

FATE OF AERIALY APPLIED HEXAZINONE
IN PRE-EMERGENCE SITE PREPARATION
IN A NEW BRUNSWICK FOREST

By

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ABSTRACT

A clearcut site near St. Leonard, New Brunswick was treated with hexazinone, 3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione, at 3.1 and 3.8 kg ai/ha by a fixed wing aircraft equipped with a conventional boom and nozzles. On-target deposit at soil plots was highly variable, averaging 2.53 kg/ha with 37% CV. Off-target drift monitored with 400 cm² deposit plates decreased rapidly to 0.006 kg/ha at 70 and 100 m downwind. In spiked soil trials, recovery varied with concentration and residue, with means ranging from 91.5 - 98.3%, 62.9 - 88.6% and 101.4 - 104.2% for hexazinone and its metabolites A, 3-(4-hydroxycyclohexyl)-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione and B, 3-cyclohexyl-6-(methylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione, respectively. Hexazinone recovery in fresh and air-dried samples of spiked humus soils was 114 and 110%, respectively. A consistency of 6.9% CV for hexazinone subsampling, extraction and analysis was determined from 50 homogenized air-dried soils. Log-log hexazinone residue disappearance relationships with time (up to 537 days after application) were found with correlation coefficients of the means ranging from $r = -0.83$ to -0.87 , with 5% of the initial residue calculated to remain after 118 and 97 days for upper (0-15 cm) and lower (15-30 cm) soil layers, respectively. Hexazinone leaching to the lower soil layer was dependent on rainfall. Residue value reporting formats $\mu\text{g/g}$, $\mu\text{g/mL}$ and kg/ha were compared. Initial off-target residue values in soils reflected the off-target drift rate from application. Lateral residue movement at stations 10 and 20 m downslope (5%) was found from 6 to 61 days after application. Lateral residue movement to 50 m downslope was found in the first two weeks. Hexazinone residues were detected in streamwater throughout the 45 day period that runoff in 6 storm events was monitored. Residues decreased both with time after application (from 30.8 to 3.7 ppb at 6 and 45 days, respectively, 50 m downstream) and with distance downstream (lower residues values 800 m and not detected 1500 m downstream).

INTRODUCTION

Registration of hexazinone for Canadian forestry application is incomplete: a temporary registration has been in effect since 1984. Unlike the other two fully registered forestry herbicides in Canada (2,4-D and glyphosate), hexazinone useage is restricted to ground application only for conifer release and site preparation prior to reforestation (Reynolds et al. 1986). Study of the behavior of hexazinone in the Canadian forest environment is required before full registration may be granted, owing to different environmental conditions prevailing where many studies were conducted, including temperatures, soil types and precipitation patterns (rainfall/snow), and the use strategies intended (e.g. pre-emergence aerial application for site preparation).

Registration of existing herbicides for forestry use in Canada has focused on efficacy and environmental protection. The validity of laboratory-generated models in predicting the herbicide movement and fate in ecosystems required verification with systematic field evaluation (Neary et al. 1983). The persistence and mobility of hexazinone in soils was found to be dependent on soil type and climate. Field soil studies reported in the USA and elsewhere indicated that hexazinone has a half-life of between 1 and 6 months (Rhodes 1980; WSSA 1983), and the potential for off-site movement of at least 2 m down a 12-22 degree slope (Barring and Torstensson 1983; Harrington et al. 1982). Herbicide movement in water from application with a pelleted form of hexazinone (Velpar Gridball) was also studied. In a stream oversprayed by hexazinone pellets, water-borne hexazinone decreased to less than half of the initial concentration within 1 hour after application at a point adjacent to the treated area (Miller and Bace 1980). When stormflow and baseflow were monitored through 26 storm events in a 13 month period, 0.53% of the hexazinone applied was calculated as lost through runoff (Neary et al. 1983). And in another study, no residues were found in groundwater and springflow beyond 20 m from the treated area (Neary 1984).

The specific objectives of this study were to:

- 1) determine hexazinone deposit on the forest floor and its persistence and leachability in New Brunswick loam soils,
- 2) determine the off-site mobility of hexazinone in soil on a slope,
- 3) monitor the off-site movement of hexazinone in snowmelt, baseflow and stormflow,
- 4) measure the off-target drift deposit from aerial application,
- 5) measure the occurrence and disappearance of two primary metabolites A and B.
- 6) establish a new reporting method for hexazinone residues in soil on an area (kg/ha) basis to provide direct comparison with the rate of application.

MATERIALS AND METHODS

Experimental Site Description

Two 3.7 ha experimental plots were located on J.D. Irving property near St. Leonard, in the northwest corner of New Brunswick. The former northern hardwoods site was clearcut in 1980-81. Prior to herbicide treatment, the few scattered residual snags (10-20 m tall) were felled to allow accurate aerial application. The dominant weed species was raspberry [*Rubus idaeus* L. var *strigosus* (Michx.) Maxim.]. Other brush species included pin cherry (*Prunus pensylvanica* L.f.), striped maple (*Acer pensylvanicum* L.), mountain maple (*A. spicatum* Lam.), red maple (*A. rubrum* L.) and sugar maple (*A. saccharum* Marsh.). The intended crop species for planting was white spruce [*Picea glauca* (Moench) Voss]. Naturally regenerated balsam fir (*Abies balsamea* (L.) Mill) were also observed on the site.

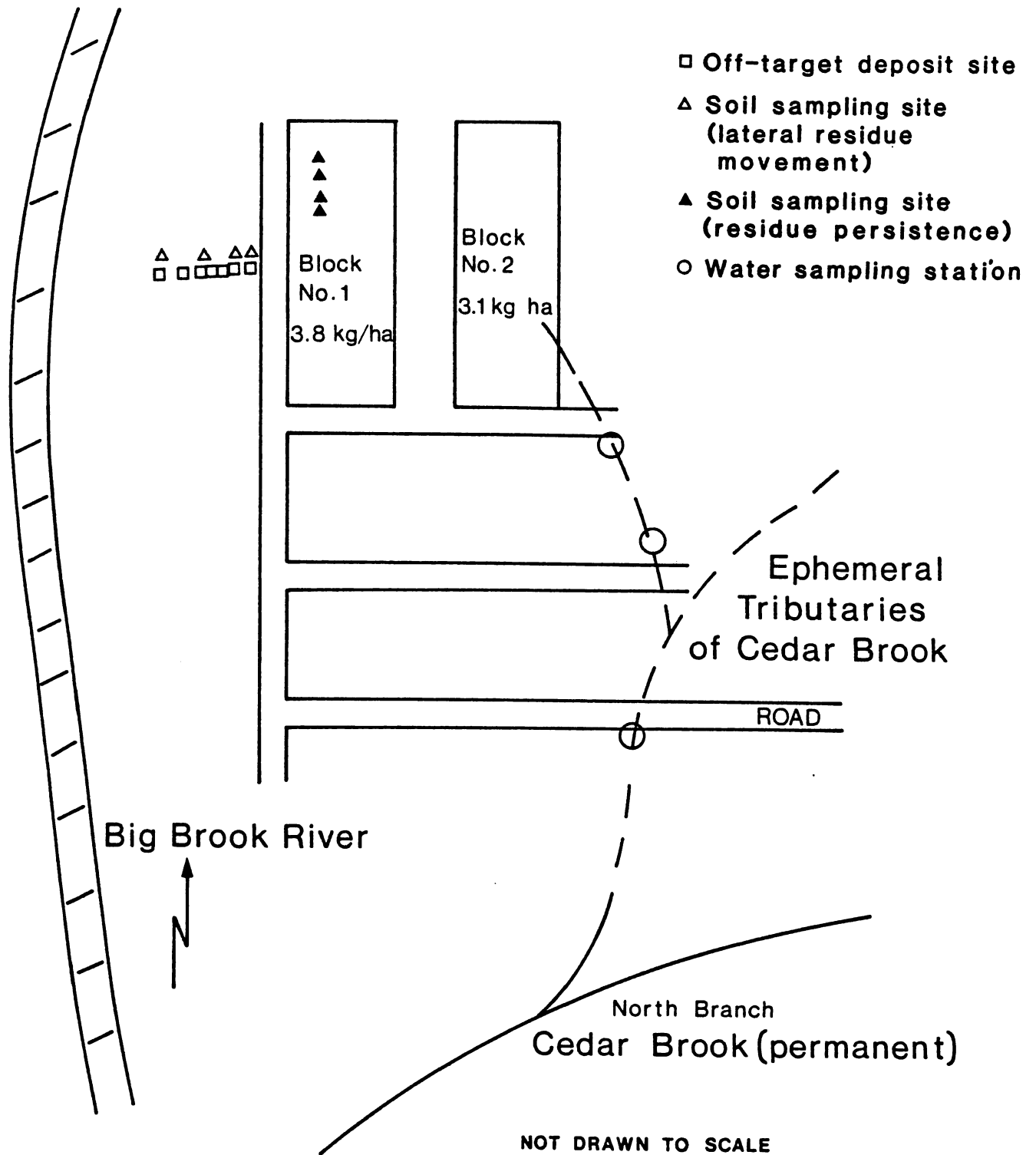
The experimental site was generally flat and located within two drainage systems. Spray Block No. 1 drained to the west directly into Big Brook River (Fig. 1). The surface gradient was 5% for the first 150 m west of Block No. 1 and before the clearcut boundary, then 10-20% for the remaining 350 m of uncut buffer to the river. Average vegetation heights were less than 0.5 m and at a uniform 15 m in the clearcut and uncut areas, respectively. Off-target

