Environmental Impacts of Lead Pellets at Shooting Ranges & Arsenical Herbicides On Golf Courses in Florida

June 2000

Lena Q. Ma
Willie Harris
Jerry Sartain
University of Florida

State University System of Florida
Florida Center for Solid and Hazardous Waste Management
University of Florida
2207-D NW 13'' Street
Gainesville, FL 32609
www.floridacenter.org

Report #00-03

ACKNOWLEDGMENTS

This research was sponsored by the Florida Center for Solid and Hazardous Waste Management. The authors would like to thank Captain. Ed Tyer of the State of Florida Game and Fresh Water Fish Commission **for** his assistance and **support** in this research project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

DSMA: Disodium Methanearsenate

EPA: Environmental Protection Agency

FDEP: Florida Department of Environmental Protection

FDACS: Florida Department of Agriculture and Consumer Services

GCs: Golf Courses

GFAAS: Graphite Furnace Atomic Absorption Specstroscopy

MDLs: Method Detection Limits

MSMA: Monosodium Methanearsonate

NA: Question Not Answered

OW: Open Water

QA/QC: Quality Assurance/ Quality Control

RQAP: Research Quality Assurance Plan

RPD: Relative Percent Difference

ANNUAL REPORT

March 14, 1999 - June 14, 2000

PROJECT TITLE: Environmental Impacts of Lead Pellets at Shooting Ranges & Arsenical Herbicides on Golf Courses in Florida

PRINCIPAL INVESTIGATORS: Lena Q. Ma, W.G. Harris and J. B. Sartain

QUALITY ASSURANCE OFFICER: Ming Chen

AFFILIATION: Soil and Water Science/University of Florida

Gainesville, FL 32611-0290

COMPLETEION DATE: 3/31/2002 **PHONE: 352-392-1951**

KEY WORDS: lead pellets, shooting range, arsenical herbicide, golf course, heavy metals, soil contamination, environmental impact, and Florida

ABSTRACT: Lead and arsenic are both trace elements of environmental concern due to their adverse impacts on humans and animals. The objectives of this project were to evaluate the environmental impacts of lead pellets at shooting ranges & arsenical herbicides on golf courses in Florida. We have obtained an FDEP approved comprehensive quality assurance plan and established a comprehensive database for shooting ranges and golf courses in Florida. The environmental impacts of arsenical herbicides on golf courses were evaluated via a comprehensive statewide survey. 155 completed questionnaires were received out of > 1300 that were sent out and 96% of the responding facilities used arsenical herbicides (MASA/DSMA) for post-emergent weed control in the past 3 years. Arsenic contamination in soils of Florida golf courses was observed from the data submitted to FDEP by several golf courses. The maximum arsenic concentrations in soils of these golf courses ranged from 5.3 to 250 ppm, with an average of 69.2 ppm. Soil samples from 6 publicly-owned shooting ranges were collected and lead concentrations were determined using EPA method 3051a. Total lead concentrations in surface soils ranged from a few hundred to tens of thousand ppm from both rifle/pistol and shotgun shooting ranges in central Florida. Lead contamination in soils of Florida shooting ranges is therefore a serious problem. Research on remediation of lead contaminated soils and best management practices in shooting ranges should be conducted.

EXECUTIVE SUMMARY

Annual Report

March 14, 1999 - June 14, 2000

PROJECT TITLE: Environmental Impacts of Lead Pellets at Shooting Ranges & Arsenical Herbicides on Golf Courses in Florida

PRINCIPAL INVESTIGATOR: Lena Q. Ma

AFFILIATION: Trace Metal Chemistry/Soil and Water Science/University of Florida

ASSOCIATE INVESTIGATOR: Willie Harris

AFFILIATION: Soil Mineralogy/Soil and Water Science/University of Florida

ASSOCIATE INVESTIGATOR: Jerry Sartain

AFFILIATION: Turf grass fertility/Soil and Water Science/University of Florida

QUALITY ASSURANCE OFFICER: Ming Chen

AFFILIATION: Soil Chemistry /Soil and Water Science/University of Florida

Gainesville, FL 32611-0290 352-392-1951

COMPLETEION DATE: 3/31/2002

OBJECTIVES

- Evaluate the environmental impacts of lead pellets at shooting ranges in Florida
  - ✓ Determine lead concentrations in soil, plant and water in selected shooting ranges;
  - ✓ Investigate the effects of soil properties on lead retention capacity and bioavailability;
  - ✓ Examine the impacts of weathering on lead leachability and bioavailability in a soil.
- Evaluate the environmental impacts of arsenical herbicides on golf courses in Florida
  - ✓ Determine arsenic concentrations in soil, green and water in selected golf courses;
  - ✓ Investigate the effects of soil properties on arsenic retention capacity and bioavailability;

- ✓ Examine the impacts of agrichemicals on arsenic leachability and bioavailability in a soil.

METHODOLOGY

Preliminary survey/literature search will be conducted to obtain information on primary contributors of lead and arsenic from shooting ranges and golf courses in Florida. Based on the survey/literature search, up to 500 soil/plant/water samples will be collected and analyzed from 5-10 sites to determine metal contamination extent and sources in soil/plant/water. Metal leachability (impacts on surface and groundwater) and bioavailability (impacts on human and wildlife) in selected samples will be determined. In addition, selected samples will be subjected to EPA TCLP and SPLP tests to determine their toxicity and to fractionation procedures to determine their chemical and mineralogical properties. The impacts of weathering and agricultural chemicals on lead and arsenic leachability and bioavailability in soils will be determined.

RATIONALE

Results from this study will be useful to both FDEP for environmental regulation and the respective industries for pollution control purposes.

RESULTS

- ♦ Obtained an approved comprehensive quality assurance plan from FDEP.
- ♦ Established databases for ~230 shooting ranges and ~1,100 golf courses in Florida..
- ♦ Surveyed ~100 skeet shooting ranges and ~1,100 golf courses in Florida. Two survey forms were sent out to collect information on the management of skeet shooting ranges and golf courses in Florida. The surveys included questions on general information of facilities and environmental habitats as well as waste handling practices regarding to potential lead and arsenic contamination. 155 completed questionnaires were received from golf course (15%), whereas only limited number of shooting ranges returned the survey.
- ♦ Florida led the United States in both the number of golf courses and the application rates of organic arsenical herbicides in turfgrass management during the past 3 years. Though ~3/4 of golf courses in Florida were aware the potential adverse environmental impacts of organic arsenical pesticide, only a few had arsenic cleanup arrangement in their facilities.
- ♦ Preliminary data were reviewed on arsenic concentrations in soils from several golf courses in central and south Florida.

- More than 300 soil samples and several groundwater samples from six publicly owned ranges in Florida were collected. Soil pH, concentrations of Pb and a few other metals in those samples were analyzed.
- Twelve monthly progress reports were submitted to the Florida Center for Solid and Hazardous Waste Management. Several presentations were given to national or state level symposiums.

CONCLUSIONS

- Florida currently has over 1400 golf courses, nearly half of them located in the southeast and central west region, especially in Palm Beach County, representing 15% of the total responding golf courses in the survey. Nearly 3/4 were private or semi-private, 3/4 were within cities or less than 5 miles from cities, and 1/3 had operated for more than 30 years.
- Golf courses in Florida averaged to have 149 acres area, 23 holes and 10 open bodies of water, and 48,645 golf rounds per year. These golf courses used N, P, K, Ca, Mg, S, and micronutrients as chemical fertilizers and consumed 329,364 gallons of water for irrigation on a daily basis.
- Bermuda was the major turfgrass type, poor soil or soil compaction and insect are major management problems. Dallis grass was the major problem weed species and MSMA was the primary arsenic herbicide used in Florida golf courses for post-emergent weed control in the past 3 years.
- Arsenic contamination in soils of Florida golf courses is obvious as reflected by the maximum arsenic concentrations in soils of several golf courses ranged from 5.3 to 250 ppm, with an average of 69.2 ppm.
- Total lead concentrations in surface soils from 6 publicly owned shooting ranges ranged from a few hundreds to tens of thousands ppm from both rifle/pistol and shotgun shooting ranges in central Florida. Lead contamination in soils of Florida shooting ranges is therefore a serious problem and much research on remediation of lead contaminated soils and best management practice are urgently needed.

1. Introduction

Lead and arsenic are both trace elements of environmental concern due to their adverse impacts on humans and animals. Many anthropogenic processes, such as use of lead pellets at shooting ranges and application of arsenical herbicides on golf courses, have significantly increased concentrations of these elements in the environment. Therefore, it is very important to evaluate their impacts on the environment.

1.1. Lead in Shooting Ranges

Shooting has become a popular sport for recreation. Lead contamination of soil at shooting ranges from the use of lead shot/bullets as ammunition is under increasing scrutiny as a potentially significant source of lead pollution. Heavily contaminated soils have been found at shooting ranges that have been in operation for many years (Murray et al., 1997). Although the metallic lead found in the soil at shooting ranges may be deposited over a restricted area, the high lead concentrations may represent a potential threat to human and animal health. In addition, many shooting ranges are located adjacent to environmentally sensitive wetlands, streams, and lakes, and lead from these ranges is obviously being disbursed directly into wetland and aquatic environments (Scheuhammer and Norris, 1995).

Large amounts of metallic lead are deposited on the soil of shooting ranges worldwide. Annual deposition of metallic lead of 200 to 6,000 tons was reported for the Netherlands, Denmark, Canada, England, and USA (Van Bon et al., 1988; Jorgensen and Willems, 1987; Scheuhammer and Norris, 1995; Mellor and McCartney, 1994; Humberg and Babcock, 1982). Recent investigations of outdoor shooting ranges in the US documented Pb levels in soils of >1,000 mg kg^{-1} at six of eight sites investigated. For example, Murray et al.(1997) found that Pb concentrations at an outdoor shooting range in Michigan were 10-100 times greater than the background Pb concentration in the soils of the adjacent properties. Lead concentrations of 3,400 to 5,000 mg kg^{-1} in skeet shooting ranges in northern England and central Sweden were reported (Mellor and McCartney, 1994; Lin et al., 1995). In addition to the soil contamination, total lead concentrations were also elevated in surface water in the shot fall zones at six skeet ranges in New Jersey (Stansley et al., 1992).

In lead shot, Pb comprises 95-97% of the weight, with Sb contributing 0.4-2.0 %, arsenic 0.2-0.8, and Sn, Se, Mn, Cd, Cr, Cu, and Ni having average concentrations > 30 $\mu g\ g^{-1}$ (Fisher and Hall, 1986). It has been assumed that lead pellets in soil are stable and therefore has not been considered as a source of environmental lead contamination, except by direct ingestion of shot or sinkers by animals. However, ultimately all of the metallic lead in pellets may be transformed into dissolved and particulate species and spread over the environment at a decomposition rate of ~1% a year (Jorgensen and Willems, 1987). It is also estimated that all of the metallic lead pellets deposited in the soil in Denmark will be decomposed within 100-300 years. Weathering products of Pb shot include cerussite ($PbCO_3$), hydrocerussite ($Pb(CO_3)_2(OH)_2$), and small amounts of anglesite ($PbSO_4$) (Sever, 1993; Shreir, 1976). Lin et al. (1995) found that an average of 5% of metallic pellet lead had been transformed to lead carbonate and lead sulfate in a period of 20-25 years in shooting range soils in central Sweden. Murray et al.(1997) observed elevated Pb levels in subsurface soil where Pb concentrations in surface soil were high, indicating Pb mobilization through the soil profile. The principal cause of Pb mobilization appears to be the dissolution and oxidation of metallic Pb to form Pb carbonates or sulfate compounds, which was found on crust materials coating lead pellets. Sever (1993) reported several pathways through which mobilized lead particles from decomposition of lead pellets may be distributed through the environment, including: 1) airborne dust particles; 2) waterborne particles in storm or river runoff; 3) dissolved lead in storm runoff or other surface water; and 4) dissolved lead in groundwater.

Lead contaminated soils at shooting ranges are of particular concern in Florida because the water table is generally shallow and wetland environments are widespread. The rate of erosion, oxidation, and dissolution of metallic lead pellets in the environment depend on various factors. Aerobic and acid conditions enhance pellet breakdown (Scheuhammer and Norris, 1995). On the other hand, Pb pellets were relatively inert in alkaline soils, being of limited consequence when considering environmental contamination (Tsuji and Karagatzides, 1998). In Florida, several natural factors, such as low soil pH, low clay and organic matter content and high rainfall (Chen et al., 1998), can accelerate lead pellet weathering and thus potentially contaminate the environment. However, little information is available as to the impacts of these Pb pellets on the environment in Florida.

