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# Sulfometuron persistence and movement in soil and water in North Dakota<sup>1</sup>

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## Abstract:

The lateral movement, soil persistence and aqueous hydrolysis of sulfometuron [2-([[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]} amino sulfonyl)-benzoic acid] was evaluated. Sulfometuron applied at 140 g a.i. ha<sup>-1</sup> from slopes to nontarget areas was minimal and was not detected in the 0-to-30-cm-soil depth, when sampled up to 120 cm downslope from the treated area on 2, 8, or 16% slopes 1 year after treatment. The highest sulfometuron concentration found downslope from the treated area was less than 1 µg kg<sup>-1</sup> regardless of the slope. Sulfometuron moved beyond the soil column (70 cm deep) in Fairdale loam [fine-loamy, mixed (calcareous), frigid, Mollic Udifluvents], Felor silty clay loam (fine-loamy, mixed, Typic Agriborolls), and Barnes stony loam (fine-loamy, mixed, Udic Haploborolls) soils when leached with 45.7 cm of water for 48 hours compared to only 35 to 50 cm deep when leached with the same amount of water over 9 weeks. Sulfometuron degradation increased as soil temperature and moisture increased. Sulfometuron was detected for an average of 429 days in Felor silty clay loam at pH 6.1, 8° C, and 45% field capacity but only 218 days in the same soil at 90% field capacity and 16° C. Degradation was slower in Renshaw and Sioux sandy loam [(undifferentiated soil mixture) fine-loamy over sandy or sandy skeletal, mixed Udic Haploborolls and sandy-skeletal, mixed Udorthentic Haploborolls] with a pH of 7.4 and averaged >700 days, regardless of environmental conditions. Sulfometuron hydrolysis was similar regardless of solution pH with an average of 63% <sup>14</sup>C-sulfometuron remaining after 28 days in water at pH 5, 7,

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and 9. The average half-life of  $^{14}\text{C}$ -sulfometuron was 31 and 65 days in ultraviolet-irradiated and dark control samples, respectively.

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Sulfometuron has shown potential for control of leafy spurge (*Euphorbia esula* L.), a long-lived perennial weed that is difficult to control. Sulfometuron at 70 to 140 g ha<sup>-1</sup> applied with low rates of auxin herbicides such as picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) will control leafy spurge topgrowth and disrupt root bud initiation (Lym and Messersmith, 1988). Picloram is the most effective and consistent herbicide for leafy spurge control (Lym and Messersmith, 1985); however, it cannot be used near trees, surface water, or areas with sandy soil and a high water table. Thus, sulfometuron may be useful in a long-term leafy spurge control program especially if it could be used in environmentally sensitive areas where picloram and other auxin herbicides cannot be used.

Sulfometuron is degraded by hydrolysis and microorganisms in soil and has an average half-life of 4 weeks in acidic soil (Harvey *et al.*, 1985). Hydrolysis seems to predominate during the initial degradation of sulfometuron in acidic soils. Sulfometuron decomposes in soil at a rate primarily dependent on soil pH and moisture content (Anderson and Dulka, 1985). The principal nonvolatile degradation product of sulfometuron is saccharin (1,2-benzisothiazol-3-one,2,3-dihydro 1,1-dioxide), a synthetic sweetener. This novel breakdown product may make sulfometuron more acceptable by the general public for widespread leafy spurge control than herbicides presently used.

Soil organic matter and clay content do not appear to affect the soil affinity for sulfometuron (Wehtje *et al.*, 1987). Sulfometuron was more mobile than metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] or atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl-1,3,5-triazine-2,4-diamine)] in five Alabama soils.

Herbicides may move from treated to untreated areas in surface runoff water following heavy rainfall. Picloram and 2,4,5,-T [2,4,5-trichlorophenoxy)acetic acid] applied to native grass were detected at high concentrations (400-800  $\mu\text{g L}^{-1}$ ) in runoff water following heavy precipitation compared to less than 5  $\mu\text{g L}^{-1}$  when major rainfall occurred more than 30 days after treatment (DAT) (Bovey *et al.*, 1974). Plant washoff was the main source of herbicide in the runoff water. Dicamba (3,6-dichloro-2-methoxybenzoic acid), picloram, and 2,4,5,-T movement from target areas in runoff water was influenced by cultural practice, nature and rate of application, and slope of the application site (Trichell *et al.*, 1968). Initial herbicide runoff was generally greater on grass than fallow plots.

