USGA - GREEN SECTION RESEARCH

PROJECT: Evaluation of Management Factors Affecting Volatile and Dislodgeable Foliar Residues of Turfgrass Pesticides

ANNUAL REPORT: (5/1/97 – 12/5/97)

COOPERATING DEPARTMENTS AND PRINCIPAL LEADERS:

J.M. Clark, G.R. Roy, J.D. Doherty, A. Curtis,
Massachusetts Pesticide Analysis Laboratory, Department of Entomology,
Box 32410, University of Massachusetts, Amherst, MA 01003-2410

R.J. Cooper, Department of Crop Science,
North Carolina State University, Raleigh, NC. 27695-7620.

EXECUTIVE SUMMARY

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 the determined using the USEPA Hazard Quotient (HQ) method (Murphy et al., 1996ab).

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, ipridione, propiconizole, thiophanate methyl. Application of ethoprop, isazafos 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, isazafos 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 1). Chlorpyrifos, which is in the high vapor pressure category, had a maximum inhalation HQ of 0.1 an day 2. This is due to the high reference dose of chlorpyrifos compare to the other organophosphorous insecticides. Similarly, ethoprop, isazafos and diazinon had dermal HQs greater than 1.0 on day 1 (15 min post application, Table 2). 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 x 10-6 mm Hg (i.e., isofenphos vapor pressure, Table 1) to 5.6 x 10-6 mm Hg (i.e., isazafos vapor pressure, Table 1). 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 2) to 0.0009 (i.e., see diazinon, Table 2).

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, isazafos 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*. In order to more 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 will be found to be in excess of the true exposure to pesticides on a golf course.

Table 1: Inhalation hazard quotients (IHQs) for turfgrass pesticides in the high (i.e., vapor pressures > 1.0×10^{-5} mm Hg), intermediate (i.e., vapor pressures between 1.0×10^{-5} mm Hg and 1.0×10^{-7} mm Hg) and low (i.e., vapor pressures < 1.0×10^{-7} mmHg) vapor pressure groups.

Pesticide	Vapor Pressure (mmHg)	OPP RFD (mg/kg/day)	Day 1 (IHQs)	Day 2 (IHQs)	Day 3 (IHQs)
(High V.P.)					
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
Isazafos	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
Propiconizole	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 V.P.)					
Thiophanate-Methyl	7.1 E-8	0.08	n/d	n/d	n/d
Ipridione	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 measu red on that sampling day.

Table 2: 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
Isazafos	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
Propiconizole	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]
Ipridione	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 trichlofon.
b - Data not available

PREVIOUS WORK

Previous studies have shown that volatile and dislodgeable foliar residues resulting from the application of turfgrass pesticides to golf courses cannot be deemed as completely safe as judged by the USEPA Hazard Quotient (HQ) method (Murphy et al., 1996). During the first two years of our study, 13 turfgrass pesticides were screened for their potential volatile and dislodgeable foliar residues. From these residues, both dermal and inhalation doses were estimated and hazard quotients were calculated. HQs below 1.0 are deemed as safe doses, while HQs greater than 1.0 indicates that their safety is less certain. (USGA - Green Section Semi - Annual report, 11/1/96 - 4/30/97). Ten of the 13 compounds screened never resulted in either inhalation hazard quotients (IHQs), or dermal hazard quotients (DHQs) greater than 1.0 at any time after application. However, three compounds, ethoprop, diazinon, and isazafos, all of which are organophosphate insecticides, resulted in IHQs greater than 1.0 through day 3 post application. Ethoprop and isazafos also had DHQs greater than 1.0 at 15 min, 5 hrs, and 8 hrs post application, and both were below 1.0 by day 2 post application. Diazinon had a DHQ greater than 1.0 at 15 min post application and had fallen below 1.0 by 5 hrs post application.

Since the vapor pressure of a compound is a key determinant in how much it will volatilize, our goal was to determine a critical vapor pressure below which no turfgrass pesticide will volatilize to the extent that it results in an IHQ greater than 1.0. That vapor pressure has been determined to be between 3.3 x 10-6 mm Hg (i.e., isofenphos vapor pressure, Table 1) to 5.6 x 10-6 mm Hg (i.e., isazafos vapor pressure, Table 1). Similarly, we determined there was a critical OPP reference dose (RfD) above which no turfgrass pesticide resulted in a DHQ greater than 1.0. That RfD is between 0.0005 mg/kg/day (i.e., see isofenphos, Table 2) to 0.0009 mg/kg/day (i.e., see diazinon, Table 2).