1.2. Arsenic in Golf Courses

In addition to lead contamination from shooting ranges, arsenic contamination from golf courses is another concern in Florida. Currently, there are over 14,000 golf courses in the USA and there are approximately one million hectares of turfgrass in the golf course industry (Smith and Bridges, 1996). To keep up with the demand of rapidly increasing number of golfers in the US, it has been estimated that approximately 4,000 to 5,000 golf courses must be built over the next 10 years. In Florida alone, there are more than 1,000 golf courses (Swancar, 1996) and South Florida is reported to have the highest number of golf courses per capita in the country (Markels, 1998).

Although agriculture is the largest user of herbicides in North America, turfgrass is typically the most intensively managed system. The major concern for the impacts of herbicides on the environment is their potential entrance into drinking water via movement into surface water and groundwater from treated sites. Most golf courses are constructed with mixtures of sand, soil, and peat and have high infiltration rates with underdrains of 10 cm of gravel and drainage tiles. The combination of high rate of pesticide application, frequent irrigation and a good drainage may result in pesticide loss from golf courses. Herbicides transport to surface water via runoff water and erosion has been studied extensively (Smith and Bridges, 1996; Smith and Tillotson, 1991), but information on the mobility and contamination hazard of herbicides used in turf grass is limited.

Modern golf courses are subject to intense management, including frequent application of organic arsenical herbicides to control weeds. Organic arsenical herbicides consist of pentavalent arsenic with a methyl substitute linked directly to the arsenic atom. The more widely used herbicides include sodium or ammonium salts of methane arsenic acids. Monosodium methane arsenate (MSMA) is the most widely used arsenical herbicide in Florida golf courses (Johnson, 1997). Prior to the introduction of organic arsenical herbicides in the 1950's, considerable amounts of calcium and lead arsenates were used to control weeds (Murphy and Aucott, 1998). It is estimated that 25,000 tons of lead arsenate and 9,000 tons of calcium arsenate were applied to soils in New Jersey from 1900 to 1980.

Johnson and Hiltbold (1969) studied the fate of three organic arsenical herbicides (MSMA, DSMA and MAMA) applied to golf courses and found that arsenic concentrations decreased with depth and greater arsenic application rates resulted in greater arsenic leaching. In addition, application of greater amount of MSMA resulted in greater accumulation of arsenic in plant tissues. They also found that higher arsenic application rate resulted in lower arsenic recovery in the top 30 cm of the soil due to arsenic movement to deeper depths. Duble et al (1978) found significant arsenic concentrations in both drainage and runoff from golf courses. Arsenic concentrations as high as 8 ppm were found in the drainage water from the golf course with average arsenic concentrations of 1-3 ppm. In addition, the effects of phosphate fertilizer application on arsenic leachability in arsenic contaminated soil was investigated by Daveport and Peryea (1991) and Woolson et al. (1973). Daveport and Peryea (1991) found that addition of phosphate fertilizer significantly increased the amount of arsenic leached from the soil. Phosphorus source and rate, and quantity of leaching water all influenced arsenic leachability in the soil. However, little information is available on potential arsenic accumulation in soils and greens and arsenic leachability of golf courses in Florida.

The objectives of this project were to evaluate the environmental impacts of lead pellets at shooting ranges and arsenical herbicides on golf courses in Florida. Results from this study will be useful to both FDEP for environmental regulation and the respective industries for pollution control purposes.

2. SCIENTIFIC APPROACH

To better serve Florida DEP and per the request of the Florida Center, we have performed additional research on a previous Center supported project titled “Background concentrations of trace metals in Florida surface soils. Total-recoverable arsenic concentrations in 450 Florida surface soils were determined using the EPA Method 3051a. A database containing both total-total and total-recoverable arsenic background concentrations in Florida surface soils was established and incorporated in the final report (http://www.floridacenter.org/publications/special_wastes_pubs.htm). This additional work has delayed this current research project for a few months.

2.1. Comprehensive Quality Assurance Plan Implementation

A comprehensive quality assurance plan was submitted electronically to the Florida Department of Health, Bureau of Laboratories at Jacksonville, FL and was approved by the FDEP Quality Assurance Section on September 1, 1999, which assures the generation of valid data on this project.

2.2. Literature Review on Lead/Arsenic Issue

More than 220 articles related to lead and arsenic in soils has been obtained and a database of ~230 shooting ranges and ~1,100 golf courses in Florida has been established. The database includes name, address, zip code, contact person, phone number, as well as counties and regions of the shooting ranges/golf courses in Florida. Summary statistics and geo-reference technologies were also included in the database, which makes it more useful.

2.3. Survey of Shooting Ranges and Golf Courses in Florida

Two separate survey forms were designed to collect quantitative data on the operation and management of shooting ranges and golf courses in Florida. The surveys included questions on general information of facilities and environmental habitats as well as waste handling practices regarding to potential lead and arsenic contamination. The lead survey was sent out to over 100 shooting ranges in Florida and the arsenic survey was sent out to ~1,100 golf courses in Florida. Follow up phone calls and second around survey were sent out to ensure satisfactory statistical results.

2.4. Preliminary Data on Arsenic Concentrations in Soils of Golf Courses in Florida

Based on the information submitted to FDEP from 11 golf courses in Florida, arsenic concentrations in soils of these golf courses in Florida were significantly elevated. The maximum arsenic concentrations in these soils varied from 5.3 to 250 ppm, with an average of 69.2 ppm. Clearly, arsenic contamination is obvious in soils of these golf courses.

2.5. Sampling and Data Analysis on Lead Concentrations in Soils of Shooting Ranges in Florida

We have initiated several meetings regarding shooting range issues in Florida, including a meeting with FDEP staff in Tampa on August 19, 1999 and a meeting with staff from Florida Fish & Wildlife Conservation Commission on December 8, 1999. We were granted a permission to conduct research using 6 publicly-owned shooting ranges located in different parts of Florida. Field trips to publicly owned ranges in north central Florida and the Panhandle area were made and 300 soil samples were collected from different types of ranges including rifle (200 yard and 100 yard), pistol, and shotgun ranges. Water samples were also collected based on availability. Soil pH, concentrations of Pb and a few other metals in those samples were analyzed using the EPA Method 3051a extraction and Flame/GFAAS determination.

2.6. Reports/Presentations

Twelve monthly progress reports were submitted to the Florida Center for Solid and Hazardous Waste Management. Four presentations were given in several national and state conferences, e.g.1) background concentrations of arsenic in selected Florida soils was presented in the Soil Science Society of America 91st Annual Meeting at Salt Lake City on Nov.2, 1999, 2) arsenic background concentration study was presented at the Arsenic Task Force Meeting in FDEP on November 18, 1999, 3) background concentrations of arsenic in Florida soils was presented in the 5th Florida Remediation Conference at Orlando on November 18, 1999, and 4) background concentrations of arsenic in Florida surface soils was presented at the 5th Contaminated Soils Forum at FDEP on May 17, 2000.

3. SURVEY OF GOLF COURSES IN FLORIDA

3.1. Introduction

Florida leads the US in the number of golf courses, which is currently estimated at 1,400, counting one tenth of all golf courses in the US (Balogh and Walker, 1992), and also leads the US in the number of golf courses being constructed (Unruh and Elliott, 1999). Value-added to Florida's economy in 1991-1992 by all sectors of the turfgrass industry totaled $7.3 billion, with golf courses contributing 35% (Hodges et al., 1994). However, to control turfgrass weeds on golf courses, $11.2 million are spent on herbicides each year in Florida, averaging $10,700 per course in 1991-1992 (Hodges et al., 1994). In 1995, Florida golf courses reported an average herbicide

expenditure per course of $16,832 (Anonymous, 1996), compared with $6,554 per course in the other 49 states. Arsenic used for turfgrass maintenance had been detected in groundwater from several golf courses in central and southern Florida (Swancar, 1996). However, the interaction of soil and arsenical herbicide used on golf courses has not been previously evaluated. A survey was therefore developed to collect quantitative data on the application of arsenic based herbicides in Florida golf courses. The survey included questions on general golf course operation and management as well as specific questions about the use of organic arsenic herbicides. A copy of the 4-page survey is included at the end of this report (Appendix A).

3.2 Methodology

In developing the survey, we used information from the literature obtained during the early months of the study. It was reported that Florida had over 1,400 golf courses in 1999 (Unruh and Elliott, 1999) and about 1011 courses in 1990 (Balogh and Walker, 1992). A database of 1086 golf courses was established based on information on the web, i.e. Florida Golf Guide (http://www.floridagolfguide.com), Absolutely Florida (http://www.funandsun.com/1tocf/golf), and Golf Here (http://www.golfhere.com/florida.htm). A total of 1086 cover letters with individual name and address were printed out using Mergemail software and were sent out together with a survey form and a self-addressed envelop via University of Florida Institute of Food and Agricultural Science USPS mail system. Most responses were returned within the first two months. Only a few responses were returned in the third and the fourth months.

Geographical distributions of golf courses in Florida (Fig 1) indicate that on an area basis, southeast and central west led the state in the number of golf courses with 25% and 21% of all the courses, respectively. The 1086 golf courses in the database distributed unevenly in 59 of 67 counties in Florida (Table 1).

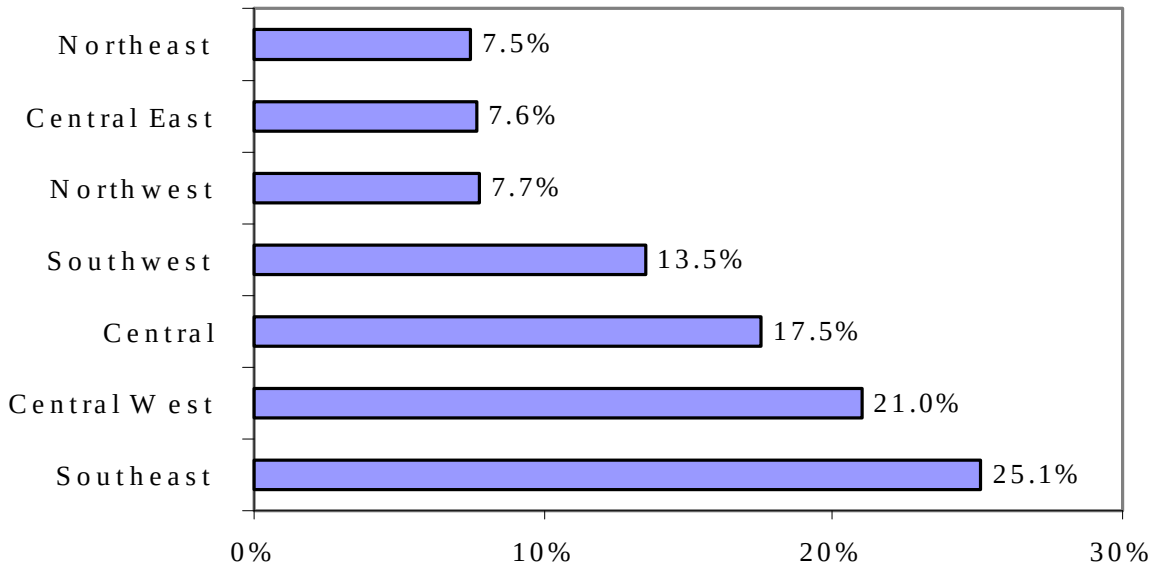

Fig 1. Geographical Distribution of 1086 Golf Courses in Florida

Fig 2. Map of Florida Regions for Golf Course Distribution

Table 1. Distribution of 1086 golf courses in different regions and counties in Florida

Region	County	# of Courses	Region	County	# of Courses
C		190	NE		81
	Sumter	2		Baker	1
	Osceola	14		Columbia	2
	Seminole	15		Putnam	2
	Highlands	18		Nassau	5
	Marion	20		Alachua	8
	Lake	31		Clay	8
	Orange	44		Flagler	9
	Polk	46		St. Johns	19
CW		179		Duval	27
	Hardee	2	NW		84
	Desoto	3		Gulf	1
	Citrus	14		Hamilton	1
	Hernando	18		Holmes	1
	Pasco	26		Jefferson	1
	Manatee	30		Suwannee	1
	Hillsborough	40		Taylor	1
	Sarasota	46		Wakulla	1
	Pinellas	49		Walton	1
CE		88		Levy	2
	Okeechobee	1		Gadsden	4
	St. Lucie	15		Jackson	5
	Indian River	19		Santa Rosa	7
	Brevard	25		Leon	9
	Volusia	28		Bay	11
SE		279		Escambia	13
	Hendry	2		Okaloosa	22
	Glades	4		Madison	1
	Monroe	8	SW		146
	Dade	35		Charlotte	15
	Martin	42		Collier	62
	Broward	58		Lee	69
	Palm Beach	118	**Total**	**59**	**1086**

3.3. Overall Survey Results

Fifty of the 1086 letters were returned due to either “insufficient address” or “no mail receptacles”, so the actual survey forms received was 1035, or 95% of the letters mailed out. There were 155 usable survey responses received before the closing date or a return ratio of 15%.

