HERBICIDE USE AND THE QUALITY OF SURFACE RUN-OFF WATERS*

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Movement of agricultural chemicals in surface run-off waters has received increasing attention because of their potential effects on downstream areas, especially the quality of receiving waters. Surface run-off can occur under a variety of situations, however, only those typical of southern Saskatchewan conditions will be highlighted in this presentation.

Losses of Herbicides in Spring Snow-melt

It is well established that 90% or more of surface run-off in southern Saskatchewan can be attributed to spring snow-melt (Nicholaichuk 1967). Only those herbicides which are carried over the winter would be subject to losses in this manner. Most of the herbicides used in southern Saskatchewan are applied in spring or early summer, as pre- and post-emergence treatments. Under normal soil moisture conditions, little or no carry-over of these herbicides to the following spring can be expected (Smith 1982), and are thus not subject to significant losses in surface run-off.

However, herbicides are now being applied in the fall, e.g. 2,4-D for stinkweed and flixweed control and either triallate or trifluralin to control wild oats in the following growing season. A portion of these herbicides is expected to be lost in the run-off from spring snow-melt. A six-year study, to determine losses of fall-applied 2,4-D in spring snow-melt, has just been completed (Nicholaichuk and Grover 1983).

Table 1. Loss of fall-applied 2,4-D in run-off from snow-melt.

Year	Run-off volume		Concentration		Amount lost		% of Applied	
	range	mean	range	mean	range	mean	range	mean
	(mm)		(µg/L)		(g/ha)		(%)	
1976-81	0-101	48	13-45	31	0-40	17	0-10	4

The magnitude of 2,4-D losses in the spring run-off varied from 0% in 1977, when there was no run-off, to as high as 10% in 1976, with an average loss being 4% of the amount applied over six years (Table 1). The amount of loss was related directly to the volume of run-off in any given year ($r^2 = 0.96$). Concentrations of 2,4-D in the run-off water varied from <0.1 to 45 µg/L. However, the concentration of 2,4-D in the Swift Current creek, the recipient of the run-off waters, was always below the detection limit (0.1 µg/L). It may be pointed out that the maximum permissible level of 2,4-D in water is 100 µg/L (U.S., EPA, (1976).

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Losses of Herbicides from Irrigation Supply Canals Treated with Soil Sterilants

Herbicides, usually at soil sterilant rates, are used to control weeds in intermittently-filled irrigation supply canals in southern Saskatchewan. Although both soil sterilants and non-residual contact herbicides have shown varying degrees of effectiveness in controlling weeds in irrigation supply canals, such control has been gained only with concomitant herbicide contamination of irrigation water (Korven 1975; Smith et al. 1975; Grover et al. 1980). These studies have shown that the greatest herbicide contamination potential occurs from the initial flush of irrigation water passing through the supply canal.

Table 2. Concentration of herbicides in the initial flush and in subsequent irrigations.

Herbicide	Concentration of herbicide in Initial flush	1st irrig.	2nd irrig.	3rd irrig.	10th irrig.
	(µg/L)				
bromacil	31	9	1	< 1	< 1
monuron	66	26	4	< 1	< 1
atrazine	240	45	25	< 1	< 1
simazine	690	150	120	70	< 1

It has been suggested that this initial flush be diverted to a waste drainage system, prior to beginning irrigation (Smith et al. 1975). This pracice, although reducing the hazard of herbicide damage to the irrigated crop, would transfer any herbicide residues removed in the initial flush of the supply canal to the receiving waters, usually a river downstream of the drain or waste canal.

A study was carried out to assess the potential environmental impact of diverting the initial flush from the main supply canal in the Val Marie irrigation district into the Frenchman river. The main supply canal had been treated previously with 35.8 kg/ha diuron. The amount of diuron removed in the initial flush was about 0.5% of the amount applied (Grover et al. 1982). The maximum concentration of diuron in the initial flush and the total amount of diuron removed per ha of treated canal are listed in Table 3.

Table 3. Concentration of diuron and the total amount and percent removed in the initial flush.

Herbicide	Rate	Max. conc. (in the initial flush)	Amt. removed (in the initial flush)	% of applied (in the initial flush)
	(kg/ha)	(µg/L)	(g/ha)	(%)
diuron	35.8	200	180	0.5

The maximum concentration of diuron in the Frenchman river was 27.5 μg/L and occurred at the point of entry. However, 100 m downstream, the concentrations of diuron had decreased to less than 2 μg/L indicating a rapid dilution of the amount received.

Losses of Herbicides During 'Herbigation'

Attempts have recently been made to apply herbicides in flood-irrigation water. This method called 'herbigation' is the preferred application method in certain parts of the world, e.g. Imperial Valley in southern California. It has recently been shown that total losses of EPTC, both during and immediately after application in irrigation water, were much greater by volatilization to the atmosphere than those incurred in the tail water, being 73.6% and 7.0%, respectively (Table 4)(Cliath et al. 1980).

Table 4. Amounts of EPTC volatilized from water and wet soil during and after a flood irrigation application to alfalfa, and amounts of EPTC found in tail waters.

