Fall 1979

Leachable Phosphorus Levels of Urban Street Trees: Contributions to Urban Runoff

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LEACHABLE PHOSPHORUS LEVELS OF URBAN STREET TREES: CONTRIBUTIONS TO URBAN RUNOFF

Intelligent environmental management of urban areas depends upon a thorough understanding of urban ecosystem properties, such as structure, energy flow and materials cycles. This report examines the phosphorous cycle in urban runoff – a portion of the urban phosphorous cycle – which is involved in diffuse (non-point) source pollution from urban areas. The goals of my research were to determine if street tree leaves and seeds are a source of phosphorous in urban runoff and if so, how these levels varied between tree species.

Several studies have been done regarding the role of urban runoff phosphorous in lake eutrophication. Kluesener and Lee (1974), studying Lake Wingra in Madison, Wisconsin, concluded that runoff contributed 81% of the phosphorous to the lake. In the Minneapolis Chain of Lakes, runoff contributed from 47 to 97% of the phosphorous (Shapiro and Pfannkuch, 1974). Both studies implicated tree leaves as a major phosphorous source, especially in the fall when run-off phosphorous level peaked.

Numerous studies have been made concerning leaf phosphorous levels in various natural systems (Mitchell, 1937; Huzalak, 1973). These studies did not examine leachable leaf phosphorous but were concerned only with total leaf phosphorous. Only Cowen and Lee (1973) reported an examination of leachable tree leaf phosphorous levels, using oak and poplar leaves (species unspecified) in Madison, Wisconsin. They found that poplar had more leachable phosphorous than oak leaves (54ug/gm. oak vs. 140ug/gm. poplar leaf) and that the amount of phosphorous leached increased with leaching time and the amount of leaf fragmentation.

METHODS

Tree leaves and seeds were collected from 52 Milwaukee and Shorewood (an adjacent suburb) residential street trees representing 13 species, in September and October, 1978. Leaves were collected after they had fallen, but before they were washed by significant (more than 0.25in.) rainfall. Tree species diameter at breast height (DBH) and location were noted. Leaves and seed were air dried at approximately 70°F. for at least two weeks. The phosphorous analysis used was modified from the method of Cowen and Lee (1973).

Samples of entire leaves were weighed, placed in acid-washed 1.2 liter glass cylinders to which one liter of distilled water was added. The leaves soaked for two hours, after which the liquid was poured off and leaves washed with an additional liter of water. The total leachable phosphorous in the water was determined using persulfate digestion followed by ascorbic acid determination with a Spectronic 20 spectrophotometer (American Public Health Association, 1976.). Calibration curves were prepared daily using distilled water and prepared standards of 2.5, 10 and 50 ug/1. Phosphorous. Using the levels of total phosphorous in the water and the calibration curves, amount of leachable phosphorous per gram of leaf tissue was determined. Duplicate leachate samples were analyzed and if the results differed by more than 10%, additional leaves were leached. In all, 24 pairs of replicates were analyzed.

RESULTS

Only tree species for which three or more samples were analyzed are included here (Table 1). Values for leachable leaf phosphorous ranged from 410.8 ug/g. leaf to 20.1 ug/g. leaf, levels comparable to those from Cowen and Lee (1973).

In general, the amount of leachable phosphorous present in the tree leaves decreases with size (age) of the tree (Fig. 1). This trend is apparent with silver and sugar maple, basswood, green ash, honey locust and Hessian ash. White ash, except for one 10 in. DBH tree, also follows this trend. The pattern in Schwedlers Norway maple and little leaf linden appears to be reversed as larger trees exhibit higher leachable phosphorous levels. However, sample size is small.

Data for weeping willow, American elm, Chinese elm and pin oak are inadequate to determine trends. These species are planted rarely as street trees or are being removed by disease (as is the American elm.).

Leachable phosphorous levels in tree seeds were generally low (Table 1) compared to leaf levels and never exceeded 77.6 ugP/g. seed.