3.3.1 SECTION I: FACILITY INFORMATION

QUESTION #1. Company Name

There were 127 facilities put their names and addresses in this survey or 81% of the responses.

QUESTION #2. Company Address

About one half of the responded facilities located at southeast and central west Florida, representing 27% and 22% of the total responding courses (Table 2). These golf courses distributed at 34 of 67 counties in Florida. Palm Beach lead the state with the highest number of golf courses, representing 16% of the total responding courses in Florida (Table 3 and Fig.3).

Table 2. Number and percentage of responding golf courses in different regions

Region	Number	Percentage
Southeast	42	27%
Southwest	21	14%
Central east	11	7%
Central	24	15%
Central west	34	22%
Northeast	8	5%
Northwest	11	7%
NA†	4	3%
Total	155	100%

† NA = Question not answered

Table 3. Number and percentage of golf courses distributed in each county

County	Number of Facility	Percentage
Alachua	1	0.6%
Bay	1	0.6%
Brevard	2	1.3%
Broward	8	5.2%
Charlotte	1	0.6%
Clay	2	1.3%
Collier	10	6.5%
Dade	2	1.3%
Duval	4	2.6%
Escambia	2	1.3%
Hendry	1	0.6%
Hernando	1	0.6%
Highlands	1	0.6%
Hillsborough	10	6.5%
Indian River	3	1.9%
Lake	1	0.6%
Lee	10	6.5%
Leon	5	3.2%
Manatee	3	1.9%
Marion	3	1.9%
Martin	8	5.2%
Okaloosa	2	1.3%
Orange	6	3.9%
Osceola	1	0.6%
Pasco	2	1.3%
Pinellas	7	4.5%
Polk	9	5.8%
Santa Rosa	1	0.6%
Sarasota	11	7.1%
Seminole	3	1.9%
St. Johns	1	0.6%
St. Lucie	1	0.6%
Volusia	5	3.2%
NA	4	2.6%
Total	155	100.0%

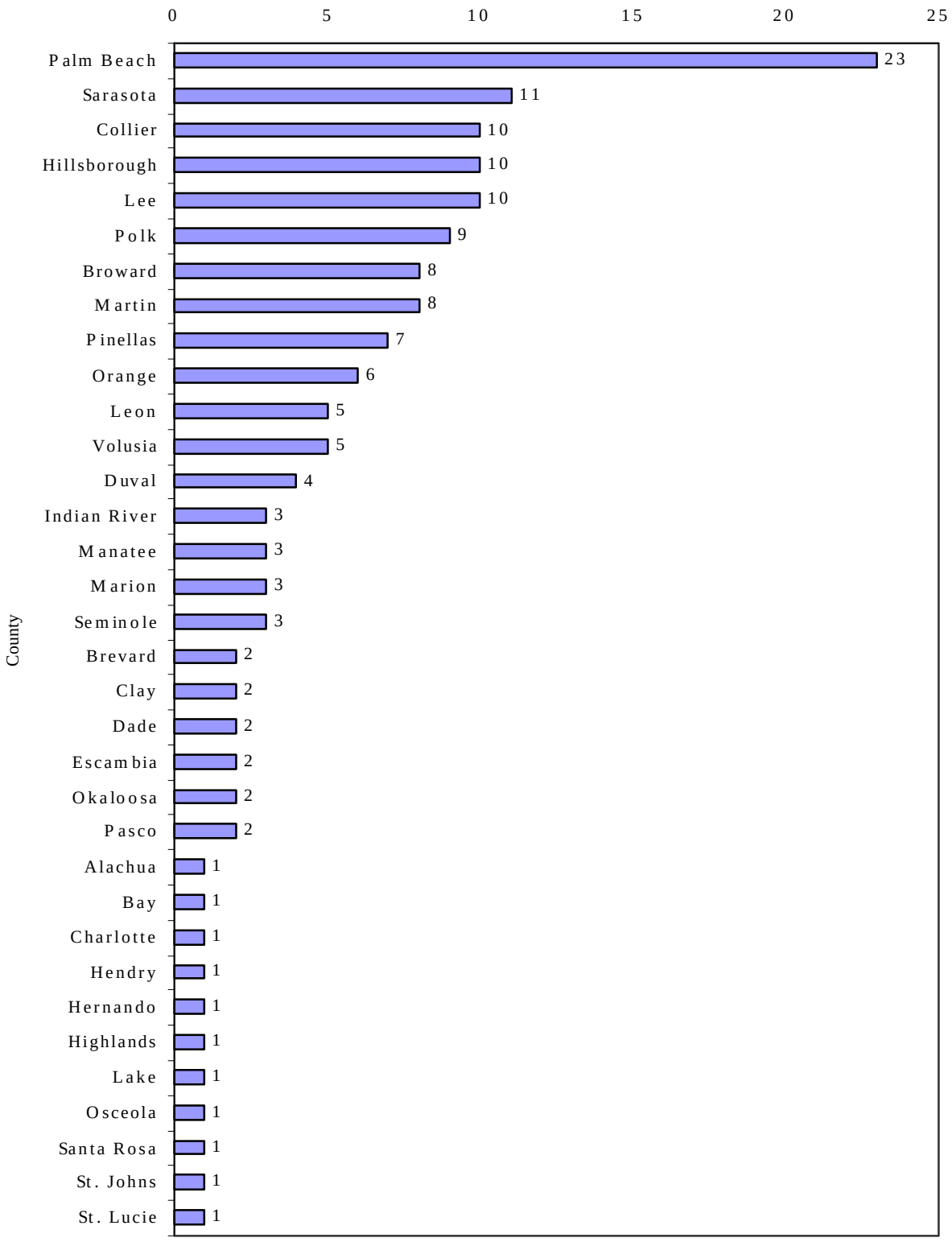

Fig.3. Number of golf courses distributed in each county in Florida

3.3.2. SECTION II: FACILITY DESCRIPTION

QUESTION #3. Type of Facility

Three-fourths of the golf courses that responded to this survey were private or semi-private, representing 46% and 28% of total responding courses, respectively. One-fourth were public or other (military, municipal, or resort) golf courses. Those results were consistent with those reported by the *Florida Golf Guide*: 37% private, 30% semi-private, 21% public, 7% resort, 4% municipal, and 1% military, as well as Hodges et al (1994): 60% private, 17% semi-private, 12% public, 6% resort, 3% municipal, and 1% military.

Based on this survey, there are probably 623 private, 397 semi-private, 271 public, 63 resort, 27 military, and 18 municipal golf courses in the State of Florida (Table 4).

Table 4. Distribution and estimation of private and public golf courses (GCs) in Florida

Facility type	# of GCs	Distribution of GC	Statewide estimated GCs
Private	69	44.5%	623
Public	30	19.4%	271
Semi-private	44	28.4%	397
Other, military	3	1.9%	27
Other, municipal	2	1.3%	18
Other, resort	7	4.5%	63
Total	155	100.0%	1,400

QUESTION #4. How long has your facility been in operation?

One-third (34%) of the responded golf courses had been in operation for more than 30 years. Another one-third had been in operation for 10 to 20 years. There were only a few golf courses that were in operation for less than 5 years.

Based on this survey, between 1970 and 1990, the number of golf courses in Florida increased from approximately 479 to 1,220 (Table 5), an increase of 155%, which was much faster than that in the United States as a whole during the same period. It was reported that

between 1968 and 1990, the number of golf courses in the United States increased from approximately 9,600 to 14,000, an increase of 46% (Balogh and Walker, 1992).

Table 5. Number of years Florida golf courses (GCs) were in operation

Years	# of GCs responded	% of GCs responded	Estimated # of GCs
< 5 Years	5	3.2%	45
5-10 years	15	9.7%	135
10-20 years	49	31.6%	443
20-30 years	33	21.3%	298
> 30 years	53	34.2%	479
Total	155	100.0%	1,400

QUESTION #5. Approximately how large (acres) is your facility?

One-third (33%) of the responded golf courses had size between 100-150 acres. One-forth (26%) had size <100 acres, and two-fifths (40%) had size over 150 acres.

Based on this survey, total acreage of golf courses in Florida in 1999 was approximately 208,871 acres, averaging 149 acres per golf course (Table 6). These results are greater than those reported by Hodges et al (1994) with total acreage devoted to Florida's golf facilities being estimated at 131,300 acres in 1991-1992, averaging 125 acres per golf course. The acreage was estimated at 105,701 acres (42776.5 ha) and averaging 105 acres per golf course in 1990 by Balogh and Walker (1992). It is obvious that the acreage used by golf courses are increased significantly over the years.

Table 6. Acreage occupied by golf courses (GCs) in Florida

Acres	# of GCs responded	% of GCs responded	Estimated # of GCs	Estimated acres
< 50	12	7.7%	108	2,710
50-100	28	18.1%	253	18,968
100-150	51	32.9%	461	57,581
150-200	28	18.1%	253	44,258
200-250	13	8.4%	117	26,419
250-300	8	5.2%	72	19,871
> 300	14	9.0%	126	37,935
NA	1	0.6%	9	1,129
Total	155	100.0%	1,400	208,871

QUESTION #6. How many holes is your facility?

About 69% of the surveyed golf courses were 18-hole courses, 26% had 18+ holes, and 4% were 9-hole courses (Table 7). These results differed from those of Hodges et al (1994): 78% 18-hole, 17% 18+-hole, and 5% were 9-hole. This is possible because some clubs have more than one 18-hole golf courses, and we did not specifically separate them into different courses in this survey. However, based on this survey, there were approximately 31,866 golf holes in Florida, which is greater than the number (13,851+2,016+747=16,614 holes) provided by Balogh and Walker (1992).

Table 7. Number of holes in golf courses of Florida

Holes	# of GCs responded	% of GCs responded	Estimated # of GCs	Estimated holes
9	6	3.9%	54	488
18	107	69.0%	966	17,396
27	14	9.0%	126	3,414
36	18	11.6%	163	5,853
45	2	1.3%	18	813
54	7	4.5%	63	3,414
> 54	1	0.6%	9	488
Total	155	100.0%	1,400	31,866

QUESTION #7. How many rounds of golf are played per year?

About 36% of the surveyed golf courses had golfers playing <40,000 rounds of golf per year, 32% with 40,000-60,000 rounds per year, and 28% with >60,000 rounds per year (Table 8). This is consistent with the results of Hodges et al (1994) who reported 9-hole rounds played averaged 12,000 rounds per course, 18-hole round played averaged 45,000 rounds per course, and 18+-holes played 39,000 rounds per course during 1991-1992 in Florida. Compared to the number (44,518,000 rounds per year) provided by Balogh and Walker (1992) in 1990, total annual golf rounds played in Florida golf courses increased by 53% to approximately 68,103,226 rounds per year, averaging 48,645 annual rounds of golf per course.

Table 8. Actual and estimated number of golf round played in Florida golf courses of per year

	Responded		Statewide estimation	
Rounds/Year	# of GCs	% of GCs	# of GCs	Rounds of golf per year
< 10,000	4	2.6%	36	180,645
10,000-20,000	12	7.7%	108	1,625,806
20,000-40,000	40	25.8%	361	10,838,710
40,000-60,000	50	32.3%	452	22,580,645
60,000-80,000	30	19.4%	271	18,967,742
80,000-100,000	6	3.9%	54	4,877,419
> 100,000	7	4.5%	63	6,322,581
NA	6	3.9%	54	2,709,677
Total	155	100.0%	1,400	68,103,226

QUESTION #8. How far the facility is from the nearest city?

