

nitrite in the studies reported here was apparently small. If a large percentage of the nitrate supplement would have been reduced to nitrite, a greater increase in the concentration of DA-sulmet in the blood would be expected. For example, in previous studies approximately 71% of the ^{14}C activity in the blood was present as [^{14}C]-DA-sulmet 24 h after swine were fed 1.5 kg of feed containing 110 ppm of [^{14}C]sulmet and 1000 ppm of nitrite (Paulson and Feil, 1987). Six hours after rats were fed a meal containing 100 ppm [^{14}C]sulmet and 0, 10, 100, or 1000 ppm of nitrite, the percentages of ^{14}C activity in the blood that was present as [^{14}C]-DA-sulmet were 0.6, 1.2, 5.1, and 32.6, respectively (Paulson, 1986).

The studies reported here also demonstrated that the concentrations of sulmet and N^4 -Ac-sulmet in the blood were not altered by even the highest level of nitrate supplementation. This supports the conclusion that only a small proportion of the nitrate supplement was reduced to nitrite. When swine were given a 1.5-kg meal containing 110 ppm of [^{14}C]sulmet and 1000 ppm nitrite, the concentrations of both sulmet and N^4 -Ac-sulmet in blood were dramatically lowered (Paulson and Feil, 1987).

These observations are important as they relate to the effectiveness of sulmet used as an antibiotic in animal production. The highest level of nitrate supplementation (1000 ppm) tested in these studies is in excess of the levels of nitrate normally present in commercial swine diets (Wright and Davison, 1964). Thus, it is unlikely that the nitrate usually present in swine diets significantly alters the effectiveness of sulmet when used as an antibiotic and growth-promoting agent in commercial swine production.

Registry No. NO_3^- , 14797-55-8; NO_2^- , 14797-65-0; sulfamethazine, 57-68-1; deaminosulfamethazine, 6149-31-1; N^4 -acetylsulfamethazine, 100-90-3.

LITERATURE CITED

Hartman, P. E. Nitrate and Nitrites. Ingestion, Pharmacodynamics and Toxicology. *Chem. Mutagens* 1982, 7, 211-294.

Mitchell, A. D.; Paulson, G. D. Depletion Kinetics of ^{14}C -Sulfamethazine {4-amino-N-(4,6-dimethyl-2-pyrimidinyl)benzene[U- ^{14}C]sulfonamide} Metabolism in Swine. *Drug Metab. Dispos.* 1986, 14, 161-165.

Nelson, P. A.; Paulson, G. D.; Feil, V. J. The Effect of Nitrite on ^{14}C -Sulphathiazole (4-amino-2-thiazolylbenzene[U- ^{14}C]sulphonamide) Metabolism in the Rat. *Xenobiotica* 1987, 17, 829-838.

Paulson, G. D. The Effect of Dietary Nitrite and Nitrate on the Metabolism of Sulphamethazine in the Rat. *Xenobiotica* 1986, 16, 53-61.

Paulson, G.; Struble, C. A Unique Deaminated Metabolite of Sulfamethazine [4-amino-N-(4,6-dimethyl-2-pyrimidinyl)benzenesulfonamide] in Swine. *Life Sci.* 1980, 27, 1811-1817.

Paulson, G. D.; Feil, V. J. Evidence for Diazotization of ^{14}C -Sulfamethazine {4-Amino-N-(4,6-dimethyl-2-pyrimidinyl)benzene[U- ^{14}C]sulfonamide} in Swine. The Effect of Nitrite. *Drug Metab. Dispos.* 1987, 15, 841-845.

Paulson, G. D.; Giddings, J. M.; Lamoureux, C. H.; Mansager, E. R.; Struble, C. B. The Isolation and Identification of ^{14}C -Sulfamethazine {4-amino-N-(4,6-dimethyl-2-pyrimidinyl)-[^{14}C]benzenesulfonamide} Metabolites in the Tissues and Excreta of Swine. *Drug Metab. Dispos.* 1981, 9, 142-146.

Paulson, G. D.; Mitchell, A. D.; Zaylskie, R. G. Identification and Quantitation of Sulfamethazine Metabolites by Liquid Chromatography and Gas Chromatography-Mass Spectrometry. *J. Assoc. Off. Anal. Chem.* 1985, 68, 1000-1006.

Paulson, G. D.; Feil, V. J.; MacGregor, J. T. Formation of a Diazonium Cation Intermediate in the Metabolism of Sulphamethazine to Desaminosulphamethazine in the Rat. *Xenobiotica* 1987, 17, 697-707.

Woolley, J. L.; Sigel, C. W. The Role of Dietary Nitrate and Nitrite in the Reductive Deamination of Sulfadiazine by the Rat, Guinea Pig, and Neonatal Calf. *Life Sci.* 1982, 30, 2229-2234.

Wright, M. J.; Davison, K. L. Nitrate Accumulation in Crops and Nitrate Poisoning in Animals. *Adv. Agron.* 1964, 16, 197-247.

