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Measuring Transport of Lawn-Applied Herbicide Acids from Turf to Home: Correlation of Dislodgeable 2,4-D Turf Residues with Carpet Dust and Carpet Surface Residues

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Transport of lawn-applied herbicides into the home via walking over treated turf, defined here as track-in, was measured at five different times out to 1 week after application. Residues of turf-applied 2,4-D and dicamba were measured in carpet dust and on the carpet surface after track-in. Both carpet dust levels and carpet surface dislodgeable residue levels were highly correlated with turf dislodgeable residue levels. Turf dislodgeable residues were 0.1–0.2% of turf application levels. Transfer of herbicides from turf to carpet dust was 3% of the turf dislodgeable residues. Transfer from turf to carpet surface was 0.3% of the turf dislodgeable residues. Herbicide 2,4-D was measured in the carpet dust of suburban homes at the 0.1–5 μg/g levels that are predicted by this efficiency of mass transfer. New tools used to collect these samples included the polyurethane foam roller dislodgeable residue sampler and the high-volume solid surface sampler.

Introduction

Agricultural pesticide studies have documented pesticide transport and translocation through plants, soil, water, and air (*1–14*). Although pesticide applications are designed to deposit the formulation onto a target (e.g., plant, soil, or insect), inadvertent translocation and deposition often occurs via spray drift, soil resuspension, and volatilization. These translocation mechanisms combined with phase redistribution, long-range transport, and deposition from air to water, soil, fog, and rain have been described in micro- and macroenvironmental transport studies.

The same transport phenomena that occur for agricultural pesticides may also be expected for lawn-applied pesticides. However, inadvertent deposition is not limited to neighboring crops but also includes the indoor residential environment. One transport route in the residential setting that has not been investigated, and may impact chronic indoor exposure, is the transport of residues into the home on shoes and feet by walking over treated turf. This transport mode is defined here as track-in.

Measurements of pesticide levels in indoor air and house dust have led researchers to conclude that segments of the U.S. population may undergo chronic exposure due to residential pesticide applications (*15–19*). In some cases, the presence of insecticides (e.g., chlorpyrifos) can be ascribed to the indoor use of whole room foggers and sprays (*15*). The presence of other pesticides (e.g., chlordane, heptachlor, dieldrin) appears to be due to infiltration and migration into the home of materials that were originally applied to foundations (*16, 18, 19*). The presence of pesticides such as carbaryl and chlorothalonil, which are applied to shrubs or in gardens, suggests that pesticide residues have been carried in on shoes and/or clothing. Because of the analytical methods used, these studies did not show whether turf-applied herbicide acids, such as 2,4-D, were also transported into homes.

Transport of pesticides into the home carries significant implications for human exposure. Carpets, house dust, and home furnishings become long-term sinks for the pesticides; the common environmental weathering factors such as wind, rain, soil microbes, and sunlight are not available for degradation. Residues on floors and surfaces can become a source of exposure for young children through the hand to mouth route of ingestion, as has been fully documented for lead exposure (*20*).

While pesticide formulations contain materials to increase adhesion to the target surface, a fraction of the formulation will be dislodgeable. Dislodgeable pesticide residues are typically measured to ascertain safe re-entry times for workers or homeowners into pesticide-treated areas. Dislodgeable residues have been measured on turf, ornamental plants, and agricultural crops (*21–24*) and, in some cases, also compared with workers' dermal and urinary levels. In these studies, the collection of dislodgeable residues involved vigorous wiping or washing of the treated vegetation. While this sampling method may be useful for estimating a worst case scenario, it may not be representative of actual human contact with treated turf.

The study described here examined the temporal profile of dislodgeable turf residues of two commonly used residential post-emergent herbicides (2,4-D and dicamba) and determined whether these herbicides can be tracked into a home with normal walking and entry into the home. The study was designed to evaluate a new dislodgeable residue collection method and to compare dislodgeable turf residues with residues that are transported by foot traffic. Transport under controlled conditions was then compared with levels of these herbicides in actual homes.

Experimental Methods

Design. At five discrete times after herbicide application, study participants walked through a treated turf plot and

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then over a section of carpet to simulate the transfer that might occur with a homeowner walking across turf (e.g., to a mailbox). Dislodgeable turf residues were collected prior to walking; dislodgeable carpet surface residues and carpet dust were collected after walking.

Turf Plots and Application. A section of residential lawn that had not been treated with herbicides for at least 10 years was platted into identically sized plots. Each turf plot measured 6.1 m × 6.1 (20 × 20 ft); the margin between individual plots was approximately 3 m. One turf plot, reserved exclusively for collection of turf dislodgeable residues, was divided into 20 30-cm-wide segments. The remaining turf plots, for human track-in, were divided into a right side and left side, each side being 2.9 m wide × 6.1 m long. The center 30-cm-wide strip was reserved for collection of a single dislodgeable turf residue sample. The composition of the turf was approximately 70:10:20 blue-grass:fine fescue:weeds. Weeds included dandelion, crab-grass, and plantain.

