Nutrient Leaching Concerns in Turf Management

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It is impossible to overstate the importance of groundwater supplies to our nation. Groundwater, the water pumped from wells below the soil surface, presently accounts for 50% of our nation's drinking water. In rural areas, 95% of drinking water supplies come from groundwater. Protecting this non-replaceable natural resource should be a priority of every citizen.

There are many chemicals that can be considered potential contaminants of groundwater. The list usually includes pesticides, leachate from landfills, organics (such as cleaning solvents, gasoline, and oil), and nitrates from septic fields or fertilizers. The issue having the potentially greatest ramifications for Turfgrass is nitrates from fertilizers.

Nitrates have been associated with several environmental problems including surface water quality (eutrophication), productivity of both managed and natural ecosystems, acid rain, and the depletion of the stratosphere ozone by nitrous oxides. When one considers groundwater as a major drinking water source, however, the effect of nitrates on human health is the greatest concern. The list of potential health risks associated with nitrates includes birth defects, cancer, nervous system impairments, and the "blue baby" syndrome, or methemoglobinemia, which is the major health hazard of consumption of nitrates. Methemoglobinemia occurs when nitrite reduces the oxygen-carrying capacity of the blood. This condition occurs most often in infants less than 3 months old who are not on solid foods. Citrus fruits or Vitamin A supplements reduce the chance of methemoglobinemia. Older children or adults are generally not affected by nitrates (or nitrites) in water or food. About 86% of the adult intake of nitrates comes from vegetables and only 1% from water. The average person in the U.S. consumes 22.5 mg (0.0008 ounces) of nitrate-N per day.

The US EPA recommends the maximum concentrate limit of 10 mg of nitrate nitrogen per liter, or 10 ppm, in drinking water. The lowest level recorded to cause a health problem was 20 mg nitrate-N per liter. There have been virtually no reports of methemoglobinemia in the US in recent years. One recent report (1982) concerned a 6 week old infant whose formula was prepared with well water containing 121 mg nitrate-N per liter. The symptoms quickly disappeared when the well water was no longer used.

The other health-related effects of nitrates in drinking water have not been widely confirmed and are considered more speculative in nature. Thus, new research will have to show a clear health risk before stronger measures will be taken to reduce the nitrate levels acceptable in drinking water.

Historical Perspective of Turfgrass Fertilization and Ground Water Quality Problems

In the early 1970s, one of the first parts of the country to find high nitrate levels in municipal drinking wells was Long Island, NY. With about 28% of the land area of Long Island's two counties (Nassau and Suffolk) being used in turfgrass culture, coupled with a high average rate of nitrogen applied (2.3 lbs N/1000 ft^2/yr), implications were made that turfgrass fertilizers contaminated groundwater. The controversy was further fueled by preliminary research results. A study done on a "lawn type" turfgrass situation showed that between 20-80% of the nitrogen applied was accounted for by plant uptake. The conclusion was that an average value of 50% of the nitrogen fertilizer applied ended up in the plant, and the rest would leach (Selleck et al, 1980). It was assumed that nitrates not taken up by the plant must leach into the groundwater.

In the last 10 years a wealth of knowledge has been generated to further understand the fate of nitrogen applied to turfgrass. Even though about half of the nitrogen applied to turfgrass does end up in the plant, the other half can be found either stored in the soil, lost to the atmosphere, leached into groundwater, or transported as runoff into surface water.

Fertilizer nitrogen found to be stored in the soil and thatch was shown to be between 36-47% of the amount applied (Starr and DeRoo, 1981). Nitrogen lost back to the atmosphere from an application to a turfgrass site occurs from 2 different processes: ammonia volatilization and denitrification of nitrate. If urea is used as the fertilizer source, ammonia volatilization can be as high as 40% of the fertilizer applied (Nelson et al, 1980). However, if weather conditions are dry or the urea is irrigated in, the losses are almost zero (Bowman et al, 1987). Research on denitrification as related to turfgrass is limited to only one report which noted that on soils that are either cool ($\leq 68°F$) or not saturated, little or no denitrification occurred. However, on warm soils ($> 86°F$) that were saturated, 93% of the applied nitrogen was denitrified and lost back to the atmosphere (Mancino et al, 1988). It is fair to say that, on average about 25-35% of the fertilizer nitrogen applied may be lost back to the atmosphere, especially if urea is used as the nitrogen source.