The objectives of this study were to determine: (i) the potential for lateral movement of sulfometuron from slopes to nontarget areas; (ii) sulfometuron movement and persistence in various soil types where the spurge is found; and (iii) factors influencing sulfometuron aqueous hydrolysis.

# Materials and methods

## Surface movement

A field experiment to determine the surface movement of sulfometuron applied to a sloped area was established on 10 and 13 June 1986 at sites near New England and Valley City, ND, respectively. Sulfometuron at  $140 \text{ g ha}^{-1}$  was applied on natural slopes of 2, 8, and 16%. Treatment areas were 2.4- by 9.1-m plots arranged in a completely random design and replicated three times. The predominant vegetations were bluegrass spp. (*Poa* spp.) at Valley City and bluegrass spp. and wheatgrass spp. (*Agropyron* spp.) at New England.

Soil samples were collected from inside the plot and in increments of 15, 30, 60, and 120 cm downslope from the treated area in August 1986 and June 1987 (100 and 360 days after treatment, respectively). Soil samples also were collected 240 cm downslope from the treated area in June 1987. Triplicate soil cores 30 cm deep were collected per interval and divided into segments of 0 to 15 and 15 to 30 cm. Soil samples were air dried at  $25^\circ \text{ C}$  and screened through a 6-mm sieve. Soil properties are given in Table 1 and precipitation received during the study is listed in Table 2.

Sulfometuron concentration was determined by a corn (*Zea mays* L.) root bioassay (Anderson, 1985). The standard curve was prepared adding sulfometuron at 0.0625 to  $8 \mu\text{g kg}^{-1}$  in 10 mL water to 385 g of untreated soil. The soil was then air dried and thoroughly mixed. Soil for the standard curve and the unknown samples were placed in styro-foam containers (without drainage holes) and watered to 80% field capacity (gravimetric water content at 0.03 MPa). 'Pioneer 3737' corn seeds were pregerminated at  $24^\circ \text{ C}$  for 48 hours and four seedlings, with radicles 1 to 5 cm long, were planted 5 to 10 cm deep in each pot. The pots were arranged in a completely random design and placed in a growth chamber at  $18^\circ \text{ C}$  and a 16-hour photoperiod (light intensity of  $184 \mu\text{E m}^{-2} \text{ s}^{-1}$ ). The pots were rerandomized daily and watered as needed throughout the experiment.

The corn seedlings were harvested after 6 days and the longest root of each seedling was measured to the nearest 1 mm. Each treatment had four replications and the experiment was repeated in two independent experiments. A linear standard curve was calculated using regression analysis (SAS Institute, 1982), and the mean root length for field samples were compared to those from known concentrations to estimate sulfometuron concentrations.

## Movement and persistence in soil

An experiment was conducted in the greenhouse to determine sulfometuron mobility in soil. Soil columns more closely approximate field conditions in determining herbicide movement in soil than most other methods (Weber and Whitacre, 1982; Wu and Santelmann, 1975). Soil from 0 to 30 cm deep was collected near three leafy spurge infestations in North Dakota. The soils included Barnes stony loam from Valley City, Felor silty clay loam from New England, and Fairdale loam from Chaffee, ND (Table 1). Soils were air dried at  $21^\circ \text{ C}$  and screened through a 6-mm sieve.

**Table 1. Soil properties at the various experiment locations in North Dakota.**

Location	Soil series	OM	Sand	Silt	Clay	pH	Field	Bulk
		content					capacity†	density‡
			%			%		g cm <sup>-3</sup>
Chaffee	Fairdale loam	3.8	51	39	10	7.8	–	1.1
Valley City	Barnes stony loam	4.0	49	41	10	6.8	20	1.2
New England	Felor silty clay loam	3.7	12	49	39	6.1	24	1.2
Hunter	Renshaw and Sioux sandy loam	2.3	61	29	10	7.4	0.8	-

† Gravimetric water content at 0.03 MPa.

‡ Based on column volume of 3530 cm<sup>3</sup>.

Soil columns were 70-cm-long PVC pipe (8.1 cm i.d.). The columns were cut longitudinally to allow for separation of the column after the leaching period. Silicone sealer was applied around the inside diameter at 10-cm increments to reduce boundary water flow along the side walls (Weber and Whitacre, 1982). Silicone was applied to the junction of the column halves, and the halves were joined and fastened by metal clamps. Soil was added to the soil columns and uniform packing was accomplished using a mechanical soil packer. The packed columns were placed in distilled water and allowed to saturate bottom-to-top by capillary action. The saturated columns were placed on a soil mound and allowed to drain for 48 hours.

