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February 25, 2002

Illinois Pollution Control Board
Attn: Dorothy Gunn, Clerk
James R. Thompson Center
100 West Randolph Street
Suite 11-500
Chicago, IL. 60601

Subject: Prefiled Testimony of Dr. David Zenz, P.E.
Docket No. R02-19

Please find enclosed the testimony of Dr. David R. Zenz, P. E. to be presented at the Illinois Pollution Control Board (IPCB) Meeting of March 25, 2002. This IPCB meeting is scheduled for 10:30 a.m. and will take place at the James R. Thompson Center in Chicago.

The testimony will be in the matter of the Illinois Association of Wastewater Agency (IAWA) proposal before the IPCB regarding ammonia-nitrogen water quality standards in Docket Number R02-19.

Please note that copies of the enclosed testimony have been sent to all persons on the existing service list for R02-19.

If you have any questions, please call me at 312-938-0300 (ext. 4221).

Very truly yours,

CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.

David R. Zenz, Ph.D., P. E.
Senior Associate

Cc: M. Callahan
M. Zima
D. Schmidt

**TESTIMONY PRESENTED TO THE
ILLINOIS POLLUTION CONTROL BOARD
IN THE MATTER OF:**

PETITION OF THE ILLINOIS ASSOCIATION OF WASTEWATER AGENCIES WATER QUALITY STANDARDS AMMONIA-NITROGEN

DOCKET NUMBER: R 02-19

MARCH 25, 2002

BY

**DR. DAVID R, ZENZ, P.E.
SENIOR ASSOCIATE
CONSOER TOWNSEND ENVIRODYNE ENGINEERS, INC.**

Introduction

The Illinois Association of Wastewater Agencies (IAWA) has presented a proposal to the Illinois Pollution Control Board (IPCB) requesting that the IPCB adopt new water quality standards for ammonia-nitrogen in the State of Illinois. The technical content of the petition is based upon the United States Environmental Protection Agency's (USEPA's) 1999 Update of Ambient Water Quality Criteria for Ammonia published in final form in the Federal Register on December 22, 1999 (Vol. 64, No. 245). This update was prepared by USEPA after an extensive review of the available literature on ammonia toxicity to aquatic life. In the 1999 update, USEPA has issued freshwater aquatic life criteria for ammonia which supercedes all previous criteria.

The IPCB's existing water quality standards for un-ionized and total ammonia-nitrogen in Part 302 were issued in 1996 [Docket Number R94-1B]. Clearly, the IPCB should carefully consider the IAWA petition since the basis of the IAWA's Petition is the USEPA's 1999 update. The 1999 update indicates that the states should consider the USEPA's 1999 ambient water quality criteria for ammonia in the development of water quality criteria standards which are protective of aquatic life. Since the 1999 update serves as a guide to the states in developing water quality standards for ammonia, the IAWA petition should be given serious consideration by the IPCB.

Focus of Testimony

My testimony will focus on the issue of the capabilities of wastewater treatment technology to meet ammonia-nitrogen National Pollutant Discharge Elimination System (NPDES) permit limits

which would ultimately result from IPCB's existing ammonia water quality standards. This issue was considered by the IPCB when it deliberated the existing IPCB water quality standards for ammonia based upon the previous version of the national guidance which has been superceded by the 1999 updated guidance document for ammonia.

Credentials

I have a Bachelor of Science Degree in Civil Engineering and Master of Science and Doctor of Philosophy Degrees in Environmental Engineering. All these degrees are from the Illinois Institute of Technology.

I received my Illinois Professional Engineering License in 1972. The license number is 062-031137.

I was certified through examination by the American Academy of Environmental Engineers as a specialist in wastewater treatment in 1986. The certificate number is 86-20007.

For thirty years, I was employed in the Research and Development Department of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). For my entire career at the MWRDGC, I worked in the Research and Technical Services Division which is responsible for developing wastewater treatment processes for use by the MWRDGC. I was employed by the MWRDGC from 1967 through 1997 during which the MWRDGC developed and implemented biological nitrification (ammonia removal) processes to meet IPCB water quality standards for ammonia.

