1. We welcome the following new members of OCEESA:
OCEESA New Members (2-28-02)

Dr. Wei Lin, Assistant Professor, Civil Engineering Department,
North Dakota State University, Fargo, North Dakota 58105

Dr. David Kuang-Ye Cheng, President, Accord Engineering, Inc.
2472 Chambers, Suite 250, Tustin, California 92780

2. Mr. Anmin Liu, our OCEESA Vice President in 2001, is our new OCEESA President in 2002. Congratulations to Mr. Liu, the OCEESA President in 2002.

3. Results of Election of OCEESA Officers of 2002

VICE PRESIDENT (2002)         Dr. Abraham Shou-Chien       Battelle Memorial Institute
SECRETARY (2002)                  Dr. Chein-Chi Chang              District of Columbia Water and Sewer Authority
   Dr. Francis Hun-I Chang   Kinectrics Inc., Toronto, Canada
   Dr. Ning-Wu Chang         Department of Toxic Substances Control, California EPA
   Dr. Jing-Yuan Wang        Nanyang Technological University, Singapore
DIRECTOR (2002)
   Dr. Ing-Yih Cheng        Environmental Monitoring Division, City of Los Angeles, California

Congratulations to our new Vice President, Secretary-Treasurer, and new Directors and Officers! We are looking forward to their excellent service and contributions to OCEESA in 2002.

4. The continuing directors (2001-2002) of OCEESA are as follows:
   Mr. Edward T. Chen                      Houston Department of Solid Waste Manage
   Dr. Lee-Hua Miaw                        Spectra-Probe, Inc.

5. Dr. Tsen C. Wang, OCEESA President in 2001, has become Ex Officio of OCEESA in 2002.
   OCEESA directors, who have just completed their 2 years term (2000-2001) ending December 31, 2001, are listed below:
   Dr. Ruth R. Chang           California Environmental Protection Agency
   Dr. I-Ming Chou             U.S. Geological Survey
   Dr. Frank H. Wu             Integral Energy and Environmental Engineering

Our sincere thanks to their outstanding services to our OCEESA during the past year.

6. Congratulations to Dr. Ing-Yih Cheng, who has recently retired as Manager, Environmental Monitoring Division, City of Los Angeles, California.

7. Dr. Cary T. Chiou, an OCEESA member and a former OCEESA Director in 1998-2000, is recently honored by Environmental Science and Technology for his published research - Partition Coefficient and Bioaccumulation of Selected Organic Chemicals (ES&T, v. 11, p. 475-478, 1977). The paper is among the 10 high-impact environmental research papers based on the numbers of citations received between 1980 and 2001. A special report on the 10 high-impact papers and the authors appeared in the December 1, 2002 issue of ES&T. In 1999, Dr. Chiou’s 1979 paper in Science received the Outstanding Publication Award from AEES
8. Mr. Anmin Liu, OCEESA President, has approved OCEESA Journal to electronic journal and will be posted on OCEESA web site. OCEESA members are encouraged to visit OCEESA web site. There will be no hard copy mailed to members. We will continue to mail the annual OCEESA membership directory to members.

OCEESA members are encouraged to visit our OCEESA web site and update their membership information.

EDITOR'S NOTE

The editors of this issue of OCEESA Journal are Dr. Tsen C. Wang, Dr. Anmin Liu and Dr. Abraham Shou-Chien Chen. The editors for the next issue, August 1, 2002, are Dr. Ning-Wu Chang, Dr. Ing-Yih Cheng, Dr. Chein-Chi Chang, Mr. Edward T. Chen and Dr. Lee-Hua Miaw. OCEESA members are encouraged to submit before July 15, 2002, news items and papers with a maximum length of 5 typed pages (single space, letter size 10, put all figures and tables after your text) and a PC disk (in Word File) to: Dr. Yung-Tse Hung, Editor-OCEESA Journal, Professor, Civil Engineering Department, Cleveland State University, Cleveland, Ohio 44115-2440 USA. Tel: (216) 687-2596 FAX: (216) 687-5395 Email: y.hung@csuohio.edu Please also email your complete manuscript in electronic version (as attachment of email) to Dr. Hung before the deadline. Photos and pictures must be scanned and must be put in electronic version.
OCEESA World Wide Web Homepage: http://www.oceesa.org

OCEESA OFFICERS OF 2002

President Mr. Anmin Liu AML Environmental Engineering Consultants
Vice President Dr. Abraham Shou-Chien Chen Battelle Memorial Institute
Secretary/Treasurer Dr. Chein-Chi Chang District of Columbia Water and Sewer Authority
Directors (2001-2002) Mr. Edward T. Chen Houston Department of Solid Waste Manage
Dr. Lee-Hua Miaw Spectra-Probe, Inc.

Dr. Francis Hun-I Chang Kinectrics Inc., Toronto, Canada
Dr. Ning-Wu Chang Depart. of Toxic Substances Control, California EPA
Dr. Jing-Yuan Wang Nanyang Technological University, Singapore

Director (2002)
Dr. Ing-Yih Cheng Environ. Monitoring Division, City of Los Angeles, California

Ex-Officio: Dr. Tsen C. Wang Harbor Branch Environmental Lab
Executive Director: Dr. Yung-Tse Hung, Cleveland State University

Advisors: Dr. Shoou-Yuh Chang Dr. John C. P. Huang Dr. Wen-Chi Ku Dr. Thomas To Shen
Dr. Don Tsye-Lang Tang Dr. Ching-Tzone Tien Dr. Jen-Tai Yang

Assistant Executive Director: Dr. Howard H. Lo, Cleveland State University

LIST OF OCEESA PRESIDENT

1. 1980-81 (6-1-80 to 5-31-81) Dr. Robert Hsi-Lin Howe (Deceased)
2. 1981-82 (6-1-81 to 5-31-82) Dr. Howard Ju-Chang Huang
3. 1982-83 (6-1-82 to 5-31-83) Dr. Edward Shing-Ke Chian
4. 1983-84 (6-1-83 to 5-31-84) Mr. Eugene Y. Hsi (Deceased)
CALL FOR PAPERS

8th MTEPC (Mainland Taiwan Environmental Protection Conference)
October 14-18, 2002  Hsinchu, Taiwan

The 8th MTEPC (2002) will be held in Hsinchu, Taiwan, October 14-18 (M-F), 2002. The meeting will be held at International Conference Hall, Electronic Information Building, Chiao Tung University, Hsinchu, Taiwan. OCEESA members are asked to send form of intention to submit a paper by email and also by air mail to Dr. Yung-Tse Hung (Deadline: February 28, 2002). OCEESA members are encouraged to submit 300-500 words abstract, preliminary registration form (please see below for format), and a one page resume by both regular mail and by email to the following (deadline: March 25, 2002):

Dr. Yung-Tse Hung, Professor
Civil Engineering Department
Cleveland State University
Cleveland, Ohio 44115-2440 USA
Tel: (216) 687-2596 Fax: (216) 687-5395
Email: y.hung@csuohio.edu

Submitting a full paper to OCEESA is required before you will be allowed to make presentation of paper at the conference.

Deadline for receiving intention of submitting paper by OCEESA: February 28, 2002 (Th)
Deadline for receiving abstract by OCEESA: March 25, 2002 (M)
Notice of acceptance of abstract by OCEESA: April 1, 2002 (M)
Deadline of receiving full paper by OCEESA: July 1, 2002 (M)

Guidelines for abstract:
A. 300 to 500 words abstract (single space typing for text, letter size 10)
B. To include the following in the abstract:
   1. Title of paper
Theme of 8th MTEPC: Sustainable Environmental Technology and Management

Topics of Papers for 8th MTEPC:
1. Environmental Status of Mainland-Taiwan and Case Studies
2. Environmental Planning and Management
3. Sludge Treatment and Utilization
4. Water Resources Protection and Drinking Water Treatment
5. Global Warming Effects and Mitigation
6. Air Quality and Air Pollution Control
7. Water Pollution Control- Treatment of River Sediments
8. Clean Technology and Waste Minimization
9. Toxic Management of Environmental Pollutants
10. Environmental System Analysis
11. Environmental Pollution Control of High-Tech Industry
12. Other Fields of Environmental Protection

Upon acceptance of abstracts, you will be sent the author guide for submitting your complete manuscript with a PC disk containing your paper and resume. As in the past, OCEESA presenters are required to pay three years OCEESA membership dues. There may be some possibility of small assistance toward travel expenses, for OCEESA presenters, should fund raising become successful.

For further information, please contact Dr. Yung-Tse Hung, or Mr. Anmin Liu, Chair, 8th MTEPC - OCEESA Planning Committee and President, OCEESA, or Dr. Abraham Shou-Chien Chen, Vice President, or Dr. Chein-Chi Chang, Secretary-Treasurer, OCEESA. Mr. Liu can be reached at Tel: (310) 891-3088 Email: anminliu@madiaone.net Dr. Chen can be reached at Tel: (614) 424-5641 Fax: (614) 424-3667 Email: chena@battelle.org Dr. Chang can be reached at Tel: (202) 787-2459 Fax: H: (410) 461-3923 Email: chein-chi_chang@dcwasa.com

Please send your form of intention to submit a paper by email and also by air mail to Dr. Yung-Tse Hung (Deadline: February 28, 2002).

Please send by both email and also by air mail your preliminary registration form, your abstract and 1 page resume to Dr. Yung-Tse Hung (deadline: March 25, 2002).

OCEESA Intention of Submitting Paper Form for 8th MTEPC (Due: February 28, 2002)

1. Full Name (in English):
2. Full Name (in Chinese):
3. Country of Your Passport:
4. Citizen of U.S. (Yes or No):
5. Green Card Holder of U.S. (Yes or No):
6. Position with Employer:
7. Name of Employer:
8. Home Mailing Address:
OCEESA Preliminary Registration Form for 8th MTEPC (Due: March 25, 2002)

1. Full Name (in English):
2. Full Name (in Chinese):
3. Country of Your Passport:
4. Citizen of U.S. (Yes or No):
5. Green Card Holder of U.S. (Yes or No):
6. Position with Employer:
7. Name of Employer:
8. Home Mailing Address:

9. Telephone (Office):
10. Fax (Office):
11. Telephone (Home):
12. Fax (Home):
13. Email Address (Office):
14. Email Address (Home):
15. Title of Paper:
16. Topic Area of your paper:
   (Please select a number from topic areas in the call of abstract announcement above, select from 1 to 12)
16. Resume (1 page): Resume to be submitted with your registration form and abstract. Please follow resume format below.