Sulfometuron equivalent to 140 g ha<sup>-1</sup> was applied to the surface of each soil column in 10-mL water and allowed to equilibrate for 48 hours. Water equivalent to the average annual precipitation of 45.7 cm (2350 mL) was applied to the top of the column at a rate of 0.8 mL min<sup>-1</sup>. Water was applied continuously for about 48 hours or applied weekly in 5.1 cm (260 mL) increments for 9 weeks. The leachate was not collected. An enema bag of water hung above the soil column and the rate of water flow was regulated with a hose clamp. Glass wool was placed on the soil to distribute water over the entire surface. Maximum movement of sulfometuron in soil was determined by the 48 hours regime while the 9 weeks leaching period more closely approximated actual field conditions.

The columns were allowed to drain for 48 hours after the leaching period, the column halves were separated, and the soil was divided into 5-cm increments the entire column length. Soil segments were air dried, placed in styrofoam containers, and assayed for sulfometuron using a corn root bioassay as previously described.

The effect of soil temperature and moisture content on sulfometuron persistence was evaluated in three soil types. The soils included Barnes stony loam, Felor silty clay loam, and Renshaw and Sioux sandy loam from Valley City, New England and Hunter, ND, respectively (Table 1). The soils were dried and screened as previously described. Each soil was treated with 4 µg kg<sup>-1</sup> of sulfometuron by adding the herbicide suspended in 10 mL of distilled water to 500 g of oven-dried soil. The herbicide was thoroughly incorporated in the soil and then placed in 11- by 11- by 5-cm, deep plastic pots and the pots were capped. There were four replications per treatment and the experiments were repeated.

For the temperature study the soils were brought to 45% field capacity (0.15, 0.20, and 0.06 kg kg<sup>-1</sup> water content for the stony loam, silty clay loam, and sandy loam, respectively), and placed in constant temperature chambers at 8, 16, or 24° C. The effect of soil moisture on sulfometuron persistence was determined by adjusting the water content to 23, 45 or 90% field capacity (0.13, 0.15, and 0.19 kg kg<sup>-1</sup> for the stony loam; 0.18, 0.20, and 0.24 kg kg<sup>-1</sup> for the loam; and 0.055, 0.06, and 0.07 kg kg<sup>-1</sup> for the sandy loam), respectively. All soil for the moisture study was maintained at 16° C.

For both experiments, corn root bioassays were conducted monthly as previously described, until the root growth in treated soil was at least 80% of that in nontreated soil. All soil was adjusted to 45% field capacity prior to each bioassay either by adding water or allowing to air dry 48 hours prior to planting. Each sulfometuron treatment had a paired control treatment of untreated soil. The soil was allowed to dry 48 hours following harvest, remixed and brought to the appropriate moisture content before being returned to the constant temperature chamber.

## Hydrolysis and photolysis

Two 20-mL water samples, each containing 36 µg L<sup>-1</sup> (0.11 KBg mL<sup>-1</sup>) of uniformly pyrimidine-ring-labeled <sup>14</sup>C-sulfometuron (specific activity 1.13 GBg mmol<sup>-1</sup>; >99% radiochemical purity) in distilled water, were buffered to pH 5, 7, or 9 by adding the appropriate buffer<sup>2</sup>. The solutions were maintained in the dark at 25° C in closed vials. Two 1-mL aliquots were taken from each vial; 1, 3, 7, 14, 21, and 28 days after treatment and assayed for sulfometuron and its metabolites.

The first 1-mL aliquot was assayed for total radioactivity using liquid scintillation spectrometry. The second aliquot was concentrated to dryness under N<sub>2</sub> and frozen until analysis for <sup>14</sup>C-sulfometuron. The <sup>14</sup>C-sulfometuron was redissolved in 1 mL of 80% acetonitrile, concentrated under N<sub>2</sub> to 30 µL, and spotted on 5- by 20-cm silica 60 thin layer chromatography (TLC) plates. The plates were developed to a 15-cm solvent front in chloroform acetic acid (19:3, v/v) to separate parent acid and metabolites. The <sup>14</sup>C was detected with a radiochromatogram scanner and *R<sub>f</sub>* values were calculated compared to <sup>14</sup>C-sulfometuron standards. Areas of the thin layer chromatography plates that contained <sup>14</sup>C were scrapped and quantified using liquid scintillation spectrometry.

