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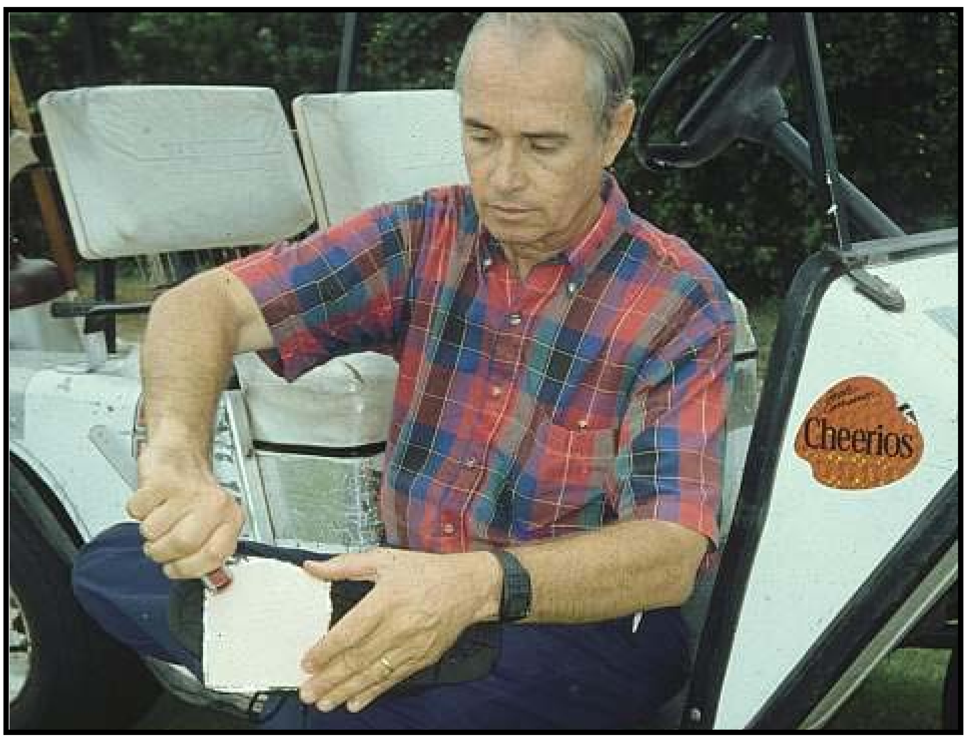

For the pesticides they studied, researchers at the University of Florida concluded that under most reasonable golfing scenarios, that golfers are not incurring any serious risk due to dislodged or volatilized pesticides used for maintaining turfgrass on golf courses.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 215 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Dislodgeable Residues of Chlorpyrifos and Isazofos and Implications for Golfer Exposure

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SUMMARY

Dermal contact with dislodgeable residues of pesticides from recently treated turfgrass areas in golf courses may result in golfer exposure. Florida researchers used two pesticides to measure the extent to which applied pesticides can be transferred to golfers playing a round of golf.

- Dislodgeable residues of chlorpyrifos and isazofos were determined by various methods, in an attempt to simulate a golfer's dermal and oral pathways. Several methods of sampling were used in determining dislodgeable residues.
- Less than 2 % of applied isazofos could be recovered from the turf surface by vigorous wiping action immediately after application. Following irrigation and drying, at four h ours after application, isazofos residues decreased 94% following a scheduled irrigation event. At 24 hours after application residues averaged 0.02 % of the isazofos applied.
- Chlorpyrifos residues on clubface, golf balls, and golf grips declines rapidly after application. A 95% reduction occurred between the one and four-hour sampling periods for chlorpyrifos detected on club face. Chlorpyrifos residues on golf grips were only detected one hour after application.
- The data indicate that even under extreme circumstances, golfers will experience little risk from dislodgeable residues of chlorpyrifos. While the data for isazofos appears more threatening, it should be remembered that golfers are unlikely to encounter these pesticides on every round of golf they play over a period of many years.