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Mobility of Two Sulfonylurea Herbicides in Soil

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Intact field soil cores were used to compare the mobility of DPX-A7881 [2-[[[[[4-ethoxy-6-(methylamino)-1,3,5-triazin-2-yl]amino]carbonyl]amino]sulfonyl]benzoate], a new sulfonylurea herbicide, and chlorsulfuron [2-chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide] in four soils. DPX-A7881 was generally less mobile than chlorsulfuron in soil. This was explained on the basis of the reduced water solubility of DPX-A7881 relative to chlorsulfuron (1.7 and 300 ppm, respectively, at pH 5.0). Enhanced mobility of both herbicides in soil was related to higher soil pH and low organic matter content.

DPX-A7881, a new sulfonylurea herbicide, is currently being evaluated for selective broadleaf postemergence weed control in non-triazine tolerant canola, such as *Brassica campestris* L. Tobin and *Brassica napus* L.

Westar, for which no herbicide is presently registered in Canada.

The movement of a herbicide through the soil profile has important implications with respect to its efficacy in

controlling weeds and crop injury (Mersie and Foy, 1986), as well as its potential for environmental pollution. If surface-applied, a slight downward movement is desirable as it brings the herbicide into the soil zone of germinating weed seeds; further movement, however, can result in loss of weed control efficacy and damage to deeper rooted crops (Bailey and White, 1970). Leaching of herbicides through soil is an environmental concern because of the potential for reaching the water table and contaminating the groundwater (Hamaker, 1975).

The factors identified as affecting movement of organic chemicals through the soil profile are adsorption to soil colloids and water solubility of the herbicide (Upchurch and Pierce, 1957), in addition to water amount and flow rate and physical properties of the soil (Hartley, 1960). Thus, pesticide mobility in soils is influenced by both soil and pesticide factors (Bailey and White, 1970; Helling, 1970).

The soil properties implicated in the enhanced adsorption of chlorsulfuron and sulfometuron methyl [methyl 2-[[[(4,6-dimethylpyrimidin-2-yl)amino]carbonyl]amino]sulfonyl]benzoate] include greater organic matter content (Harvey et al., 1985; Mersie and Foy, 1986) and acidic soil pH conditions (Harvey et al., 1985; Mersie and Foy, 1985, 1986; Nicholls and Evans, 1985; Thirunarayanan et al., 1985; Shea, 1986; Wehtje et al., 1987). The greater degree of adsorption in low-pH soils has been attributed to binding of the undissociated molecular species and the decreased water solubility of the sulfonylurea herbicides.

The mobility of chlorsulfuron (Fredrickson and Shea, 1986; Mersie and Foy, 1986; Anderson and Humburg, 1987) and sulfometuron methyl (Harvey et al., 1985; Wehtje et al., 1987) was found to be enhanced at higher soil pH and/or relatively lower organic matter content, reflecting the influence of these soil properties on herbicide adsorption. The purpose of this study was to determine the mobility of DPX-A7881 relative to chlorsulfuron in four soils using intact field soil cores.

MATERIALS AND METHODS

Soils. The four soils were chosen to provide a range of organic matter, clay content, and soil pH. The physical and chemical characteristics of the soil profile of each of the soils are given in Table I. The Asquith sandy loam, Bradwell sandy loam, and Sutherland clay soils are classified as Typic Haploborolls; the Meota sandy loam is an Udic Haploboroll.

Soil Column Preparation. The leaching columns, constructed from poly(vinyl chloride) (PVC) pipe (40-cm length, with an inside diameter of 10 cm), were pushed into the soil profile at each of the four sampling sites to obtain intact field soil cores. Since the moisture throughout the soil columns was close to field capacity, for each site, preleaching with water to bring the soil moisture of each core up to field capacity was omitted. The soil cores were covered with cheesecloth at the base and positioned on wire mesh screens.

Herbicide Application. A 10.0 ppm (grams of active ingredient (AI)/volume water) stock suspension of DPX-A7881 or chlorsulfuron was prepared; the herbicide suspension was applied uniformly to the soil surface by pipet, at a rate of 0 or 30 g of AI ha⁻¹ (surface area basis); a 0- or 2.4-mL aliquot of the suspension was brought up to 5 mL with distilled water and uniformly distributed over the soil surface. The herbicide was allowed to equilibrate with the soil for a period of 24 h, with the tubes covered with polyethylene bags to prevent water evaporation from the soil surface.