deposit stations and lateral residue movement plots were located on the 5% portion of the slope (Fig. 1) on an old logging road about 10 m wide and 1 m below ground level, perpendicular to the middle of the western edge of Block No. 1. Off-target deposit stations were at distances of 5, 10, 20, 30, 40, 50, 75 and 100 m, and soil plots for lateral residue movement studies were at 10, 20, 50 and 100 m downslope. Five more off-target deposit stations were established in the opposite direction from the eastern boundary of Block No. 1 at distances of 10, 20, 30, 40 and 50 m as a backup for the main site in case the wind direction changed unfavourably. Four soil plots for monitoring herbicide residue persistence and leaching were within spray Block No. 1. The plots were located in the first spray swath, about 50 m apart in the upper portion of the spray block. Overland flow from snowmelt was absent at the time of herbicide application. Spray Block No. 2 drained to Cedar Brook through ephemeral stream channels which flowed only during snowmelt and spring storm events (Fig. 1). Water sampling stations were established along these stream channels at 50, 800 and 1500 m downstream from the southeastern corner of Block No. 2 to monitor herbicide runoff. The 50 m station collected snowmelt runoff from Block No. 2, observed at the time of herbicide application. Water samples from the 800 m station were collected from a 20 cm deep pool (0.5 m diameter), and those from the 50 and 1500 m stations were sampled on the downstream (south) side of road culverts. The loam soils of this area contained about 4% organic matter and had a pH of 5.2.

Herbicide Application

The two spray blocks (84 x 445 m each, separated by a 50 m buffer) (Fig. 1) were treated on 19 May 1984 with hexazinone (Velpar L at 240 g ai/L) at 3.8 kg ai/ha and 3.1 kg ai/ha for blocks No. 1 and 2, respectively. Hexazinone was aerially applied at 88 L/ha and 96 L/ha for blocks No. 1 and No. 2, respectively, using an AIRFOIL boom with 66 WHIRLJET 1/8 B-10 No. 3 conetip nozzles (32 +tips, 34 -tips) set at 180 degrees, and a fixed wing aircraft (Turbo Thrush Commander). The plane flew 193 km/h at an 18 m elevation.

Figure 1. Study site locations near St. Leonard, New Brunswick.



Application was completed with 5 longitudinal swaths per plot. Flags were used for marking the location of individual swaths.

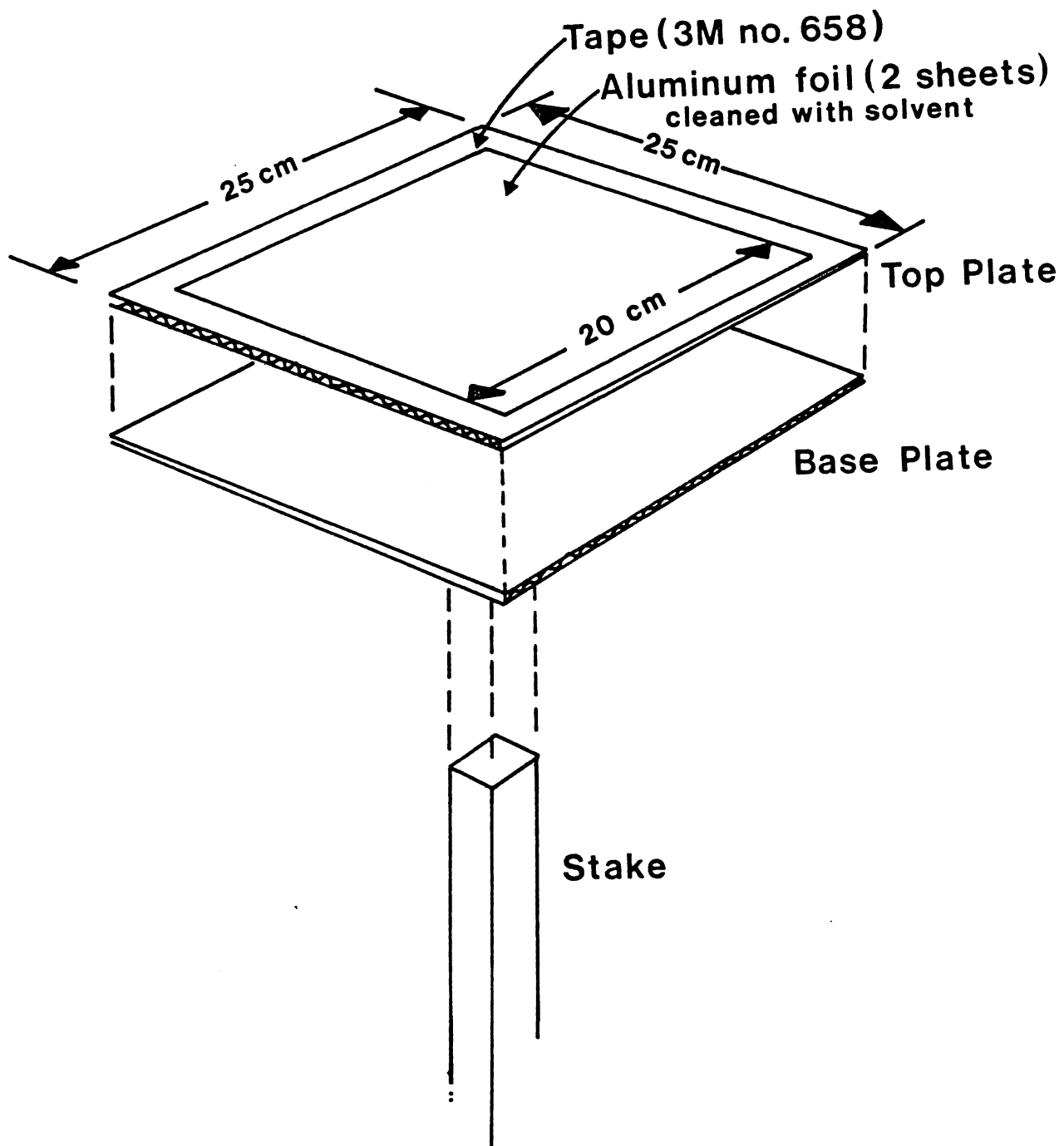
The sky was clear at the time of application, with 2 mm of rain two days prior to and after, and 27 mm of rain 5 days after treatment. An east wind (3-5 km/h) blew during treatment of Block No. 1, and a west wind of the same speed during treatment of Block No. 2. Relative humidity (64%) and air temperature (15°C) were recorded during application in a field weather station.