Maintaining the aesthetics of a golf course requires the use of pesticides to control the debilitating effects of insects, weeds, disease, and nematodes. During the early 1990s, approximately 5 kg ha^{-1} of active ingredient (ai) of herbicides and almost 15 kg ha^{-1} of insecticides were applied annually to golf courses in the United States (21). Given the public concern regarding the use of such chemicals for cosmetic reasons in landscaping, it is important to determine if the public, and more specifically golfing enthusiasts, should be concerned about exposure to chemicals applied on golf courses.

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Dermal contact with dislodgeable residues of pesticides from recently treated turfgrass areas in golf courses may result in golfer exposure. Golfers generally have some form of direct or indirect dermal contact with the turfgrass surface. During the course of a round, golfers handle golf balls, golf grips, and golf club faces, all of which are frequently in contact with the turfgrass surface. In addition, golfers make direct dermal contact with the turfgrass on hands. Any one, or a combination, of these actions may result in pesticide exposure if dislodgeable residues are present on the turf.

In the United States alone 547 million rounds of golf were played by 26.5 million golfers in 1997 (7). Unfortunately, little research has investigated potential risks that may exist to this large and growing portion of the U.S. population. In the past, studies focused on pesticide exposure to pesticide applicators (5, 6) and crop harvesters (9, 10, 11, 13).

Concerns regarding pesticide exposure in agriculture have resulted in several studies pertaining to dislodgeable residues in crops ranging from soybean to citrus (2, 3, 10, 12, 13, 19, 20). Most of these studies were similar in that they attempted to determine levels at which dislodgeable residues exist in order to address concerns regarding human exposure.

Dislodgeable residues from turfgrass have also received some attention. Thompson et al. (22) used dampened cheesecloth to determine dis-

Various methods were used to sample the amount of pesticide residue that could be transferred to club faces, golf balls, and club grips.

lodgeability of 2,4-D applied to Kentucky bluegrass (*Poa pratensis* L.) in both field and growth room studies. In that study, less than 0.01 % of the applied chemical was dislodged from the turfgrass, which received 18 mm of natural rainfall approximately one hour following application. However, seven days were required to reach the 0.01% level with no rainfall.

Dissipation over time of chlorpyrifos and dichlorvos from a clover (*Trifolium sp.*) and fescue (*Festuca sp.*) lawn were examined by Goh et al. (8). Residues were chemically extracted directly from leaf tissue. Residues of dichlorvos reached safe levels within four hours after application in irrigated plots and 14 hours in non-irrigated plots. Chlorpyrifos residues were within safe levels immediately following application for irrigated plots. Non-irrigated plots required six hours to reach safe levels.

Sears et al. (17) reported the effects of time, sunlight, rainfall, mowing and pesticide formulation (granular vs. liquid) on residues of diazinon, chlorpyrifos, and isofenphos from Kentucky bluegrass. In this study, the damp cheesecloth wipe method was employed. Dislodgeable residues following the application of diazinon as a liquid formulation were 20 times more than that of diazinon applied as a granular formulation. Rainfall reduced dislodgeable residues, while-mowing did not.

Murphy et al. (14, 15) used dampened cheesecloth to determine dislodgeable residues of triadimefon, mecoprop (MCPP), trichlorfon, and isazofos from 'Penncross' creeping bentgrass (*Agrostis palustris* Huds.). Irrigation reduced dislodgeable residues of trichlorfon and isazofos, whereas dislodgeable residues of triadimefon and MCPP were the greatest immediately after application and decreased with time.

Few studies have directly related the transfer of dislodgeable pesticide residues to golfers. Murphy et al. (14, 15) used the model of Zweig et al. (24) to assess the impact of golfer dermal exposure to triadimefon, MCPP, trichlorfon, and isazofos. The Zweig et al. (24) model determined that the dermal exposure rate (mg hr^{-1}) of fruit harvesters was five thousand times greater than dislodgeable residues (μg cm^{-2}) determined on leaf tissue. The transfer of dislodgeable residues to fruit harvesters is likely far greater than that of golfers, due to the fruit harvesters' extensive and frequent contact with vegetation. Therefore, while the use of the Zweig et al. model has been accepted, it is likely overestimating golfer exposure to pesticide residues.