Water Application. Following the equilibration period, filter paper disks were placed on top of each core, underlain with an approximately 1-cm-thick layer of glass wool, to avoid puddling and to assist in uniform dispersion of the water throughout the soil core surface area. With use of the Technicon autoan-

Table I. Physical and Chemical Characteristics of the Soil Profiles

soil	profile depth, cm	horizon	texture	fc, ^a %	H ₂ O, ^b %	pH ^c	om, ^d %
Asquith ^e	4	Ap	SL	16.4	14.6	7.0	2.1
	8		SL	16.0	16.3	6.7	2.0
	12		SL	15.3	17.0	6.6	1.8
	16		SL	13.8	15.8	7.0	1.6
	20	18-Bs	SL	12.8	12.3	6.7	1.4
	24		SL	12.7	14.5	6.9	1.3
	28		SL	11.3	14.5	7.0	1.0
	32		LS	10.9	10.0	7.0	0.8
	36		LS	10.6	10.1	7.0	0.8
Bradwell ^f	4	Ap	SL	15.3	17.1	5.5	2.9
	8		SL	15.2	17.4	5.5	2.2
	12		SL	15.2	15.1	5.6	2.1
	16	13-Bs	SL	15.3	15.0	5.5	1.9
	20		SL	15.1	17.9	5.5	1.7
	24		SL	15.1	17.9	5.5	1.7
	28		SL	14.9	17.6	5.5	1.7
	32		SL	15.0	17.3	5.9	1.3
36		SL	15.0	16.4	5.9	1.0	
Meota ^g	4	Ap	SL	19.4	16.1	6.9	5.1
	8		SL	19.0	18.6	6.7	4.4
	12		SL	18.1	19.4	6.8	4.2
	16	15-Bs	SL	16.2	16.1	6.9	2.7
	20		SL	15.1	12.6	6.9	2.2
	24		SL	14.9	12.2	7.0	2.0
	28		SL	13.1	12.1	7.0	1.8
	32		SL	13.8	11.8	6.8	1.7
	36		SL	13.6	11.8	7.3	1.7
	Sutherland ^h	4	Ap	C	37.4	29.9	7.0
8		C		38.1	36.5	7.1	4.5
12			C	37.2	38.4	7.1	4.2
16		13-Bs	C	36.2	37.2	7.5	2.9
20			C	37.4	34.2	7.6	2.7
24			C	36.9	33.1	7.6	2.7
28			C	38.2	39.8	7.4	2.2
32		29-C	HC	39.0	36.6	7.6	
36	HC		38.9	39.4	7.3		

^a Field capacity (w/w) (0.03 MPa). ^b Soil moisture content (w/w) prior to leaching. ^c Measured in 1:1 soil-deionized water suspension. ^d Walkley-Black colorimetric determination. ^e Key: % sand, 53.7; % silt, 27.8; % clay, 18.5 for top 15 cm of soil. ^f Key: % sand, 61.8; % silt, 24.6; % clay, 13.6 for top 15 cm of soil. ^g Key: % sand, 71.5; % silt, 15.8; % clay, 12.6 for top 15 cm of soil. ^h Key: % sand, 6.2; % silt, 34.1; % clay, 59.7 for top 15 cm of soil.

alyzer proportioning pump, water was allowed to drip on the top of each core at a rate of 1 cm h⁻¹. The tubes were rotated periodically at regular time intervals to improve the uniformity of the water application to the soil core surface. The water applied during the leaching process was either 3.3, 6.7, or 10 cm. To ascertain the influence of a nonionic surfactant, Agral 90 [(nonylphenoxy)polyethoxyethanol], on the mobility of DPX-A7881 in Asquith soil, the surfactant was added to the herbicide suspension, at a rate of 0.5% (v/v), and later leached with 6.7 cm of water.

The soil cores were allowed to drain for 24 h (48 h for Sutherland clay) after water addition was complete. The tubes were kept covered with polyethylene bags at both ends to prevent water evaporation. The soil cores were then sectioned into 4-cm portions, and the moisture content was measured gravimetrically to determine the soil moisture content throughout the core volume and the position of the wetting front. After the soils were air-dried, they were crushed to pass through a 2-mm sieve. Bioassays were then conducted for each soil core section. Four soil cores were replicated per treatment, and the experiment was repeated.

Bioassays. A lentil (*Lens culinaris* L. Laird) radicle bioassay was developed for the determination of phytotoxic residue levels of DPX-A7881 in soil, with a detection limit of 1 ppbw (Beckie and McKercher, 1989), while a corn (*Zea mays* L. F1 hybrid-Funks G4646) radicle bioassay (Rother, 1987) was used for the estimation of residue levels of chlorsulfuron in the treated