The formulation contained dimethylamine salts of 2,4-D, mecoprop, and dicamba (K-Gro Broadleaf Weed Killer; K-mart). The formulation was diluted and applied professionally (190-L tank sprayer, Lesco Model 032070, with 1.9 L/min nozzle delivery rate, Green Guard Gun Model JD9-C), giving turf levels of 26.7 ± 10.0 mg/m^2 for 2,4-D and 1.7 ± 0.9 mg/m^2 for dicamba. Application loading was determined from analysis of duplicate 100 cm^2 α-cellulose deposition coupons (Whatman Inc.), backed by aluminum foil, placed within the boundaries of each turf plot. Post-application irrigation is not used with a spray application as herbicidal action is achieved via foliar absorption.

Track-In Platforms. Two different sizes of rigid plywood platforms were constructed of 1.3-cm-thick plywood sheet on bases of 2 × 4 in. untreated lumber. The larger platforms (1.2 m × 1.8 m × 5 cm) were covered with a 1.2 m × 1.2 m piece of a residential stain-resistant, non-directional, nylon carpet (Mohawk Carpet Mill) and a residential entryway mat consisting of a rubber base with short polypropylene fibers (Ideal Rubber Products Co). The smaller platforms (1.2 m × 1.2 m × 5 cm) were covered only with the nylon carpeting. Just prior to use, each carpet platform was vacuumed to remove residual dust/dirt and loose fibers, 1.5 g of a sieved (<150 μm) residential house dust was applied over the carpet surface, and four lanes of equal size were marked on the carpet.

Simulating Human Track-In. At a specified time after herbicide application, five study participants walked 20 times each across both right and left sides of a given turf plot. Schematic representation of one cycle of walking is shown in Figure 1. The five participants staggered their starting times by a few seconds, maintained their order and distance from each other throughout an experiment, and randomized their walks so as to cover all areas of the treated turf. As seen in Figure 1, in each experiment, each participant walked alternately through right and left sides of the lawn plot to minimize differences in transfer. The footsteps taken to traverse the turf plot were recorded and averaged 8−12 steps per trip. Calculations based on the number of footsteps and shoes sizes showed that approximately 83% of the available turf area could have been covered by walking.

After walking across one or the other side of the turf plot, the participant stepped directly onto the track-in platform. As shown in Figure 1, after walking on the left side of the lawn plot, the participant wiped both feet on the
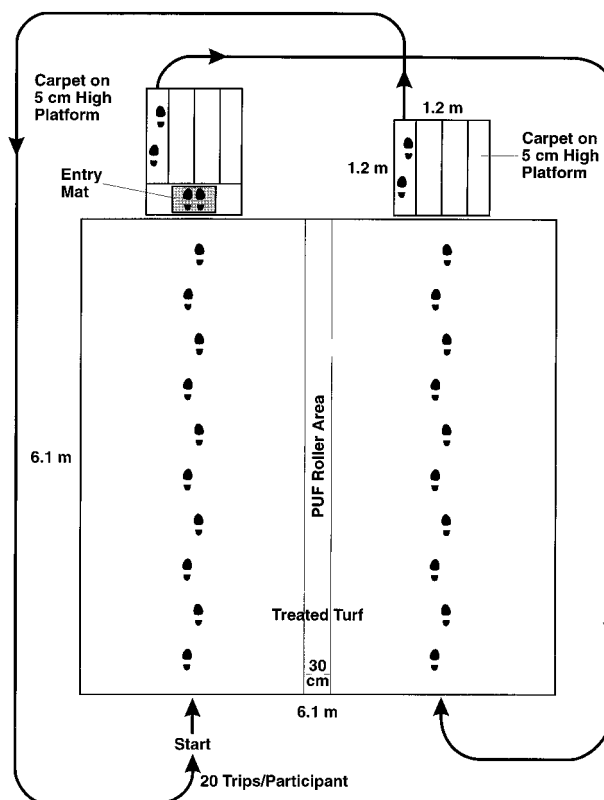

FIGURE 1. Schematic representation of one cycle of walking performed by one participant for track-in simulation. Five participants each completed 20 cycles of walking in a single experiment.

entryway mat and then stepped onto the carpet; after walking on the right side of the lawn plot, the participant proceeded directly onto the carpet. Participants were directed in sequence to one of the four lanes marked on each carpet. Each participant walked over the carpeting in that particular lane with two footsteps before stepping off. At the conclusion of each track-in experiment, each participant had walked in each lane of each carpet five times.

New platforms, carpets, entry mats, and shoes were used for each experiment. The shoes were all similar in design: rubber-soled, casual shoes with continuous, slightly ridged tread. Either three women and two men or four women and one man, averaging 66-75 kg, participated in the experiments. The protocol was approved by the Battelle Human Subjects Review Committee in compliance with government regulations.