Nevertheless, using the Zweig et al. model, Murphy et al. determined that exposure to dislodgeable residues of triadimefon and MCPP in a 15-day study was below levels expected to cause adverse health effects. However, Murphy et al. found dislodgeable residue levels of isazofos and DDVP, a transformation product of trichlorfon, at concentrations that may cause adverse effects two days after application for DDVP, and two and three days after application for isazofos.

Two dislodgeability studies have been reported in which actual golf equipment was used for sampling (2, 18). Borgert et al. (1) quantified the dislodgeable residues of three insecticides (diazinon, isazofos, chlorpyrifos) 24 hours after application of a 'Tifdwarf' bermudagrass (*Cynodon dactylon* L. X *C. transvaalensis*) green. Using materials such as cotton fabric, leather, and golf balls, the authors developed preliminary and limited risk calculations to estimate the toxicological significance associated with golfer exposure to the green. Residues dislodged by golf grips were estimated in this study using data collected from pesticides dislodged from leather. Snyder et al. (18) found that dislodgeable residues of the organophosphate nematicide fenamiphos produced hazard quotients exceeding the 1.0 threshold for safe exposure for up to three hours after application.

A goal of the present study was to expand the existing dislodgeability database to include golf clubs and other routes of exposure specific to golfers in the sampling. The specific objectives of this study included: (1) determination of dislodgeable residues of chlorpyrifos and isazofos following their application to turfgrass; and (2) risk assessment based on the field data, thereby determining if this exposure may be toxicologically significant.

Materials and Methods

The study was conducted on a 'Tifgreen' bermudagrass (*Cynodon dactylon* L. X *C. transvaalensis* Davy-Burt) USGA putting green and a 'Tifway' (*Cynodon dactylon* L. X *C. tranvaalensis*) bermudagrass rough located adjacent to the USGA putting green at the Univ. of Florida's Ft. Lauderdale Research and Education Center (FLREC). Maintenance of the putting green was similar to that of putting greens located at golf courses throughout Florida: mowing every morning (except during experimental sampling periods) at 5 mm with watering and pesticide application (i.e., pesticides of non-interest to this study) as needed. The rough was maintained at a height of 8.5 cm. It was mowed three times a week, with water and pesticide applications (i.e., pesticides of non-interest to this study) being made as needed. Irrigation was not applied to this area during sampling.

With the lone exception of determining dislodgeable residues from a chipping club face from rough mowed turf, all of the dislodgeable sampling was conducted on putting green turf. Dislodgeability samples were taken from the putting green and the rough over a two-day period beginning on June 3, 1997 and ending on June 4, 1997.

There were five 1 x 12 meter plots. Chlorpyrifos (Dursban) and isazofos (Triumph) were applied at 1:00 p.m. (ambient temperature 32C; calm conditions). Following the first set of samplings, approximately 0.34 cm of irrigation was applied to the putting green. Thereafter, samples were taken at approximately four and 24 hours after pesticide application. Samples were taken from randomly selected, undisturbed locations on each plot with five replications taken in all cases. On October 29, 1997, a second application of chlorpyrifos and isazofos were applied to the rough to determine the quantity of residues dislodged by a single golf swing. The pesticides were applied at 10:55 a.m. (ambient temperature 21C; calm conditions). Samples were taken from randomly chosen, undisturbed locations within the treated area over a 24-hour period.

All insecticides were applied using a one-meter wide, two nozzle (flat fan Tee Jet 8006), CO_2 backpack sprayer at approximately 30 psi. Chlorpyrifos and isazofos were applied at the labeled rate of 0.229 g ai m^{-2}, with total application time never exceeding 15 minutes.

Several methods of sampling were used in determining dislodgeable residues. They were: 1) damp cheesecloth wipe, 2) golf ball putt, 3) golf grip roll, 4) chip and wipe I, and 5) chip and wipe II (single swing of the club). Each method was replicated five times for a given sampling time. The areas sampled were marked with orange spray paint to prevent overlapping of sampling areas. Samples were placed in glass jars following collection, sealed, and immediately stored at -20C until extraction.

