Volatilization and Dislodgeable Residues Are Important Avenues of Pesticide Fate

by DR. R. J. COOPER,
DR. J. M. CLARK,
and DR. K. C. MURPHY
University of Massachusetts
at Amherst

Figure 1. A high-volume air sampler was used to collect volatile loss of pesticides.

VOLATILIZATION can be defined simply as the loss of chemicals from plant and/or soil surfaces by evaporation into the atmosphere. Post-application vaporization of pesticide residues was reported as early as 1946 when scientists concluded that revaporized residues of the herbicide 2,4-D had damaged cotton growing some distance from a 2,4-D-treated field in New Mexico. Numerous field studies during the past 20 years have identified volatilization as a potentially significant avenue of loss from pesticide-treated areas. A review of volatilization by Taylor reported losses as high as 90% following application to field crops or moist soil.

Although the quantity and duration of pesticide volatilization from soil and field crops have been studied, volatile losses following pesticide application to turfgrass areas has not been well documented. A dense, perennial turfgrass ground cover is quite different from a plowed field or corn planting, and might be expected to provide a different environment for volatilization. Characterizing pesticide volatility from

Table 1
Pesticides of Interest and Selected Characteristics for Each

Pesticide	Trade Name	Use	Vapor Pressure (mm Hg at 25°C)	Application Rate (lbs ai/acre)
MCPP	Mecomec 4	Herbicide	0	2.0
Triadimefon	Bayleton	Fungicide	1.5×10^{-8}	1.4
Isazofos	Triumph 4E	Insecticide	9.0×10^{-5}	2.0
Trichlorfon	Proxol 80SP	Insecticide	2.0×10^{-6}	8.1

turfgrass is of interest not only because of environmental contamination concerns, but also as a factor that might contribute to reduced effectiveness of the material. The following USGA-sponsored research study was conducted to evaluate the amount of volatile loss following application of several commonly used turf pesticides.

In addition to its potential volatile loss into the atmosphere, a pesticide will usually be present in substantial amounts on the foliage of treated turf following application. Pesticide residues on the leaf surface are referred to as dislodgeable foliar residues (DFR). The amount and longevity of DFR were evaluated along with volatility during the study.

Research Methods

All experiments were conducted at the University of Massachusetts Turfgrass Research Facility in South Deerfield, MA. During June 1991, a large area was seeded with Penncross creeping bentgrass at 1 lb/1000 sq ft. Throughout the study maintenance of the experimental area was similar to that of a golf course fairway, including mowing at a height of ½" three times per week, and irrigation and pesticide applications (pesticides of non-interest to this study) as needed.

Pesticides applied during the study are listed in Table 1. These materials were chosen for study because they are commonly used on golf courses throughout the country, and little information was available regarding their volatility or foliar residue behavior on turfgrass. For each application, a circular plot with a radius of 33 feet was sprayed. All materials were applied using a 12-nozzle boom sprayer operating at 40 psi with the label-recommended spray volume. Applications were always made before 9:00 a.m., at the highest label rate, in order to assess the maximum potential volatility and DFR levels.

Air samples were collected on approximately 120 milliliters of Amberlite XAD-4 polymer resin contained in a high-volume air sampler located 28 inches above the center of the treated area (Figure 1). For approximately 4 hours, air was drawn through the pesticide adsorption resin at a rate of 28 cu ft per minute. After determining average wind speed at the center of the plot, and the pesticide concentration of the adsorption resin, the amount of airborne (volatile) pesticide loss was calculated using a model developed by Wilson and his associates.

Volatile residues were collected immediately after application (i.e., during application and for an additional 30 minutes) and during consecutive 4-hour sampling periods until 7:00 p.m. on the first day of each experiment. Sampling continued from 7:00 a.m. to 7:00 p.m. on days 2 and 3, and from 9:00 a.m. to 5:00 p.m. on days 5, 7, 10, and 15 of each experiment.

Figure 2
Volatilization of the Fungicide Triadimefon Following Application to Creeping Bentgrass

