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Influence of Moisture on Chemical Transferability from a Nylon Carpet

R. L. Williams, C. E. Bernard, R. I. Krieger

Personal Chemical Exposure Program, Department of Entomology, University of California, Riverside, CA 92521, USA

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Chemicals are common components of integrated pest management in residences, restaurants, shopping malls, public institutions and other facilities that require pest control. Homeowners and professional applicators used an estimated 136,000,000 pounds of active ingredient for home and garden treatments in 1997 (USEPA, 1999). Active ingredients are formulated and applied with a variety of inert ingredients, most commonly water. Pest management activities inevitably result in unintentional and unavoidable human exposure that is typically well below levels of health concern, but perceptions vary. Exposure measurements that correctly represent potential human exposure are essential for responsible risk assessment and risk management decisions. This paper focuses on the relationship of moisture and the estimated transferability of surface pesticide residue.

Small amounts of residue are distributed on surfaces, particularly carpet, following indoor applications. Carpets have received particular attention due to their prevalence in residential environments (Ross et al., 1990) and ease of sampling relative to other irregular indoor surfaces. Several types of chemical measurements of fate and transport can be made on carpeted surfaces. Coarse measurements of potential human exposure may be derived from nominal application rates (Berteau et al., 1989) or total extractable residue, e.g. Soxhlet as a function of time. More refined methods include measurement of transferable chemical residue, which measure the portion of chemical residue that transfers to another surface during contact. The concept of dislodgeable residue has been borrowed from agricultural exposure studies (Iwata et al., 1977) and recast as transferable chemical residue for indoor measurements (Ross et al., 1990, 1991). Measurements of transferable chemical residue are typically made using non-destructive methods that can be utilized to determine chemical availability and estimate potential human exposure. Transferable chemical residue sampling methods include vacuuming (Roberts et al., 1992), surface wipes (Camann et al., 1996; Lu and Fenske, 1999), dragged or rolled cotton cloth (Vaccaro et al., 1991; Ross et al., 1991), rolled polyurethane foam (USEPA, 1994; Lu and Fenske, 1999), and cotton whole body dosimetry (Ross et al., 1990; Krieger et al., 2000). The use of whole body dosimetry is most representative of chemical contact-transfer to humans (Krieger et al., 2000). Measurements of chemical

