The Fate of Pesticides and Fertilizers in a Turfgrass Environment

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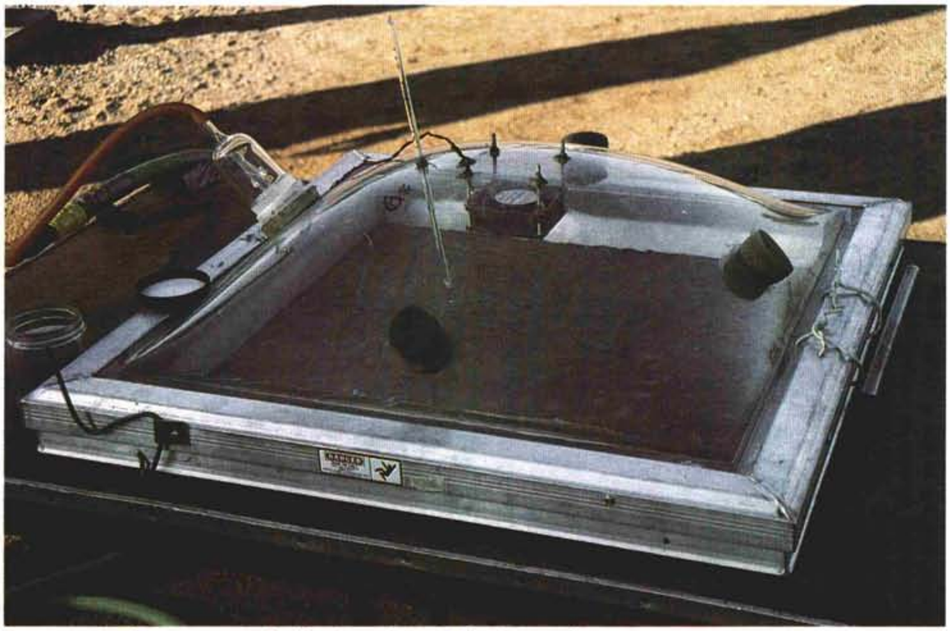


A system used to measure volatilization of pesticides from turfgrasses.

ENVIRONMENTAL protection has become a national issue in the past several years. While concerns focused on cleaning up contaminated surface waters in the 1970s, the focus in the 1980s and into the 1990s has been on groundwater. More than one-half of the population of the United States relies on groundwater for all or part of its potable water. Up to 95% of rural residents obtain their water supplies from wells. Domestic uses account for only 18% of the groundwater used in this country, while almost two-thirds of the groundwater withdrawn in the U.S. is used for irrigation. In California, up to 20 billion gallons of groundwater is used every day for all irrigation purposes. The heavy dependence on groundwater for both domestic and agricultural uses makes groundwater a very valuable resource that must be protected from contamination.

Widespread use of pesticides has been made in agriculture during the past 40 years. California alone accounts for 25% of the pesticides applied in the United States. Prior to 1979, little monitoring of groundwater for the presence of pesticides was practiced because it was assumed that they were not sufficiently long-lived and mobile to pose a threat to groundwater. However, the discovery of a soil fumigant, 1,2-dibromo-3-chloropropane (DBCP) in well water in Lathrop, California, triggered widespread groundwater sampling programs. As a result, approximately 10,000 wells in the state have been analyzed for pesticide residues. The monitoring program detected more than 50 different pesticides in 23 California counties.

To try to prevent or minimize future groundwater contamination by pesticides, AB2021, the Pesticide Contamination Prevention Act, was passed in 1985. As a result of this bill, the use of several pesticides is being restricted in some areas of the state. In addition, the California EPA's Department of Pesticide Regulation is monitoring the groundwaters and soils of the state for the presence of more than 50 other pesticides. If these compounds are detected, their use may be restricted as well.

In addition to pesticides, nitrates have received a great deal of attention. Contamination of groundwater by nitrates is one of the major sources of non-point source pollution in the United States. A recent survey by the United States Geological Survey (USGS) suggested that the use of fertilizers in agriculture is a large contributing factor to elevated nitrate levels.

There has also been concern expressed over exposure to pesticides by routes other than drinking water. In California, a number of pesticides have been designated as potential toxic air contaminants. Thus, consideration of pesticide volatilization is an important aspect to consider in an environmental fate study, both from a pesticide efficacy and an environmental contamination standpoint.

