The Impact of Soil Type and Precipitation on Pesticide and Nutrient Leaching from Fairway Turf

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THREE YEARS AGO, in a project funded by the United States Golf Association, a team of researchers from Penn State University, the University of Massachusetts, and Cornell University set out to establish a more comprehensive knowledge base as to the fate of pesticides and fertilizers applied to experimental fairways in large-scale field research facilities. The three universities divided the research objectives based upon the specialized facilities at each site. The same pesticide and fertilizer materials were used at each site to give the project cohesiveness. Penn State University investigated the extent of pesticide and nutrient runoff from fairway-type turf consisting of either creeping bentgrass or perennial ryegrass. The University of Massachusetts examined volatilization and foliar dislodgeability of pesticides applied to fairway-type turf (creeping bentgrass). Cornell University studied the impact of soil type and precipitation on pesticide and nutrient leaching from fairway-type turf (creeping bentgrass). The results of the Penn State University and University of Massachusetts studies are found elsewhere in this issue.

The objectives of Cornell University's portion of this project were to determine pesticide and nutrient leaching from high-maintenance fairway-type turf as influenced by:

- Soil texture (sand, sandy loam, and silt loam)
- Pesticide properties (persistence and mobility)
- Rainfall differences (moderate and very heavy rainfall patterns)
- Turfgrass maturity (density and organic matter accumulation)

A second objective of this project was to determine the impact of the addition of organic matter (peat) at the time of construction on pesticide leaching from experimental, sand-based putting greens.

During the summer of 1993 we experienced major lightning storm damage to our main research facility, so as of this date not all of the objectives of this research project have been met.

This study was designed to examine a wide range of conditions that are known to affect pesticide leaching. For example, the soils used ranged in texture from sand, with a high potential for pesticide leaching, to a silt loam soil, which has a nominal potential for pesticide leaching. The pesticides used also reflect a range in potential for leaching, with mecoprop (MCPP), trichlorfon (Proxol), and isazofos (Triumph) having a high potential for leaching, and triadimefon (Bayleton) having an intermediate potential for leaching. Climatic factors, like the amount of rainfall and/or irrigation, that also influence pesticide leaching were also evaluated in this project. Table 1 summarizes all the factors studied.

Experimental Conditions

These experiments were conducted in the field to simulate actual golf course conditions, but without the golfers. The sites were

Table 1
Factors Evaluated in Golf Course Environmental Research Project, Cornell University

	Soil		Pesticide	Climatic	
Site	**Texture**	**Leaching**	**Name**	**Leaching**	**Rainfall/Irrigation**
Fairway	Sand	High	Isazofos	High	Above normal
	Sandy loam	Intermediate	Mecoprop	High	Normal
	Silt loam	Nominal	Triadimefon	Intermediate	
			Trichlorfon	High	
Green	Sand	High	Triadimefon	Intermediate	Normal
	Sand/peat (80/20)	Intermediate			

Table 2
Pesticides and Fertilizers Applied in Fairway and Green Study

Common Name	Trade Name	Formulation	Rate* of Application	Date of Application
Fairways				
Isazofos	Triumph	4 E	1.5 oz/1000 sq ft	Aug. 25, 1992
Mecoprop	Mecomec	Potassium salt	1.5 oz/1000 sq ft	Sept. 24, 1991
Trichlorfon	Proxol	80 SP	3.75 oz/100 sq ft	July 2, 1992
Triadimefon	Bayleton	25 WP	2 oz/1000 sq ft 4 oz/1000 sq ft	Sept. 24, 1991 Oct. 11, 1991
Fertilizer	Scotts	29-3-7	1 lb N/1000 sq ft	Sept. 1991 Oct. 1991 June 1992 Sept. 1992 Oct. 1992
Greens				
Triadimefon	Bayleton	25 WP	4 oz/1000 sq ft	Oct. 25, 1992

*For pesticides, rates are the amount of product applied

mowed frequently and were fertilized/irrigated at rates typically used on golf courses.

