

## **Summary of Experience in Evaluating the Impact of Domestic Wastewater Discharges on Receiving Waterbody Quality**

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Dr. G. Fred Lee has been involved in evaluating water quality impacts of domestic wastewater discharges throughout his more than five-decade-long professional career. After earning his PhD degree at Harvard University in environmental engineering with minors in aquatic chemistry and public health in 1960, Dr. Lee held faculty teaching and research positions in environmental engineering and science at several major US universities for the following 30 years. During his academic career he taught graduate-level courses in water and wastewater treatment, and evaluation and control of water pollution from domestic and industrial wastewater discharges and other sources, and conducted more than \$5-million in research in these areas. Several of those projects were specifically devoted to evaluating the water quality impacts of domestic wastewater treatment plant discharges. He published about 500 professional papers and reports on his research and findings; about 50 of those papers and 50 of those reports were devoted to various aspects of treatment and water quality impacts of domestic wastewaters. A list of those papers and reports is available upon request; many are available as downloadable electronic files on Drs. G. Fred Lee and Anne Jones-Lee's website, [www.gfredlee.com](http://www.gfredlee.com). A summary of the more relevant projects and study areas is provided below.

### **Domestic Wastewater Discharges of Nutrients**

One of the major thrusts of Dr. Lee's evaluation of domestic wastewater discharges has been the impact and control of aquatic plant nutrients (phosphorus and nitrogen compounds) on the excessive fertilization of waterbodies. In the 1960s while holding the position of Professor of Water Chemistry and Director of the Water Chemistry Program in the Department of Civil and Environmental Engineering at the University of Wisconsin, Madison Dr. Lee devoted particular attention to excessive fertilization of the US Canadian Great Lakes and inland lakes and reservoirs. The research of one of his graduate students included studies on the removal of phosphorus in domestic wastewater treatment plant discharges with advanced treatment processes. That PhD dissertation resulted in the paper,

Malhotra, S. K., Lee, G. F., and Rohlich, G. A., "Nutrient Removal from Secondary Effluent by Alum Flocculation and Lime Precipitation," *Air & Water Pollut.* 8:487- 500 (1964).  
<http://www.gfredlee.com/Nutrients/MalhotraNutrRemAlum.pdf>

In the 1970s Dr. Lee served as the US representative for the international Organization for Economic Cooperation and Development (OECD) Eutrophication Study. That Study was a five-year, \$50-million investigation of about 200 waterbodies conducted by 22 countries in Western Europe, North America, Japan, and Australia to evaluate the impacts of nutrient loads on the algae-related water quality of lakes and reservoirs. Of particular concern in that effort were the impacts of nitrogen and phosphorus compounds discharged by domestic wastewater treatment plants on the excessive fertilization of waterbodies. Dr. Lee was also selected by the US EPA to evaluate, and develop the synthesis report for, the US part of the OECD Eutrophication Study.

That effort led to his development of a summary paper, which appeared as a feature article in the journal, Environmental Science and Technology:

Lee, G. F., Rast, W. and Jones, R. A., "Eutrophication of Water Bodies: Insights for an Age-Old Problem," Environ. Sci. & Technol. 12:900-908 (1978).  
<http://www.gfredlee.com/Nutrients/Eutrophication-EST.pdf>