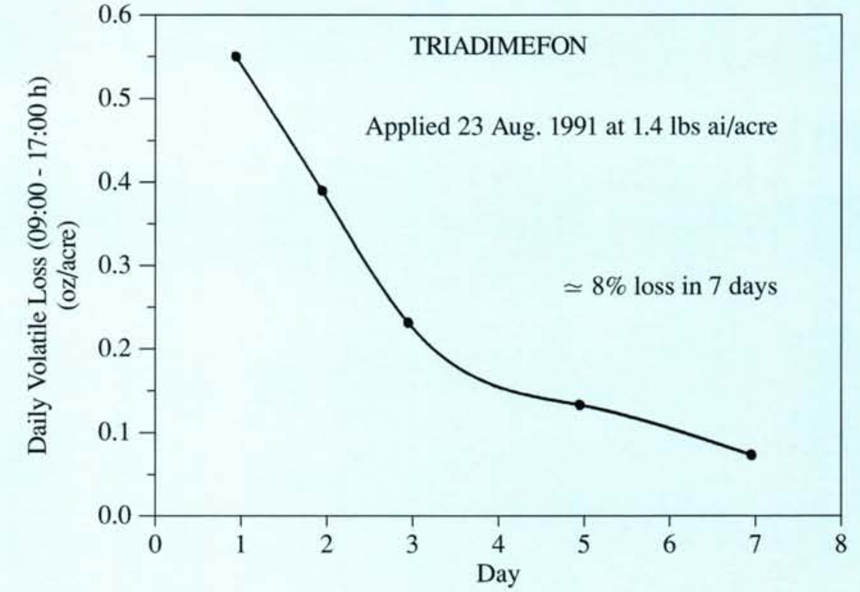
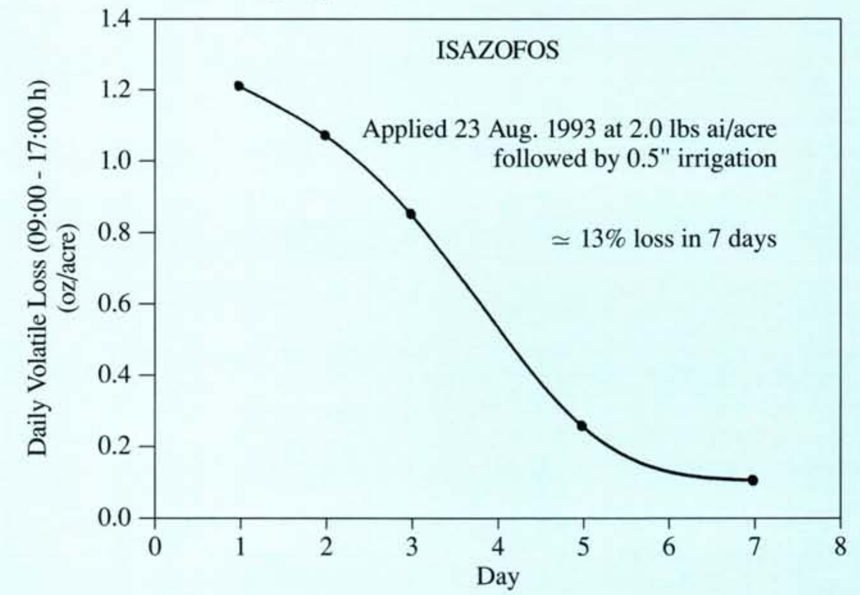


Figure 3
Volatile Loss of the Insecticide Isazofos Following Application for White Grub Control



Isazofos application was followed immediately by ½" of irrigation. Trichlorfon was applied twice; once with ½" of irrigation immediately after application and once without post-application irrigation.

Dislodgeable foliar residues were determined by wiping a 1 sq ft area of treated turf with a piece of water-dampened cheesecloth to remove pesticide residues. DFR samples were obtained 15 minutes, 3 hours, and 8 hours after application on day 1, and at noon on all other sampling days during the studies.

Results and Discussion

Volatile Loss

MCPP is a herbicide used to control broadleaf weeds in turf, such as clover, ground ivy, and chickweed species. It is often used alone or in a combination product for bentgrass areas. In this study, MCPP was applied at a rate of 2.0 lbs of active ingredient (ai) per acre. On the day of application, only 0.6% of applied herbicide was lost due to volatilization. Volatile loss on day 2 after treatment was determined to be 0.2%, with no volatilization being detected on day 3 or for the remainder of the evaluation. Thus, MCPP exhibited extremely little volatilization potential, showing a total pesticide loss into the atmosphere of less than 1% of the application.

In the northern United States, fungicides are often the most frequently applied golf course pesticide. Triadimefon, a commonly used fungicide, was evaluated after application at a rate of 1.4 lbs ai/acre (Figure 2). Triadimefon loss was most rapid during the 2-hour period immediately following application, with a total loss of 2.5% of the pesticide on day 1 of the study. On day 2, volatility remained substantial, with an additional 2.4% of the application lost. Volatility had declined notably on day 3 of the study so that only 1.5% of applied triadimefon was detected. Although detectable on days 5 and 7 of the study, volatilization loss was substantially less than 1% on both of those sampling days.

Through 2 weeks of sampling, approximately 8% of the triadimefon application was lost by evaporation into the atmosphere, with 7.3% being lost within 5 days of the application. This two-phase pattern of volatile loss, with the greatest loss occurring during the 3-5 day period after application, followed by greatly reduced loss during the second week, is similar to patterns of volatile loss reported from soil and field crops.

