Brookston mal drainé à faible fraction de carbone organique, et un loam Guelph bien drainé à forte fraction de carbone organique.

Les taux de dissipation et les pertes d'atrazine et de metolachlore sont modifiés par les fractions de carbone organique des types de sol, mais non par l'importance de l'aire spatiale.

Les données obtenues sur le terrain qui sont présentées dans ce rapport sont utiles pour la validation des modèles de transport de pesticides. La technologie de drainage/sous-irrigation réglés est un outil rentable permettant de minimiser la migration de polluants agricoles dans l'eau souterraine.

ABSTRACT

The dissipation and loss of atrazine and metolachlor were evaluated for well drained and poorly drained soils, using field data measured in an agricultural watershed and two field plots. Controlled drainage/subirrigation was applied in one of the field plots. The dissipation and loss of atrazine and metolachlor were affected by the organic carbon fraction of the soil and not affected by the magnitude of the spatial area. The atrazine had the longest $t_{1/2}$ (half-life) in Guelph loam. Both atrazine and metolachlor had faster dissipation rates in the surface runoff and tile drainage from the field plots than in runoff from the agricultural watershed. The applied atrazine loss in combined surface runoff and subsurface drainage was 1.87%, 1.75% and 0.39% respectively, for field plots with and without controlled drainage/subirrigation, and the agricultural watershed. Similarly, the applied metolachlor loss in combined surface runoff and subsurface drainage was 1.19%, 1.16% and 0.13% for field plots with and without controlled drainage/subirrigation and the agricultural watershed, respectively. Controlled drainage/subirrigation increased the herbicide loss in surface runoff but decreased herbicide loss in subsurface drainage.

Key words - atrazine, metolachlor, subirrigation, herbicide dissipation, organic carbon, herbicide loss.

RÉSUMÉ

On a évalué la dissipation et la perte d'atrazine et de metolachlore dans des sols bien drainés et mal drainés, à l'aide de données obtenues sur le terrain dans un bassin versant agricole et deux parcelles. On a appliqué la technique du drainage/sous-irrigation réglés à l'une des parcelles. La dissipation et la perte d'atrazine et de metolachlore subissaient l'influence de la fraction de carbone organique du sol, mais n'étaient pas touchées par l'importance de l'aire spatiale. L'atrazine avait la plus longue $t_{1/2}$ (demi-vie) dans le loam Guelph. Les taux de dissipation de l'atrazine et du metolachlore étaient plus élevés dans les eaux de ruissellement et dans les eaux de drainage des parcelles que dans les eaux de ruissellement du bassin versant agricole. La perte d'atrazine appliquée, dans les eaux de ruissellement superficielles combinées aux eaux de drainage subsuperficielles, était de 1,87, 1,75 et 0,39 % pour les parcelles avec et sans drainage/sous-irrigation réglés et le bassin versant agricole, respectivement. De même, la perte de metolachlore appliquée, dans les eaux de ruissellement superficielles combinées aux eaux de drainage subsuperficielles, était de 1,19, 1,16 et 0,13 % pour les parcelles avec et sans drainage/sous-irrigation réglés et le bassin versant agricole, respectivement. La technique du drainage/sous-irrigation réglés augmentait la perte d'herbicides dans les eaux de ruissellement superficielles mais diminuait cette perte dans les eaux de drainage subsupercielles.

Mots clés - atrazine, metolachlore, sous-irrigation, dissipation des herbicides, carbone organique, perte d'herbicides.

INTRODUCTION

Herbicides are an integral component of agricultural production. Rain is necessary to sustain crop growth but excessive rain contributes to overland flow and tile discharge to receiving water. Herbicides are most susceptible to overland and subsurface transport in runoff events soon after their application (Gaynor et al., 1992). Research has focussed on small plot and simulation studies to characterize factors related to transport. Tillage, herbicide formulation, the rate of herbicide applied, soil type and incidence of rain after herbicide application are major factors related to herbicide loss (Glenn and Angle, 1987; Frank and Logan, 1988; Barnes et al., 1992). Quantitative determination of disappearance rates is useful in predicting the geographical extent of impact zones (Carey, 1993).

Watershed monitoring has been useful in identifying the magnitude of herbicide concentration and load from agricultural practices. Herbicide concentrations in streams and rivers draining agricultural watershed are generally an order of magnitude or more smaller than those measured in runoff from simulation or small plot studies (Wauchope, 1978; Wauchope and Leonard, 1980). This probably relates to dilution by water draining noncropped areas. Herbicide loss may also be less in the watershed studies than in simulation or field plot studies because of factors related to transport mechanisms from the farm gate to the stream or river. Physical and chemical processes involved in the movement of pesticide have been described elsewhere (Bailey et al., 1974, Wauchope, 1978; Woolhiser et al., 1988).