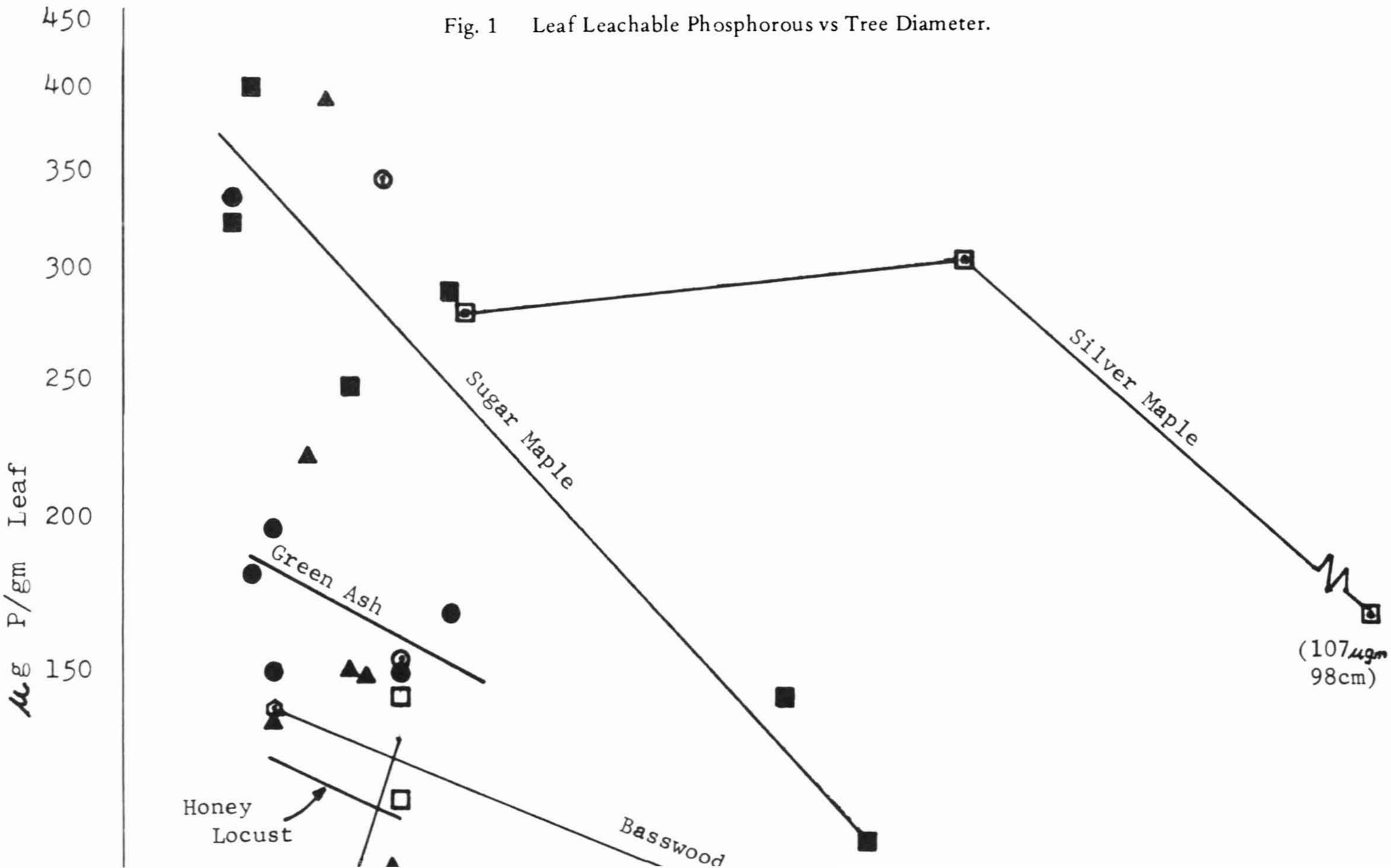
Several trees, especially very small ones, show excessively high levels of leachable leaf phosphorous (these are noted in Table 1). Interviews with the landowners of the sampled trees suggest that these high levels of phosphorous can be traced to heavy fertilization of newly planted trees. For instance, one of the highest phosphorous levels recorded (405.7 ug P/g. leaf for honey locust) was of leaves from a young tree, where the landowner had inserted several tree fertilizer spikes into the ground near the tree base. These abnormally high levels were not included in determination of average leaf phosphorous, because it appears their values were not normal for the species.