On- and Off-Target Deposit

Deposit collectors, consisting of upper collection and lower base plates were constructed (Fig. 2). The plates were of corrugated cardboard 25 x 25 cm. The upper plate was lined with two layers of aluminum foil sheets (22 x 22 cm), prewashed with methanol and taped on the edges, leaving an untaped collection surface of 20 x 20 cm (Feng and Klassen 1986). The two plates were taped together after a carpet tack was used to secure the lower base plate onto the station stake. The deposit plates were placed 10 cm above the ground in clearings surrounded by a few scattered pieces of slash, and shrub vegetation bare of foliage and less than 1 m in height. Eight main off-target drift deposit stations were located west of treatment Block No. 1 with five supplementary stations in the east as described above. Sixteen on-target deposit stations were at the locations of 4 soil plots, with collectors on the 4 sides of each plot. One station was in line with an off-target deposit station.

Deposit samples were packaged about 30 min after herbicide application when the collection surfaces were dry. Clean vinyl disposable gloves and forceps were used for removing the tape from the aluminum foil collection surfaces. Care was taken so that no contaminated articles contacted the aluminum foil sheets. The upper sample sheets were folded and then wrapped with the lower sheets before being placed in labelled plastic bags (25 x 40 cm) (Feng and Klassen 1986). Samples were cooled in an ice chest immediately after collection. Temperatures were maintained near 0°C during shipping from the field freezers (-5°C) to the

Figure 2. Assembly of a plate deposition collector.



analytical lab in Sault Ste. Marie, Ontario, using insulated commercial coolers and a covering of frozen cooler packs.

Soil Sampling

Preparations for soil sampling included removal of slash and large debris from the soil plots. Vegetation was trimmed down to about 1 cm above the ground inside and to 0.5 m outside of each plot to allow full herbicide deposition on the ground to generate a "worst case" scenario. Disturbance to the forest floor was kept to a minimum.

One soil core was collected at each of the 4 residue persistence plots (16 m²) and the 4 lateral residue movement sites 1 day before and 1 hour, 3, 6, 13 days, 1, 2, 3, 4, 5, 6, 12, 18 months after treatment. Soil cores were taken with a Campbell soil auger (9.2 cm diameter) (Fig. 3), and divided into subsamples, separating soils 0-15 cm from soils 15-30 cm below the surface, and further dividing humus from mineral soils within each 15 cm core layer whenever applicable. Sampling and packaging techniques were similar to those described by Feng and Klassen (1986). Samples were immediately cooled and kept in ice-filled coolers (Coleman) after collection, and frozen (-5°C) within 8 hours. Temperature of the samples were maintained near 0°C in commercial coolers during shipping to the analytical laboratory. Prior to analysis, the samples were maintained at -14°C at the analytical laboratory.

Water Sampling

Runoff water samples were collected at the three stations described above one day before treatment and with collection times selected to correspond with the major rain events immediately following treatment. Five storm events were sampled in a 45-day period between May 25 and July 3, 1984. Between storm events, water samples were collected in periods at 3, 7 and 14 days post-storm event and before the start of the next storm event. Samples were taken by collecting approximately 900 mL in 1 L polypropylene bottles prewashed with methanol. Samples were cooled immediately in an ice-filled cooler and frozen (-5°C) within 2 hours after

collection. Shipping to, and storage at, the analytical laboratory was similar to that for the soil and deposit samples described above.

Sample Preparation

Deposit Samples: Hexazinone residues on the deposit collectors were extracted from the aluminum foil with a procedure described by Feng and Klassen (1986) and summarized as follows. The aluminum foil was initially rinsed with 150 mL of extracting solution (acetone/water; 80:20; V/V) then cut into strips, sonicated (3 min) and shaken (3 min) on a reciprocating shaker with 3 x 150 mL extracting solution in a Teflon bottle (Fig. 4). The rinse and washings were pooled and flash-evaporated in a rotary evaporator under reduced pressure at 60°C until only the aqueous phase (100 mL) remained. Residues were extracted by partitioning with 3 x 100 mL ethyl acetate, and passed through a 30 g anhydrous sodium sulfate column, which was pre-washed with ethyl acetate. The extracts were either diluted with ethyl acetate or concentrated using a vacuum rotary evaporator and a N-Evap (Organomation model III) to 10-2500 mL before gas chromatographic (GC) analysis.

Soil Samples: Soil core sections were prepared for extraction by weighing, air-drying (to 5% moisture content), homogenizing and sieving (2 mm mesh) the soils, as described by Feng and Klassen (1986). Total weights of fresh samples, air-dried samples and pebbles (>2 mm diameter) contained in the samples and discarded later, were measured. The weights were used for the calculation of moisture content and net soil weight, used for residue data transformation from ($\mu\text{g/g}$) to area (kg/ha) and volumetric (mg/L) bases (Feng and Klassen 1986). The processed soils were also used to determine soil texture and chemical properties.

Hexazinone residues were extracted and purified based on Holt's (1981) method. Holt's method was modified to prevent fine clay particles from entering the filtrate before cleanup by liquid/liquid partition, and formation of precipitates in the final concentrates during cold storage. The method was also simplified by avoiding chromatographic column cleanups and derivatization by trifluoroacetic anhydride that created unstable (8h) final products and a

wide range of percent recovery (64-124% in soils). The modified method is briefly summarized as follows. An aliquot of 25 g processed air-dried soil was weighed in a 250 mL Nalgene bottle (Nalge 2107), wetted with 15 mL of distilled water, capped tightly and shaken horizontally for 15 min on an Eberbach reciprocating shaker at 280 excursions per minute. Sixty mL of acetone was then added. After being shaken for another 15 min, the sample was centrifuged at 350 x g (1150 rpm, rotor radius 23.8 cm) for 10 min. The extracts were filtered through a Millipore Filter Apparatus (47 mm) with Mitex disc filters (5 μ m, Millipore LSWP 04700) under reduced pressure. Soils were extracted twice more, each with 75 mL of an acetone-water solution (80:20; v/v), 2 min of agitation and 10 min of centrifugation similar to that described above. The extracts were filtered through the same apparatus described above, combined with the first extract, and the acetone was flash-evaporated in a vacuum rotary evaporator at 60°C. The remaining aqueous solution was washed and extracted with 3 x 50 mL of n-hexane and 3 x 75 mL of chloroform, respectively. Chloroform extracts were combined, passed through anhydrous sodium sulfate, and flash-evaporated to dryness. The residues were re-dissolved in 50 mL of acetonitrile and washed twice each with 50 mL of n-hexane. The acetonitrile phase was flash-evaporated to dryness. The residues were finally dissolved in 2-10 mL of ethyl acetate and filtered with Millex SR (0.5 μ m) filter units (Millipore SLSR 025NB) before GC analysis. After preliminary analysis, if a concentrated sample extract contained more than twice the concentration than that in the mix-standard solution (see Gas Chromatography), the sample extract was diluted to near the concentration of the mix-standards and was re-analyzed.

