Stormwater Runoff Water Quality Newsletter
Devoted to Urban/Rural Stormwater Runoff
Water Quality Management Issues

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This issue of the Newsletter presents information on nutrient-related urban stormwater runoff water quality issues based on a series of studies that was conducted by Dr. G. Fred Lee and his associates. Beginning in the 1960s, while holding the position of Professor of Water Chemistry at the University of Wisconsin-Madison, Dr. Lee initiated some of the first studies ever conducted on the water quality characteristics of urban stormwater runoff. Those studies were prompted by the International Biological Program (IBP) study of the impact of nutrient loads to lakes on eutrophication-related water quality. One of focal points of the IBP program was Lake Wingra located in Madison, Wisconsin. Lake Wingra is an urban lake; much of its watershed is urban residential area. Information on the characteristics of Lake Wingra is available at, http://limnology.wisc.edu/lake_information/other_yahara_lakes/wingra.html.

Working with graduate students, Dr. Lee initiated studies on the amounts of nitrogen and phosphorus in urban residential stormwater runoff. In addition, studies were conducted on the amounts of N and P in the stormwater residential runoff that was available to support algal growth. As part of the International Field Year for the Great Lakes, Dr. Lee expanded the Lake Wingra studies to several urban areas in the US part of the Lake Ontario watershed.

These studies represented comprehensive studies that became the PhD dissertations and master theses for several graduate studies. Results of these studies were published in peer-reviewed journal articles. These papers have been scanned and placed on Drs. Anne Jones-Lee and G. Fred Lee's website (www.gfredlee.com). They have applicability to the current interest in urban stormwater runoff as a source of nutrients leading to excessive fertilization of waterbodies. A summary of these studies is presented in this newsletter.

Amounts of P and N in Urban Stormwater Runoff

In order to determine the amount of nutrients entering Lake Wingra from the residential area of the watershed it was necessary to determine the amounts of nutrients (N and P compounds) per unit of residential area per unit time (N or P mass load/unit area/yr). Kluesener established an automatic sampling system in a stormwater sewer for which information was also available on the flow of the stormwater in the storm sewer. He monitored 17 precipitation events during 1970 and 1971. Samples were collected every 5 to 10 minutes from the time of initiation of runoff during the runoff event. These samples were analyzed for ammonia, nitrate, organic N, dissolved reactive P, total P, sodium, and total suspended solids.

A paper summarizing the Klusener PhD dissertation studies was published as,

> Kluesener, J. W., and Lee, G. F., "Nutrient Loading from a Separate Storm Sewer in Madison, Wisconsin," Journ. Water Pollut. Control Fed. 46(5):920-936 (1974).

This paper has been scanned and is available at,
http://www.members.aol.com/annelhome/KluesenerLeeNutrLoad.pdf.

Representative data collected in this study are included in this paper. Kluesener and Lee reported that the rainfall runoff yield was 12 to 19%, i.e., 12 to 19% of the rainfall was present in the runoff from the area. About 27% of the watershed monitored was covered by impervious surfaces (streets, rooftops, driveways, and sidewalks). The concentrations of N and P in the runoff were variable during the runoff event, frequently showing elevated concentrations with the first flush. The soluble reactive P concentrations were typically 0.2 to 0.4 mg/L P with some values in the range of 1.6 to 1.8 mg/L P. Total P concentration varied in the range of 1 to 2 mg/L P. Nitrate and ammonia were typically 0.2 to 0.6 mg/L N. Organic N ranged from about 0.1 to 0.9 mg/L N. These concentrations of N and P compounds represent potentially significant sources of N and P that can lead to excessive fertilization of receiving waters for the urban runoff.

Kluesener and Lee found that urban runoff in the Lake Wingra watershed amounted to 0.57 lb of reactive (soluble) P/acre/year and 0.98 lb of P/acre/year of total P.

Nutrient Export Coefficients

As part of the US Organization for Economic Cooperation and Development (OECD),

> Lee, G. F.; Rast, W. and Jones, R. A., "Eutrophication of water bodies: Insights for an age-old problem," Environmental Science & Technology 12:900-908 (1978). http://www.members.aol.com/apple27298/Eutrophication-EST.pdf

studies on nutrient loads to lakes and reservoirs Rast and Lee,

> Rast, W., and Lee, G. F., "Nutrient Loading Estimates for Lakes," *Journ. Environ. Engr*. **109**(2):502-518 (1983).
> http://www.members.aol.com/annelhome/NutrientLoadingEstRast.pdf

evaluated the amounts of N and P compounds contributed from about 100 watersheds for 38 waterbodies located across the US. "Table 2" extracted from that paper presents a summary of the results of those studies. Examination of this table shows that urban area phosphorus nutrient export coefficients are about two times higher than the export coefficients from agricultural (row crops) areas. This difference is due in part to the somewhat greater amount of runoff in urban areas than in agricultural areas due to the greater amount of impervious surfaces. Urban areas contributed about 10 times more P per unit area per unit time than forested areas; both urban and agricultural areas contributed much greater amounts of P per unit area per unit time than forested areas. About the same amounts of nitrogen were derived from urban and agricultural areas; the atmosphere, through precipitation, was the primary source of N in the runoff.

TABLE 2.—Watershed Nutrient Export Coefficients

Watershed land use (1)	Watershed export coefficient, in grams per square meter times year (2)
(*a*) Total Phosphorus	
Urban	0.1
Rural/agriculture	0.05
Forest	0.005–0.01
Atmosphere[a]	0.025[b]
(*b*) Total Nitrogen	
Urban	0.5 (0.25)[c]
Rural/agriculture	0.5 (0.2)[c]
Forest	0.3 (0.1)[c]
Atmosphere[a]	2.4 (1.0)[b,c]

[a]Atmospheric load consists of precipitation and dry fallout directly onto the surface of the water body.