Since leaving the MWRDGC in 1997, I have been employed at Consoer Townsend Envirodyne Engineers, Inc. (CTE) where I have been working with clients who have been struggling to meet the ammonia water quality standards adopted by the IPCB in R94-1(B). Most notably these clients are the Urbana and Champaign Sanitary District and the DeKalb Sanitary District.

I have published and/or presented over 70 technical papers on wastewater treatment and biosolids management. Ten of these technical papers deal with biological nitrification. A full listing of these technical papers are contained in the attached resume.

I have received a number of awards. Most notably, I received the Presidents Award from the Association of Metropolitan Sewerage Agencies and the Sidney Bedell Award from the Water Environment Federation. In 1998, I was named the Alva Todd Professor because of accomplishments as an Adjunct Professor in the Department of Environmental Engineering at the Illinois Institute of Technology.

A complete resume giving the details of my education and experience is attached.

Permit Limits Based upon Existing IPCB Water Quality Standards for Ammonia-Nitrogen

The IPCB enacted the existing water quality standards for ammonia in 1996. These water quality standards (Section 302) include numerical values for un-ionized ammonia-nitrogen, which are converted by the IEPA into site specific NPDES permit limits. Basically, IEPA uses available receiving stream data on flow, temperature and pH to calculate ammonia-nitrogen permit limits for a particular treatment plant. Of course, permit limits are highly variable

depending upon the particular receiving stream and treatment plant performance under compliance with existing ammonia standards.

Compliance with Existing IPCB Ammonia Water Quality Standards

It is difficult to say how many plants in Illinois would be unable to meet the existing 1996 IPCB water quality standards for ammonia. In testimony from the IEPA in R94-1 (B), the Agency indicated that a significant number of wastewater treatment plants would not be able to meet the 1996 IPCB standards. The agency testified that 19 out 181 facilities over 1 mgd capacity were at risk of non-compliance with the IPCB standards. The Agency indicated that they were fairly certain that most of these facilities would have to be at least partially redesigned to meet the standards. The IEPA did not study the impact of the 1996 water quality standards for ammonia-nitrogen on the over 600 wastewater treatment plants with design flows less than 1 mgd. The Agency also did not study the impact upon industrial discharges of ammonia to publicly owned treatment plants (POTWS).

There are two municipal agencies in the State of Illinois which are definitely impacted by the existing IPCB ammonia water quality standards for which I have first hand knowledge. These are the DeKalb Sanitary District and the Urbana and Champaign Sanitary District.

The DeKalb Sanitary District (DSD) wastewater treatment plant processes an annual average flow of about 6.4 mgd. The current NPDES permit for the DSD requires compliance with the IPCB's 1996 water quality standards by December, 2003. The permit limits which take effect in

December 2003 require the DSD to meet a monthly average ammonia-nitrogen concentration of 1.2 mg/l from November through March and 1.3 mg/l from April through October.

For the Urbana and Champaign Sanitary District's (UCSD) Southwest Plant (Design Flow of 5.9 mgd) the IEPA has issued a NPDES permit requiring compliance with IPCB's 1996 water quality standards by November 2003. This permit has a monthly average limit of 0.7 mg/l of ammonia-nitrogen throughout the year. For UCSD's Northeast Plant (design flow of 17.3 mgd) the IEPA also requires compliance with the 1996 IPCB ammonia water quality criteria by November 2003. The monthly average permit limits are 0.9 mg/l from April-October and 1.0 mg/l, November through March.

Ability of Biological Nitrification Systems to Achieve Effluent Ammonia-Nitrogen Concentrations Less than 1.5 mg/l

Today, POTWs in Illinois remove ammonia from effluents before discharge to receiving streams using biological nitrification systems. These systems are designed to contain a high population of nitrifying organisms which can convert (oxidize) ammonia (NH_3) to nitrate (NO_3). Unfortunately, biological treatment systems for ammonia removal are notoriously affected by low temperature. During the winter months, sewage temperatures in Illinois can be as low as 45° F when the reaction rate of nitrifying organisms is relatively low. It is typical for effluent ammonia concentrations to rise during the winter months.