Water Samples: Hexazinone residues in 500 mL water samples were extracted by partitioning three times each, with 200 mL ethyl acetate. The amount of ethyl acetate used in partitioning was proportionally increased when larger volumes of water sample were to be extracted. The extracts were pooled and concentrated by using a vacuum rotary evaporator and a N-Evap to 2-10 mL before GC analysis.

Gas Chromatography

Purified sample concentrates in ethyl acetate were analyzed alternatively with mix-standard solutions containing 2.5, 5.0 and 10.0 ppm of hexazinone and metabolites B and A, respectively, on a Varian VISTA 6000 GC equipped with a thermoionic specific detector (TSD) and a VISTA data system (DS402). The specific gas chromatographic conditions were as follows: chromatographic column: 60 cm glass, 2 mm i.d., packed with 10% SP2250DA on 100/120 Supelcoport, and with Acid-treated glasswool plugs.

temperatures: Injector - 260°C; Detector - 300°C; Column

Temperature Program - 240°C (2.5 min) - 10°C/min - 280°C (3.5 min).

gas flow rates: N₂ (Linde, UHP grade) - 33 mL/min; H₂ (Linde, prepurified) - 4.5 mL/min; air (Linde, zero gas grade) - 175 mL/min.

Retention times under these GC conditions were 2.6, 3.5 and 5.5 minutes for hexazinone and its metabolites B and A, respectively. Peak heights were used for the calculation of residue concentration. When a sample injected showed more than 5 ppm of hexazinone, the sample was diluted to near 2.5 ppm with ethyl acetate, and re-analyzed. The average of two corresponding peak heights (i.e. hexazinone) was obtained from a mix-standard solution analyzed immediately prior to and after sample analysis. A $\pm 10\%$ margin (rejection threshold) from the average value (hexazinone) was calculated for the acceptance or rejection of the sample analysis. When the difference between the average value and either one of the standard peaks (hexazinone) was less than 10% of the average value, the average value was accepted and used proportionally in calculating the residue concentration in the sample. When the difference was greater than 10% of the average value, the sample analysis was rejected. Alternate analyses of standard solution and the sample were repeated sequentially for at least 3-4 times until the standard peak height stabilized. The average value of the two standard peak heights was then used proportionally in calculating the residue concentration in the sample.

RESULTS AND DISCUSSION

On-Target Deposition

Hexazinone deposition averaged 2.53 kg ai/ha at 16 stations monitored in the target area, accounting for 66.3% of the planned application rate. The high variation of deposit values (37% CV or coefficient of variation) (Table 1) indicated that the type of aerial dispersal system used gave an uneven application under the given operational conditions. Variation was also high at collection stations clustered around soil plots, with averages (n=4) of 2.94 (40% CV), 2.21 (42% CV), 1.99 (45% CV) and 2.98 kg/ha (18 % CV) for soil plots 1, 2, 3 and 4, respectively (Table 1). Hexazinone's metabolites A and B were not detected in any of the 16 samples, indicating that appropriate sample handling and storage techniques were followed.

Table 1. Hexazinone deposited at treated soil plots as indicated by plate deposition collectors (400 cm²)

Replication	Hexazinone (kg/ha)				Total
	Plot 1	Plot 2	Plot 3	Plot 4	
1	2.78	3.47	1.47	2.54	
2	4.65	1.52	1.72	2.55	
3	2.24	1.52	1.44	3.61	
4	2.11	2.34	3.33	3.23	
Mean	2.94	2.21	1.99	2.98	2.53
CV	40%	42%	45%	18%	37%

Off-Target Drift Deposit

Wind direction at the time of application was from the east, conducive for monitoring off-target deposit at the main site on the western side of the spray block. The alternate drift site on the eastern side of the spray block was abandoned. Hexazinone deposition 10 m within the treated zone was 2.43 kg ai/ha, or 63.6% of the planned application rate. This deposition value was slightly lower (96%) than the average deposition from the same spray swath at the soil plots (2.53 kg/ha) about 80 m north. Off-target deposit decreased rapidly with distance, from 9720 to 25.3 μ g per deposition plate at 10 m within and 100 m downwind of the treated zone, respectively (Table 2). Linear regression analysis indicated a log-log relationship for deposit and distance downwind, $\log Y = 2.47 - 2.33 (\log X)$ for Y = hexazinone deposited (kg/ha) and X = distance downwind (m). Data values fit very closely to the linear regression curve, with a significant correlation coefficient (r) of -0.97. The coefficient of determination (r^2) indicated the regression equation accounted for 94% of the variation in data values. Extinction rates calculated from the regression equation indicated 50, 10, 1 and 0.5% of full hexazinone deposition (2.43 kg/ha) would be expected at 10.6, 21.1, 56.7 and 76.2 m downwind, respectively.

Table 2. Hexazinone drift deposit at downwind distances by aerial application with conventional boom and nozzles

Downwind* Distance (m)	Hexazinone Residues	
	Per Plate (μ g) **	Calculated (kg/ha)
-10	9720	2.43
10	3410	0.85
20	1236	0.31
30	725	0.18
40	266	0.067
50	203	0.050
75	24.1	0.006
100	25.3	0.006

* Wind speed (3-5 km/h); relative humidity (64%); air temperature (15°C).

** Detection limit was 0.25 μ g per plate.

Recovery of Hexazinone in Soils

In spiked soil trials, recovery varied with concentration and with residue analyzed. Percent recovery of hexazinone and its metabolites A and B from soil spiked at 1,4 and 2 µg/g were 98.3%, 88.6% and 104.2%, respectively (Table 3). When the soil was spiked with lower hexazinone concentrations at 0.1, 0.4 and 0.2 µg/g, recoveries were 91.5%, 62.9% and 101.4%, respectively (Table 3). Subsequent soil residue values were adjusted for recovery by the appropriate recovery values.

Table 3. Percent recovery of hexazinone and its metabolites A and B from spiked soil samples

Replication	Percent Recovery		
	Hexazinone	Metabolite-A	Metabolite-B
Spiked Conc.	(1 µg/g)	(4 µg/g)	(2 µg/g)
1	103.7	94.2	108.8
2	100.4	91.6	104.2
3	96.3	88.9	101.8
4	100.7	93.9	108.4
5	77.5	74.0	84.3
6	108.1	100.9	116.2
7	97.7	104.6	107.3
8	99.1	60.1	97.6
9	101.1	89.5	109.0
Mean ± SD	98.3 ± 8.5	88.6 ± 13.7	104.2 ± 9.1
Spiked Conc.	(0.1 µg/g)	(0.4 µg/g)	(0.2 µg/g)
1	101.6	55.6	102.7
2	82.8	72.4	87.1
3	82.4	52.9	89.2
4	89.7	63.0	99.3
5	94.9	66.9	105.8
6	96.0	59.1	99.0
7	93.4	70.2	127.0
Mean ± SD	91.5 ± 7.1	62.9 ± 7.4	101.4 ± 13.2

Hexazinone Recovery Through Air Drying

Recovery of hexazinone from soil samples spiked prior to air drying was measured to determine whether degradation occurred during drying. Dao et al. (1982) found that air drying field samples did not modify soil properties nor the adsorption capacity of soils. When frozen samples were air dried in this study, the rapid loss of 70% of the total moisture content in the first day minimized the possibility of microbial degradation of hexazinone in the samples. Further drying yielded an average 3.8% moisture content from an initial average 31.3% found in fresh field samples.