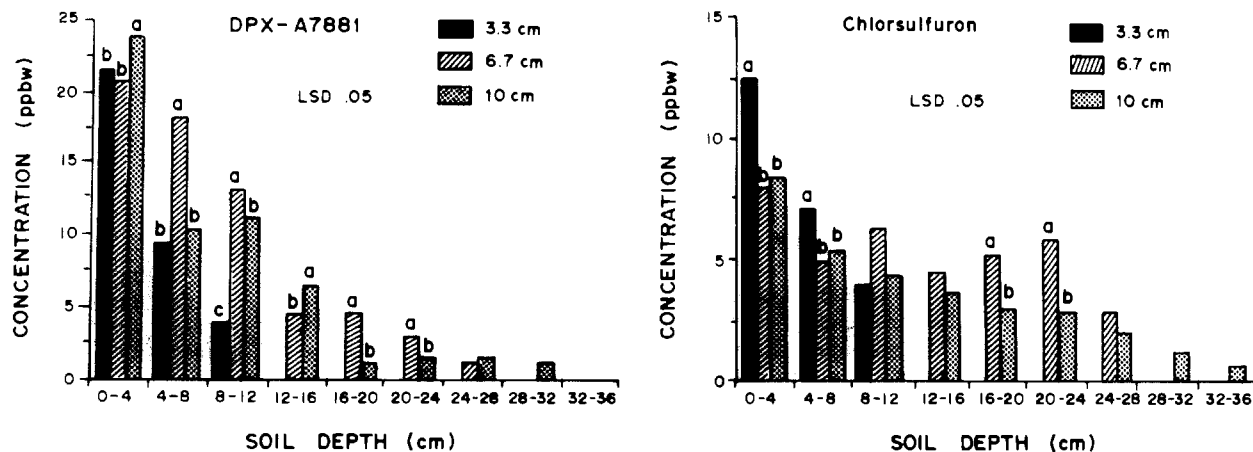


Figure 1. Effect of amount of applied water on the depth of movement of DPX-A7881 and chlorsulfuron in Asquith soil. Columns with the same letters, for each soil core section, are not significantly different at the 5% level according to the protected LSD (Fisher's) test using lentil radicle length as the test parameter (absent letters indicate a nonsignificant *F* value).

soils, with a similar detection limit. The lentil bioassay for DPX-A7881 gave improved precision over the corn bioassay but was sensitive to a narrower range of chlorsulfuron concentrations in soil than the corn bioassay.

The soil from each core section was placed in a polyethylene bag and the soil moisture brought up to 40% of field capacity with distilled water; the contents were mixed and then left to equilibrate for 24 h. The soil moisture was then raised to 80% of field capacity, and the contents were transferred to a 9 × 9 × 9 cm plastic horticultural pot lined with parafilm. For the DPX-A7881 treatments, three pregerminated lentil seeds were planted into the soil in each pot; after 4.5 days (sandy loam soils) or 5 days (clay soil), the plants were removed from the soil and the radicle lengths measured.

Due to differences in physical and chemical properties throughout the soil profile, standard curves were constructed for each soil and each herbicide at every 12-cm soil depth increment; this increment was chosen due to the general similarity of response of radicle length in the untreated soils, as determined by the bioassay. For DPX-A7881, radicle length inhibition was regressed on herbicide concentration in soil in the construction of the standard curves, yielding highly significant coefficients of determination (R^2), ranging from 0.96 to 1.00 for the four soils.

RESULTS AND DISCUSSION

The effect of the quantity of water used for leaching DPX-A7881 in Asquith soil, assessed by the lentil bioassay, is depicted in Figure 1. The herbicide was leached to a depth of 12, 28, and 32 cm following a water application of 3.3, 6.7, and 10 cm, respectively. The greater depth of herbicide movement with an increase in the amount of water applied is similar to that found by others. The depth of movement coincided closely to the position of the wetting front (16, 32, and 36 cm). The application of DPX-A7881 plus Agral 90 adjuvant did not influence the depth of movement of the herbicide (Figure 2). Thus, any change in the lipophilicity of the herbicide formulation, on influencing the sorption-desorption balance of DPX-A7881 molecules to soil colloids, was not evident.

Examination of Figure 1 reveals that chlorsulfuron was detected at 12-, 28-, and 36-cm depths following the three water applications. This coincides closely with the position of the wetting front. Therefore, the mobilities of DPX-A7881 and chlorsulfuron in Asquith soil were very similar. The close relation between the position of the wetting front and depth of herbicide movement suggests a high leaching potential in coarse textured soils, of neutral pH, with organic matter contents of 2% or less in the A and B horizons. Applications of 6.7 and 10 cm of

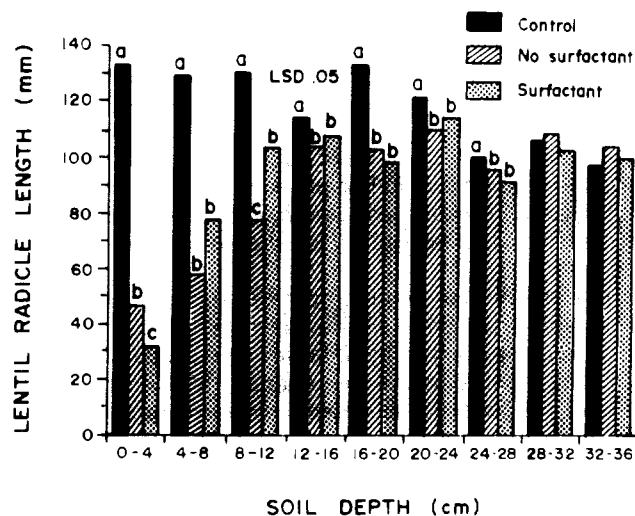


Figure 2. Influence of a surfactant Agral 90 on the depth of movement of DPX-A7881 in Asquith soil.

water resulted in a more even distribution of chlorsulfuron throughout the soil profile compared to DPX-A7881, although the distributions of both herbicides were skewed toward the upper area of the soil profile.