About 75% of the surveyed golf courses were "within cities" or "<5 miles" from cities, and only a few courses (<2%) had a distance over 20 miles from cities (Table 9).

Based on this survey, approximately 1,047 golf course in Florida were less than 5 miles from cities, 208 between 5-10 miles, 90 between 10-20 miles, 18 between 20-30 miles, and 9 courses in a distance >30 miles from cities.

Table 9. Distance of Florida golf courses from nearest city

Distance from cities	# of GCs responded	% of GCs responded	Statewide estimation
Within city	74	47.7%	668
<5 miles	42	27.1%	379
5-10 miles	23	14.8%	208
10-20 miles	10	6.5%	90
20-30 miles	2	1.3%	18
>30 miles	1	0.6%	9
NA	3	1.9%	27
Total	155	100%	1,400

QUESTION #9. What Kind of Water Body the Facility is Adjacent to?

About 25% of the surveyed golf courses are adjacent to pond or lakes, 6% to wetland, 4% to stream/river, 2% to salt-water marsh, 1% to estuary, and 43% to more than one water bodies (Table 10).

Based on this survey, approximately 81 golf courses in Florida were close to wetland, 27 to salt-water marsh, 352 to pond/lakes, 9 to estuary, and 54 to stream/rivers.

Table 10. Types of water body Florida golf courses have

Bodies of Water	# of GCs responded	% of GCs responded	Statewide Estimation
Wetland	9	5.8%	81
Salt-water march	3	1.9%	27
Pond/lake	39	25.2%	352
Estuary	1	0.6%	9
Stream/river	6	3.9%	54
Others	13	8.4%	117
Multi-water body	66	42.6%	596
NA	18	11.6%	163
Total	155	100.0%	1,400

QUESTION #10. How Many open bodies of water (pond/lakes) at your facility?

About one-third of the surveyed golf courses had 5-10 open bodies of water at the facility, one-third had less than 5 open bodies of water, and the other one-third had more than 10 open bodies of water in the facility (Table 11).

Based on this survey, the total open bodies of water in Florida golf courses were approximately 13,413, averaging 9.6 per course.

Table 11. Number of open waters (OW) in Florida golf courses (GCs)

# of open waters	# of GCs responded	% of GCs responded	Estimated GCs	Estimated # of OW
None	5	3.2%	45	0
1-5	42	27.1%	379	948
5-10	52	33.5%	470	3,523
10-20	36	23.2%	325	4,877
20-30	12	7.7%	108	2,710
> 30	4	2.6%	36	1,084
NA	4	2.6%	36	271
Total	155	100.0%	1,400	13,413

3.3.3. SECTION III: FACILITY MANAGEMENT INFORMATION

QUESTION #11. What is the major turfgrass type in your facility?

Bermuda grass was the major turfgrass type in Florida golf courses, which represented 99% of total responding courses. Minor type turf grass includes bahia grass (4%), perennial rye (<6%), St. Augustine grass (2%), and centipede grass (1%) (Table 12). These results differ from turfgrass production on Florida sod farms during 1991-1992 (Hodges et al., 1994), which consists of St. Augustine grass (72%),Bahia grass (20%), Bermuda grass (4%), and Centipede grass (4%). Much of these grasses were probably used on lawns. Unruh and Elliott (1999) reported that Bermuda grass were the primary grass on Florida golf courses.

Table 12. Major type of turfgrass in Florida golf courses (GCs)

Turfgrass type	# of GCs	Percentage
Bahia	1	0.6%
Bermuda	138	89.0%
Perennial rye	1	0.6%
Bahia/Bermuda	3	1.9%
Bahia/Bermuda/St.Augustine	1	0.6%
Bahia/Bermuda/St.Augustine/Centipede	1	0.6%
Bermuda/St.Augustine	1	0.6%
Bermuda/Perenial rye	8	5.2%
Bermuda/Perenial rye/Zoysia	1	0.6%
Total	155	100.0%

QUESTION #12. What are the major turfgrass management problems at your facility?

The most common turfgrass management problem of Florida golf course is poor soil or soil compaction (62%). Insects (52%) and weed control (25%) were among the most frequently reported turfgrass management problems for Florida golf courses. Other reported turfgrass management problems include nematodes (5%); drainage (3%); fungi (1%); water quality (1%); soil fertility (1%); money (1%); labor (1%); shade (1%); sodium (1%); and water retention (1%) (Table 13).

Table 13. Major and other management problems in Florida golf courses (GCs)

Major management problems	Number of GCs	Percentage of GCs
Insects	13	8.4%
Poor soils or soil compaction	24	15.5%
Weeds	5	3.2%
Other	19	12.3%
Insects/Poor soils	4	2.6%
Insects/Poor soils/Other	19	12.3%
Insects/Poor soils/Weeds/Other	11	7.1%
Insects/Poor soils/Weeds	4	2.6%
Insects/Other	24	15.5%
Insects/Weeds/Other	3	1.9%
Insects/Weeds	2	1.3%
Poor soils/Other	20	12.9%
Poor soils/Weeds/Other	1	0.6%
Poor soils/Weeds	4	2.6%
Poor soils/Soil fertility	1	0.6%
Weeds/Other	1	0.6%
Total	155	100.0%

Other specified problem	Number	Percentage
Drainage	4	4.1%
Fungis	2	2.1%
Money	1	1.0%
Nematodes	8	8.2%
People	1	1.0%
Shade	1	1.0%
Sodium	1	1.0%
Water Quality	2	2.1%
Water retention	1	1.0%
NA	76	78.4%
Total	97	100.0%

QUESTION #13. What type of irrigation water is used in your facility?

Among water sources for irrigation, well water was the largest source, representing 43% of the responded golf courses in this survey (Table 14). Irrigation from surface water was the next most consumptive source, with 37% of total responded golf courses in this survey. Use of recycled water as an irrigation source accounted for 35% of the total responded golf courses. Use of city water supply was negligible, with less than 2% of total responded golf courses in this survey. Apparently there was more recycled water used in these past years, in comparison with only 14% in 1991-92 period (Hodges et al., 1994).

Table 14. Types of irrigation water used in Florida golf courses

Water used for turfgrass irrigation	Number	Percentage
No Irrigation	1	0.6%
Surface water	40	25.8%
Well water	43	27.7%
Recycled or claimed water	42	27.1%
Well/Surface water	12	7.7%
Well/Surface/recycled water	6	3.9%
Well/City water supply	2	1.3%
Well/Recycled water	3	1.9%
Surface/Recycled water	3	1.9%
Surface/City water supply	1	0.6%
NA	2	1.3%
Total	155	100.0%

QUESTION #14. Approximately how many thousand gallons of irrigation water are used in the facility?

The most common water consumption used for turfgrass irrigation was between 250-500 thousand gallons per day, representing 36% of total responding golf courses in this survey.

Based on this survey, approximately total 500,387,097 gallons of irrigation water were used per day for Florida golf courses, averaging 357,419 gallons per course (Table 15). These results were a little greater than those of Hodges et al. (1994), which reported that total water consumption was 345,000,000 gallons per day, averaging 329,364 gallons per course, with increases of 45% and 8%, respectively.

Table 15. Amount of irrigation water used in Florida golf courses

Amount of Irrigation	# of GCs	% of GCs	Estimated GCs	Estimated amount
<100,000	23	14.8%	208	10,387,097
100,000-250,000	39	25.2%	352	44,032,258
250,000-500,000	55	35.5%	497	186,290,323
500,000-750,000	14	9.0%	126	79,032,258
750,000-1,000,000	7	4.5%	63	55,322,581
>1,000,000	12	7.7%	108	108,387,097
NA	5	3.2%	45	16,935,484
Total	155	100.0%	1,400	500,387,097

QUESTION #15. What type of fertilizer or soil amendments has been used in your course?

The most common fertilizers used in Florida golf courses were major nutrients N, P, K, representing 99%, 97% and 97% of total responded golf courses in this survey, respectively (Table 16 and Fig. 4). Micronutrients and S, Ca, Mg were the next most consumptive fertilizers, representing 89% and 88% of total responded golf courses in this survey, respectively. Organic manure accounted for 56%, and lime was 32% of total responded golf courses.

Table 16. Types of fertilizers used in Florida golf courses (GCs)

Fertilizers	Number of GCs	Percentage of GCs
NPK	1	0.6%
NPK/Lime	2	1.3%
NPK/lime/ScaMg	3	1.9%
NPK/lime/SCaMg/Micronutrient	36	23.2%
NPK/lime/SCaMg/Micronutrient/OM	55	35.5%
NPK/lime/Micronutrient	4	2.6%
NPK/lime/Micronutrient/OM	1	0.6%
NPK/lime/OM	1	0.6%
NPK/SCaMg/Micronutrient	15	9.7%
NPK/SCaMg/Micronutrient/OM	24	15.5%
NPK/SCaMg/OM	2	1.3%
NPK/Micronutrient	5	3.2%
NP/OM	1	0.6%
NK/Lime/SCaMg/Micronutrient	2	1.3%
N/Lime/OM	1	0.6%
Micronutrients/OM	1	0.6%
NA	1	0.6%
Total	155	100.0%

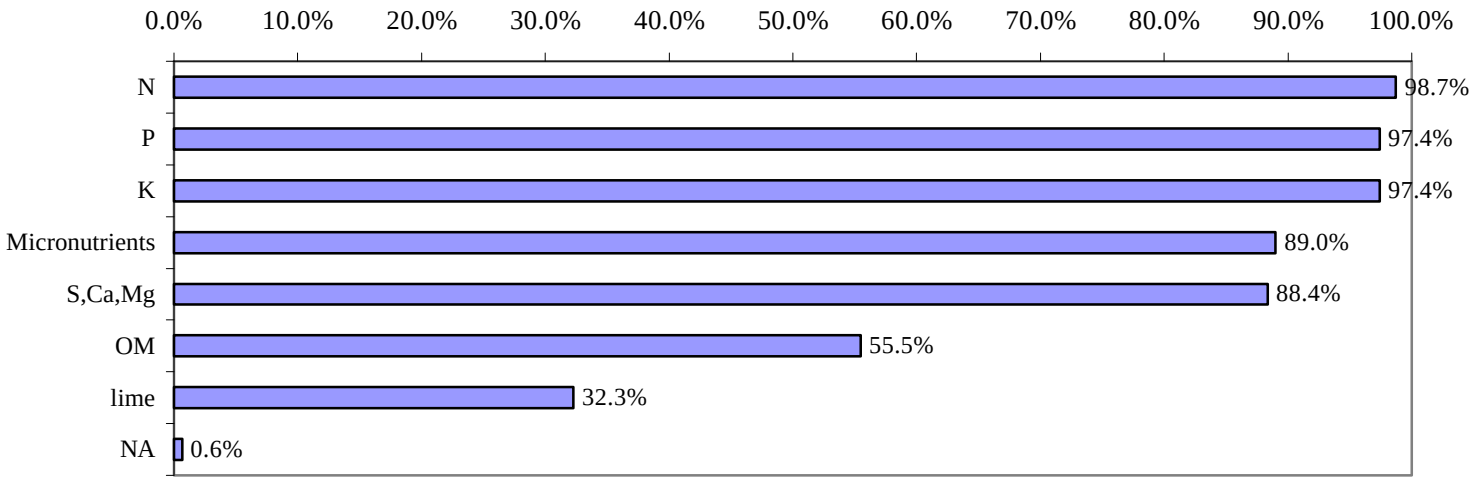

Fig. 4. Types of fertilizers used in Florida Golf courses

QUESTION #16. What is the major weed species in your facility?

Dallis grass was the most common weed species in Florida golf courses, representing 61% of total responding golf courses in this survey (Tables 17 and 18, Fig. 5). Crab grass, and goose grass were reported by approximately one-third of the total responding courses, sedges about one-forth, and annual blue grass about one-fifth of the total responding courses. Dollar weed and broad leave weeds were experienced to a less degree, about 13% of responding courses. These results differ from those of *Floridaturf* (www.floridaturf.com), which indicates that high intensity problem weeds, in order of importance, were: goose grass (60%), crab grass (42%), annual bluegrass (19%), pennywort=dollarweed, hydrocotyle umbellata L. (5%), and spurges, chamaesyce spp. (5%).