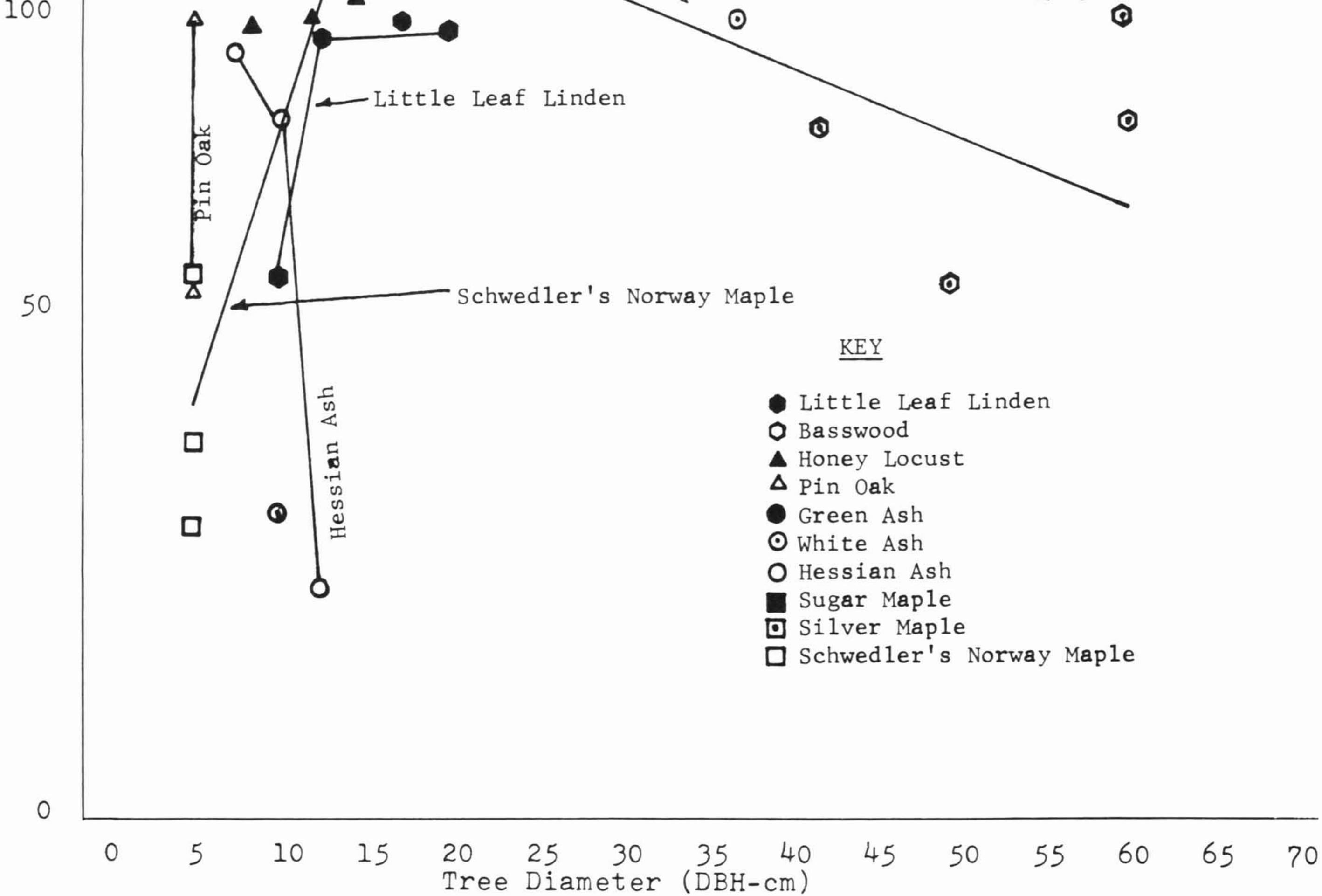
DISCUSSION

To determine tree leaf leachable phosphorous ranking, arbitrary size classes, 0 to 10 cm., 10.5 to 20 cm. and 20.5 cm. and above, were chosen and the data grouped according to these classes (Table 1). Outlying data points were not used in these determinations and in addition, only species which had two or more samples in each size class were used for the determination of size classes averages.