Sampling. The two pieces of sampling equipment included a modified polyurethane foam roller dislodgeable residue sampler (PUF roller; Southwest Research Institute) and a vacuum sampler designed for controlled collection of carpet dust samples. Both are illustrated in Figure 2. The PUF roller consists of an aluminum frame mounted on aluminum wheels (15, 25). Interchangeable PUF sleeves (8 cm length × 8 cm o.d.) are mounted onto an aluminum core that is inserted between the two sides of the frame. A linear sampling rate of 40 ± 4 cm/s was used for collection of dislodgeable turf residues. Dislodgeable residues were collected from the outer two lanes of each carpet at a linear sampling rate of 17 ± 2 cm/s. Each PUF sleeve was transferred directly from the aluminum core to a zippered polyethylene freezer bag for storage on dry-ice in the field and at a −78 °C freezer storage until extraction.
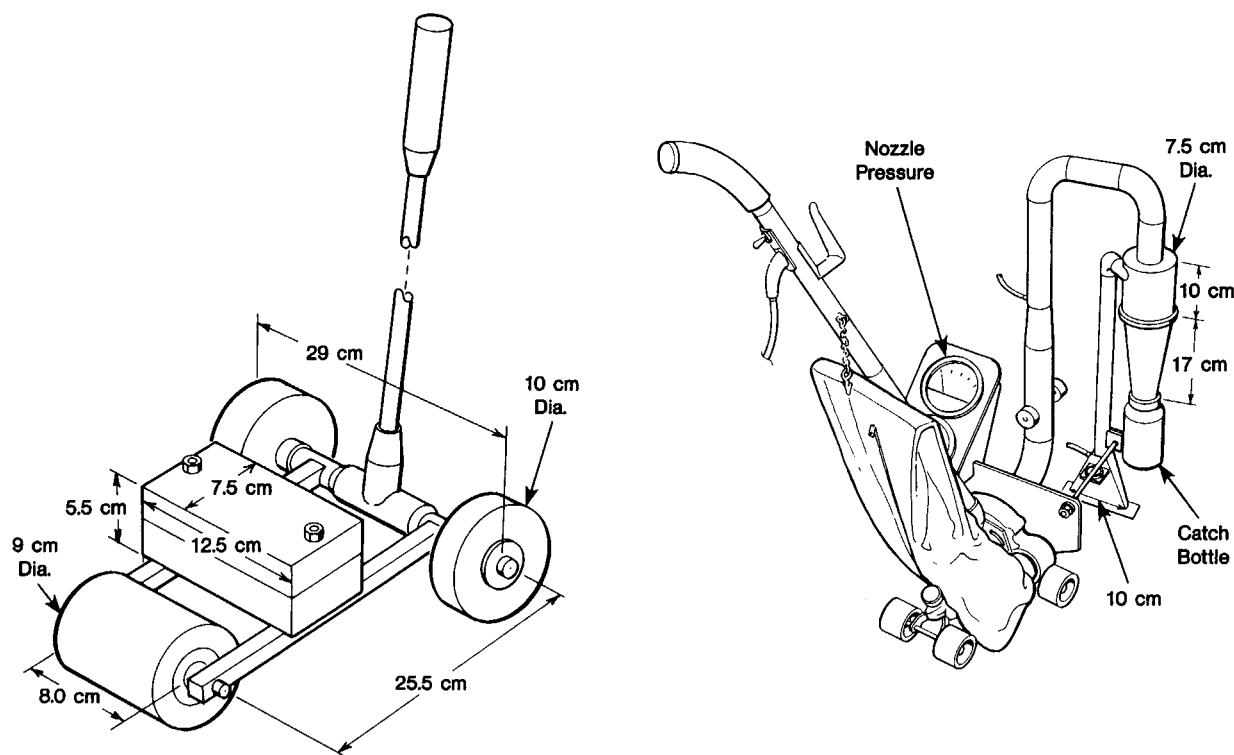
FIGURE 2. (Left) PUF roller used for collection of dislodgeable pesticide residues from turf and carpet surfaces. (Right) HVS3 used for collection of carpet dust.

TABLE 1

Recovery of Herbicide Acids and Relative Response for Detection by GC/ECD and NCI GC/MS

| analyte | spike (μg) | recovery (%) | | | relative response[a] | | effective anal. ratio[b] | |
		dust[c]	PUF[d]	soil[e]	ECD[f]	NCI[g]	ECD	NCI
dicamba	0.5	87 ± 2	84 ± 6	70 ± 3	3.0	0.35	0.3	0.04
mecoprop	100	89 ± 11	100 ± 1	112 ± 13	0.003	0.36	0.002	0.18
2,4-D	1.0	84 ± 9	105 ± 4	93 ± 4	1.0	1.0	1.0	1.0
2,4-D salt	1.0	na[h]	89 ± 4	na	N/A[i]	N/A	N/A	N/A
MCPA[j]	100	87 ± 1	106 ± 4	99 ± 5	0.005	0.10	N/A	N/A
3,4-D	1.0	91 ± 9	105 ± 3	93 ± 8	0.69	1.1	N/A	N/A
2,4,5-TP[k]	0.2	104 ± 1	97 ± 3	na	4.9	13	N/A	N/A
2,4,5-T[l]	0.2	73 ± 1	100 ± 2	na	4.3	21	N/A	N/A
PCP[m]	0.1	98 ± 6	97 ± 2	95 ± 4	25	21	N/A	N/A

[a] Relative response, response with respect to 2,4-D. [b] Effective analysis ratio, relative response × relative concentration in formulation; relative concentrations in formulation are 2,4-D = 1, mecoprop = 0.5, dicamba = 0.1. [c] 50 μL of spike to 1 g of house dust. [d] 50 μL of spike to one PUF sleeve. [e] 50 μL of spike to 1 g of clay soil. [f] GC/ECD. [g] NCI GC/MS. [h] na, not analyzed. [i] N/A, not applicable. [j] 2-Methyl-4-chlorophenoxyacetic acid. [k] 2,4,5-Trichlorophenoxypropionic acid. [l] 2,4,5-Trichlorophenoxyacetic acid. [m] Pentachlorophenol.

