PESTICIDES: ARE GOLFERS SAFE?

University of Florida studies suggest that pesticides do not pose any significant health threat to golfers.

by GEORGE H. SNYDER, JOHN L. CISAR, and CHRISTOPHER J. BORGERT

ARTICLES about pesticide usage on golf courses and the dangers to which golfers are exposed because of these pesticides often appear in the popular press. These articles make good press with eye-catching headlines, but they often raise concern by citing potential hazards without providing any scientifically based analyses. In order to provide data that can be analyzed scientifically, the United States Golf Association has provided grants totaling millions of dollars to university scientists to conduct research into the fate of pesticides applied to golf turf and to assess the associated risks to golfers.

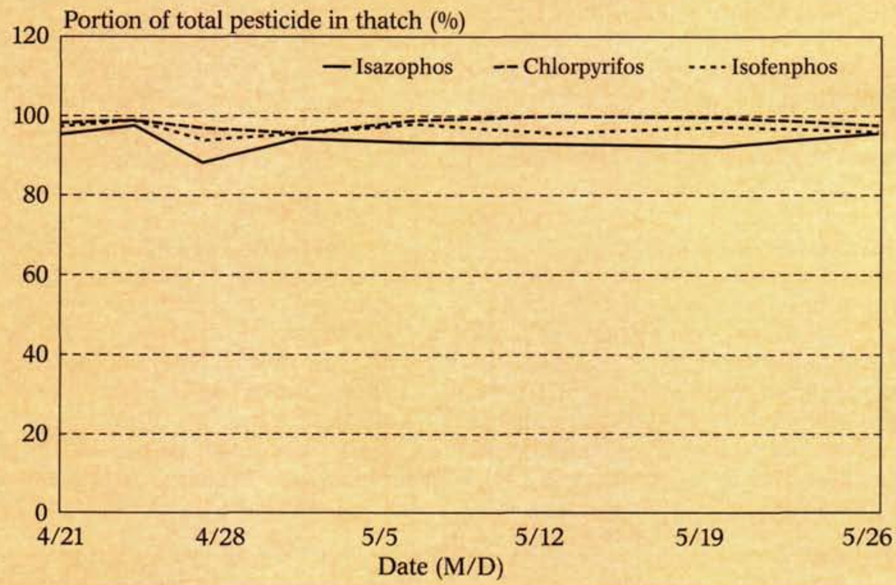
While no single university study has provided all the answers to this complex issue, each has made headway in answering specific components of the puzzle. For example, our work has focused on pesticide leaching, pesticide removal in clippings, pesticide dislodgeability from turf surfaces, and pesticide losses by volatilization. Because dislodgeability and volatilization can result in direct golfer exposure to pesticides, we have conducted assessments of the risks to golfers posed by such pesticide losses. We concentrated our studies on the class of pesticides known as organophosphates (OP) because of their widespread use, effectiveness as insecticides and nematicides, and because they are known to be toxic to humans at certain levels of exposure.

Table 1
Pesticide leached following application at labeled rates to a USGA green, expressed as a percent of the amount applied*

Pesticide	Application Date	Amount Leached *% of applied*
Chlorpyrifos	Jan. 27, 1992	0.15
	April 21, 1992	0.38
Fonophos	Nov. 13, 1991	<0.01
	Jan. 27, 1992	0.02
Isazophos	April 21, 1992	0.09
	Sept. 17, 1992	0.02
Isofenphos	April 21, 2001	0.02
	Sept. 17, 1992	0.01
Ethoprop	Sept. 17, 1992	0.07

*Data extracted from Cisar and Snyder (7)

Figure 1
Following application of three organophosphate pesticides, most of the pesticide that was observed in the thatch and soil was located in the thatch portion