Recovery of hexazinone through air-drying soil was measured in 500 g humus with a 56% moisture content. The humus was thoroughly blended prior to and after application of hexazinone by the Ontario Ministry of Natural Resources Lab in Maple, Ontario, at 0.5 kg ai/ha to a 5 cm layer. Samples were in transit for 2 days (0°C) as described by Feng and Klassen (1986), and held in cold storage (-14°C) for one month prior to analysis. One half of the sample (250 g) was air-dried for 3 days, then homogenized, as described by Feng and Klassen (1986). Four aliquots each of wet (25 g) and dried (15 g) soil samples were analyzed for hexazinone recovery. Bulk densities were measured for both wet and dried samples to enable values to be reported in different formats. Bulk density data permitted the conversion from traditional residue reporting on a weight basis ($\mu\text{g/g}$) to either a volumetric ($\mu\text{g/mL}$) or an area (kg/ha) basis. The latter reporting format allowed direct comparison between samples of different porosity or composition. Air drying trial recovery results were reported in all three bases ($\mu\text{g/g}$; $\mu\text{g/mL}$; kg/ha) to illustrate the benefits of the new reporting format. Results (Table 4) indicated that the air-drying procedure described by Feng and Klassen (1986) provided a superior residue value consistency (4% CV) than analysis of wet soils directly (33% CV). Results also indicated that there was no loss of hexazinone through air-drying (110% recovery) compared to the wet samples (114% recovery) (Table 4).

Table 4. Hexazinone recovery in fresh and air-dried samples from spiked (0.5 kg/ha) humus soils

Replication	Hexazinone Residues					
	Wet Soil			Air-Dried Soil		
	µg/g	µg/mL	kg/ha	µg/g	µg/mL	kg/ha
1	1.03	0.93	0.46	2.54	1.11	0.56
2	1.11	0.99	0.50	2.58	1.13	0.57
3	1.06	0.95	0.47	2.45	1.07	0.54
4	1.90	1.70	0.85	2.38	1.05	0.52
Mean	1.28	1.14	0.57	2.49	1.09	0.55
CV	33%	33%	33%	4%	4%	4%
Recovery			114%			110%

The overall consistency of procedures used for subsampling, residue extraction, cleanup, and analysis by gas chromatography was examined. Fifty replicated subsamples from a homogenized air-dried mineral soil were individually processed and analyzed. Results (Table 5) indicated high reproducibility, with a mean hexazinone residue concentration of 0.84 µg/g, 6.9% CV and a range of 0.66 - 0.95 µg/g. The modifications made in this study to Holt's (1981) procedures for extraction and analysis improved both simplicity and reproducibility.

Hexazinone Residue Persistence and Leaching in Soils

Hexazinone residue concentrations measured in soils at 0-time (1.99 kg/ha) were 79% of that indicated by on-target deposition collector plates (2.53 kg/ha) and 52% of the planned application rate. The unexpectedly low residue values in the soil were probably from residue loss during handling or shipping. Recovery trials described in the previous section indicated that thoroughly blended fresh humus soils at 56% moisture content could be handled and stored with no residue loss. However, the concentrated nature of residues in a thin surface layer containing all or most of the residue applied may be the cause of the apparent residue loss when in contact with the inner wall of the sample bags. The vulnerability of these high

Table 5. Consistency of hexazinone subsampling, extraction and analysis from homogenized air-dry soils collected in a field trial

Replication	ppm ($\mu\text{g/g}$)	Replication	ppm ($\mu\text{g/g}$)
1	0.823	26	0.856
2	0.834	27	0.831
3	0.831	28	0.859
4	0.862	29	0.854
5	0.833	30	0.878
6	0.868	31	0.758
7	0.830	32	0.804
8	0.887	33	0.844
9	0.738	34	0.835
10	0.814	35	0.784
11	0.834	36	0.658
12	0.873	37	0.731
13	0.918	38	0.769
14	0.818	39	0.790
15	0.947	40	0.806
16	0.935	41	0.806
17	0.792	42	0.820
18	0.788	43	0.953
19	0.896	44	0.838
20	0.823	45	0.815
21	0.851	46	0.834
22	0.910	47	0.931
23	0.796	48	0.901
24	0.779	49	0.913
25	0.840	50	0.887

Mean \pm SD (% CV) = 0.838 ± 0.058 (6.9%) (n = 50)

Range: 0.658 - 0.953

residue concentrations in the surface layer would probably persist until a rainfall initiated leaching into lower layers. In this study, rainfall occurred prior to the soil collection on day 6, but samples from day 3 may have incurred similar losses as those from 0-time. To avoid potential residue losses through contact with sample bags in future 0-time samples, the following procedure is recommended:

- 1) Half-fill a set of glass jars (5 cm deep and 10 cm diameter) with pre-spray soils obtained from the field.
- 2) Expose the jars to herbicide application at the soil plots.

- 3) Re-fill the jars to the top with pre-spray soils and seal the jar with a glass cover.
- 4) Weigh the whole sample and calculate the bulk density to enable the residues analyzed in $\mu\text{g/g}$ to be converted to kg/ha to directly compare with the deposition or application rates.

Hexazinone residues disappeared rapidly from the upper 15 cm layer (Table 6). Log-log residue disappearance relationships were found in the upper layer (Appendix 3, 4):

a) $\log Y = 0.207 - 0.533 (\log X)$

where: Y = residues (kg/ha) and X = days after application with $r = -0.87$ and $r^2 = 0.76$.

b) $\log Y = 0.133 - 0.511 (\log X)$

where: Y = residues ($\mu\text{g/g}$) and X = days after application with $r = -0.86$ and $r^2 = 0.75$.

Hexazinone residue leaching into the lower 15-30 cm soil layer was indicated by the 6th day after application, after the first rainfall (Table 6). Log-log residue disappearance relationships were found in the lower layers (Appendix 3, 4):

a) $\log Y = 0.256 - 0.581 (\log X)$

where: Y = residues (kg/ha) and X = days after application with $r = -0.85$ and $r^2 = 0.73$.

b) $\log Y = 0.137 - 0.569 (\log X)$

where: Y = residues ($\mu\text{g/g}$) and X = days after application with $r = -0.86$ and $r^2 = 0.74$.

Residue disappearance was calculated for the combined total of upper and lower soil layers. Residue values in different soil layers are additive in the kg/ha format, derived through bulk densities of the samples. A residue disappearance relationship was found for the total soil layers (Appendix 3):

$\log Y = 0.264 - 0.390 (\log X)$

where: Y = total residues (kg/ha) and X = days after application with $r = -0.83$ and $r^2 = 0.68$.

Residue values in the upper and lower layers are not additive in the $\mu\text{g/g}$ format and an extinction rate for their total could not be calculated.