Fairway Studies

Fairways comprise the largest area of the more highly maintained portion of golf courses. Fairways therefore are where the largest quantity of pesticides and fertilizers are used on a high-quality golf course. Fairways usually are built with on-site soils that can range from very sandy soils to very fine-textured clays. It is known that the extent of either pesticide or nutrient leaching is highly dependent on soil properties. Thus, it is important to study nutrient/pesticide leaching from fairway areas representing several soil types.

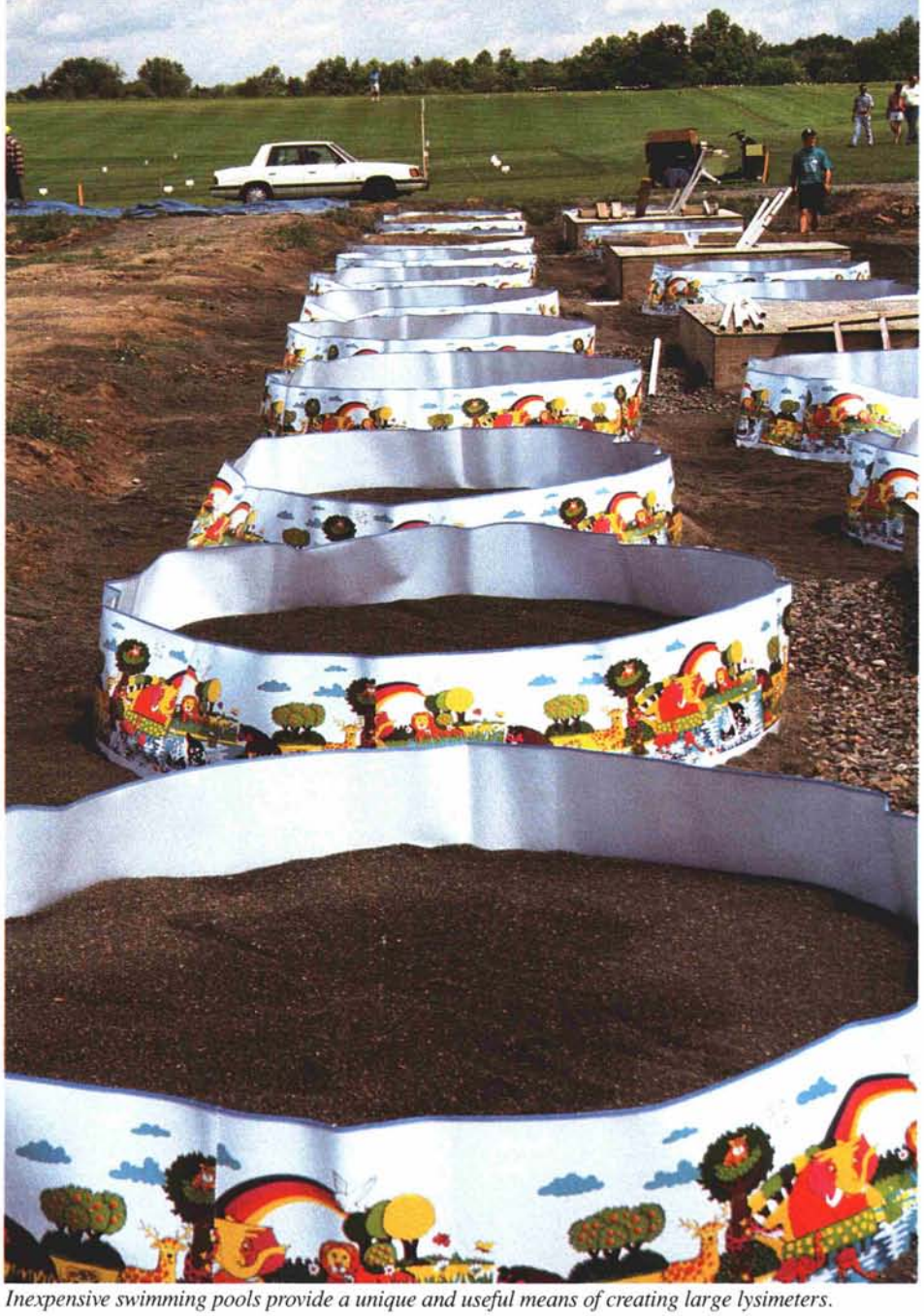
This research was conducted at the ARESTS (Automated Rainfall Exclusion System for Turfgrass Studies) Facility at the Cornell University Turfgrass Field Research Laboratory in Ithaca, NY. This facility is designed to control all water going onto the turf (rainfall and/or irrigation) and collect all the water passing through the soil (leachate). During the months of May through October, a large cover on wheels (called a rainout shelter) quickly covers the experimental site if rain occurs. This allows us to control the amount of rainfall and irrigation during the growing season. In this study we used historic weather data and applied irrigation water that reaches the plots to mimic a normal rainfall pattern and an above-normal rainfall pattern. In this way we could determine if certain kinds of weather-type years are likely to result in greater pesticide/nutrient leaching than others.