That paper described empirical relationships between P load and eutrophication-related water quality characteristics for a diverse group of lakes and reservoirs across the US, relationships that were in keeping with those subsequently developed upon the entire OECD study database. (Those relationships formed the foundation of what has become known as the Vollenweider-OECD eutrophication modeling approach, in recognition of the conceptual contributions of Dr. R. Vollenweider.) Following the completion of their work on the US OECD database, Dr. Lee and colleagues continued the OECD-type eutrophication studies of waterbodies, beyond the OECD database, expanding the total database to more than 700 waterbodies of varied character located in areas covering most of the world. They also investigated and documented the predictive capability of the modeling approach using load and response data collected before and after P load reductions to about a dozen waterbodies. Lee's and his associates' studies on excessive fertilization of waterbodies resulted in their development of procedures to reliably evaluate the impact of a domestic wastewater discharge on planktonic algae-related water quality characteristics of a lake or reservoir and to reliably quantify the impact on those characteristics that would be caused by altering the phosphorus load discharged by a treatment. Lee's professional papers and reports on his work in this area are available on Drs. Lee and Jones-Lee's website [[www.gfredlee.com](http://www.gfredlee.com)] in the Excessive Fertilization section [[http://www.gfredlee.com/Nutrients\\_Algae.html](http://www.gfredlee.com/Nutrients_Algae.html)].

An example of the use of the Vollenweider-OECD eutrophication modeling approach for assessing the impacts of nutrient loads on eutrophication-related water quality is Lee's investigation of Lake Ray Hubbard, a major domestic water supply reservoir for Dallas, Texas. The water supply water quality of that reservoir had been deteriorating due to the growth of algae supported by the nitrogen and phosphorus discharged into the reservoir from its watershed. Of particular concern was the impact of nutrient-rich domestic wastewaters discharged to the tributaries. While serving as Professor of Engineering and Director of Institute of Environmental Studies at the University of Texas at Dallas, Dr. Lee directed a comprehensive study of nutrient sources to Lake Ray Hubbard. With his graduate students he evaluated, employing the OECD Eutrophication Study results, the impacts on water supply-related water quality of increasing urbanization of the reservoir's watershed with the attendant increases in domestic wastewater discharges. They also evaluated the impacts of implementation of advanced treatment of the domestic wastewaters to remove phosphorus, on the algae-related water quality. A summary paper on those studies is available as:

Archibald, E. M. and Lee, G. F., "Application of the OECD Eutrophication Modeling Approach to Lake Ray Hubbard, Texas," Journ. AWWA 73:590-599 (1981).  
<http://www.gfredlee.com/Nutrients/OECDLakeRayHub.pdf>

Lee, G. F. and Meckel, E., "Estimated Impact of Diversion of Garland-Rowlett Wastewater Treatment Plant Effluent on Water Quality in Lake Ray Hubbard," Occasional Paper No. 30,

Department of Civil & Environmental Engineering, New Jersey Institute of Technology, Newark, NJ, March (1978).

Drs. Lee and Jones-Lee have conducted similar studies on lakes, reservoirs, estuaries, and coastal marine waters in the US and other countries. Many of their papers and reports discussing their findings are available on their website, including:

Jones, R. A. and Lee, G. F., "Impact of Phosphorus Removal at the Danbury, Connecticut Sewage Treatment Plant on Water Quality in Lake Lillinonah," *Water, Air, Soil Pollut.* 16:511-531 (1981). [http://www.gfredlee.com/Nutrients/Impact\\_P\\_Removal\\_Lillinonah.pdf](http://www.gfredlee.com/Nutrients/Impact_P_Removal_Lillinonah.pdf)

Jones, R. A. and Lee, G. F., "Development of Water Quality Management Program for the Rawhide Electric Generating Station Cooling Impoundment: A Domestic Wastewater Reuse Project," In: *Water Reuse in the Future*, Proc. AWWA Denver, CO, pp 1945-1978 (1982). [http://www.gfredlee.com/ReclaimWW/Rawhide\\_Wastewater\\_Reuse.pdf](http://www.gfredlee.com/ReclaimWW/Rawhide_Wastewater_Reuse.pdf)

### **Impacts of City of Madison, Wisconsin's Domestic Wastewater Treatment Plant Discharge on Receiving Water Quality**

While at the University of Wisconsin, Madison, Dr. Lee and his graduate students conducted studies on the impact of the Madison Metropolitan wastewater effluent on water quality in the lower Madison lakes, Waubesa and Kegonsa. They also evaluated the impact on those lakes of diverting that effluent around the lakes and discharging it into Bad Fish Creek and downstream waterbodies. The following papers were developed from those studies:

Sonzogni, W. C., Fitzgerald, G. P., and Lee, G. F., "Effects of Wastewater Diversion on the Lower Madison Lakes," *Journ. Water Pollut. Control Fed.* 47:535-542 (1975).