The vacuum sampler used is the high−volume solid surface sampler (HVS3; Cascade Stack Sampling Systems, Inc.), which is a modified residual vacuum cleaner (*15, 26, 27*). Constant pressure applied to the 10-cm-wide flat nozzle provides a sampling flow rate of 700 L/min (25 cfm) at a nozzle pressure drop of 23−25 cm of water. The cyclone has a nominal cut point of 5 μm of geometric mean diameter; particles > 5 μm are collected in a removable polyethylene catch bottle located below the cyclone. Previous studies have shown that more than 99% of carpet dust particles sampled by the HVS3 are collected below the cyclone (*26*). For collection of the dust/dirt-bound residues from the carpet after track-in, the middle two lanes of each carpet were vacuumed. An individual catch bottle was used for each sample; the bottles were stored at −78 °C until extraction.

Analytical Methods. Each PUF sleeve was cleaned before use by extraction in a zippered polyethylene bag,

with the solvent squeezed manually through the PUF sleeve 10 times. PUF sleeves were extracted in sequence once (1×) with 200 mL of distilled/deionized water and then with 150 mL of 70:30 v/v acetonitrile:phosphate buffer (0.1 M sodium acid phosphate) at pH 3 (4×). Sleeves were squeezed to near dryness and dried further for 30 min using a vacuum dessicator held at ~83 kPa (23−25 in. of Hg) at 40 °C with a 10 mL/min stream of dry N_2. Conditioned PUF sleeves were 34% by weight salt/water; a minimal amount of acetonitrile remained, as evidenced by the pliable nature of the PUF.

The surrogate recovery standard 3,4-dichlorophenoxy-acetic acid (3,4-D; 1 μg) was added to each PUF sleeve before extraction with 150 mL of 70:30 acetonitrile:phos-phate buffer pH 3 (4×) using the technique described above; 150 mL of distilled/deionized water (DIDE water) was added to the extract, and the pH was adjusted to 12 with 1 M NaOH. Rotary evaporation at 48 °C was used to remove
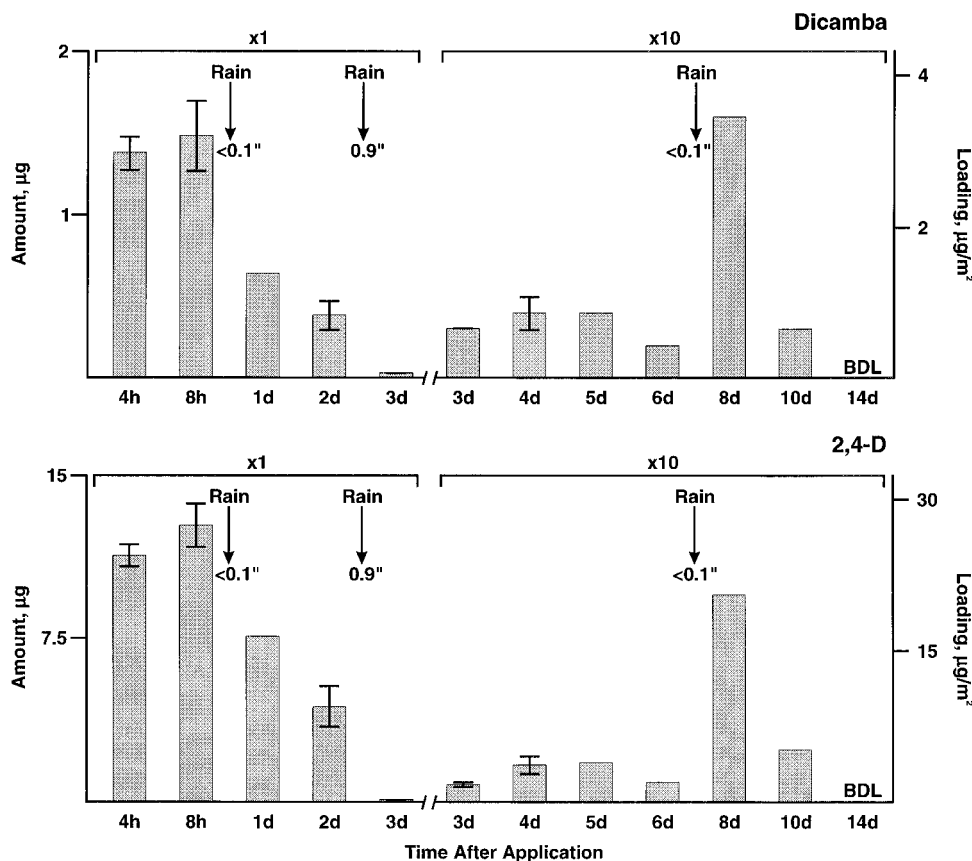
FIGURE 3. Temporal profiles of dislodgeable turf residues of dicamba (top) and 2,4-D (bottom). Scale on right for loading (amount/area) of dislodgeable turf residues corresponds to the 1× amount of dislodgeable turf residues. BDL, below detection level.

approximately 400 mL of acetonitrile. The extract was partitioned with 25 mL of hexane (2×); the aqueous extract was acidified to pH 1.