The purpose of this research project was to study the fate of pesticides and fertilizers applied to turfgrass in an environment that closely resembles golf course conditions. The goal was to obtain information on management practices that will result in healthy, high-quality turfgrass while minimizing detrimental environmental impacts. By simultaneously looking at interactions between soils, turfgrasses, irrigation amounts, pesticides, and fertilizers, questions about "best management practices" for turfgrass growth and maintenance will be able to be answered.

METHODS

Site Construction

A site was constructed specifically for the purposes of this project at the Turfgrass Research Facility at the University of California, Riverside. The site consists of 36 plots, each of which measures 12 ft × 12 ft. The fairway area consists of 24 plots, 12 each of two different soil types (a sandy loam and a loamy sand) that were located randomly in the fairway area. Because the soil types were distributed randomly in the fairway area, borders were constructed to contain the soil in its respective plot. The putting green area has 12 plots that were constructed using 18"

Table 1
Summary of Results from Nitrogen and Pesticide Leaching and Pesticide Volatilization Experiments

Turfgrass Species	Source of N	Irrigation	Soil	N Leached (%)	2,4-D Leached (%)	Carbaryl Leached (%)	2,4-D Volatilized (%)	Carbaryl Volatilized (%)
Creeping	SCU	100% ETc	sand/peat	0.56	7.580	0.0240	1.05	0.030
Bentgrass	SCU	130% ETc	sand/peat	0.55	2.250	0.0450	0.96	0.034
(putting green)	Urea	100% ETc	sand/peat	0.71	4.180	0.0690		
	Urea	130% ETc	sand/peat	1.69	2.490	0.0220		
Tifway II	SCU	100% ETc	loamy sand	0.47	0.071	0.0027	0.52	0.038
Bermudagrass	SCU	130% ETc	loamy sand	0.58	0.260	0.0100	0.72	0.047
(fairway)	Urea	100% ETc	loamy sand	0.30	0.280	0.0180		
	Urea	130% ETc	loamy sand	0.75	0.190	0.0045		
	SCU	100% ETc	sandy loam	0.67	0.071	0.0017	0.43	0.025
	SCU	130% ETc	sandy loam	1.71	0.300	0.0230	0.50	0.021
	Urea	100% ETc	sandy loam	0.57	0.042	0.0032		
	Urea	130% ETc	sandy loam	0.63	0.056	0.0015		

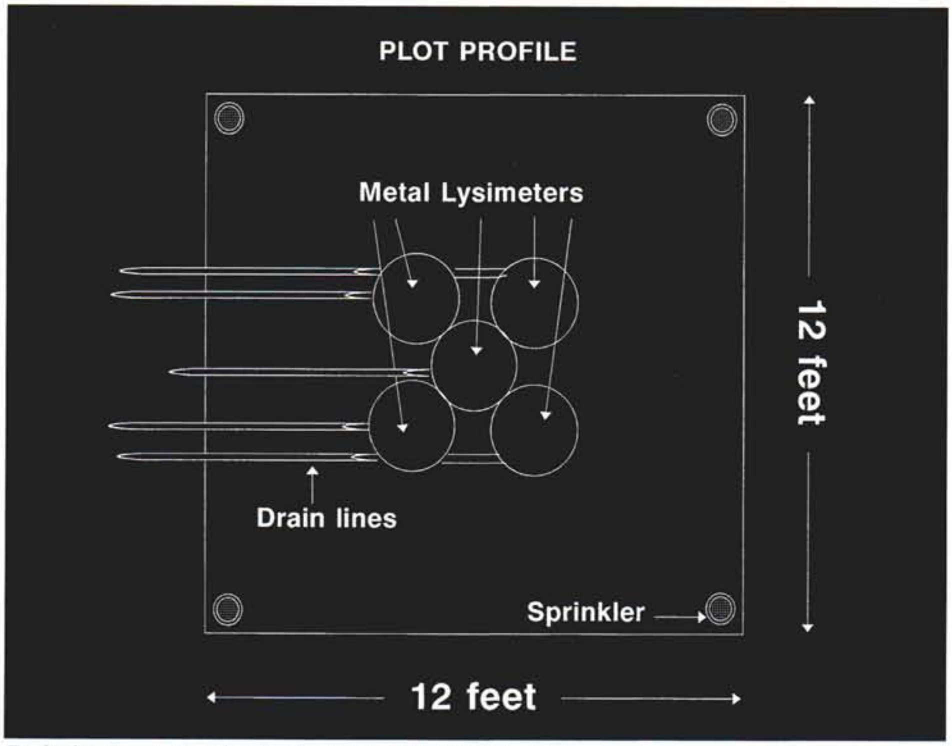
[1]Average of three replicate values

of Caltega IV green sand with 15% sphagnum peat.