The IEPA testified in R92-1 (B) (Mr. Studer, November 1994) that biological nitrification is capable of achieving monthly average ammonia concentrations of 1.5 mg/l from April through

October and 4.0 mg/l from November through March. This prompted the IEPA to request that the IPCB adopt the concept of effluent modified waters (EMW) for facilities which could not consistently meet the monthly averages of 1.5 mg/l/4.0 mg/l. The IPCB enacted the EMW concept advocated by IEPA. This was an attempt to rectify the disparity between protective water quality standards and the technical feasibility of providing treatment to meet these standards.

The United States Environmental Protection Agency (USEPA) in September of 1993 published its latest manual on Nitrogen Control (EPA/625/R-93/010). The manual (Page 39) discussed the performance of various ammonia removal technologies. In this discussion, the USEPA indicates that there are three levels of biological nitrification possible with so called "mechanical plants" using suspended and attached growth technologies. The three levels of treatment are:

1. Stringent: <2.5 mg/l of effluent NH_3-N
2. High: 2.5 to 5.0 mg/l of effluent NH_3-N
3. Intermediate: 5-10 mg/l of effluent NH_3-N

Pages 68 and 69 of the USEPA manual gives design examples to illustrate the design principles for biological nitrification processes. "Stringent" effluent limits for one design example are as follows:

NH_3-N

Effluent NH_3-N Limits, mg/l

Monthly Average	Weekly Average
2	3

Given good operation and adequate capacity, biological nitrification systems whether fixed film (trickling filter) or suspended growth (activated sludge) can produce monthly average ammonia-nitrogen concentrations less than 2.5 mg/l. Typically, well operated suspended growth systems with adequate capacity should be able to produce effluent ammonia-nitrogen concentrations of 1.5 mg/l. However, fixed film systems typically contain 1.0 to 3.0 mg/l of effluent ammonia-nitrogen (Metcalf and Eddy, Wastewater Engineering, Treatment Disposal, McGraw Hill, Inc. New York, N.Y., 1991) and do not produce consistent effluent ammonia-nitrogen levels of 2 mg/l (USEPA, Process Design Manual for Nitrogen Control, 1992).

The inherent variability in performance of biological-nitrification systems is well illustrated in the Water Environment Federation Manual of Practice Number 8 (Design of Municipal Wastewater Treatment Plants, 1998). The manual (Page 11-186) discusses the performance of activated sludge (suspended growth) systems designed for nitrification. Table 11.45 of the manual contains the following data on performance of single stage nitrification plants:

	Plant A	**Plant B**	**Plant C**	**Plant D**
NH_3-N, mg/l				
Range:	0.06-16	0.5-1.2	0.4-3.2	-
Annual Average:	2.1	0.7	1.3	1.7

The data clearly shows that a suspended growth system can produce average effluent ammonia-nitrogen concentrations of 0.7 mg/l but a range of values up to 2.1 can and does occur.

On page 179 of USEPA's Nitrogen Control Manual (EPA/625R-93/010) the performance of fixed film (trickling filters) nitrification systems are discussed. The performance of three plants in the Midwest are highlighted which had effluent ammonia-nitrogen levels as follows:

	Plant A	Plant B	Plant C
NH_3-N, mg/l			
Range:	0.8-4.8	0.3-3.0	0.2-3.0
Average:	2.0	0.5	0.2

Based upon an assessment of the data from the Midwest plants and those from other localities, the USEPA manual concludes that "The results indicate that all plants were achieving less than 2.0 mg/l of ammonia-nitrogen 50 percent of the time with four of the plants at less than 2.0 mg/l 90 percent of the time. The plants were all operating with conservative ammonia surface loading rates".