The ARESTS Facility is composed of 27 free-draining lysimeters (plots) that are 12 ft × 12 ft, each containing nine 15"-deep plots divided into three soil types (sand, sandy loam, and silt loam). Each plot is individually irrigated. The site was seeded with Penncross creeping bentgrass in May of 1991. All of the systems are linked with a data acquisition/control system via computer. The site was completed in 1987 but reseeded with Penncross creeping bentgrass in May of 1991. The site was mowed three times per week (clippings removed) and irrigated so that at least 1" of rainfall/irrigation was applied per week.

Pesticides and fertilizer were applied to all but one plot of each soil type, which served as the untreated control treatment. The materials, rates, and dates of applications are shown in Table 2.

Putting Green Study

Highly sandy sites, such as putting greens, are often cited as being the most susceptible to nutrient and pesticide leaching due to high permeability, low organic carbon content, and low cation exchange capacity (CEC).



Inexpensive swimming pools provide a unique and useful means of creating large lysimeters.

During construction, the opportunity exists to modify sand with amendments that possibly will reduce both nutrient and pesticide leaching by increasing the amount of organic carbon and the CEC level. Thus, the objective of this section of the project was to determine the effect of an organic amendment (peat) on the leaching of pesticides from sand-based experimental putting greens. The site for this study is the Cornell University Turfgrass Field Research Laboratory, Ithaca, NY. The site was constructed during 1992 and sodded with washed creeping bentgrass on October 5-6, 1992. Plots consisted of 8 ft diameter USGA putting green profiles containing 12" of root zone mix, a 2" layer of coarse sand, and 4" of gravel at the bottom. Each plot was constructed using a small swimming pool that includes one outlet to collect the leachate. Reed sedge peat amendment was added to the slightly calcarious sand at a ratio of 80:20 sand to peat (v/v). Unamended sand was included as a treatment for comparison. Triadimefon was applied during the week of October 25, 1992.

For both studies there were four replicate plots of each treatment, and averages are shown in the accompanying tables.

Research Findings

The nature of these studies is such that we collected leachate samples from a depth of 15", which is considered the most important zone for retaining and degrading pesticides/nutrients. Under real-life conditions, this water must move deeper through the soil until it reaches the water table. Therefore, the

data presented here are not groundwater quality data, but are estimates of the maximum concentration of pesticide/nutrient that could reach groundwater, assuming a water table depth of 15". On sites with deeper water tables, concentrations would be less.

Pesticides

It was not surprising that pesticides leaching from experimental fairways were influenced by soil type, the characteristics of the individual pesticide, and the amount of precipitation/irrigation, as shown in Tables 3 and 4. This type of experiment is considered a *worst case scenario*: using highly mobile pesticides over a shallow water table on highly leachable soil (sand) and having a rainfall/irrigation pattern likely to cause leaching. However, the extent of the leaching was quite surprisingly high in these unusual cases. For example, 50% to 62% of the applied mecoprop (MCPP) leached from the newly established sand experimental fairway plot. This suggests that newly seeded turf, or other turf stands with very low shoot density, that is grown on very sandy soil is susceptible to pesticide leaching, assuming other factors important to pesticide leaching are present. Results from other research studies and from monitoring studies of actual golf courses have found mecoprop does not leach to any great extent.