The controversy of nitrates in groundwater as it relates to a specfic turfgrass use like golf courses centers around the nature and management of golf course turfs. When people think of greens and tees, some think of very sandy, highly modified soils which drain very easily, are heavily irrigated, and do not hold nutrients. Added to the perception that golf courses use heavy amounts of fertilizer it is easy to see how some people might conclude that golf courses contaminate groundwater with nitrates. There are a number of weaknesses in this conclusion. First, the highly sand portions of most golf courses are confined to greens and possibly tees, though this is usually true on courses older than 20 years. This relates to about 2 to 4 acres of the 60 to 100 acres of turf on a "typical" 18 hole golf course. To put this in perspective, for a state like New York with approximately 1,000 golf courses, there would be about 2,000 acres of greens and tees out of a total of 30 million acres in the state, or 0.00007% of the land area. Comparing this with lawns (700,000 acres or 2.3%) or cropland (6 million acres or 20%), the portion of golf courses having the highest potential for nitrate leaching represent an insignificant threat to the environment as a whole.

Second, research information on greens-type sites containing high amounts of sand do not support the conclusion that golf courses are prone to heavy nitrate leaching, especially with today's trend toward lower nitrogen use rates and the use of slow release sources. Early work done on USGA specification greens of Bermudagrass (Brown et al, 1982) found that 22% of the fertilizer, in this case ammonium nitrate applied at an excessive rate of 3 lbs/1000 ft^2 in February, leached in the first 50 days after it was applied. However, when rates of nitrogen more typical of standard maintenance practices were applied (1 to 1.5 lbs per application) to straight sand greens of either bentgrass or Bermudagrass, nitrate leaching was only 1-2% of the amount of nitrogen applied, (Sheard et al, 1985 and Synder et al, 1981) even for urea. In the case of Bermudagrass (Synder et al, 1981), the average concentration of nitrate in the drainage water was 0.2 mg nitrate-N/l, far below the safe drinking water standard of 10 mg/l.

Third, research findings from sites with less sandy soils, more typical of fairways, older greens and tees, roughs, and general lawn area sites, further support the conclusion that Turfgrass <u>does not</u> contaminate groundwater with high levels of nitrates. In an unirrigated (Starr and DeRoo, 1981) or conservatively irrigated "lawn type" site with season-long fertilizer rates of 4 lbs N/1000 ft^2 or less (Morton et al, 1988), nitrate levels leaving the root zone were not significantly higher than those of unfertilized plots.

Fourth, when research does show nitrate leaching from turfgrass areas, that leaching fortunately lends itself to being controlled by the best management practices. These situations most often occur as follows: when excessive nitrogen amounts are used (Brown et al, 1977), more often when highly water soluble nitrogen sources are used (urea, ammonium nitrate, ammonium sulfate or potassium nitrate [Synder et al, 1978]), when nitrogen fertilizer is applied in a dormant or semi-dormant period of limited plant uptake and greater water percolation through the soil (Petrovic et al, 1986 and Synder et al, 1984) and where excessive irrigation has caused greater amounts of leaching (Snyder et al, 1984, Brown et al, 1977, and Morton et al, 1988).

<u>Managing Turfgrass to Minimize Nitrate Leaching into Groundwater</u>.

There are several factors important in determining the leaching potential of a fertilizer applied to turf. These factors include: the source of nitrogen and how readily available or soluble it is, the rate of application, the season of the year of the application, irrigation practices and soil type. Fortunately, a turfgrass manager has control over the first three factors; thus, nitrate leaching <u>can be</u> kept near zero or at least at an acceptable level. What follows is a discussion of these factors as they relate to Turfgrass management.

Nitrogen Sources

Understanding the various nitrogen sources is essential to minimizing the nitrate leaching problem. The worst possible situation occurs when a large amount of water soluble nitrogen is present in the soil and a substantial volume of water passes through

Table 1. The properties of nitrogen sources used on golf courses.

Nitrogen Source	Type	Percentage Nitrogen	Low* Temp. Response	Initial** Response	Residual† Response	Water‡ Solubility	Foliar‡ Burn Potential	Acidifying‡ Potential	Leaching Potential
Ammonium nitrate	Synthetic inorganic	33	G	F	L	H	H	M	H
Ammonium sulfate		21	G	F	L	H	H	H	H
Activated sewage Sludge (Milorganite)		Natural organic		4-7	M-P	M-S	E	L	LLL
Digested sewage		1-3	M-P	S	E	L	L	L	L
IBDU	Synthetic organic		31	M	M-S	M-E	L	L	LM
Urea		45	G	F	L	H	H	M	H
Ureaformaldehyde		38	P	M-S	E	L	L	L	L
Sulfur-coated urea		32	M	M	M-E	M-L	L	M	M

* G, Good; M, Moderate; P, Poor
** F, Fast, M, Medium, S, Slow
† E, Extended; M, Moderate; L, Little
‡ H, high, M, Moderate, L, Low

the soil. There are two ways to avoid this situation. One is to use slow release nitrogen sources that control the amount of soluble nitrogen present at any one time. The second involves very light, but frequent, surface applications of soluble nitrogen sources; this may be done by using standard application procedures or by fertigation. Nitrogen sources that release nitrogen at a slow rate are called slow release nitrogen sources. The slow release property is sometimes a result of synthetic or natural organics requiring microbial activity to convert the nitrogen to a plant available form. In some cases, water very slowly dissolves the nitrogen. Finally, the slow release property can be due to the soluble nitrogen being physically protected with a coating. Table 1 summarizes the properties of the major nitrogen sources used for turfgrass fertilization.