The damp cheesecloth wipe method was executed by firmly wiping a dampened piece of cheesecloth four times in four directions over a 603 cm^2 area of the plot demarcated by a template. The cheesecloth was held firmly in place using an aluminum holder. A 10 x 10 cm piece of aluminum foil was placed between the cheesecloth and the holder, reducing transfer of pesticide onto the holder which could lead to the contamination of subsequent cheesecloth samples. Both the cheesecloth and aluminum foil were placed in the glass sampling jar.

The golf ball putt method was executed by putting a golf ball 36 times over a 0.5 x 4 m area

After Dr. John L. Cisar swung a golf club through grass treated with pesticide (center), an analysis was made of pesticides on the club head that were wiped off with damp cheesecloth by Mr. Raymond H. Snyder (right).

of the putting green. The golf grip roll method was executed by placing and rolling (three revolutions) a standard size rubber golf grip on the turf surface. A metal rod (0.218 kg) was inserted into the grip to insure firm contact with the turf and to allow the grip to be rolled and transported without being touched.

The chip and wipe I method was executed by swinging the golf club (pitching wedge) in such a manner that the club face made contact with the blades of turf without penetrating the soil surface. The club was swung five times over a new area of turf each time. After each swing, the club face and back was wiped with a single, damp piece of cheesecloth. No attempt was made to remove any blades of turf which may have become attached to the club face and back while swinging before wiping with cheesecloth. Five swings constituted one replication of which there were five. A second version of the chip and wipe method (chip and wipe II) was conducted in a similar manner as the chip and wipe I method described above except that one swing constituted a replication rather than five swings.

Dislodgeable residues of chlorpyrifos and isazofos were determined by various methods in an attempt to simulate a golfer's dermal and oral pathways. Damp cheesecloth wipe residues were used and adjusted based on one-third the surface area of a man's hand (23), to estimate the quantity of residues dislodged by human hand to turfgrass contact. Residues dislodged by the golf ball putt method served to provide the quantity of residues available for both dermal and oral exposure. The golf grip roll and chip and wipe II method provided the quantity of residues available for dermal contact.

For purposes of this study, a theoretical golfer was generated. This theoretical golfer was intended to serve as an extreme case of dermal and oral exposure. It is likely that most golfers will not exhibit all the same behavior or receive as high a level of exposure as the theoretical golfer developed in this study.

The following behaviors were assumed for the theoretical golfer:

1) One time placement of a single hand on the putting green surface.
2) Handling of a golf grip following placement and rolling (three revolutions) of the golf club on the putting green surface.
3) Handling of a golf ball following two putts on the putting green surface.
4) Handling of a golf club face and back following chipping (one chip per hole) onto the putting green surface.
5) One placement of a golf ball into the mouth following its use on the putting green surface.
6) Use of a bare hand to handle the golf grip and golf ball, remove debris from the clubhead, and touch the turfgrass surface of the putting green.

Risk Assessment Models

Chlorpyrifos and isazofos are classified as acetlycholinesterase inhibitors (14). Therefore, assessing risk using the hazard index approach to assess potential non-cancer effects is appropriate. 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 reference dose (RfD) exposure (1). If the resulting hazard index is less than or equal to one, 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).

In the models used in this study, a transfer coefficient of 1.0 is assumed. For example, 100% of the pesticide dislodged by the golf ball is assumed to transfer from the golf ball to a golfer's hand. This is a conservative estimate since in reality, 100% transfer is not likely. Exposure also is assumed to occur every day for a lifetime. For golfers this may not be entirely realistic, since most golfers do not play daily. The body weight was determined for an average weight female golfer, again to provide a more conservative estimate. The exposure points used in the models were based on the theoretical golfer previously described. The following equations, which represent the dermal and oral doses, form the basis upon which all of the equations used in the models are built.

