TWIN LAKES GOLF COURSE WATER QUALITY STUDY

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ABSTRACT

The aim of this stormwater runoff study and literature review was to determine the quality of turf runoff from a golf course and compare the results to the existing literature related to this topic. Stormwater and baseflow samples were collected from a background stream station upstream of the golf course and from two stations located on Twin Lakes Golf Course, Fairfax County, VA, that receive runoff from areas treated with fertilizers and other turf chemicals. Samples were collected in the spring of 1992, prior to chemical application, and continued throughout the summer and fall when chemical application is most frequent. Baseflow samples were collected at the same stations during the spring and summer of 1993. A literature search indicated that a greater number of studies were conducted using turf plots with underlying drainage systems and simulated rain events. Some studies were designed to evaluate the potential for impact to groundwater and surface waters. Our study of Twin Lakes Golf Course was designed to determine if the potential exists for water quality impairment of the receiving stream resulting from the movement of nutrients, pesticides, herbicides, and fungicides that are applied using the current management practices. Nutrient levels were found to be slightly elevated when compared to the background station. Of four samples collected and analyzed for 13 pest control agents, only one sample was found to contain a fungicide slightly above the detection limit.

INTRODUCTION

In the recent past, with the increasing awareness of stormwater or non-point source pollution from various urban and agricultural land uses, the use of fertilizers, pesticides, and other chemicals used to maintain turf has been questioned. Golf courses in particular are subject to intense management including frequent application of turf chemicals. The concern is such that they are one of the sources that are currently being considered by the U.S. Environmental Protection Agency (EPA) for further regulation through permitting of the stormwater discharge under the National Pollutant Discharge Elimination System (NPDES). This may require certain Best Management Practices for applying these chemicals. Nutrient enrichment is one of the leading causes of water quality impairment that the Chesapeake Bay has experienced, though the primary source of these high nutrient levels is the nitrogen and phosphorus that is applied to agricultural fields within the watershed. Nutrients and other turf chemicals were the main focus of this water quality study and literature review.

LITERATURE REVIEW

'Me literature search uncovered over 45 reports and articles and was conducted for the purpose of determining how the results of other stormwater runoff studies involving turf chemicals compared to the results of the study conducted at Twin Lakes Golf Course. The literature found relating to this subject studied nutrient, pesticide, and sediment runoff and leachate from golf course turfgrasses, cropland, vineyards, home lawns, and grazed grassland with the purpose of determining the deleterious effects on surface and ground waters. This review focused on those studies that directly involved golf course turf and impacts due to fertilizer and other chemical applications. Although some studies found that turf chemicals do runoff into receiving waters, the amounts were limited and varied with differing conditions.

Studies have documented the detection of pesticides in groundwater. A groundwater monitoring study of golf courses on Cape Cod detected 10 of the 17 pesticides for which analysis was performed. Chlordane was the only pesticide above the health guidance level. None of the 12 currently registered turf pesticides targeted in the study were detected above 20 percent of the health guidance level (HGL) (Miles, Leong and Dollar, 1992). Most were detected at concentrations less than or equal to 6 percent of their HGL. This study is particularly significant since the soils were highly permeable and depth to groundwater was shallow. Chlordane is not used at Twin Lakes Golf Course.

Many of the experiments involved simulated rainfalls of varying intensities, initiated at different lengths of time from chemical application. In one study turfgrass was established on sloped plots by either sodding with 100 percent Kentucky bluegrass or seeding with either of two species mixtures (Harrison, 1989). Maintenance methods were used that are typical of professional contractors in the northeastern U.S. including regularly scheduled applications of nutrients and pesticides. Irrigation runoff and, when possible, natural events were monitored and sampled. The average concentrations of N03 - N, P04 - P and K in runoff and leachate samples were less than 5 mg/l. Nutrient concentrations were found to be about the same as those observed in tap water. This study showed that less than 5 percent of the nutrients and less than 2 percent of the pesticides were present in the runoff for the worst case events-those immediately following applications. They concluded that these losses to surface runoff did not appear to pose a significant hazard at this site. The dense, high quality turfgrass used in this study affected the overland flow process to such a degree that runoff was insignificant. They go as far as to suggest that appropriately managed turfgrass stands may be successful as a water quality treatment medium.