Both the UCSD and the DSD employ fixed film nitrification systems to remove ammonia-nitrogen. Since both are currently faced with the imposition of monthly average NPDES permit limits from 1.2 mg/l to as low as 0.7 mg/l, it appears obvious that the existing 1999 IPCB water quality standards are an extremely stringent standard for these two municipalities. Both UCSD and DSD are faced with the very real possibility of not being able to meet the IPCB's existing water quality standards with their existing fixed film biological nitrification systems. Again this is not an atypical situation given the IEPA testimony in R92-1(B) which predicted that at least 19 POTWs in Illinois greater than 1 mgd in capacity would have to undergo redesign because of the IPCB existing standards.

Options for Meeting the Existing IPCB Standards

For some treatment plants like those of the DSD and UCSD, it will be necessary to consider using a physical/chemical process to consistently and reliability reduce ammonia levels to below

1.5 mg/l. Such physical/chemical systems would be employed as an add-on process to remove or "polish" the relatively small amounts of ammonia remaining after biological nitrification.

There is relatively little experience with physical/chemical systems used as the principal ammonia removal system and almost no experience using such systems to polish an effluent from a biological nitrification system. The physical/chemical systems which are potential candidates for removing the small amounts of ammonia from nitrified effluents are:

1) Ammonia Stripping
2) Ion Exchange
3) Reverse Osmosis
4) Breakpoint Chlorination

Ammonia stripping would involve adding lime to elevate the pH of the effluent to 10.5 to 11.5 and providing sufficient air to strip out the ammonia. The high pH allows the ammonia to be easily released from solution as a gas. This system has little application in the Midwest due to ice formation in the air stripping equipment. Also the large lime dosages to raise effluent pH, the high capital cost of the air stripping equipment and lime scale formation on the air stripping equipment make the process costly and unreliable.

Ion exchange involves passing an effluent through an ion-exchange resin. The ammonium ion becomes attached to the resin. Ultimately the resin becomes saturated with ammonium ion and the resin must be regenerated with a high pH salt solution which removes the ammonium. The

regenerant solution contains high levels of ammonia and must be disposed of or treated in some way.

The capital costs of the ion exchange system are very high. The system requires significant maintenance and annual chemical costs are high. The biggest difficulty is disposal of the concentrated regenerant.

Reverse osmosis appears to offer the potential of a viable method of polishing a nitrified effluent. But there simply is not enough experience in the use of this method for polishing effluents. The chief concern is excessive plugging and/or contamination of the reverse osmosis membranes and the pumping costs associated with the high pressures needed to force effluent through the membranes.

Breakpoint chlorination involves adding sufficient chlorine to oxidize the ammonia present in the effluent. The ammonia is chiefly converted to nitrogen gas which is released to the atmosphere during the breakpoint reaction. About 10 mg/l of chlorine are required to remove 1 mg/l of ammonia from an effluent.

The breakpoint chlorination process can be readily adapted to chlorination/dechlorination systems routinely used for disinfection at a municipal plant. The process would require adding higher amounts of chlorine than that required for coliform kills and the resulting higher chlorine residual would require larger amounts of dechlorinating chemicals.

The chemical addition equipment of the existing chlorination/dechlorination system would have to be modified but the contact chamber for disinfection would not. The contact time for disinfection is about 15 minutes while the breakpoint reaction occurs in 15 seconds.

The chief drawback with breakpoint chlorination is the production of higher amounts of triholomethanes than that of a disinfection process.

Effect of the IAWA Petition

A comparison of the USEPA's 1999 update ammonia criterion with the existing 1996 IPCB water quality standards reveals that use of the 1999 update criterion to develop ammonia-nitrogen permit limits would generally yield higher numerical values. This is especially true for plants whose downstream receiving waters have high pH. Therefore the adoption of the IAWA petition would give some relief to those agencies like DSD and UCSD whose are faced with the very really possibility of spending considerable sums to polish their effluents to levels of ammonia-nitrogen less than 1.5 mg/l.

Summary and Conclusions

1. Because of the inherent variability of biological nitrification treatment systems, it is not possible for some systems to consistently and reliability achieve monthly average ammonia-nitrogen permit limits less than 1.5 mg/l year round.