Sulfometuron photolysis was evaluated in distilled, well, and river water. The well water was from a farm near Fargo, ND, and had a pH of 8.3. A sample from the Red River of the North was obtained in Fargo, ND, and was slightly cloudy with suspended sediment and a pH of 7.2. The distilled water pH was 6.0. Four 20-mL aliquots of each water type was placed in glass vials and 720 µg L<sup>-1</sup> (2.22 K.Bg) of <sup>14</sup>C-sulfometuron was added. Two vials of each water type were covered with quartz glass and placed at a distance of 1 to 2 cm under two 20-W ultraviolet lamps which provided light in the 300- to 400-m region. The remaining two vials of each water type were wrapped with aluminum foil and were kept in the dark as an untreated control. All vials were shaken continuously. Two 1-mL aliquots were collected and assayed for <sup>14</sup>C-sulfometuron and metabolites by

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<sup>2</sup> Potassium and sodium phosphate (pH 5), potassium acid phthalate (pH 7), sodium carbonate and bicarbonate (pH 9), Orion Application Solution, Orion Research, Inc., Cambridge, MA.

TLC as previously described. There were two replications for both the hydrolysis and photolysis experiments, and each study was repeated.

## Results and discussion

### Surface movement

Sulfometuron generally did not move downslope from the treated area at Valley City or New England (Fig. 1). The highest sulfometuron concentration detected outside the treated area was less than  $1 \mu\text{g kg}^{-1}$  at either location.

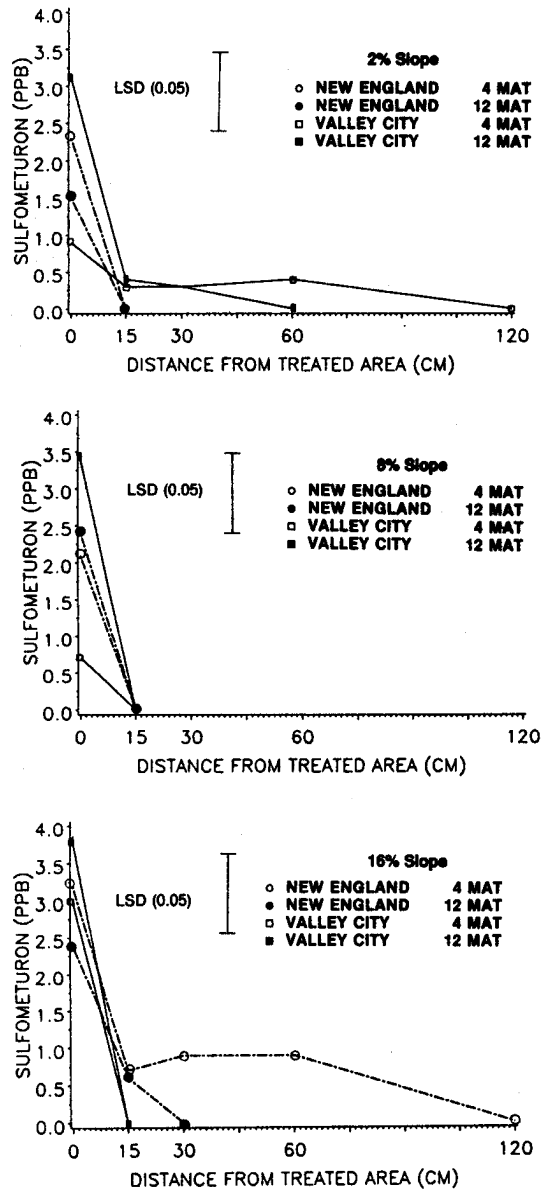


Fig. 1. Sulfometuron concentrations in the 0- to 15-cm depth at 4 and 12 months after treatment when applied to 2, 8, and 16% slopes at New England and Valley City, ND.

Sulfometuron movement from treated slopes was minimal at Valley City 120 DAT (Fig. 1). Sulfometuron did not move from the treated area on the 8 or 16% slope. However, sulfometuron was found at concentrations from 0.4 to 0.5  $\mu\text{g kg}^{-1}$  15 and 60 cm downslope from the treated area on the 2% slope in the 0-to 15-cm soil depth. The unexpected movement of herbicide from the 2% slope and not the steeper slopes may be attributed to the greater vegetation and litter observed on the 2% slope compared to the 8 and 16% slope. The vegetation on the 2% slope may have retained higher sulfometuron concentrations than the vegetation on the 8 or 16% slope. Movement of plant litter downslope and subsequent precipitation would have washed sulfometuron from the plant material. Sparser vegetation on the steeper slopes allowed much of the applied sulfometuron to reach the soil surface and become adsorbed. This is similar to picloram movement on slopes which was affected by vegetation, as indicated by over three times as much picloram in runoff water from treated grass plots compared to fallow plots (Trichell *et al.*, 1968).