Note: Format of resume: name, position, department, employer, complete contact information, education, academic experience, industrial experience, professional engineering registration, professional association, major field of competence, list of publications (incl. presentations)
OCEESA President’s Message

Anmin Liu, P.E.
OCEESA President

President
AML Environmental Engineering Consultants
Lomita, CA. 90717
Email: anminliu@attbi.com

I truly felt that it is an extreme honor to be at the position of the President of OCEESA. It surly humbles me to be among such an elite group of professional expertise in the environmental field.

Then I asked myself, what is my job here? To answer this question, I have the history of OCEESA revealed in front of my eyes as long as I know it. I found out that OCEESA has progressed tremendously in every aspect of an organization should be. But I also found out that OCEESA’s pulsing activities were limited to MTETS and SATEC. And of course, we will continue to administer, participate and to do our best to make these two events successful. Meanwhile, let us take a look at ourselves, what is our strength? what are our shortcomings? In addition to the above-mentioned two events, what are our plans for future years? Now, it seems that I realized what is my job here; I do not even dare to say that my job is to answer those questions, but I do want to initiate some thinking along those lines, and I want to welcome ideas, opinions, suggestions from all members of OCEESA and then we will set up a map, a dynamic map for our organization to tread on systematically. As Dr. Tsen C. Wang said last year, this is your Association, your involvement is critical to the life of the Association.

In addition to the vision, the critical issue is to increase our membership. Everyone of us has the responsibility of recruiting new members to join us. But on the other hand, we do need to promote the benefits of joining OCEESA. I would challenge our Officers and Board Directors to create an information booklet to describe OCEESA and its privileges and benefits.

This year, I would like to establish a base line for OCEESA’s future map, to accomplish this map, I do need not only the help of Officers and the Board Directors, I also need every member to communicate with us on your perspectives so we all can walk on together. So, let us work together.

I wish everyone of you have a successful year!
OCEESA Past President’s Annual Report of 2001

Dr. Tsun C. Wang, Ph.D., P.E.
Past President, OCEESA
Environmental R & D Manager
Harbor Branch Environmental Laboratory
Fort Pierce, Florida 34946

Year 2001 ends with Horses galloping toward 2002. Happy Horse Year. I would like to take this opportunity to thank your support and participation in our activities. Indeed, we had a very good year. The 7th MTETS, April 20-25, 2001, Wuhan, China drawled a recorded crowd to present papers and meeting. In August, OCEESA joined University of Virginia and US EPA International Office to cosponsor Wetland Protection Conference chaired by Prof. Yu of U. of VA was a big success. SECTA by CIE/USA held in Beijing administered by Mr. Anmin Liu and Dr. James Hwang [Environmental and Energy session] also proved to be a significant accomplishment toward Sino-US cooperation. Our OCEESA representatives to CIE/USA did play an active role to promote environmental science and engineering in CIE’s agenda. Please see separate reports prepared by both Anmin and James for detail information. Also thanks to Dr. James Hwang, a well-established entrepreneur and distinguished scientist and engineer, for inviting OCEESA to join Jade-Mountain Technology for International Strategy Forum held in DC. Special thanks to all of your support, Together we did put OCEESA’s activities and reputation on the map once again.

We are proud of OCEESA members. We do have the first rate talent and professional background spreading around the world. During the year, some of our distinguished members received national and international recognition. Congratulation to Dr. Paul Bao-Ho Liao and Dr. Cary Cheng-Tsair Chiou for their accomplishment. We also noticed that our Journal published more articles and our paying members are increasing during the year. OCEESA is a big step moving forward. We are in debt and gratitude to our executive director, Prof. Yung-Tse Hung for his organization and tireless effort to serve our association. Appreciation is also extend to his lovely wife, Mrs. Louisa Ming-Hwa Hung, for her support of Prof. Hung and OCEESA. We thank Prof. Hung's willingness and acceptance to serves as permanent executive director of OCEESA and the permanent Editor-In-Chief of the OCEESA Journal for years to come.

Thanks also to Mr. Anmin Liu, our Vice President, Dr. Abraham Shou-Chien Chen, our Treasurer/Secretary, and board of directors for their steering and guidance. Through Dr. Larry Kongpu Wang's assistance, our educational committee chaired by Dr. Chein-Chi Chang did open up dialogue with Zhejiang University, China, and Harbin Institute of Technology, China, to explore on-site Internet educational courses and journal publications. There are not any conclusion yet to report to board of directors for discussion. Dr. Chang may continue the effort through the coming year.

At the end, we like to thank our nomination committee did such a good job to review candidate's qualification for 2002 officers. The committee did recommend an open election for qualified members to join the election. We had great success to draw a pool of excellent candidates willing to serve the association. It is great feeling to see our member's enthusiasm and sincerity. A big Hug and Thanks.

Financially, we are in good hands. With sustainable operation in mind, we tried to preserve our assets and operate activities with our fund generated through interest earned and donations. We would like to thank Taiwan youth Commission and several donors for their generosity. May you have a continuing success, happiness and health.

Good Luck and Best wishes to our members and Officers.
Sino-American Technology and Engineering Conference (SATEC’01) Report

Dr. Shoou-Yuh Chang, Ph.D.
Professor, Civil Engineering Department
North Carolina A & T State University
Greensboro, North Carolina 27411

The 5th SATEC was held in China from October 14 to 26, 2001. The conference was sponsored jointly by the Chinese Institute of Engineers/USA, the State Economic and Trade Commission of PRC and the State Administration of Foreign Experts Affairs of PRC. There were eight sessions planned with the objective to promote high technology development collaborations among the regions and to propose effective solutions to China’s industry needs. Energy and Environmental Protection is one of eight sessions that focus on energy generation, industrial waste management, and applications of various environmental technologies to industries.

Prior to the Conference, Environmental session speakers and their spouses were divided into three groups and visited various industries and waste treatment facilities to exchange ideas on waste treatment and offer suggestions for improving treatment efficiencies or planning strategies.

The three groups are:

1) New Energy and Steel Residues group, flew to Hangzhou, Zhejiang Province. Members include: Dr. and Mrs. Francis H. Chang, Mr. and Mrs. Shi-Long Chang and Mr. Almon Memeng Shen (group leader). They visited Hangzhou Denga General Breeding Farm (Theme: Methane Technologies) and Hangzhou Iron and Steel Group Co.(Theme: Waste Residue Utilities). They also toured cities of Hangzhou and Shaoxing.

2) Clean Combustion and Pollution Control group, flew to Qingdao, Shandong Province. Members include: Dr. John T. Tang, Dr. Ting Wang and Dr. and Mrs. James S. Whang (group leader)
The members visited Qingdao Power Station (Theme:Cleaner coal fired technologies) and Qingdao Tianren Environment Co.(Theme: Flue Gas Cleaning-up and Industrial Wastewater Treatment). They also toured city of Qingdao and Laoshan Mountain.

3) Wastewater Treatment, flew to Jining, Shandong Province (Members include: Mr. and Mrs. Jyi-Hong Chen, Mr. and Mrs. Anmin Liu (also the Administrator of the SATEC ’01 U.S. Organization Committee) and Dr. and Mrs. Shoou-Yuh Chang (group leader). The members visited Linghua Group Co., Shandong LuKan Group Co., and Shandong TaiYang Paper Co. (Theme: Industrial Waste Water Treatment) and conducted a Collaboration Workshop on Industrial Wastewater Treatment for Shandong Province (Theme: Industrial Wastewater Treatment). They also toured Confucian and Mencian Temple and Tai Mountain.

After the four-day plant tour the three groups came back to Beijing and started the group presentations and discussions on October 19 and 20. The technical paper presentations by the overseas experts are listed as follows:

**Titles of Paper and Authors for the Energy and Environmental Engineering Session**

Effective Energy and Environmental Protection Policies for Sustainable Development
James S. Whang, AEPCO, Inc., Rockville, MD, USA

Financial Analysis of Large-Scale Biogas Plants
Francis H. Chang, Kinectrics Inc., Toronto, Canada

Industrial Waste Recycling & Reuse in Steel Manufacturing in Taiwan
Shi-Long Chang, China Steel Corp., Kaohsiung, Taiwan

Evaluation of Municipal Wastewater Systems in China
Shoou-Yuh Chang, North Carolina A&T State University, Greensboro, NC, USA
Current Status and Trends of Municipal Sewage Treatment and Sludge Disposal/Utilization in Taiwan
Jyi-Hong Chen, Sinotech Engineering Consultants Ltd., Taipei, Taiwan

Methane Gas Utilization Technology Assessment
Almon Memeng Shen, Brown & Caldwell, Walnut Creek, CA, USA

Review of Air Pollutant Control Technologies and Their Assessment
John T. Tang, Global Energy and Environmental Service Company Ltd., Shatin, Hong Kong

Comparison of Coal Based Power Generation Techniques and Their Impact on Environment
Ting Wang, University of New Orleans, LA, USA

The overseas Energy & Environmental Protection Session members then exchanged ideas with our counterpart experts in China to draft our session’s report and recommendations for the Closing Ceremony in Beijing. It was also essential that PRC counterpart experts were involved in this report preparation effort because they were more aware of the local conditions. To prepare a final written "Summary & Recommendations" report in Chinese, which was recited at the Closing Ceremony on October 23, was one of the most important responsibilities for our mission because it summarized and highlighted the team’s efforts and findings.

China’s Premier, Mr. Zhu Rongji, received all speakers and their spouses in People’s Hall in the morning of October 22. “Cross-session” seminars for all SATEC’01 attendees were then conducted in the afternoon of October 22 and morning of October 23. Seven of our "overseas" speaker-colleagues gave talks on the topics of common interest, such as high-tech industry development and management, biotechnology, strategy alliance, etc. The closing ceremony was scheduled on the afternoon of October 23. Each session chair read his/her session’s recommendations. Dr. James Whang read our Energy & Environmental Protection Session’s recommendations. It should be noted that our session had received great remarks because that we completed an exemplary report and that we were the first session to complete the report. The farewell banquet was held on the evening of that day and the official 01’SATEC came to an end. Most of the eight session teams then enjoyed a post conference two-day tour to Chengde Summer Palace.