When movement of the herbicides was examined in Bradwell soil (Figure 3), the depth of leaching observed was less than in the Asquith soil, except for chlorsulfuron at the low water application. DPX-A7881 was leached to a depth of 8 and 12 cm when 3.3 and 6.7 cm of water, respectively, was applied; chlorsulfuron, however, was leached to greater soil column depths of 12 and 16 cm. The position of the wetting front for the two water applications was similar to Asquith soil. Since the soil adsorption and water solubilities of the sulfonylureas are pH-dependent, with enhanced adsorption and reduced solubilities at low pH, the reduction in the mobility of the two herbicides is a probable reflection of this. The two soils have been noted to have similar textures and organic matter contents, thus precluding these properties as factors differentiating relative herbicide movement between the two soils.

The depth of leaching of DPX-A7881 and chlorsulfuron in Meota soil (Figure 4) indicates a similar extent of movement compared to Bradwell soil. The wetting front of the leachate water in the soil columns was at 16- and 32-cm depth for the two water application rates. The similarity in depth of movement of both herbicides, compared to the results for the Bradwell soil, as well as the

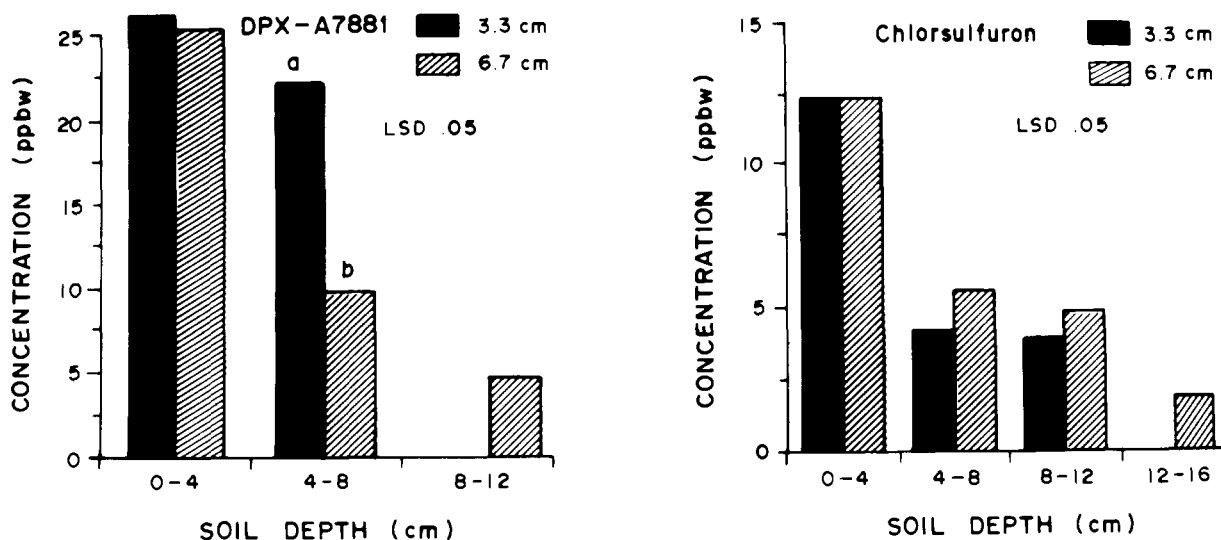


Figure 3. Effect of amount of applied water on the depth of movement of DPX-A7881 and chlorsulfuron in Bradwell soil.