To enable us to obtain samples of leachate from each of the plots, collection devices had to be constructed. Lysimeter assemblies, consisting of 5 metal cylinders, were placed in the center of each of the 36 plots. Each of the lysimeters has a metal drain pipe at the bottom that extends the length of the field and terminates at a retaining wall on the south side. The lysimeter assembly and drain system were fabricated using only metal so that there was no potential for pesticide adsorption. This allowed us to make a quantitative determination of the mass of pesticide leaching through the turfgrass.

The irrigation system was designed so that each of the 36 plots could be irrigated individually. Each plot has 4 sprinklers, one at each corner. The entire irrigation system is outside of the lysimeter assembly so that there is no potential for adsorption of the pesticides to the PVC pipe. The irrigation is controlled electronically; scheduling was determined based on the evapotranspiration requirements of the turfgrass.

Sod was laid on the plots in February 1992. Creeping bentgrass (*Agrostis palustris*) was installed on the green plots, and hybrid bermudagrass (*Cynodon dactylon* by *Cynodon transvaalensis* var. Tifway II) on the fairway plots.



Each plot was equipped with a lysimeter assembly consisting of five metal cylinders with metal drainpipes on the bottom.

Experimental Design

All turfgrass soil-type combinations were subjected to two irrigation regimes: 100% crop evapotranspiration (ETc) and 130% ETc beginning in March 1992. The 100% ETc treatment is the optimal amount of water required by the turfgrass to grow and maintain itself in a healthy state. Thus, 130% ETc is above the optimum water requirement, but is well within the range of standard practice within the industry.

Two fertilizer treatments were established for the plots. The green plots were fertilized at a rate of 1 lb N/1000 sq ft per month, and the fairway plots at a rate of 0.5 lb N/1000 sq ft per month. The two fertilizer sources were urea and sulfur-coated urea (SCU). The SCU applied to the green plots was in the form of miniprills to minimize losses during mowing operations. Fertilizer was hand-applied twice per month to each plot individually to ensure even distribution of the fertilizer.

Trimec® Bentgrass Formulation (pbi/Gordon Corporation, Kansas City, MO) was applied to all plots in May and August, 1993. This formulation contains 0.45 lb 2,4-D per gallon in the form of a dimethylamine salt. The herbicide was applied at a rate of 1.8 oz and 3.2 oz per 1000 sq ft for the green and fairway plots, respectively. Sevin® brand

XLR plus (Rhone-Poulenc Ag Company) insecticide was applied to the plots in August, 1993, at a rate of 6.1 oz and 10.7 oz per 1000 sq ft for the green and fairway plots, respectively. This formulation of carbaryl contains 4 lb active ingredient per gallon.

Sample Collection

Samples of drainage water were collected from each of the 36 plots on a weekly basis. The samples were analyzed to determine the concentration of nitrate, phosphate, carbaryl, and 2,4-D present. Drain volumes were measured and recorded several times per week, allowing a calculation of the mass of nutrients and pesticides leaching from the plots.

The volatilization of 2,4-D and carbaryl was measured during an experiment conducted in August, 1993. Immediately after pesticide application, a volatilization flux chamber was placed directly on the turf in each of the designated plots. The air above the surface of the turfgrass was pulled out of the chamber at a very low rate (approximately 10 liters/minute). As it was removed, the air was passed through a polyurethane foam plug (PUF) that adsorbed any pesticides present in the air. Air from outside the chamber was drawn into the chamber to replace the air that was removed. Any pesticides in the outside air were removed as the air was drawn into the chamber. The PUFs were replaced every four hours. The position of the flux chamber was rotated between two marked spots on the plots to minimize damage to the turfgrass. The volatilization experiment was conducted for 7 days.

RESULTS AND DISCUSSION

Leaching Studies

The mass of nitrate-N that leached through the turf was calculated by multiplying the volume of water that drained through the lysimeters in a given plot each week by the concentration of nitrate-N in the leachate that week. Between April 1992 and December 1993, 47.85 g of nitrogen was applied to the 13.2 sq ft surface area of each fairway lysimeter. Of that amount, between 0.30% and 1.71% (less than 1 g) was not used by the turfgrass and leached through the plots. These results are summarized in Table 1. An analysis of variance showed that there was no significant difference in the percent of nitrate-N leached through the plots caused by the different treatments (i.e., soil type, fertilizer type, or irrigation amount).