$$\text{Dermal Dose} = \frac{(QPH + QPB + QPG + QPCF) \times DP}{BW}$$

$$\text{Oral Dose} = \frac{QPB \times DP}{BW}$$

where:
QPH = Quantity of pesticide dislodged by a hand.
QPB = Quantity of pesticide dislodged by a golf ball.
QPG = Quantity of pesticide dislodged by a golf grip.
QPCF = Quantity of pesticide dislodged by a golf club head
DP = Dermal permeability coefficient (0.10).
BW = Female body weight (56 kg).
Total Dose = Dermal Dose + Oral Dose
Hazard Quotient = Total Dose / RfD Dose

Residue Analysis

Methylene chloride was used to extract isazofos and chlorpyrifos from cheesecloth and golf balls. Each sample was shaken mechanically in the same glass jar that it had been placed during sampling, with 150 ml of methylene chloride for 15 minutes and then decanted into a 500 ml round-bottom evaporation flask. This procedure was conducted three times per sample. The solvent extracts were concentrated using a rotary evaporator to reduce the sample to dryness. The pesticide concentrate then was increased to a final volume of 10 ml using methylene chloride and decanted into a crimp-top vial.

Due to the presence of co-extractants from the extraction of the grips with methylene chloride, a modification of the methylene chloride method described above was necessary. An extracting solution comprised of methanol, water, and sulfuric acid was developed. The extracting solution (150 ml) was added to the jar containing the sample. The sample was shaken for 30 minutes and the extracting solution was decanted through a Buchner funnel into a 500 ml filter flask. This extraction procedure was conducted three timesfor each sample.

Solvent extracts were transferred to a 1 L separatory funnel. Deionized water (200 ml) and sodium chloride (60 g) were then added to the separatory funnel and shaken for 30 minutes. Methylene chloride (100 ml) was added to the separatory funnel and shaken for approximately two minutes. Following shaking, the separatory funnel was placed on a holder. The methylene chloride phase was collected and the extracting procedure was repeated two more times. Prior to transfer of the methylene chloride fraction to a round-bottom evaporation flask, sodium chloride (15 g) was added and stirred for three to five minutes. Addition of sodium chloride prevented the possible transfer of water to the round-bottom evaporation flask, thus decreasing the time required to concentrate the extract solution. Methylene chloride was removed using a rotary evaporator. The sample was increased to a final volume of 10 ml using methylene chloride, and decanted into a crimp-top vial.

The extracted solvent was analyzed by HP 5890 - A series II gas chromatography with a 10 m x .53 mm, HP - 5 cross linked 5% phenolmethyl silicon capillary column and a flame photometric detector. Sample solutions and appropriate standards were injected using the following instrument parameters: pressure 20 psi; oven temperature 180 - 225 C @ 10 degrees per minute; injector temperature 200 C; detector temperature 250 C; helium carrier gas flow rate 15 ml/min; on-column injection of 1µL sample^{-1}; and retention

TIME (hours)	Damp Cheesecloth	Golf Ball	Club Grip	C+W[3] I	C+W II
	----------------------------------micrograms/sample +/- S.D.[1]	----------------------------			
1	194.0 +/- 89.0	6.1 +/- 3.0	0.1 +/- 0.2	51.7 +/-12.6	33.3+/-10.9
4[2]	11.2 +/- 3.0	0.7 +/- 0.2	0.0	18.1 +/- 2.6	3.0 +/- 0.6
24	3.1 +/- 0.8	0.3 +/- 0.1	0.0	6.1 +/- 3.7	1.0 +/- 0.6
<u>orthagonal contrasts</u>					
1h vs. 4h P>F	0.0005	0.0023	0.2261	0.0001	0.0001
1h vs. 24h P>F	0.0004	0.0034	0.2261	0.0001	0.0001

[1]S.D. = Standard Deviation
[2]After irrigation
[3]Chip and Wipe

Table 1. Dislodgeable residues for all parameters following application of isazofos on 3 June 1997 and 29 October 1997 (for Chip+Wipe II only).

times of isazofos = 0.777 min and chlorpyrifos = 1.165 min. The detection limit was 0.1 µg sample^{-1}. The data were analyzed over time for each pesticide using orthagonal contrast procedures (16).