2. In some cases, existing IPCB water quality standards for un-ionized ammonia have resulted in monthly average effluent limits for ammonia-nitrogen lower than 1.5 mg/l.

3. Physical/chemical ammonia removal systems may have to be employed to meet monthly average ammonia-nitrogen permit limits of less than 1.5 mg/l.

4. There is little experience with physical/chemical systems used to remove relatively small amounts of ammonia-nitrogen from effluents. Some of these systems are relatively costly and/or difficult to operate and/or may have negative environmental impacts.

5. The enactment of the ammonia-nitrogen permit limits based upon water quality standards in the IAWA petition will provide some relief to dischargers now faced with meeting monthly average permit ammonia-nitrogen permit limits of less than 1.5 mg/l.

DAVID R. ZENZ, PH.D., P.E.
SENIOR ASSOCIATE

EDUCATION

B.S. Civil Engineering, 1965, Illinois Institute of Technology
M.S. Environmental Engineering, 1967, Illinois Institute of Technology
Ph.D. Environmental Engineering, 1968, Illinois Institute of Technology

EMPLOYMENT HISTORY

Consoer Townsend Envirodyne Engineers, Inc., 8/25/97 to Date
Experience With Other Firms - 30 Years in municipal sludge management and municipal wastewater treatment with the Metropolitan Water Reclamation District of Greater Chicago

REGISTRATIONS

Professional Engineer, Illinois, 1972

PROFESSIONAL SOCIETIES & HONORS

Water Environment Federation
Diplomate of the American Academy of Environmental Engineers
Chairman, Water Environment Federation Residuals Management Committe, 1979 -1982
Peer Review Committee, Standards for the Disposal of Sewage Sludge, USEPA Proposed Rule 40 CRF Part 257 and 503, 1989
President, Illinois Water Environment Association, 1990-1991
Director, Illinois Water Environment Association, 1993-1996
Chairman, Illinois Association of Wastewater Agencies, Sludge Management Committee, 1980-Present
Chairman, Illinois Water Environment Association, Biosolids Committee, 1997-Present
Vice President - Technical, Illinois Association of Wastewater Agencies, 1996-1997
Member, Biosolids Committee, Association of Metropolitan Sewerage Agencies, 1976-Present
Co-Chairman, Air Quality Committee, Association of Metropolitan Sewerage Agencies, 1990-1997
Illinois Association of Wastewater Agencies, Illinois Award, 1994
Association of Metropolitan Sewerage Agencies, President's Award, 1997

WORK EXPERIENCE:

Dr. Zenz worked for nearly 30 years in the Research and Development Department of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) in various capacities including:

Manager of Research and Technical Services, 1991-1997
Coordinator of Research, 1972-1990
Head of the Wastewater Treatment Research Section, 1970-1972
Research Project Leader, 1968-1970

As part of the MWRDGC's pretreatment and industrial user charge program, Dr. Zenz participated in many technical studies of food processing industries which discharge to the MWRDGC's treatment plants. Such studies included:

- Pilot plant treatability studies
- Inspection and review of food processing treatment plant performance
- Evaluation of existing and proposed food processing treatment technology

During his tenure with the MWRDGC, Dr. Zenz was connected with virtually every aspect of the MWRDGC's operation, including:

- Development and operation of the MWRDGC's 15,000 acre sludge application to land project in Fulton County, Illinois

- Development and operation of the MWRDGC's sludge give-away program in the Greater Chicago area.
- Development and operation of the following sludge processing systems currently used at the MWRDGC, including:

  - Anaerobic Digestion
  - Centrifugal Dewatering
  - Agitation Dewatering
  - Gravity Thickening
  - Gravity Belt Thickening
  - Centrifugal Thickening

- Development and operation of wastewater treatment operations currently used at the MWRDGC, including:

  - Two stage biological nitrification
  - Single stage biological nitrification
  - Sand filtration
  - Chlorination-Dechlorination
  - In-stream Aeration

During his tenure at the MWRDGC, Dr. Zenz was involved in pilot and full testing of both wastewater treatment and sludge processing systems, including:

WASTEWATER TREATMENT SYSTEMS

Bio-Discs
Biological Phosphorus Removal
Chemical Phosphorus Removal
Biological Denitrification
Ozonation
Ion-Exchange
Multi-Media Filtration

SLUDGE PROCESSING SYSTEMS

Alkaline Stabilization
Composting
Vacuum Filtration
Belt-Filter Dewatering
Thermophilic Digestion
High Energy Radiation

PUBLICATIONS

"Effective Phosphorus Removal by the Addition of Alum to the Activated Sludge Process" by Zenz and Pivnicka, Proceedings of the 24th Annual Purdue Industrial Waste Conference, 1969.

"Sensors for the Analysis and Control of Biological Processes" by Zenz, McAloon, and Weddle, presented to the Division of Water and Air Chemistry, American Chemical Society, April 1969.

"Ozonation of Microstrained Secondary Effluent" by Zenz and Weingarden, presented at the Symposium on Ozonation in Sewage Treatment held in Milwaukee, Wisconsin, 1971.

"Chemical and Biological Quality of Municipal Sludge" by Peterson, Lue-Hing, and Zenz. "Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland" 1973.

"Metro Chicago Studies on Nitrification" presented at the Third U.S./Japan Conference on Sewage Treatment Technology by Zenz, Lynam, Lue-Hing, and Richardson, February 1974.

"Suspended Solids Removal Processes Studies at Metro-Chicago," by Zenz, Lynam,, Lue-Hing, and Richardson, Presented at the Third U.S./Japan Conference on Sewage Treatment Technology. February 1974.

"Digested Sludge Recycle to Farmland - Effect on Public Health, Environmental Quality, and Row Crop," by Zenz, Peterson, Brooman, and Lue-Hing, presented at the 47th Annual WPCF Meeting in Denver, Colorado, October 1974.

"Filtration of Suspended Solids in Secondary Effluents (**A** Case Study)," by Zenz, Lynam, LueHing, and Richardson, Proceedings of the 3rd International Pollution Engineering Congress, Chicago, Illinois, September 1974.

"USEPA Guidelines on Sludge Utilization and Disposal - A Review of its Impact Upon Municipal Wastewater Treatment Agencies," by Zenz, Lynam, Lue-Hing, Rimkus, and Hinesly, Presented at the 48th Annual WPCF Conference in Miami Beach, Florida, October 1975.

"Studies on the Inactivation of Viruses During Anaerobic Digestion of Sludge," by Bertucci, Lue-Hing, Zenz, and Sedita. Paper presented at the 48th Annual Water Pollution Control Federation Conference, Miami Beach, October 1975.

"Biological Nitrification of Sludge Supernatant by Rotating Discs," by Lue-Hing, Obayashi, Zenz, Washington, and Sawyer. JWPLF, January 1976.

"Inactivation of Viruses During Anaerobic Digestion," by Bertucci, Lue-Hing, Zenz, and Sedita, JWPCF, July 1977.

"Biological Nitrification of a High Ammonia Content Sludge Supernatant Under Ambient Summer and Winter Conditions by Use of Rotating Discs," 47th Annual New York Water Pollution Control Conference, N.Y. City, January 20-22, 1975. Lue-Hing, Obayashi, Zenz, Washington, and Sawyer.

"Determination of the Design Parameters for a 30 MGD Two-Stage Nitrification Plant," Presented at the Technology Transfer National Conference on Nitrogen Control,USEPA, Chicago, Illinois, July, 1976. Lue-Hing, Richardson, Sawyer, and Zenz.

"Heavy Metal Uptake and Control Strategies Associated with Sewage Sludge Fertilized Crops," Presented at National Conference on Disposal of Residues on Land, St. Louis, Missouri, September 1976. Lue-Hing, Hinesly, Peterson, and Zenz.

"Evaluation of Unit Processes for Dewatering Anaerobically Digested Sludge at Metro Chicago's Calumet Sewage Treatment Plant," Presented at WPCF Conference, Minneapolis, Minnesota, October 1976. Zenz, Sawyer, Watkins, Lue-Hing, and Richardson.