One practice a Turfgrass manager can adopt is the use, whenever possible, a slow release nitrogen source to protect against an uncontrollable event which could lead to unusually high potential for leaching. Such an event occurs, for instance, when a significant amount of rainfall (1" or 2") is encountered within several days of applying a highly soluble nitrogen source at the high rate of 1 lb N/1000 ft^2. Another sound practice is to apply a soluble nitrogen source frequently, but at a lower rate (1/10 to 1/4 lb N/1000 $ft^{2)}$. This "spoon feeding" approach avoids substantial leaching, even from sources that have a high potential for leaching.

So why not use only slow release nitrogen sources to protect groundwater quality? In general, the slow release nitrogen sources give poor to moderate response in cool weather. In such weather, therefore, it is necessary to use highly soluble nitrogen sources. Slow release nitrogen sources generally are also more expensive and are usually applied in a dry form, which under some circumstances is inconvenient. If the turfgrass manager superintendent is following the "spoon feeding" approach, it would be more appropriate to use highly water soluble nitrogen sources. However, on less highly managed turfgrass sites the golf course that are fertilized (fairways, roughs and grounds areas), it may be wise to use slow release nitrogen sources exclusively in order to reduce the potential for nitrate leaching.

Nitrogen Application Rates and Timing

One of the major goals of any fertilizer program is to provide the "optimum amount" of a given nutrient necessary to sustain the desired response. The "optimum amount" can vary from site to site and from grass to grass within a given site. Thus, general fertilizer programs have been broadly developed, recognizing the need for local adjustment. There has been a trend over the past 10 years to reduce the total yearly amount of nitrogen fertilizer applied to some turfgrass sites. This has occurred in response to a variety of concerns including the desire for a fast putting surface, the need to reduce maintenance costs, the relationship between higher nitrogen levels and the plants ability to withstand environmental extremes and an increased awareness of environmental concerns.

From a groundwater quality perspective, the time of year to avoid fertilizing with higher amounts of soluble nitrogen is when the temperatures are cool (reflecting little or no plant uptake) and precipitation is plentiful. Generally, this occurs in late fall (November-December) for cool-season grasses and early spring (February) for warm-season grasses. At this time more water is percolating through the soil into the groundwater, the plant is not taking up much nitrogen, and only limited amounts of nitrogen are being tied up by microbes. The net result is a much greater potential for substantial nitrate leaching. If nitrogen must be applied at this time, the turfgrass manager should use either lower rates of soluble nitrogen sources or use slow release sources.

Irrigation Management

Proper irrigation is extremely important. First, it is obvious there is a need to conserve and manage our fresh water supplies. Second, irrigation, and particularly over-irrigation, results in significantly more nitrate leaching under some conditions. Therefore, in terms of water conservation and water quality, proper irrigation is critical.

An efficient irrigation program is one that relies on a well designed and installed system and a procedure for adjusting irrigation events based on rainfall and plant water needs. The former is the responsibility of the designer/contractor, while the latter is under the control of turfgrass manager. Programming of the irrigation system should be based on replacing the amount of water which is used by the plant and not supplied by rainfall. This implies that no water is wasted through over-irrigation and that soluble chemicals, such as nitrates, do not leach. The turfgrass manager must use the latest technology available to make the irrigation programs as efficient as possible. Such technology includes irrigation controllers directly linked to instruments such as rain gauges, tensiometers, or to other data related to evapotranspiration. This information can then be used to support the irrigation program.

Other Approaches

There are several other approaches to consider to reduce potential nitrate leaching. These include the following: utilizing grasses or other plants which have a low nitrogen requirement; collecting, treating, or recycling runoff or drainage water; and amending soils to retain nitrogen. These should be considered as minor in comparison to the previous section, but can be a valuable part of an overall plan to reduce the potential for nitrate leaching.

One approach to limit the potential of nitrate leaching is to reduce the total amount of nitrogen applied to given site. This can be accomplished by either decreasing the amount of land devoted to higher nitrogen-requiring grasses, or by using lower nitrogen-requiring grasses. Reducing the size of fairways and roughs as an example is a start in the right direction. Utilizing grasses, where applicable, with a lower nitrogen requirement can also accomplish this goal. A list of the relative ranking of the nitrogen requirements of common turfgrasses is shown in Table 2. Wherever possible, grasses with lower nitrogen requirement should be used.