Annual Progress Report: (11/1/96 - 12/5/97)

<u>Objective 2 (Year 3)</u>

2.1 Evaluation of selective turfgrass management practices to minimize potential volatile and dislodgeable foliar residues of turfgrass pesticides.

Progress in Completing Objective 2.

The turfgrass practices that were evaluated were the addition of tank mixture adjuvents during pesticide applications. One adjutant was the spreader/sticker Exhalt 800, the other the wetting agent Aqua Gro®-L. The products that were evaluated were Oftonol (a.i., isofenphos), Turcam (a.i., bendiocarb), and Mocap (a.i., ethoprop). The sampling schedule and procedures were the same as previously described with the exceptions that sampling only took place for three days post application (days 5 and 7 were eliminated), since the only residues of concern took place during the first three days. Also, dermal wipes were taken at 15 min post application (before watering in), 2 hrs post application, and 5 hrs post application.

Week 1 (May, 28-30): On May 28 (day 1), the above mentioned compounds were applied at recommended label rates to plots # 1 and 3 (Fig.1). The tank mixture used on plot # 1 contained no spreader/sticker, whereas the tank mixture used on plot #3 contained the spreader/sticker Exhalt 800. The sampling schedule and procedures were as previously described. An additional air sampler was placed midway between the two plots to monitor for any cross contamination. Samples were analyzed following the methods previously described.

Week 2 (June,10 - 12): On June 10 (day 1) applications were made to plots #2 and 4 (Fig.1). The application to plot # 2 did not contain the wetting agent , whereas the application to plot # 4 contained the wetting agent AquaGro®-L The same procedures were followed in week 2 as was described for week 1.

Week 3 (July, 8 - 10): Week 3 applications were a duplicate of week 1. However, for week 3 plot #1 contained the spreader/sticker Exhalt 800, while plot # 3 did not. The reason for the reversal is that plot # 3 is a newly established plot (Fall, 1995) and therefore does not have a significant thatch buildup as does plot # 1 (established Spring, 1991). This reversal served as a control for thatch effect.

Week 4 (July, 29 - 31): Week 4 applications were a duplicate of week 2. Again, to control for thatch effect, plot # 2 contained the wetting agent Aqua Gro®-L, while plot # 4 did not.

The overall sampling strategies described above resulted in two applications to plots in the presence and absence of the spreader/sticker Exhalt 800, and two applications to plots in the presence and absence of the wetting agent Aqua Gro®-L. The application of these four sets resulted in 72 air samples and 120 dermal wipes (triplicates of each wipe sample were performed).

Objective 3 (year 3).

3.1 Determination of the importance of thatch accumulation on the dissipation of volatile and dislodgeable foliar residues of turfgrass pesticides.

Ethoprop, isofenphos, and bendiocarb were evaluated to accomplish objective 3. A simultaneous application to two plots was done on August 26, 1997. Plot #1, which was established in the fall of 1990, served as our mature thatch plot, while plot 4, which was established in the fall of 1995, served as our no thatch plot (Fig.1). On September 9, 1997 an additional application was made to plot #2 (Fig 1.) which was also established in the fall of 1990, but was dethatched on July 27, 1997. On August 30, 1997 plot #1 was aerated, and on September 23, 1997 an application to plot #1 was done. Sampling and analysis strategies were the same as described in objective 2.

The above application resulted in an additional 36 air samples, and 60 dermal wipes.

RESULTS
FIELD DATA

Air concentrations of volatile residues were used to calculate inhalation hazard quotients (IHQs) and dislodgeable foliar residues were used to calculate dermal hazard quotients (DHQs). Results for ethoprop and isofenphos are presented in tables 3, 4, 5, and 6.