Parameters require to model herbicide loss have been derived primarily from field plots or simulation studies and the results extrapolated to the watershed scale. We have compared herbicides loss from an agricultural watershed with that from field plots to aid understanding of scaling factors useful in extrapolating field plot data to a watershed scale.

METHODS AND PROCEDURE

Agricultural watershed

In spring 1990, a small agricultural watershed in the Nissouri Creek watershed, located in Oxford County in Southwestern Ontario (Figure 1) was instrumented to collect runoff samples for herbicide loss and nutrients transport studies (Ng et al., 1993). The watershed is about 35 km^2 in area, measured upstream from the hydrometric gauging point. Conventional cultivation procedures are employed. The major farm crop is corn (>50%), with the remaining area (30%) planted with hay, soybeans, cereals, cash crops and fruits. Lesser land use includes forest, feedlots, country roads and residences. Almost all the cultivated acreage of the area is subsurface tile drained (Ontario Ministry of Environment, 1989). The modification of natural drain patterns may have some effects on the hydrologic regime of the watershed by reducing surface runoff and peak flow, and extending duration of the runoff hydrograph.

The soil types classified as Guelph loam (45%), Embro silt loam (36%), and Honeywood-Guelph complex (12%). Both Guelph loam and Embro silt loam are well drained soils. They represent more than 81% of the area of the watershed. The overland slopes of the area, ranging from 0.5 to 5%, represent more than 85% of the watershed. The remaining 10% and 4% of the land areas, respectively, have slopes greater than 5% and smaller than 0.5%.

Runoff samples were collected sequentially by a Sigma sampler Model 702 and composited (1 litre) during runoff events. The runoff samples were extracted for alachlor atrazine, de-ethylatrazine (metabolite), metolachlor, cyanazine at the Pesticide and Trace Contaminants Laboratory, Ontario Ministry of Agriculture and Food, in Guelph, Ontario.

Herbicides are usually applied at the beginning of the planting season. The dates and herbicide amounts applied were based on the questionnaire survey of farm operators. Fifty five questionnaires were dispatched to the 55 active farm operators in the study area with a 65% return. An aerial map flown in April, 1989 with scale 1:5000 supplied by the Upper Thames Conservation Authority, combined with field reconnassiance, was used to identify locations of forest, cultivated areas, ponds and feedlots.

Results of the questionnaire indicated that the area weighted average rate of 2.11 kg/ha of atrazine and 2.48 kg/ha of metolachlor were applied. The rate of metolachlor application is within the recommended ranges of 1.92 to 2.64 kg/ha for preemergent treatment (Ontario Ministry of Agriculture and Food, 1994), whereas the rate of atrazine application is higher than the recommended values of 1.01 to 1.49 kg/ha (Ontario Ministry of Agriculture and Food, 1994) and a surveyed value of 1.84 kg/ha in Nissouri Creek by the Ontario Ministry of Environment (1989). The higher dosage of atrazine used in current year is believed to be due to the resistency of the weed. The areas grown for corn and other crops in 1990 determined by questionnaire survey were 1470 ha and 850 ha respectively.

Field Plot

In the spring of 1991 sixteen plots, each 15 m wide by 70 m long, with an area of 0.1068 ha (including berm), were established. The field plots are located at Eugene F. Whelan Experimental Farm of Agriculture Canada, near Woodslee, Ontario, on a poorly drained Brookston clay loam.

The layout of field plots has been described by Tan et al. (1993). Each plot contains two 104 mm diameter tile drains, arranged in parallel, 60 cm deep at 7.5 m spacing (Figure 2). The slope of the subsurface drain is 0.08% and the plot surface is flat. The arrangements of experiment on plots comprised tillage type, controlled drainage/subirrigation and crop type, in two replications for a total of sixteen plots (Tan, et al., 1993).

Two of the prescribed experiments on plots were selected for this study. These experiments on field plots were designated as Design #1 (no controlled drainage/ subirrigation) and #2 (controlled drainage/subirrigation). The plots were moldboard ploughed and planted with corn in 76 cm wide rows on May 14, 1992. Atrazine was applied to these treatments at a rate of 1.10 kg/ha and metolachlor at a rate of 1.68 kg/ha, after planting. The herbicide was applied in a 38 cm band over the seeded row. Thus, 550 g/ha of atrazine and 840 g/ha of metolachlor were actually applied to the plot area compared to a broadcast application.