Another study compared nutrient and sediment losses from turf via runoff and leaching with losses from agronomic crops (Gross, Angle and Welterlen, 1990). This study used experimental plots of turf-type tall fescue/Kentucky bluegrass grown on slopes of 5 to 7 percent. Over the 2-year study period, 18 rainfall events produced measurable runoff. The concentrations found were very low in the runoff from the turfed area, which they attribute to the denseness and hydraulic resistance provided by the turf. This study concluded that properly managed and judiciously fertilized turf is not a significant source of nutrients, pesticides, or sediment in surface or groundwater.

At least two papers were reviewed that defend the use of irrigation following chemical application for decreasing the average losses of these chemicals (Kelling and Peterson, 1975; Mugass, Agnew and Christips, t991). Losses of fertilizer were 10.6 percent of that applied when a simulated storm was applied immediately after fertilizer application. The losses were reduced to 1.7 percent of the amount applied when application was followed by a recommended watering before the simulated storm.

In a frequently cited 2-year field study conducted by the University of Rhode Island using turf plots, runoff only occurred twice: after a week of rain and irrigation totaling about 5 inches and after a winter rainstorm when soil was frozen (Petrovic, 1990). The concentration of inorganic N in the runoff from these events ranged from 1. 1 to 4.2 mg/l, which is considerably lower than the drinking water standard of 10 mg/l.

As part of the Greendale Monitoring Program, phosphorus and nitrogen loads were calculated for three storms at stations upstream and downstream of the Greendale Golf Course. These storm loads represented only 1 percent of the applied TP and about 2 percent of the applied TN (Camp Dresser and McKee, 1991). This assumes that these increased nutrient loadings at the downstream station were solely a result of the November fertilization at the golf course. These increases could have been affected by sources between the two stations. This same study concluded that the sediment load at the upstream station was 13 percent greater than the total load at the station downstream from the course. They speculate that the ponds located on the course are trapping the suspended sediments. Results of other studies show that turfgrass itself can be responsible for reducing sediment loss even if it is of a low density (Gross et. al., 1991).

One study concluded that the herbicide 2,4-D poses a significant environmental concern for at least a few weeks after application (Hall, Bowhey and Stephenson, 1987). This study used plots of turfgrass placed on an incline of 28%. Their results show that up to 10 percent of the 2,4-D can be dislodged from sod grown outdoors two weeks after its application. The slope of 28% is steeper than most areas of the Twin Lakes Golf Course. Because runoff is greater on steep slopes, the 10% 2,4-D loss should be considered a maximum potential loss rate for Twin Lakes. Similarly, in a study that examined arsenic pollution from runoff and leachate, concentrations were found as high as 14 mg/l, which exceeds acceptable limits for irrigation water established by the U.S. Public Health Service (Duble, Thomas and Brown, 1978). Twenty individual golf greens were constructed using Bermuda grass grown on mixtures of sand, soil, and peat with a drainage system to facilitate sample collection. Irrigation and natural events were sampled. As expected, heavy rains produced increased concentrations.

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The degree of nitrogen leaching from fertilizer application to turfgrass is highly variable (Petrovic, 1990). Some of the research reports little or no leaching while other studies report that as much as 80 percent may leach in the form of N03 . Although many factors affect these concentrations, soil type, irrigation, nitrogen source, nitrogen application and plant uptake rates, and season are the main considerations.

These studies have shown that when runoff occurs from turf, similar to the type used on golf courses, the chemicals applied to the turf may be present in either the runoff or the leachate. These concentrations are usually lower than any published criteria and usually do not seem to justify significant environmental concern. Instances where the concentrations of the chemicals are high seem to occur when a rain event closely follows the application of the chemical or when the chemicals have been over applied. "Because of the encouraging results of many of these studies, most support the continued implementation of management practices for the proper use and application of these chemicals. Environmental concern is justified when these chemicals are misused.

METHODS

The sampling locations were selected so that runoff that enters and leaves the golf course may be characterized. Figure 1 shows the location of all sampling points. Station 1, located east of the golf course, is a small stream that drains a residential/ forested area and flows through the golf course and into the lakes. Data from this background station indicates the quality of water that is unaffected by golf course activities. Stations 2 and 3, located at the outfalls of the two lakes, were selected because they receive the majority of the runoff from the areas in which fertilizer and other chemicals are applied.

