Pesticide Mobility and Persistence in a High-Sand-Content Green

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SEVERAL STUDIES dealing with the mobility and persistence of pesticides labeled for use on turfgrass in Florida were conducted over a three-year period (1991 through 1993) at the University of Florida's Ft. Lauderdale Research and Education Center (FLREC) and the Everglades Research and Education Center (EREC) in Belle Glade. These studies were conducted on a research green built by the Florida Golf Course Superintendents Association at the FLREC approximately a year before our studies began. John Foy, USGA Green Section agronomist for the Florida Region, assisted in this effort. The green was constructed generally in line with USGA recommendations, but as often happens, certain modifications were made due to local conditions and materials available. In addition, the green was very large, over one-half acre in size, to accommodate a number of studies over a period of years.

The green, which was sprigged with cv. Tifdwarf bermudagrass, has 10" to 12" of root zone mix and is underlaid with 4" PVC drain tiles covered by a layer of coarse gravel. In the portion of the green where our studies were conducted, the root zone mix and coarse gravel are separated in the traditionally recommended method by a 2" layer of very coarse sand.

The root zone mix is somewhat coarser than the published USGA recommendation, which resulted in a higher-than-ideal saturated hydraulic conductivity and lower water-holding capacity. Thus, the studies were performed under conditions more conducive to percolation than should occur in a USGA green constructed strictly according to suggested particle ranges. However, it is probable that many so-called "USGA greens" in south Florida have hydraulic properties similar to the test area we used in this study.

The golf course superintendents provided the personnel and instructions for maintaining the green throughout the study. They made all decisions pertaining to irrigation, fertilization, mowing, and cultivation. We requested that no pesticides be used on the portion of the green allotted to our studies, but with this one exception, the green was otherwise maintained in a manner typical of that being used for golf courses in south Florida.

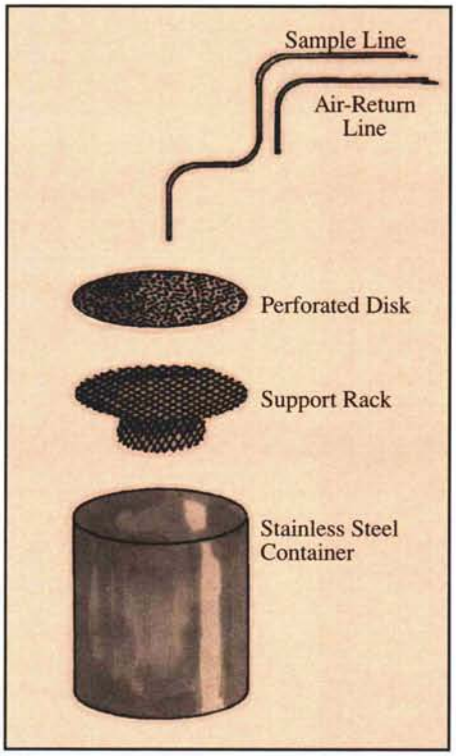


Figure 1. Lysimeter detail, exploded view, showing the support rack and sample line.

Following construction of the green, we installed lysimeters for collecting percolate water. The lysimeters were made from stainless steel "40 quart" stock pots obtained from a restaurant supply house. These pots were approximately 14" in diameter and 16" deep. A stainless steel rack was fabricated to suspend the soil profile a few inches off the bottom of the lysimeter to create a reservoir for collecting percolate (Figure 1).

We excavated a hole in the green to accommodate the lysimeter, which was placed with the top rim 4" below the surface so it would not interfere with aerification procedures. During excavation, we carefully noted the depths of the gravel, coarse sand, and root zone mix. Then, using the same soil materials, supplemented as necessary with additional gravel, intermediate sand, and root zone layers within the profile materials that were retained during construction of the green, the soil profile was reconstructed in the lysimeter, i.e., gravel was placed on the rack in the bottom of the lysimeter, coarse sand was placed over the gravel, and the root zone mix was placed over the coarse sand. All the layers corresponded to the same depths that were observed during the excavation of the hole. The sod piece removed prior to the excavation was replaced over the lysimeter. A total of six lysimeters were installed in the green.