Precipitation was almost 12 cm above normal following herbicide application until soil samples were collected (100 DAT) (Table 2). Heavy precipitation immediately following herbicide application could result in greater sulfometuron movement than was found in this study. However, there was never more than 3 cm of precipitation within a 24-hour period during this study, so rapid downward movement of sulfometuron was unlikely.

**Table 2. Monthly precipitation at the various experiment sites in North Dakota.**

Year/month	Location/precipitation			
	Valley City		New England	
	Actual	Dev.†	Actual	Dev.†
	cm			
<u>1986</u>				
April	14.2	+10.1	5.2	+0.8
May	5.4	-0.6	8.7	+1.8
June	7.4	-1.6	10.8	+1.2
July	13.4	+6.5	7.3	+1.9
August	12.3	+6.4	2.4	-1.8
September	7.4	+2.4	12.4	+8.7
October	0.8	-1.9	0.9	-1.0
November	3.6	+2.0	2.7	+1.3
December	0.2	-1.9	0.0	0.0
Total	64.7	+21.4	50.4	+12.9
<u>1987</u>				
January	0.8	-0.4	0.2	-0.8
February	2.0	+0.9	0.9	-0.4
March	3.1	+1.3	4.9	+3.2
April	0.6	-3.5	0.1	-4.4
May	10.2	+4.2	7.4	+0.6
Total	16.7	+2.5	13.5	-1.8

† Deviation from 30-year average.

Sulfometuron was not detected downslope from the treated area on the 2 or 8% slope at New England 120 DAT (Fig. 1). New England received near normal precipitation (20.3 cm) following herbicide application in June until soil samples were collected in September (Table 2). Sulfometuron was found at 0.6 and 0.9  $\mu\text{g kg}^{-1}$  at 15 and 30 cm, respectively, downslope from the treated area on the 16% slope. Sulfometuron movement on the 16% slope may have resulted from rainfall washing herbicide adsorbed to soil particles downslope. Vegetative cover at New England was similar on all the slopes and was less dense than at Valley City. Therefore, more sulfometuron would reach the soil surface at New England than Valley City.

Sulfometuron was not found 15- to 30-cm-deep downslope from the treated area at either location regardless of slope except 0.5  $\mu\text{g kg}^{-1}$  was detected on the 16% slope 30 cm from the treated area at New England (data not shown). Sulfometuron concentrations within the treated area 15 to 30 cm deep ranged from 0 to 0.4  $\mu\text{g kg}^{-1}$  at Valley City (Barnes stony loam) and 0.6 to 1.1  $\mu\text{g kg}^{-1}$  at New England (Felor silty clay loam).

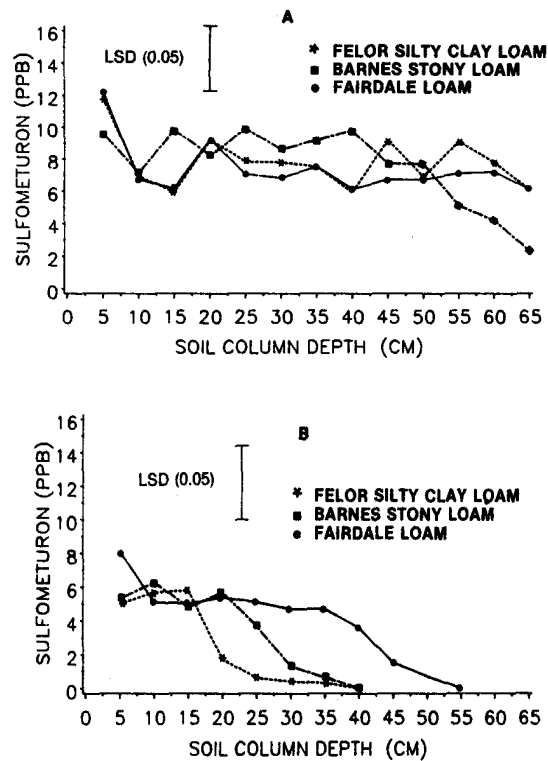
Sulfometuron concentrations 0 to 15 cm deep were generally lower at both locations 12 months after treatment (MAT) than 120 DAT (Fig. 1). However, sulfometuron concentrations tended to be higher in the treated area in June 1987, then September 1986, on all the slopes at Valley City. Sulfometuron also was found at higher concentrations 15 to 30 cm deep within the treated area 12 MAT compared to 120 DAT (data not shown). The higher concentrations found 12 MAT apparently were from herbicide that had washed off plant material after soil samples were collected in 1986.