We also observed in one case that leaching of the pesticide trichlorfon (Proxol) was unaffected by soil type. This is highly unusual for studies of this nature. However, with some understanding of the nature of this part of the study, the results can be explained. First, a highly water-soluble pesticide that does not easily bind to organic matter was applied, and a large amount of rainfall was received within the first eight days after application (4.4" and 9.6" for the normal and above-normal precipitation treatments, respectively). Highly water-soluble pesticides that do not easily bind onto organic matter can move through the soil via water if they are not quickly degraded. The extreme rainfall that occurred within the first eight days after application resulted in a large amount of pesticide leaching, primarily due to a water flow process known as preferential flow. In this case, water very rapidly moves through soil either in macropores (worm holes, cracks in soil, etc.) in non-sand soils (i.e., sandy loam and silt loam) or in other preferential pathways. The data from this study strongly confirms that preferential water flow did occur on these soils, caused by the heavy rainfall, and that pesticide leaching was heavily influenced by this preferential water flow.

The label for the pesticide isazofos (Triumph) states not to apply this material on sandy areas due to a potential for leaching into groundwater. Our results confirmed that isazofos does leach from sand, but the good news is that very little leaching was observed in the finer-textured soils (sandy loam and silt loam).

Pesticide properties are very important in understanding the potential for pesticide leaching. Triadimefon (Bayleton) is considered to have the lowest potential for leaching of the four pesticides used in these studies. For each soil, by precipitation treatments, the leaching of triadimefon was the lowest of the four pesticides. Little or no leaching was observed on the two finer-textured soils, and some leaching occurred from the sand experimental fairways that were only four months old.

The data are not shown due to the fact that triadimefon leaching from experimental greens was negligible. It is important to point out that these greens were sodded with a dense, washed creeping bentgrass sod two weeks before the pesticide was applied. This dense turf effectively eliminated pesticide

Table 3
The Percentage of Applied Pesticide Leached and Maximum Concentration of Pesticide Found in the Drainage Water from Experimental Fairways

Soil	Precipitation	Pesticide			
		Isazofos	MCPP	Trichlorfon	Triadimefon
		% of Applied Pesticide Leached / Maximum Concentration			
Sand	Normal	10.4 767*	51.00 1900	1.18 140	1.00 190
	Above normal	5.6 544	62.12 1400	3.44 467	2.44 118
Sandy loam	Normal	0.04 15	0.79 21	1.13 118	0.06 8
	Above normal	0.09 122	0.46 70	4.41 302	0.01 5
Silt loam	Normal	0.68 77	0.44 130	0.63 71	0.24 43
	Above normal	0.30 34	1.25 89	3.33 504	0.28 66

*Maximum concentration of pesticide detected in the drainage water (leachate), in ug/L (ppb)

Table 4
The Maximum Concentration of Nitrate and Phosphate Detected in the Drainage Water (Leachate) from Experimental Fairways

Soil	Precipitation	Sampling Period			
		Sept. 13 - Dec. 31, 1991		Jan.-Aug. 10, 1992	
		Nitrate	Phosphate	Nitrate	Phosphate
		– – – Maximum Concentration, mg/L – – –			
Sand	Normal	12.2(1)*	0.17	4.3	0.19
	Above normal	13.2(1)*	0.15	4.8	0.17
Untreated		<0.5	0.06	0.5	0.11
Sandy loam	Normal	3.5	0.08	3.6	0.11
	Above normal	3.1	0.11	3.5	0.09
Untreated		1.7	0.54	0.5	0.11
Silt loam	Normal	4.3	0.11	6.6	0.11
	Above normal	5.9	0.11	5.8	0.12
Untreated		<0.5	0.32	1.1	0.27

*Number in ( ) equals the number of samples above the 10 mg/L drinking water standard for nitrate nitrogen. Only 2 of the 1385 samples analyzed thus far were above 10 mg/L.

leaching (all of the leachate samples were below the detection limit of 5 µg/L), regardless of the root zone composition (sand vs. sand/peat). These data support the notion that dense turfed sites, even on straight sand, are not likely to be prone to pesticide leaching.

