Evaluation of Management Factors Affecting Volatile Loss and Dislodgeable Foliar Residues

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Goals:

- *The role of vapor pressure and temperature will be evaluated in terms of developing a screening system for turfgrass pesticides*
- *Pesticides with possible safety concerns will be further evaluated in the context of best management practices, including the role of spray volume and adjuvants.*
- *The role of thatch accumulation on the dissipation of volatile and dislodgeable residues will be assessed.*

Cooperators:

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Volatilization can be a major route of pesticide loss following application to turfgrass. Consequently, a significant proportion of applied pesticides may be available for human exposure via volatile and dislodgeable residues. Volatile residues were determined from small circular turf plots with high volume air samplers using the Theoretical Profile Shape method and dislodgeable residues were concurrently determined by wiping treated turfgrass with water-dampened cheesecloth. Inhaled doses were estimated from the volatile residues and dermal doses were estimated using the dislodgeable residues. Inhalation and dermal hazards were determined using the USEPA Hazard Quotient (HQ) method.

Our research to date has established that there are volatile and dislodgeable pesticide residues available for golfer exposure following application to turfgrass and that not all of these exposures can be deemed completely safe by the above criteria. Of the 13 pesticides examined, however, 10 were deemed safe in that their application never resulted in HQ greater than 1.0. Included in this "safe" group are the organophosphous insecticides, isofenphos, trichlorfon, chlorpyrifos; the carbamate insecticides, bendiocarb, carbaryl; the pyrethroid insecticide, cyfluthrin; and the fungicides, chlorthalonil, iprodione, propiconazole, thiophanate methyl. Application of ethoprop, isazofos and diazinon, nevertheless, did result in HQs greater than 1.0 and cannot be deemed as completely safe by the above criteria. These three pesticides are all organophosphorous insecticides that belong to the high vapor pressure group and have the lowest reference dose (i.e., highest toxicity rating) as established by the USEPA Office of Pesticide Programs. Ethoprop, isazofos and diazinon had inhalation HQs greater than 1.0 through day 3, the maximum inhalation HQs all occurred on day 1, and all were below 1.0 after day 3 following application (Table 8). Chlorpyrifos, which is in the high vapor pressure category, had a maximum inhalation HQ of 0.1 on day 2. This is due to the high reference dose of chlorpyrifos compare to the other organophosphorous insecticides. Similarly, ethoprop, isazofos and diazinon had dermal HQs greater than 1.0 on day 1 (15 min post application, Table 9). However, only ethoprop had a dermal HQ greater that 1.0 through day 1 (8 hr post application).

From these findings, we have determined that the critical vapor pressure below which no turfgrass pesticide will volatilize to the extent that it will result in an inhalation HQ greater than 1.0 to be between 3.3×10^{-6} mm Hg (i.e., isofenphos vapor pressure, Table 8) to 5.6×10^{-6} mm Hg (i.e., isazofos vapor pressure, Table 8). Similarly, we have determined the critical OPP reference dose above which no turfgrass pesticide will result in a dermal HQ greater that 1.0 to be between 0.0005 (i.e., see isofenphos, Table 9) to 0.0009 (i.e., see diazinon, Table 9).

In order to mitigate the exposure potential of the organophosphorous insecticides that have high vapor pressures and inherent high toxicity, we evaluated the practical use of spray tank adjuvants. Two adjuvants were examined as to their abilities to suppress volatile and dislodgeable residues: Aqua Gro-L, a non-ionic surfactant/penetrant; and Exhalt 800, an encapsulating spreader/sticker. Neither product resulted in significant and meaningful differences in the exposure potential of these problematic insecticides. Additionally, we determined the importance of thatch accumulation on the dissipation of volatile and dislodgeable foliar residues following the application of these problematic insecticides. Neither aeration nor dethatching of turfgrass plots resulted in significant and meaningful differences in the exposure potential of these organophoshorous insecticides.

In summary, the large majority of the turfgrass pesticides evaluated in this study were deemed safe using the USEPA Hazard Quotient method. Pesticides that were not deemed completely safe by these criteria were all organophosphorous insecticides with high vapor pressures and inherent high toxicity. Because effective organophosphorous and carbamate insecticide alternatives are available that do not share these problematic features, the use of ethoprop, isazofos and diazinon on turfgrass should be minimized and applied only when a delayed reentry period is practical.