Sugar maple was the only species for which sufficient data were collected to examine all three size classes. Other species had data in two classes except for silver maple, Hessian ash, basswood and little leaf linden. For this reason no

Fig. 1 Leaf Leachable Phosphorous vs Tree Diameter.





100
50
0
Little Leaf Linden
Pin Oak
Schwedler's Norway Maple
Hessian Ash
KEY
Little Leaf Linden
Basswood
Honey Locust
Pin Oak
Green Ash
White Ash
Hessian Ash
Sugar Maple
Silver Maple
Schwedler's Norway Maple
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Tree Diameter (DBH-cm)

Table 1

Leachable total phosphorous in urban street tree leaves and seeds by Size Classes: (0-10 cm) (A-F), 10.5-20 cm (a-e) and 20.5 cm (1-3).

Species	*DBH (cm)*	*ug P/g.*	*Average ug P/gm*	*Relative Ranking by Size Class*
Acer platanoides	5.0	26.3	43.2	A
(Schwedler's Norway Maple)	5.0	35.3		
	5.0	67.9		
	15.0	149.9	135.6	b
	15.0	121.2		
Acer saccharinum	19.0	288.7#		
(Silver Maple)	49.0	311.8	204.7	3
	107.0	97.6		
Acer saccharm	5.0	333.5	372.1	F
(Sugar Maple)	6.2	410.8		
	12.2	252.8	275.7	e
	18.0	298.6		
	38.0	146.8	130.8	2
	43.0	114.7		
Fraxinus americana	10.0	28.5#		
(White Ash)	14.0	351.8#	*	
	15.0	162.0#		
	37.2	105.4#		
Fraxinus excelsior	7.5	92.4	89.1	C
(Hessian Ash)	10.0	85.8		
	12.5	20.1		
Fraxinus pennsylvanica	5.0	344.7#	*	
(Green Ash)	6.0	187.4	181.5	E
	8.5	199.0		
	8.5	158.1		
	14.1	153.3		
	17.5	105.8	143.1	d
	18.0	170.2		
Gleditisia tricanthos	7.5	143.7	122.9	D
(Honey Locust)	8.5	102.2		
	9.5	224.1#	*	
	10.5	405.7#	*	
	12.0	101.8		
	12.0	160.6	133.2	b
	13.0	157.1		
	14.5	113.2		

Species	*DBH (cm)*	*ug P/g.*	*Average ug P/g.*	*Relative Ranking by Size Class*
Quercus palustris	5.0	60.8	81.5	B
(Pin Oak)	5.0	102.2		
Salix babylonia	16.5	37.2#		
(Weeping Willow)	32.0	38.7#		
Tilia americana	7.5	145.6#		
(Basswood)	42.5	81.9		
	49.0	61.0	83.2	1
	61.0	84.0		
	60.0	105.8		
Tilia cordata	10.0	60.5#		
(Little Leaf Linden)	12.5	99.5	86.5	a
	20.0	99.6		
Ulmus americana	37.0	111.3#		
(American Elm)	37.0	205.7#		
Ulmus pumila	24.0	114.1#		
(Chinese Elm)	30.5	63.0#		

Seeds	*Tree Number*	*ug P/g.*	*Average ug P/g.*
Acer saccharum	1	31.9	40.8
(Sugar Maple)	2	49.6	
Fraxinus pennsylvanica	1	77.6	77.6
(Green Ash)			
Tilia cordata	1	47.4	39.2
(Little Leaf Linden)	2	31.0	

value omitted from size class averages.
* data with unusually high levels (see text).

Table 2

Relative Ratings:	Total Leachable Phosphorous Levels for Urban Street Trees
High:	Sugar Maple Leaves Silver Maple Leaves (probably)
Medium:	Green Ash Leaves Basswood Leaves Honey Locust Leaves
Low:	Sugar Maple Seeds Green Ash Seeds Little Leaf Linden Seeds
Insufficient Data:	Noway Maple, Hessian Ash, White Ash, Little Leaf Linden and Pin Oak.

attempt was made to determine absolute numeric ranking for street tree species. Rather, a relative ranking system was developed, utilizing Table 1 and Fig. 1 in order to rank leachable phosphorous levels from high to low (Table 2).