Sonzogni, W. C. and Lee, G. F., "Phosphorus Sources for the Lower Madison Lakes," *Trans. Wisc. Academy Sciences, Arts and Letters* LXIII:162-175 (1975).

Lee, G. F., "The Effects of Madison Metropolitan Wastewater Effluent on Water Quality in Badfish Creek, Yahara and Rock Rivers," *Trans. Wisc. Academy Sciences, Arts and Letters* 65:163-179 (1977).

### **Land Application of Domestic Wastewaters**

Dr. Lee developed several papers on potential problems that can be caused by land application of domestic wastewaters including:

Lee, G. F., "Potential Problems of Land Application of Domestic Wastewaters," In: *Land Treatment and Disposal of Municipal and Industrial Wastes*, Ann Arbor Science, pp 179-192 (1976).

Jones, R. A. and Lee, G. F., "Chemical Agents of Potential Health Significance for Land Disposal of Municipal Wastewater Effluents and Sludges," *Proc. Conference on Municipal Wastewater and Sludges*, Univ. of Texas at San Antonio, pp 27-60 (1978).

### **Toxicity of Wastewater Effluents from Colorado Front Range Cities in Receiving Waters**

Drs. Lee and Jones conducted field studies to assess the aquatic life toxicity of domestic wastewater effluent from several Colorado Front Range cities, including Fort Collins (2 treatment plant discharges), Loveland, Colorado Springs, and Pueblo. The focus of those studies was the definition of acute lethal toxicity within and outside of the wastewater discharge plume in the receiving waters using in-stream caged fish toxicity tests. Summary papers on those studies include:

Heinemann, T. J., Lee, G. F., Jones, R. A. and Newbry, B. W., "Summary of Studies on Modeling Persistence of Domestic Wastewater Chlorine in Colorado Front Range Rivers," In: Water Chlorination-Environmental Impact and Health Effects, Vol. 4, Ann Arbor Science, Ann Arbor, MI, pp 97-112 (1983).  
<http://www.gfredlee.com/SurfaceWQ/Cl-Persist-Heinem.pdf>

Newbry, B. W., Lee, G. F., Jones, R. A. and Heinemann, T. J., "Studies on the Water Quality Hazard of Chlorine in Domestic Wastewater Treatment Plant Effluents," In: Water Chlorination-Environmental Impact and Health Effects, Vol. 4, Ann Arbor Science, Ann Arbor, MI, pp 1423-1436 (1983).  
<http://www.gfredlee.com/SurfaceWQ/Cl-WWTPEff-Newbry.pdf>

Dr Lee also developed:

Lee, G. F. and Jones, R. A., "Domestic Wastewater Dechlorination," Effluents, New Jersey Water Pollution Control Association 20:15-17 (1986).

Lee, G. F., "Application of the Hazard Assessment Approach for Evaluating the Need for Pueblo, CO to Remove Ammonia and Chlorine from Its Domestic Wastewater Discharges to the Arkansas River," Testimony before the Colorado Water Quality Control Commission, December (1980).

### **Lubbock, Texas Wastewater Reuse**

Drs. Lee and Jones conducted a study of the impact of reclaimed wastewater from the city of Lubbock, Texas on the sanitary quality of the Yellowhouse Canyon Lakes. Their findings were published as:

Lee, G. F. and Jones, R. A., "Indirect Reuse of Domestic Wastewater for Recreational Lakes: Evaluation of the Sanitary Quality of the Yellowhouse Canyon Lakes, Lubbock, Texas," In: Proceedings AWRA Symposium, "Water Supply and Water Reuse: 1991 and Beyond," San Diego, CA, pp. 1945-1975, June (1991).

