Leaves as Source of Phosphorus

William F. Cowen and G. Fred Lee
Water Chemistry Program, University of Wisconsin, Madison, Wis. 53706

■ Oak and poplar leaves were leached with distilled water in laboratory columns to simulate the release of soluble phosphorus (P) forms to urban runoff. Most of the soluble phosphorus leached was reactive in a molybdenum blue analysis. The leaves tested yielded 54-230 μg P/g of leaves. Consecutive leachings of an oak leaf sample yielded soluble P in amounts related to the effective soaking period between leachings and to the number of preceding leachings. Cut up leaves released almost three times as much soluble P as intact leaves. Leaves collected from the littoral zone of Lake Mendota leached less P than control leaves collected on the shore nearby. The moisture retained on leaves after a rainstorm contained significant soluble reactive P. The results of this investigation point to the importance of proper leaf pickup and control in order to minimize the phosphorus content of urban drainage during the fall of the year.

Recent studies by Kluesener (1971) on the nutrient sources for Lake Wingra, Madison, Wis., have shown that urban land runoff transported 0.57 lb of P/acre/year of dissolved reactive P and 0.98 lb of P/acre/year of total P to the lake. The runoff contained unusually high levels of dissolved reactive P in November and May. The high May level was attributed by Kluesener to the leaching of tree seeds and flowers in the street, by runoff water; lawn and garden fertilizer applications in the spring were discounted because they were applied on pervious surfaces where runoff yields were negligible. The high November levels were thought to result from the leaching of piles of leaves in street gutters by the runoff.

The concentrations of phosphorus found by Kluesener (1971) for urban drainage in Madison were similar to those found by Weibel et al. (1964) for Cincinnati, Ohio. Storm water runoff in Cincinnati carried a total soluble phosphorus load of 0.94 lb of P/acre/year (Weibel. 1969). The potential significance of plant materials as a source of phosphorus in runoff waters has been investigated by Timmons et al. (1970). They found that plant materials such as alfalfa or bluegrass may contribute significant amounts of phosphorus to agricultural runoff. This report presents the results of a follow-up study to assess the potential of leaves as a source of phosphorus to urban runoff.

Experimental Procedures

Initial studies were made on oak and poplar leaves collected from Madison, Wis., in October 1971. Later studies were performed on oak leaves collected in November 1971; these samples were collected on the shore of Lake Mendota or from the nearby littoral zone of the lake under the water. The sample collected on shore was split into two groups, one for a consecutive leaching experiment with intact leaves, the other for a leaching study with cut up leaves. Oak leaves were also collected in November after a rainstorm (12 hr before collection), so that the leaves were still moist.

Leaf samples were leached by soaking the leaves in glass chromatography columns for 1 hr. in 250-300 ml of distilled water, followed by percolation of 700-750 ml of distilled water through the column. The water volume was maintained at 250-300 ml in the columns during the percolations. After 1.5 hr of percolation at about 8.4 ml/min, the columns were drained into the effluent collection vessels to give a total leachate volume of 1000 ± 60 ml. Rain-soaked leaves were washed quickly (3-4 min) with 300 ml of distilled water in a column to collect the surface moisture from the leaves without additional leaching by the wash water.

Leaf leachates were analyzed for color with a Hellige Aquatestor. Phosphorus was determined after filtration through a 0.45-μ pore size Millipore filter. Dissolved reactive P was measured colorimetrically with the John (1970) modification of the Murphy and Riley molybdenum blue procedure, and total soluble P was measured by the same method after persulfate digestion (Standard Methods, 1971). Soluble unreactive P was computed by the difference between total soluble and dissolved reactive P. Total P in leaf tissue was measured following nitric acid predigestion and nitric-sulfuric-perchloric acid (10:1:4 by volume) digestion.

Results

Table I shows the yield of soluble P leached from oak and poplar leaves collected in October 1971. Although the two types of leaves released different percentages of their total P to the water, the compositions of soluble P forms in the leachates were approximately the same for both types. Soluble unreactive P was 14% of total soluble P from poplar leaves and 18% of total soluble P from oak leaves.

The results from consecutive leachings of a November

Table I. Soluble P Leached from Oak and Poplar Leaves

Leaves	Soluble P leached, μg/g of leaves: Reactive	Unreactive	Total	Soluble total P leached % total P in leaves
Oak[a]	44	10	54	5.4
Poplar[b]	120	20	140	21

[a] 7.86 grams, air-dry wt; leachate vol 960 ml; total P in leaves, 1000 μg/g.
[b] 9.32 grams, air-dry wt; leachate vol 950 ml; total P in leaves, 675 μg/g.