Ethoprop Results With and Without the Spreader/Sticker (Tables 3A and 3B):

Application #1 on the plot without the spreader/sticker resulted in a maximum IHQ of 110, which occurred during the first 60 minutes post application. Application #1 on the plot with the spreader/sticker resulted in an IHQ of 325. IHQs on both plots continued to decline, but were still over 1.0 on day 3. The application with the spreader sticker shows two to three times higher IHQs than the plot without the spreader/sticker. However, application #2 with and without the spreader/sticker did not show this same trend. A maximum IHQ of 69 occurred during the first hour post application on the plot without the spreader/sticker, while a maximum IHQ of 69 on the plot with the spreader sticker occurred during hours two and three post application. Comparing the results from the two plots, the IHQs were very similar through day 3. There was no significant difference in the IHQs with or without the spreader/sticker in the tank mixture. The very high IHQs measured from application #1 on the plot with the spreader/sticker are probably due to application error.

Application #1 on the plot without the spreader/sticker resulted in a maximum DHQ of 40 which occurred at 15 min post application. The plot with the spreader/sticker resulted in a maximum DHQ of 12.7, also 15 min post application, DHQs were still above 1.0 at 2 hrs post application and 5 hrs post application. By day 2 DHQs had fallen below 1.0. Application #2 resulted in maximum DHQs of 18 and 13 for the plots with and without the spreader/sticker respectively, and DHQs had fallen below 1.0 by 2 hrs post application

Isofenphos Results: With and Without the Spreader/Sticker (Table 4A and 4B)

Application #1 resulted in a maximum IHQ of 0.18 and 0.35 on plots without and with the spreader/sticker, respectively. The IHQs from the application with the spreader/sticker were approximately twice as high through day 3. Again, this trend did not continue during the second application, where a maximum IHQ of 0.11 and 0.16 respectively were measured.

Application #1 resulted in a maximum DHQ of 0.23 and 0.52 with and without the spreader/sticker, respectively, while maximum DHQs of 0.32 and 0.2 resulted from application #2. Isofenenphos did not result in IHQs greater than 1.0 at any time post application.

Ethoprop Results With and Without the Wetting Agent (Tables 5A and 5B):

Application #1 to plots with and without the wetting agent Aqua Gro®-L resulted in maximum IHQs of 123 and 99 respectively. While application #2 resulted in maximum IHQs of 51 and 34 respectively. After application #1, IHQs were above 1.0 through day 2, and fell below 1.0 by day 3. After application #2, IHQs were above 1.0 through day 3.

Application #1 to plots with and without the wetting agent resulted in maximum DHQs of 1.8 and 3.3 respectively, both occurring at 15 min post application and had fallen below 1.0 by 2 hrs post application. Application #2 resulted in maximum DHQs of 10.0 and 4.8 at 15 min post application, and also had fallen below 1.0 by 2 hrs post application.

Isofenphos Results With and Without the Wetting Agent (Tables 6A and 6B):

Application #1 to plots with and without the wetting agent resulted in maximum IHQs of 0.18 and 0.15 respectively. While application #2 resulted in maximum IHQs of 0.07 for both. Not at any time post application did the application of isofenphos result in IHQs greater than 1.0.

Application #1 to plots with and without the wetting agent resulted in maximum DHQs of 0.08 and 0.09 respectively, which occurred at 15 min post application. Application #2 resulted in maximum DHQs of 0.33 and 0.15 at 15 min post application. Isofenenphos did not result in DHQs greater than 1.0 at any time post application.

Ethoprop Results for Thatch vs. No Thatch (Table 7):

Application to plot #1 (thatch) resulted in a maximum IHQ of 108, which occurred during the first hour post application. Plot #4 (no thatch) had a maximum IHQ of 97 during the first hour post application. Both plots 1 and 4 declined at similar rates, and were still above 1.0 on day 3.

Maximum DHQs occurred at 15 min post application, 5.6 for plot #1 and 4.9 for plot #4. DHQs for both plots fell below 1.0 by 2 hrs post application.

Isofenphos Results for Thatch vs. No Thatch (Table 7):

Application to plot #1 (thatch) resulted in a maximum IHQ of 0.25, which occurred during the first hour post application, while plot #4 (no thatch) had a maximum IHQ of 0.09 during the first hour post application. Isofenenphos did not result in IHQs greater than 1.0 at any time post application.

Maximum DHQs for both plots 1 and 4 were 0.1 and occurred 15 min post application.

Ethoprop Results for Dethatched Plot (Table 8):

Application to the dethatched plot resulted in a maximum IHQ of 63.7, which occurred during the second and third hours post application. IHQs remained above 1.0 through day 2. Day 3 sampling was canceled due to rain.