These results follow observations by Bovey *et al.* (1974) that large concentrations of 2,4,5,-T and picloram occurred in grass soon after treatment but decreased after heavy rainfall with a corresponding increase in the soil concentration of both herbicides. Sulfometuron breakdown by photolysis and volatilization is minimal under field conditions (Beyer, 1986). Therefore, sulfometuron would tend to remain on plant material until removed by precipitation or the plant tissue decayed. Anderson (1985) suggested that metsulfuron [-2-([[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl}amino]-sulfonyl)benzoic acid], a similar sulfonylurea herbicide, was retained on straw and later was washed off by simulated rainfall. Rainfall intensity needed to remove metsulfuron was influenced by the amount of straw present.

## **Movement and persistence in soil**

Sulfometuron was highly mobile in all soil types evaluated when leached continuously with 45.7-cm water over 48 hours but not 9 weeks. Sulfometuron when leached continuously moved the entire column length (70 cm) in Fairdale loam, Felor silty clay loam and Barnes stony loam (Fig. 2A). Sulfometuron movement was uniform in all soils with concentrations ranging from 10 to 6  $\mu\text{g kg}^{-1}$  at 10 to 50 cm deep, respectively. The highest concentration of sulfometuron was found in the top 5-cm segment of each soil type. The high water volume leached through the column may have provided similar soil solution pH and sulfometuron solubility in the saturated-flow conditions for all soil types thus allowing for similar sulfometuron movement.





**Fig. 2. Sulfometuron movement in three soils leached with 45.7 cm of water with (A) continuously for 48 hours or (B) with 5.1 cm for 9 weeks in a 70-cm-long column (8.1 cm i.d.).**

These data are in agreement with soil TLC and other soil column studies in which sulfometuron was intermediate to highly mobile (Harvey *et al.*, 1985; Wehtje *et al.*, 1987). However, an unrealistically high water volume for one application was used in this experiment.

Sulfometuron movement was less when the soil columns were leached for 9 weeks compared to 48 hours (Fig. 2B). Sulfometuron was detected 50 cm deep in Fairdale silty loam but only 35 cm deep in Barnes stony loam and Felor silty clay loam, respectively. Sulfometuron concentration was less than 1  $\mu\text{g kg}^{-1}$  below 20 cm in the Felor loam.

The difference in sulfometuron mobility in the three soil types was probably related to the differences in soil pH. Sulfometuron mobility increases as soil pH increases (Harvey *et al.*, 1985). The Fairdale silty loam pH was 7.8 while the Barnes stony loam and Felor loam pH was 6.8 and 6.1, respectively (Table 1).

The amount of sulfometuron that remained in all three soils leached for 48 hours was about 54% of applied (Fig. 2). However, the amount of sulfometuron that remained in Fairdale loam, Barnes stony loam, and Felor silty clay loam soils leached for 9 weeks was 24, 15, and 11% of applied, respectively. The sulfometuron concentration that remained after 9 weeks was greatest in the Fairdale loam which had the highest pH. Sulfometuron degradation probably accounted for the lower concentrations found in the three soil types leached for 9 weeks compared to 48 hours.

Sulfometuron persistence decreased as soil temperature increased in the Felor silty clay loam and Barnes stony loam soils, but temperature did not affect persistence in the Renshaw and Sioux sandy loam soil (Table 3). Sulfometuron inhibited corn root growth for 155 days at 24° C in the Felor silty clay loam and Barnes stony loam soils but increased to an average of 394 days at 8° C. Sulfometuron degraded much more slowly in Renshaw and Sioux sandy loam than in the other two soils and was detected for an average of 690 days at 8 or 16° C. The experiment was concluded after 24 months and corn root growth in the Renshaw and Sioux sandy loam at 24° C was still 36% less than in the untreated control.

**Table 3. Sulfometuron persistence in three soils maintained at three temperatures and 45% field capacity.**

Soil temperature ° C	Soil		
	Felor silty clay loam	Barnes stony loam	Renshaw and Sioux sandy loam
8	429	358	708
16	288	408	672
24	155	155	> 730‡
LSD (0.05)	13	16	NS

†Length of time required before inhibition of corn root growth by sulfometuron was <20%.

