The principal environmental concerns over turf culture fall into two general categories. First, and of greatest concern, is the introduction of toxic chemicals into the domestic landscape through the use of synthetic fertilizers and pesticides. These are viewed as a threat to the health of people through direct contact at time of application and indirectly as contaminants of ground and surface waters which are often used as domestic water supplies. The second is a concern over the wisdom of using scarce resources, e.g. water, energy and plant nutrients, for the growing of turf when they could be used for more critical purposes. When such resources become truly limiting, it is argued, turf and landscape maintenance must be assigned a lower priority than agricultural, industrial or critical domestic uses. Thus turf and landscape maintenance with its heavy reliance on water, chemicals and energy is not sustainable in a resource limited society.

Are these concerns legitimate? Is it inevitable that turfgrass management must change dramatically in the years ahead? Does turfgrass science have anything to say about these questions?

As with most environmental questions, it is difficult to respond with a definitive yes or no. It might be better to analyze the nature of the concern and determine what issues are supported by science and what are not. The questions outlined above are too large and complex to be treated in a single issue of *Turf Grass Trends*, so I will concentrate on a single concern in the belief that it is fairly typical of the turfgrass environmental controversy. Nitrate leaching from turf and its role in water pollution is representative of turf management concerns.

The alarm is sounded

Is there any basis for concern over nitrate washing out of turf and contaminating domestic wells and underground water resources or is this issue a creation of environmental extremists? In many rural and suburban areas of our country more than 50% of the population depends on private wells drawing on subterranean aquifers as its sole water supply. Even many small-to medium-sized cities draw much of their water from underground supplies which are replenished in part by rainfall percolating through the overlying soil. There is no question that ground water resources are important and that the maintenance of their quality is essential to the stability and growth of many communities. So the concern over ground water quality is valid. The question is: how much of a threat to water quality is the growing of turf on soils overlying ground water reserves?

The first serious questions over the environmental soundness of turf management were raised by suburban communities on Long Island, New York. During the 1950s and early 60s, an alarming increase in the nitrate content of water from many domestic and small municipal wells was observed. The U.S. Public Health Service had determined that nitrate-nitrogen levels greater than 10 parts per million (ppm or mg/L) posed a health risk especially to newborn babies. Nitrate can bind to the hemoglobin of the blood reducing its capacity to carry oxygen. This can cause a kind of asphyxiation called methemoglobinemia. Small children and babies are most susceptible to this poisoning where it is known as the "blue baby" syndrome. Thus when wells began to approach or even exceed the 10 ppm nitrate-nitrogen limit, people became justifiably concerned. The open question was not over the presence of nitrate in well water but over its source.

Because children's health was at stake, rational discussion did not always prevail. It soon became

Arguments against threshold nitrogen applications

by Dr. Richard Hull

In many discussions of nitrate leaching from turf, the concept of threshold application rate is introduced. As I understand it, a threshold rate of nitrogen fertilizer is the largest amount which when applied will not cause an increase in soil water nitrate and, therefore, will not promote nitrate leaching. It is stated that so long as the threshold rate is not exceeded, nitrate leaching will not occur and ground water quality is not endangered. Apparently it represents the amount of fertilizer nitrogen that can be absorbed by grass roots and soil microbes without causing excess nitrate to accumulate in the soil water.

Personally, I do not like the threshold concept. To be sure, several investigators, myself included, have applied nitrogen at several rates and observed that at a specific rate, soil water nitrate levels increased. Below that rate, nitrate remained constant and low. There obviously was a threshold rate which when exceeded caused nitrate levels to increase. The problem I have with the threshold rate is that it is different for every form of nitrogen used and every grass to which it is applied. It also will change dramatically with the time of the growing season.