Isofenphos Results for Dethatched Plot (Table 8):

Application to the dethatched plot resulted in a maximum IHQ of 0.12, which occurred during the second and third hours post application. Isofenphos did not result in IHQs greater than 1.0 at any time post application.

Work Still in Progress:

Due to the fact that we were still conducting field work in October, there still is some sample analysis pending. Samples still need to be analyzed for bendiocarb. However, based on the results of ethoprop and isofenphos, we believe the same trends will be shown for bendiocarb. Dermal samples from the dethatching experiment, and both volatile and dermal samples from the aeration experiment are pending.

Work is still ongoing with Dr. Doug Haith at Cornell University which involves modeling the volatilization of the compounds screened in the first year of our study. From this, an algorithm that would help predict which compounds may result in potentially undesirable exposures will be developed.

CONCLUSIONS

During the first year of our study, it was shown that volatile and dislodgeable foliar residues following the application of ethoprop, isazafos, and diazinon were at levels that could not be deemed safe by the above criteria (HQs > 1.0). It was our hypothesis that the addition of a wetting agent (penetrant) or a spreader/sticker (encapsulator) to the tank mixture could possibly mitigate these exposures. It was believed that the wetting agent would move the compound deeper into the thatch, possibly even through the thatch so that it would be less available to form volatile residues. Similarly, it was thought that the spreader/sticker would bind the compound more tightly and would also be less available to form volatile residues. Ethoprop the compound generating the highest Hqs, along with isofenphos and bendiocarb, two borderline compounds, were applied with and without the tank mixture adjuvents. Neither adjuvant showed any significant difference in either volatile or dislodgeable foliar residues between the application containing the adjuvant and the application without the adjuvant. Therefore, the addition of these two adjuvants were unsuccessful at mitigating the unwanted exposures.

Similarly, we wanted to see what role thatch was playing on the dissipation of volatile residues. It is well established that thatch has a great ability to bind pesticides and prevent them from moving downward. However, it was unclear whether that binding ability would leave the compound more or less available as a volatile residue: Therefore, an application was done to a plot that had a mature thatch layer, and one that was newly established. Results from this application show no difference between the two plots (Table 6). In addition, the mature plot was dethatched and an application made. The results were compared to previous applications to the mature plot. Again, no significant difference in residue levels was shown. Therefore, thatch management will likely be ineffective at mitigating unwanted exposures.

Table 3A: Inhalation hazard quotients (IHQs) for ethoprop following application with and without the spreader/sticker (SS) Exhalt 800.

	Ethoprop			
Sample	**Applications without SS**		**Applications with SS**	
	Application #1 **(IHQs)**	*Application #2* **(IHQs)**	*Application #1* **(IHQs)**	*Application #2* **(IHQs)**
Day 1 S1	110	69	325	55
Day 1 S2	79	55	193	69
Day 1 S3	56	28	66	31
Day 2 S1	38	7.2	c	8.7
Day 2 S2	31	3.5	80	4.7
Day 2 S3	6.1	3.4	18	2.7
Day 3 S1	6.7	2.2	15	1.6
Day 3 S2	3.6	1.0	9.5	0.8
Day 3 S3	2.4	0.9	8.2	0.6

c- sample canceled

Table 3B: Dermal hazard quotients (DHQs) for ethoprop following application with and without the spreader/sticker (SS) Exhalt 800.

	Ethoprop			
Sample	**Applications without S/S**		**Applications with S/S**	
	Application #1 **(DHQs)**	*Application #2* **(DHQs)**	*Application #1* **(DHQs)**	*Application #2* **(DHQs)**
Day 1 S1 (15 min post app.)	40	13	12.7	18
Day 1 S2 (2 hr post app.)	1.1	0.4	2.0	0.8
Day 1 S3 (5 hr post app.)	0.9	0.3	1.7	0.3
Day 2 (12:00 P.M)	0.4	b/d	0.8	b/d
Day 3 S1 (12:00 P.M.)	0.3	b/d	0.8	b/d

b/d - below detection limit

Table 4A: Inhalation hazard quotients (IHQs) for isofenphos following application with and without the spreader/sticker (SS) Exhalt 800.