Correspondence to: R. I. Krieger

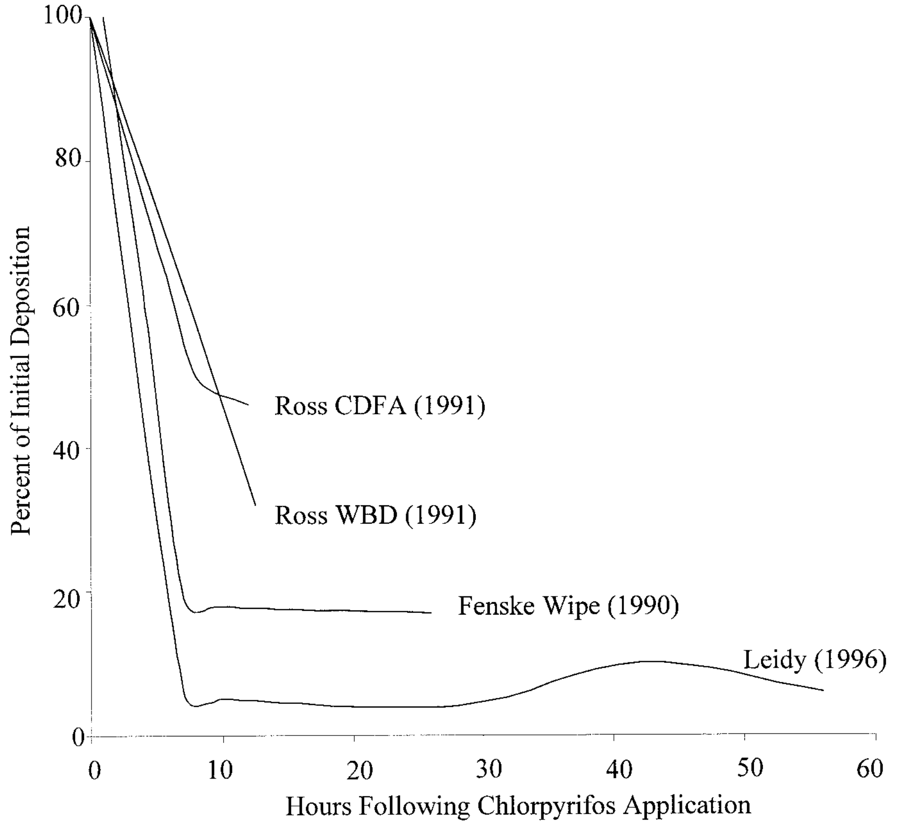

Figure 1. Transferable surface residue measurements of chlorpyrifos following application. Reported as percent of initial levels from key studies.

transferability made using the modified California roller method are highly correlated with chemical transferred to whole body dosimeters worn during a structured activity program. The procedures have been previously used to predict human absorbed dosage (Ross et al., 1990, 1991; Krieger et al., 2000) and are currently the basis for regulating residential exposure (USEPA, 2001). Clarifying the relationship between indoor environmental sampling and potential chemical transfer to humans is essential to estimate absorbed daily dosages that reliably represent levels of exposure measured by biomonitoring (Krieger, 1998; Krieger et al., 2000).

This study includes measurement of total chemical residue, transferable chemical residue, and percent moisture following indoor chemical application. Subsequently water-only applications were made to the treated nylon carpet to evaluate the relationship between transferable chemical residue and percent carpet moisture.

Table 1. Total chemical residue, percent moisture, and percent transferable residue following a chlorpyrifos and two water-only applications.

Time (hours)	Total Chemical Residue (μg/cm²)	Percent Moisture[a]	Percent Transferable Residue[b]
Day 1: Control			
-0.25	Non-Detect	0.33	Non-Detect
Chemical Application			
0.25	46.3	5.53	31.5
0.75	47.2	6.61	27.1
1.50	52.3	3.81	12.2
2.25	41.1	1.12	9.0
3.00	53.5	0.92	4.5
3.75	54.0	1.35	4.1
Day 2: Control			
23.75	47.8	0.44	2.1
Water-only Application			
24.15	70.9	6.74	30.3
25.15	57.4	5.55	24.4
26.15	40.3	4.54	17.6
27.15	58.6	0.92	3.6
28.15	77.2	0.65	3.0
Day 3: Control			
47.75	46.4	0.35	1.5
Water-only Application			
48.15	43.8	7.66	30.9
49.15	54.3	7.13	12.2
50.15	59.8	2.79	12.5
51.15	48.4	2.11	6.4
52.15	48.0	1.65	3.1

[a]Percent moisture measured with Denver Instrument IR-200.
[b]Percent Transferable Residue
= (Amount Transferred by California Roller ÷ Total Chemical Residue) × 100

MATERIALS AND METHODS

Plush nylon carpet (3.7 x 1.5 m; Queen-Palomino, Shaw Industries, Inc.; Dalton, GA) was purchased from a local retailer and placed in a Riverside, CA residence. The carpet was divided into 18 sampling sites. Each site contained the following: two pre-cut carpet swatches (100 cm²) for total chemical residue measurement; an area designated for measurement of transferable chemical residue with the modified California roller (1100 cm²), and two pre-cut carpet swatches (25 cm²) for moisture analysis.

The carpet was treated with chlorpyrifos (200 ml of 6.6% Green Light® Many Purpose Dursban® Concentrate II was diluted to 1000 ml with de-ionized water).

At 24 hours and again after 48 hours the carpet was treated with water-only. The applications were made using a pressurized Tee-Jet nozzle system fixed to a wheeled cart (Bernard et al., 2001) and pulled at a pace of approximately 0.6 m/s. Total chemical residue, transferable chemical residue, and percent moisture were measured on day 1, day 2, and day 3 at times indicated in Table 1.