A slow release nitrogen source will have a higher threshold rate than will a readily soluble material and its threshold rate will be greater than recognized that there were three likely sources for the increased nitrate: agricultural fertilizers, leach field releases from domestic septic systems and fertilizers used on home lawns, golf courses, etc. Because these communities had been largely agricultural for many years, it was initially concluded that leaching from potato and vegetable farms was not a likely source of the nitrate in wells. On the other hand, residential and commercial development had increased dramatically in eastern and central Long Island so that seemed a more likely source of the problem. In response, many communities installed municipal sewage systems to eliminate their reliance on individual septic tanks. However, this often did not result in a significant lowering of the nitrate content in well water. Attention was then turned to lawn fertilizers as the only remaining source of nitrate contamination. The Long Island problem was of course experienced by other communities but more importantly the alarm had been sounded.

Many suburban residents became convinced that they would eventually have similar nitrate problems and that lawn maintenance was the cause. This has resulted in local ordinances restricting lawn size or the amount of fertilizer that can be used to maintain turf. Golf courses and sod farms are specifically excluded from the list of acceptable land uses in many ground water sensitive areas of the Northeast and elsewhere.

Evidence revisited

The evidence which implicated turf fertilizer use as the cause of well contamination by nitrate can now be viewed with a bit more objectivity than was possible during the 1960s. Much research has been reported and the science of environmental monitoring and cause-and-effect assessment has become much more sophisticated. One problem with many of the early reports on nitrate contamination of domestic wells was a lack of valid controls. Before one can suggest the source of contamination, one must know what the background level of the contaminant is and from that calculate the amount of increase attributable to a specific land use. Such background readings should be of water upstream from the site under study. To determine upstream for subterranean aquifers, detailed ground water maps are needed; a tool not always available when well contamination was first studied.

Land use in most urban/rural interface areas is such a mosaic of residential, commercial, agricultural and unused or forested lands that it is all but impossible to ascribe contaminants found in a well to any specific land use category. That is surely true of nitrate which is contributed to ground water in some quantity by every land use. This was demonstrated in studies of nitrate contamination in ground water using the relative abundance of the natural heavy isotope of nitrogen: ^{15}N. Nitrogen-15 exists in nature as 0.366% of atmospheric nitrogen; the remaining 99.634% being the lighter ^{14}N isotope. When synthetic fertilizers are made from atmospheric nitrogen, they contain 0.366% or less ^{15}N. As nitrogen compounds react with biological and chemical processes in the soil or within organisms, the lighter ^{14}N is often preferentially lost in various gaseous forms (N_2, N_2O, NH_3) and the remaining nitrogen becomes enriched in the heavier ^{15}N. (See figure on page 1.) Thus nitrogen from animals present in manure normally contains between 0.370 and 0.375% ^{15}N. These small differences in the ^{15}N content of different nitrogen sources was used as a means of identifying the origin of nitrate present in well water. Preliminary studies using clearly defined watersheds in agricultural areas suggested that nitrate

a nitrate salt. That seems obvious enough but it can be complicated by the fact that the rate at which slow release materials are oxidized and release nitrogen to solution depends heavily on soil temperature, moisture status, and microbial activity which is linked to available organic matter. Thus, the same fertilizer might show greatly different threshold levels when applied on the same day to turf growing under differing conditions on different soils. We have also demonstrated that turfgrass species and cultivars of a species differ in their efficiency of nitrate uptake. That means a fertilizer will show a lower threshold application rate when used on an inefficient grass and a higher rate on a grass that absorbs nitrate more readily. Under northern conditions, turfgrasses absorb nitrate much more effectively in the spring than they do in late summer and early fall. We observed marginal increases in soil water nitrate following a 5 lb/1000 sq-ft application of urea-N made on May 15th. In early September, the same plots experienced a marked increase in soil water nitrate following a urea application of 1 lb N/1000 sq-ft.

So, under any given set of conditions at a specific time of the year, a threshold application rate can be determined for any nitrogen fertilizer However, of what use is this value to the turf manager if it can change by several hundred percent under different conditions and at a different time? Consequently I see little value in reporting threshold rates for nitrogen fertilizers because they are so unique to a given set of conditions and of no practical use to the turf manager. It is far better for a manager to understand the principles behind nitrate leaching than to base fertilization practices on a notion of threshold application rates. ■