The efforts of the two chairs of our session (Dr. James Whang and Ms. Jing Li) and all session members have made this meeting a great success. We all feel that the sponsoring organizations were very efficient. The hosts at the Friendship Hotel in Beijing were very cordial and accommodations very good. We believe all speakers have enjoyed the Conference. I am sure that our session members would like to continue our efforts in making contribution to the China’s environmental protection and clean energy production. The members appreciated all the organizing members for their warm reception and sincere hospitality. Their efforts have made our work easier and tours more exciting.

* This report is essentially a group report 1st drafted by Shoou-Yuh Chang, with suggestions by Francis Chang and comments by James Whang and Anmin Liu.
5th SATEC, Oct 14-18, 2002, Beijing, China. From left, second: Dr. Francis Han-I Chang, Fourth: Dr. James Shia-Pin Whang
Minutes of OCEESA Membership Meeting at 7th MTETS, April 22, 2001, Wuhan, China
Anmin Liu
President, AML Environmental Engineering Consultants
Lomita, California

Time: 5:40 pm - 6:10 pm, April 22, 2001 (S)

Attendees: Dr. Francis Hun-I Chang, Dr. Shou-Yuh Chang, Dr. Yung-Sung Cheng, Ms. Helen Lu-Sheng Hsu, Dr. Yung-Tse Hung, Dr. Robert Chang-Chun Lao, Mr. Anmin Liu, Dr. Karen Chun-Lan Liu, r. Thomas To Shen, Dr. Chi-Li Charles Tang, Dr. Jing-Yuan Wang, Dr. Tsen-Cheng Wang, Dr. Jen-Tai Yang, Dr. Rubin Yu, Dr. Pao-Chiang Yuan

Location: Cafeteria, Academic Exchange Center (Lu Jia San Zhuang), Wuhan University, Wuhan, Hubei, China

A. Call to Order

The OCEESA membership meeting was called to order at 5:40 pm, April 22, 2001 (S), by Dr. Tsen-Cheng Wang, OCEESA President. Dr. Wang asked Mr. Anmin Lin, OCEESA Vice President, to take minutes for the meeting for Dr. Abraham Shou-Chien Chen, OCEESA Secretary-Treasurer.

B. Agenda

1. Report of OCEESA attendance at 7th MTETS
2. Taiwan Youth Commission Funding, OCEESA Workshop or conference in D.C.
3. Proposed OCEESA distance learning course at Zhejiang University
4. OCEESA finance, dues receipt and expenses
5. OCEESA Journal publication, OCEESA web page
6. Federation of Overseas Chinese Environmental Association

C. Discussions

1. Dr. Tsen-Cheng Wang welcomed our OCEESA members and spouses who attending the 7th MTETS. He thanked our OCEESA members for presenting papers at the conference and teaching the pre-conference workshop at member’s expenses. He mentioned that it is a financial sacrifice for our OCEESA presenters attending 7th MTETS. He reported that 29 OCEESA members and 10 spouses, totaling 39 people, attended 7th MTETS. A total of 28 member presented 29 regular papers and 3 plenary papers at the 7th MTETS. This is the highest number of papers presentation and highest number of OCEESA participants at any MTETS. The travel subsidy for OCEESA members presenting papers at the 7th MTETS was $150 each presenter. The low subsidy this time is due to the fact that no funding was received from Taiwan Youth Commission, which can be used for 7th MTETS. The subsidy came from OCEESA account. OCEESA pre-conference workshop was offered on April 20, 2001 (F) at Lake View Garden Hotel (Hu-Bing Hua-Yuan Jio Dien), Wuhan, China. A total of 16 OCEESA members taught the workshop on a volunteer basis. OCEESA workshop instructors was provided free meals for 4-20-01 and a one night free lodging on 4-19-01 by Wuhan University. About 20 environmental engineers and officers from governmental environmental protection agencies and design institutes and local industries have attended workshop offered by OCEESA and Wuhan University.

2. Dr. Tsen-Cheng Wang reported that the our OCEESA has obtained $2000 funding from Taiwan Youth Commission for 2001. The fund must be used in OCEESA sponsored conference or workshop held in U.S. and that there must be paper presenters or workshop participants from Taiwan in addition to OCEESA presenters and participants. Dr. Wang mentioned that OCEESA workshop was being planned in Washington, D.C. sometime in August 2001. Dr. Wang will keep OCEESA members informed of the progress of the planning of the OCEESA Workshop.

3. Dr. Wang reported that there was discussions between Dr. Chein-Chi Chang, OCEESA workshop committee chair, and Zhejiang University regarding offering a distance learning environmental engineering course by OCEESA members to graduate students in environmental engineering at Zhejiang University, Hanzhou, China. Harbin
Institute of Technology may be also interested in the offering of distance learning course by our OCEESA. OCEESA members are encouraged to contact Dr. Chein-Chi Chang for possible participation in the teaching of the course.

4. Dr. Wang reported the status of OCEESA finance. There is some problem associated with OCEESA financial picture. OCEESA incomes are from member dues, which is $25 a year. 80% of dues ($20 out of $25) is returned to OCEESA local chapters, 20% of dues ($5 out of $25) is returned to CIE/USA. This 80% of the membership dues is the fund for OCEESA journal publications and other routine operations. In addition, our OCEESA web site cost is about $500 per year. The travel subsidy from OCEESA representatives to attending CIE/USA annual meeting was $400 per representative in 2001 and we had 4 OCEESA representatives for CIE/USA January 2001 annual meeting (usually 3 OCEESA representatives). OCEESA expenses are much higher than the membership dues receipt every year. OCEESA is spending more than it receives from dues payment per year. Dr. Wang emphasized the importance of sustainable financial operation of OCEESA and responsible financial operation. Dr. Wang requested the OCEESA financial committee to develop a plan for sustainable OCEESA financial operation.

5. There were discussions regarding OCEESA Journal publications and OCEESA web pages. Some of the suggestions included to have OCEESA news posted on OCEESA web pages and to keep publication of OCEESA Journal 2 times a year.

6. Dr. Rubin Yu reported that he is the President of Federation of Overseas Chinese Environmental Associations in 2001, for which OCEESA is one of the member association. He mentioned that he will explore the possibility of conference sponsored by Taiwan EPA. However, the funding could be a big problem. He will keep OCEESA posted of any development.

The meeting was adjourned at 6:10 pm, April 22, 2001.
INTRODUCTION TO BIOGAS PLANTS
FOR AGRICULTURAL INDUSTRY

Francis H. Chang, Ph.D., P.Eng
Senior Project Manager, Kinectrics Inc.
Toronto, Ontario, Canada M8Z 6C4
e-mail: francis.chang@kinectrics.com

1.0 Introduction

In a previous article the basics of anaerobic digestion for treating organic wastes were briefly discussed [1]. The principal reactions for the production of biogas, a gas containing approximately 60% methane (CH₄), 40% carbon dioxide (CO₂) and trace amounts of other gaseous compounds, from organic matters are shown in Figure 1. Natural gas is composed of similar constituents except that the methane content is above 97% and thus the heating value is much higher. These reactions are accomplished by different types of bacteria that flourish under different reaction conditions. The proper design of a process will ensure that good yields of biogas can be obtained for the particular feedstock under consideration. There are three main applications for anaerobic digester: livestock waste, municipal organic solid waste and sewage waste water.

Biogas production from animal waste was studied as early as the 1800’s and was actually utilized to light the street lights in Paris [2,3], but the practical use has been limited to that of a low grade fuel gas. In the mid-eighties, the early biogas plants for the digestion of animal manure were constructed in Germany. East Germany focused on large centralized biogas plants; whereas in West Germany mainly farm-scale biogas plants were constructed at first. In China, numerous small biogas units have been developed since 1950’s to solve the energy problem in the rural communities. Reportedly, by 1999 there were over 1 million rural households in Szechwan province alone that had anaerobic digesters and beneficially utilized biogas. Biogas stoves and gaslights had been widely used, and as a result much of the forestry was spared from excessive cutting for firewood [4].

2.0 Current Status

The real technological breakthrough came in the last fifteen years, when gas engines have been modified to work with the low-heat-content biogas; the engine shaft power drives an electric generator to produce electric power and the engine block heat and exhaust heat are recovered to provide byproduct thermal output. Today, most of the biogas units in Europe are equipped with power genset. In Germany there are about 1,600 biogas plants in operation on farms and most farm-scale plants range from a few tonnes per day to about 50 tonnes/day of waste. There are also several large centralized plants that were typical results of the former East German central planning. These large centralized plants can process over 300 tonnes/day of waste. The best known examples of the large centralized plants are in Denmark. There are 20 such large plants in operation currently and 12 of these can process over 120-320 tonnes/day of waste. The large ones can produce electric output of over 1 mega watt (MW). The planning, design and construction of these biogas plants, whether farm-scale or centralized, require specialized engineering skill. This paper will introduce the procedure for the design and construction of such plants with focus on the livestock waste of the agricultural industry.

3.0 Design and Construction

The procedure for the design and construction of a biogas plant, regardless of the scale, will include these basic steps: (1) Process Design and Mass-Energy Balance, (2) Equipment Sizing and Specification, (3) Site Preparation, (4) Equipment Installation, and (5) Commissioning and Start-up.