An octadecyl hydrocarbon-bonded silica solid-phase extraction cartridge (C18 SPE; 6 mL, 500 mg loading; Baker) was conditioned in sequence with 10 mL of methanol, 10 mL of DIDE water, and 4 mL of 1:10 acetonitrile:0.025 M phosphoric acid. After loading, the cartridge was dried for 2 h and then eluted with 2 mL of 1:1 diethyl ether: hexane (2×).

The combined eluate was concentrated to near dryness; the internal standard 2,6-dichlorophenoxyacetic acid (2,6-D; 1 μg) was added, and the extract was brought to a final 1-mL volume with 95:5 methyl-*tert*-butyl ether:methanol (v/v). Methylation was accomplished using ethereal diazomethane generated in-situ from Diazald, carbitol, and 37% aqueous KOH. After methylation, solutions were allowed to stand for 30 min and then purged with dry N_2. Multilevel calibration standards were generated in duplicate for each analysis set.

HVS3-collected dust/dirt samples (hereafter refered to as dust) were sieved to 150 μm to remove carpet fibers; weighed; spiked with 1 μg of 3,4-D; sonified with 25 mL of the extraction solvent; and then centrifuged. To 20 mL of the extract, 10 mL of DIDE water was added, and the pH was adjusted as above. Rotary evaporation was used to remove approximately 15 mL of acetonitrile. The extract was partitioned gently with 20 mL of hexane (2×) and 300 μL of Antifoam A (Sigma); 175 mL of DIDE water was added, and the pH was adjusted to 1. The SPE cleanup and derivatization were performed as described above.

Sample extracts were analyzed using gas chromatography with an electron capture detector (GC/ECD; Hewlett-Packard 5890 GC). Chromatographic conditions included the following: 60 m DB-5 column (0.25 mm i.d., 25 μm film thickness; J&W Scientific); temperature program from 100 to 150 °C at 6 °C/min, 150−215 °C at 2 °C/min, and 215−300 °C at 25 °C/min. Confirmation of analytes in residual house dust samples was accomplished using full mass scan (*m/z* 100−300) gas chromatography/mass spectrometry with negative chemical ionization (NCI GC/MS; Finnigan 4500), with sensitivity comparable to GC/ECD. Analyses utilized methane reagent gas at 1 Torr, source temperature of 180 °C, 150 eV electron energy, and chromatographic conditions similar to those above. Base peaks were the phenoxy anions.

The dust applied to the carpets for the track-in experiments contained trace levels of dicamba, 2,4-D, and pentachlorophenol. Recovery of the pentachlorophenol was used to correct for native amounts of dicamba and 2,4-D in the track-in carpet dust samples.

The recoveries of selected herbicide acids and pentachlorophenol from house dust, clay soil, and PUF sleeves are listed in Table 1 together with analyte relative responses using GC/ECD and NCI GC/MS. When relative responses and concentration ratios in the formulation are both considered, for an effective analyte analysis ratio, GC/ECD provides the better detection mode for the two structurally dissimilar analytes of the formulation. Percent recovery of the surrogate standard 3,4-D in PUF sleeves was 90 ± 15 (*n* = 42) and in dust was 94 ± 8 (*n* = 12) for this study. The GC/ECD detection limits for dicamba and 2,4-D were 0.002 and 0.004 μg/mL, respectively; detection limits were 0.02 μg/mL in PUF extracts.