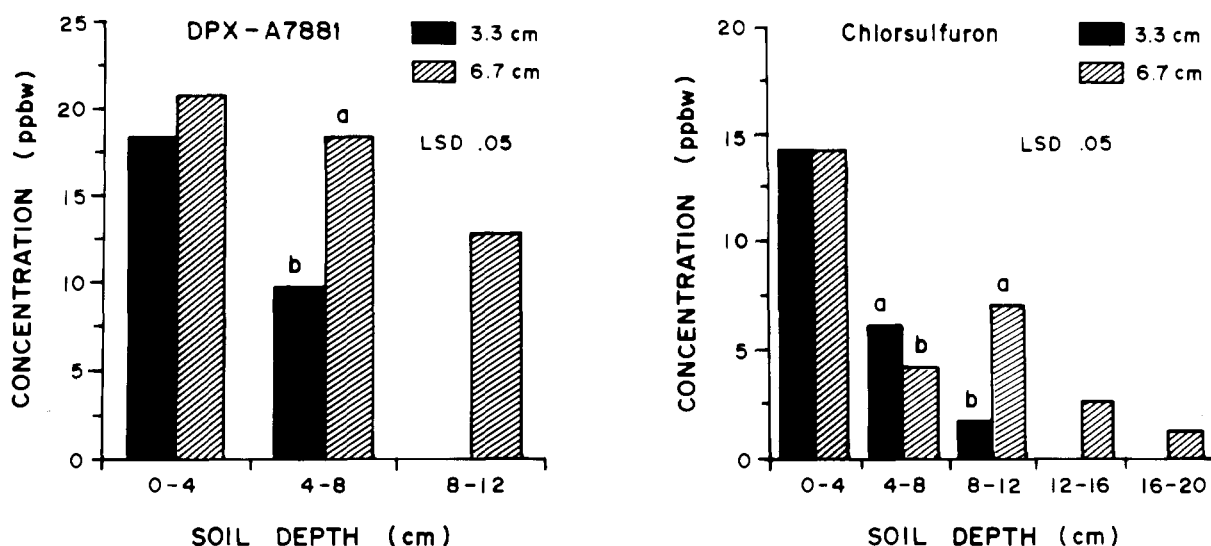


Figure 4. Effect of amount of applied water on the depth of movement of DPX-A7881 and chlorsulfuron in Meota soil.

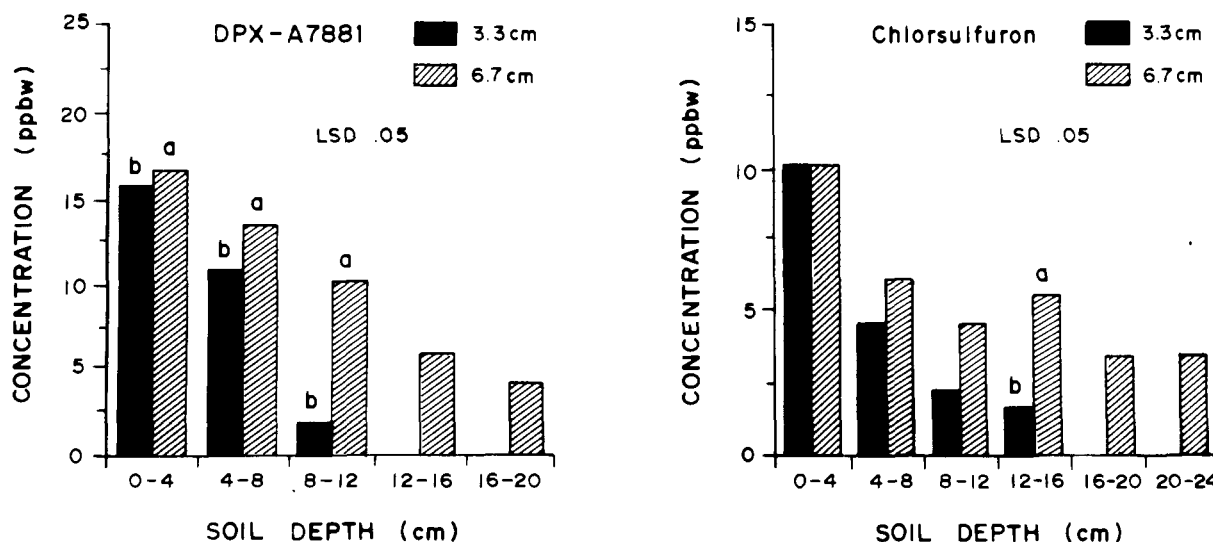


Figure 5. Effect of amount of applied water on the depth of movement of DPX-A7881 and chlorsulfuron in Sutherland soil.

marked reduction in mobility relative to that noted for the Asquith soil, points to the role of organic matter content in restricting the movement of these herbicides. DPX-A7881 exhibits greater binding to organic matter in soil than many other sulfonylureas (Hutchison et al., 1987).

Thus, although the pH range of the Meota soil was near 7.0, similar to the Asquith soil, the expected comparable mobilities of both herbicides, on the basis of pH, was not realized since organic matter restricted herbicide movement in the Meota soil.

Table II. Herbicide Concentrations in the Soil Profiles

soil	profile depth, cm	soil concentration, ^a ppbw			
		3.3 cm H ₂ O		6.7 cm H ₂ O	
		DPX-A7881	chlorsulfuron	DPX-A7881	chlorsulfuron
Asquith	4	22 [b]	12+ ^b	21 (a) [b]	8 (b)
	8	9 (a) [c]	7 (b) [a]	18 (a) [a]	5 (b) [ab]
	12	4 [a]	4 [a]	13 (a) [a]	6 (b)
	16			4 [b]	4 [b]
	20			4	5 [a]
	24			3 (b)	6 (a) [a]
Bradwell	28			1 (b)	3 (a)
	4	26 [a]	12+	25 [a]	12+
	8	22 (a) [a]	4 (b) [b]	10 (a) [c]	6 (b) [a]
	12		4 [a]	5 [c]	5
Meota	16				2 [c]
	4	18 [c]	14+	21 [b]	14+
	8	10 (a) [bc]	6 (b) [a]	18 (a) [a]	4 (b) [a]
	12		2 [b]	13 (a) [a]	7 (b)
	16				3 [bc]
Sutherland	20				1 [c]
	4	16 [c]	10+	17 [c]	10+
	8	11 (a) [b]	4 (b) [b]	14 (a) [b]	6 (b) [a]
	12	2 [b]	3 [ab]	10 (a) [b]	5 (b)
	16		2	6 [a]	6 [a]
	20			4	3 [b]
	24				3 [b]