(1) Based on the desired process and the input substrate data, a process flow diagram similar to that shown in Figure 2 is usually prepared by a process engineer. The numbered streams will be used for performing the mass and energy balance
calculations for the plant.
Figure 1
THE ANAEROBIC DIGESTION (AD) PROCESS

Reactions:

(1) Hydrolysis (by enzymes of acetogens):
\[ \text{C}_6\text{H}_{13}\text{NO}_5 + \text{H}_2\text{O} + \text{H}^+ \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{NH}_4^+ \]

(2) Acetogenesis (by acetogens):
\[ \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 0.1115 \text{C}_5\text{H}_7\text{NO}_2 + 0.744 \text{CH}_3\text{COOH} + 0.5 \text{CH}_3\text{CH}_2\text{COOH} + 0.5 \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + 0.454 \text{CO}_2 \]

(3) Hydrogenesis (by hydrogenogens):
\[ \text{CH}_3\text{CH}_2\text{COOH} + 1.786 \text{H}_2\text{O} \rightarrow 0.0458 \text{C}_5\text{H}_7\text{NO}_2 + 0.924 \text{CH}_3\text{COOH} + 2.778 \text{H}_2 + 0.924 \text{CO}_2 \]
\[ \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + 1.84 \text{H}_2\text{O} \rightarrow 0.0545 \text{C}_5\text{H}_7\text{NO}_2 + 1.86 \text{CH}_3\text{COOH} + 1.92 \text{H}_2 \]

(4) Homoacetogenesis (by homoacetogens):
\[ \text{CO}_2 + 2.073 \text{H}_2 \rightarrow 0.0487 \text{C}_5\text{H}_7\text{NO}_2 + 0.378 \text{CH}_3\text{COOH} + 1.146 \text{H}_2\text{O} \]

(5) Methanogenesis (by methanogens):
\[ \text{CO}_2 + 3.813 \text{H}_2 \rightarrow 0.022 \text{C}_5\text{H}_7\text{NO}_2 + 0.89 \text{CH}_4 + 1.256 \text{H}_2\text{O} \]
\[ \text{CH}_3\text{COOH} \rightarrow 0.022 \text{C}_5\text{H}_7\text{NO}_2 + 0.945 \text{CH}_4 + 0.06 \text{H}_2\text{O} + 0.945 \text{CO}_2 \]
(2) From the flowsheet data and mass and energy calculation results each piece of the major equipment can be sized and specified to the equipment suppliers to obtain price information. Chemical, mechanical and electrical engineers are often involved at this stage depending on the nature of the equipment. Figure 3 shows some of the main components. Items not shown here but are also very important include heat exchangers, pasteurization unit [5], gas desulphurizer and generator.

(3) Site civil work will be required to provide the proper foundation for the heavy equipment, housing for the machinery that cannot be exposed outdoors. Figure 4 shows a typical farm-scale biogas plant with the digester tank shown on the right, the gas holder in this case is underground; the housing at the back accommodates the engine and electrical system. Civil engineer and construction contractors are usually responsible for this phase of the work.
Equipment installation and Commissioning and Start-up are field works performed by mechanical, electrical and instrumentation contractors and site project engineers until the whole plant can perform according to specification, and then the plant is transferred to the owner.

Figure 4 shows a typical farm-scale biogas plant where the waste is simply pumped from the barn to the digester. For centralized plants where 50-80 farms are serviced by a single large plant, the waste has to be transported by tank trucks. The following data are from an example of a plant that serves 50 farms [6].

**Main data**
- Animal manure: 230 tons/day
- Alternative biomass: 36 tons/day
- Biogas production: 5.7 mill. Nm$^3$/year
- Digester capacity (2 x 3000 m$^3$): 6000 m$^3$
- Process temperature: 52°C
- Sanitation: MGRT 2.5 hours at 60°C
- Gas storage capacity: 170 m$^3$
- Utilisation of biogas: CHP-plant
- Gross power potential: 4.0 MW
- Net power production: CHP-plant
- Transport vehicle: Vacuum tankers/slurry pipelines
- Average transport distance: 5 km
- Investment cost: ($9.7 m CDN) 55.7 mill. DKK
- Government grant: ($2.4 m CDN) 13.9 mill. DKK
- Contractor: Herning Municipal Utilities/Hedseselskabet
- Operation start-up: 1996

Figures 5 show a few of the centralized large biogas plants in Denmark [6]. The transportation trucks are necessary for collecting the livestock wastes but the transportation distance is limited to a circular area of about 5-km radius. Beyond this distance the transportation fuel cost will render the operation uneconomical.

4.0 Conclusion

An introduction to the basics of biogas plant and their construction has been presented. With biogas technology rapidly gaining recognition as an integrated solution to agricultural, environmental and energy problems this introduction hopefully will interest the innovative farmers and engineers to pursue more in-depth understanding and try to adapt. Extensions of the application to municipal solid waste disposal and sewage gas utilization are relatively straightforward.
Figures 5: Large Centralized Biogas Plants in Denmark

REFERENCES:


With 143 refineries as of January 1, 2002, petroleum refining is one of the largest industries in the United States. Its total crude processing capability of 16.6 million barrels per day (bbl/d) represents more than one-fifth of the world’s total refining capacity of 81.2 million bbl/d.¹

It’s a big industry confronting some big environmental problems. Many refinery waste streams – air emissions, wastewater and solid wastes – contain hazardous materials. As a result, refineries have been hit hard by environmental regulations and unfavorable public opinion, and Congress mandated in 1984 that refineries minimize waste.

Refinery waste is difficult to manage and dispose of. In California, refiners turned to waste minimization, or pollution prevention, en masse in 1991 when the state’s Source Reduction and Hazardous Waste Management Review Act of 1989, commonly referred to as Senate Bill (SB) 14, went into effect.² Inspired by the U.S. Environmental Protection Agency’s (EPA’s) and California’s regulations, other states have pursued similarly restrictive paths.

Under the California law, refiners were each required to prepare a Source Reduction Evaluation Review and Plan and a Hazardous Waste Management Performance Report. Their efforts are paying off. To date, California refineries have successfully implemented waste minimization programs for more than 10 years.

But the most efficient way to reduce refinery waste doesn’t start with a law or a report. It starts with uncovering and eliminating the sources.

Where It All Comes From

Cleaning up sloppy housekeeping habits is by far the fastest and least costly path to waste reduction. Keeping areas free of solids and debris, fixing leaks promptly to prevent the washing or leaching of contaminants into sewers, and installing devices to capture or filter escaping aqueous and solid wastes are good ways to reduce waste and curb the need to reuse or recycle materials.

Refiners who can cut the amount of recycling necessary at their plants are ahead of the game because the myriad of processes performed at refineries makes the reusing and recycling of materials very complicated matters.

According to an EPA survey, many of the more than 150 separate processes used in petroleum refineries generate large quantities of hazardous waste.³ Refinery operations typically involve separating crude molecular constituents, molecular cracking, molecular rebuilding, and solvent finishing to produce products such as gasoline, fuel oil, diesel and jet fuel, kerosene, lubrication oil, asphalt, and wax.

Typical wastes generated from refinery processes include bottom sediments and water from crude storage tanks, spent amines, spent acids and caustics, spent clays, spent glycol, catalyst fines, spent Stretford solution and sulfur, coking fines, slop oil, and storage tank bottoms (See Figure 1).⁴ Most are hazardous wastes.
Wastes generated from wastewater treatment systems include API/CPI separator sludge, dissolved-air flotation or induced-air flotation, pond and tank sediments, and biosolids (See Figure 3). Of these, only the biosolids from the biological wastewater treatment system may be nonhazardous.

The amount and type of wastes generated in a refinery depend on a variety of factors such as crude capacity, number of refining processes, crude source, and operating procedures. A 130,000 bbl/d integrated refinery on the West Coast generates about 50,000 tons per year of hazardous waste (including recycled streams and unfiltered sludges). The major waste streams are wastewater treatment plant sludge, spent caustics, Stretford solution and sulfur, and spent catalysts.

A much simpler 50,000 bbl/d refinery generates only 400 tons per year of hazardous waste. Major waste streams in this refinery are wastewater treatment plant sludge (dewatered by pressure filtration), spent catalysts, and spent clay filter media.

What Works, What Doesn’t

A pollution prevention program usually consists of:

- Conducting a waste survey.
- Screening waste streams for minimization opportunities.
- Developing minimization options.
- Screening minimization options.
- Evaluating high priority options.
- Scheduling and implementing desirable options.
- Evaluating and reviewing program performance periodically.

For a waste minimization program, refinery managers must provide the necessary staff and other resources to accomplish their goals. A team committed to the tasks is usually assembled. Because a refinery is a complex facility and there are numerous emission sources and waste streams to take into account, the team should consider and give the highest priority to:
• Pollution prevention hierarchy. The order of preference (highest to lowest) is source reduction, recycling, treatment, and secure land disposal.
• Reduction of waste volume. Volume reduction will usually reduce costs for handling, treatment, and disposal.
• Ease of implementation.
• Proven performance.
• Safety and health risks to employees and the public.

Some waste minimization approaches are proving to be more successful than others. Studying several refineries for waste minimization opportunities led to these eye-opening conclusions:

• Housekeeping is the most cost-effective way to minimize waste.
• Solids that enter the refinery’s wastewater treatment system are classified as hazardous waste automatically. Therefore, refineries can lower the volume of hazardous waste generated by keeping non-hazardous waste out of the treatment system.
• Raw material (e.g., crude source) substitution is difficult because the choice of material is dictated by economics, availability, and the process units at the refinery.
• Process modifications can be implemented but may require considerable research and development.
• In-plant and offsite reuse of wastes plays a major role in waste minimization.

The 130,000 bbl/d Example

Take the example of the 130,000 bbl/d West Coast refinery that generates approximately 50,000 tons per year of hazardous waste. Since 1984, this refinery has initiated waste management practices to handle:

• Spent caustic. At the end of 1990, 100 percent of the spent caustic was recycled onsite or offsite. The alkylation/dimersol and fluid catalytic cracking unit (FCCU) spent caustic is recycled to neutralize acidic wastewater. The virgin light-ends spent caustic is transported offsite for reuse at a paper manufacturing facility. The alkylation unit propane spent caustic is used in three other alkylation unit caustic washes. A Minalk Treating System was installed at the FCCU to replace an existing Merox Treating System to convert mercaptans to disulfide. This replacement reduces FCCU spent caustic generation by 1,700 tons/yr.
• Stretford solution. Since 1987, 100 percent of the waste Stretford solution has been shipped to a metals reclamation facility. Vanadium is reclaimed as vanadium pentoxide.
• Wastewater treatment sludge. In 1987, the refinery started a program to recycle this sludge to the coker within the refinery. At the end of 1990, 60 percent of the sludge was recycled to the coker. The remaining 40 percent was dewatered onsite at a belt filter press and then landfilled offsite or incinerated. Since 1986, the refinery has paved five plant areas to reduce the amount of dirt and debris washing into the sewer.
• Catalysts, desiccants, and catalyst inerts. In 1988, the refinery began to recycle nonhazardous catalysts, desiccants, and catalyst fines. It recycles electrostatic precipitator fines, Claus catalyst, and catalyst support inerts for use in cement manufacture. Two other catalysts, zinc oxide and iron chromate from the hydrogen plant, are reprocessed at smelters to recover the metals.

