Potential Contributions of Urban Vegetation to Phosphorus in Storm Water

By Oscar J. Peterson

Lake eutrophication becomes a hot topic in Madison every year because of highly publicized algal blooms in lakes Mendota and Monona. The media has often aired some misleading accusations as to the causes of the problem. Last fall I became interested in the issue when a classmate assaulted golf courses and lawn care companies as the root cause of lake eutrophication. This led to my examination of the problem and the conduct of some research that I saw as being needed to fill in some gaps in our knowledge of the sources of phosphorus in urban landscapes.

BACKGROUND

Lakes start out being oligotrophic, meaning that they are low in nutrients, clear, rich in oxygen and generally unproductive with regard to aquatic life. As time passes, the water becomes more and more nutrient enriched, aquatic plant life increases, oxygen levels in the water decline due to plant respiration and decay, and the lake slowly fills with sediments. As this happens, lakes become eutrophic. Oxygen becomes limiting to game fish, the water becomes murky, filled with weeds and algae and the lake is unappealing for recreation purposes. Understandably, people want to stop, or at least slow this natural process.

The rate at which eutrophication occurs depends on many different variables: depth and size of the lake, climate, geography, surrounding land use and vegetation and amounts of nutrients annually added to the water. Of these, nutrient supply is the one where control is most realistic. This typically leads to restrictions or regulations regarding sediment control, boundary vegetation and fertilizer use.

Nitrogen and phosphorus are the two most important nutrients. But it should be noted that the sources of these nutrients are not entirely or, perhaps even predominantly the product of human activity. When the Department of Natural Resouces rated 12 state lakes, Mendota ranked fourth as being naturally eutrophic (11). In other words, Lake Mendota would be eutrophic even if man and all of his influences were excluded.

Because of the vast amounts of nitrogen that cycles through the environment and the high mobility of the nutrient, nitrogen is seldom the limiting factor in algae and weed growth. In more than 80% of Wisconsin lakes phosphorus is the limiting factor (3). There are several reasons for this. One is the low solubility of P in water. The nutrient rarely leaches because of the formation of insoluble calcium, iron and aluminum precipitates (10). In fact, one way to inactivate P in is to add chemicals that contain aluminum (9).

The sources of P entering lakes can be split into two major categories: natural and man-induced. Natural sources can come from vegetation, precipitation, wildlife, fish and the weathering of lake sediments. The contribution from precipitation is usually small. For Lake Mendota, precipitation is thought to contribute less than 2% of the annual P input (3). On the other hand, wildlife can contribute substantial amounts of P. One study reported that ducks add almost 400 grams of P per duck per year (3). Fish, bottom feeders in particular, release and recycle P in lakes. Phosphorus stored in bottom sediments gets stirred up by fish, thereby making sediment P accessible to algae (1). Removal of bottom-feeding fish, especially carp, has been tried as an algae control measure in some small lakes, as has dredging of the sediments.

Major man-induced P sources come from multiple sources: fossil fuels; untreated sewage; fertilizers; manure; erosion; and decaying plant material. Not long ago, sewage was a main source of P in lakes. With the introduction of P-free detergents and mandatory sewage treatment, this is no longer the case. Conservation tillage and other erosion control practices have reduced agriculture's contribution of P to lakes. Turf fertilizers are now thought by many people to be a major P source and have recently received the brunt of the media's attention. These accusations ignore

the growing body of scientific literature regarding the effects of fertilization on P loss from managed turf and other sources of P in urban environments.

Runoff losses of P from fertilized lawn-type turf in the Madison area have averaged less than 0.12 lb/acre and more than one-half of the loss occurred from frozen soil (6). Even if all of this P were attributed to the fertilizer applied, it would still amount to less than 0.7% of the fertilizer P applied. Runoff loss of P from a golf course fairway receiving eight applications of P-bearing fertilizer per year was no greater than that found in the irrigation water itself (7). From these two studies it becomes evident that P losses from turf are typically very small and fertilizer may very well not be the primary source. Even if the contribution of P from turf fertilizer were notable, the total impact in urban settings is questionable. One short-term study in Madison has indicated that only about 14% of the P in storm water can be attributed to home lawns during the growing season (2).