‡Corn root growth was 36% less than the control when the experiment concluded.

Sulfonylurea herbicides generally have a longer half-life in sandy compared to loam or clay soils, but persistence also is influenced by soil pH, moisture, and temperature (Anderson and Dulka, 1985; Anderson, 1985). Soil pH was slightly higher and organic matter lower in the Renshaw and Sioux sandy loam at Hunter compared to the loam soils at New England and Valley City (Table 1). Microbial breakdown is important in sulfometuron soil degradation (Anderson and Dulka, 1985) so variation in soil microflora between the soil types may account for the differences in persistence.

The differences in sulfometuron persistence between the Felor silty clay loam and Barnes stony loam compared to the Renshaw and Sioux sandy loam soil may be due to a difference in soil moisture content. Sulfometuron degraded in 386 days in the Renshaw and Sioux sandy loam soil at 90% field capacity, but still inhibited corn root growth 25 and 54% at 45 and 23% field capacity, respectively, after 730 days (Table 4). Increasing soil moisture also decreased sulfiameturon persistence in the Felor silty clay loam and Barnes stony loam soils but to a much lesser degree than in the Renshaw and Sioux sandy loam soil. Sulfometuron in the Felor silty clay loam and Barnes stony loam soils degraded an average of 86 days sooner at 90% compared to 23% field capacity. Since sandy soils dry quickly, sulfometuron likely would persist for 2 or more years in sandy soils in North Dakota, especially in dry areas.

**Table 4. Sulfometuron persistence in three soil types maintained at three moisture levels and 16° C.**

Soil water content (% field capacity)	Soil		
	Felor silty clay loam	Barnes stony loam	Renshaw and Sioux sandy loam
23	291	281	>730‡
45	281	253	>730‡
90	218	183	386
LSD (0.05)	12	14	91

†Length of time required before inhibition of corn root growth by sulfometuron was <20%.  
‡Corn root growth was 25 and 54% less than the control for the sandy loam soil at 45 and 23% field capacity, respectively, when the experiment concluded.

## Hydrolysis and photolysis

The half-life for sulfometuron hydrolysis was 40 days and was not influenced by pH in this study (Table 5). An average of 65, 56, and 68% of unhydrolyzed <sup>14</sup>C-sulfometuron remained after 28 days incubation in distilled water at pH 5, 7, and 9, respectively. Two breakdown products were also detected, Sulfometuron-metabolite I ( $R_f = 0.25$ ) and Sulfometuron-metabolite II, which remained at the origin ( $R_f = 0$ ). Sulfometuron-metabolite I may be methyl 2-(aminosulfonyl)benzoate and Sulfometuron-metabolite II could be saccharin, which are the major degradation products of sulfometuron (Harvey *et al.*, 1985); however, these compounds were not investigated further in this study. Degradation to more polar materials was indicated because the amount of original <sup>14</sup>C extracted into acetonitrile decreased from an average of 104 to 73% after 1 and 21 days, respectively.

These findings disagree with those of Harvey *et al.* (1985) who found that sulfometuron stability in water was markedly influenced by pH. Only 22% of the original <sup>14</sup>C-sulfometuron remained after 30 days at pH 5 compared to 87 and 91% at pH 7 and 9, respectively, in their studies. The reasons for the difference in findings between this study and those of Harvey *et al.* are not known. Both experiments were conducted at room temperature and used distilled water to dissolve <sup>14</sup>C-sulfometuron. One difference was this study used acetonitrile to extract <sup>14</sup>C-sulfometuron from solution, while Harvey *et al.* (1985) used methylene chloride. Also, they conducted the study using a much higher sulfometuron concentration (5 µg L<sup>-1</sup>).

Sulfometuron was degraded more rapidly under ultraviolet light than in the dark and in distilled compared to river or well water (Table 6). Although there was little evaporation of water (<5%) from the irradiated samples, there was considerable loss of <sup>14</sup>C-material. The half-life of <sup>14</sup>C-sulfometuron in the distilled, river, and well water samples was 37, 33, and 22 d, respectively, when exposed to ultraviolet light compared to an average of 65 days for samples stored in the dark. There was an average radioactive material loss of 31 and 18% for irradiated and nonirradiated samples, respectively.