Table 17. Types of weeds present in Florida golf courses (GCs)

Weed Species	# of GCs	% of GCs
Annual bluegrass	3	1.9%
Annual blue/Crab/Dallis/Goose/Spurgegrass/Broadleaved/Dollarweed	1	0.6%
Annual blue/Crab/Dallis/Goosegrass/Dollar weed	1	0.6%
Annual blue/Crab/Dallisgrass/Broadleaved/Dollar weed	2	1.3%

Annual blue/Crab/Dallisgrass/Dollarweed	2	1.3%
Annual blue/Crab/Dillis/Goosegrass	1	0.6%
Annual blue/Crab/Dillisgrass	1	0.6%
Annual blue/Crab/Goose/Spurgegrass/Broadleaved/Dollarweed	1	0.6%
Annual blue/Crab/Goosegrass	1	0.6%
Annual blue/Crab/Goosegrass/Broadleaved weed	1	0.6%
Annual blue/Crab/Goosegrass/Dollar weed	1	0.6%
Annual blue/Crab/Sandspur/Dallis/Goosegrass/Broadleaved/Dollar weed/Other	1	0.6%
Annual blue/Dallis/Goosegrass	6	3.9%
Annual blue/Dallisgrass	1	0.6%
Annual blue/Dallisgrass/Broadleaved/Dollarweed/Other	1	0.6%
Annual blue/Dallisgrass/Dollarweed	2	1.3%
Annual blue/Dallisgrass/Dollarweed/Other	1	0.6%
Annual blue/Dallisgrass/Other	2	1.3%
Annual bluegrass/Broadleaved weeds	1	0.6%
Annual bluegrass/Dollarweed	1	0.6%
Annual bluegrass/Other	1	0.6%
Broadleaved Weeds	1	0.6%
Broadleaved weeds/Other	1	0.6%
Crab/Dallis/Goosegrass	1	0.6%
Crab/Dallis/Goosegrass/Broadleaved/Dollar weed	1	0.6%
Crab/Dallis/Goosegrass/Dollarweed	1	0.6%
Crab/Dallis/Goosegrass/Other	2	1.3%
Crab/Dallisgrass	12	7.7%
Crab/Dallisgrass/Broadleaved weed	2	1.3%
Crab/Dallisgrass/Broadleaved weed/Other	1	0.6%
Crab/Dallisgrass/Other	2	1.3%
Crab/Dallisgrass/Other	1	1.0%
Crab/Goose/Spurgegrass/Broadleaved weed	1	0.6%
Crab/Goosegrass	1	0.6%

Crab/Goosegrass/Broadleaved/Dollar weed	1	0.6%
Crab/Goosegrass/Dollarweed	8	5.2%
Crab/Sandspur/Dallisgrass/Dollar weed	1	0.6%
Crab/Sandspur/Goose/Spurgesgrass/Broadleaved/Dollar weed	1	0.6%
Crabgrass	3	1.9%
Crabgrass/Other	2	1.3%
Dallis/Goosegrass	1	0.6%
Dallis/Goosegrass/Other	2	1.3%
Dallisgrass/Broadleaved weeds	1	0.6%
Dallisgrass/Dollarweed	3	1.9%
Dallisgrass/Dollarweed/Other	1	0.6%
Dallisgrass/Other	12	7.7%
Dillisgrass	31	20.0%
Dollarweeds	1	0.6%
Goose/Spurgegrass/Dollarweed	1	0.6%
Goosegrass	3	1.9%
Goosegrass/Broadleaved weeds	1	0.6%
Goosegrass/Other	2	1.3%
Other	19	12.3%
NA	2	1.3%
Total	155	100.4%

Table 18. Other major weed species in Florida golf course

Specified weeds	Number	Percentage
Allxandergrarr	1	2.0%
Bahaia	1	2.0%
Bull paspalum	3	6.0%
Bull paspalam/Dove weed/Nutsedge	1	2.0%
Bullgrass	3	6.0%
Bullqust	1	2.0%
Kyllinga	1	2.0%

Nutsedge	7	14.0%
Nutsedge/Purple	1	2.0%
Sedges	25	50.0%
Sedges/Torperse	1	2.0%
Sedges/Yollew purple	2	4.0%
Signal grass	1	2.0%
Torpedo grass	1	2.0%
Torpedo grass/Dcommon bermuda	1	2.0%
Total	50	100.0%

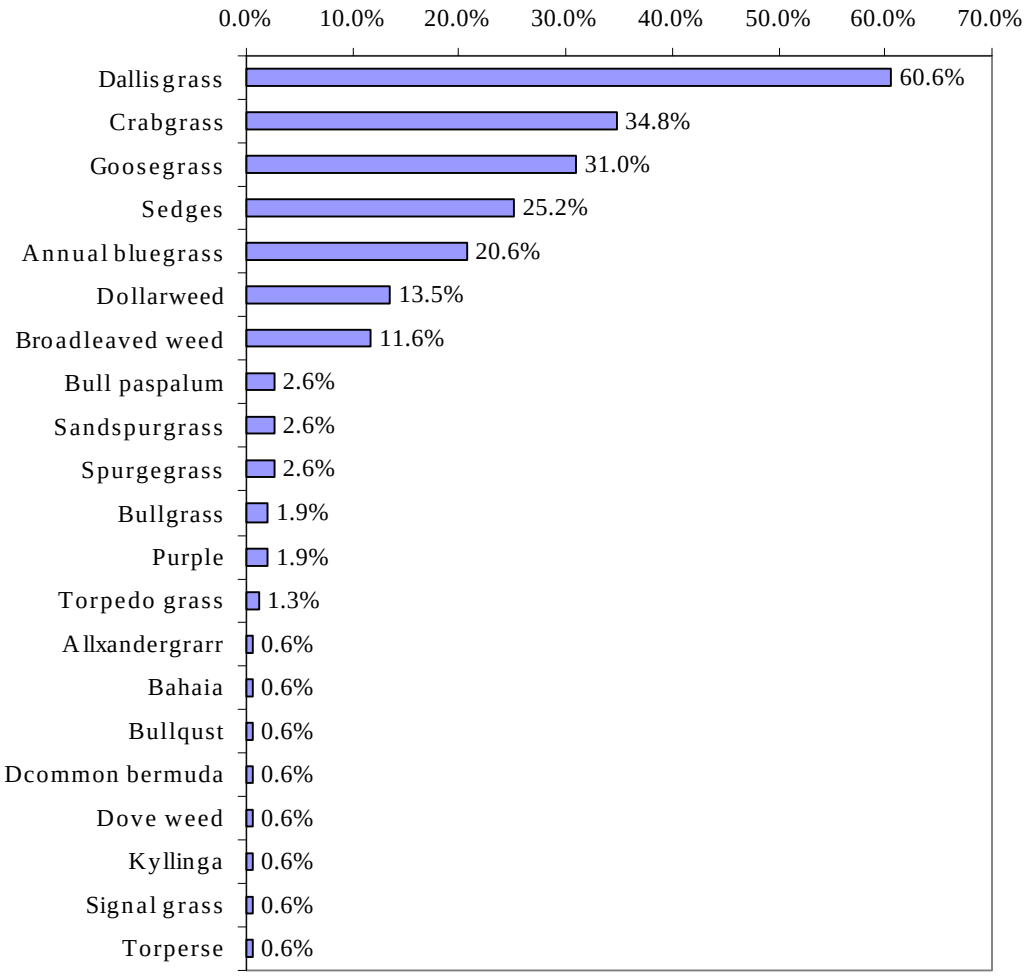

Fig. 5. Distribution of major weed species on Florida golf courses

3.3.4. SECTION IV: PESTICIDE APPLICATION INFORMATION

QUESTION #17. Have any of the following organic arsenic herbicides been used at your facility for post-emergent weed control in the past 3 years?

Both MSMA and DSMA were registered as the major herbicides used for turfgrass management in golf courses (Balogh and Walker, 1992). Approximately 96% of total responding Florida golf courses used organic arsenic herbicides for post-emergent weed control in the past 3 years. MSMA was the most commonly used herbicide, representing 96% of the total responding golf courses in this survey (Table 19 & Fig. 6). The use of DSMA for turfgrass management in Florida golf courses was less common, representing 9% of total responding courses.

Table 19. Herbicides used in Florida golf course

Arsenic herbicides	# of GCs	% of GCs
No As herbicides	5	3.2%
Yes, MSMA	130	83.9%
Yes, MSMA/CMA	1	0.6%
Yes, MSMA/DSMA/MAMA	1	0.6%
Yes, MSMA/DSMA	13	8.4%
Yes, MSMA/MAMA	2	1.3%
Yes, but no specification	2	1.3%
No Answer	1	0.6%
Total	155	100.0%

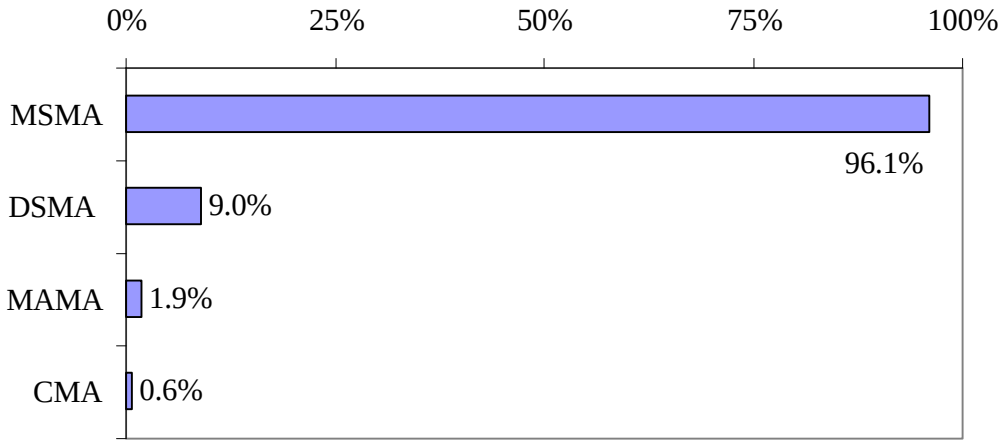

Fig. 6. Usage of herbicides on Florida golf courses

QUESTION #18a. If the answer to the above question includes DSMA or MSMA, what is the approximate rate per application?

The most common application rates of arsenical herbicides application in Florida golf courses were 2.0-3.0 lb/ acre, representing 29% of responding golf courses in this survey (Fig. 7).

Based on this survey, approximately 88,160 pound MSMA/DSMA herbicides were used in 1,400 Florida golf courses, averaging 63 lb per course annually (Table 20), with wall to wall application.

Table 20. Application rates of arsenical herbicides used on Florida golf courses (GCs)

Application	# of GCs	% of GCs	Estimated #	Estimated	Estimated
0.25	21	13.5%	190	2,229	209
0.5	14	9.0%	126	1,981	186
1.0	22	14.2%	199	9,785	916
2.0	27	17.4%	244	29,477	2,761
3.0	11	7.1%	99	7,339	687
Other, 0.25-0.5	1	0.6%	9	8	1
Other, 0.75-1.0	2	1.3%	18	67	6
Other, 1.25-1.65	12	7.7%	108	4,221	395
Other, 2.25-2.75	18	11.6%	163	16,376	1,534
Other, 3.25-4.0	4	2.6%	36	1,189	111
Other, 6.25-8.0	4	2.6%	36	2,305	216
Other, per label	4	2.6%	36	647	61
NA	15	9.7%	135	9,098	852
Total	155	100.0%	1,400	84,722	7,934

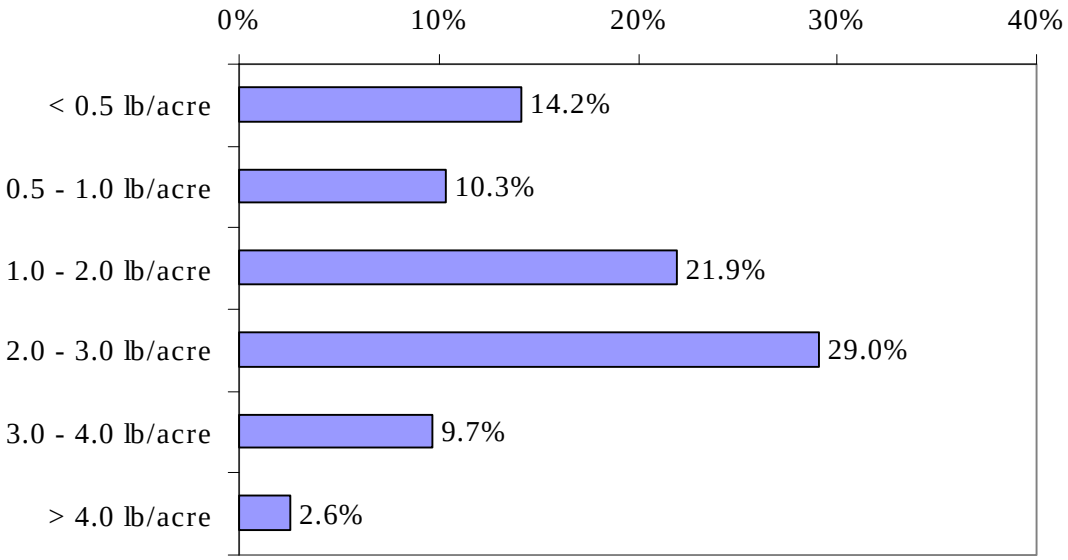

Fig. 7. Application rates of arsenical herbicides on Florida golf courses

QUESTION #18b. Spray times per year?

