Does Fertilizer/Pesticide Use on a Golf Course Put Water Resources in Peril?

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NOT TOO LONG AGO, construction of a golf course was considered to be an ecologically sound and practical use of land. It often preserved green space in otherwise intensely developed sites, and provided a recreational opportunity convenient to residents. Golf courses were an extremely popular and environmentally harmonious component of the suburban/urban ecosystem.

What has happened? Why are golf courses now considered by some to be analogous to toxic waste dumps? Of course, the answer to these questions is complex, and probably has more to do with sociological and psychological issues than it does with answers that can be provided by turfgrass scientists and their research.

However, significant research is being conducted to address these concerns. Before discussing this research, it would be prudent to discuss some of the other aspects of why golf courses have created such environmental concern.

Ever since the book *Silent Spring* was published, a pesticide consciousness has prevailed in this country that has led to important and necessary legislation and regulation of pesticide development, sale, and use. However, as the Environmental Protection Agency has stiffened requirements for registration of new compounds, required additional information for re-registration, and identified various contaminated dump sites, the various forms of news media have consistently provided the public with a one-dimensional view of pesticides. From Times Beach to the apple and alar scare, our mass media have tended to sensationalize any story pertaining to pesticides. The death of a navy man who had played golf at Army-Navy Country Club was attributed to pesticide exposure (Daconil). Where was the press when the case was tried in court, and Daconil exposure was ruled out as a cause of death (even to the satisfaction of the widow)?

Such positive information about pesticides is rarely seen by the public, if it ever is. Unfortunately, the public depends heavily on the news media for its daily dose of education. Therefore, opinions about issues are shaped by the articles the public reads or the news stories it sees and hears. As long as doom and gloom are perceived to be

Figure 1.

what the public wants to know, the one-sided presentation of information pertaining to pesticides will continue.

The public's perception of pesticide use is shallow and for the most part uneducated. Most people believe that when a pesticide is applied to anything, it either leaves the site in runoff or seeps into the ground and contaminates groundwater. They have no comprehension of ultra-violet light degradation, volatility, soil and organic matter attenuation, and microbial degradation. The fate of a pesticide applied to any site is an extremely complex arrangement of possibilities that cannot be explained in the simple terms that serve as popular perceptions. Consequently, for the past two decades, almost any use of pesticides has been perceived to cause a negative impact on all aspects of the environment. By association, golf courses, the former providers of green space and natural setting, have been found to be on the hit list of environmental groups.

Twenty years ago, *Golfdom* magazine (Vol. 43, No. 4) published an article entitled "Golf Resort of the Future." The article quoted a National Golf Foundation report that indicated 40 percent of the new golf clubs under construction were part of large real estate developments. This sounds familiar even today, with the country going through a golf course construction boom. The article discussed our mobile society and the need for planned communities. It mentioned lush, rolling, clean, green recreational areas, surrounded by houses and apartment buildings. Emphasis was always placed on the open spaces and the importance of natural settings within any development. Permitting such projects and the likelihood of their approval by planning commissions, zoning hearing boards, and other agencies was enhanced by the inclusion of a golf course. Things have certainly changed. A golf course in a development plan today precipitates concerns about fertilizer and pesticide use, and their impact on runoff and groundwater.

The golf course community has always been concerned about water quantity and quality. In 1968 James Moncrief, Director of the Green Section's Southern Region, wrote about water in the November issue of the GREEN SECTION RECORD. In addition to hydrology and the principles of applying water to land, he discussed groundwater and chemicals in the water. His primary message dealt with being certain of the quantity and quality of available water before irrigation systems were installed.

He was concerned with the health of the turf should it be irrigated with water of inferior quality. The concern today is for whether or not what is applied to the turf unnecessarily degrades the quality of the water emanating from the golf course.

Ironically, in the same GREEN SECTION RECORD issue (in fact, the next article), Dr. A. Robert Mazur, then an agronomist with the USGA and now a turfgrass specialist at Clemson University, published an article entitled "The Fate of Herbicides." The basic thrust of the story dealt with those pesticide issues discussed previously in this article.