Percolate samples were removed from the lysimeter reservoirs through 0.25" stainless steel tubes that extended from the bottom of the lysimeters to glass collection flasks in a small building adjacent to the green. A second tube extended from just below the support plate to the building to provide air return during percolate withdrawal. The percolate water could be removed from the lysimeter in a few minutes or less by applying a vacuum to the collection flasks. Only stainless steel and glass were used in the lysimeters to minimize pesticide adsorption to sampling device surfaces. Complete details about the lysimeters were published in the *International Turfgrass Research Journal*, Volume 7, 1993.

Near the end of the study, we had the opportunity to install lysimeters in three new greens that were being constructed at a golf course in West Palm Beach. These lysimeters are similar to the ones at the FLREC, except that percolate flows by gravity to collection flasks placed in valve boxes off the back edge of the greens. In this way, golf course personnel can retrieve the percolate water without a vacuum pump. We found that, when working with a cooperative and understanding construction crew, the lysimeters could be installed quite easily during construction of the green. The lysimeters, which are functioning well, have not been used in pesticide studies as yet, but we hope to be able to use them in the future.

Pesticide analyses were conducted in a laboratory developed especially for the project at the EREC. The lab, which was built with University of Florida funds, includes two computer-controlled gas chromatographs (GC), a high-performance liquid chromatograph (HPLC), and the equipment required for extracting pesticides from water, soil, thatch, and clippings. The analyses were performed in accordance with a quality assurance/quality control (QA/QC) plan that was approved by the USGA. We also analyzed samples submitted by the USGA's Quality Control Officer to verify the accuracy of our methodology and procedures.

Experiments

The major part of our work determined the persistence and mobility of organophosphate (OP) insecticides and nematicides. Studies involving the herbicides 2,4-D and dicamba are in the final stages of completion at this writing and will be reported at a later date. The materials were applied at recommended rates according to the label instructions. Samples of the thatch, soil, and clippings were taken for several weeks after pesticide application. Percolate was collected twice each week and after rainfalls that produced significant percolation.

We also investigated pesticide dislodgeability (contact removal from turf surfaces) in order to gauge the degree of exposure golfers receive when playing on pesticide-treated greens. In these studies, we measured pesticide residues on leather, cotton or polyester cloth, and golf balls 24 hours after spraying several OP pesticides. These data were used by faculty of the University of Florida Center for Environmental and Human Toxicology for a model risk assessment study that was published in the *USGA Green Section Record*, Volume 33(2), March/April 1994.

Table 1
Organophosphate Pesticides Used on the USGA Green in Persistence and Mobility Studies

Trade Name	Common Name	Dates Applied	Form	Rate ($g \cdot ai \cdot m^{-2}$)
Nemacur	Fenamiphos	13 Nov. 1991	10G	1.125
		27 Jan. 1992	10G	1.125
Dyfonate	Fonofos	13 Nov. 1991	5G	0.439
		27 Jan. 1992	5G	0.439
Dursban	Chlorpyrifos	27 Jan. 1992	1G	0.117
		21 April 1992	2E	0.229
Triumph	Isazofos	21 April 1992	4E	0.229
		15 Sept. 1992	4E	0.229
Oftanol	Isofenfos	21 April 1992	2E	0.229
		15 Sept. 1992	2E	0.229
Mocap	Ethoprop	15 Sept. 1992	10G	2.245

Table 2
Organophosphate Pesticide Recovered in Clippings and in Percolate Water, Expressed as a Percent of Amount Applied