Soil and water sampling and water management procedures have been described elsewhere (Soultani et al., 1993, Tan et al., 1993). Herbicide concentrations in water and soil samples were determined by a gas chromatograph (Gaynor et al., 1992). Designs #1 and #2 are similar in all respects except Design #2 includes a controlled drainage/subirrigation control structure. This structure is used to control drainage or facilitate subirrigation during the growing season. Water for subirrigation is pumped from a storage pond, and conveyed to the control structure via an underground 50 mm diameter polyethylene pipe. The control structure records the volume of the subirrigation water delivered. Subirrigation was initiated for only one day on June 17 because there was sufficient moisture supply during the field season. A total of 46 m^3 irrigation water was delivered to eight plots equipped with subirrigation devices. If the delivered irrigation water is assumed to be evenly distributed, each of the eight plots would receive a total of 5.8 mm in addition to the subsequent rainfall.

RESULTS AND DISCUSSION

Rainfall and runoff

Table 1 presents the sampling date, cumulative rainfall, cumulative runoff and atrazine and metolachlor concentrations associated with the days after application at which runoff events occurred for the Nissouri Creek and the field plots. The antecedent days between sample collection periods are also shown. Rain patterns were similar between the Nissouri Creek and field plots. Total cumulative rain for the seven month period was similar at the two sites thus allowing comparison of the data even though different years were considered.

The ratio of cumulative runoff to cumulative rainfall for Nissouri Creek, Design #1 and Design #2, were 0.20, 0.31 and 0.29, respectively. The larger ratio for Design #1 and Design #2 on Brookston clay loam probably reflects water flow to tile drains through soil cracks and shallow water table (average 0.65 m from surface) compared to Nissouri Creek watershed of 1.10 m. The Brookston clay loam is classed as a poorly drained soil but extensive cracking occurs during the summer months (Evans and Cameron, 1983). Cumulative runoff was similar between Design #1 (199.6 mm) and Design #2 (191.7 mm) indicating controlled drainage/subirrigation had no effect on combined surface and subsurface runoff.

Controlled drainage/subirrigation altered the proportion of runoff to the surface and tile. In Design #1, 12% of the rain was lost as surface runoff whereas for Design #2, 23% of the rain was lost through this source. The proportion of rain lost as surface runoff or tile discharge could not be calculated for Nissouri Creek because stream flow includes runoff from all sources within the watershed. The increased surface runoff from controlled drainage/subirrigation (Design #2) could be detrimental to water quality since atrazine and metolachlor are considered moderately to highly water soluble herbicides and herbicide concentration is highest on the soil surface. On the other hand, the increased proportion of water discharged through the tile in Design #1 could increase the probability of groundwater contamination although much of the herbicide in the aqueous phase could be discharged through the tile and not reach the groundwater. No data is available on vertical movement of herbicides past tile drains.

Dissipation rates of atrazine and metolachlor in water and in soil

Peak herbicide concentrations (Table 1) in the Nissouri Creek watershed are lower than those in runoff from the field plots probably because of the dilution effect of runoff from areas within the watershed which received no herbicide and also the time of herbicide application to each farm area was not carried out concurrently. Data for the field plots represent edge of field concentrations where all runoff originates from the herbicide treated field. Similar observations have been made by others (Baker, 1985).

Herbicide concentrations in the Nissouri Creek watershed were highest in runoff between 26 and 79 days after first collection period (Table 1). In the field plots, a total of 72.0 mm of rain was received in the first two runoff events following herbicide application but herbicide concentration of the resulting runoff of less than 10 mm was lower than that in runoff 25 to 39 days after application. No surface runoff occurred from the field plots before 39 days after application which could account for the low concentrations observed. Herbicide concentration of the tile discharge was less than 16 μg/L compared to higher flow weighted herbicide concentration in subsequent combined surface runoff and tile drainage events.

The volumes of the first two rain events in the Nissouri Creek were low (13.7 and 31.8 mm) and resulted in little runoff (1.8 and 0.8 mm, Table 1). Consequently, atrazine and metolachlor concentrations were low compared to the next rain of 63.7 mm which produced 11.1 mm of runoff. The lower concentrations of herbicide in runoff in the first two events in the Nissouri Creek could also relate to differences in time of herbicide application on the various farm operations. The low concentration of herbicide in these initial events relates to vertical movement of the herbicide into the soil and binding to soil particles because of the lower antecedent soil moisture content. Herbicide binding to soil increases as soil moisture content decreases (Hance, 1965). Generally, herbicide concentration in runoff decreases with time after application (Pantone et al., 1992). The concentration of herbicide in the runoff is dependent upon antecedent soil moisture condition, rainfall volume, and time of occurrence of runoff event after herbicide application (Triplett et al., 1978).

Herbicide concentration in runoff and in soils dissipates with time following a first order rate function (Triplett et al., 1978; Pantone et al., 1992; Walker, 1987). The log transformation of the first-order dissipation rate is given below.

$$\ln C = \ln a + bt \text{.......................} (1)$$

where C is the herbicide concentration, in μg/L for water and in μg/kg for soil, intercept a is in μg/L for water and in μg/kg for soil, ln is the natural logarithm, b is the slope and t is time in days.