^a Means followed by the same letters are not significantly different ($P = 0.05$) according to the LSD (protected) test. Letter(s) in parentheses denotes comparison of the two herbicide concentrations within the soil layer for the specified water application; letter(s) in brackets refers to comparison of concentrations of each herbicide between similar layers of the four soils. ^b + denotes upper concentration sensitivity limits of the bioassays.

When DPX-A7881 and chlorsulfuron were leached in Sutherland soil columns (Figure 5), slightly greater movement was found compared to the Meota soil, which is similar in organic matter and soil pH; chlorsulfuron was leached to greater column depths relative to DPX-A7881. The leaching behavior of both herbicides in the Sutherland clay indicates low adsorption to the clay colloids, due to charge repulsion, which has been noted for chlorsulfuron by other workers. Therefore, the mobility of DPX-A7881 in soil would not be expected to be directly influenced by the clay content.

The herbicide concentrations are listed in Table II, with mean comparisons indicated between herbicides within each soil layer and also between soil types within each layer for both herbicides. Generally, the results indicate that although DPX-A7881 leaches less readily than chlorsulfuron, both herbicides remain concentrated in the upper layers of all four soils. This was less evident, however, when chlorsulfuron was leached with 6.7 cm of water in Asquith soil, a soil with a relatively high leaching potential. This general pattern is a reflection of the water application rate, which more realistically represents the average rate of water infiltration into field soils and favors the establishment of adsorption equilibria between the herbicide and the soil colloids, rather than higher rates frequently used in past soil column studies.

DPX-A7881 is less mobile in the soil than chlorsulfuron. This implies that DPX-A7881 is adsorbed to a greater extent to the soil colloids (principally organic matter) than is chlorsulfuron. The close similarity in molecular structure and polarity of the two chemical compounds, as well as their pK_a values, would suggest that other factor(s) are involved in their differential mobility in soil. The most obvious reason for these observed results is their relative solubility in water. DPX-A7881 is much less water soluble than is chlorsulfuron; for example, at pH 5.0, DPX-A7881 has a water solubility of 1.7 ppm, whereas the solubility of chlorsulfuron in water is 300 ppm. Since adsorption and leaching are often related to water solubility within a given herbicide class (Ward and Upchurch, 1965;

Bailey et al., 1968; Gray and Weirich, 1968), this may explain the reduced leachability of DPX-A7881 in soil. Although soil factors affect the movement of DPX-A7881 in soil, the amount of water infiltrating into the soil with time can greatly influence its movement through the soil profile.

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Registry No. DPX-A7881, 97780-06-8; chlorsulfuron, 64902-72-3.

LITERATURE CITED

- Anderson, R. L.; Humburg, N. E. Field Duration of Chlorsulfuron Bioactivity in the Central Great Plains. *J. Environ. Qual.* **1987**, *16*, 263-266.
- Bailey, G. W.; White, J. L. Factors Influencing the Adsorption, Desorption, and Movement of Pesticides in Soil. *Residue Rev.* **1970**, *32*, 29-92.
- Bailey, G. W.; White, J. L.; Rothberg, T. Adsorption of Organic Herbicides by Montmorillonite: Role of pH and Chemical Character of Adsorbate. *Soil Sci. Soc. Am. Proc.* **1968**, *32*, 222-229.
- Beckie, H. J.; McKercher, R. B. Soil Residual Properties of DPX-A7881 Under Laboratory Conditions. *Weed Sci.* **1989**, *37*, 412-418.
- Fredrickson, D. R.; Shea, P. J. Effect of Soil pH on Degradation, Movement, and Plant Uptake of Chlorsulfuron. *Weed Sci.* **1986**, *34*, 328-332.
- Gray, R. A.; Weirich, A. J. Leaching of Five Thiocarbamate Herbicides in Soils. *Weed Sci.* **1968**, *16*, 77-79.
- Hamaker, J. W. The Interpretation of Soil Leaching Experiments. In *Environmental Dynamics of Pesticides*; Haque, R., Freed, V. H., Eds.; Plenum Press: New York, 1975; pp 115-133.
- Hartley, G. S. Physico-chemical Aspects of the Availability of Herbicides in Soils. In *Herbicides and the Soil*; Woodford, K. K., Sagar, G. R., Eds.; Blackwell: New York, 1960; pp 63-78.