**Table 5. Sulfometuron hydrolysis in distilled water at three pH levels.**

Incubation time	pH compound <sup>1</sup>								
	5			7			9		
	Sulf.	Met. I	Met. II	Sulf.	Met. I	Met. II	Sulf.	Met. I	Met. II
d	%								
0	98	0	0	99	0	0	98	0	0
1	86	18	3	83	19	3	83	14	3
3	84	11	3	78	11	3	72	6	3
7	82	15	3	80	16	3	81	9	3
14	83	12	3	84	12	3	84	8	3
21	63	5	3	64	5	3	68	3	3
28	65	8	3	56	8	3	68	5	3
LSD									
(0.05)	12	8	NS	12	8	NS	12	8	NS
Regression	Y = 7.88 + 1.053x‡			(R <sup>2</sup> = 0.79)			Half-life = 40 d		

†Sulf. = <sup>14</sup>C-sulfometuron, Met. I = Sulfometuron-metabolite I (Rf = 0.25), and Met. II = Sulfometuron-metabolite II (Rf = 0).

‡ Rate of sulfometuron hydrolysis: x = days after treatment; Y = amount hydrolyzed.

The major nonvolatile breakdown product in the irradiated sample was Sulfometuron-metabolite I, which averaged 11 and 2% in the irradiated and nonirradiated samples, respectively, after 28 days (Table 6). Sediment in the river water appeared to have little effect on sulfometuron breakdown compared to well water, but photolysis was fastest in distilled water.

These findings are similar to those of Harvey *et al.* (1985), except sulfometuron photolysis was more rapid in their study. Nearly all the <sup>14</sup>C-sulfometuron was degraded in 7 to 14 days under the conditions of their experiment. This was probably because they used a more intensive ultraviolet source than used in this study.

These results indicate that sulfometuron at 140 g ha<sup>-1</sup> or less applied to soils with a pH of 7.0 or less has little potential for movement into groundwater. However, considerable sulfometuron movement may occur when surface applied to saturated soils with a pH above 7.0 or if heavy precipitation is received in a short time span. Many soils in North Dakota have a pH of 7.0 or greater but the average annual rainfall is 41 cm or less. Sulfometuron degradation is nearly twice as rapid when exposed to ultraviolet light than in the dark. The expected sulfometuron rate to control leafy spurge is 88 g ha<sup>-1</sup> or less (Lym and Messersmith, 1990). Thus, the potential for ground water contamination from sulfometuron applied for leafy spurge control should be minimal. Less sulfometuron movement should occur under actual field conditions than were observed in this study.

**Table 6. Sulfometuron photolysis in three water sources.**

Water source	pH	Time	Light source compound <sup>†</sup>					
			Ultraviolet			None		
			Sulf.	Met. I	Met. II	Sulf.	Met. I	Met. II
		d	%					
Well	8.3	1	88	2	7	92	2	5
		3	88	3	6	84	2	9
		7	81	4	12	84	3	11
		14	71	5	8	82	2	5
		21	69	6	4	72	3	8
		28	56	8	7	79	2	4
Regression			Y = 7.27 + 1.16x‡ (R <sup>2</sup> = 0.80)			Y = 8.24 + 0.66x (R <sup>2</sup> = 0.63)		
Half-life			(37 d)			(63 d)		
River	7.2	1	89	3	7	88	2	8
		3	84	3	12	84	3	11
		7	73	5	10	81	3	6
		14	66	8	6	82	2	4
		21	62	7	4	70	3	9
		28	50	9	7	69	2	4
Regression			Y = 9.36 + 1.22x (R <sup>2</sup> = 0.69)			Y = 8.74 + 0.88x (R <sup>2</sup> = 0.79)		
Half-life			(33 d)			(47 d)		
Distilled	6.0	1	87	3	7	91	2	7
		3	91	3	4	86	3	11
		7	83	6	8	90	3	8
		14	65	9	9	89	2	2
		21	55	12	6	73	3	11
		28	40	17	10	79	2	5
Regression			Y = 5.55 + 2.03x (R <sup>2</sup> = 0.93)			Y = 6.36 + 0.51x (R <sup>2</sup> = 0.62)		
Half-life			(22 d)			(85 d)		
LSD (0.05)			6	3	NS	6	NS	NS

†Sulf. = <sup>14</sup>C-Sulfometuron; Met. I = Metabolite I (R<sub>f</sub> = 0.25); and Met. II = Metabolite II (R<sub>f</sub> = 0).

‡Rate of sulfometuron hydrolysis; x = days after treatment, Y = amount hydrolyzed.

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