The constituents selected for analysis include nutrients, pesticides, herbicides, and fungicides. Nutrient analyses were performed on all water samples collected from each station. These data indicate both the general water quality and the changes in nutrient levels caused by fertilizer application practices. The data from the first storm on March 18, 1992, was collected prior to any fertilizer application that season. The remaining samples were collected during the summer and fall when fertilizers were being applied regularly. Other chemicals including pesticides, herbicides, and fungicides were applied throughout the year and were analyzed in the samples collected after their application to tees, greens, or fairways. If a particular turf chemical had not been applied since the previous sampling event, and it had not been detected in the previous samples, that chemical was not targeted for analysis. All samples were collected in laboratory-supplied sample bottles with the appropriate preservative.

Seven storm events were sampled in 1992. Four baseflow events were sampled in 1993. Table 1 presents the analytical results. Samples in 1992 were usually taken as close to the peak of the storm as possible when runoff was occurring. During the August 4 and October 9 rainfall events, the outfalls were not discharging, and Station 1 was dry. Therefore, the samples were collected directly from the lakes. Outfall discharges were observed most often during the spring, prior to irrigation. The water level in the ponds drops below the weir elevations during the summer months when

the lakes are used as a water supply for turf irrigation. Consequently, the lakes are able to store a significant amount of runoff during summer rainfall events. Runoff was absent during many of the summer 1992 thunderstorms that each produced less than 1.3 in of precipitation. Dames & Moore staff conducted at least six site surveys when no runoff was produced at either lake. Because stormwater impacts were found to be limited, samples collected during 1993 were collected during baseflow to determine impacts that occur under those conditions. Although runoff at Twin Lakes was limited or absent during many of the rainfall events monitored, the results of the Twin Lakes Study were consistent with much of the literature reviewed. These results are discussed in detail in Section 4.0.

RESULTS

The nutrient parameters analyzed were chosen for their significance as indicators of general water quality. Ammonia is one indicator that occurs in elevated concentrations whenever pollutant sources are close by. Ammonia is an intermediate form of nitrogen and is slowly converted to nitrate under aerobic conditions. Typical ammonia concentrations downstream of wastewater discharges are approximately 5 mg/l (McCutcheon, 1993). Ammonia concentrations are usually less am 3mg/l and may be as low as 0.01 mg/l in uncontaminated streams. Ammonia was not detected in the majority of the samples collected from Twin Lakes as part of this study. Ammonia was detected following only one rainfall event at Stations 1 and 3 and following only two rainfall events at Station 2. Detected concentrations were very low (0. 4 and 0. 1 mg/1) and were not considered elevated.

Total phosphorus (TP) is usually measured in streams at low concentrations of 0. 1 mg/l or less. Polluted waters may contain concentrations of 1 mg/l or more, and excessive algae growth may occur at levels of 0.05 mg/l. In general, Stations 2 and 3 had higher T? concentrations than Station 1. These values can be considered slightly elevated. In some instances TP levels were higher at Station 1 than at Stations 2 and 3. A statistical analysis was conducted for TP and nitrate to determine if there were significant differences in nutrient concentrations between the stations. Statistical data is presented in Table 2. It can be seen that the average TP concentration is highest at Station 1 and lowest at Station 3. A comparison of confidence limits for the three stations indicates that there is no significant difference between tile stations. The trend of the data suggests that the two lakes are trapping phosphorus.

Nitrate data for Stations 1, 2, and 3 indicate that the average concentration for Station 3 is greater than the average concentrations for Stations 1 and 2. The lower confidence limit value for Station 3 is less than the upper confidence limit values for Stations 1 or 2, indicating that Station 3 nitrate concentrations are not significantly different from Stations 1 and 2.

The hypothesis that the lakes are trapping nutrients is supported by nitrogen levels in lake sediments. Relatively high nitrogen levels (0.31 to 0.53 percent) were found in the sediments collected from the lakes. The Federal Water Quality Administration Criteria for Maximum Allowable Contaminants in Dredged Material indicates that a normal TKN level for sediments is 0. 10 percent dry weight (Anon, 1973). Sediment data from Twin Likes suggest that the lakes may be acting as sinks, trapping excess fertilizer as it settles through the water column.

Stormwater samples collected in 1992 were also analyzed for a number of golf course chemicals. These chemicals are Team, Scotts Crab/Goose (oxadiazon, bensulide), Daconil, Bayleton, Subdue, Dursban, Banner, Rubigan, Chipco, Acti-done, Turcam, and 2, 4-D. Only one sample tested indicated detectable levels of a turf chemical used on the golf course. The fungicide Banner was found at Station 3 at a level that barely exceeded the detection limit. All other fungicides, insecticides, and herbicides were at levels below their detection limits. For this reason, analysis of these chemicals was not performed on samples collected in 1993. It is anticipated that the two lakes are trapping the chemicals or are allowing the chemicals to degrade so they are not released to the receiving stream. Preliminarily, this suggests that the management practices that the County employs for maintaining the course are not having a negative impact on the water quality of the receiving stream. Current management practices for turf chemical application seem to be adequate at Twin Lakes to protect the receiving stream from water quality impairment.