Table II. Consecutive Leaching of Oak Leaves

Leaching no.[a]	Soaking period prior to percolation, hr	Leachate color, units	Soluble P leached, μg/g of leaves: Reactive	Total
1	1	15	230	230
2	2.5	15	160	160
3	22.5	30	270	270
4	1	5	74	74

[a] 7.47 leaves, oven-dry wt; leachate vol: no. 1 = 1007 ml; no. 2 = 1055 ml, no. 3 = 1000 ml, no. 4 = 1000 ml.

[1]Current affiliation: G. Fred Lee & Associates, El Macero, CA, gfredlee@aol.com, www.gfredlee.com

1971 oak leaf sample are given in Table II. No soluble unreactive P was found in any of the leachates. Soluble P yields were high in the first leaching and also in the third leaching, which had a long soaking period before it. The second and fourth leachings, which had relatively short soaking periods, yielded less phosphorus than did the other two leachings. Even though the first and fourth leachings had the same soaking period, the fourth showed significantly less phosphorus release. Apparently, the pool of leachable phosphorus had been reduced by the three previous leachings. Leachate color appeared to be somewhat related to the soluble phosphorus yields.

Oak leaves collected from the littoral zone of Lake Mendota leached relatively small amounts of soluble P compared to the control leaves collected on the shore nearby (Table II, leaching no. 1). Table III shows the yields from duplicate leachings of the Lake Mendota leaves, which might have been soaking for as long as a month in the lake water. A total soluble P range of 88-99 µg P/g of leaves was found, compared to 230 µg P/g for the control sample. The soluble unreactive P was probably not significant.

In contrast to the Lake Mendota leaves, oak leaves cut into small pieces leached 650 µg P/g of leaves, almost three times the level for intact leaves (230 µg P/g). All the soluble phosphorus leached from the cut leaves was reactive P. The leachate color was 180 units from the cut leaves, compared to 15 units from the intact leaves (Table II, leaching no. 1).

Wet oak leaves collected in November after a rainstorm contained 23 µg P/g of leaves as dissolved reactive P in the layer of moisture retained on their surfaces. The leaves had been soaking in their surface moisture for about 12 hr prior to collection.

Discussion

The column percolation procedure simulates conditions in nature where leaves are leached by precipitation for 2.5 hr. The resulting surface moisture on the leaves contains extracted soluble reactive phosphorus which can be carried away by overland flows of runoff. The concentrations of soluble P in the runoff should decrease as the number of antecedent leaching events increase, as demonstrated by leachings no. 1 and no. 4 in Table II. The concentration of soluble P in the runoff should be increased as the length of antecedent soaking periods increases, as shown by leaching no. 3 in Table II. In addition, any physical damage to the leaves would tend to increase their contribution to runoff phosphorus loads. Exposure of vein surfaces by cutting the leaves was shown to result in large amounts of leachable P compared to tests with intact leaves. Timmons et al. (1970) reported that the drying and freezing of bluegrass or alfalfa greatly enhanced the release of soluble P in laboratory leaching studies similar to those presented here. The burning of leaves in street gutters would be an extreme case of physical damage, and this treatment would be expected to result in almost quantitative yields of total leaf phosphorus to runoff.

Table III. Leaching of Lake Mendota Oak Leaves

Sample	Leachate color, units	Soluble-P in leachate, µg/g of leaves: Reactive	Unreactive	Total
A[a]	20	84	4	88
B[b]	25	97	2	99

[a] 3.29 grams, oven-dry wt; leachate vol = 990 ml.
[b] 4.66 grams, oven-dry wt; leachate vol = 1000 ml.

It is clear that even intact leaves may potentially fertilize many liters of runoff water above the critical concentrations of phosphorus often cited as causing excessive growths of algae or aquatic plants in natural waters. The results of these studies may be of particular importance to the urban environment since they may account in part for the relatively high concentrations of phosphorus found in urban drainage (Weibel, 1969; Kluesener. 1971). Tree seeds may also contribute to the high concentrations; preliminary leaching studies with elm seeds by the procedures given above showed that 350 µg P/g dissolved reactive P, 70 µg P/g dissolved unreactive P, and 420 µg P/g total soluble P was leached from seeds containing 5100 µg P/g total P.

It is apparent from these results that municipalities should initiate a program of rapid leaf pickup during the autumn leaf litter period in order to minimize nutrient transport to lakes and streams from urban runoff. Burning and storing of leaves in the gutter prior to pickup should he prohibited. Property owners should store leaves and other plant debris in such a way as to avoid contact with precipitation which could ultimately result in urban runoff.

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