[b](Grams per square meter of waterbody · yr).

[c]Parenthetical values are export coefficients to be used in calculating nitrogen loads for waterbodies in the western U.S. after Rast and Lee (24).

Leaves as a Source of Phosphorus in Urban Runoff

W. Cowen, at the time a graduate student in the University of Wisconsin Madison Water Chemistry Program, conducted a study of the leaching of phosphorus from tree leaves. These studies were summarized in,

> Cowen, W. and Lee, G. F., "Leaves as a Source of Phosphorus," Environ. Sci. & Technol. 7:853-854 (1973).
> http://www.members.aol.com/annejlee/CowenLeavesP.pdf

These studies examined the potential leaching of phosphorus from leaves that fall to the street during the fall of the year. These studies showed that 54 to 230 µgP/g of leaf were rapidly leached in distilled water with most of the P in soluble P form. From about 5 to 21 percent of the total P in oak and poplar leaves was readily leachable upon contact with water. These studies point to the potential importance of removal of leaves from streets during the fall of the year to reduce the amount of P in runoff.

Algal Available Nutrients in Runoff Waters

While it is known that soluble ortho P is readily available to support algal growth, there was a lack of information on the amount of algal available P in particulate P in urban and rural runoff. Cowen's PhD dissertation at the University of Wisconsin Madison Water Chemistry Program was devoted to investigation of the algal-available P in Madison, Wisconsin urban stormwater runoff. These studies were summarized by,

> Cowen, W. F., and Lee, G. F., "Phosphorus Availability in Particulate Materials Transported by Urban Runoff," Journ. Water Pollut. Control Fed. 48(3):580 591 (1976). http://www.members.aol.com/annelhome/AvailPParticulatesCowen.pdf

They also conducted detailed studies of algal available P in the Lake Ontario watershed. These are reported in,

> Cowen, W., and Lee, G. F., "Algal Nutrient Availability and Limitation in Lake Ontario during IFYGL – Part I. Available Phosphorus in Urban Runoff and Lake Ontario Tributary Waters," EPA-600/3-76-094a, US EPA Environmental Research Laboratory, Duluth, MN, October (1976).

Using several techniques including acid, base, anion exchange resin leaching, and algal growth studies, the amounts of algal-available P in urban runoff from several areas of Madison were determined. As an overall average for all samples, 30 percent of the particulate P was available to *Selenestrum* in 19 to 22 days. Based on these studies they concluded that the algal available P could be estimated as being equal to the soluble ortho P plus 0.3 of the particulate P.

Cowen and Sirisinha conducted studies on amounts organic N in urban stormwater runoff in Madison, Wisconsin that becomes algal available nitrogen (ammonia, nitrite and nitrate) upon 82 to 100 days of incubation. These studies were summarized in,

> Cowen, W. F., Sirisinha, K., and Lee, G. F., "Nitrogen Availability in Urban Runoff," Journ. Water Pollution Control Federation 48(2):339-345 (1976). http://www.members.aol.com/annejlee/NAvailCowenSirisinha.pdf

They also conducted studies on these issues in the Lake Ontario watershed that were reported in,

> Cowen, W., Sirisinha, K., and Lee, G. F., "Algal Nutrient Availability and Limitation in Lake Ontario during IFYGL – Part II. Nitrogen Available in Lake Ontario Tributary Water Samples and Urban Runoff from Madison, Wisconsin," EPA-600/3-77-045, US EPA Environmental Research Laboratory, Duluth, MN, May (1977).

They found that in fresh stormwater runoff 4 to 66 percent of the total N was in a form that could be used by algae. After incubation, about 70 percent (range of 57 to 82 percent) of the organic N was converted to algal available N. Overall, in urban stormwater runoff essentially all of the particulate organic N is converted over time to algal available N.

The International Joint Commission for the Great Lakes organized a conference devoted to developing a phosphorus management strategy. Dr. G. Fred Lee was invited to present a paper summarizing the state of information on algal available P. This paper was published as,

Lee, G. F., Jones, R. A., and Rast, W., "Availability of Phosphorus to Phytoplankton and its Implications for Phosphorus Management Strategies," Published in: Phosphorus

Management Strategies for Lakes, Ann Arbor Science Publishers, Inc. pp. 259-307.(1980). http://www.members.aol.com/duklee2307/Avail-P.pdf

This paper presents a discussion of the information available on algal available P in urban and agricultural stormwater runoff. It presents the results of Dr. Lee's and his associates' work as well as that of others, on algal available P. The overall conclusion was that from 70 to 80 percent of the particulate P in urban and agricultural erosional particulates is not available to support algal growth.

Recently, Lee provided guidance on how the amount of algal available P in particulate runoff can be determined in,

> Lee, G. F., "A Proposal for Assessing Algal-Available Phosphorus Loads in Runoff from Irrigated Agriculture in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, November (2006). http://www.members.aol.com/annejlee/AlgalAssayAvailP.pdf

He also discussed the importance of not assuming that all particulate P is available or can be expected to be converted to algal available P in,

> Lee, G. F., "Assessing Algal Available Phosphorus," Proceedings of US EPA Science Symposium: Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins, Minneapolis, MN, November 7-9 (2006). http://www.members.aol.com/annejlee/AvailPEPASymp06.pdf

Overall Conclusion

Overall, urban stormwater runoff represents a potentially significant source of N and P compounds that can lead to excessive fertilization of waterbodies receiving the runoff. In evaluating the impacts of P in urban and agricultural stormwater runoff, it is important to focus on algal available forms rather than on total forms. Best Management Practices for controlling P in runoff from urban and agricultural areas should focus on soluble ortho P.