Isofenphos				
Sample	**Applications without SS**		**Applications with SS**	
	***Application #1* (IHQs)**	***Application #2* (IHQs)**	***Application #1* (IHQs)**	***Application #2* (IHQs)**
Day 1 S1	0.18	0.11	0.35	0.11
Day 1 S2	0.16	0.11	0.27	0.16
Day 1 S3	0.06	0.03	0.1	0.03
Day 2 S1	0.04	0.03	c	0.04
Day 2 S2	0.05	0.01	0.11	0.02
Day 2 S3	0.01	0.01	0.01	0.01
Day 3 S1	0.02	0.02	0.03	0.02
Day 3 S2	0.01	b/d	0.02	b/d
Day 3 S3	0.01	b/d	0.02	b/d

c - sampling period canceled
b/d - below detection limit

Table 4B: Dermal hazard quotients (DHQs) for isofenphos following application with and without the spreader/sticker (SS) Exhalt 800.

Isofenphos				
Sample	**Applications without S/S**		**Applications with S/S**	
	***Application #1* (DHQs)**	***Application #2* (DHQs)**	***Application #1* (DHQs)**	***Application #2* (DHQs)**
Day 1 S1 (15 min post app.)	0.52	0.2	0.23	0.32
Day 1 S2 (2 hr post app.)	0.03	0.02	0.06	0.03
Day 1 S3 (5 hr post app.)	0.02	0.008	0.04	0.01
Day 2 (12:00 P.M)	0.01	b/d	0.02	0.01
Day 3 S1 (12:00 P.M.)	0.01	b/d	0.02	b/d

b/d - below detection limit

Table 5A: Inhalation hazard quotients (IHQs) for ethoprop following application with and without the wetting agent (W/A) Aqua-Gro®

Ethoprop				
Sample	**Applications without W/A**		**Applications with W/A**	
	***Application #1* (IHQs)**	***Application #2* (IHQs)**	***Application #1* (IHQs)**	***Application #2* (IHQs)**
Day 1 S1	99	34	116	51
Day 1 S2	72	27	123	32
Day 1 S3	32	10	63	13
Day 2 S1	6.0	5.3	41	17
Day 2 S2	5.1	4.7	26	11
Day 2 S3	c	2.4	c	4.9
Day 3 S1	0.6	3.1	0.4	3.2
Day 3 S2	0.2	5.2	1.0	3.4
Day 3 S3	0.5	1.9	0.7	1.9

c - sampling period canceled

Table 5B: Dermal hazard quotients (DHQs) for ethoprop following application with and without the wetting agent (W/A) Aqua-Gro®

Ethoprop				
Sample	**Applications without W/A**		**Applications with W/A**	
	***Application #1* (DHQs)**	***Application #2* (DHQs)**	***Application #1* (DHQs)**	***Application #2* (DHQs)**
Day 1 S1 (15 min post app.)	3.3	4.8	1.8	10.0
Day 1 S2 (2 hr post app.)	0.5	0.22	0.6	0.42
Day 1 S3 (5 hr post app.)	0.3	0.49	0.3	0.48
Day 2 (12:00 P.M)	b/d	0.22	b/d	0.26
Day 3 S1 (12:00 P.M.)	b/d	b/d	b/d	b/d

b/d - below detection limit

Table 6A: Inhalation hazard quotients (IHQs) for isofenphos following application with and without the wetting agent (W/A) Aqua-Gro®

Isofenphos				
Sample	**Applications without W/A**		**Applications with W/A**	
	***Application #1* (IHQs)**	***Application #2* (IHQs)**	***Application #1* (IHQs)**	***Application #2* (IHQs)**
Day 1 S1	0.15	0.07	0.18	0.07
Day 1 S2	0.1	0.07	0.11	0.04
Day 1 S3	0.04	0.02	0.06	0.02
Day 2 S1	0.03	0.01	0.09	0.03
Day 2 S2	0.02	0.01	0.07	0.03
Day 2 S3	c	b/d	c	0.01
Day 3 S1	0.01	b/d	0.01	0.01
Day 3 S2	0.01	b/d	0.01	b/d
Day 3 S3	b/d	b/d	b/d	b/d

c - sampling period canceled
b/d - below detection limit

Table 6B: Dermal hazard quotients (DHQs) for isofenphos following application with and without the wetting agent (W/A) Aqua-Gro®

Isofenphos				
Sample	**Applications without W/A**		**Applications with W/A**	
	***Application #1* (DHQs)**	***Application #2* (DHQs)**	***Application #1* (DHQs)**	***Application #2* (DHQs)**
Day 1 S1 (15 min post app.)	0.09	0.15	0.08	0.33
Day 1 S2 (2 hr post app.)	0.02	0.02	0.02	0.02
Day 1 S3 (5 hr post app.)	0.006	0.02	0.008	0.01
Day 2 (12:00 P.M)	0.007	0.01	0.006	0.01
Day 3 S1 (12:00 P.M.)	b/d	b/d	b/d	b/d

b/d - below detection limit

Table 7A: Inhalation hazard quotients (IHQs) for ethoprop and isofenphos, following application to a plot with a mature thatch layer, and a newly established plot.