Additionally, we have shown that some organophosphate insecticides that possess high toxicity and volatility may result in exposure situations that cannot be deemed completely safe as judged by the USEPA Hazard Quotient determination. This assessment, however, must be viewed in terms of the assumptions that were used in making these estimations. In all instances, maximum pesticide concentrations were used for the entire four hour exposure period, maximum rates for pesticide applications were used, and dermal transfer coefficients and dermal permeability factors were taken from non-turfgrass situations that are likely to exceed those that would take place on a golf course. Because of this, we view such estimates as *worst case scenarios*. To accurately predict the health implications of pesticide exposure to golfers, a relevant dosimetry evaluation of golfers, playing golf on a golf course, needs to be carried out. With more accurate exposure estimates, it is our belief that the exposure levels reported here would be found to be in excess of the true exposure to pesticides on a golf course.

Table 8. Inhalation hazard quotients (IHQs) for turfgrass pesticides in the high (i.e., vapor pressures > 1.0 x 10-5 mm Hg), intermediate (i.e., vapor pressures between 1.0 x 10-5 mm Hg and 1.0 x 10-7 mm Hg) and low (i.e., vapor pressures < 1.0)

Pesticide	Vapor Pressure (mmHg)	OPP RFD (mg/kg/day)	Day 1 (IHQs)	Day 2 (IHQs)	Day 3 (IHQs)
High Vapor Pressure					
DDVP *	1.6 E-2	0.0005	0.06	0.04	0.02
Ethoprop	3.5 E-4	0.000015	50	26	1.2
Diazinon	9.0 E-5	0.00009	3.3	2.4	1.2
Isazofos	5.6 E-5	0.00002	8.6	6.7	3.4
Chlorpyrifos	2.0 E-5	0.003	0.09	0.1	0.04
Intermediate V.P.					
Trichlorfon	3.8 E-6	0.002	0.02	0.004	0.004
Bendiocarb	3.4 E-6	0.005	0.02	0.002	0.002
Isofenphos	3.3 E-6	0.0005	n/d	0.02	n/d
Chlorthalonil	5.7 E-7	0.015	0.001	0.001	0.0003
propiconazole	4.2 E-7	0.0125	n/d	n/d	n/d
Carbaryl	3.1 E-7	0.014	0.0005	0.0001	0.00004
Low Vapor Pressure					
Thiophanate-Methyl	7.1 E-8	0.08	n/d	n/d	n/d
Iprodione	3.8 E-9	0.061	n/d	n/d	n/d
Cyfluthrin	2.0 E-9	0.025	n/d	n/d	n/d

n/d = non - detected.
note: The IHQs reported in table 1 are the maximum daily IHQs measured on that sampling day.

Table 9. Dermal hazard quotients (DHQs) for turfgrass pesticides listed with increasing RfDs from top to bottom through day 3 post application.

Pesticide	OPP RfD (mg/kg/day)	Day 1 (DHQs)			Day 2 (DHQs)	Day 3 (DHQs)
		15 Minutes	5 Hours	8 Hours	12:00 P.M	12:00 P.M
Ethoprop	0.000015	16.0	1.64	1.35	0.23	0.34
Isazofos	0.00002	1.05	1.17	0.97	0.16	0.21
Diazinon	0.00009	3.0	0.28	0.22	0.04	0.05
Isofenphos	0.0005	0.32	0.05	0.05	0.01	0.01
DDVP[a]	0.0005	0.06	0.003	0.003	n/d[a]	n/d[a]
Trichlorfon	0.002	0.64	0.007	0.009	0.008	0.005
Chlorpyrifos	0.003	0.17	0.02	0.016	0.003	0.004
Bendiocarb	0.005	0.31	0.006	0.01	0.006	0.0008
Propiconazole	0.00125	0.0002	0.003	0.0002	0.0005	0.0002
Carbaryl	0.0014	0.003	0.00008	0.0001	0.00006	0.000002
Cyfluthrin	0.0025	---[b]	---[b]	---[b]	---[b]	---[b]
Iprodione	0.0061	0.0004	0.0003	0.0003	0.0004	0.0003
Thiophanate-methyl	0.008	---[b]	---[b]	---[b]	---[b]	---[b]

[a] - DDVP was not applied, but is the breakdown product of trichlorfon.

[b] - Data not available.