California SB 14 regulations required the refinery to further evaluate source reduction. The following are some of the measures identified by the refinery for further evaluation and implementation:

• Modification of the coker silo area to reduce dirt and debris to the wastewater treatment system.
• Reuse of the waste Stretford sulfur stream at a sulfuric acid manufacturer.
• Use of a transportable treatment unit to oxidize thiosulfate salts in the Stretford solution to allow them to be recycled in the Stretford process.
• Installation of sulfur de-entrainment devices in the Claus Plant sulfur condensers to reduce sulfur waste.
• Installation of asphalt lips around sewers to inhibit entry of dirt and debris.
• Evaluation of increasing the amount of wastewater-treatment sludge recycled to the coker.
Conclusion

As more and more refineries adopt successful waste minimization techniques, sharing their experiences will be the key to helping the entire refining industry reduce waste and achieve cost-effective compliance with environmental regulations. In California, 10 years of successful implementation of the SB 14 regulations have paid off in helping refineries to minimize wastes significantly. The refineries have gone through two rounds of updating and review since 1990 (every four years) to ensure implementation of state-of-the-art technologies.

References


METHANIZATION OF FOOD WASTE USING
A HYBRID ANAEROBIC SOLID-LIQUID (HASL) BIOREACTOR

Wang Jing-Yuan and Xu Hai-Lou
Environmental Engineering Research Center, School of Civil and Environmental Engineering
Nanyang Technological University, Blk. N1, 50 Nanyang Avenue, Singapore 639798

Abstract
A hybrid anaerobic solid-liquid (HASL) bioreactor is an enhanced two-phase anaerobic digestion system, which is
distinctive from the traditional two-phase system with an upflow anaerobic sludge blanket (UASB) reactor as the
methanogenic phase (Rm) and a circulation of treated leachate between the acidification and methanogenic phases.
Methanization of food waste in HASL bioreactors was investigated in Runs A, B and C, where the HASL bioreactors
were operated at 35°C with 8, 4 and 0 day of pre-acidification, respectively. The volatile fatty acids (VFAs) produced
in the acidification reactor were efficiently removed in Rm. Almost 100% of the methane yield was from Rm with
methane content of up to 71%. The significant methanization was also confirmed by the treatment efficiency of
HASL system. The results show that the HASL bioreactor is suitable for effective and efficient methanization of
food waste in terms of methane production rate and methane content.

Key words: methanization; food waste, hybrid anaerobic solid-liquid bioreactor, UASB

INTRODUCTION
Anaerobic digestion of organic municipal solid waste (MSW) has been drawing lots of attention in the world over
the last decade. It is an alternative for MSW management to not only reduce the volume of waste but also generate
salable biogas, for energy recovery (Barlaz et al. 1992). However, the accumulation of volatile fermentation
intermediates in the anaerobic system usually results in slow digestion process. In order to increase the degradation
rate, two-phase process has been studied (Mata-Alvarez 1987). Although to some extent, two-phase system
overcome some problems encountered in conventional anaerobic processes, the biogas production is still quite slow
and the methane content in biogas is not as high as that in high-rate anaerobic wastewater reactors.

Upflow anaerobic sludge blanket (UASB) reactor has been widely applied in treating high-strength organic
wastewater. The advantage of UASB technology is its ability to retain high biomass concentrations in the reactors by
means of sludge granulation (Tay et al. 2000). The sludge granules, where anaerobic consortia grow in a dense and
eco-physiological way, can powerfully biocatalyze and convert organic compounds into biogas (Schmidt and Ahring
1996). The idea of methanogenesis in an UASB reactor was employed in this study.

The objectives of this study were (i) to develop a mesophilic hybrid anaerobic solid-liquid (HASL) bioreactor to
improve food waste biomethanization, (ii) to study the feasibility of biomethanization of food waste with
methanogenesis in an UASB reactor, and (iii) to investigate the digestion processes.

HASL BIOREACTOR SET-UP
A HASL bioreactor consisted of one reactor treating solid waste (R1, R2 and R3 in Runs A, B and C, respectively)
and another reactor treating wastewater (Rm), as illustrated in Fig. 1. The acidification reactors R1, R2 and R3 were
designed as 5.4 liters recycle reactors. The methanogenic reactor Rm was an UASB reactor with a working volume
of 3.0 liters (Teo et al. 2000). Mature sludge granules adapted to VFA wastewater were collected from a 5-L UASB
reactor, which had been operated at 35°C for 6 months (Teo et al. 2000). Prior to the HASL operation in Run A, Rm
was filled with 1.0 L of the granular sludge and 1,000 mg COD/L of the above wastewater, and operated for one
week with an influent of 5,000 mg COD/L and an OLR of 10.0 g COD/L/day. An effluent of less than 500 mg
COD/L (COD removal was more than 90%) and an average methane content of biogas of 75% indicated that Rm was
active in methanogenesis.
OPERATING CONDITIONS

The reactors were operated in a temperature-controlled room at 35±1°C. After the pre-acidification stage, the acidification reactor was connected to UASB reactor Rm to establish a HASL bioreactor. The leachate from acidification phase (R1/R2/R3) was diluted with the effluent from methanogenic phase (UASB reactor Rm). This mixture, as a new influent, was fed into Rm. Rm effluent was divided into two streams, S1 and S2. S1 was circulated to R1, while S2 was used to dilute R1 leachate and pumped back into Rm (Fig. 1). The flow rates of S1 and S2 were adjusted according to the COD concentrations in R1 leachate and Rm effluent.

Fig. 1. Schematic of a HASL bioreactor.

In Runs A, B and C, 1.8 kg, 2.0 kg and 3.0 kg of the shredded food waste (the average particle size was 6.0 mm) were loaded to R1, R2 and R3, respectively. The food waste was collected from a canteen of the university. It contained the components associated with food preparation such as residual fruits, vegetables, eggshell, and spoiled noodles. The moisture content and the volatile solids (VS) content in % total solids (TS) are listed in Table 1. The seed sludge with 5.0 g/L of suspended solid (SS) and 2.9 g/L of volatile suspended solid (VSS) was collected from an anaerobic digester of the Ulu Pandan Sewage Treatment Plant in Singapore. The seed sludge was slowly added to R1/R2/R3 to completely saturate the waste as evidenced by the liquid level in the column.

<table>
<thead>
<tr>
<th></th>
<th>operation time (day)</th>
<th>pre-acidification (day)</th>
<th>food waste loading (kg)</th>
<th>moisture content (%)</th>
<th>VS (TS %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run A</td>
<td>16</td>
<td>8</td>
<td>1.8</td>
<td>88.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Run B</td>
<td>16</td>
<td>4</td>
<td>2.0</td>
<td>88.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Run C</td>
<td>16</td>
<td>0</td>
<td>3.0</td>
<td>89.5</td>
<td>93.5</td>
</tr>
</tbody>
</table>

All the experiments in Runs A, B and C were operated for 16 days. In Run A, pre-acidification in R1 was initiated by inoculating food waste-filled R1 with seed sludge and immediately recycling the leachate with a recirculation rate of 1.0 ml/min. After 8 days of leachate recycling, R1 was connected to Rm. In Run B, the operating conditions were the same as those in Run A except the operation time of pre-acidification stage. In each experiment of Run B, 4 days of leachate recycling in R2 was employed. The HASL stage was commenced by replacing R1 with R2 to couple to Rm. There was no pre-acidification stage in Run C. The operating conditions are summarized in Table 1.

RESULTS AND DISCUSSION

Runs A and B
The pre-acidification stages in Runs A and B were 8 and 4 days, respectively. Rapid acidification in R1/R2 was observed in terms of pH, total VFA (TVFA) and COD levels of the leachate. As recycle reactors, R1 and R2 went acid quickly (Graven and Pohland 1987; Griffin et al. 1998). R1 leachate pH decreased from 7.2 to about 4.5 in the first day, and remained in the range of 5.2-5.7 during the following 7 days without pH controlling (Fig. 2). Four days of pre-acidification in Run B showed a similar pH variation as that in Run A. R2 leachate pH decreased from 7.0 to about 4.7 in the first day, and gradually increased to 5.4 on day 4 (Fig. 2). Both TVFA and COD levels in R1/R2 leachate increased rapidly in the first few days without nutrients addition (Fig. 3 and Fig. 4). In Run A, R1 leachate TVFA increased from 280 mg/L to over 13,000 mg/L in the first 4 days, while COD level increased from 5,900 mg/L to about 16,000 mg/L in the first 2 days. Further leachate recycling did not give significant increases in both TVFA and COD concentrations (i.e., days 4-8 for TVFA and days 2-8 for COD). Based on the above observation, the pre-acidification stage in Run B was run for 4 days. R2 leachate TVFA and COD concentrations were 14,900 mg/L and 15,000 mg/L, respectively, on day 4. It seemed that the food waste materials in R1 had been acidified well in 4 days.

![Figure 2. Variation of R1/R2/R3 leachate and Rm effluent pH levels in Run A, B and C.](image)

When R1 was coupled to UASB reactor Rm on day 8 in Run A, the HASL stage was commenced. The results showed that VFAs from the acidification phase (R1) were carried to the methanogenic phase (Rm) after dilution, where VFAs were converted to methane and carbon dioxide. In acidification phase, R1 leachate pH increased gradually from 5.3 on day 8 to 7.3 on day 16, while in methanogenic phase, Rm effluent pH remained constant, in the range of 7.4-7.6 (Fig. 2).
Fig. 3. Variation of R1/R2/R3 leachate and Rm effluent TVFA concentrations in Run A, B and C.

The OLR of Rm was about 8.0-10.0 g COD/L/day during days 8-10, but decreased gradually to 1.6-1.7 g COD/L/day during days 13-16 mainly due to the decrease in R1 leachate COD level. This indicated that Rm adapted very well to the acidified feed influent from R1. It was probably due to the dilution of VFAs prior to their entering into the UASB reactor and/or the sludge granules which had been operated with the synthetic wastewater of pH 5.5-6.0. The effective biodegradation in Rm was observed in terms of COD removal (74-93%) and TVFA removal (77-99%). At the end of operation, Rm effluent COD and TVFA levels were 230 mg/L and 25 mg/L, respectively (Fig. 3 and Fig. 4). After 8 days of HASL operation, R1 leachate COD and TVFA levels also decreased largely to 830 mg/L (or by 95%) and 670 mg/L (or by 95%), respectively.