Drs. Lee and Jones also developed several papers on surface and groundwater quality concerns associated with the use of reclaimed domestic wastewater:

Lee, G. F. and Jones-Lee, A., "Public Health and Environmental Safety of Reclaimed Wastewater Reuse," In: Proc. Seventh Symposium on Artificial Recharge of Groundwater, University of Arizona Water Resources Research Center, Tucson, AZ, pp. 113-128, May (1995). <http://www.gfredlee.com/ReclaimWW/pubhealth.pdf>

Lee, G. F. and Jones-Lee, A., "Total Dissolved Solids and Groundwater Quality Protection," In: Artificial Recharge of Ground Water, II, Proc. International Symposium on Artificial Recharge of Ground Water, American Society of Civil Engineers, NY, pp. 612-618 (1995).

[http://www.gfredlee.com/Groundwater/tds\\_gw.pdf](http://www.gfredlee.com/Groundwater/tds_gw.pdf)

Lee, G. F. and Jones-Lee, A., "Water Quality Aspects of Groundwater Recharge: Chemical Characteristics of Recharge Waters and Long-Term Liabilities of Recharge Projects," In Artificial Recharge of Ground Water, II, Proc. Second Internat Symp on Artificial Recharge of Ground Water, American Society of Civil Engineers, NY, pp. 502-511 (1995).  
<http://www.gfredlee.com/Groundwater/ascegw.pdf>

Lee, G. F. and Jones-Lee, A., "Monitoring Reclaimed Domestic Wastewater Usage on Public Parkland Vegetation to Reduce Risks," Water Engineering & Management, 142:28-29,37 (1995).

Lee, G. F. and Jones-Lee, A., "Appropriate Degree of Domestic Wastewater Treatment Before Groundwater Recharge and for Shrubbery Irrigation," AWWA, WEF 1996 Water Reuse Conference Proceedings, American Water Works Association, Denver, CO, pp. 929-939, February (1996). <http://www.gfredlee.com/ReclaimWW/awwawat2.pdf>

### **Hammond, Indiana – Impacts of Domestic Wastewater Treatment Plant Discharge on Water Quality**

In the 1990s Drs. Lee and Jones-Lee served as consultants to the Hammond, Indiana Sanitary District in their evaluation of impacts of combined sewer overflows (CSO's) and wastewater discharges on water quality in the Grand Calumet River. Of particular concern was the impact of heavy metals in the treatment plant effluent and CSOs on river quality. They also reviewed Natural Resources Damage Action against the District by the US Fish and Wildlife Service on the West Branch of the Grand Calumet River. They developed the report:

Lee, G. F., "Comments on January 13, 2004, Draft Preliminary Problem Formulation Tech Memorandum for the West Branch of the Grand Calumet River, Lake County, Indiana, Prepared by Tetra Tech for the US Fish and Wildlife Service," Comments Submitted to the U.S. Fish and Wildlife Service on behalf of the Sanitary District of Hammond, Indiana, by G. Fred Lee & Associates, El Macero, CA, February (2004).  
<http://www.gfredlee.com/HazChemSites/Hammond-GCR-Comments.pdf>

### **Sacramento San Joaquin Delta Studies**

In 1989 while he held the position of Distinguished Professor of Civil and Environmental Engineering at the New Jersey Institute of Technology and Director of the Site Assessment and Remediation Division of a multi university hazardous waste research center, Dr. Lee served as a consultant to the Delta Wetlands water supply project to evaluate the anticipated water quality in proposed water supply reservoirs on Delta islands. Drs. Lee and Jones-Lee found that the levels of aquatic plant nutrients contributed to the area from the Delta watershed and within the Delta would be expected to support excessive growths of algae in the proposed Delta water supply reservoirs which would result in their having poor water quality for water supply purposes. Of concern were the nutrient loads that would be contributed from domestic wastewater treatment plants in the Delta watershed.