In Table 1, concentrations of the two herbicides in runoff of Nissouri Creek and of the field plots show a steady disappearance rate with time after they attained the probable maximum concentration. The herbicide concentrations at the beginning of the sampling period were lower than those later on. In order to calculate and optimize the probable maximum 'a' and the slope of 'b' in equation (1), the herbicide concentrations sampled on 04/21/90 and 05/05/90 for Nissouri Creek watershed and the herbicide concentrations sampled on 05/14/92, 05/26/92 including atrazine of replication plot 1 sampled on 06/08/92 for field plots were excluded from the regressional analysis. The first-order dissipation equations fit the data well and allow calculation of the half-life values. The results of regressional analysis and half-life values are presented in Table 2.

The dissipation rates of atrazine and metolachlor in soils from field plots, and the dissipation rate of atrazine from the Nissouri Creek watershed reported by the Ontario Ministry of the Environment (1989) are included in Table 2 for comparison.

The dissipation rate, as quantified by the slope coefficient, for atrazine and metolachlor concentrations in runoff water, was faster for the field plots than for the

Nissouri Creek (Table 2). The ratio of 'b' between Design #1 and Design #2 (Table 2) is 0.96. Dissipation rate of Design #2 (controlled drainage/subirrigation) had about 4% higher than Design #1 (no controlled drainage/subirrigation). This suggests the effect of 5.8 mm of subirrigation water administered on June 17. The ratio of the dissipation rate between the field plots and the Nissouri Creek was 1.6 for atrazine and 2.7 for metolachlor. The greater dissipation rate for the field plots could be attributed to response factors related to the edge of field effects, whereas a longer response factor or lag time would be expected for the herbicide to travel from the site of application to the Nissouri Creek. The variation in application time among different farms may also have contributed to the longer response time or dissipation rate of these herbicides in the Nissouri Creek relative to the field plots.

Organic carbon content of the soils may also affect the rate of dissipation of these herbicides in runoff. The average organic carbon content of soils in the Nissouri Creek watershed is 2.66% and for the field plots 1.27%. The ratio of organic carbon between Nissouri Creek watershed and the field plots is 2.1. Thus, herbicide would be less available for transport or have longer persistence in soils from the Nissouri Creek watershed than from the field plots.

Slope and intercept values relating herbicide residues to time after application were calculated from the first order rate equation for soils from the field plots and the Nissouri Creek watershed (Table 2). Atrazine was monitored in the Embro and Guelph soils from the Nissouri Creek watershed and atrazine and metolachlor from the Brookston soil in the field plots. The Guelph loam and Embro silt loam accounted for 81% of the predominant soil types in the Nissouri Creek watershed.

Controlled drainage/subirrigation had no effect on atrazine or metolachlor dissipation in the Brookston soil from the field plots ($P>0.05$). Soil moisture related to herbicide dissipation did not differ between drainage and controlled drainage/subirrigation. Initial residues, as indicated by the intercept values of the regression equations, were lower for the Brookston soil than for Guelph and Embro soils because herbicide was applied to the field plots in a band as opposed to broadcast application to the Nissouri Creek watershed soils. Slope coefficients did not differ between Brookston and Embro soils but were smaller for Guelph soil indicating greater persistence in this soil type. Longer soil persistence would increase the lag time for herbicide to be found in streams draining the watershed.

Loss of atrazine and metolachlor in runoff

The first-order equation was fitted to the data for Nissouri Creek, and Design #1 and Design #2. Dissipation rates for the individual herbicides were calculated for each soil and expressed as the coefficient of regression 'b'. From the coefficient of regression (Table 2), atrazine and metolachlor are retained for a longer time in Nissouri Creek and less loss occurred after herbicides application. This may be related to the high organic carbon fraction (2.66%) in Nissouri Creek of the well drained Guelph loam series. The organic carbon fractions in Design #1 and Design #2 average 1.27% with no difference between plots. The soil organic carbon fraction is considered to be the best single predictor for sorption (Rao and Jessup, 1983). Our soil organic carbon fractions were determined at sampling depths (0-15 cm) for both Nissouri Creek watershed and the field plots in 1992 and in 1993, respectively. We assume that the organic carbon fractions determined for both sites are representative for the Nissouri Creek's 1990 field year as well as the 1992 field year for Designs #1 and #2, because the cultivation practices have remained unchanged. Jones (1986) reported that in some high organic matter soils the movement of herbicide residues such as aldicarb may be as much as ten folds slower than the rate of water movement.