About 37% of responding golf courses using double spray, 23% using triple spray, 13% with multiple spray, and 3% with single spray (Table 21).

Table 21. Application methods of arsenical herbicides used on Florida golf courses (GCs)

Spray time/year	Number	Percentage
Single spray	4	2.6%
Double spray	56	36.1%
Triple spray	36	23.2%
Single/Double spray	1	0.6%
Other, 4-5 sprays	2	1.3%
Other, 6 sprays	1	0.6%
Other, 10-12 sprays	1	0.6%
Other, Multiple spot spray	16	10.3%
Other, spray as necessary	10	6.5%
NA	28	18.1%
Total	155	100.0%

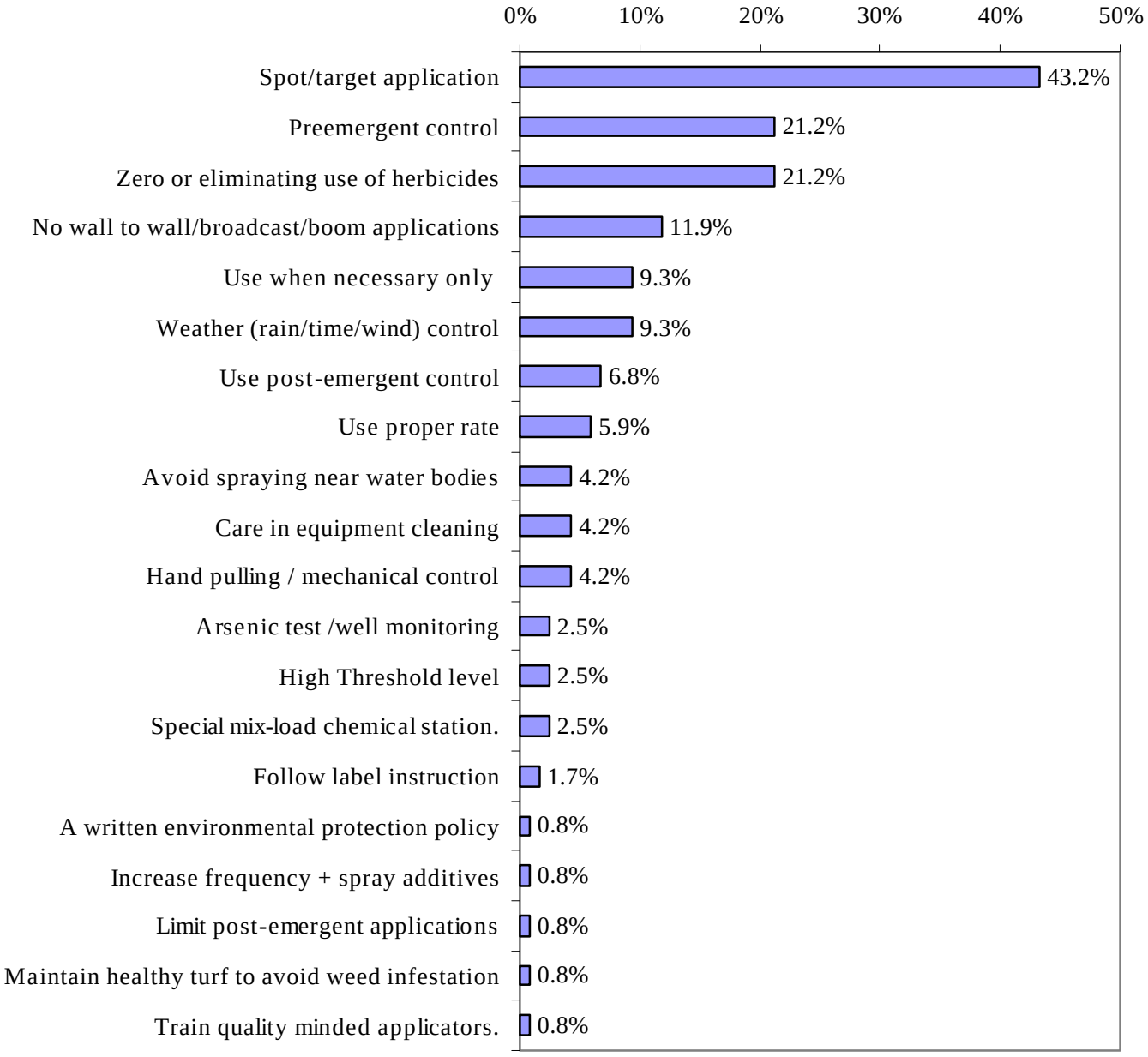

Fig. 8. Methods to minimize potential arsenic contamination on Florida golf courses

QUESTION #19a. Is your facility aware that there is concern that organic arsenical pesticide is a possible cause of arsenic contamination in the environment?

About 76% (118 golf courses) of the responding facilities were aware that there is concern that organic arsenical pesticide is a possible cause of arsenic contamination in the environment, 23% (35) were not and 1.3% (2) don't know.

QUESTION #19b. If it does, what steps have been taken to minimize this possibility?

Responses to this question indicate that to minimize the possibility of arsenic contamination, 20 different steps were commonly taken (Fig. 8).

QUESTION #20. If the answer to the above questions includes organic arsenicals, does the facility have arrangements for arsenic cleanup?

Only 18% (28 golf courses) of the responding golf courses had arrangement for arsenic cleanup, 58.1% didn't, 1.3% were unsure, and 22.6% didn't answer the question.

QUESTION #20b. If it does, what are those arrangements?

Only <10% of total responding golf courses had actually arrangement for arsenic cleanup (Fig. 9). Only 1% of the courses had staff trained and 1% had arsenic cleanup contract companies.

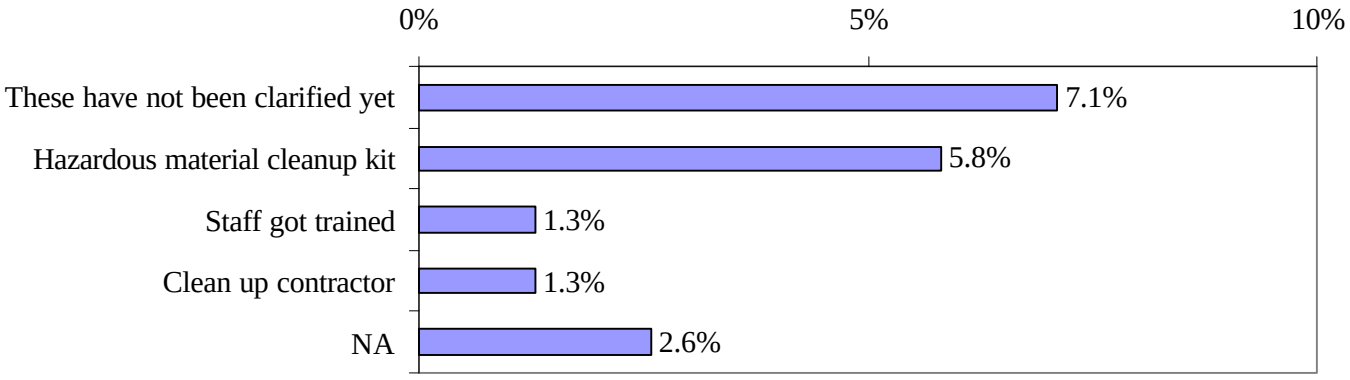

Fig. 9. Measures to control potential arsenic contamination on Florida golf courses

QUESTION #21. What other kind herbicides have been used in your facility besides the arsenic herbicide?

Besides the organic arsenic herbicides, 2,4-D was the most common herbicides used in Florida golf courses, representing 84% of the total responding courses (Table 22). Methibubuzin (sencor tuff), diclofop (illoxan), and pronamide (kerb) were among the most frequently reported herbicides used in Florida golf courses, representing two-thirds of total responding golf courses in this survey. Image (imazaquin), MCPP/MCPA (mecomec 4), asulam (asulox), fluazifop (fusilade T&O), and sethoxydim (vantage) to a lesser degree. Other herbicides includes basagran, manage, fenoxaprop (acclaim), trimec, roustar, ethofumesate (prograss), bentazon, drive, barricade, pendamethaun, DNA's, dicamba, three way, and clyphosate.

Table 22. Non-arsenical herbicides used on Florida golf courses

Other herbicide type	Number	Percentage
2,4-D	130	83.9%
Methibubuzin (Sencor Tuff)	115	74.2%
Diclofop (Illoxan)	110	71.0%
Pronamide (Kerb)	102	65.8%
Image (Imazaquin)	71	45.8%
MCPP/MCPA (Mecomec 4)	51	32.9%
Asulam (Asulox)	26	16.8%
Fluazifop (Fusilade T&O)	16	10.3%
Sethoxydim (Vantage)	11	7.1%
Fenoxaprop (Acclaim)	5	3.2%
Ethofumesate (Prograss)	2	1.3%
Other, Basagran	8	5.2%
Other, Manage	8	5.2%
Other, Trimec	4	2.6%
Other, Roustar	3	1.9%
Other, Bentazon	2	1.3%
Other, Drive	2	1.3%
Other, Barricade	1	0.6%
Other, Pendamethaun	1	0.6%
Other, DNA's	1	0.6%
Other, Dicamba	1	0.6%
Other, Three way	1	0.6%
Other, Clyphosate	1	0.6%
NA	3	1.9%

3.3.5. SECTION 5. ARSENIC CLEAN-UP INFORMATION

QUESTION #22. Is the facility adjacent to any potential arsenic contaminated sites?

Only 56 golf courses responded to this question. The responses indicate that only a few golf courses are adjacent to potential arsenic contaminated sites, such as CCA sites, and orange groves. No golf courses are adjacent to smelters, cattle dips, phosphorus mine, and cotton field (Table 23).

Table 23. Potential arsenic contaminated sites near Florida golf courses

Potential Arsenic Contaminated Sites	Number	Percentage
Wood-treatment	5	3.2%
Smelters	0	0.0%
Orange grove	7	4.5%
Cattle dips	0	0.0%
Cotton field	0	0.0%
Phosphate mine	0	0.0%
Other, Airport	2	1.3%
Other, Housing	14	9.0%
Other, Native woods	2	1.3%
Other, Waterway	1	0.6%
Other, Wetland	2	1.3%
Other, Farm	1	0.6%
Other, Cypress reserve	1	0.6%
Other, Park	1	0.6%
Other, Golf facility	1	0.6%
None of above	19	12.3%
NA	99	63.9%
Total	155	100.0%

QUESTION #23. Soil type?

Most of the responding golf courses were built on sand or sandy soils, representing 73% of all responding golf courses in this survey (Table 24, Fig. 10). Clay, loamy, organic soils were reported by one-eighth of all responding courses. Limestone, marl or shell and rocky soils to a

lesser degree, about 5-7% of the responding courses. Saline soil was negligible, with less than 2% of total responding courses.