Table 6. Hexazinone residue persistence and leaching in New Brunswick loam soils

Days* Post- Spray	Soil** Layer	Hexazinone		Metabolite A		Metabolite B		Cumulative Rainfall (mm)
		kg/ha	µg/g	kg/ha	µg/g	kg/ha	µg/g	
0	U	1.99±0.19	1.65±0.40	ND	ND	ND	ND	0
	L	ND	ND	ND	ND	ND	ND	
	T	1.99±0.19						
3	U	1.87±0.81	1.46±0.59	(0.26)***	(0.20)	ND	ND	2
	L	ND	ND	ND	ND	ND	ND	
	T	1.87±0.81						
6	U	1.44±0.44	1.30±0.21	0.09±0.01	0.08±0.01	(0.09,0.08)	(0.07,0.06)	29
	L	0.60±0.42	0.46±0.31	ND	ND	ND	ND	
	T	2.04±0.56						
13	U	0.67±0.12	0.58±0.06	(0.09)	(0.07)	(0.08)	(0.06)	113
	L	0.27±0.20	0.23±0.17	ND	ND	ND	ND	
	T	0.94±0.20						
31	U	0.52±0.28	0.52±0.36	(0.15,0.05)	(0.12,0.09)	(0.12,0.06)	(0.07,0.12)	172
	L	0.53±0.38	0.44±0.32	(0.16,0.08)	(0.10,0.08)	(0.15,0.09)	(0.09,0.09)	
	T	1.05±0.60						
61	U	0.14±0.10	0.12±0.09	ND	ND	ND	ND	344
	L	(0.13±0.14)	(0.09±0.10)	ND	ND	(0.08)	(0.06)	
	T	0.27±0.11						
87	U	0.10±0.04	0.11±0.09	ND	ND	(0.06)	(0.06)	419
	L	(0.17±0.12)	(0.12±0.09)	ND	ND	(0.11,0.09)	(0.7,0.08)	
	T	0.27±0.22						
122	U	0.09±0.09	0.07±0.04	ND	ND	(0.13)	(0.08)	465
	L	0.13±0.06	0.10±0.06	ND	ND	(0.09)	(0.07)	
	T	0.22±0.13						
157	U	(0.05±0.11)	(0.05±0.10)	ND	ND	ND	ND	539
	L	0.06±0.03	(0.06±0.04)	ND	ND	ND	ND	
	T	0.11±0.09						
361	U	(0.04±0.04)	(0.03±0.04)	ND	ND	ND	ND	Snow
	L	(0.05±0.06)	(0.05±0.05)	ND	ND	ND	ND	
	T	(0.09±0.07)						
453	U	ND	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	ND	
	T	ND						
537	U	ND	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	ND	
	T	ND						

* 0-time on 19 May 1984.

** U = Upper (0-15 cm); L = Lower (15-30 cm); T = Total (0-30 cm).

*** Values in () indicate less than four detectable values, otherwise n=4.

ND = Not Detectable; Limit of Detection = 0.03, 0.10 and 0.06 µg/g for hexazinone, metabolite A and B, respectively, and about 0.02 kg/ha for hexazinone.

Residue disappearance, calculated from the regression equation for upper and lower soil layers, indicated that 5% of the initial residue (2.53 kg/ha) would remain at 118 and 97 days after application, respectively. Actual data also suggested that in New Brunswick loam soil, hexazinone did not persist after 6 months, or one growing season (Table 6). Hexazinone's metabolites A and B were found in samples between 6 and 122 days after application, but in small quantities (Table 6).

The similarity of soil chemical properties and textures collected from the soil plots (Table 7) masked improvement in r and r^2 values for residue disappearance relationships generally offered by the kg/ha format. Only about 15% of the soil cores from the upper 15 cm layer contained an organic layer separable from mineral horizons. Bulk densities of organic layers may be highly variable. Differences in format results, with kg/ha showing greater consistency (Table 4) and therefore higher r and r^2 values, would be more pronounced if a variable organic layer is prevalent. High spatial variability of residues in field soils (Table 6) were also found in other studies and may be from both extrinsic and intrinsic sources (Rao and Wagenet 1985).

Table 7. Chemical properties and texture of New Brunswick loam soils

Layer	Upper (0 - 15 cm)		Lower (15 - 30 cm)		Total (0 - 30 cm)	
	Mean	SD	Mean	SD	Mean	SD
%N	0.125	0.023	0.142	0.080	0.135	0.059
%P	0.0012	0.0003	0.0022	0.0012	0.0018	0.0010
%K	0.0093	0.0040	0.0059	0.0032	0.0074	0.0037
pH	5.13		5.06		5.09	
CEC (meq/ 100g)	16.558	2.533	17.001	6.639	16.811	4.923
%OM	3.194	0.794	4.228	2.724	3.785	2.056
%Sand	47.4	1.8	48.2	2.6	47.9	2.2
%Silt	33.0	2.0	32.2	3.9	32.5	3.0
%Clay	19.6	2.1	19.6	2.2	19.6	2.0
number of replicates	3		4		7	

The moisture content of soils varied little during the 537 day sample schedule. The mean moisture content of the upper layer ($27.2\% \pm 5.9$) was very comparable to that of the lower layer ($27.9\% \pm 5.2$). A minor peak in moisture content in the upper layer was found on the 6th day after application after the first rainfall. Lower layer samples from the 6th day also contained the highest residue concentrations (0.6 kg/ha), indicating residue leaching during the first rainfall. Station No. 2 indicated the greatest leaching from the upper layer (1.06 kg/ha) to the lower layer (1.16 kg/ha) on the 6th day and also had the highest moisture content (41.7%) and no separable organic layer. These results related hexazinone residue leaching directly to the initial rainfall and to soil porosity, which restricts or inhibits the flow of soil water.

Off-Site Residue Movement Down a Slope

The 0-time residue concentrations in soil samples collected at distances off-target down a 5% slope reflected the rate of off-target drift from the aerial application. The extinction rates were similar but values were lower in soil samples (0.47, 0.13 and 0.03 kg/ha) than from deposition collectors (0.85, 0.31 and 0.050 kg/ha at 10, 20 and 50 m downwind, respectively (Table 2, 8). The lower soil residue values may be from residue loss through the sample bags as described in the previous section. A significant ($p < 0.05$) log-log extinction rate relationship ($\log Y = 1.36 - 1.70 \log X$) was found for 0-time where Y = residue in soils (kg/ha) and X = distance (m) downwind, with $r = 0.999$ and $r^2 = 0.998$.

Increased residue concentrations at off-target sites after the initial rainfall indicated some lateral hexazinone movement. The stations at 10 and 20 m down a 5% slope showed lateral hexazinone movement from 6 to 61 days after application (Table 8). Lateral hexazinone movement at 50 m downslope was found in trace amounts near the detection limit in the first two weeks. No residues were detected in soil samples from 100 m downslope at any time in the sample schedule. Downslope hexazinone residue movement was also observed in other studies (Harrington et al. 1982; Barrington and Torstensson 1983). Vertical hexazinone leaching

from the upper to lower soil layers also occurred in the off-target stations (Table 8). This vertical leaching suggests that soil samples collected only from surface layers may be insufficient to appropriately monitor residue runoff down a slope. Hexazinone metabolites A and B were not detected in any of the off-target samples. The limits of detection were 0.03, 0.10 and 0.06 $\mu\text{g/g}$ for hexazinone, metabolite A and B, respectively.

Off-Site Residue Movement in Stormflow and Baseflow (Snowmelt)

Six storm events were monitored for hexazinone residue in streamwater between 25 May and 3 July 1984. Hexazinone residue was found throughout the 45 day period and during each storm event (Table 9). Residues decreased to about 10% in samples collected at the station 50 m downstream from 30.8 ppb in the first storm event to 3.7 ppb in the 6th storm event. These findings were in agreement with those made by Neary et al. (1983; 1986), that residues in runoff peaked in the first storm after application. No metabolite A or B residues were detected in any of the water samples in this study. A lag time was indicated by the absence of detectable hexazinone (i.e. <0.5 ppb) in samples collected 800 m downstream during the first storm event and first day of the second storm event (Table 9). The magnitude of the second storm event (the largest with 84 mm rainfall) was probably required to generate sufficient flow to transport residues longer distances in the otherwise slowly flowing ephemeral stream. The flow in all six storm events was insufficient to transport hexazinone residue in detectable quantities to the station 1500 m downstream (Table 9). The duration of residue lateral movement in soils discussed in the previous section (6-61 days) roughly coincides with the period that samples were collected (and residues detected) in storm runoff.