In the putting green plots, between 0.56% and 1.69% of the applied nitrogen leached through the turfgrass. Once again, none of the treatments caused any significant differences in the observed mass of nitrate-N that leached through the plots.

The mass of 2,4-D that leached through the plots varied considerably, from approximately 0.055% on the sandy loam plots receiving 100% ETc to approximately 5% on the green sand plots receiving 100% ETc (Table 1). An analysis of variance using all the plots confirmed that the soil type significantly affected the mass of 2,4-D that leached through the soil. This result is not unexpected, as pesticides can be adsorbed to the clay fraction of soil. The pesticide 2,4-D has an adsorption coefficient of approximately 20 cm^3/g. This compound would not be expected to adsorb to a great extent to the soil, although it will adsorb if clay is present. The sandy loam soil contains 12.9% clay; thus, adsorption would be expected to be greater in this soil than the other soils, which have clay contents of less than 2%. When only the fairway plots were considered, soil type did not significantly affect leaching, reflecting the small differences in clay content between the two fairway soils.

The mass of carbaryl that leached through the plots was very low, ranging from 0.0015% to 0.07%. When all plots were considered, the soil type was significantly correlated with the mass leached, similar to the situations with 2,4-D. However, when only the fairway plots were considered, soil type was not significantly correlated with the mass of carbaryl leached.

Volatilization Studies

Volatilization of 2,4-D into the air above the turfgrass was measured during an experiment performed in August, 1993. The mass of 2,4-D that volatilized from the plots is shown in Table 1. The percent volatilized ranged from less than 0.5% to approximately 1%. An analysis of variance indicated that there was a significant difference in the percent that volatilized between the green, fairway, and control plots. The difference between the green and fairway plots was also significant, suggesting that the differences may be due to the turfgrass species or to the difference in cutting height.

The mass of carbaryl that volatilized from the plots was very small: between 0.021% and 0.047% of the amount applied. No significant differences in the percent of carbaryl volatilized resulted from the different treatments.

Turfgrass Quality

The turfgrass was rated approximately every two weeks to enable us to assess any effects of the different treatments on the quality of the turfgrass. No significant differences were found for any of the plots as a result of the different irrigation or fertilizer treatments. However, there was a significant difference in the quality of the turfgrass on the sandy loam plots compared to the loamy sand plots. The scores for the loam plots averaged approximately one rank higher than the loamy sand plots during the same week.

CONCLUSIONS

The overall conclusion that can be made on the basis of the experiments performed at the University of California, Riverside, is that, in general, there is very little potential for groundwater or air contamination from turfgrass chemicals under our conditions. The only exception noted was for the leaching of 2,4-D in the putting green plots where the soil was too sandy to prevent the movement of a portion of the chemical below the rootzone. Specific conclusions from this research are:

1. Under the conditions of this study (i.e., biweekly applications of urea and sulfur-coated urea), little leaching of nitrate-nitrogen (generally less than 1% of the amount applied) was measured. No significant differences in percent leached as a result of irrigation amount or fertilizer type was documented.
2. Leaching of 2,4-D was very low in soils that contained some clay to adsorb the pesticide; however, up to 7.5% leaching was measured in sand. Irrigation amount did not significantly affect the amount of leaching.
3. Less than 0.1% of the carbaryl leached, regardless of soil type. Irrigation amount did not significantly affect the amount of leaching.
4. Little volatilization of 2,4-D was measured ($\leq 1\%$) from any of the plots, although the difference in the amount volatilized was significantly different between the two turfgrass species used.
5. Little volatilization of carbaryl was measured ($\leq 0.05\%$) from any of the plots; no significant differences between the treatments occurred.
6. Neither fertilizer type nor irrigation amount caused any significant differences in the quality of the turfgrass as determined by biweekly turfgrass ratings.

These results cannot necessarily be extrapolated to all golf course situations, however. For example, some modifications in the fertilizer application program had to be made for the purposes of this study. The SCU was applied on a biweekly basis to make it on the same schedule as the urea, which would not be the case on a golf course. Thus, the amount applied at any one time was relatively small compared to what might be applied on a golf course. This could have had an impact on the amount of leaching measured. We are planning to conduct further studies that follow a more typical golf course fertilization program to try to answer this question.