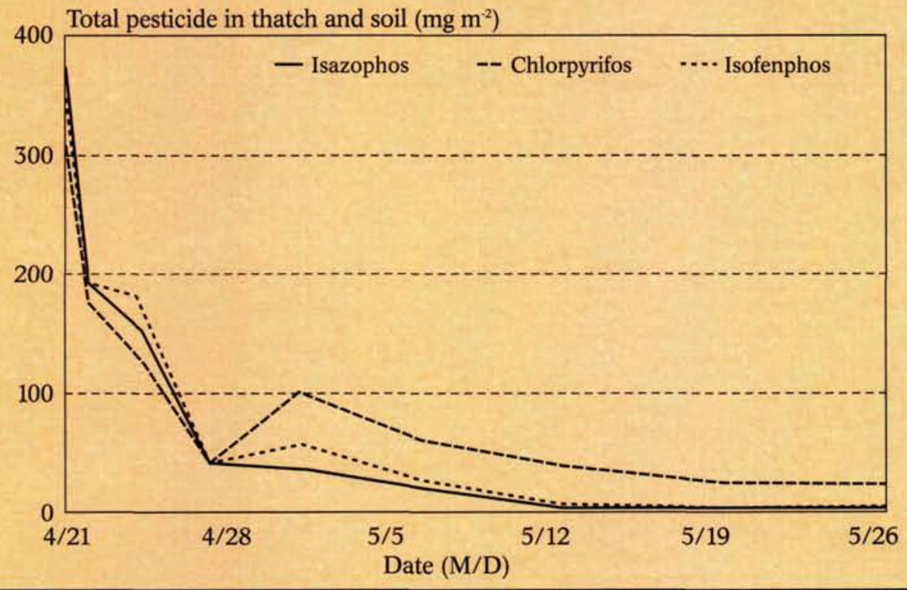


Pesticide Leaching

Following application at labeled rates, we measured pesticide in thatch, soil, and in percolate. The field work was conducted at the University of Florida/IFAS St. Lauderdale Research and Education Center using a special facility that has stainless-steel lysimeters installed in a research golf green ('Tifdwarf' bermudagrass) patterned after USGA specifications for putting green construction (2). The lysimeters were used to collect percolate water from the golf green for several months after pesticide application. The pesticides generally were applied as liquid sprays. With one exception, which will be discussed later, less than 1% of the applied pesticide was found in the percolate water (Table 1).

There are two reasons why so little pesticide was recovered in percolate water. First, the pesticides were strongly adsorbed by and retained in the thatch layer (Figure 1). For most of the OP pesticides studied, very little pesticide actually made it through the thatch and into the soil. Secondly, the pesticides were degraded by microorganisms that essentially use the pesticides as a food source. Consequently, the concentration of pesticide in the thatch/soil decreased rapidly with time (Figure 2).

Figure 2
Three organophosphate pesticides rapidly disappeared from thatch and soil following application to a USGA green due to microbial degradation



The exception that we found to the generalization that OP pesticides are strongly adsorbed in the thatch layer, and therefore undergo little leaching, was for the nematicide fenamiphos (Nemacur), and particularly for its metabolites (breakdown products), which also can be toxic. Following an application of fenamiphos, of the total metabolites in the 0-15 cm (0-6 inch) layer, we observed only 20% being in the thatch (7). Nearly 18% of the applied fenamiphos was observed as metabolite in the leachate.

It has been established that following fenamiphos applications, microbial populations that can readily degrade the pesticide rapidly increase in the soil and remain there for years (6). Therefore, when additional fenamiphos applications are made, microbial breakdown of the fenamiphos and of its metabolites can be very rapid. In agreement with this, when we applied fenamiphos a second time, only 1.1% of that applied was detected in percolate water in the form of metabolites. Nevertheless, this is considerably more than was found for other OP pesticides. For this reason, we developed a sand-sized soil amendment (patent pending, University of Florida) that absorbs fenamiphos and its metabolites without reducing the rate of water percolation (8).

Grass Clippings

Organophosphate pesticide removal in grass clippings for several weeks after application also amounted to less than 1% of that applied, in most of the trials, when the pesticides were applied as sprays. In some cases, somewhat more was recovered in clippings when granules were used as the carrier, presumably because some granules were picked up by the mower (3). For both liquid and granular application, pesticide removal in clippings generally declined quite rapidly with time.