Numerous studies have shown that there are two peaks in the P in urban runoff: at the time of snowmelt and late in fall. The fall peak in P coincides with the time of leaf fall (4). Since these are times of the year that lie outside the normal schedules for turf fertilization, one has to question the sources of the P. The most logical source of P in snowmelt is surface plant residue. One study has shown that the P in tree leaves is subject to leaching (4). The same may be true for turfgrass leaves. It is this aspect of potential lake eutrophication that interested me because it is such an obvious source of P and has received little attention.

RESEARCH

In the fall of 1994 clippings from Kentucky bluegrass and creeping bentgrass and fallen leaves from white pine, burr oak, Chinese elm, Russian mulberry and sugar maple were collected and brought into the laboratory. Amounts of water soluble P were measured in the fresh grass clippings, air-dried clippings, frozen clippings and clippings frozen and then air-dried. The same P determination was made on air-dried leaves, leaves that were frozen for 8 weeks and leaves that were allowed to decompose for 8 weeks at 90° F. The purpose of these various treatments was to simulate fall, winter thaw, and spring leaching of P. Total P content of the grass and leaf samples was measured to allow calculation of the percentage of tissue P that was leachable.

RESULTS AND DISCUSSION

Percentages of leachable P in the turfgrass clippings varied with the source of the clippings and treatment prior to extraction of the P (Table 1). More P was leached from the creeping bentgrass clippings than the Kentucky bluegrass clippings. This may be because the bentgrass clippings were much finer and had a higher percentage of cellar contents exposed for P extraction. Air-drying, freezing and freezing plus air-drying progressively increased the percentages of total P in the grass clippings that were soluble in water. This progression clearly indicates that grass residues are most prone to leaching loss of P in the spring of the year. Clippings subjected to simulated overwintering released 3 to 4.5 times more P than did the fresh clippings.

Tree specie seemed to have a big effect on the the percentages of P that leached from the air-dried leaves (Table 1). These ranged from a low of 5.5% for burr oak to 33% for Chinese elm. Freezing of the leaves prior to water extraction of P greatly reduced the percentage of P removed from the Chinese elm leaves, but had little effect on the other species. Partial decomposition of the leaves had the effect of generally reducing the percentage of P that was leachable. This surprising result may be explained by the fact that tree leaves are relatively nutrient poor as far as microbial decomposition is concerned. It is entirely possible that leaf P was immobilized as microbial P during the decay process. From these observations, the conclusion is that more P will be leached from tree leaves in the fall than in the spring.

The total concentrations of P in the grass clippings and tree leaves and the amounts of P leached are presented in Table 2. The concentrations of P in the Kentucky bluegrass and creeping bentgrass clippings differed by only 170 mg/kg, or 0.017%. Yet, the amounts of P leached differed 2- to 3-fold. This supports the earlier assumption that finess of the clippings has a much greater influence on P leachability than does total P content. This also indicates that changes in clipping P concentration as a result of fertilization will not have much effect on the amounts of P leached from grass clippings.

The amounts of P leached from the grass clippings and tree leaves provide some basis for estimating their potential contributions to urban runoff water. To do this, one has to come up with some estimates of the dry weights of tree leaves and the dry weight of tissue on the surface of a good quality turf when snowfall occurs. For 20-year old trees, the leaf dry biomass for deciduous trees is in the range of 7.5 kg (personal communication, Prof. T Gower, Forestry Department). Assuming these leaves fall to occupy an area of approximately 1,000 ft2, one can then use the figures in Table 2 for P leached from air-dried leaves to estimate potential runoff loss of P. This would be a worst-case scenario. The values one arrives at are a high of 0.024 lb P/1,000 ft2 for a Chinese elm tree to a low of 0.0003 lb P for a pine tree that produces only about 1/3 the leaf biomass of deciduous trees.

TABLE 1. Water leachable P in grass clippings and tree leaves when subjected to various treatments.

	Percent of P leached				
Grass or tree	Fresh	Air-dried	Frozen	Frozen & dried	Decomposed
Kentucky bluegrass	7.0	10.2	20.3	31.7	—
Creeping bentgrass	19.7	23.4	39.0	58.5	—
Chinese elm	—	33.0	8.8	—	25.9
White pine	—	8.5	9.2	—	4.4
Burr Oak	—	5.5	4.1	—	6.1
Russian mulberry	—	6.6	7.0	—	3.8
Sugar maple	—	20.8	25.8	—	13.6

TABLE 2. Amounts of total and water leachable P in grass clippings and tree leaves when subjected to various treatments.