Thatch vs. No Thatch

Sample	Ethoprop		Isofenphos	
	***Thatch* (IHQs)**	***No Thatch* (IHQs)**	***Thatch* (IHQs)**	***No Thatch* (DHQs)**
Day 1 S1	108	97.2	0.25	0.09
Day 1 S2	58.3	83.6	0.06	0.05
Day 1 S3	44.2	35.6	0.02	0.02
Day 2 S1	4.9	14.2	0.02	0.05
Day 2 S2	2.7	10.7	0.01	0.02
Day 2 S3	1.6	8.1	b/d	b/d
Day 3 S1	0.8	3.3	0.01	0.01
Day 3 S2	1.0	5.5	0.01	0.01
Day 3 S3	c	c	c	c

c - sampling period canceled
b/d - below detection limit

Table 7B: Dermal hazard quotients (DHQs) for ethoprop and isofenphos, following application to a plot with a mature thatch layer, and a newly established plot.

Thatch vs. No Thatch

Sample	Ethoprop		Isofenphos	
	***Thatch* (DHQs)**	***No Thatch* (DHQs)**	***Thatch* (DHQs)**	***No Thatch* (DHQs)**
Day 1 S1 (15 min post app.)	5.6	4.9	0.12	0.1
Day 1 S2 (2 hr post app.)	0.3	0.7	0.01	0.01
Day 1 S3 (5 hr post app.)	c	c	c	c
Day 2 (12:00 P.M)	0.15	0.3	0.01	0.01
Day 3 S1 (12:00 P.M.)	0.3	0.3	0.01	0.01

c - sampling period canceled

Table 8: Inhalation hazard quotients (IHQs) for ethoprop and isofenphos, following dethatching to a plot with a mature thatch layer.

Dethatched Plot		
Sample	**Ethoprop (IHQs)**	**Isofenphos (IHQs)**
Day 1 S1	39.5	0.11
Day 1 S2	63.7	0.12
Day 1 S3	50.5	0.06
Day 2 S1	5.4	0.01
Day 2 S2	6.5	0.02
Day 2 S3	4.1	0.01
Day 3 S1	c	c
Day 3 S2	c	c
Day 3 S3	c	c

c - sampling period canceled

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Updated 8/4/97

PERSONAL:

Name: *J. Marshall Clark*
Date of Birth: May 10, 1949
Place of Birth: Michigan City, Indiana
EMAIL: JClark@ENT.UMASS.EDU

EDUCATION:

B.S. (Zoology) University of Wisconsin-Madison.	1972
M.S. (Entomology, specialty in Insecticide Toxicology) University of Wisconsin-Madison, "Metabolism of Toxaphene by Aquatic Sediments and a Camphor-degrading Pseudomonad."	1977
Ph.D.(Entomology, specialty in Insecticide and Environmental Toxicology) Michigan State University, "Pyrethroid Inhibition of Neural ATPases."	1981
Personnel Training Certificate, EPA Good Laboratory Practice Standards, Garndal Associates, New Orleans, LA, 3/2-4/93.	1993

POSITIONS HELD:

Professor, Department of Entomology, University of Massachusetts, Amherst	1994-present
Associate Professor, Department of Entomology, University of Massachusetts, Amherst	1987-1994
Laboratory Director, Massachusetts Pesticide Analysis Laboratory, CFNR, University of Massachusetts, Amherst	1984-present
Assistant Professor, Department of Entomology, University of Massachusetts, Amherst	1981-1987

OTHER PROFESSIONAL EXPERIENCE:

Executive Committee, Agrochemicals Div., American Chemical Society.	1994-present
Toxicology Study Section Member, NIH/Tropical Medicine and Parasitology.	1994-1997
Toxicology Panel Member, USDA/NRICGP, Assessing Pest Control Strategies (51.6)	1994
Editorial Board, Pesticide, Biochemistry and Physiology, Academic Press, New York, NY.	1991-present
Toxicology Panel Member, USDA Competitive Grant (CRGO) Review Panel (Entomology/Nematology section).	1989
Editorial Board, Environmental Pollution (Series A and B) Elsevier Applied Science Publ. Ltd. Essex, U.K.	1986-1995

PROFESSIONAL HONORS, AWARDS AND CITATIONS:

Graduated with Distinction, University of Wisconsin-Madison.	1972
Graduate School Scholarship, Michigan State University.	1978, 1979
Doctoral Research Award, Entomological Society of America, North Central Branch.	1980
Robert R. Driesback Memorial Award, Michigan State University.	1980
Lilly Teaching Fellowship, University of Massachusetts.	1990
Paul Dahm Memorial Lecturer, Iowa State University.	1995

PROFESSIONAL SOCIETIES:

The Society of Toxicology
The Society for Neurosciences
The American Chemical Society-Agricultural Chemicals and Environmental Chemistry Divisions
Japan Society for Bioscience, Biotechnology and Agrochemistry
The Entomological Society of America
The Society of Environmental Toxicology and Chemistry - Charter Member

PERTINENT PUBLICATIONS: (In addition to the following publications, Dr. Clark has edited 2 books, written 16 book chapters and review articles, 61 refereed publications and published 39 abstracts)

Book Chapters and Review Articles:

Van Driesche, R.G., J. Carlson, D.N. Ferro and J.M. Clark. 1987. "Pesticides and Suburban Agriculture." In, Sustaining Agriculture Near Cities, Selected Proceedings of a Conference at Tufts University. Soil Conservation Society of America. Ed. by William Lockeretz. pp. 49-64.

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Clark, J.M. and F. Matsumura. 1979. Metabolism of Toxaphene by Aquatic Sediment and a Camphor-degrading Pseudomonad. Arch. Environ. Contam. Toxicol. 8:285-298.

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Potter, T.L., Carpenter, T., Putnam, R., Reddy, K. and Clark, J.M. 1992. Rapid Analysis of Herbicides and Degradation Products in Water. J. Agric. Food Chem. 39: 2184-2187.

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Clark, J.M., Edman, S.J., Nagy, S., Van Houten, J. and Hecht, F. 1995. Insecticidal action on calcium channels of *Paramecium tetraurelia*. Pestic. Sci. 44(1): 79-81.

Clark, J.M., Murphy, K.C. and Cooper, R.J. 1995. Fate and Exposure to Pesticides Following Treatment of Turfgrass. Pestic. Sci. 43(2): 247-250.

Martin, P.J.S., Clark, J.M. and Edman, J.D. 1995. Preliminary study of synergism of acid rain and diflubenzuron. Bull. Enviro. Contam. Toxicol. 54: 833-836.

Zhu, K.-Y. and Clark, J.M. 1995. Rapid construction of nested deletions of recombinant plasmid DNA for dideoxy sequencing. BioTechniques: Benchmarks 18(2): 2-4.

Murphy, K.C., Cooper, R.J. and Clark, J.M. 1996. Volatile and dislodgeable residues following Trichlorfon and Isazofos application to turfgrass and implications for human exposure. Crop Sci. 36: 1446-1454.

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Tessier, D.M. and Clark, J.M. 1995. Quantitative assessment of the mutagenic potential of environmental degradative products of alachlor. J. Agric. Food Chem. 43: 2504-2512.

PERSONAL:

Name: **Gerard R. Roy**
Date of Birth: July 19, 1964
Place of Birth: Holyoke, Massachusetts
EMAIL: GROY@ENT.UMASS.EDU

EDUCATION:

A.S. (Environmental Science) Holyoke Community College. 1992

B.S. (Environmental Science) University of Massachusetts, Amherst. 1994

M.S. (Entomology) University of Massachusetts, Amherst. 1998

PROFESSIONAL EXPERIENCE:

Data Processing Group Leader, Hamilton Standard. 1983-1990

Laboratory Technician, Tighe and Bond Environmental Consultants. 1991-1994

Laboratory Analyst, Massachusetts Pesticide Analysis Laboratory. 1993-Present

ACADEMIC HONORS AND AWARDS:

Outstanding Environmental Science Student, Holyoke Community College. 1991

Cum luade, Holyoke Community College. 1992

Cum laude, University of Massachusetts, Amherst. 1994

TEACHING:

Laboratory Assistant, Entomology 590C, 1995
Methods of Environmental Toxicology and Chemistry.