Results

Isazofos

Isazofos residues dislodged by damp cheesecloth immediately after application averaged 194.0 µg sample^{-1} (Table 1) which calculates to 3216.3 µg m^{-2}. Thus for isazofos, less than 2 % of that applied could be recovered from the turf surface by vigorous wiping action immediately after application. Following irrigation and drying, at four hours after application, isazofos residues decreased 94% (0.08% of that applied) following a scheduled irrigation event (Table 1). At 24 hours after application, residues averaged 51.6 µg m^{-2} or 0.02 % of the isazofos applied.

Isazofos residues recovered from golf balls decreased after irrigation and with time (Table 1). Isazofos residues dissipated 88% between one and four hours after application. By 24 hours after application, isazofos residues recovered were less than 0.5 µg per sample. Isazofos residues dislodged by golf grips were only recovered one hour after application (Table 1). At four and 24 hours after application, no residues or an undetectable amount of residues were dislodged.

Dislodgeable residues of isazofos decreased with time as determined by the chip and wipe method I procedure (Table 1). Residues recovered within one hour after application dissipated by 65% and 88% at four and 24 hours after application, respectively. Isazofos residues also decreased with time using the chip and wipe method II procedure (Table 1). After application, residues averaged 33.3 µg per sample. A 90% reduction in residues was measured four hours after application.

Chlorpyrifos

Residues of chlorpyrifos dislodged using damp cheesecloth decreased from 155 µg per sample to 1.90 µg per sample over 24 hours (Table

2). An irrigation event occurring between the one and four hour sampling periods likely contributed to the dissipation of chlorpyrifos residues. A 95% reduction in residues occurred within this time frame. On an area basis, 2570 µg chlorpyrifos m^{-2} (1.1 % of that applied) was dislodged from the turf surface immediately after after application, while at four and 24 hours, 0.06 and 0.01% of the applied chlorpyrifos was recovered.

Chlorpyrifos residues on golf balls decreased over time (Table 2). Again, irrigation between the one-hour and four-hour sampling period likely contributed to the reduction in residues. At 24 hours after application, only 8% of the residues measured one hour after application were recovered. Chlorpyrifos residues on golf grips were only detected one hour after application (Table 2). An average of less than one µg per sample was detected.

Dislodgeable residues of chlorpyrifos recovered via the chip and wipe method I procedure decreased with time (Table 2). Residues at one hour after application averaged 41.7 µg per sample. A 72% decrease in residues was observed four hours after application. By 24 hours after application, chlorpyrifos residues had decreased by 80% from the one-hour sampling period.

Chlorpyrifos residues recovered by the chip and wipe method II procedure decreased with time (Table 2). Dislodgeable residues averaged 29.0 µg per sample one hour after application. Residues decreased 94% and 95% by four and 24 hours after application, respectively.

Dislodgeable residues of the two pesticides decreased rapidly after application. The rapid decline of chlorpyrifos residues is in agreement with the findings of Goh et al. (8), Sears et al. (17), Murphy et al. (14) and Snyder et al (18). Several factors may have contributed to their rapid dissipation. Irrigation applied after application likely washed a portion of the applied pesticides from the turfgrass canopy into the soil and thatch. The insecticides are adsorbed and/or absorbed by the plant.

Finally, both pesticides have shown some degree of volatility. It should be noted that isazo-

TIME (hours)		Damp Cheesecloth	Golf Ball	Club Grip	C+W[3] I	C+W II
		---micrograms/sample +/- S.D.[1]---				
1		155.0 +/- 80.0	5.8 +/- 2.2	0.4 +/- 0.9	41.7 +/-11.0	29.0+/-11.7
4[2]		8.3 +/- 0.9	0.8 +/- 0.1	0.0	11.7 +/- 5.4	1.7 +/- 0.6
24		1.9 +/- 0.4	0.5 +/- 0.2	0.0	8.6 +/- 5.1	1.5 +/- 1.0
<u>orthagonal contrasts</u>						
1h vs. 4h	P>F	0.0010	0.0016	0.2555	0.0001	0.0001
1h vs. 24h	P>F	0.0008	0.0020	0.2555	0.0001	0.0001