It has been suggested that the slower rate of volatile loss typically observed after the first week may have two explanations. The first explanation suggests that remaining residues are less available because they lie deeper within the plant canopy and are trapped in the irregular areas of leaves, stems, and leaf/stem junctions. A second possibility is that since pesticide residues are most available immediately after application, with time the easily evaporated residues are removed until only those residues that are most strongly adsorbed or that have penetrated the leaf surface remain. Both processes contribute to reduced volatility over time, and the relative importance of each has not been determined.

During August 1993, the insecticide isazofos was applied to the fairway at 2.0 lbs ai/acre, followed by 0.5" of irrigation to facilitate movement into the soil for control of white grubs (Figure 3). Maximum volatile loss occurred from 11:00 a.m. to 3:00 p.m. on the day of application, with a total loss of 5.8% for day 1. Volatile loss declined to 3.4% on day 2, 2.7% on day 3, and 0.8% on day 5. Total loss of isazofos by evaporation for the first 7 days following application was 13%. During the second week following application, far less than 1.0% volatility was recorded. This confirmed the two-phase nature of our previous volatility research and the tendency for most volatile loss to occur during the first 7 days following application.

The final pesticide evaluated was the insecticide trichlorfon (Figure 4), another organophosphate insecticide used to control soil-inhabiting insects. Trichlorfon was applied once, followed by 0.5" of irrigation, and again separately with no post-application irrigation. The application rate on both occasions was 8.1 lbs ai/acre. Following the June 1993 application and irrigation, volatile loss of trichlorfon and DDVP (a breakdown product of the insecticide) totaled only 1.8% for day 1 of the study and reached a maximum of 3.8% on day 2 (Figure 4). Volatile loss on day 3 was about 3% of the application and declined to less than 1% by day 5. In total, when trichlorfon was applied and watered-in, volatile loss was approximately 9%.

Trichlorfon volatility following application during September 1991, with no post-application irrigation, is shown in Figure 5. Combined volatile loss of trichlorfon and DDVP on day 1 was 2.8% of the applied compound. This level of loss is substantially higher than that observed following the trichlorfon application with post-application irrigation. Total volatile loss increased on day 2 and then declined for the remainder of the study. Without post-application watering, trichlorfon loss totaled 13% compared to 9% when irrigated. Also, withholding post-application irrigation resulted in less conversion of trichlorfon to its more toxic breakdown product, DDVP.

Dislodgeable Foliar Residues

Following pesticide applications, especially when applying liquid materials, there remains a residue of pesticide on the turfgrass foliage. The quantity and duration of the dislodgeable foliar residues for pesticides studied is summarized in Table 2.

Maximum DFR for MCPP was measured 15 minutes after application and amounted to less than 1% of the application. At 3 hours post-application, when the leaf was dry, residues had dissipated to only 0.14% of the application.

Foliar residue losses of triadimefon 15 minutes after application totaled 2.4% of the total applied product. Residue levels decreased to about 1% by 3 hours after application. As with MCPP, dislodgeable foliar residues were substantially reduced once the spray solution had dried.

Irrigation following the isazofos application reduced DFR from 1.8% of the application when measured 15 minutes after application to almost none (0.01%) 3 hours later. Immediate post-application irrigation of trichlorfon (Table 2) provided a rapid decline in DFR similar to that observed with isazofos. Trichlorfon applied without irrigation resulted in foliar residue levels 4 times higher than for irrigated turf.

Table 2
Dislodgeable Foliar Residues Following Pesticide Application

Sampling Period	MCPP	Triadimefon	Isazofos*	Trichlorfon + DDVP	
	% of applied				
Day 1				non-irrigated	irrigated*
15 min.	0.60	2.4	1.80	—	—
3 hr.	0.10	1.5	0.01	2.0	0.3
8 hr.	0.10	1.0	0.00	1.1	0.2
Day 2	0.08	0.6	0.06	1.0	0.4
Day 3	0.00	0.6	0.02	0.7	0.3
Total for Study	1.00	6.2	1.90	4.8	1.2

*Application followed by 0.5" irrigation

Conclusions

Pesticide volatilization ranged from less than 1% for MCPP to 13% for the insecticides isazofos and trichlorfon during the week following application. The cumulative percentage loss was directly related to vapor pressure. Maximum volatility occurred when solar radiation, surface temperature, and wind speed were greatest.

The pattern of volatile loss was diphasic, with nearly all the measured volatile residues lost within the first week. Irrigating treated turf immediately after application greatly reduced initial volatile loss. The availability of dislodgeable residues declined rapidly following application, with levels typically 1% or less by 8 hours after application. Post-application irrigation was very effective in reducing leaf residues. Foliar residues of isazofos and trichlorfon were reduced to less than 1% of the initial application concentration as a result of post-application irrigation.