Table 24. Soil types of Florida golf courses

Soil Type	Number	Percentage
Sand	74	47.7%
Clay	9	5.8%
Loam	9	5.8%
Saline	1	0.6%
Limestone, marl or shell	3	1.9%
Organic (Very black)	11	7.1%
Rocky	1	0.6%
Sand/Clay	10	6.5%
Sand/Clay/Loam/Organic	1	0.6%
Sand/Clay/Loam/Rock	1	0.6%
Sand/Clay/Organic	2	1.3%
Sand/Clay/Rocky	1	0.6%
Sand/Loam	7	4.5%
Sand/Saline	1	0.6%
Sand/Saline/Limestone	1	0.6%
Sand/Limestone	3	1.9%
Sand/Limestone/Rocky	2	1.3%
Sand/Organic	6	3.9%
Sand/Organic/Rocky	2	1.3%
Sand/Rocky	2	1.3%
Clay/Limestone/Organic	1	0.6%
Loam/Limestone	1	0.6%
Loam/Organic	1	0.6%
Limestone/Organic	1	0.6%
Limestone/Rocky	1	0.6%
No Answer	3	1.9%
Total	155	100.0%

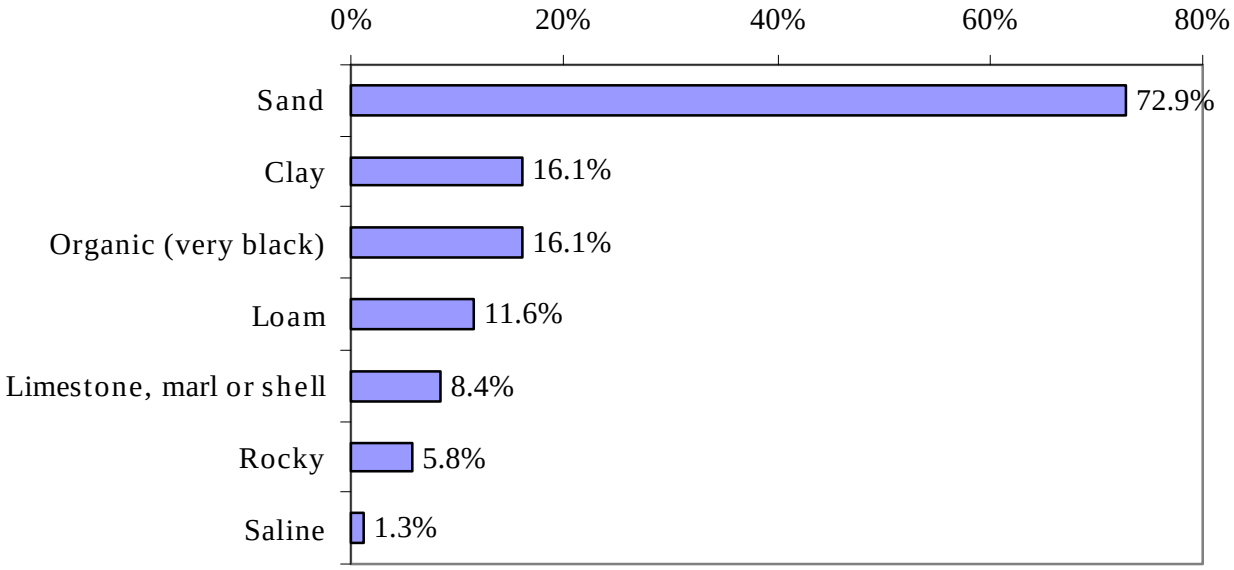

Fig 10. Soil types of Florida golf courses

QUESTION #24a. Do you know the current arsenic concentration in soils at your facility?

Of the 153 facilities that answered this question, only 5 said they had a soil test number for arsenic, 61 didn't know and 87 said they did not.

QUESTION #24b. IF YES: Do you know the soil arsenic cleanup goals in the State of Florida?

Of the 5 facilities that answered this question, 3 said they know the soil arsenic cleanup goals in Florida, and 2 said they did not.

QUESTION #24b. IF YES: How do your soils differ in arsenic concentration from the current Florida soil arsenic cleanup goals (0.8 ppm for residential soil & 3.7 ppm for industrial site)?

Of the 3 facilities that answered this question, one said that only one soil sample from their facilities above the soil arsenic cleanup goals in Florida, and 2 said below.

QUESTION #25. Do you want a free-of-charge soil arsenic report for your facility?

Of the 145 facilities that answered this question, 95 said they want a free-of charge soil arsenic report for their facilities, 49 said they did not.

QUESTION #26. Would you like to receive a copy of the results from this survey?

Of the 146 facilities that answered this question, 120 said did want a copy of the results from this survey, and 26 said they did not.

4. DISTRIBUTION OF LEAD CONCENTRATION AT SHOOTING RANGES IN FLORIDA

4.1. Materials and Methods

Rifle/Pistol Range: This is a standard public rifle/pistol shooting range in central Florida, which has targets at 15, 25, 50, and 100 meters. Lead pellets were observed within 20 m from the firing stand (Fig.11, Fig.12). Most pellets were observed in front of the backstop berm (Fig 13). A total of 15 soil samples were taken from the range with 14-year in operation. Five samples (0-10, 10-30, 30-50, 50-100, and 180-200 cm) were collected from a soil profile in the rifle/pistol shooting range at a distance of 30 m from the firing stand. Eight surface samples (0-10cm) were collected along a single transect in the range at 10, 20, 30, 40, 60, 80, 100 m from the firing stand. Two samples were collected from the top and middle of the berm.

Shotgun Range: Most of clay debris was observed between 20 and 60 meters from the firing stand (Fig.14). Four surface soil samples (0-5 cm) were collected along a single transect through the center at 30, 60, 120, and 150 m from the firing stand. A clay sample was also collected to check the potential impact of lead concentration of the clay in soils.

Laboratory Analyses: The soil samples were air-dried, ground with a mortar and pellets and passed through a 1-mm sieve. Any lead pellet or debris of bullet were separated from the coarse fraction and counted. The soils were digested with EPA method 3051a (Chen and Ma, 1998). Concentrations of Al, Fe, and Pb were analyzed on a Perkin-Elmer 3030 flame AA at wavelengths of 309.3, 271.9nm, and 217.5 nm, respectively. When the lead concentrations is

lower than 300 ppm, A Pekin-Elmer SIMMA 6000 GFAA was used to run the samples, which has a low detection limit (MDL=0.02 ppm). Phosphorus concentrations were analyzed using UV-VIS. Soil pH was determined by using a combination electrode after mixing 5.00 g soil with 5 ml distilled deioned water for 24 hour.

4.2. Lead Concentrations in Soils of Two Different Shooting Ranges

QA/QC: Elemental recoveries of Al, Fe, and P from NIST SRM 2710 were 28%, 80% and 114%, with relative percent differences (RPD) of 2.6%, 0.12%, and 3.5%, respectively. Lead recovery was 86.5%, with an RPD of 1.72%.

Fig. 11. Backstop Berm of the Rifle/Pistol Range

Fig. 12. Rifle/pistol range targets

Fig. 13. Bullets on top of the background soils

Fig. 14. Shotgun Shooting Range

The recovery of the instrument in the determination of lead were >86% with soil Pb concentration ranging from 300 ppm to 20,000 ppm using the flame AA (Table 25).

Table 25. Recovery of various elements using flame-AA

Element	Target value (ppm)	Determined (ppm)	Recovery (%)	RPD (%)†
Al	64,400	18,061	28.0	2.60
Fe	33,800	27,030	80.0	0.12
P	1,060	1,213	114	3.49
Pb	5,532	4,786	86.5	1.72

† RPD (%) = relative percent difference.

Rifle/pistol Shooting Range: The greatest lead densities of the bullet debris were found in the middle of berm, with a value of 18% on a weight basis (Table 26). Total lead concentrations in the surface soils ranged from 875 to 4,448 ppm, with the greatest at 20-40 meters from the

shooting area (2,213-4,448 ppm). Concentrations of both Al, Fe, and P were also high at the distance of 30 meters from the firing line. However, the highest Pb concentration (10,138-17,850 ppm) was determined in the berm. Most soils had Pb concentrations much greater than the FDEP soil cleanup goals for residential soil (500 ppm) and industrial soil (1,000 ppm).

The elevated soil pH in the berm with high contents of lead bullets may be related to the corrosion of the lead bullets, which has been reported by Astrup et al (1999).

Table 26. Elemental concentrations in soil of a rifle/pistol shooting range

Distance (meters)	Total Pb (ppm)	Bullet debris (%,w/w)	Total Al (ppm)	Total Fe (ppm)	pH (H_2O, 1:1)	P (ppm)
10	1,201		2,365	1,825	6.72	77.1
20	2,214		2,652	1,549	6.69	61.6
30	4,448		3,932	2,278	6.11	160.2
40	2,213		1,342	871	6.33	53.6
60	1,793		1,263	1,133	5.55	74.0
80	875		2,509	1,750	5.43	120.0
100	1,723	9.1	2,500	1,433	5.52	130.7
Top of Berm	10,138	4.7	4,433	2,320	6.79	88.6
Middle of Berm	17,850	18.4	1,704	1,440	7.73	44.0

Soil pH value was found to be the greatest in the surface layer (0-10 cm) of the soil (Table 27). Total Al concentration was found to be the highest in subsurface (10-30 cm) layer of the soil profile. Phosphorus concentration was found to be the highest in the bottom layer (180-200 cm), with a transition trend from high to low within top 50 cm. Total lead concentration decreased dramatically along depth of the soil profiles. The greatest lead concentration (2,357-2,690 ppm) remained in the top layer (0 -10 cm) and the lowest lead concentration was found at surface layer of the profile (9.0-9.8 ppm). There is a transition trend from high to low in lead concentration, however, may indicate impact of lead shot in soils.

Table 27. Elemental concentrations in a soil profile of a rifle/pistol shooting range

Depth of Sampling (cm)	Total Pb (ppm)	Total Al (ppm)	Total Fe (ppm)	pH (H_2O, 1:1)	Total P (ppm)
0-10	2,357	2,654	1,190	6.74	79.0
0-10 (replicate)	2,690	2,095	961	6.76	55.6
10-30	83.0	11,147	1,988	5.88	52.8
30-50	13.2	3,626	1,957	5.02	49.6
50-100	9.0	3,408	2,018	4.80	62.6
180-200	9.8	2,281	1,440	5.06	128.3

Shotgun/clay Shooting Range: The greatest clay debris was observed at 30 meters from the shooting area, with a value of 30% on a weight basis (Table 28). Soil pH and concentrations of Al, Fe, and P were found to be the highest at 30 meters from the shooting area. Total lead concentration in the clay debris was low (26.6 ppm). Lead concentrations in soils were greatest at 30 meters from the shooting area (15,368-ppm) and decreased to 330-ppm at 150 meters. The pattern of lead pellet accumulation along the transect was different from that of the total lead concentrations. There was ~50 pellets per 100 gram soil sample at 30 meters, but more than 60 pellets per 100 gram soil sample at 60 and 120 meters. Thereafter pellets decreased to less than 10 per 100 gram soil sample at 150 meters from the shooting area.

Table 28. Elemental concentrations in soil of a shotgun/clay shooting range

Distance (meter)	Clay debris (%, w/w)	Total Pb concentration (ppm)	Pellet (/100 g soil)	Pellet (%, w/w)
30	30	15,368	50	4.4
60	5	438	83	6.7
120	0	386	61	2.8
150	0	330	9	0.64

Distance (meter)	Total Al (ppm)	Total Fe (ppm)	pH (H_2O, 1:1)	Total P (ppm)
30	2,021	1,179	7.8	162.6
60	1,280	1,070	6.0	83.6
120	1,248	892	4.9	51.3
150	798	646	4.8	27.5
Clay	667	1,231	10.4	198.0

Clearly, lead contamination is obvious in both ranges and more detailed research is on-going.