[1] S.D. = Standard Deviation
[2] After irrigation
[3] Chip and Wipe

Table 2. Dislodgeable residues for all parameters following application of chlorpyrifos on 3 June 1997 and 29 October 1997 (for C+W II only).

fos and chlorpyrifos, which were applied at the same rates, dislodged similar levels of residues suggesting that within a particular class of pesticide, application rate and not the pesticide is important. In an earlier paper on this subject, Snyder et al. (18), reported that the organophosphate nematicide fenamiphos applied at 1.123 g a.i. m^{-2} (a rate approximately five times higher than either chlorpyrifos or isazofos) had dislodgeable residues that were proportionally higher compared to values reported herein for chlorpyrifos or isazofos.

Risk Assessment

The data in Table 3 indicate that even under extreme circumstances, golfers will experience little risk from dislodgeable residues of chlorpyrifos. While the data for isazofos appears more threatening, it should be remembered that golfers are unlikely to encounter these pesticides on every round of golf they play over a period of many years.

The quantity of the chemicals dislodged was influenced by time and irrigation. Dislodgeable residues of isazofos and chlorpyrifos decreased following irrigation. In addition, a notable decrease in dislodgeable residues was seen 24 hours after application. Application rate appears to have the greatest influence on the quantity of dislodgeable residues. The higher the rate of application, the more residues are potentially available for exposure. By using an application rate sufficient to alleviate a particular pest problem without applying excessive amounts of pesticides, the quantity of residues available for exposure can be minimized.

Insecticide residues were recovered by all of the dislodgeability methods used in this study. This finding reveals that the potential for pesticide exposure is present by means of a number of path-

Insecticide	Behavior	Hazard Quotient
Isazofos	Golfer plays on 18 greens 30 minutes after pesticide application every day for a lifetime (70 years)	55.12
	Golfer plays on 18 greens after pesticide application and irrigation every day for a lifetime	3.95
	Golfer plays on 18 greens the day after application and irrigation every day for a lifetime	1.30
Chlorpyrifos	Golfer plays on 18 greens within 1 hour after pesticide application every day for a lifetime (70 years)	0.31
	Golfer plays on 18 greens after pesticide application and irrigation every day for a lifetime	0.02
	Golfer plays on 18 greens the day after application and irrigation every day for a lifetime	0.01

Note: Hazard Quotients of 1.0 or less indicate little risk to the golfer.

Table 3. Hazard Quotients calculated for OP insecticides and behavioral scenarios.

ways. This knowledge enables one to reduce the potential intake of pesticide residues by modifying one's behavior in a manner such that the number of exposure pathways is diminished. For example, the use of towels to clean golf balls and club heads, rather than the hand or mouth, could appreciably decrease exposure.

The risk assessment models used in this study indicate that golfer exposure to isazofos immediately following application may exceed acceptable daily intakes for chronic exposure (i.e. hazard quotients > 1). Following irrigation, only isazofos yielded dislodgeable residues that may exceed acceptable chronic daily intakes (i.e. hazard quotients > 1). Only isazofos had a hazard quotient greater than one the day following application. The hazard quotients for chlorpyrifos never exceeded one.

It is important to recognize that exceeding a chronic RfD does not imply an acute toxic hazard. Chronic reference doses are daily doses of a chemical that could be received every day of one's life without producing toxicity. Typically, acute reference doses are many times greater than chronic reference doses. Therefore, golfer exposures by the pathways considered in this study for isazofos and chlorpyrifos are unlikely to produce acute toxicity, even if exposure occurs within a half-hour of application. Clearly, delaying reentry beyond a few hours reduces exposure to levels below those that may be of concern for even subtle effects from long-term exposure.

The RfD value of a particular pesticide is an integral part of the risk assessment model. It plays a large part in determining whether or not a toxicologically significant effect will occur. For example, similar quantities of both chlorpyrifos and isazofos were recovered, however, because of the small RfD value determined for isazofos, exposure to isazofos at similar levels to that of chlorpyrifos is estimated to be a great deal more hazardous. Therefore, choosing a pesticide that is less toxic can reduce the hazards associated with pesticide exposure.

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