Dislodged Pesticides

From our studies with OP pesticides, it appears that most of the pesticides dissipate rapidly, and there is little loss in clippings or percolate. These loss mechanisms should pose little hazard to golfers or to the environment. However, there are two pesticide loss pathways by which direct golfer exposure can occur: dislodging from the turf surface directly or indirectly to a golfer's skin and inhalation of pesticides volatilized from the turf. We have investigated both of these loss pathways and have estimated potential risks for several scenarios under which golfers might be exposed to pesticides.

All chemicals can be toxic to some organisms at some dose. The question to be determined in our studies was whether a golfer is likely to receive a toxic dose as a result of exposure to pesticides applied to maintain golf turf. Toxicity may be immediate or may occur only after many years of exposure. The U.S. Environmental Protection Agency (USEPA) provides values that can be used for assessing the risk of exposure to various pesticides (10). Pesticides sprayed on turf surfaces may contact golfers directly when a player touches the turf or indirectly when the golfer touches various items (club heads, golf balls, etc.) that have come in contact with the turf. In an extreme case, the golfer may have oral contact with certain of these items and thereby ingest some pesticide.

A series of studies was conducted by University of Florida graduate student Raymond H. Snyder to evaluate the risks to golfers from pesticide doses associated with these exposures. These studies measured the amount of pesticide that could be dislodged by various means. For example, after applying a pesticide at the labeled rate, moist cheesecloth was rubbed vigorously over the turf surface. This procedure was assumed to estimate, and probably greatly overestimated, the maximum amount of pesticide that might be dislodged by touching the turfgrass. Golf grips were placed on the turf and rolled around, and a golf ball was putted across the surface twice. Following an application of pesticide to turf several inches tall, a club head was swung through the grass to simulate chipping out of a rough. The amount of pesticide on the golf grips, golf ball, and club face

Table 2
Pesticide dislodged by vigorously wiping the turf surface with damp cheesecloth at various intervals following pesticide application*

Time After Application	Pesticide		
	Fenamiphos	Isazofos	Chlorpyrifos
	----- % of applied -----		
15 minutes	2.89	1.40	1.12
3 hours (irrigated)	0.10	0.08	0.06
20 hours	0.00	0.02	0.01

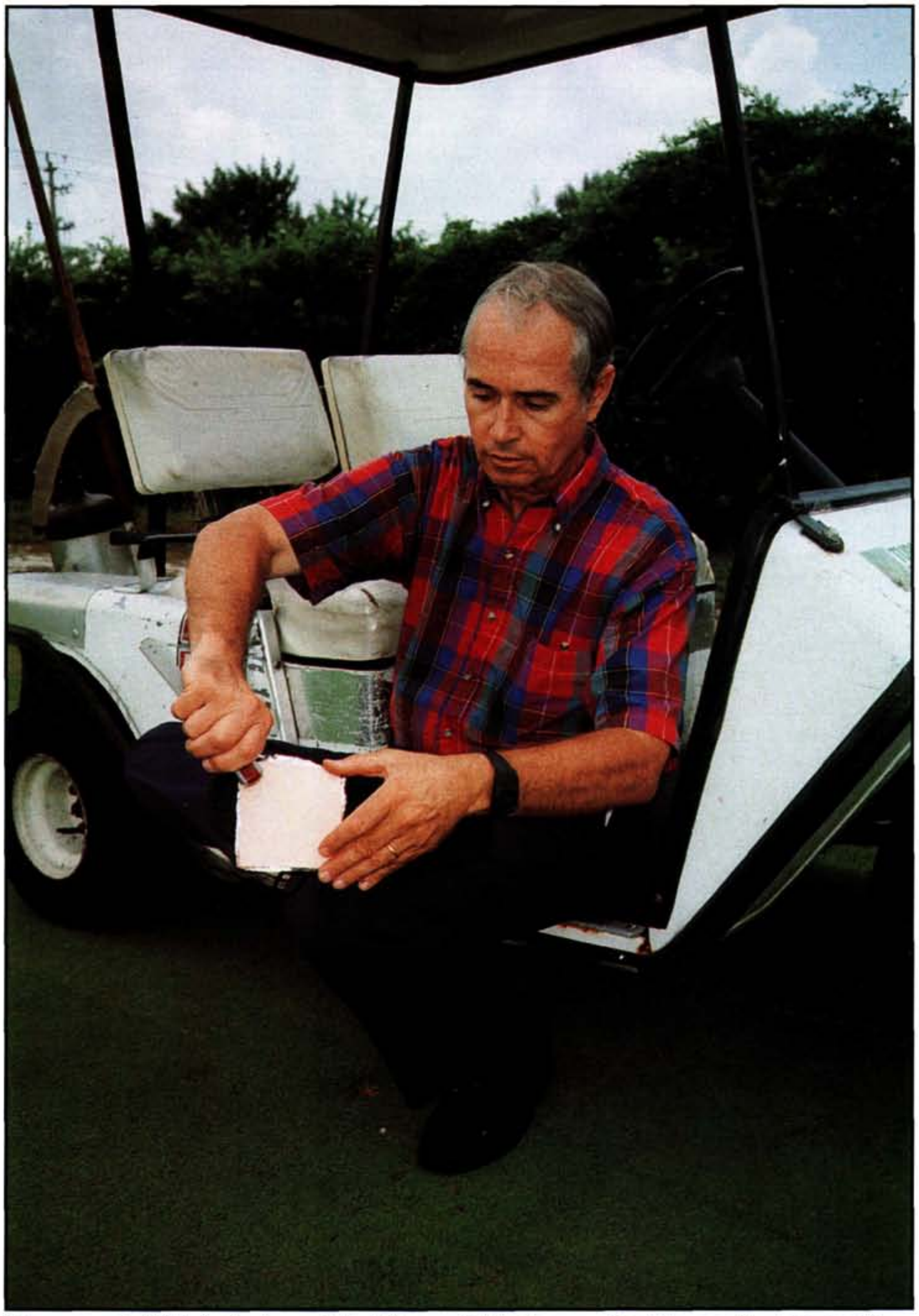
*Data from R. H. Snyder (9)