In Run B, Rm OLR decreased from 9.5 g COD/L/day on day 5 to 1.7 g COD/L/day on day 10. Effective COD and TVFA removals (77-90% and 90-100%, respectively) in Rm were observed. At the end of operation, 300 mg/L of COD and 0 mg/L of TVFA (VFAs were not detected in non-diluted Rm effluent) in Rm effluent were obtained (Fig. 3 and Fig. 4). R2 leachate COD and TVFA decreased by 97% (to 500 mg/L) and 99% (to 120 mg/L), respectively. No significant TVFA/COD removal was observed in day 10-16. This might be either because the remaining COD fraction was more difficult to degrade or the environmental conditions were less favorable.

Fig. 4. Variation of R1/R2/R3 leachate and Rm effluent COD concentrations in Run A, B and C.
In comparison with the pre-acidification stage, where only CO₂ was detected in the head-space of R1/R2, the methane production rate and cumulative methane yield in Rm increased rapidly in the HASL stage (Fig. 5). Both in Run A and Run B, about 99% of the total methane yield was from the methanogenic phase. The methane content of Rm biogas was 60-72% with an average of about 68% in Run A, and 66-72% with an average of 70% in Run B. The low methane production rate (0-0.15 L/d) in R1/R2 was probably due to the Rm effluent, which could not bring enough methanogenic bacteria to R1/R2. As an UASB reactor, Rm retained its biomass in the form of sludge granules, biomass washout was scanty (Young and Dahab 1983).

![Graph showing methane production]

Fig. 5. Rm methane production in Run A, B and C.

In Runs A and B, 57-60% of VS added in R1/R2 was removed with a methane yield of 0.25 L/g VS added. Total organic carbon (TOC) and total COD reduction were 77-79% and 79-80%, respectively.

Run C

Run C was designed with alternative operating conditions. First, the waste loading was 50% and 67% more than that in Run A and Run B, respectively, due to the high treatment capacity of Rm that had been demonstrated in Run A/B. Second, there was no pre-acidification stage in Run C. The methanogenesis was simultaneous with the acidification process. In the acidification phase, R3 leachate pH decreased from 6.6 to 5.0 in the first day in spite of a leachate-effluent circulation between R3 and Rm (Fig. 2). This was probably due to the rapid acidification of food waste and the low circulation rate. R3 leachate pH increased to 6.0 on day 4, and then slowly increased to 7.1 at the end of operation. The VFAs produced in R3 were removed more rapidly than those in R1/R2 (Fig. 3). The accumulation of VFAs was reduced (the highest TVFA concentration in R3 leachate was 20-25% lower than that in R1/R2). TVFA removal of 80-98% was observed in Rm. At the end of operation, R3 leachate and Rm effluent TVFA were 430 mg/L and 20 mg/L, respectively.

In a control experiment, where the pre-acidification of 3.0 kg food waste was conducted with 4 days of leachate recycling (flow rate was 1.0 ml/min). The leachate pH decreased to about 4.5 (lower than that in Run C) in the first day, and COD concentration increased to about 18,000 mg/L on day 1, and 26,000 mg/L in day 2-4. But in Run C, R3 leachate COD level increased from about 10,000 on day 0 to 19,500 mg/L on day 2, and then decreased rapidly, indicating the COD removal was efficient. On day 12, R3 leachate and Rm effluent COD concentrations were 325 mg/L and 175 mg/L, respectively, with COD removal of 60-89% in Rm. No significant TVFA/COD removal or methane generation was observed in day 11-16.

Rm methane production rate was about 10-12 L/day in day 0-5 (Fig. 5). From day 9, methane production gradually
leveled off. This coincided with the decreases in R3 leachate COD and TVFA concentrations. 100% of the methane yield was from the methanogenic phase with an average methane content of 71% (66-72%). The concentrated methane generation and high methane content will be beneficial to energy recovery. No active methane fermentation was developed in acidification phase as well as Runs A and B.

At the end of Run C, 62% of volatile solids added in R3 was removed with a methane yield of about 0.25 L/g VS added. TOC and total COD reduction were 78% and 80%, respectively.

CONCLUSIONS

The use of UASB reactor as the methanogenic phase resulted in a rapid biogas generation with a high methane content (68-71%). The increased methane content (68% in Run A, 70% in Run B and 71% in Run C) indicates that the UASB reactor can be used repeatedly with an improvement of performance.

The hydrolysis/acidification was a rapid process in anaerobic digestion of food waste. The operation of Run C, where there was no pre-acidification stage, shows that a continuous/semi-continuous HASL operation is possible.

The HASL bioreactor system is effective for methanization of the biodegradable food waste.

The high methane content biogas with almost 100% of the methane yield from the methanogenic phase favors the application of the HASL bioreactor to practical solid waste management.

REFERENCES


It is my honor and pleasure to be here with you – China’s business leaders and decision-makers. You are the people who can determine the course of history. Progress occurs when courageous, skillful leaders seize the opportunity to change things. Today, I ask you to seize the opportunities to change things for the better by protecting the air we breathe, the water we drink and the land on which we live.

Enhancing the standard of living is a major undertaking by all concerned. Social and economic development is the very first step of that venture, but such development must be sustainable. Sustainable development means meeting the needs of the present without degrading the needs of future generations. We are living in a changing society. Change is happening all the time on the economic, political, and social scenes. Change occurs in science and technology, including how the public regards pollution and environmental needs. Changing environmental science and technology and socioeconomic development require changing current pollution management programs.

The environmental issues we are facing in this 21st century are much more diversified and quite different from those of the past. It is no longer sufficient for us to protect the environment and resources equipped only with 20th century knowledge, information and skills such as media-specific, end-of-pipe, and command-and-control approaches of waste management practices and technologies. If we hope to become successful in protecting our environment and natural resources, we must give up the mindset of “learn what’s taught” and replace it with life-long learning attitudes for new knowledge, information and skills for sustainable development.

My talk begins with environmental concepts and practices along with China’s environmental pollution problems as a result of rapid socio-economic development. Discussions include challenges and opportunities plus the roles of academia, government, industry and general public. I hope that my remarks will help you to understand better the issues of environment and development as well as meet the challenges and opportunities on the path to sustainable development in China.

Environmental Concepts and Practices

Government has a major role and responsibility in setting environmental protection regulations and standards that reflect a broad range of environmental, health, economic, and scientific factors, as well as other concerns. There are, however, significant economic and environmental benefits in allowing generators of all pollution sources to participate in the deciding how to achieve the needed levels of protection, cost-effectively. But first, we have to understand clearly what are the pollution sources and problems.

First, we need to learn and understand pollution sources and then the three principles of environmental pollution. Major pollution sources are such as industry, agriculture, energy, transportation, commerce, construction and consumer-related activities. Industries source, for example, releases pollutants and wastes into the environment as well as produces certain environmentally harmful products and services. Environmentally harmful products include asbestos, leaded gasoline, DDT, PCBs, CFCs, certain kinds of plastics, disposable diapers, cosmetics, fertilizers, pesticides, and herbicides, as well as discarded toxic by-products and used products. Environmentally harmful services include certain services in management, product and process design, equipment manufacturing and supply as well as some government policies, regulations, implementation plans, and education and training.

With that recognition, I address environmental pollution from a practical point of view and draw the
following three principles of environmental pollution, which are comparable to some of the thermodynamic laws familiar to most engineers and scientists.

Shen’s Three Principles of Environmental Pollution

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>First principle</td>
<td>Pollution from human activities is unavoidable.</td>
</tr>
<tr>
<td></td>
<td>Pollution is created by releasing pollutants and wastes into the environment as well as by producing certain environmentally harmful products and services as a result of careless human activities related to social and economic development.</td>
</tr>
<tr>
<td>Second principle</td>
<td>Prevent pollution whenever possible.</td>
</tr>
<tr>
<td></td>
<td>As a result of the first principle, pollution needs to be cost-effectively managed. Pollution can be prevented or minimized, but may not be completely eliminated. The remaining residual pollution from human activities must be properly treated and disposed in order to protect human health and the environment.</td>
</tr>
<tr>
<td>Third principle</td>
<td>Minimal pollution is acceptable.</td>
</tr>
<tr>
<td></td>
<td>Ecosystems can safely handle and assimilate certain amounts of pollution. If pollution is within the environmental quality standards, its impacts to human health and the environment can be acceptable. We must work within the confines of the natural laws to prevent pollution problems in a new planned and economically feasible fashion.</td>
</tr>
</tbody>
</table>

China’s shifts in industrial systems are creating new growth opportunities while creating new environmental and social inequities at the same time. Coming to grips with complexities of economic development, environmental quality and social equity requires a broad, research-based foundation. New environmental knowledge and information will provide the needed grounding for policy-makers, scholars, activist and business strategists.

China’s environmental future will be determined in significant part by what happens in the rapidly industrializing and urban development. The steep scale of urban population and industrial growth in major cities and the energy- and materials-intensive character of the development process constitute a dark shadow over the city and its environment. And yet this challenge is also an opportunity. Current cleaner production and pollution prevention programs can make a most profound point that reconciles economic and environmental goals. This will be possible only through a shift to new technologies and systems that dramatically reduce environmental impact per unit of prosperity.

Together we must take steps to reach out to the people in communities and regions, both nationally and internationally to learn a better way to manage the quality of our environment and natural resources while encouraging socio-economic development. We must prepare to look beyond existing waste management strategies to pollution prevention strategies. Nor can we afford to wait. The time to act is now – on the road to sustainable development.

China’s Environmental Problems

The scope of China's environmental problems is quite complex, involving poverty, culture, and political situations, as well as technical, social and economic development conditions. As a developing socialist country, China’s economic strength is limited. With a population of 1.25 billion (20% of the world’s population) and relatively low economic, scientific and technical capabilities, China’s socioeconomic development before 1986 was difficult and inefficient. Industries did not adhere to a standard of environmental performance and environmental agencies lacked sufficient
funds and authority to enforce environmental regulations. Since 1986, China has exhibited vigorous economic growth unmatched elsewhere in the world. The impressive record, however, has been marred by significant deterioration of the environment. Protection of environmental quality hence has become a necessity rather than a luxury.