High Level — **Low Level**

Dicamba

2,4-D

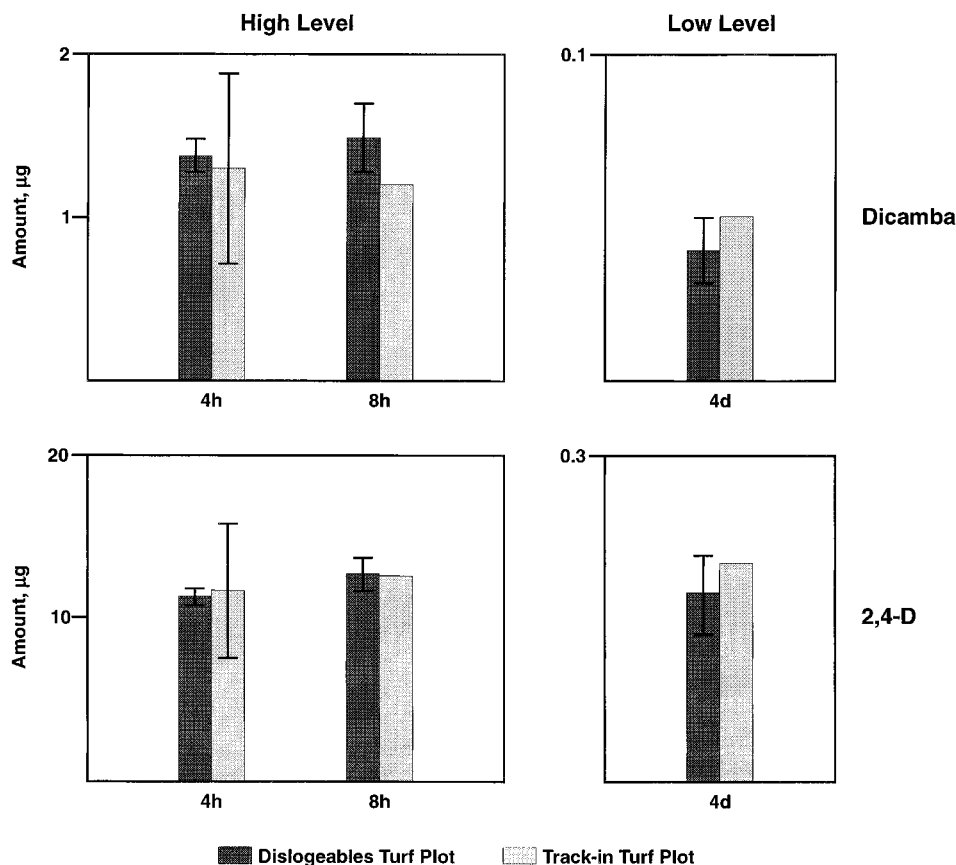■ Dislogeables Turf Plot   ▨ Track-in Turf Plot

FIGURE 4. Comparison of reproducibility of PUF roller collection of turf dislodgeable residues: intraplot variability and interplot variability. (Left) Comparison for relatively high turf levels. (Right) Comparison for relatively low turf levels.

Results and Discussion

Dislodgeable Turf Residues. The temporal profiles of dislodgeable turf residues for dicamba and 2,4-D collected from the single 20-segment turf plot are shown in Figure 3. The major factor governing the reduction in dislodgeable residues within the first few days after application was the rainfall. A trace amount of rain fell at night after track-in experiments conducted 4 and 8 h after application. A much heavier rain, 2.3 cm in 2 h, fell on the morning of the third day after application ($t = 3.0-3.1$ d after application). The dislodgeable turf residue sample denoted 3 d was collected 8 h after the rain, when the turf was dry. A trace amount of rain also fell 7 d after application.

Dislodgeable turf residues increased approximately 10% between 4 and 8 h after application, possibly due to further drying of the applied material. The reduction in dislodgeable turf residues between 8 h and 1 day was approximately 50%, with a further reduction of approximately 40% between 1 and 2 d after application. While most of that decrease between 8 h and 1 d measurements may be attributable to rain as wash-off, decreasing amounts of dislodgeable turf residues, as in 2d vs 1d, have been measured over time without rain or irrigation (*23, 28*) due to enhanced adsorption/binding to the turf surface.

The profile of dislodgeable turf residues is expanded in the right half of Figure 3 to accommodate the lower analyte levels following the rain. As seen there, a second phenomenom due to rain is observed that runs counter to the wash-off effect observed with the initial rains. In particular, samples collected the day after rain (4- and 8-d samples) show slight increases in 2,4-D relative to the previous sample. Since PUF roller contact is made only with turf,

we believe that this increase may be due to competitive adsorption between water and herbicide, as has been shown previously for other pesticides in soil (*29*).