was measured to estimate the amount of pesticide that could be dislodged by these methods and potentially be transferred to a golfer's skin.

Wiping the turf surface with damp cheesecloth dislodged considerably more pesticide than any of the other methods. But even for this method, less than 3% of the applied pesticide could be dislodged only minutes after application. Several hours later, following irrigation, no more than 0.1% was dislodged even by this very aggressive method (Table 2).

Using the dislodgeability data, some of the golfer behaviors that could lead to contact with pesticides were investigated. They included a) placing a hand on the turf surface following an application of pesticide, b) handling golf grips that had been placed on the turf surface, c) handling a golf ball that had been putted twice across a pesticide-treated green, d) touching a club face and back following chipping onto a green, e) kissing or licking a golf ball that had been putted on a treated green. Since the studies did not involve human subjects, pesticide was dislodged from the turf and the golf equipment by means that no doubt were far more thorough in dislodging pesticide than by casual touch. Therefore, the studies added an extra margin of safety above that margin incorporated into the USEPA figure used to calculate risks (generally 10- to 10,000-fold).

Because very little scientific information exists about the behaviors that expose golfers to pesticides, a theoretical golfer was created to simulate both high and worst-case estimates of dermal and oral exposure. For purposes of the study, this theoretical golfer was assumed to exhibit behavior that exceeds what any real golfer would reasonably do. It was assumed that on each hole of golf the theoretical golfer did each of the five previously listed behaviors that could lead to contact with pesticide that had been applied to turfgrass. Since none of the pesticides studied have shown any carcinogenic effects, risk was assessed using the hazard index approach to assess potential non-cancer effects. This approach compares the average daily intake (dermal and oral) of each pesticide to a published acceptable level of daily intake for chronic or subchronic exposure (RfD) (1). If the resulting hazard index is less than or equal to 1.0, the chemicals are considered unlikely to represent a risk to human health. If the hazard index is greater than one, a potential risk to human health may exist (4).



The research field study showed that the pesticide dose received by a golfer very much depended on the time period and irrigation cycle after a pesticide application.

The field study showed that the pesticide dose received by the theoretical golfer very much depended on the time period after application, and on irrigation following pesticide application. Increasing either factor reduced the golfer's estimated dose of pesticide. Thus, the golfer's risk also depended on these two factors (Table 3). For behaviors leading to hazard indexes greater than 1.0, some level of risk might exist. These behaviors range from the absurd, such as playing 18 greens 30 minutes after pesticide application every day for a lifetime of 70 years, thereby resulting in an unacceptable risk from some pesticides, to more reasonable, although still unlikely, scenarios producing no measurable risk (hazard index of less than 1.0).