The accuracy of analysis of hexazinone in water samples was demonstrated with the results of a spike-recovery trial. The recovery of 5 ppb hexazinone in water was $100.4 \pm 7.6\%$ at $n=4$.

Table 8. Lateral hexazinone movement (kg/ha) down a 5% slope

Days* Postspray	Soil** Layer	Off-Site and Downslope Distance				Cumulative Rainfall (mm)
		10 m	20 m	50 m	100 m	
0	U	0.47	0.13	0.03	ND	0
	L	ND	ND	ND	ND	
	T	0.47	0.13	0.03	ND	
6	U	0.74	0.20	0.05	ND	29
	L	0.31	0.07	ND	ND	
	T	1.05	0.27	0.05	ND	
13	U	0.49	0.21	0.11	ND	113
	L	0.21	0.34	ND	ND	
	T	0.70	0.55	0.11	ND	
31	U	0.66	0.21	0.04	ND	172
	L	0.36	0.22	ND	ND	
	T	1.02	0.43	0.04	ND	
61	U	0.38	0.06	0.02	ND	344
	L	ND	0.12	ND	ND	
	T	0.38	0.18	0.02	ND	
87	U	0.09	0.05	ND	ND	419
	L	0.12	0.14	ND	ND	
	T	0.21	0.19	ND	ND	
122	U	0.03	ND	ND	ND	465
	L	0.07	ND	ND	ND	
	T	0.10	ND	ND	ND	
157	U	0.05	ND	ND	ND	539
	L	ND	ND	ND	ND	
	T	0.05	ND	ND	ND	
361	U	0.05	0.07	ND	ND	Snow
	L	ND	ND	ND	ND	
	T	0.05	0.07	ND	ND	
453	U	ND	0.04	ND	ND	
	L	ND	ND	ND	ND	
	T	ND	0.04	ND	ND	
537	U	ND	ND	ND	ND	
	L	ND	ND	ND	ND	
	T	ND	ND	ND	ND	

* O-time on 19 May 1984.

** U = Upper (0-15 cm); L = Lower (15-30 cm); T = Total (0-30 cm).

ND = Not Detectable; Limit of Detection about 0.02 kg/ha.

Table 9. Sample collection times during storm events and hexazinone residue concentration in streamwater at three downstream distances

Days* Postspray	Storm Event No.	Days Poststorm	Cumulative Rainfall (mm)	Hexazinone (ppb)		
				50 m	800 m	1500 m
6	1					
8			29	30.8	ND	ND
11	2	2	29	17.9	ND	ND
13			74	13.4	ND	ND
16		3	113	19.1	5.1	ND
20			116	10.4	3.1	ND
27	3	7	116	6.5	0.9	ND
31	4		134	7.7	0.7	ND
34			172	7.1	0.8	ND
38	5	3	175	5.7	0.8	ND
45	6		201	3.9	0.7	ND
			236	3.7	1.0	ND

* 0-time at 19 May 1984.

ND = Not Detectable; Limit of detection was 0.5 ppb.

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Table 9. Sample collection times during storm events and hexazinone residue concentration in streamwater at three downstream distances

Days* Postspray	Storm Event No.	Days Poststorm	Cumulative Rainfall (mm)	Hexazinone (ppb)		
				50 m	800 m	1500 m
6	1		29	30.8	ND	ND
8		2	29	17.9	ND	ND
11	2		74	13.4	ND	ND
13	2		113	19.1	5.1	ND
16		3	116	10.4	3.1	ND
20		7	116	6.5	0.9	ND
27	3		134	7.7	0.7	ND
31	4		172	7.1	0.8	ND
34		3	175	5.7	0.8	ND
38	5		201	3.9	0.7	ND
45	6		236	3.7	1.0	ND

* 0-time at 19 May 1984.

ND = Not Detectable; Limit of detection was 0.5 ppb.

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Appendix 1. Hexazinone residue persistence and leaching data (kg/ha)

Days* Postspray	Soil** Layer	Station Number				Mean	SD
		1	2	3	4		
0	U	2.10	1.71	2.11	2.03	1.99	0.19
	L	ND	ND	ND	ND	ND	
	T	2.10	1.71	2.11	2.03	1.99	0.19
3	U	2.07	1.01	1.49	2.89	1.87	0.81
	L	ND	ND	ND	ND	ND	
	T	2.07	1.01	1.49	2.89	1.87	0.81
6	U	1.69	1.06	1.94	1.08	1.44	0.44
	L	0.57	1.16	0.53	0.13	0.60	0.42
	T	2.26	2.22	2.47	1.21	2.04	0.56
13	U	0.83	0.64	0.53	0.66	0.67	0.12
	L	0.20	0.52	0.30	0.05	0.27	0.20
	T	1.03	1.16	0.83	0.71	0.93	0.20
31	U	0.18	0.52	0.86	0.53	0.52	0.28
	L	0.28	0.13	0.87	0.84	0.53	0.38
	T	0.46	0.65	1.73	1.37	1.05	0.60
61	U	0.05	0.18	0.27	0.06	0.14	0.10
	L	0.11	ND	0.08	0.32	0.13	0.14
	T	0.16	0.18	0.35	0.38	0.27	0.11
87	U	0.09	0.11	0.06	0.15	0.10	0.04
	L	0.17	ND	0.26	0.23	0.17	0.12
	T	0.26	0.11	0.32	0.38	0.27	0.12
122	U	0.20	0.09	0.05	0.03	0.09	0.08
	L	0.22	0.09	0.12	0.10	0.13	0.06
	T	0.42	0.18	0.17	0.13	0.23	0.13
157	U	ND	0.21	ND	ND	0.05	0.11
	L	0.06	0.03	0.05	0.10	0.06	0.03
	T	0.06	0.24	0.05	0.10	0.11	0.09
361	U	ND	0.08	ND	0.06	0.04	0.04
	L	0.11	ND	ND	0.10	0.05	0.06
	T	0.11	0.08	ND	0.16	0.09	0.07
453	U	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	
	T	ND	ND	ND	ND	ND	
537	U	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	
	T	ND	ND	ND	ND	ND	

* 0-Time on 19 May 1984.

** U = Upper (0-15 cm); L = Lower (15-30 cm); T = Total (0-30 cm).
ND = Not Detectable; Limit of Detection about 0.02 kg/ha.

Appendix 2. Hexazinone residue persistence and leaching data ($\mu\text{g/g}$)

Days* Postspray	Soil** Layer	Station Number				Mean	SD
		1	2	3	4		
0	U	1.44	1.35	1.57	2.23	1.65	0.40
	L	ND	ND	ND	ND	ND	
	T	1.44	1.35	1.57	2.23	1.65	0.40
3	U	1.55	0.76	1.33	2.19	1.46	0.59
	L	ND	ND	ND	ND	ND	
	T	1.55	0.76	1.33	2.19	1.46	0.59
6	U	1.30	1.40	1.49	1.00	1.30	0.21
	L	0.49	0.87	0.35	0.13	0.46	0.31
	T	1.79	2.27	1.84	1.13	1.76	0.47
13	U	0.61	0.54	0.65	0.52	0.58	0.06
	L	0.15	0.31	0.42	0.04	0.23	0.17
	T	0.76	0.85	1.07	0.56	0.81	0.21
31	U	0.14	0.43	0.51	1.01	0.52	0.36
	L	0.30	0.08	0.53	0.83	0.44	0.32
	T	0.44	0.51	1.04	1.84	0.96	0.65
61	U	0.03	0.14	0.24	0.06	0.12	0.09
	L	0.07	ND	0.05	0.23	0.09	0.10
	T	0.10	0.14	0.29	0.29	0.21	0.10
87	U	0.09	0.08	0.04	0.24	0.11	0.09
	L	0.11	ND	0.15	0.22	0.12	0.09
	T	0.20	0.08	0.19	0.46	0.23	0.16
122	U	0.12	0.07	0.05	0.03	0.07	0.04
	L	0.18	0.05	0.07	0.09	0.10	0.06
	T	0.30	0.12	0.12	0.12	0.17	0.09
157	U	ND	0.19	ND	ND	0.05	0.10
	L	0.05	0.03	0.03	0.12	0.06	0.04
	T	0.05	0.22	0.03	0.12	0.11	0.09
361	U	ND	0.08	ND	0.05	0.03	0.04
	L	0.09	ND	ND	0.09	0.05	0.05
	T	0.09	0.08	ND	0.14	0.08	0.06
453	U	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	
	T	ND	ND	ND	ND	ND	
537	U	ND	ND	ND	ND	ND	
	L	ND	ND	ND	ND	ND	
	T	ND	ND	ND	ND	ND	

* 0-Time on 19 May 1984.