Table 2. Nitrogen requirement ranking of turfgrasses.

Low	Moderate	High
red fescue	perennial ryegrass	
chewings fescue	Kentucky bluegrass	
hard fescue	Annual bluegrass	
tall fescue		--------Creeping bentgrass------------------
------------ colonial bentgrass ---------------		
---------------- zoysiagrass --------------------		

Many new golf courses and other turfgrass sites are also using native plants, wild flowers, or ornamental grasses in non-play areas. Generally, these plants are beneficial because they need lower amounts of water and nutrients (especially nitrogen), and require less mowing. The use of these plants can make the game more challenging and can make the course more aesthetically appealing. Most importantly, these plants help to conserve natural resources.

There are other physical systems that can be incorporated into an overall water quality management program. Included in this are collecting and possibly treating surface runoff and subsurface drainage water. Research to date, concludes that runoff from turfgrass sites has not been shown to not be a big problem. Where runoff appears to be a problem, attempts could be made to intercept the water. Providing a level "grassed" intercept zone just below the sloped site would encourage infiltration of the water into the soil. A catchment system could also be used to hold runoff; such a system could be linked with the irrigation supply to recycle the runoff. Before an extensive system of this nature is installed, it must be shown that a problem does exist. For almost all situations this drastic of a measure is not necessary.

New golf course construction, where drainage systems are being installed, provides an opportunity to collect and recycle drainage water which could contain trace amounts of either nutrients or pesticides. Recycling of water by applying it back to the turfgrass surface will put any chemicals in the water through the natural biological filter and not into groundwater. The holding and recycling of drainage water may require the development of new technology. With regulations in some parts of the country requiring a "zero" level of any contaminate reaching the groundwater, mandatory drainage water recycling systems may be a way of life in the near future.

Amending sand for putting green construction may prove to be a valuable means of reducing nitrate leaching. Sand, by nature, does not absorb nutrients (low cation exchange capacity), especially the inorganic forms of nitrogen (ammonium and nitrate) as well as potassium. Most sources of nitrogen fertilizers generally go through a conversion from ammonium to nitrate (nitrification). Ammonium, being a cation (+ charge), is held in soils having a high cation exchange capacity (not sand). Nitrate, on the other hand, is an anion (- charge) and is not held in soil, so it is easily leached if water is passing through the soil. The ideal amendment would stop nitrogen from leaching but still allow the green to have the physical properties of good drainage and aeration, and to resist compaction. Clay has good cation holding properties but would destroy the physical properties of the green. One material potentially meets both criteria - natural zeolite. One natural zeolite called clinoptilolite, is a secondary mineral with a high silica content formed from volcanic rock. Major deposits of clinoptilolite are found in the western part of the U.S. Clinoptilolite can be crushed and screened to sand-size particles with good physical properties and a cation exchange capacity like clay. Initial studies have shown that the physical properties of sand mixtures containing 5% clinoptilolite, are maintained at the same time that the clinoptilolite protects the ammonium from being converted to nitrate (Ferguson et al,1988). Large scale field testing is now underway to determine to what extent clinoptilolite-amended sand will resist nitrate leaching.

Summary

As shown in this article, turfgrasses can easily be managed so that nitrates from fertilizers do not contaminate groundwater supplies. The following are practices which can accomplish this goal:

1. Apply frequent light rates of nitrogen, or

2. Use slow release nitrogen sources, even though they may be more costly.

3. Avoid fertilizing at times of the year when turfgrass is naturally slow growing, especially in cool weather.

4. Conservatively irrigate to both save water and reduce leaching.

5. Reduce the scope of the "heavily managed" areas and use less energy- demanding plants where possible.

When one compares these practices to traditional row crop agriculture, turfgrasses are far less likely to contaminate groundwater with nitrates. The following are typical row crop agricultural practices:

1. Only 1, possibly 2, nitrogen applications per growing season.

2. Single application rates up to 4 times higher than turfgrass.

3. Only highly water soluble nitrogen sources are used due to the high cost of slow release nitrogen sources.

4. Irrigation is often not as highly controlled as that found on turfgrass site, thus resulting in a greater potential for leaching.

5. Less diffuse and extensive surface root system to take up nutrients.

One study has compared the nitrate leaching losses from "lawns" and from row crop agriculture. Corn leaching losses were 36% of applied nitrogen fertilizer as compared to 12% for turfgrasses grown on similar soils with similar irrigation practices (Gold and

Sullivan, 1988). Thus, row crop agriculture resulted in 3 times more nitrate leaching than turfgrass.

In summary, turfgrass has have been viewed by some as having a negative impact on the environment. With good management practices, groundwater quality can be protected from nitrate contamination.

Suggested Further Readings

For more detailed technical information than presented in this paper, please refer to these publications:

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