The calculated indexes also are very dependent on the pesticide studied. Considering three contrasting pesticides, for example, the calculated risks are much higher for fenamiphos than for chlorpyrifos (Table 3). But even for fenamiphos, the chances of any of the behaviors leading to hazard indexes

Table 3
Hazard indexes calculated for various pesticides and behavioral scenarios[1]

Behavior	Hazard Index[2] Fenamiphos	Isazofos	Chlorpyrifos
Golfer plays on 18 greens 30 minutes after pesticide application every day for a lifetime (70 years)	152.00	55.12	0.31
Golfer plays on one green 30 minutes after pesticide application and on the remaining 17 greens after pesticide application and irrigation every day for a lifetime	17.05	6.80	0.04
Golfer plays on 18 greens after pesticide application and irrigation every day for a lifetime	9.08	3.95	0.02
Golfer plays on 18 greens the day after application and irrigation every day for a lifetime	0.84	1.30	0.01
Golfer plays on 18 greens 30 minutes after pesticide application two times a week for 35 years	21.65	7.86	0.04
Golfer plays on one green 30 minutes after pesticide application and on the remaining 17 greens after application and irrigation two times a week for 35 years	2.43	0.97	0.01
Golfer plays on 18 greens after application and irrigation two times a week for 35 years	1.29	0.56	0.003
Golfer plays on 18 greens the day after application and irrigation two times a week for 35 years	0.12	0.19	0.002

[1]Data from R. H. Snyder (9) [2]Hazard risk less than 1.0 produces no measurable risk

greater than 1.0 are minuscule, because fenamiphos cannot be used legally more than twice per year on any one area.

Furthermore, there are behaviors a golfer can easily avoid to further reduce the risk posed by pesticides. For example, it is known that a much higher proportion of pesticide is absorbed into the body following oral versus dermal exposure (2.5% of the pesticide that reaches a golfer's skin is assumed to be adsorbed into the body, but 100% of the pesticide ingested by oral exposure is assumed to be adsorbed). Therefore, simply avoiding the "kissing or licking the golf ball" behavior is a good way to reduce whatever dose of pesticide might be received.

Pesticide Volatilization

A portion of the pesticide applied to golf turf is volatilized into the atmosphere. Inhalation of volatilized pesticides represents another way that pesticide can enter the body. We and others (5) have observed that more pesticide may be lost from turf by volatilization than by leaching or dislodging. For example, we have observed losses by volatilization, measured only during daylight hours, ranging from 2.5% to 13.6% of that applied (Table 4), which are greater losses than we observed due to leaching, dislodging, or clipping removal for some of the same pesticides.

Table 4
Pesticide volatilized over a three-day period, excluding nighttime periods, expressed as a percent of the amount applied

Pesticide	Study Year 1999	2000
Ethoprop	11.3%	13.6%
Fonofos	7.2%	--
Chlorpyrifos	--	6.0%
Isophenfos	2.5%	2.8%

Risks associated with inhalation of volatilized pesticides also can be calculated when USEPA chronic reference dose (RfD) data are available. The average daily inhaled dose of pesticide for a 70 kg adult (154 pounds) playing a 4-hour round of golf can be estimated as (5):

$$D = (C{*}R{*}4h)/70\text{ kg} \quad \text{(Equation 1)}$$

where D = daily inhaled dose of pesticide (micrograms kg^{-1}), C = measured air concentration of pesticide (micrograms m^{-3}), and R = adult breathing rate during moderate activity (2.5 $m^3\ h^{-1}$).

For chlorpyrifos, the USEPA chronic reference dose (RfD) is 3.0 micrograms $kg^{-1}\ d^{-1}$. Using Equation 1 and assuming that all inhaled pesticide is absorbed by the body, it can be calculated that the concentration (C) of chlorpyrifos in air that provides a daily inhaled dose (D) equal to the RfD is 21 micrograms kg^{-1} m^{-3}. This value was not exceeded in either of the two studies we have conducted (Table 5), indicating that golfer exposure to volatile losses of chlorpyrifos poses little health hazard.