The formulation that was applied included the monochloro herbicide mecoprop as well as the dichloro herbicides dicamba and 2,4-D. At the concentration applied, and with the GC/ECD analysis method used, mecoprop could not be detected in these sample extracts. Using NCI GC/MS, which provides better sensitivity for mecoprop,
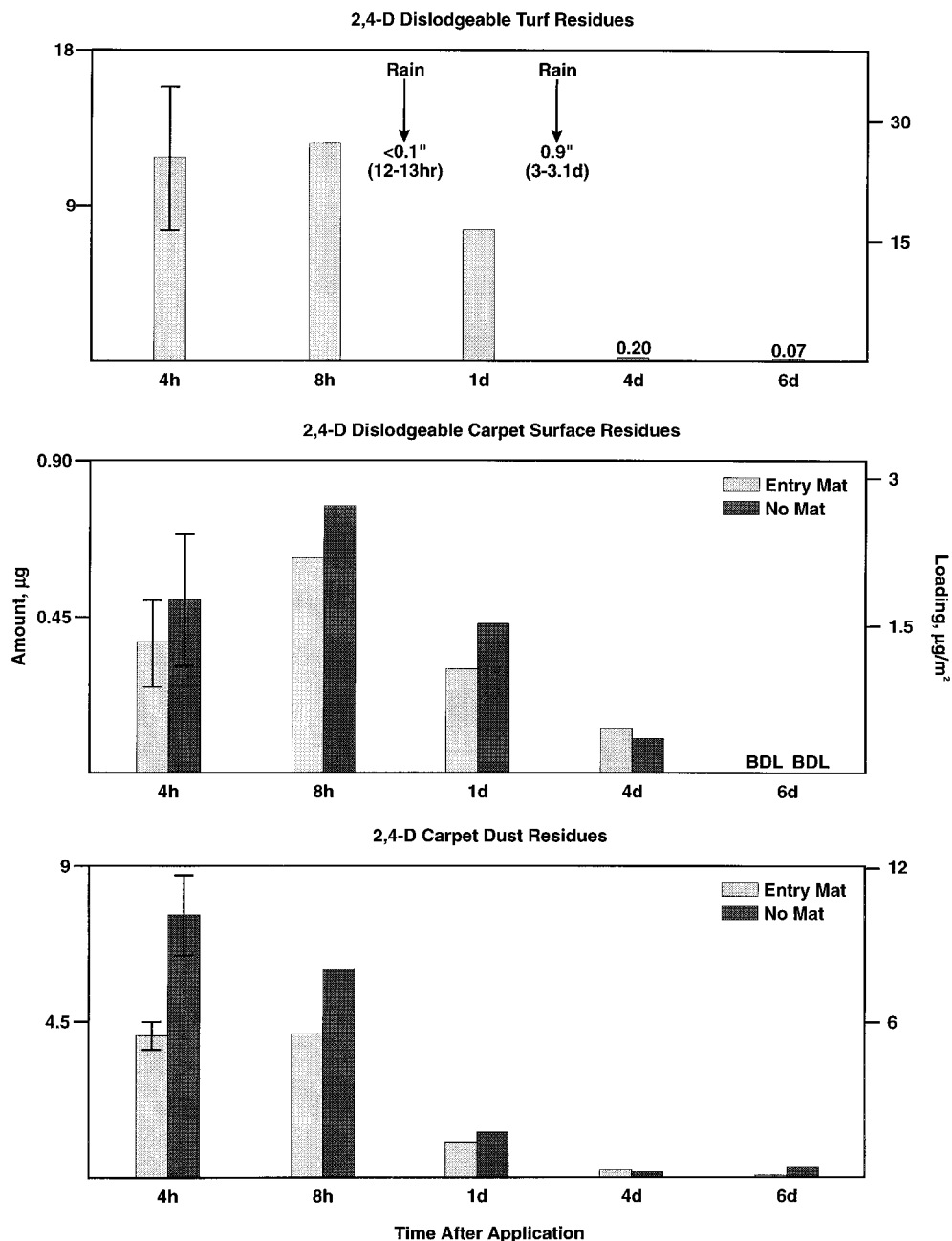
2,4-D Dislodgeable Turf Residues

2,4-D Dislodgeable Carpet Surface Residues

2,4-D Carpet Dust Residues

FIGURE 5. Temporal profiles of dislodgeable turf residues (top), dislodgeable carpet surface residues (middle), and carpet dust residues (bottom) of 2,4-D. BDL, below detection level.

we confirmed that mecoprop is indeed present as a turf dislodgeable residue along with dicamba and 2,4-D.

The inter- and intraplot reproducibility obtained with the PUF roller turf collection method is good given the expected variability in collection via contact with a nonuniform surface. The deviations from the mean for duplicate samples (DM) from the 20-segment turf dislodgeable plot were 4—7% at 4 h and 8—14% at 8 h at relatively high levels of dicamba and 2,4-D, and 24—25% at 4 d at much lower herbicide levels (see Figure 4). The DM for turf dislodgeable residues from the two track-in turf plots used 4 h after application was higher, 35—45%; however, variability in application loading for the individual turf plots (rsd of 37% for 2,4-D) may largely account for this difference.

Track-In from Turf to Carpet. The temporal profiles of 2,4-D in carpet dust and on the carpet surface that result from this simulation of track-in are shown in Figure 5. Data

for dicamba are very similar and are not shown. The turf dislodgeable residue data shown at the top of Figure 5 are those amounts collected from the center lane of the individual turf plots used for human track-in.

Both the dislodgeable 2,4-D residues from the carpet surface and the 2,4-D residues in the carpet dust parallel the profile of the dislodgeable tuf residues. The profiles of dislodgeable carpet surface residues and carpet dust residues for 2,4-D with and without the entryway mat are also very similar. The entryway mats reduced dislodgeable carpet surface residues by approximately 25% at 4 h, 8 h, and 1 d after application. The entryway mats reduced carpet dust residues by an average of 33% at these times, with greatest effect observed when track-in of material is greatest. Replicate track-in experiments at 4 h after application show acceptable reproducibility for the simulation procedure, with 10—40% DM for replicate samples.

The fact that the dislodgeable carpet surface residues and carpet dust residues do not decrease as quickly as the turf dislodgeable residues is not entirely surprising given the difference in applied force between the PUF roller and a participant's foot. The roller appears to contact soil to only a limited extent. In contrast, as evidenced by the dirty footprints on the carpet at the end of an experiment, human track-in may result in track-in of soil-bound residues in addition to turf residues.