Suggestions for Reducing Exposure to Volatile Foliar Residues

• Whenever a choice exists among products or formulations that are equally suitable for a job, choose the less volatile one. Consult your sales representative or refer to the label and material safety data sheets to learn the differences among materials. Be aware that different formulations of a particular herbicide can have significantly different volatility potential. For example, the acid, sodium salt, and amine formulations of 2,4-D have low volatility, while the ester formulation of this herbicide is extremely volatile.

• Weather conditions on the day of application greatly influence volatilization. High wind speeds increase airborne loss of pesticides; thus, if the weather is calm, volatility will be lessened. High air temperatures also increase volatilization. In fact, researchers have reported a three- to four-fold increase for each 18°F increase in temperature. Making applications on cool, cloudy days or in the late afternoon when temperatures are cooling can help to reduce initial volatility.

• Be sure to water-in pesticides immediately after application if the label says to do so. Rainfall and irrigation transport the pesticide deeper into the turf canopy where it can bind to the thatch or soil. This will help to reduce volatile losses. Our research has shown that after many pesticides have dried on the leaf, they are not easily dislodged. Timely irrigation can be a very effective tool to reduce both volatile losses and dislodgeable residue levels.

Figure 4
Volatile Loss of the Insecticide Trichlorfon and the By-Product DDVP Following Application at 8.1 lbs ai/acre With 0.5" of Irrigation

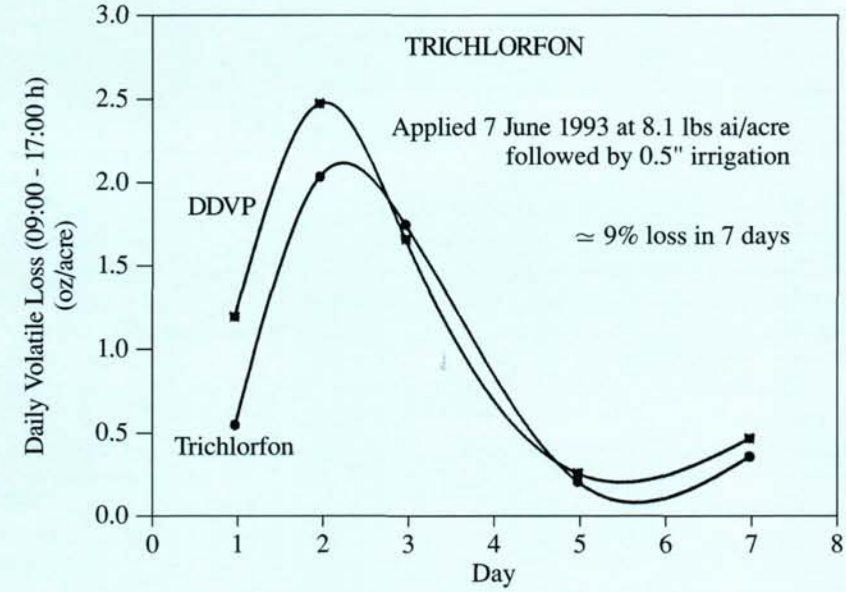
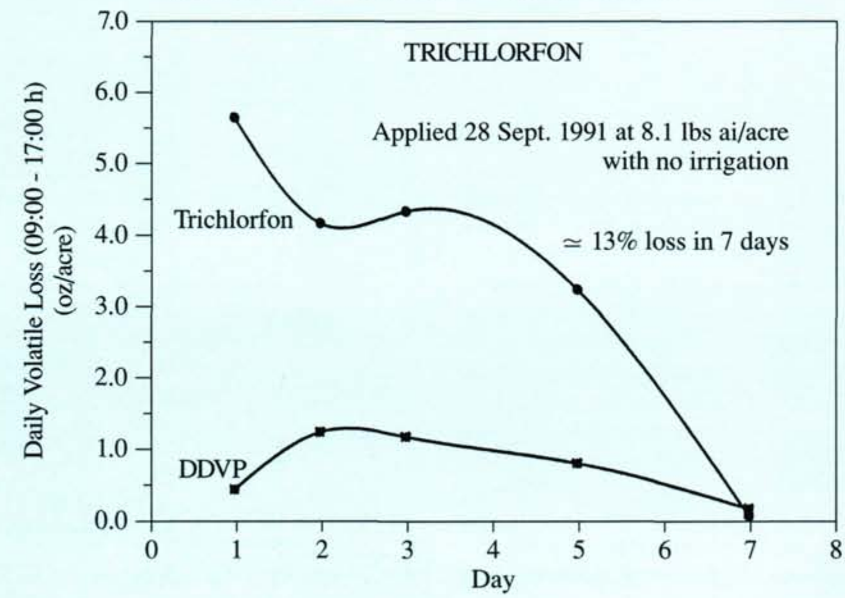


Figure 5
Volatile Loss of the Insecticide Trichlorfon Following Application at 8.1 lbs ai/acre Without Irrigation



Additional Reading

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