		Total Recovery (% of that applied) in	
Pesticide	**Dates Applied**	**Clippings**	**Percolate**
Fenamiphos	13 Nov. 1991	——	0.06
	27 Jan. 1992	0.38	0.04
Metabolites of fenamiphos	13 Nov. 1991	——	17.69[1]
	27 Jan. 1992	0.14[1]	1.10[1]
Fonofos	13 Nov. 1991	——	<0.01
	27 Jan. 1992	1.17	0.02
Chlorpyrifos	27 Jan. 1992	7.87	0.15
	21 April 1992	0.52	0.08
Isazofos	21 April 1992	0.43	0.09
	15 Sept. 1992	0.38	0.02
Isofenfos	21 April 1992	0.79	0.02
	15 Sept. 1992	0.89	0.01
Ethroprop	15 Sept. 1992	0.44	0.05

[1]Metabolites expressed as a percent of the parent compound applied

Results

For most of the OP pesticides we studied (Table 1), some consistent patterns emerged. Less than 1% of the applied pesticide was removed in clippings, except when granular formulations were used (Table 2). It is likely that some granules that still contained pesticide were recovered with the first or second mowing after pesticide application. For example, we calculated that 7.9% of the chlorpyrifos applied as a 1% granular material was removed with the clippings, whereas only about 0.5% of that applied as a liquid (2E) was recovered in the clippings, even though the application rate used for the liquid was double that for the granular material.

Even less of the OP pesticides appeared in the percolate water; in most cases, less than 0.1% of that applied (Table 2). So what happened to the pesticide? Most of it was retained in the thatch layer until it eventually was decomposed by microorganisms that use it as a source of "food." There was one notable exception to this trend, however. While only a small fraction (0.05%) of the nematicide fenamiphos (Nemacur) was observed in the percolate water, a substantial amount of its sulfoxide and sulfone metabolites, which retain the toxicity of the parent fenamiphos, was observed in the percolate. The metabolites are products created from the parent compound by microorganisms, and they are of environmental concern. They are more water soluble than fenamiphos itself, and for that reason are less well adsorbed by the thatch and more easily transported through the soil with percolate water (Figure 2).

Considerably more metabolite was observed in percolate following the first application of fenamiphos (averaging 17.7% of the fenamiphos applied), which also was the first application of any OP pesticide to the green, than following the second application (1.1%) made a month later. Previous research has suggested that microorganism populations will shift or adjust to use fenamiphos, and presumably for the metabolites, as a source of energy after fenamiphos is introduced into a soil. These microorganisms persist for several years. Therefore, it is reasonable to assume that more rapid degradation of the parent compound and metabolites will occur with repeat applications of fenamiphos.

As part of the dislodgeability studies, we also measured the amount of chlorpyrifos and isazofos transferred from bermudagrass leaves to cotton cloth following application as a liquid. Less than 1% of the applied pesticide was found on the cloth immediately after spraying the pesticides. Only about 15% of that amount was picked up after irrigating with 0.2" of water. Several hours later, that amount was reduced again by half. By the end of 24 hours, only 1% of the original amount dislodged was found on the cotton cloth.

Implications for Golf Course Management

The data indicate that many OP pesticides are strongly adsorbed in the thatch layer, where they remain until they are microbiologically degraded. Relatively little pesticide was removed with the clippings or dislodged onto various materials. In most cases, only a very small portion of the applied pesticide was detected in percolate water. Nevertheless, practices such as proper irrigation following pesticide application, avoiding application during expected rainy periods, treating only pest-affected areas, and using the lowest rate consistent with the control of the target pest — practices that were not a part of our studies — should further reduce pesticide leaching and are strongly encouraged.