"Studies on Single-Stage Nitrification at the Calumet Sewage Treatment Plant, Illinois," Presented at the Annual Water Pollution Control Federation Meeting, October 1976, Minneapolis, Minnesota, Prakasam, Lue-Hing, Bogusch, and Zenz.

"Environmental Impacts of Land Application of Sludge," JWPCF, October 1976. Zenz, Peterson, Brooman, and Lue-Hing.

Public Health aspects of Digested Sludge Utilization, R&D Report No. 76-15," Presented at Cornell University 8th Annual Waste Management Conference, "Land as a Waste Management Alternative," Rochester, N.Y., April 1976. Bertucci, Lue-Hing, O'Brien, Sedita, and Zenz.

"Pilot Plant Studies on Single-Stage Nitrification at the Calumet Sewage Treatment Plant," May 1976, Central States Water Pollution Control Association. Prakasam, Lue-Hing, Bogusch, and Zenz.

"Wastewater Disinfection: The Case Against Chlorination," Presented at The Forum on Ozone Disinfection, The International Ozone Institute, Chicago, Illinois, June 1976. Lue-Hing, Lynam, and Zenz.

"New Directions in MSD Research," Presented at the Technology Transfer National Conference on Nitrogen Control, USEPA, Chicago, Illinois, July 1976, LueHing, Obayashi, Zenz, and Prakasam.

"Biological Nitrogen Control Case Example, Calumet Nitrification Study," Presented at the EPA Technology Transfer Conference, July 1976, Chicago, Illinois. Lue-Hing, Bogusch, Zenz.

"Inactivation of Viruses During Anaerobic Digestion" Journal of The Water Pollution Control Federation, Bertucci, Lue-Hing, Zenz, and Sedita, July 1977.

United States Sludge Disposal Regulations - Impacts Upon municipal Sewage Treatment Facilities - Comparison with Experimental Results," Zenz, Peterson, and Lue-Hing, Presented at Sewage Sludge Utilization and Disposal Seminar, Toronto, Canada, February 1978.

"Effects of Urban Non-Point runoff and Treated Municipal Wastewater on a Man-Made Channel in Northeastern Illinois," Presented at the 26th Annual Meeting of the North American Benthological Society, Winnipeg, Manitoba, Canada. Polls, Lue-Hing, Zenz, and Sedita, May 1978.

"A Water Quality Sampling Program in Support of a 208 Planning Process in Northeastern Illinois," Presented at AWPA Special Symposium on Establishment of Water Quality Monitoring Programs," San Francisco, California. Polls, Lanyon, Lue-Hing, Sedita, and Zenz, June 1978.

"Fish Survey of Northeastern Illinois Streams," Presented at the Eleventh Annual Meeting of the Mississippi River Research Consortium, University of Wisconsin, LaCrosse, Wisconsin. Dennison, Carlson, Zenz, and Lue-Hing.

"Bacterial Levels Resulting from the Land Application of Digested Sludge," Presented at the Conference of Applied Research and Practice on Municipal and Industrial Waste, Madison, Wisconsin. O'Brien, Sedita, Zenz, and Lue-Hing, September 1978.

"Evaluation of Dewatering Equipment for Anaerobically Digested Sludge," by Zenz, Sawyer, Watkins, Lue-Hing, and Richardson. Journal of the Water Pollution Control Federation, August 1978.

"Use of Municipal Sludge in Reclaiming Soils," Halderson and Zenz. Proceedings of Conference on Reclamation of Drastically Disturbed soils, American Society of Agricultural Engineers. 1978.

"Pilot-Scale Studies of Single-Stage Nitrification," Prakasam., Lue-Hing, Bogusch, and Zenz, Journal of The Water Pollution Control Federation, July 1979.

"Response of Plankton in Surface Waters After Five Years of Incorporating Municipal Sludge to Soil MSDGC Land Reclamation Site - Fulton County, Illinois," Presented at The Second Annual Conference of Applied Research and Practice on municipal and Industrial Waste," Madison, Wisconsin. Schmeelk, Sedita, Zenz, Lue-Hing, September 1979.