REFERENCES CITED

1. Anonymous. 1996. 1996 golf course superintendents report. Golf Course Superintendents Association of America, Lawrence, KS.
2. Balogh, J.C. and W.J. Walker (ed.) 1992. Golf course management and construction: environmental issues. Lewis Publishers. Chelsea, MI.
3. Chen, M., L.Q. Ma, and W.G. Harris. 1999. Background concentrations of 15 trace metals in Florida soils. J. Environ. Qual. 28:1173-1181.
4. Chen, M. and L.Q. Ma. 1998. Comparison of four EPA digestion methods for trace metals using certified and Florida soils. J. Environ. Qual. 27:1294-1300.
5. Davenport, J. R. and F. J. Peryea. 1991. Phosphate fertilizers influence leaching of lead and arsenic in a soil contaminated with lead arsenate. Water Air Soil Pollution. 57-58:101-110.
6. Duble, R.L. & J.C. Thomas. 1978. Arsenic pollution from underdrainage and runoff from golf greens. Agron. J. 70:71-4.
7. Fisher, F.M. and S.L. Hall. 1986. Heavy metal concentrations of duck tissues in relation to ingestion of spent shot. P. 37-42. *In* J.S. Feierabend and A.B. Russell (ed.) Lead poisoning in wild waterfowl-a workshop. Cooperative Lead Poisoning Control Information Program, Washington, DC, USA.
8. Hodges, A.W., J.J. Haydo, P.J. van Blockland, and A.P. Bell. 1994. Contribution of the turfgrass industry to Florida's economy, 1991-92: A value-added approach. Economics Report ER 94-1. University of Florida. Gainesville, FL.
9. Johnson, L.R. and A.E. Hiltbold. 1969. Arsenic content of soils and crops following the use of methanearsonate herbicides. Soil Sci. Soc. Am. Proc. 33:279-282.
10. Johnson, B. J. 1997. Sequential application of preemergence and postemergence herbicides for large crabgrass control in tall fescue turf. Weed Technology. 11: 693-7.

11. Jorgensen, S.S. and M. Willems. 1987. The transformation of lead pellets in shooting range soils. Ambio. 16: 11-15.

12. Lin, Z. X., B. Comet, U. Qvarfort and R. Herbert. 1995. The chemical and mineralogical behavior of Pb in shooting range soils from central Sweden. Environmental pollution. 89:303-309.

13. Liu, D. and R.J. Manuire. 1997. Transformation of the new antifouling compound Irgarol 1051. Wat. Res. 31:2363-9.

14. Markels, A. 1998. The greening of America. Audubon. 7/8:42-49.

15. Murphy, E. A. and M. Aucott. 1998. An assessment of the amount of arsenical pesticides used historically in a geographical area. Sci. Total Environ. 218:89-101.

16. Murray, K., A. Bazzi and e. al. 1997. Distribution and mobility of lead in soils at an outdorr shooting range. J. Soil Contamination. 6:79-93.

17. Ruby, M. V. and A. Davis. 1996. Estimation of lead and arsenic bioavailability using a physoilogically based extraction test. Environm. Sci. Technol. 30: 422-430.

18. Scheuhammer, A.M. and S.L. Norris. 1995. A review of the environmental impacts of lead shotshell ammunition and lead fishing weights in Canada. Occasional Paper. N. 88. Canadian Wildlife Service, National Wildlife Research Center, Hull, Quebec, K1a 0H3.

19. Sever, C. 1993. Lead and outdoor reanges. Pages 87-94. In National shooting range symposium proceedings, 17-19 October, Salt lake city, Ultah.

20. Shreir, L.L.1976. Corrosion. V. 1. Metal/ Environment reactions, chapter 4.3. Newnes-Butter-worth.

21. Smith, A. E. and D. C. Bridges. 1996. Movement of certain herbicides following application to simulated golf course greens and fairways. Crop Sci. 36:1439-45.

22. Smith, A. E. and W. R. Tillotson. 1991. Potential leaching of herbicides applied to golf course greens. Pesticides in urban environment: fate and significance, San Francisco, ACS.

23. Stansley, W., L. Widjeskog and D. E. Roscoe. 1992. Lead contamination and mobility in surface water at trap and skeet ranges. Bull. Environ. Contam Toxicol. 49:640-647.

24. Suzuki, T., H. Kondo, K. Yaguchi, and T. Maki. 1998. Estimation of leachability and persistence of pesticides at golf courses from point-source monitoring and model to predict pesticide leaching to groundwater. Environ. Sci. Technol. 32:920-9.

25. Swancar, A. 1996. Water quality, pesticide occurrence, and effects of irrigation with reclaimed water at golf courses in Florida. Water-resources investigations report 95-4250. Tallahassee, USGS.

26. Tessier, A. and P. G. C. Campbell. 1988. Partitioning of trace metals in sediments. *In* J. R. Kramer and H. E. Allen (eds.) Metal speciation: theory, analysis and application. p 183-199. Lewis Pub., Chelsea.

27. Tsuji, L. J. S. and J. D. Karagatzides. 1998. Spent lead shot in the western James Bay region of northern Ontario, Canada: soil and plant chemistry of a heavily hunted wetland. Wetlands. 18:266-271.

28. Unruh, J.B. and M. Elliott (ed.) 1999. Best management practices for Florida golf courses: putting green construction, water management, fertilization, cultural practices and pest management. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

29. USEPA. 1994. Proceeding under section 7003 of the solid waste disposal Act. Westchester county Sportsmen's Center. Administrative Order of Consent. Docket No. II RCRA-94-7003-0204. 25pp.

30. USGS. 1997. Copper hazards to fish, wildlife, and invertebrates: a synoptic review. Biological Science Report. USGS/BRD/BSR-1997-0002.

31. Van Bon, J. and J. J. Boersema. 1988. Sources, effects and management of metallic lead pollution: the contribution of hunting, shooting and angling. Second international TNO/BMFT conference on contaminated soil, Hamburg, Kluwer. Academic Publishers.

32. Woolson, E. A., J. H. Axley and P. C. Kearney. 1973. The chemistry and phytotoxicity of arsenic in soils: II. Effects of time and phosphorus. Soil Sci. Soc. Amer. Proc. 37:254-259.

Appendix A: Sample Cover Letter for Golf Course Questionnaire

DATE

Address XXX

Dear Sir or Madam,

As part of an on-going research project, the University of Florida has been asked to perform a survey concerning the operation and management of arsenic-based herbicides in golf courses in Florida. All information gathered during this survey will be reported on a STRICTLY ANONYMOUS BASIS. You are under no obligation to return this survey but the information you provide us can be invaluable. Only if we get your answers and opinions on this subject can we begin to put together a factual and accurate database. We would appreciate it very much if you would take a few minutes and fill out the enclosed survey and return it to us in the enclosed self-addressed envelope.

Again all information provided to us will be reported to the agency concerned on a STRICTLY ANONYMOUS BASIS. The results of our research will be available to your organization if desired. Please mark the appropriate box on the questionnaire if you would like a copy of our final report summarizing arsenic chemistry in golf course soils in Florida.

If you would like any further information or have questions concerning this survey, please feel free to contact me, by calling (352) 392-9063 or write to the address included on the return envelope. You can also contact my lab manager: Ms. Elizabeth Kennelley. Her phone number is (352) 392-8663 and e-mail address is edke@gnv.ifas.ufl.edu.

You are welcome to contact Dr. Jerry Sartain, who is a turf grass fertility specialist in our department at 352-392-7271 ext 330.

Sincerely,

Lena Q. Ma, Ph. D.
Associate Professor

cc: John Schert, Florida Center for Solid and Hazardous Waste Management

CONFIDENTIAL SURVEY

SECTION 1: Facility Information

This information is for internal use only and will not be released to any other sources. You are not required to give this information in order to participate in the survey. If you prefer not to fill in this information please skip to Section 2 and complete the information requested there.

1. Company Name_____

2. Company Address :_____

   City _____ State: _____ Zip Code:_____

   Phone Number with area code: _____

   Contact Person_____

SECTION 2: Facility Description

3. Type of Facility:

   private public semi-private other (please specify)_____

4. How long has your facility been in operation?

   < 5 yr 5-10 yrs 10-20 yrs 20-30 yrs > 30 yrs

5. Approximately how large (acres) is your facility?

   < 50 50- 100 100-150 150-200 200-250 250-300 > 300

6. How many holes in your facility?

   9 18 27 36 45 54 > 54

7. On average, approximately how many THOUSAND ROUNDS are played per year?

   < 10 10-20 20-40 40-60 60-80 80-100 > 100

8. Is your facility located in a rural area? : Yes No

   IF YES: how far is your facility from the nearest city?

   <5 miles 5-10 miles 10-20 miles 20-30 miles > 30 miles

Survey (con't)

9. Is your facilities located on or adjacent to :

Wetland	estuary
Salt-water marsh	stream/river
Pond/lake	other bodies of water

10. Approximately how many open bodies of water (pond/lakes) at your facility?

None 1-5 5-10 10-20 20-30 > 30

SECTION 3: Facility Management Information

11. What is the major turfgrass type in your facility?

bahiagrass	bentgrass
bermudagrass	centipedegrass
St. Augustinegrass	zoysiagrass
perennial ryegrass	mixed
other (please specify):_____	

12. What are the major turfgrass management problems that you have at your facility?

insects	weeds
poor soils or soil compaction	soil fertility
other (please specify):_____	

13. What type of irrigation water is used in your facility?

no irrigation	city water supply
well water	recycled or claimed waste water
surface water	Other (please specify)
_____	

14. Approximately how many THOUSAND GALLONS of irrigation water are used in your facility per day?

<100 100-250 250-500 500-750 750-1,000 > 1,000

15. What types of fertilizers or soil amendments have been used in your courses?

nitrogen	sulfur, calcium, or magnesium
phosphorus	micro-nutrient (such as iron, manganese, et al)
potassium	organic manure (compost, sludge, or wastes)
lime	other (please specify) _____

16. What is the major problem weed species in your course?

annual bluegrass	broadleaved weeds
crabgrass	dallisgrass
dollarweed	goosegrass
sandspurgrass	spurgesgrass
other (please specify):_____	

Survey (con't)

SECTION 4: Pesticide Application Information

17. Have any of the following organic arsenic herbicides been used at your facility for postemergence weed control in the past 3 years? Yes No

IF YES, please check appropriate box:

CMA (CAMA, Calar, Ortho Crabgrass Killer, or Formula II)
DSMA (Ansar, Methar 30, Namate, or disodium methanearsenate)
MAA (methylarsonic acid, or methanearsenate acid)
MAMA (monoammonium meththanearsonate, or monoammonium salt of MAA)
MSMA (Daconate 6, Daconate Super, Dal-E-Rad, Crab-E-Rad, 120 herbicide, 912 herbicide, Drexar 530, Check Mate, Dimension, Herb-All, Merge 823, Pennant, Silvisar, Trans-Vert, or monosodium methanearsonate)
other (please specify):_____

18. If the answer to the above question includes DSMA or MSMA, please check the appropriate rate per application:

0.25 lb/acre 0.5 lb/acre
1.0 lb/acre 2.0 lb/acre
3.0 lb/acre other: _____

AND, spray times per year, if possible:

single double triple other: _____

19. Is your facility aware that there is concern that organic arsenical pesticide is a possible cause of arsenic contamination in the environment? Yes No

If it does, what steps have been taken to minimize this possibility?

_____
_____

20. If the answer to the above questions includes organic arsenicals, does the facility have arrangements for arsenic cleanup? Yes No

If it does, what are those arrangements?

_____
_____

Survey (con't)

21. What other kind herbicides have been used in your facility besides the arsenic herbicide? Please check appropriate box.

2,4-D	image (imazaquin)
MCPP/MCPA (Mecomec 4)	asulam (asulox)
diclofop (Illoxan)	fluazifop (Fusilade T & O)
fenoxaprop (Acclaim)	methibubuzin (Sencor Turf)
pronamide (Kerb)	sethoxydim (Vantage)
ethofumesate (Prograss)	other (please specify):_____

SECTION 5 : Arsenic Clean-up Information

22. Is your facilities adjacent to:

wood-treatment	cattle dips
smelters	cotton field
orange grove	phosphate mine
other (please specify): _____	

23. Would you classify your soil as mostly:

sand	limestone, marl or shell
clay	organic (very black)
loam	rocky
saline	other (please specify): _____

24. Do you know the current arsenic concentration in soils at your facility?

Yes No don't know

IF YES: Do you know the soil arsenic cleanup goals in the State of Florida?

Yes No don't know

IF YES: How do your soils differ in arsenic concentration from the current Florida soil arsenic cleanup goals (0.8 ppm for residential soil & 3.7 ppm for industrial site)?

higher lower the same level

25. Do you want a free-of-charge soil arsenic report for your facility? Yes No

26. Would you like to receive a copy of the results from this survey? Yes No

Thank you for completing the survey. Please mail survey in the self addressed envelope provided.