Total chemical residue ($\mu g/cm^2$) was determined following Soxhlet extraction with ethyl acetate (Optima, Fisher Scientific; Pittsburgh, PA). Transferable chemical residue ($\mu g/cm^2$) was measured by rolling a short-handled modification of the California roller 25 times forward and back over 100% cotton sheets positioned on the treated carpet (1050 cm^2; Ross et al., 1991). The dosimeters were extracted with ethyl acetate using an Eberbach shaker for two 10-minute cycles. Percent transferable residue was calculated by dividing the amount transferred to the cotton cloth following rolling ($\mu g/cm^2$) by the total chemical residue ($\mu g/cm^2$) and multiplying by 100:

$$\left(\frac{\text{Transferable chemical residue}}{\text{Total chemical residue}} \right) \text{ x } 100 = \text{Percent transferable}$$

Chlorpyrifos concentrations were determined by generating a chlorpyrifos standard curve with fenitrothion (Chemservice; West Chester, PA) as an internal standard using a Hewlett Packard 5890 gas chromatograph (Palo Alto, CA) equipped with a HP-5 column and a flame photometric detector. Recovery of chlorpyrifos spikes from carpet and cotton cloth were 96% and 104%, respectively.

Moisture analysis was measured with a Denver Instrument IR-200 (Arvada, CO). The IR-200 reports percent moisture, gravimetrically determined from weight loss following heating with infrared.

RESULTS AND DISCUSSION

The total chemical residue determined by Soxhlet extraction of treated carpet over a 52-hour period was 52.6 ± 9.7 $\mu g/cm^2$ (Table 1). All measurements were within two standard deviations of the mean. Total chemical residue indicates a stable chemical reservoir that did not decline during the sampling period.

Transferable chemical residue was highest following the chlorpyrifos application and each subsequent water-only application and declined rapidly (Table 1; Figure 2). The rapid decline in transferable chemical residue measured with cotton cloth and modified California roller contrasts with relatively constant measurements of total chemical residue. These differences are important when considering which type of residue sampling best represents potential human contact with treated surfaces.

The percent moisture measurements declined rapidly following the chlorpyrifos and water-only applications (Table 1). The percent moisture was higher than

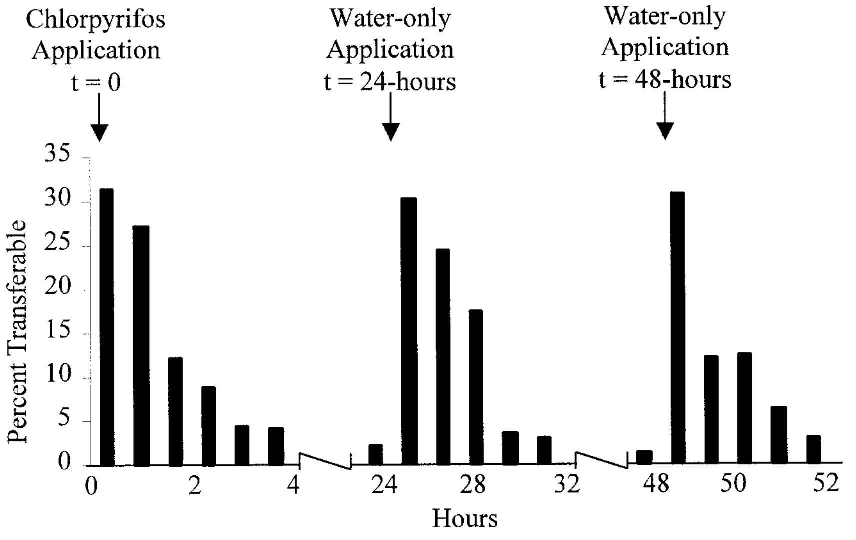

Figure 2. Percent transferable residue measured by cotton cloth and modified California roller following a single chlorpyrifos application followed by two water-only applications. Actual sampling times are listed in Table 1.

controls when the carpet felt dry to the touch. Such subjective evaluation from touching carpet would be misleading compared to sensitive analytical measurements and is probably not a suitable reference point for consumers that use water-based products indoors.