INVITED LECTURES AND POSTERS PRESENTED

Poster, Turf Day, Turfgrass Research Facility, University of Massachusetts, Amherst, MA. June 10, 1997. "Evaluation of Management Factors affecting Volatile and Dislodgeable Foliar Residues".

Invited Lecturer, N.A.P.I.A.P, North East Regional Meetings, Northampton, MA. August 24, 1997. "Evaluation of Management Factors affecting Volatile and Dislodgeable Foliar Residues".

CURRICULUM VITAE

Jeffery J. Doherty

Massachusetts Pesticide Analysis Laboratory
101 Agricultural Engineering
University of Massachusetts
Amherst, MA 01003
(413) 545-4626
email: jjdoherty@ent.umass.edu
fax: (413) 545-5858

Address Correspondence to:
45B Summer Street
Northampton, MA 01060
(413) 586-5267

Education:

B.S.
University of Massachusetts, Amherst, MA
Plant and Soil Science
January, 1992

M.S.
University of Massachusetts
Plant Pathology
Expected March, 1998

Applied Experience:

March, 1996-
present

Analyst, Massachusetts Pesticide Analysis Laboratory, University of Massachusetts, Amherst, Massachusetts

Responsibilities include:
-Analysis of pesticide formulations, use dilutions, and residues in environmental matrices
-Operation and maintenance of high pressure liquid chromatographs equipped with PDA fluorescence detector, gas chromatographs equipped with mass spectrometer, NPD, FPD, ECD, FID, and ELCD detectors, wet chemistry, immunoassays, and computer based data handling systems.
- Personnel training/supervision and laboratory QA/QC.
- Development and evaluation of analytical methods.
- Environmental sampling of air, soils, vegetation, and water.

September, 1991- January, 1992	**Research Assistant, Plant Disease Diagnostic Laboratory, University of Massachusetts, Amherst Massachusetts**

-Assisted with the development of a weather-based disease prediction model and the use of actinomycetes as a biological control agent.
- Isolated fungi, bacteria, and actinomycetes from air, soil, water, and plant material
- Maintained teaching collection of bacteria, fungi, and actinomycetes.

Teaching Experience

Plant Pathology 500 General Plant Pathology	1993, 1994
Plant Pathology S04 Turfgrass Pathology	1994
Entomology 685 Analysis of Pesticidal Chemicals	1995
Environmental Science 535C Methods in Environmental Contamination and Toxicology	1997

Book Chapters and Review Articles

1. Clark, J.M., G. Roy, J.J. Doherty, & R.J. Cooper. 1998. "Evaluation of management factors affecting volatile loss and dislodgeable foliar residues". *In* Fate of Turfgrass Chemicals and Pest Management Approaches. Eds. J.M. Clark, M.P. Kenna. ACS Symposium Series XXX, ACS Books, Washington, D.C. 1998 (in prep).

2. R. Cooper, K.C. Murphy, G. Roy, J.J. Doherty & J.M. Clark. 1998. "Determination of volatile and dislodgeable residues from pesticide-treated turfgrass". *In* Fate of Turfgrass Chemicals and Pest Management Approaches. Eds. J.M. Clark, M.P. Kenna. ACS Symposium Series XXX, ACS Books, Washington, D.C. 1998 (in prep).

3. G.L. Schumann, J.J. Doherty, B.B. Clark & J.M. Clark. 1998. "Environmental fate of sterol-inhibiting fungicides applied by three separate application means. *In* Fate of Turfgrass Chemicals and Pest Management Approaches. Eds. J.M. Clark, M.P. Kenna. ACS Symposium Series XXX, ACS Books, Washington, D.C. 1998 (in prep).

Journal Articles

1. Doherty, J.J., Clark, J.M., Schumann, G.L., and Clark, B.B. 1997. Environmental fate of fenarimol, propiconazole, and triadimefon applied to Kentucky bluegrass utilizing three separate application schemes. Crop. Sci. (submitted).

2. Doherty, J.J., Clark, J.M., Schumann, G.L., and Clark, B.B. 1997. Conversion of triadimefon to triadimenol in a turfgrass system. (in prep).