In 1999 Drs. Lee and Jones-Lee became advisors to the SJR Low-DO TMDL Steering Committee to evaluate the causes and the control of low-DO conditions that develop in the Deep

Water Ship Channel near the Port of Stockton. Drs. Lee and Jones-Lee were selected to serve as the principal investigators for a \$2-million CALFED grant investigation of the SJR low-DO problem. They developed a synthesis report as well as several other papers and reports on the findings of those studies. Those reports and papers are available on their website in the Watershed SJR Delta section.

Lee, G. F., and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003).  
<http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf>

In 2004 Drs. Lee and Jones-Lee developed the first comprehensive review of Delta water quality issues:

Lee, G. F. and Jones-Lee, A., "Overview of Sacramento-San Joaquin River Delta Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA (2004).  
<http://www.gfredlee.com/SJR-Delta/Delta-WQ-IssuesRpt.pdf>

Lee, G. F., and Jones-Lee, A., "Overview—Sacramento/San Joaquin Delta Water Quality," Presented at CA/NV AWWA Fall Conference, Sacramento, CA, PowerPoint Slides, G. Fred Lee & Associates, El Macero, CA, October (2007).  
<http://www.gfredlee.com/SJR-Delta/DeltaWQCANVAWWAOct07.pdf>

Those reviews included discussion of the impacts of the city of Sacramento and Stockton wastewater discharges to the Delta on Delta water quality.

In March 2008, on behalf of the California Water Quality Modeling Forum, Drs. Lee and Jones-Lee organized a one-day workshop devoted to Delta nutrient water quality issues. The workshop content and key findings discussed were described in:

Lee, G. F., "Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modeling," Agenda for Technical Workshop sponsored by California Water and Environmental Modeling Forum (CWEMF), Scheduled for March 25, 2008 in Sacramento, CA (2008).  
[http://www.gfredlee.com/SJR-Delta/CWEMF\\_Workshop\\_Agenda.pdf](http://www.gfredlee.com/SJR-Delta/CWEMF_Workshop_Agenda.pdf)

Lee, G. F., and Jones-Lee, A., "Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA," Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008). [http://www.gfredlee.com/SJRDelta/CWEMF\\_WS\\_synopsis.pdf](http://www.gfredlee.com/SJRDelta/CWEMF_WS_synopsis.pdf)

Attention was given in those reviews to impacts of the Sacramento Regional Sanitation District's wastewater discharges on Delta water quality.

### **Water Quality Criteria/Standards Development and Implementation**

In the late 1960s, Dr. Lee pioneered in the development of approaches for evaluating the water quality/environmental impact of chemicals. The focus of his work over the past five decades has

been the integration of aquatic chemistry and toxicology for evaluating the impacts of chemicals on water quality. Dr. Lee has been involved in the development, evaluation, and implementation of water quality criteria and state standards since the early 1960s. A summary of his experience is provided at <http://www.gfredlee.com/exp/wqexp.htm>. During the 1960s, while in the position of Professor of Water Chemistry and Director of the Water Chemistry Program at the University of Wisconsin, Madison Dr. Lee served as an advisor to the Wisconsin Department of Natural Resources on the development and implementation of water quality criteria and standards. During that time, and since then, he has served as an advisor to numerous governmental agencies including municipalities, industry, and environmental/citizen groups on water quality criteria issues. In the early 1970s, he served as an invited peer reviewer for the National Academies of Science and Engineering's "Blue Book" "Water Quality Criteria - 1972." In the late 1970s, he served as an invited member of the American Fisheries Society Water Quality Panel that conducted a review of the US EPA's 1976 "Red Book" of "Water Quality Criteria." In the early to mid-1980s he served as a US EPA-invited peer reviewer for the 1986 "Gold Book" Water Quality Criteria development approach, and for several of the specific chemical criteria, including ammonia. During the 1960's through the mid-1970's he served as an advisor to the International Joint Commission for the US-Canadian Great Lakes in developing water quality objectives for the Great Lakes and their implementation. His pioneering work on PCB's in the 1960's led to his being selected to head the US Public Health Service committee on developing drinking water standards for PCBs.