Measurements previously made using the cotton cloth and modified California roller method yielded a biphasic decline in the magnitude of transferable chemical residue from plush carpets (Bernard et al., 1999). The initial phase, including the hours immediately following chemical application, show a rapid decline in transferable chemical residue followed by longer term persistence at a much lower level during the subsequent days and weeks (Figure 1). Transferable chemical residue and percent moisture measurements were highly correlated following chlorpyrifos and water-only applications; a regression of percent transferable chemical residue versus percent moisture was significant (Figure 3; $p < 0.01$; $r = 0.89$; 17 df). Based upon these measurements, initially following application there is a higher potential for human exposure. Following a drying period, the magnitude of transferable chemical residue is much lower, but may be renewed following the introduction of moisture.

While transferable chemical residue measurements can decline greatly following application, total chemical residue remains a relatively stable chemical reservoir. Evaluation of physical or chemical factors that may influence transferable chemical residue following chemical application is of high importance to identify determinants of potential human exposure.

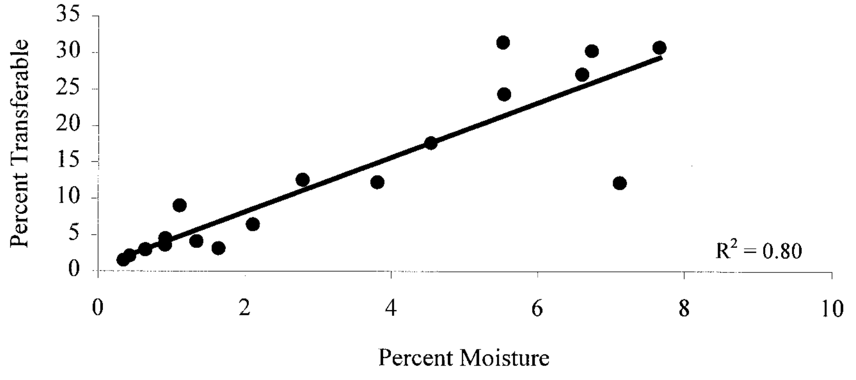

Figure 3. Correlation of percent transferable residue and percent moisture ($p < 0.01$; $r = 0.89$; 17 df).

Following residential chemical applications, it is important to establish environmental determinants of potential human exposure. Measurements of chemical residue reveal the total amount of chemical present in carpet, but fail to capture the change in transferable chemical residue, which may be more representative of potential human exposure. Current pesticide labels provide limited measures to aid users in determining safe entry intervals. Instructions range from "Keep children and pets off treated areas until spray has dried (Many Purpose Dursban® Concentrate II; Green Light Co., San Antonio, TX) to providing a 150 minute restricted entry interval, "After 2 hours, open all doors and windows, turn on air conditioners and fans and let the treated area air out for 30 minutes" (Indoor Fogger; Ace Hardware Co., Oak Brook, IL). Understanding the relationship between drying and potential human exposure may strengthen the foundation for safe use of residential chemicals. Drying time for water-based formulations is a critically important exposure mitigation factor based upon these findings.

Moisture facilitates pesticide transfer from treated carpets. The relationship between percent moisture and transferable chemical residue identified here raises many points of interest regarding potential human exposure. Small changes in percent moisture produced significant changes in transferable chemical residue. Whether this results from resuspension of chlorpyrifos in water or whether water acts to suspend and sweep away adsorbed particles is not clear at this time. Differences in residential surfaces, regional relative humidity, and the spatial distribution of human activities could influence the amount of chemical that is removed during contact and may impact the magnitude of transferability and potential human exposure. Moisture measurements may aid in the determination of entry intervals for risk assessment and risk management following indoor pesticide applications.

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