The dissipation rate is related to the residue amount being transported by the aqueous phase through the soil surface or soil column. Assuming that the herbicide application was reasonably accurate, we can make an estimate of herbicide residues as a percentage of that applied. Controlled drainage/subirrigation had no effect on the quantity of herbicides lost in surface runoff or tile drainage. Atrazine loss from the field plot averaged 1.81% of that applied compared to 0.33% from the Nissouri Creek watershed. Metolachlor losses amounted to 1.18% of the quantity applied in the field plot and 0.15% of that in the Nissouri Creek watershed. The losses of metolachlor from the Nissouri Creek watershed and field plots (Figure 3) are lower than the losses of atrazine. This confirms the low dissipation rate of atrazine.

Scale Effects

Evaluation of the scale effects on the loss of herbicide between the watershed and the field plot can be difficult, because of the significant spatial and temporal variations in the parameter field of the two study areas. In this study, evaluation of the scale effects was examined by comparison between the herbicide input and output. The herbicide input is the application rate (kg/ha) to the cropping area and the output is the measured unit load (mg/ha) at the outlet of the watershed and the outlet of the field plot. The ratios of herbicide input between the Nissouri Creek and the field plot are respectively, 3.84 and 2.95 for atrazine and metolachlor. Note that the values of field plot are averaged of Designs #1 and #2. Similarly, the ratios of the output between the Nissouri Creek and the field plot are 1.72 and 1.11 for atrazine and metolachlor respectively. The final ratios between the input and output of the watershed and of the field plot are 2.23 (3.84/1.72) and 2.66 (2.95/1.11) for atrazine and metolachlor respectively. The final ratios suggest that both atrazine (2.23) and metolachlor (2.66) appear independent of spatial variability since the values are almost the same. But they are highly dependent on the soil type.

SUMMARY

The findings of this study suggest that soil types and their organic carbon fractions are the main factors limiting field dissipation and loss of atrazine and metolachlor after application. Controlled drainage/subirrigation had no effect on atrazine

and metolachlor losses but changed the course of loss. Herbicide losses were higher in surface runoff from controlled drainage/subirrigation than from noncontrolled treatment. The quantity of herbicide lost from the field plots was higher than in the Nissouri Creek watershed because of the lower organic matter content of soil in the field plots. However, the loss appeared independent of scale effects. Herbicide concentration in the runoff and losses were highest in runoff events occurring shortly after herbicide application. The dissipation rates of atrazine and metolachlor, found in this study for the aqueous phase, were from 2 to 4 times greater than the dissipation rates in soil. These depended on the soil type and the organic carbon fraction.

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Table 1. Cumulative Rainfall, Runoff and Concentration of Atrazine and Metolachlor in Runoff

Nissouri Creek Watershed						
Sampling Date	Cumul. Rainfall (mm)	Cumul Runoff (mm)	D.A. 1st. Coll.Pd. (day)	Anteced. Period (days)	Application rate 2.11 kg/ha Atrazine con. (ug/L)	Application rate 2.48 kg/ha Metolachlor con. (ug/L)
04/21/90	13.7	1.8	0	2	1.03	ND
05/05/90	45.5	2.6	14	12	0.06	ND
05/17/90	109.2	13.7	26	2	12.20	6.77
07/09/90	323.7	54.3	79	8	14.17	5.02
08/12/90	440.0	58.1	114	4	2.13	3.32
08/19/90	464.6	67.7	121	4	1.85	1.41
09/06/90	487.7	70.0	139	5	1.20	1.45
09/14/90	541.7	79.7	147	6	1.12	1.80
10/09/90	565.1	101.7	172	2	1.35	ND
11/11/90	636.2	128.8	205	7	1.20	ND

Field Plots								
Sampling Date	Cumul. Rainfall (mm)	Cumul. runoff Ds. #1/Ds. #2 (mm)	D.A. 1st. Coll.Pd. (day)	Anteced. Period (days)	Application rate @ 550g/ha Atrazine con. (ug/L) Rep1, D/W	Application rate @ 550g/ha Atrazine con. (ug/L) Rep2, D/W	Application rate @ 840g/ha Metolachlor con. (ug/L) Rep1, D/W	Application rate @ 840g/ha Metolachlor con. (ug/L) Rep2, D/W
05/14/92	14.0	6.4/3.8	0	14	0.30/0.49	0.24/0.65	0.40/0.47	0.25/0.76
05/26/90	47.5	9.3/4.2	12	10	2.98/1.73	0.85/0.93	1.79/2.77	6.48/0.99
06/08/92	72.0	9.4/4.3	25	8	14.78/16.00	82.97/---	43.14/45.46	125.07/---
06/22/92	111.5	18.7/9.9	39	11	41.76/37.81	40.70/23.61	66.84/53.44	45.18/34.84
07/15/92	207.0	33.0/28.7	62	14	17.01/25.65	17.40/23.61	14.67/24.90	16.74/23.88
07/21/92	227.5	50.0/38.1	68	1	3.73/12.96	5.38/20.04	3.04/12.03	4.79/17.87
08/10/92	301.0	62.1/48.4	88	13	2.97/4.73	4.60/2.86	2.71/5.11	4.97/2.87
08/26/92	337.0	67.7/53.9	104	11	1.01/1.67	1.98/2.02	0.51/0.84	1.35/0.91
09/23/92	502.0	124.6/112.1	132	13	0.88/0.90	1.84/1.29	0.34/0.50	0.71/0.43
10/26/92	555.5	128.2/118.2	165	23	0.41/0.91	0.81/0.87	0.21/0.41	0.27/0.26
11/05/92	600.0	155.1/145.9	175	7	0.50/0.60	0.92/0.62	0.34/0.29	0.24/0.23
11/17/92	653.0	199.6/191.7	187	7	0.88/0.83	1.38/1.03	0.38/0.31	0.38/0.30