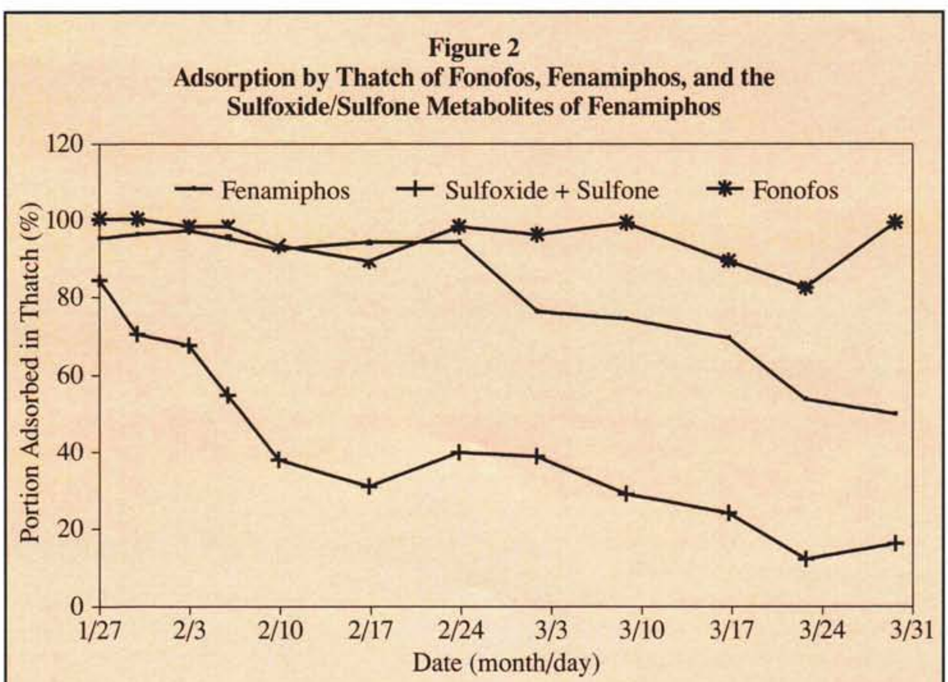
As shown by our data for fenamiphos, some pesticides are more susceptible to leaching than the majority. Superintendents should be especially aware of such pesticides. Alternative pesticides and control measures should be used when possible, and when no such alternatives exist, superintendents should use the pesticides as infrequently as possible, at as low a rate as is consistent with adequate control, limit treatment to affected areas only, and employ all measures and techniques possible to avoid leaching in the area that is treated. It is in the superintendent's best interest to use pesticides wisely.

Some individuals within the golf community would prefer that data not be collected that might indicate a possibility of environmental contamination when pesticides are used on golf courses. But while golf requires good turf for playing surfaces, we need to recognize the superintendent's responsibility for the safety of the course's employees and golfers and for protecting his or her employer from lawsuits. At times, the superintendent may have to perform a real balancing act to accommodate all of these interests, and doing so probably should not be his sole responsibility. The ideal situation would be one in which the superintendent, in conjunction with the course ownership and golfers, would jointly develop a policy for balancing the desire for turf quality against pesticide usage, including the use of alternative methods of pest control and an agreement on the choice of pesticides to be used.

The gravel, very coarse sand, and root zone mix depths were measured in the green so that the same depths could be reproduced in the lysimeters.

Regulatory agencies have demanded that some golf courses initiate environmental monitoring programs for various agricultural chemicals, including pesticides, as a condition for being allowed to begin operation or to remain in business. These monitoring programs can be very expensive to develop and maintain. Golf courses could have a few greens equipped with lysimeters similar to the methods we used. At little cost, the lysimeters could provide useful information on the quantity of percolate occurring in response to various irrigation practices. Obviously, if percolation can be avoided or minimized, nutrient and pesticide leaching will be eliminated or reduced. Periodic analysis of the percolate for nutrients and pesticides, especially following applications, would provide information about how successful management practices are in main-

Pesticide was extracted from clippings, thatch, soil, and percolate water for analysis in the Everglades-REC pesticide lab.



taining the materials in the root zone, where they are needed. Where changes in management practices are needed, the changes could be implemented before a regulatory agency begins finding the agrichemicals in groundwater. Such a proactive approach could do much to reassure surrounding communities that golf is acting in a responsible manner to minimize potential adverse environmental impacts.

Golf course superintendents must make many decisions on pesticide usage that have implications beyond mere pest control. Fortunately, the USGA has taken the lead in addressing these concerns through its sponsorship of environmental research. Research needs to be conducted on all classes of pesticides under a variety of management conditions in order to develop the best management practices that provide environmental benefits to all. Clearly, a great deal remains to be done, but the process has begun.