China’s steady and swift economic growth over the past two decades has been delivering to its people a relative prosperity that is largely defined in immediate material terms. China’s economic prosperity is taking place at great cost to China’s environmental quality and natural resources. China’s rivers, reservoirs, and other water resources are largely contaminated. Cities are the engines of economic growth. Unfortunately, cities in China are facing serious environmental problems. Its urban air is laden with harmful particulates, gases, and toxins; its solid and hazardous wastes are often dumped untreated. Environmental pollution is still growing and gradually extending from the urban areas to the rural areas. The scope of ecological destruction is expanding and intensifying. Furthermore, eco-environmental problems have begun affecting overall social and economic development.

Environmental pollution problems can also stem from mismanagement caused by a variety of reasons such as carelessness, indifference, or ignorance, as well as a lack of measurement and monitoring methods to provide baseline or background data. Such data is critical to serve as a technical basis for an engineering plan and design to prevent and control pollution, and as verification of adverse effects on health and the environment. The environment is everybody’s business: everybody is a producer and consumer of products and services, but how many people in China understand China’s critical environmental issues? The answer is very few because most of the 1.25 billion people in China do not have the opportunity to attain knowledge and information on current environmental knowledge and information.

Traditionally, China’s policy has been controlling releases of pollutants and wastes. Most environmental laws and regulations were enacted in the 1980’s, focusing on the end-of-pipe and single-medium issues (such as air, water, or land) rather than attempting “anticipation and prevention” for sustainable development. Many of the environmental professionals in government and industry were trained to apply end-of-pipe controls appropriate for the specific media. They did not have the opportunity to see environmental problems from more than one perspective. As to pollution control technologies, environmental professionals generally followed point-source control technologies of developed countries. Such technologies helped solve only short-term problems, rather than eliminate pollutants. In addition, they merely transferred pollutants from one environmental medium to another, causing potential secondary pollution problems that required further treatment and disposal.

The performance of our environmental program has being complicated by a lack of real political commitment to environmental policies and programs. The environmental protection agencies lacked sufficient funds and the authority to implement their plans and programs. As a result, they haphazardly enforced these laws and regulations that were criticized as vague and lax. Industries generally did not allocate the necessary management time and other resources to implement even potentially successful environmental programs unless they faced a real demand from local and national environmental protection agencies or the general public to improve their environmental performance. No matter how well intentioned, most industries did not behave in an environmentally sound manner.

Despite a wide range of environmental laws and regulations, enforcement at provincial and municipal levels is weak, although there is increasing evidence of a tougher approach toward environmental problems in the more affluent coastal provinces. The lack of information sharing has led local governments to misinterpret laws and regulations. Moreover, institutional obstacles within the government and legal system have also created an unequal distribution of information on laws, regulations, and enforcement mechanisms. Without knowledge and information of environmental laws and regulations, local governments could hardly implement the regulations effectively.

In spite of progress on reducing pollutants and wastes in several fronts, the overall environmental quality has continued to degrade over the past decade. Even though the control technology and knowledge are available to address the most serious issues of media-specific and point sources of pollution, governmental policy and strategies have been too conservative and fragmental in making progress. Furthermore, environmentally harmful products and
services have been neglected in environmental protection programs. This is because such pollution problems involve multiple governmental agencies and various industries without clearly identifying the responsibility of each organization to deal with pollution from environmental harmful products and services. As a result, the gap between what has been done and what is needed to protect environmental quality is widening.

Environmental issues in recent years, particularly those concerned about toxic chemicals and hazardous wastes from industrial processes, are receiving more attention in policy, program and media dimensions worldwide. Pollution from toxic chemicals and hazardous wastes is more extensive and difficult to manage than originally believed. When toxic chemicals and hazardous wastes contaminate the environment, all life is exposed to the potential high risks. To add to the problem, significant amounts of toxic pollutants are cycling and recycling in the environment not only from industrial sources, but also from urban transportation, industrial waste treatment and disposal facilities, and activities of the general public.

Challenges and Opportunities

China’s increasing market orientation requires a strategy for future environmental protection that need to go beyond the command-and-control measures of the past. Its 21st century economic policy with respect to environment is being challenged in three doctrines:

1. **Adjusting the market to work for the environment, not against it.** This means recognizing that China, with its limited resource base, is under-pricing energy and water. Prices of natural gas and water, for example, should be raised to reflect their scarcity. It means that the government should expand the use of taxes on pollution to incorporate its enormous social costs. Environmental taxes on coal and gasoline and on pollutants would use the market to clean the environment.

2. **Harnessing growth for the environment by pursuing investments with the highest environmental benefits for future generations.** Better pricing makes investments in preventive technology economic and imposes environmental discipline on firms. Pricing energy correctly would create incentives for firms to invest in more efficient technology and abatement. Public investments in research and development, urban public transits and wastewater systems, financed through increased cost recovery and better pricing, are crucial for conserving natural resources and for preventing environmental pollution and health risks.

3. **Improving administrative capabilities for the environment.** At the national level, better regulations and policy coordination could replace direct investment controls. As markets grow, regulations should spread to cover township and village industrial enterprises, which are an increasingly large source of pollution but are effectively exempt from regulation. If the government uses its powers to set national standards (for motor vehicles emissions, the energy efficiency of buildings, and so on), it will achieve major improvements in environmental quality.

Environmental policies are challenged to shift from focusing on end-of-pipe controls and after-the-fact cleanups, toward a more preventive, proactive approach. Pollution prevention strategy in industrialized nations has proved to be attractive because it saves costs, preserves resources, reduces health risks and liability, improves industrial processes and products as well as enhances company image. It also gains market competitive advantage by decreasing adverse effects on ecosystems and the environment. Furthermore, it seeks more lasting and complete solution to environmental pollution problems. Pollution prevention has proved to be far more comprehensive and systematic, and cost-effective approaches than today’s single-mode, single-pollutant and single-media focus. Unfortunately, most of Chinese industries (often either small, traditional businesses or inflexible, state-owned enterprises) require targeted intervention to persuade them to take advantage of the benefits of practicing pollution prevention. Pollution prevention opportunities take innumerable forms in the adoption of preventive technologies and total environmental management system approaches.

Economic, social, and political forces can influence environmental policies and regulations. As costs of natural resource along with waste treatment and disposal continue to increase, new opportunities of preventive-oriented activities will take place within both government and industry. Scientific and technical information is critical
for setting environmental policies and regulations and ensuring that the execution of China’s policies and regulations will manage effectively and efficiently. Thus, China’s traditional industries are challenged to reform and promote the theory and practice of pollution prevention. The basic preventive technologies should focus on production and consumption of toxic chemicals and hazardous wastes.

Environmental policies in China played a crucial role in promoting structural and technical changes. Three types of policies are particularly important:

1. *Environmental pollution prevention policies.* To create a society prepared to prevent pollution - a society that does not waste material resources and a society that exists in harmony with nature.
2. *Economic reform policies.* To learn and act on more efficient production technologies and processes expanded high-value economic activities, and increased competition.
3. *Environmental education and information policies.* To invest more funds for education and information technology with policies to forge new modes of partnership among industry, business, government and the academic community.

People in China need a vision of possibility and promise, of prosperity and well being for all. China has published in 1994 its Agenda 21 with an action plan. Clearly, China’s environmental and economic challenges needed a “clean revolution” that makes a most profound point of reconciling economic and environmental goals. Clean revolution is being promoted through a shift to new technologies and systems to reduce pollution. Now it is time for China to start a Clean Revolution in partnership with international practitioners (especially Overseas-Chinese for various reasons) to plan and implement a cost-effective program to achieve China’s vision of a clean and healthy future.

The challenges are simply too great for any scientific, engineering or management organizations to undertake alone. Together, leaders in China must take steps to reach out to the people in communities and regions, and across the nation, learning a better way to manage China’s environment and natural resources. Any socioeconomic development will result in a certain impact or risk to the environment, no matter the type of development. Industry is the indispensable motor of economic growth, which must be sustainable. However, industry must produce more with less. This is a big and difficult challenge and responsibility for industry to fulfill in China. The benefits of pollution prevention will not happen automatically; they will require better environmental policies and planning, as well as more educated workers and managers.

Despite the magnitude of environmental problems, China has an unprecedented opportunity to improve its environmental quality. Rapid economic growth in recent years makes China’s financial capability for pollution management more attainable. High rates of investment can be applied to develop cleaner, more energy-efficient industries. Management strategies that channel investment into pollution prevention and cleaner production, will increase material and energy efficiency, encourage conservation of scarce resources, reduce emissions, improve environmental quality, and lower pollution-related health costs. Pollution prevention helps further both the national environmental goals as well as industry’s interests.

China’s environmental protection programs require well-trained scientific, technical and managerial personnel, the use of advanced management techniques and modern computer facilities. Knowledge, information and skills empower people to transform natural resources into goods and services that satisfy basic needs, aspirations and development. It is education that provides people with the knowledge, information and skills that are necessary to develop and implement cost-effective policies, strategies and programs. In essence, education is the driving force of human progress. The more we know about the changing environment, the more safely we can keep up with the changes.

**Roles of Academia, Government, Industry, and General Public**

All sectors of society have a role in protecting the environment in the process of development, production and service.

- Academia must provide education/training, as well as new scientific and technical knowledge and information to
enable decision-makers to take positive and ethical actions.

- Government must establish and update environmental policies, regulations and standards based on the changing needs not only for industrial processes, but also for economic development, transportation, agriculture, energy, and land use. Government should build the principles of pollution prevention into decisions for amending or creating policies and regulations for environmental enhancement and development.

- Industry must develop and implement clean services, manufacturing processes and products that are aligned with the principles of pollution prevention. Industry will not only modify the existing products to make them less offensive to the environment, but also have to invent new products with environmental concerns beginning at the product conception. Less or no environmental adverse impact is the goal of product design.

- The general public must demand and support appropriate pollution prevention actions taken by the government and private sectors. They must also be open to the idea of modifying their pattern of purchase and consumption, among other lifestyle behaviors that are in conflict with the principles of pollution prevention and sustainable development.

Every sector of society has opportunities to take part in pollution prevention, environmental protection and sustainable development. New partnerships among all sectors of the society will have to be formed to prevent and control pollution. It is an ethical obligation and commitment we all share.

Conclusions

We need to understand the three principles of environmental pollution before we can develop workable socio-economic and environmental policies, regulations, and management strategies in a cost-effective way. Socio-economic development is necessary to improve our living standards, but such development must be sustainable. We still need to improve the education and training of professionals across all sectors of society on pollution prevention and cleaner production so that we will be able to achieve sustainable development.