Sugar maple and probably silver maple have high total leachable phosphorous levels. Green ash, basswood and honey locust appear to have medium levels.

Seeds of the three species examined have low levels of leachable phosphorous. Insufficient data are available for other species to determine rankings, although some of them (Hessian ash and pin oak) appear to have low levels.

CONCLUSIONS

Other than the 1973 study by Cowen and Lee, there is no other report on tree leaf leachable phosphorous levels. Numerous data are available on leaf total phosphorous seasonal variations for several natural ecosystems, however in most of these studies, no data on tree sizes are supplied. These reports show variations in total leaf phosphorous between species, for instance, total phosphorous as a percentage of dry weight for maples at leaffall was 0.23%, while oaks had 0.15% (Mitchell, 1973). There are no studies of total leaf phosphorous levels in urban trees.

The tendency for leachable phosphorous to decline with increasing tree size may result from two factors. Normal planting procedure in Milwaukee (Skiera, 1978) involves fertilizing the young tree, possibly accounting for higher leaf phosphorous levels. Also it is possible that young trees may not be as efficient as older trees in phosphorous translocation from the leaves before leaffall. This would also result in higher leachable phosphorous levels in young tree leaves.

My data suggest that tree leaves can be important sources of urban runoff phosphorous. Cowen and Lee (1973) demonstrated that phosphorous will continue to leach from leaves as leaching time is extended, likewise more phosphorous is available if leaves are fragmented rather than entire. Since most rainfall and subsequent leaching events are of longer duration than the two hours used in this study, it is likely that more phosphorous would be removed from the leaves. Leaching would also be increased as the leaf is broken up during aging.

Street tree planting and leaf litter pickup policy in most cities, including Milwaukee does not take into account the importance of leaves as a source of runoff phosphorous. Street trees for planting in Milwaukee, as in other cities, are mostly chosen on the basis of tree availability, tolerance to urban microclimatics, disease resistance, growth rate and form (Skiera, 1978).

Leaves are picked up only once or twice in the fall in most cities after the leaves have entirely fallen and collected in the gutters. This timing usually subjects the leaves to repeated rainfall and leaching with subsequent phosphorous runoff. Results of this study indicate that if reduction of urban runoff pollution is desired, street tree leaves should be collected several times in the fall. In addition, leaf collection should focus on those areas of the city in which trees such as sugar maple with high leaf leachable phosphorous levels have been planted.

More work is necessary before tree species can be ranked adequately. Norway maple in particular needs attention. The amount of leachable phosphorous derived from longer leaching times, yearly variation and variation in different areas of cities should be examined. It is evident that street tree leaves are a major source of urban runoff phosphorous and proper urban environmental management can play a role in reducing this impact.

LITERATURE CITED

American Public Health Association. 1976. Standard methods for the examination of water and wastewater. Fourteenth Edition. American Public Health Association, Washington, DC.

Cowen, W. F. and G. F. Lee. 1973. Leaves as a source of phosphorous. Environmental Science and Technology 7(9): 853-4.

Huzalak, J. 1973. Seasonal changes in the macronutrient and boron content in the leaves of woody species of the oak-hornbean forest. Biologia (Bratislava, Czechoslovakia) 28 (4): 263-273.

Kluesner, J. W. and G. F. Lee. 1974. Nutrient loading from a separate storm sewer in Madison, Wisconsin. Journal of the Water Pollution Control Federation 46 (5): 920-936.

Mitchell, H. J. 1937. Trends in the nitrogen, phosphorous, potassium and calcium content of the leaves of some forest trees during the growing season. Black Rock Forest Bull. 9: 30-44.

Shapiro, J. and H. O. Pfannkuch. 1974. The Minneapolis chain of lakes; a study of urban drainage and its effects 1971-1973. Interm Report No. 9. Limnological Research Center, University of Minnesota. Minneapolis, Minn.

Skiera, R. 1978. Milwaukee City Forester – personal communication.

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