- Harvey, J., Jr.; Dulka, J. J.; Anderson, J. J. Properties of Sulfometuron Methyl Affecting its Environmental Fate: Aqueous Hydrolysis and Photolysis, Mobility and Adsorption on Soils, and Bioaccumulation Potential. *J. Agric. Food Chem.* 1985, 33, 590-596.
- Helling, C. S. Movement of S-triazine Herbicides in Soils. *Residue Rev.* 1970, 32, 175-210.
- Hutchison, J. M.; Peter, C. J.; Amuti, K. S.; Hageman, L. H.; Roy, G. A. DPX-A7881: A New Herbicide for Oilseed Rape. *Br. Crop Prot. Conf.—Weeds.* 1987, V1, 63-67.
- Mersie, W.; Foy, C. L. Phytotoxicity and Adsorption of Chlorsulfuron as Affected by Soil Properties. *Weed Sci.* 1985, 33, 564-568.
- Mersie, W.; Foy, C. L. Adsorption, Desorption, and Mobility of Chlorsulfuron in Soils. *J. Agric. Food Chem.* 1986, 34, 89-92.
- Nicholls, P.; Evans, A. A. Adsorption and Movement in Soils of Chlorsulfuron and Other Weak Acids. *Proc. Br. Crop Prot. Conf.—Weeds.* 1985, 3, 333-339.
- Rother, P. A. The Effects of Monoammonium Phosphate and Urea on Crop Residues to Pre- and Postemergent Applications of Chlorsulfuron. M.Sc. Thesis, The University of Saskatchewan at Saskatoon, 1987.
- Shea, P. J. Chlorsulfuron Dissociation and Adsorption on Selected Adsorbents and Soils. *Weed Sci.* 1986, 34, 474-478.
- Thirunarayanan, K.; Zimdahl, R. L.; Smika, D. E. Chlorsulfuron Adsorption and Degradation in Soil. *Weed Sci.* 1985, 33, 558-563.
- Upchurch, R. P.; Pierce, W. C. The Leaching of Monuron from Lakeland Sand Soil I. The Effect of Amount, Intensity, and Frequency of Simulated Rainfall. *Weeds* 1957, 5, 321-330.
- Ward, T. M.; Upchurch, R. P. Role of the Amido Group in Adsorption Mechanisms. *J. Agric. Food Chem.* 1965, 13, 334-340.
- Wehtje, G.; Dickens, R.; Wilcut, J. W.; Hajek, B. F. Sorption and Mobility of Sulfometuron and Imazapyr in Five Alabama Soils. *Weed Sci.* 1987, 35, 858-864.

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Residues of Fluridone and a Potential Photoproduct (N-Methylformamide) in Water and Hydrosol Treated with the Aquatic Herbicide Sonar

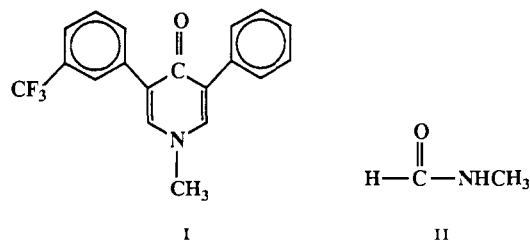
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Fluridone is the active ingredient in the aquatic herbicide Sonar. Two ponds in Florida were treated with Sonar AS (an aqueous suspension formulation) and Sonar SRP (a slow-release clay pellet formulation). Both ponds were treated at the maximum acceptable residue level for fluridone in potable water, 0.15 ppm. The dissipation of fluridone and the potential formation of N-methylformamide (NMF) as a photolysis product of fluridone were monitored. The fluridone concentration decreased to a nondetectable level (less than 0.001 ppm) in the water of both ponds 324 days after treatment (DAT). NMF was not detected in any of the 192 water samples that were collected on any of the sampling dates at a detection limit of 0.002 ppm. Hydrosol samples collected at 324 DAT in both ponds contained fluridone residues equivalent to 2.9-3.6% of the amount applied to the pond, but no NMF was detected in the hydrosol at a detection limit of 0.005 ppm.

Fluridone, 1-methyl-3-phenyl-5-[3-(trifluoromethyl)-phenyl]-4(1H)-pyridinone (I), is the active ingredient in the aquatic herbicide Sonar. The biological, chemical, and physical properties of fluridone have been reviewed (West, 1984), and the bioconcentration and field dissipation of the herbicide in aquatic environments have been summarized (West et al., 1983).

A laboratory aqueous photolysis study indicated that N-methylformamide (NMF, II) is one of several low molecular weight photoproducts of fluridone in the absence of aquatic substrates other than water (Saunders and Mosier, 1983). However, NMF was not observed in studies con-



ducted outdoors in artificial ponds with radiolabeled fluridone under natural environmental conditions (Berard and Rainey, 1981). Studies conducted with Sonar AS (an aqueous suspension formulation containing fluridone) in two ponds in Florida have also demonstrated that NMF was not a degradation product, even at fluri-

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