Herbicide	Rate	Losses from volatilization		Losses in tail water	
	(kg/ha)	(kg/ha)	(%)	(kg/ha)	(%)
EPTC	3.0	2.24	73.6	0.21	7.0

These data indicate that herbigation is an inefficient method to apply herbicides such as EPTC which have high vapor pressures. These herbicides are more likely to be lost as vapor to the atmosphere from wet soils, e.g. after and during an irrigation or an rainfall event, in amounts greater than those found in tail waters.

Losses of herbicides in irrigation return flow waters

Return flow waters from gravity or flood irrigations are generally released into either a lake or river. Since the return flow waters may originate from fields that have been treated with herbicides, there is the possibility that they may contain herbicides in amounts that would be detrimental to the water quality of the receiving water bodies.

A preliminary study (Cessna and Grover 1982), designed to monitor herbicide residues in return flow waters in order to assess both the amounts of herbicides entering the South Saskatchewan River from the Outlook Irrigation District and the fesibility of reusing the return flow waters for further irrigation, was carried out in 1981. The concentrations of seven herbicides (triallate, trifluralin, atrazine, 2,4-D, dicamba, bromoxynil and diclofop methyl) were monitored weekly (May 28 to August 3, 1981) in two of the main drainage ditches in the Outlook Irrigation District. In the following year, the study was repeated with a more frequent sampling of just one of the drainage ditches. (Cessna and Grover 1983).

Table 5. Ranges of herbicide residues found over two irrigation seasons in the return flow waters of the 1C drainage ditch in the Outlook Irrigation District

Year	2,4-D	dicamba	bromoxynil	diclofop methyl
		(μg/L)		
1981	0.1 - 9.4	0.1 - 0.3	0.1 - 0.9	0.1 - 6.0
1982	0.1 - 14.7	0.1 - 0.4	0.1 - 0.2	0.1 - 7.1

In both years, analysis of the supply water from Lake Diefenbaker indicated the possible presence of only one of the seven herbicides monitored, that being 2,4-D in amounts varying from <0.1 to 0.4 μg/L. None of the soil-applied herbicides (trifluralin, triallate, and atrazine) were detected in the return flow waters, i.e. any residues present were less than 0.1 μg/L, the limit of detection of the analytical method. All four postemergence applied herbicides were detected in the return flow waters (Table 5) with 2,4-D and diclofop methyl appearing in the greatest amounts. However, reentry of the return flow waters into the South Saskatchewan River would, with the possible exception of 2,4-D, dilute these residues below the limit of detection.

Conclusions

- Spring snow-melt is the major run-off event in southern Saskatchewan.
- Most of the herbicides used in the prairies are applied in the May-June period and are not expected to be carried over to the following spring and, thus, should not be subject to any significant losses in the spring snow-melt.
- Fall-applied herbicides are subject to losses (0 to 10%) in spring snow-melt, the relative magnitude being dependent on the volume of run-off in a given year.
- Herbigation is an inefficient method to apply volatile herbicides.
- Return flow waters from an irrigation drainage basin did not contain soil-applied herbicides, whereas the levels of post-emergence herbicides, such as 2,4-D, reached a maximum of only 15 μg/L.
- It can be expected that under all these situations, the final concentrations of herbicides in the receiving bodies of water, such as lakes or rivers, will be near or below the detection limits (0.1 μg/L), because of rapid dilution.

Literature Cited

1. Cessna, A.J. and R. Grover. 1982. Preliminary studies on herbicide contamination of irrigation return flow waters at Outlook, Saskatchewan. Water Studies Inst., Symp. No. 8 on 'Wastes and Prairie Water Quality', pp.7.

2. Cessna, A.J. and R. Grover. 1983. Magnitude and significance of herbicide levels in irrigation return flow waters at Outlook, Saskatchewan. Can. J. Plant Sci. (in preparation).

3. Cliath, M.M., W.F. Spencer, W.J. Farmer, T.D. Shoup and R. Grover. 1980. Volatilization of S-ethyl N,N-dipropylthiocarbamate from water and wet soil during and after flood irrigation of an alfalfa field. J. Agric. Food Chem. 28: 610-613.

4. Grover, R., L.A. Kerr, And A.J. Cessna. 1982. Residues of diuron in irrigation water following fall treatment of the supply canal at soil sterilant rates. Water Studies Inst., Symp. No. 8 on 'Wastes and Prairie Water Quality', pp. 7.

5. Grover, R., A.E. Smith, and H.C. Korven. 1980. A comparison of chemical and cultural control of weeds in irrigation ditchbanks. Can. J. Plant Sci. 60: 185-195.

6. Korven, H.C. 1975. Irrigation ditch maintenance with chemicals and grasses. Can. Agric. Eng. 17: 39-43.

7. Nicholaichuk, W. 1967. Comparative watershed studies in southern Saskatchewan. Trans. ASAE 1(4): 502-504.

8. Nicholaichuk, W. and R. Grover. 1983. Loss of fall-applied 2,4-D in spring run-off from a small agricultural watershed. J. Environ. Qual. (in press).

9. Smith, A.E. 1982. Herbicides and the soil environment in Canada. Can. J. Soil Sci. 62: 433-460.

10. Smith, A.E., R. Grover, G.S. Emmond and H.C. Korven. 1975. Persistence and movement of atrazine, bromacil, monuron and simazine in intermittently-filled irrigation ditches. Can. J. Plant Sci. 55: 809-816.

11. United states Environmental Protection Agency. 1976. Quality criteria for water. EPA-440/9-76-023.