Even earlier, in the July, 1964, issue of THE RECORD, Dr. Marvin Ferguson, then Mid-Continent Director of the Green Section, wrote "Pesticides — Boon or Bane?" He credited the use of pesticides for the great deal of progress that had been made in improving the quality of golf courses. He also mentioned the fears of some for the use of pesticides. He concluded that all those involved in the use or commerce of pesticides have an obligation to be aware of the potential dangers inherent in the materials they use. He made the point that all pesticides should be used according to the instructions of the manufacturer, stored safely, and handled with a knowledge of possible effects upon plants, animals, and man. Ferguson's article is just as appropriate and pertinent today.

Most of today's superintendents are well trained and educated in pest management and pesticide use. Even so, it is popularly assumed that pesticides are overused on golf courses because of the "intensive management" required to provide high-quality playing conditions for an increasingly demanding golfing public.

Pest management on golf courses is usually a fairly visible practice, and at times requires sequential applications of chemicals at specific intervals, depending on the pest.

Fertilizer use is also assumed to be relatively high to maintain aesthetic quality and a growth rate that can accommodate wear. It is not surprising, therefore, that some assume turf management has a high potential to contaminate water supplies. It is obvious that research is needed on the effects nutrients and pesticides might have on runoff and leachate.

The Water Quality Research Program at Penn State University

The facilities for this project are located at the Landscape Management Research Center near the main campus of The Pennsylvania State University. The site, located on a variable slope (9 to 14 percent), was formerly used for soil erosion research, and was allowed to return to a natural state for nearly 40 years before being renovated to accommodate this project. The soil is a Hagerstown series, originating from limestone residuum, and typical of the

TABLE 1

Concentration ranges, frequencies, and public drinking water limits of eight nutrients and pesticides applied to turf plots

Nutrient/ Pesticide	Federal Drinking Water Limit	Number of Sample Dates	Number of Dates Not Detectable	Number of Dates Below Drinking Water Limit
Nitrate-N	10 ppm	29	2	28
Phosphate-P	N/A	29	9	N/A
Potassium	N/A	29	1	N/A
Pendimethalin	N/A	24	24	N/A
2,4-D	100 ppb	24	10	20
2,4-DP	N/A	24	12	N/A
Dicamba	210 ppb	24	8	23
Chlorpyrifos	N/A	24	24	N/A

Figure 2.

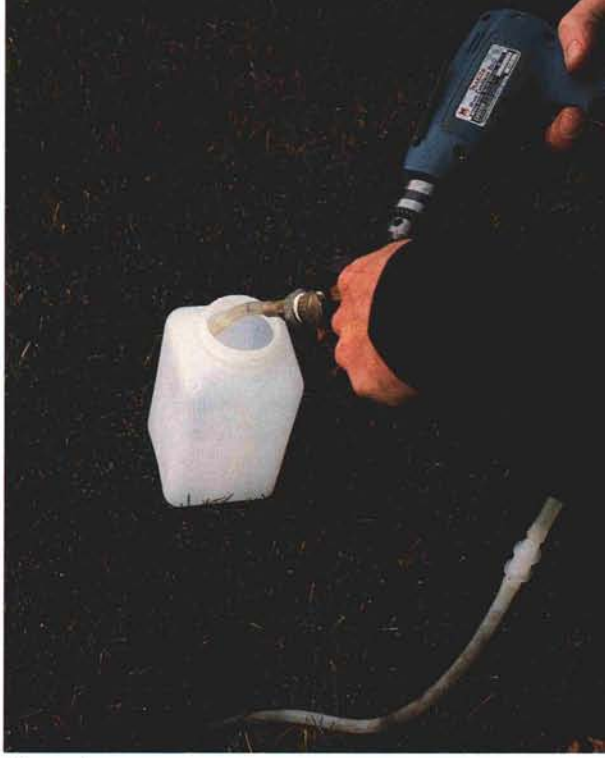

Figure 3.

karst geology found in the Ridge and Valley province of central Pennsylvania. The surface soil was texturally classified as clay (23 percent sand, 36 percent silt, 41 percent clay), based on particle size analysis at the time of tillage.

Renovation of the site took place from 1982 to 1985 and included grading, installation of individual plot irrigation systems, installation of lysimeters in the upper and lower portions of the plot slopes, restoration of collection weirs, fabrication of flow monitor and subsampling equipment, and linkage of automated datalogging and computer systems.