TABLE I
PRELIMINARY RESULTS OF TWIN LAKES STORMWATER RUNOFF SAMPLING

Date	Parameter	Station 1	Station 2	Station 3	Date	Parameter	Station 1	Station 2	Station 3
3/	Nitrate	0.3	0.3	0.2					
18/	TKN	ND	ND	ND	II/	Nitrate	ND	0.4	0.9
92	Ammonia	ND	ND	ND	2/	TKN	0.6	1.1	2.5
	Total Phosphorus	0.04	0.06	0.06	92	Ammonia	ND	ND	ND
	Orthophosphate	ND	ND	ND		Total Phosphorus	0.05	0.10	0.15
						Orthophosphorus	0.01	0.18	0.13
51	Nitrate	0.2	ND	ND		Percent Nitrogen			
8/	TXN	0.6	0.3	0.4		(Sediment)	0.31	0.33	0.53
92	Ammonia	ND	ND	ND		Percent Carbon			
	Total Phosphorus	0.14	0.07	0.10		(Sediment)	3.04	3.26	5.14
	Orthophosphate	0.04	0.01	ND					
	Team	-	< 10.0	< 10.0					
	Scotts crab/goose								
	(oxadiazon)	-	< 10.0	< 10.0					
	Scotts crab/goose								
	(bensulide)	-	<20.0	<20.0					
6/	Nitrate	ND	ND	ND	5/	Nitrate	ND	0.2	0.4
51	TKN	1.4	1.1	0.8	20/	TKN	ND	ND	ND
92	Ammonia	ND	0.1	ND	93	Ammonia	ND	ND	ND
	Total Phosphorus	0.31	0.07	0.06		Total Phosphorus	0.4	0.09	0.06
	Orthophosphate	0.20	ND	ND		Orthophosphoms	ND	ND	ND
	Daconil	--	< 10.0	< 10.0					
	Bayleton	-	< 10.0	< 10.0					
8/	Nitrate	No Flow	ND	ND	6/	Nitrate	0.11	ND	ND
4/	TKN	No Flow	1.1	1.4	30/	TKN	0.8	ND	ND
92	Ammonia	No Flow	ND	ND	93	Ammonia	0.4	ND	ND
	Total Phosphorus	No Flow	0.07	0.14		Total Phosphorus	0.06	0.17	0.03
	Orthophosphate	No Flow	ND	ND		Orthophosphoms	ND	ND	ND
	Subdue	No Flow	<20	<20.0					
	Dursban	No Flow	< 0.2	<0.2					
	Banner	No Flow	<0.4	0.41					
	Daconil	No Flow	<0.2	<0.2					
	Rubigan	No Flow	< 10.0	< 10.0					
	Chipco	No Flow	<2.0	<2.0					
	Acti-done	No Flow	< 10.0	< 10.0					
9/	Nitrate/Nitrite	ND	ND	ND	7/	Nitrate and			
6/	TKN	1.4	2.3	2.0	20/	Nitrite	0.4	0.2	0.2
92	Ammonia	ND	0.1	0.1	93	TKN	ND	2.3	2.0
	Total Phosphorus	0.2	0.07	0.06		ma	ND	ND	ND

	Turcam (bendiocarb)	-	< 10.0	-
10/ 9/ 92	Nitrate	ND	ND	No Flw
	TKN	1.1	1.4	No Flw
	Ammonia	ND	ND	No Sw
	Total Phosphorus	0.08	0.08	No Fjw
	Orthophosphate	0.02	ND	No Flw
	Turcam	--	< 10.0	No Flw
	Dursban		<0.2	No Flw
	2,4-D		< 1.0	No Flw

Total Phosphorus	0.05	0.28	0.03
I Orthophosphorus	0.04	0.04	0.03

Nutrient results in mg/liter (ppm)
All other results in ug/liter (ppb)
ND = nondetect
Station I - Mow stream
Station 2 - upper lake
Station 3 - lower lake

Detection limits are 0. 1 for ammonia, nitrate, and TKN and 0.1 for total phosphorus and orthophosphate.

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