Cumul. = Cumulativ D.A. = Day after Coll.Pd. = Collection Period Anteced. = antecedent
Rep1. = Replication plot 1 D = Surface and tile combined (without controlled drainage/subirrigation)
Rep2. = Replication plot 2 W = Surface and tile combined (with controlled drainage/subirrigaion)
con. = concentration ND = Under detection limit --- = No runoff Ds. = Design

Table 2. Statistical Analysis of Herbicide Concentration in Soil and Water

ID	Source (Water)	Herbicide	Coef. a	Slope b	Corel.Coef. r	Std. Error LN(Coef a)	Std. Error Slope b	half-life (days)
Nissouri Creek	Surface & Drain	Atrazine	19.32	-0.0164	0.857	0.5848	0.0040	42
Design #1	"	"	50.88	-0.0255	0.802	0.3520	0.0030	27
Design #2 *	"	"	67.55	-0.0267	0.859	0.3356	0.0027	26
Nissouri Creek	"	Metolachlor	11.00	-0.0134	0.895	0.3338	0.0033	52
Design #1	"	"	99.39	-0.0353	0.870	0.3793	0.0032	20
Design #2 *	"	"	124.76	-0.0363	0.894	0.3872	0.0031	19
	(Soil)							
Nissouri Creek **	E.S.Loam:0-2 cm	Atrazine	10169.00	-0.0150	0.928	0.3656	0.0014	46
"	G. Loam:0-5 cm	"	1386.00	-0.0073	0.919	0.2127	0.0008	95
Design #1	B.S.Clay:0-10 cm	"	388.69	-0.0168	0.972	0.2719	0.0018	41
Design #2 *	B.S.Clay:0-10 cm	"	347.76	-0.0147	0.920	0.4161	0.0028	47
Nissouri Creek **	E.S.Loam:0-2 cm	Metolachlor	-	-	-	-	-	-
"	G. Loam:0-5 cm	"	-	-	-	-	-	-
Design #1	B.S.Clay:0-10 cm	"	692.73	-0.0184	0.981	0.2420	0.0016	38
Design #2 *	B.S.Clay:0-10 cm	"	655.46	-0.0168	0.987	0.1802	0.0012	41