Surface preparation for turfgrass establishment consisted of rototilling (102mm depth), stone removal, rolling, and leveling by hand raking.

Plots were 6.45m by 18.9m and were separated by plastic edging material that extended 102mm into the soil. Edging was laid to eliminate inter-plot surface and near-surface movement of water or applied chemicals. Each plot (Figure 1) contained 21 pop-up sprinkler irrigation heads calibrated to deliver water at a uniform rate of 76mm/hr during 1985. In 1986, the system was fitted with nozzles calibrated to deliver 152mm/hr.

An opoxy-coated concrete weir was positioned at the bottom of each slope to intercept runoff water. The runoff was directed through a galvanized steel chute into a building that housed the flow-monitoring and subsampling apparatus (Figure 2). Pan lysimeter-type subsurface sampling devices (Figure 3) were installed 152mm below the soil surface to capture percolating water. The depth capacity of the samplers was 38mm.

The lysimeters were constructed from round, high-density polyethylene containers filled with 16mm diameter glass marbles as ballast. A piece of polyester geotextile material separating the glass ballast from the overlying soil prevented sediment from entering the lysimeters. Polyethylene fittings at the top and bottom of the containers facilitated venting and emptying the samplers. Water samples were withdrawn through a centrifugal pump.

Inside the building, water from the chute flowed through a polyethylene splitting chamber (for subsample collection) and into a partitioned galvanized steel tank. A length of eight-inch corrugated PVC pipe was suspended below the splitter to act as a baffle to minimize wave formation in the tank. Water accumulating in the receiving side of the tank flowed through a standard hydrologic V-notch into the exit chamber and was pumped to a storage/disposal tank. A float and counterweight assembly was positioned in the receiving side of the partitioned tank and was banded to a pulley attached to a potentiometer. As the float assembly responded to changing water levels in the tank (a function of runoff flow rate), it turned the potentiometer and produced a voltage signal associated with that water level and flow rate.

The voltage signal in each building was read every 60 seconds by a microprocessor-equipped datalogger in an adjacent lab. The voltage signals were converted into flow rates, and the data were recorded on a bulk storage tape drive, accessible by PC communication software. The data collection system could be activated manually, or automatically by the detection of rainfall at an adjacent weather station.

Runoff water for quality analyses was subsampled continuously from the splitting chamber over the course of any runoff event. Water was transferred at a rate of 16ml/min to a liter high-density polyethylene bottle.

Three turfgrass types were established in late June of 1985. The three experimental treatments (establishment method) were: 1) a seed mixture consisting of 25 percent Merit Kentucky bluegrass, 25 percent Julia Kentucky bluegrass, 20 percent Shadow chewings fescue, and 30 percent Citation perennial ryegrass; 2) a contractor's seed mixture containing 60 percent annual ryegrass, 20 percent common Kentucky bluegrass, and 20 percent creeping red fescue; and 3) a three-year-old Pennsylvania Certified 100 percent Kentucky bluegrass sod grown from the following seed mixture: Adelphi (25 percent), Baron (25 percent), Fylking (25 percent), and Nassau (25 percent). All treatments received a complete fertilizer (according to soil test recommendation) at planting. Soil pH was 7.0 and no lime was applied.

Plots were mowed weekly to a height of approximately two inches (clippings removed) during the growing season. Irrigation was not employed as a routine maintenance practice, however scheduled irrigations were used to produce runoff and leachate samples. Mechanical cultivation techniques such as core aeration, slicing, or spiking were not used.

Pesticides included in the study were pendimethalin, 2,4-D, 2,4-DP, dicamba, and dursban. Beginning in 1986, plots were treated with pesticides and fertilizers four times annually as follows:

Spring — Pendimethalin for preemergence control of annual grassy weeds, plus a complete, soluble fertilizer. Early summer — 2,4-D, 2,4-DP, and dicamba for postemergence control of broadleaf weeds, plus urea fertilizer.

Late summer — 2,4-D, 2,4-DP, and dicamba plus chlorpyrifos for the control of insect pest species, plus urea.

Fall — 2,4-D, 2,4-DP, and dicamba plus urea.