** U = Upper (0-15 cm); L = Lower (15-30 cm); T = Total (0-30 cm).

ND = Not Detectable; Limit of Detection 0.03 $\mu\text{g/g}$.

Appendix 3. Regression analysis of hexazinone residue extinction with time, where: $\log Y = a + b (\log X)$, Y = residue concentration in kg/ha, X = days after application*

Soil Layer	Parameter	Station Number				Total	Mean
		1	2	3	4		
Upper (0 - 15 cm)	a	0.188	0.0772	0.219	0.220	0.175	0.207
	b	-0.520	-0.399	-0.507	-0.575	-0.496	-0.533
	r	-0.811	-0.875	-0.795	-0.812	-0.809	-0.872
	r ²	0.658	0.766	0.632	0.659	0.655	0.760
	N	8	9	8	8	33	9
Lower (15 - 30 cm)	a	0.0038	0.786	0.308	-0.893	0.040	0.256
	b	-0.450	-0.992	-0.607	0.0753	-0.478	-0.581
	r	-0.769	-0.963	-0.715	-0.098	-0.584	-0.852
	r ²	0.591	0.928	0.511	0.0096	0.341	0.726
	N	7	5	7	7	26	7
Total (0 - 30 cm)	a	0.270	0.165	0.293	0.273	0.250	0.264
	b	-0.436	-0.377	-0.425	-0.400	-0.409	-0.390
	r	-0.801	-0.793	-0.750	-0.795	-0.781	-0.826
	r ²	0.641	0.629	0.563	0.632	0.609	0.683
	N	9	9	9	9	36	9

* 0-time on 19 May 1984; X on 0-time assigned to 0.1 days; Non-Detectable values were excluded from analysis.

Appendix 4. Regression analysis of hexazinone residue extinction with time, where: $\log Y = a + b (\log X)$, Y = residue concentration in $\mu\text{g/g}$, X = days after application*

Soil Layer	Parameter	Station Number				Total	Mean
		1	2	3	4		
Upper (0 - 15 cm)	a	0.482	0.0116	0.128	0.211	0.0987	0.133
	b	-0.517	-0.406	-0.499	-0.535	-0.486	-0.511
	r	-0.799	-0.829	-0.791	-0.776	-0.788	-0.864
	r ²	0.638	0.687	0.626	0.602	0.622	0.747
	N	8	9	8	8	33	9
Lower (15 - 30 cm)	a	-0.0398	0.565	0.373	-0.971	-0.0304	0.137
	b	-0.486	-0.954	-0.748	0.103	-0.503	-0.569
	r	-0.740	-0.970	-0.798	0.132	-0.595	-0.859
	r ²	0.548	0.940	0.637	0.018	0.354	0.737
	N	7	5	7	7	26	7

* 0-time on 19 May 1984; X on 0-time assigned to 0.1 days; Non-Detectable values were excluded from analysis.

Appendix 5. Soil bulk density data from the residue persistence sites Station No. Upper Layer (0-15 cm) Station No. Lower Layer (15-30 cm)

Days* Postspray	Station No. upper layer (0-15 cm)				Station No. lower layer (15-30 cm)			
	1	2	3	4	1	2	3	t 4
0	0.973	0.843	0.895	0.606	1.226	1.032	0.601	0.841
3	0.889	0.891	0.749	0.878	1.001	1.038	0.747	1.009
6	0.863	0.505	0.869	0.722	0.766	0.885	0.994	0.689
13	0.904	0.799	0.538	0.836	0.904	1.114	0.466	0.789
31	0.840	0.821	1.126	0.351	0.614	1.102	1.083	0.679
61	0.951	0.882	0.765	0.770	1.074	1.441	1.031	0.912
87	0.650	0.954	0.958	0.412	1.005	1.186	1.148	0.723
122	1.076	0.815	0.702	0.608	0.836	1.117	1.082	0.782
157	0.938	0.759	0.768	0.610	0.882	0.771	1.008	0.557
361	1.094	0.678	0.938	0.829	0.880	0.665	1.039	0.852
453	0.862	0.796	1.039	0.727	0.877	1.070	1.088	0.854
537	1.073	0.665	1.145	0.632	1.453	1.020	1.167	1.061
Mean	0.926	0.784	0.874	0.665	0.959	1.04	0.955	0.812
SD	0.124	0.121	0.180	0.163	0.219	0.199	0.225	0.142
N	12	12	12	12	12	12	12	12
Total	Mean = 0.812		N = 48		Mean = 0.942		N = 48	

* 0-time on 19 May 1984.

Appendix 6. Soil moisture content data from the residue persistence

Days* Postspray	Soil** Layer	Station Number					
		1	2	3	4	Mean	SD
0	U	25.4	31.8	27.7	30.5	28.9	2.9
	L	24.5	27.4	32.8	26.3	27.8	3.6
3	U	24.1	26.8	25.5	25.9	25.6	1.1
	L	26.7	22.5	34.1	20.0	25.8	6.2
6	U	23.4	41.7	33.4	28.1	31.7	7.8
	L	28.0	32.5	27.2	31.2	29.7	2.5
13	U	27.0	24.8	30.6	22.6	26.3	3.4
	L	30.4	24.4	42.0	37.4	33.6	7.7
31	U	21.4	35.1	26.4	36.3	29.8	7.1
	L	32.8	24.6	29.0	41.7	32.0	7.3
61	U	25.1	30.3	30.1	19.6	26.3	5.1
	L	26.7	16.6	29.6	29.3	25.6	6.1
87	U	27.6	28.7	23.2	37.6	29.3	6.0
	L	26.1	21.7	25.2	33.4	26.6	4.9
122	U	16.7	32.1	19.5	8.9	19.3	9.6
	L	22.8	23.4	21.3	22.5	22.5	8.8
157	U	21.6	34.5	25.9	24.9	26.7	5.5
	L	27.3	33.6	27.6	29.1	29.4	2.9
361	U	22.0	35.0	29.2	26.9	28.3	5.4
	L	31.5	34.9	26.7	28.8	30.5	3.5
453	U	19.9	30.7	23.2	28.3	25.5	4.9
	L	22.5	26.6	25.9	29.9	26.6	3.0
537	U	29.7	35.5	22.2	28.9	29.1	5.4
	L	20.8	27.0	25.4	27.9	25.3	3.2
Total	U	(n=48)				27.2	5.9
	L	(n=48)				27.9	5.2

* 0 - Time on 19 May 1984.

** U = Upper (0-15 cm); L = Lower (15-30 cm).