* Subirrigation Control

** Data collectd by Ministry of Environment, Ontario 1989

E.S. = Embro Silt

Coef = Coefficient

G. = Guelph

Std. = Standard

B.S. = Brookston

LN = Natural logarithms

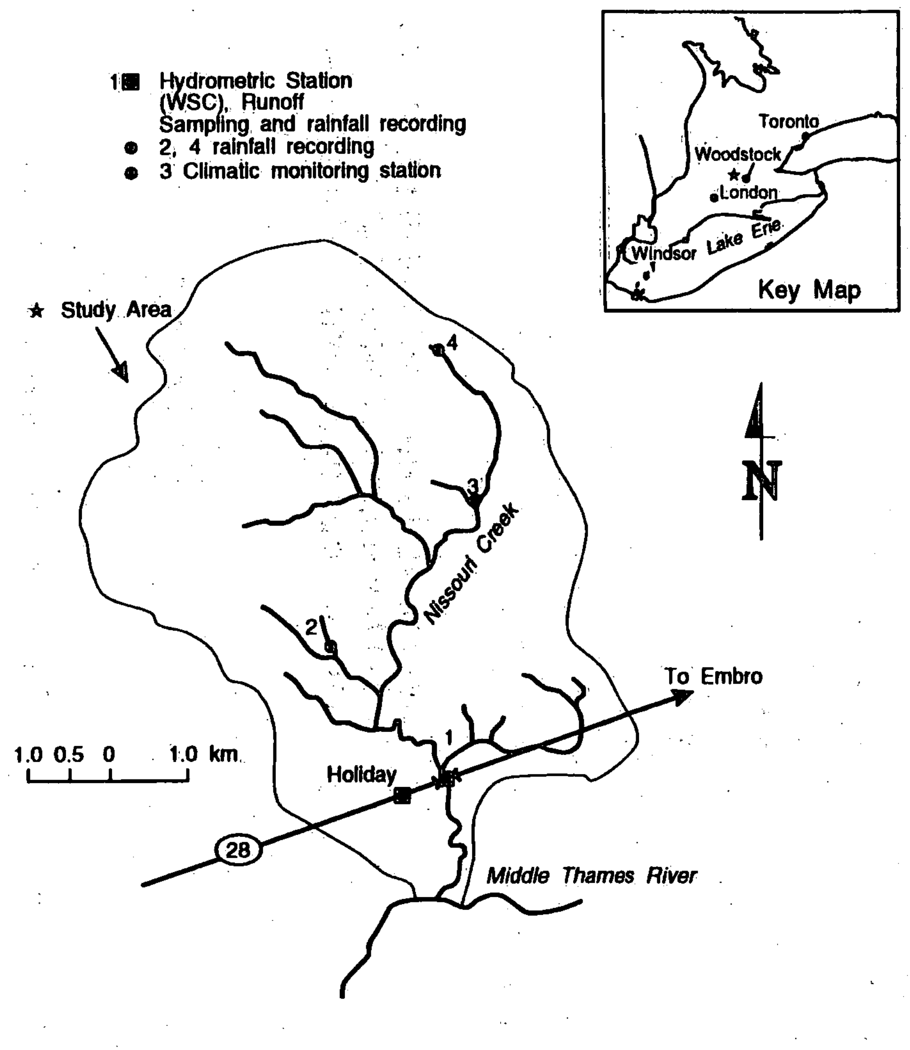

Figure 1. Nissouri Creek Watershed