Irrigations were conducted approximately one week before and two days after each chemical application in order to produce runoff and leachate samples for analyses of pesticide and nutrient concentrations. Duration was typically 90 minutes for pre-application events and 60 minutes for post-application events. In addition, all natural precipitation events were monitored for the occurrence of runoff and percolate.

Water samples were collected immediately following precipitation or irrigation events for subsequent processing and storage.

Turfgrass quality parameters (color, cover, weeds, and overall quality) were visually estimated periodically throughout the growing season to document the development of the turfgrass, and to determine whether stand quality was related to overland flow. Total vegetative cover was determined as a percent of the total area covered by vegetation (as opposed to stand density counts), and reflects the amount of exposed soil associated with each treatment. Weeds were also assessed as a percent of the total area covered by weed species (not as a percent of the total vegetative complex).

Runoff was much lower than anticipated regardless of establishment method. Runoff from sodded slopes was so low that from 1985 to 1986 the irrigation system had to be redesigned to deliver six inches per hour instead of three inches per hour. This change was required to develop hydrographs and provide subsamples for nutrient and pesticide analyses. The likelihood of six inches of natural precipitation occurring in central Pennsylvania is extremely remote. In addition, this simulated storm was imposed 48 hours after the application of fertilizer and pesticides.

Three years after establishment, slopes that were sodded still had significantly less runoff than those that were seeded. When infiltration rates were measured, sodded slopes had significantly higher rates than those that were seeded. It was concluded that sodding, as an establishment technique, provided protection for the surface soil structure. Rainfall and irrigation that fell on the site during establishment compacted the surface of seeded slopes, and this effect has persisted throughout the study. Certainly, other factors (stand density, thatch, species differences, etc.) contributed to the runoff differences.

The effect of nutrient and pesticide transport in water is largely a function of ambient concentrations of these potential contaminants and the sensitivity of non-target species. These data provide evidence of the relative transport potential of eight nutrients and pesticides, and should also be useful in predicting transport properties of chemically similar substances. This research did not define the interaction of each compound with the various environmental factors that affect the eventual fate of a given material. The rates of transport of the nutrients and pesticides examined in this study were very low, however, especially considering the amount of irrigation used to produce runoff. In addition, the transport calculations were based on concentrations determined for the treated site.

As a point of reference, U.S. Public Health Administration drinking water standards and measured concentration frequency data are shown in Table 1. The dilution effect of runoff occurring from impervious areas in actual watershed circumstances was not considered. Actual stormwater outfall concentrations of these pesticides and nutrients would be significantly less than the levels found in this study. It should be noted also that in almost all cases where pesticides were detected, the levels were lower than what is allowed in drinking water.

Conclusion

To the degree that the site employed for this project is representative of other turfgrass sites in central Pennsylvania, the impact of well-managed turfgrass on water quality appears to be positive in nature, based on the hydrologic characteristics of all three cover types and establishment methods studied. The results indicate that dense, high-quality turfgrass stands, regardless of establishment method, affect the overland flow process to such a degree that runoff is insignificant. The ability of this type of vegetative community to allow water to infiltrate and promote the metabolism of solutes suggests it might possess the ability to be employed as a water quality treatment medium.

Establishment and maintenance of turfgrass of high quality is not realized without management inputs, which include quality construction techniques, limited use, and cultural requirements, including nutrient and pest management. Levels of management inputs required to produce the turf quality necessary for positive water quality impacts have not been determined. The range of uses and existing conditions for already established sites illustrates the complexity of the situation.

It is probably safe to assume, though, that many poor-quality turfgrass areas are not recipients of sound, professional management. Although these sites may not exhibit the infiltration capacity of high-quality turf, nutrients and pesticides are less likely to have been used on them.

Last, much of the highly managed turfgrass in the United States is maintained in regions of varying degrees of urbanization. Considering the magnitude of runoff contributed by impervious surfaces, and the fact that treated turfgrass acres in those watersheds constitute only a portion of the pervious fraction of the landscape, dilution of low-level spikes of nutrients and pesticides would certainly occur. Acceptable background levels of these materials in surface water have not been determined. It is likely, however, that their concentrations in stormwater and impact on receiving bodies of water would be considerably less than other urban pollutants not associated with well-managed turfgrass areas.

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