		Amount of P leached				
Grass or tree	Total P	Fresh	Air-dried	Frozen	Frozen & dried	Decomposed
	mg/kg †					
Kentucky bluegrass	4190	292	428	850	1300	—
Creeping bentgrass	4360	859	1020	1700	2550	—
Chinese elm	4470	—	1480	394	—	1160
White pine	566	—	48	52	—	25
Burr Oak	2140	—	118	87	—	130
Russian mulberry	3910	—	256	273	—	149
Sugar maple	683	—	142	176	—	92

† Oven-dry basis.

For a good stand of Kentucky bluegrass turf, the end-of-season dry surface biomass is around 3.5 g/ft2, or 3.5 kg/1,000 ft2. At a P leaching level of 1300 mg/kg for clippings frozen and then air-dried (Table 2), the potential amount of P in snow melt approaches 0.0042 lb/1,000 ft2. Using the P leaching rate for frozen but not air-dried Kentucky bluegrass clippings reduces this figure to 0.0027 lb P/1,000 ft2, which compares very favorably with the 0.00234 lb P loss recorded by Kussow (6) for runoff from frozen turf.

Measures of P runoff losses from turf over periods that include spring melt are rare. One study done in Pennsylvania indicated a full year P loss from fertilized Kentucky bluegrass of about 0.0047 lb P/1,000 ft2 (5). Comparing this figure with the potential P contributions from tree leaves and dormant turf (0.0027 to 0.024 lb P/1,00 ft2) reveals that at least one-half the P in runoff water from home lawns is not directly derived from fertilizer.

CONCLUSIONS

Due to the high solubility of P in tree leaves and frozen grass, home lawns contribute P to storm water regardless of whether fertilizer is applied or not. The flushes of P in late fall and in snowmelt from turf likely arise predominantly from the plant residues present. Rough estimates made here suggest that elimination of P fertilization of turf could, at best, reduce lawn runoff P by 50%, but indications are the the real figure is considerably less. In the long run, banning application of fertilizer P can be expected to lead to thinning of turf stands, accentuated runoff, more sediment loss and an increase in the total P load in storm water.

REFERENCES CITED

1. Bannerman, R. 1975. Phosphorus uptake and release by Lake Ontario sediments. National Environmental Research Center, Corvallis, OR.

2. Bannerman, R.T., R. Dodds, D. Owens and R. Hughes. 1992. Sources of pollutants in Wisconsin stormwater. WDNR report to the EPA. Grant No. C9995007-01.

3. Bartsch, A. 1972. Role of phosphorus in eutrophication. National Environmental Research Center. Corvallis, OR.

4. Dorney, J. 1986. Leachable and total phosphorus in urban street tree leaves. Water, Air, and Soil Pollution 28:439-443.

5. Harrison, S.A. 1989. Effects of turfgrass establishment method and management on the quality and nutrient and pesticide content of runoff and leachate. M.S. Thesis. The Penn. State Univ.

6. Kussow, W. R. 1995. Soil disturbance effects on nutrient losses from turf. Wis. Turf Research 12:95-100.

7. Linde, D.T., T.L. Watschke and J.A. Borges. 1995. Transport of runoff and nutrients from fairway turfs. USGA Green Section Record 33(1):42-44.

8. Miller, M.H., E.G. Beauchamp and J.D. Lauzon. 1994. Leaching of nitrogen and phosphorus from the biomass of three cover crop species. Land Management Dept., Univ. of Ontario. Ontario, Canada.

9. Peterson, et. al. 1974. Nutrient inactivation as a lake restoration procedure. National Environmental Research Center. Corvallis, OR.

10. Shaw, B. 1993. Understanding lake data. Univ. of Wis. Extension Pub. G3582.

11. Uttormark. 1975. Lake classification—A trophic characterization of Wisconsin lakes. Univ. of Wis. Water Resources Center. pp 14-17.

Oscar ("Oskar") Peterson is a May 1995 graduate of the University of Wisconsin Turf and Grounds Management Program. Dr. Wayne R. Kussow was his advisor. He is employed as Assistant Superintendent at the Freeport Country Club, Freeport, IL.