The untreated plot that was set aside as a field blank (located 15 m west of treated turf plots) became an evaluation of spray drift. Analyte levels on the deposition coupons were 3% of those on the treated turf coupons. Turf dislodgeable residues collected 8 h after application were 2−3% of the levels found on treated turf plots at 8 h. Detectable analyte levels were also present in the carpet dust after track-in. The application gun used here produces a finer aerosol than that used by some commercial applicators (30), and for this reason we may have observed more drift than is common to the lawn-care industry. Spray

drift in agricultural application has been studied previously, and drift levels up to 8% of the application loading rate have been measured (31).

Quantifying Transfer from Turf to Carpet. The ability to quantitatively describe dislodgeability and transport of residues may be important in assessing the performance of a product or in setting re-entry times. These data indicate that the transfer of analytes from turf can be assessed using either the PUF roller or human track-in. The correlations (r) between 2,4-D dislodgeable turf residues and both carpet dust residues and carpet surface residues are statistically significant ($r^2 = 0.81$, $p = 0.04$, and $r^2 = 0.98$; $p = 0.01$ for dust and carpet surface, respectively) for a regression analysis in which dislodgeable turf residue is the independent variable. The transfer efficiencies of herbicide acids from turf to PUF, expressed as a percentage of the turf application level and as ppm transfer (μg of 2,4-D transferred/g of 2,4-D contacted), are listed in Table 2. These transfers for herbicide acids from turf to carpet dust and turf to carpet surface are also listed in Table 2. Transfer efficiencies from turf to PUF were on the order of 0.1−0.2%. Transfer efficiencies of 2−4% have been measured with the PUF roller for collection of higher loadings of chlorpyrifos on relatively uniform indoor carpet (32), so that the values determined here seem appropriate to the relatively non-uniform turf surface.

The 10-fold difference in transfer efficiency between turf to carpet surface and turf to carpet dust (e.g., 6 ppm vs 58 ppm for dicamba) suggests that approximately 10% of the track-in residues remain on the carpet surface, either dust-bound, as solid particles, or adsorbed to carpet fibers. For the simulation of track-in used here, 3% of the dislodgeable turf residues were transported to the carpet dust; 0.3% of the dislodgeable turf residues were available for dermal contact from the carpet surface.

Residential Exposure to 2,4-D. On the basis of the above results and assumptions listed in Table 3, we would expect to find 2,4-D in residential carpet dust up to 1 year after turf application at concentrations of approximately 0.5 μg/g and at carpet loadings of approximately 0.3 μg/m^2. These estimates are in agreement with the range of 2,4-D found in nine residential dust samples: 0.1-5 μg/g and 0.02−1.1 μg/m^2; see Table 4.

The concentrations of 2,4-D in these nine samples were determined using both GC/ECD and NCI GC/MS and are listed in Table 4. The origin of the bias between the two analysis methods (~40%) is unknown but may be due to

TABLE 4
Comparison of 2,4-D Levels in Suburban House Dust

home	children[a]	analysis concn (μg/mL)			dust concn (μg/g)[b]	area loading (μg/m^2)[b]
		GC	GC/MS	bias (%)		
1	5	1.8	2.7	53	4.85	0.89
2	2	0.65	0.84	30	0.19	0.32
3	1	0.61	0.87	43	0.62	0.31
4	2	0.38	0.47	24	0.09	0.19
5	2	0.26	0.37	41	0.15	0.13
6	4	0.23	0.33	41	0.25	0.12
7	2	0.14	0.21	54	0.05	0.07
8	0	0.04	0.05	14	0.16	0.02
9	0	0.05	0.04	20	0.97	0.03
correlation of number of children with 2,4-D dust concentration					$r^2 = 0.35$	
correlation of number of children with 2,4-D dust loading						$r^2 = 0.49$

[a] Number of children in the home. [b] Calculated value based on GC/ECD analysis result.

the calibration methods; GC/ECD analyses utilized a linear regression from a five-point calibration curve; NCI GC/MS analyses used a single-point response factor calibration. Inspection of GC/MS spectra showed the peaks to be free of interferences. These 2,4-D levels suggest track-in as a contributing transport mechanism, with the number of children correlated with both carpet loading ($r^2 = 0.49$; $p = 0.04$) and with dust concentration ($r^2 = 0.35$; $p = 0.09$) as measured in regression analyses.

In a recently reported study, the urine from matched populations of children in two Arkansas towns was analyzed for 2,4-D (*33*). The 2,4-D was detected in urine of 18% of the children from the town containing a 2,4-D manufacturing plant *and* was present in the urine of 23% of the children in the town with no manufacturing plant. The similarity of exposure rates and detection levels indicated an exposure source other than the manufacturing plant, though the source was unknown. Given the fact that children's hand-to-mouth activity promotes ingestion of contaminated carpet dust, we might assume that chronic indoor exposure will follow a lawn application and may result in measurable urinary levels. Certainly this assumption needs to be fully investigated by analysis of matched samples of house dust and urine from resident children prior to and after turf application.

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