However, it should be noted that the RfD for chlorpyrifos is rather high compared to certain other organophosphate pesticides, so the lack of a health hazard for chlorpyrifos should not be taken as a generalized lack of health hazard for other pesticides. For example, fenamiphos has a RfD of only 0.25 micrograms $kg^{-1}\ d^{-1}$. Based on Equation 1, C is only 1.75. However, this value was exceeded for only a short time in one of two studies conducted on fenamiphos volatilization (Table 5). Of course, the calculations assume exposure to the corresponding concentration of pesticide for an entire round of golf every day for a lifetime, which will not occur based on the data from our study (Table 5) and the regulatory requirement that fenamiphos be used no more than twice per year.

Conclusions

No single study can answer all the questions that have been raised about the fate of pesticides applied to golf turf and the risks they pose to golfers. We can only hope that our work provides a piece of the scientific information needed to make a comprehensive assessment of pesticide risks to golfers. However, working with a selection of OP pesticides, we generally have observed relatively small losses by clipping removal or by leaching because of the strong adsorbing ability of the thatch layer of the turf. Furthermore, under most reasonable golfing scenarios, for the pesticides we studied, we find little reason to anticipate that golfers are incurring any serious risk due to dislodged or volatilized pesticides used for maintaining turfgrass on golf courses.

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Table 5
Concentration of chlorpyrifos and fenamiphos in air following application to bermudagrass turf

Sample Time Following Application		Chlorpyrifos		Fenamiphos	
Study 1	Study 2	Study 1	Study 2	Study 1	Study 2
(hours)		($g\ m^{-3}$)			
0 - 2	0 - 1	4.24	6.39	0.39	3.15
2 - 4	1 - 2	1.02	6.48	0.00	0.04
4 - 6	2 - 3	1.22	5.27	0.09	0.02
6 - 18	3 - 4	0.32	3.52	0.00	0.02
18 - 24	4 - 5	0.19	3.18	0.00	0.02
24 - 27	5 - 19	0.08	0.51	0.01	0.01

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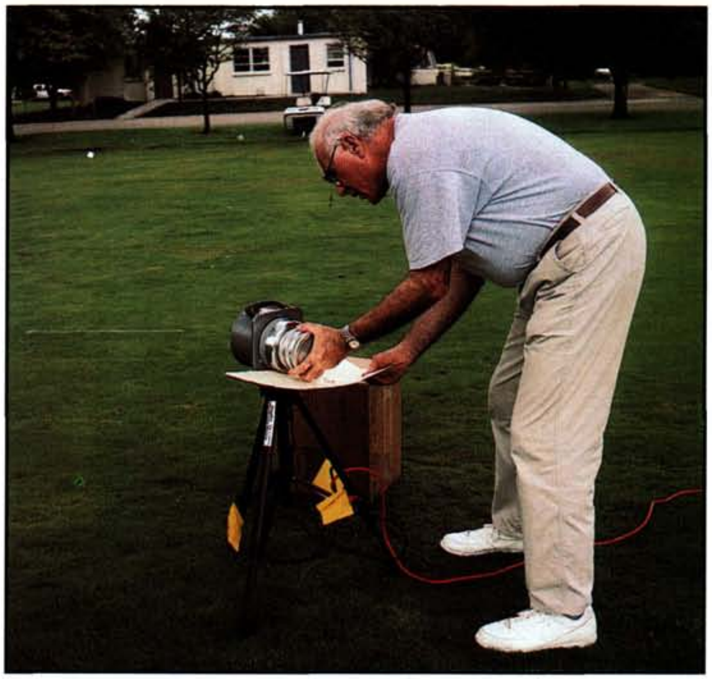

(Left) The University of Florida has conducted research to measure direct golfer exposure to pesticides used on the golf course. For purposes of this research, their theoretical golfer was exposed to situations created to simulate a worst case of exposure. (Right) A pesticide-adsorbing resin in the air sampler was used to measure the pesticide concentration in the air following its application to the turf.