"Monitoring Fish from Lakes Within a Sewage Sludge Reclaimed Strip-Mine Area in Central Illinois," presented at the Second Annual Conference on Applied Research and Practice on Municipal and Industrial Waste," Madison, Wisconsin. Dennison, Sedita, Zenz, Lue-Hing, September 1979.

"Pilot-Scale Studies on the Nitrification of Primary and Secondary Effluents Using Rotating Biological Disks at MSDGC," Zenz, Bogusch, Krup, Prakasam, and Lue-Hing. Proceedings of The First National symposium on Rotating Biological Contractor Technology," Champion, Pennsylvania, February 1980.

"Full-Scale Combined Carbon Oxidation-Nitrification at The Metropolitan Sanitary District of Chicago," Lue-Hing, C., B. Washington, D. R. Zenz, A. W. Obayashi, and T. B. S. Prakasam, Proceedings International Seminar on Control of Nutrients in Municipal Wastewater Effluents, Vol. II, pp 43-97, September 1981.

"Impact of Federal, State, and Local Regulations on Industrial Sludge Management Practices," presented at the Water Industry 181 Conference in Brighton, UK., June 1981, C. Lue-Hing, D. Zenz, and D. Lordi.

"Sludge Utilization at Metro Chicago's Fulton County Site," presented at the AMSA Conference entitled "The Sludge Management Syndrome: Burn, Barge, Bury, or BUST," Orcas Island, Washington, July 1981, David R. Zenz, James R. Peterson, and Cecil Lue-Hing.

"Municipal Sludge Management," presented at the 4th Annual Oak Ridge National Laboratory Life Science Symposium, Gatlinburg, Tennessee, October 1981, David R. Zenz and Cecil Lue-Hing.

"Metropolitan Chicago's Fulton County Sludge Utilization Program," W. E. Sopper, E. M. Seaker, and R. K. Bastian (ed.), In Land Reclamation and Biomass Production with Municipal Wastewater and Sludge, The Penn State University Press, University Park, 1982, Peterson, J. R., C. Lue-Hing, J. Gschwind, R. I. Pietz, and D. R. Zenz.

Groundwater Quality During Ten Years of Sewage Sludge Application to Strip-Mined Land; Agronomy Abstracts, p. 36, November 1982, Peterson, J. R., J. Gschwind, R. I. Pietz, D. R. Zenz, and C. Lue-Hing.

"The Efficacy of Chlorine in the Disinfection of Nitrified and Nonnitrified Activated Sludge Effluents." Presented at the Fifty-Sixth Annual Water Pollution Control Federation Conference, Atlanta, Georgia, October 1983, T. B. S. Prakasam, Eugene Bogusch, David R. Zenz, and Cecil Lue-Hing.

"Ninety-Year History of the Metropolitan Sanitary District of Greater Chicago." Presented at the Fifty-Sixth Annual Water Pollution Control Federation Conference, Atlanta, Georgia, October 1983, David R. Zenz and Cecil Lue-Hing.

"Management of Organic Residuals Separated from Industrial Wastes," B. B. Berger, Editor, Control of Organic Substances in Water and Wastewater, USEPA 600/8-83-011, p. 408, April 1983, Lue-Hing, C., T. B. S. Prakasam, and D. Zenz.

"Exertion of Five-Day Nitrogenous Oxygen Demand in Nitrifying Wastewaters," Journal Water Pollution Control Federation, Lue-Hing, D. R. Zenz, K. C. Rao, and A. Obayashi.

"Case History: Aeration System Design, Operation, Control, and Maintenance at the Metropolitan Sanitary District of Greater Chicago." Presented at the Georgia Water and Pollution Control Association and City of Atlanta, Aeration System Design, Operation, Control, and Testing Conference, Atlanta, Georgia, March 1984, C. Lue-Hing, David R. Zenz, and B. Sawyer.

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