Drs. Lee and Jones-Lee have published extensively on the development of water quality criteria and their implementation into state standards to appropriately regulate water quality impacts without significant over-regulation of wastewater and other discharges. Many of those publications are available on their website, [www.gfredlee.com](http://www.gfredlee.com) in the Surface Water section, <http://www.gfredlee.com/pwwqual2.htm#criteria>.

Dr. Lee has served as a technical consultant to several chemical companies including Procter & Gamble, FMC, and Monsanto to provide guidance in the evaluation of potential water quality impacts of new or expanded-use chemicals. His work with Monsanto included evaluating the water quality environmental impacts of phosphorus used in detergent formulations. With FMC, he helped evaluate the fate and effects of a carbon tetrachloride spill on the Ohio River water quality. For about 10 years Dr. Lee assisted Procter & Gamble in reviewing and evaluating potential water quality impacts of new products. In the early 1970s, Dr. Lee became an advisor to the President's Council on Environmental Quality (CEQ) in Washington DC to help develop programs for screening new and expanded-use chemicals for their potential environmental impacts. That effort was sparked by the finding of increasingly widespread occurrence of environmental pollution by PCBs, DDT and other organochlorine pesticides, and mercury.

During the 1970s Dr. Lee was a member of a group, composed of representatives of chemical companies, regulatory agencies, and academic professionals, that developed a series of "Pellston" workshops devoted to developing technically sound approaches for screening chemicals for environmental impact. In the late 1970s, the efforts of that group led to the development of the environmental hazard assessment approach for evaluating expected toxicological impacts and water quality impacts associated with new or expanded-use chemicals that could cause large-scale environmental pollution. Those efforts ultimately led to the

development of the Toxic Substances Control Act (TSCA). Drs. Lee and Jones together with their graduate students expanded and applied those principles to the conduct water quality hazard assessments for domestic wastewaters. Their work included the development of environmental chemistry-fate models for assessing the water quality impacts of domestic wastewater constituents such as chlorine (used for disinfection of domestic wastewaters) and ammonia using integrated laboratory and field toxicity testing. This approach became a foundation for the water quality and public health risk assessment approaches that are widely used today.

During the 1970s, on behalf of the Corps of Engineers Dredged Material Research Program, Dr. Lee conducted about \$1 million in research to develop technically sound approaches for evaluating the water quality implications of open water disposal of sediments dredged from US waterways as part of maintaining navigation depth. Dredged sediment toxicity tests were developed and evaluated for assessing whether chemicals in dredged sediments are in toxic/available forms that could be adverse to aquatic life at a dredged sediment disposal site. Those studies demonstrated that the high concentrations of most chemicals such as heavy metals in dredged sediments are in non-toxic forms. His work served as a technical foundation for the development of dredged sediment disposal criteria.

Drs. Lee and Jones-Lee have been active in reviewing the reliability of aquatic sediment criteria developed by regulatory agencies. As they have discussed, the approach followed by the California Water Resources Control Board for incorporating chemical concentration information in the evaluation of “sediment quality” is not technically valid; application of such approaches can readily lead to incorrect evaluations of sediment quality and the impacts of sediment-associated chemicals on a waterbody’s water quality.

Their website contains several papers and reports on water quality criteria and their implementation in discharge permits [[http://www.gfredlee.com/Surface\\_Water\\_Quality.html#criteria](http://www.gfredlee.com/Surface_Water_Quality.html#criteria)]. Their papers and reports on water quality criteria have application to regulating domestic wastewater discharges.