Nitrate and Phosphorus

Nitrate leaching into groundwater from golf courses and agricultural land treated with fertilizers is a concern because nitrate was found to be the major contaminant of groundwater in the United States in a recent U.S. Environmental Protection Agency groundwater quality survey of private and public drinking wells. Phosphorus leaching from golf courses could be a concern if the drainage water from the golf course ended up in surface waters like ponds, lakes, and streams where eutrophication threatens water quality.

The accepted drinking water standard for nitrate-nitrogen is 10 mg/L. Only 2 of the 1,385 leachate samples from the experimental fairways analyzed to date were above this standard. Most were way below the standard (< 1 mg nitrate-N/L). Therefore, nitrate leaching from moderately fertilized fairway turf, even from sand, is not significant.

Phosphorus levels in the leachate from the experimental fairways were seldom above the analytical detection limit of 0.05 mg/L. None of the fertilized sites had any leachate samples with concentrations greater than 0.3 mg/L, which often characterizes the phosphorus concentration of eutrophic surface waters.

Summary

As would be expected from any experiment that examines such a wide range of important factors that can affect pesticide/nutrient leaching, there is good and bad news. First the good news:

- Pesticide leaching from experimental fairways was found to be predictable and only occurs under the worst case scenarios. Thus, whenever possible, avoid applying pesticides under worst case scenarios.
- Dense, healthy turf dramatically reduces the risk of pesticide leaching, even on sites with the significant potential for leaching (sand-based putting greens).
- Nitrate and phosphorus leaching from experimental fairways was found to be minimal.

Now for the bad news:

- Turfed sites that are not dense can be prone to substantial pesticide leaching, assuming other conditions for leaching are present (e.g., mobile pesticide applied and water moving through soils).
- Preferential water flow greatly increases the potential for pesticide leaching.

These findings point to several things that golf course superintendents can do to reduce the potential for groundwater contamination via pesticide leaching:

- Know the sites on your golf course that have a high probability for leaching (sandy, low-organic-matter soils, shallow water table, thin turf, or newly seeded sites, and likelihood of excessive irrigation due to an inadequate irrigation system).
- Determine which pesticides are more likely to leach, and use them with caution on sites more prone to leaching. Information on pesticide properties is readily available, but is not listed on the pesticide label.
- Understand the conditions that are important in preferential water flow (period of heavy rainfall and excessive irrigation) and avoid the use of pesticides that are prone to leaching during these periods.

Experiments are underway to determine the effect of turfgrass stand maturity as reflected in density and organic matter accumulation (4-month-old turf vs. 3-year-old turf) on the leaching of mecoprop from experimental fairways. It is our belief that the leaching of mecoprop will be substantially eliminated on turf that has matured.

Publications from This Project:

Petrovic, A. M., R. G. Young, C. A. Sanchirico, and D. J. Lisk. 1991. *Migration of Isazofos Nematocide in Irrigated Turfgrass Soils.* Chemosphere 28:721-724.

Petrovic, A. M., R. G. Young, C. A. Sanchirico, and D. J. Lisk. 1994. *Triadimenol in Turfgrass Lysimeter Leachate After Fall Application of Triadimefon and Overwatering.* Chemosphere 28:(in press).

Petrovic, A. M. 1993. *Leaching: Current Status of Research.* J. Intern. Turfgrass Res. Soc. 1.

Petrovic, A. M., R. G. Young, J. G. Ebel, and D. J. Lisk. 1993. *Conversion of Triadimefon Fungicide to Triadimenol During Leaching Through Turfgrass Soils.* Chemosphere 26:1549-1557.

Petrovic, A. M., W. H. Gutenmann, J. G. Ebel, and D. J. Lisk. 1993. *Leaching of Mecoprop Herbicide Through Turfgrass Soils.* Chemosphere 26:1541-1547.

Petrovic, A. M., R. G. Young, C. A. Sanchirico, and D. J. Lisk. 1993. *Downward Migration of Trichlorfon Insecticide in Turfgrass Soils.* Chemosphere 27:1273-1277.

Each lysimeter has an individual collection port to sample and monitor the water moving through the different soil types.