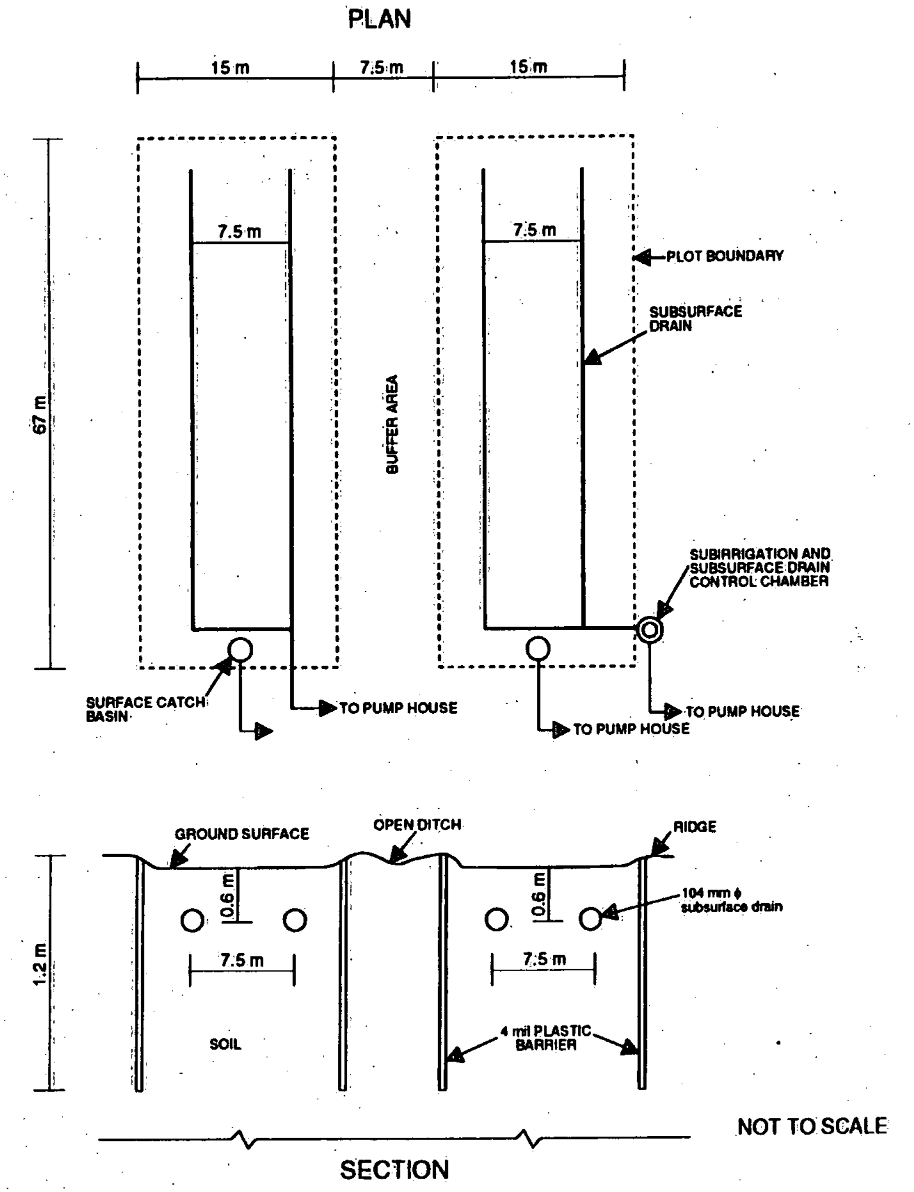

Figure 2. EXPERIMENTAL PLOT AND SUBSURFACE DRAIN DIMENSIONS

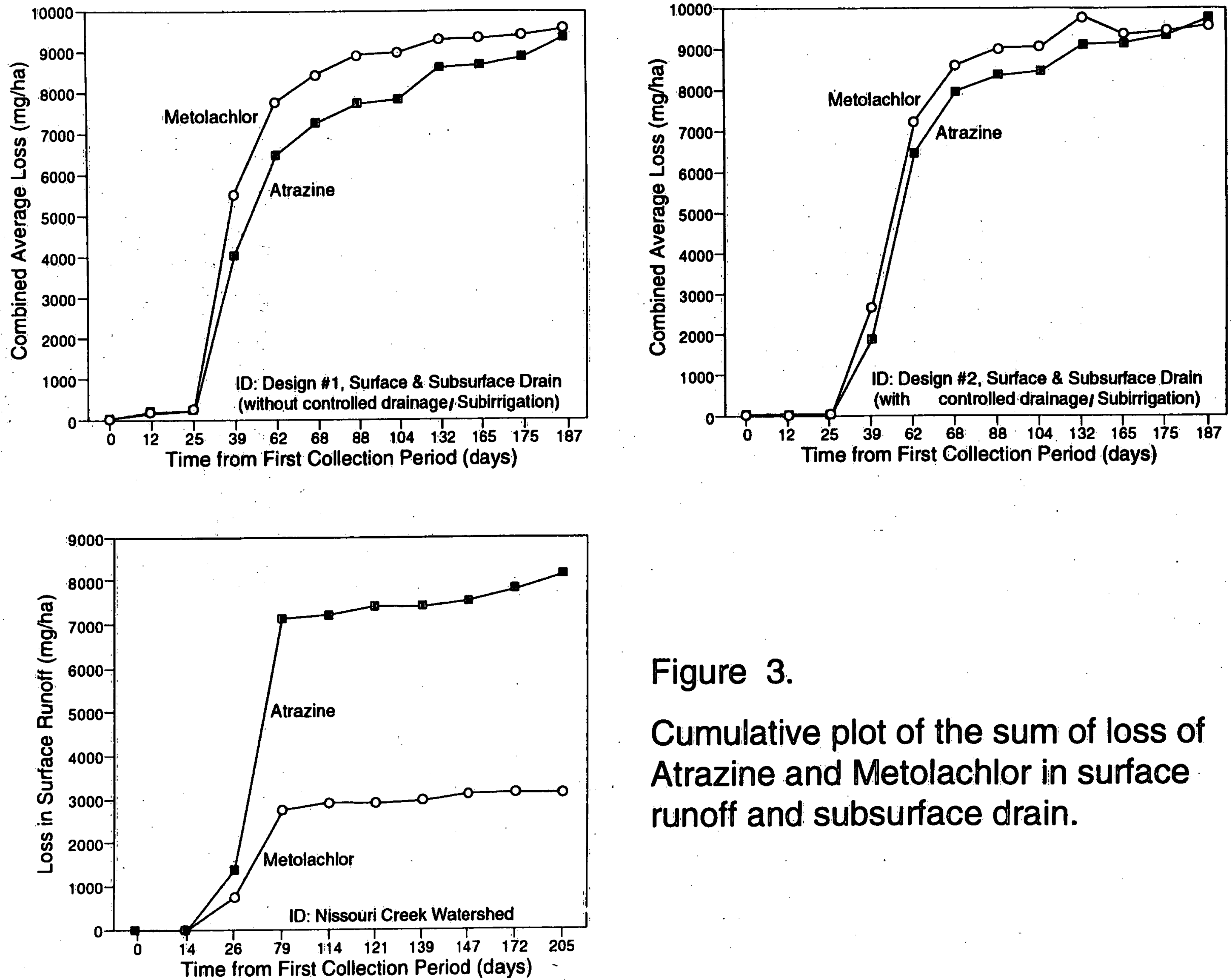

Figure 3.

Cumulative plot of the sum of loss of Atrazine and Metolachlor in surface runoff and subsurface drain.

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