China’s environmental future will be determined in significant part by what happens in its rapidly industrializing economies. The scale of urbanization and industrialization provide both a challenge and an opportunity. Precisely because so much of the urban-industrial investment has yet to take place, the following opportunities exist: (1) shaping a different development future that is far less energy-, materials-, and water-intensive; and (2) developing more rational and less costly strategies for protecting the environment (e.g., more creativity and less bureaucracy). Lastly, environmental professionals and business managers must attain the skills and knowledge to achieve their goals of a greener world through re-education and self-learning.

References


Introduction

Pig farm wastewater is a highly concentrated, large quantity potential point source of pollution. Proper treatment of pig farm wastewater is important to minimize adverse effect on environment. This paper describes various pig farm wastewater treatment processes. Intermittent aeration treatment and reactor media are discussed. A series of papers develops a two stage system for Hawaiian pig farm wastewater. The use of entrapped microbial cells immobilized in plastic beads as a media is discussed.

Case Studies

I. Evaluation Of Media For Anaerobic Reactor Attached Growth [2, 3]

In a series of tests summarized in two technical papers, the same team of authors evaluated the use of Suspended Particle-Attached Growth (SPAG) and Synthetic Fixed Media Reactor (SFMR) for swine wastewater anaerobic fermentation. Both evaluations were made in three 300 liter reactors. Two reactors were used to test the experimental media while the third reactor was used as the control without media. The SPAG media was free floating nylon mesh scrubber pads suspended in the reactor with mixing done by paddles. The SFMR media was polyester air-conditioner filter felt held in place by screens in the reactor with mixing from hydraulic recirculation. The media provided much quicker reactor performance recovery after shock loading and thermal shock. The control reactor failed for a HRT (hydraulic retention time) of one day. All media filled reactors had stable operation at a one day HRT.

II. Nitrification And Denitrification In High Nitrogen Strength Waste [5]

The purpose of this study was to check the kinetics of bio-oxidation, bio-reduction and the energy needed for nitrate reduction of high nitrogen animal wastes. Pig wastewater for this test was collected from a primary settling tank and filtered to remove particles larger than 2 mm. A high strength, ammonium, synthetic wastewater was also prepared for testing. Nitrifying bacteria from a wastewater plant were enriched by propagation in the synthetic wastewater. A soil suspension was the source of denitrifying bacteria.

The effect of initial ammonium concentration was found by injecting ammonium in various amounts (to achieve 500 to 3000 mg/l NH₄-N in 500 mg/l steps) into 100 ml containers filled with synthetic wastewater. Each container was also injected at zero time with nitrifying bacteria (0.44 mg cell protein). The containers were capped and incubated on a shaker. pH was 7.8. Ammonium, nitrate and nitrite were measured over 11 days. Nitrification rates for the various ammonium concentrations were almost identical (177 to 218 mg/day). This is contrary to some reports of high ammonium concentration inhibition. This may be due to the fact that the test nitrifying bacteria is adapted to high ammonium concentration and pH is maintained constant.

The effect of increasing initial biomass is to speedup nitrification. Initial biomass was 36, 72 or 180 mg cell protein per liter. The nitrifying rate for each of the 3 tests was constant until all substrate was metabolized. However, the rate increase was lower than a linear relation of oxidative ammonium metabolism with biomass loading would predict. Doubled biomass increased the ammonia conversion rate by a factor of 1.4 , while a 3 times increase
resulted in a 1.7 increase of conversion rate. The higher cell density was claimed to be the reason for the lower specific nitrification rate.

To test the effect of lowered oxygen concentration on nitrifying activity nitrogen oxygen mixtures of 21%, 15%, 10% and 5% oxygen were injected through a porous diffuser into the bottom of containers filled with synthetic wastewater. The gas was injected at 10 liter/mm. The synthetic wastewater contained 500 mg NH₄-N/liter. Nitrifying bacteria that had been grown in synthetic wastewater was injected. The NH₄-N concentration was monitored for 20 days for each oxygen concentration sample. The control 21% sample was nitrified at an almost constant rate from the start of the test until the NH₄ substrate was gone. All reduced oxygen samples exhibited a lag phase of 8 days prior to nitrification. The author attributed the 8 day lag to the time required for adaptation of the nitrifying bacteria to reduced oxygen. After the lag period, nitrification of the 15% and 10% oxygen samples proceeded at about the same rate as had the 21% oxygen sample. The 5% oxygen sample had a measurably lower nitrification rate than all the other higher oxygen samples. Apparently for oxygen contents above 10% in these tests oxygen was not the nitrification rate limiting factor.

Simultaneous nitrification and denitrification was tested by compared samples with undiluted wastewater, wastewater diluted 1:1 with deionized water and wastewater diluted 10:1 with deionized water. Initial ammonium concentration of the diluted samples was adjusted to about 1000 mg/l. The undiluted sample had an initial ammonium concentration close to 1600 mg/l. All three samples were completely nitrified after 17 days. However, the least diluted samples exhibited more denitrification by the end of the 27 day test. In other words the total nitrogen was higher at the test end for the diluted samples even though the undiluted sample started the test with a much higher total nitrogen. Later tests using glucose injection showed that denitrification is dependent on the presence of an electron donor.

III. Effect Of Injecting Fermented Swine Sludge In Sequencing Batch Reactors [4]

A limiting factor of treating swine waste is its low concentration of biodegradable organic matter relative to its nitrogen and phosphorus concentrations. Short chained volatile fatty acids produced from fermentation of primary sludge have been proven effective as carbon sources for denitrification and phosphorus removal of domestic wastewater. This study investigated the use of fermented swine sludge as an injection for sequencing batch reactors to provide the required carbon source.

Swine wastewater was collected, settled and diluted to give a supernatant COD of 2845 mg/l. The TKN was 148 mg/l and the T-P was 50 mg/l. Alkalinity was 561 mg/L as CaCO₃. This was the feed for the sequencing batch reactors. Waste solids were collected from the pig farm holding pit and fermented for 10 days at 29 C. The fermented waste was flocculated and settled. The supernatant was centrifuged and adjusted to a pH of 7. The COD was 23,000 mg/l and the TKN was 1400 mg/l. This was the experimental carbon source. Three 22 liter sequencing batch reactors were used. Air was sparged into the reactors. The reactors were stirred. The mixed liquor volume in each reactor was 11 liter at the start of each cycle.

The solids retention time was 20 days. The HRT was 48 hours. At the beginning of the anoxic reaction phase, step 3 above, supplemental carbon sources were added to two of the reactors. Sodium acetate was added to one reactor and fermented swine sludge to the other. Each supplemental carbon source was dosed at 190 mg of COD /liter of the reactor.

The control reactor with no supplement removed NH₄-N and SCOD well. However, almost no PO₄ was removed and denitrification was only partially complete. Both reactors with carbon supplement also removed NH₄-N and SCOD well. Both of these reactors also had good P04 removal and achieved nearly complete denitrification. The control reactor with no supplemental carbon achieved removals of 76% total nitrogen and 15 % phosphorus. Both reactors with supplemental carbon achieved removal of 90% total nitrogen and 89 % total phosphorus. Sludge phosphorus content was much higher for the reactors with supplemental carbon (7%) than that without (1%). The similar performance of the reactor supplemented with fermented swine waste sludge to the other reactor supplemented with acetate is not surprising. The fermented swine waste sludge is composed of about half acetate.

IV. Phormidium Treatment Of Anaerobically Treated Swine Wastewater [1]

The use of the Phormidium cyanobacteria for tertiary treatment of anaerobically digested swine wastewater was investigated. One Kg hog manure was suspended in 20 liter of tap water and screened through a no. 30 sieve. The
supernatant was digested in an upflow anaerobic sludge blanket reactor. The hydraulic retention time was 24 hours. The Phormidium was cultured both in glass cylinders and a glass carrousel reactor. The cylinders were continuously sparged with air and stirred. A paddle provided motion to the carrousel reactor. Continuous illumination was provided for photosynthesis. Temperature was held near 25 C. Samples were taken every 10 hours. Ammonium was removed before nitrates. Maximum nutrient removal was achieved at a 25% dilution. The dilution was necessary to eliminate a toxic level of ammonium for the Phormidium. The maximum removal was 68% of total phosphorus and 87% N-NO₃.

V. Hawaii Case Studies

Over a period of years studies were conducted to improve the treatment of wastewater from hog producers in Hawaii. In the past this wastewater has been mostly treated in anaerobic lagoons. The lagoons have large land requirements, sanitary, runoff and odor problems. To solve these problems and to recover energy, pig pen flushing water and nutrients anaerobic digesters followed by aerobic treatment have been proposed to replace the lagoons.

(A) Integrated Swine Waste Management System [10]

This preliminary study proposed using a anaerobic digester with sludge recycle followed by a ‘racetrack” aerobic algae-bacterial secondary treatment with dilution water recycle. Anaerobic digester tests were run using sludge recycle using a laboratory 0.2 m³ reactor (HDT of 6 days), and a field 20 m³ reactor (HDT of 10 days). The sludge recycle was as follows:

<table>
<thead>
<tr>
<th>Ratio of sludge recycled to effluent is as follows:</th>
<th>Flow</th>
<th>Total Volatile Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>0.25</td>
<td>3.0 to 3.5</td>
</tr>
<tr>
<td>Field</td>
<td>0.2 to 0.26</td>
<td>0.5 to 2.5</td>
</tr>
</tbody>
</table>

Problems with settling tank performance invalidated much of the 20 m³ reactor testing. The smaller reactor took 100 days to reach stable conditions. The experiments proved that sludge recycle produced slightly more methane gas with half the hydraulic retention time than earlier anaerobic digester tests without sludge recycle.

A 3.6 m³ pilot raceway was constructed for field testing. The purpose of the aerobic racetrack was to reduce the strength of the anaerobic digester effluent (2000 to 3000 mg/liter NH₄-N and 10,000 to 24,000 mg/liter COD) to a pollution level acceptable to a domestic sewer system. Increased cell protein production (from algae and bacteria cells), purifying the wastewater for hog farm reuse and providing an effluent suitable for aqua-culture or crop growing were other goals of the aerobic treatment.

Raceway effluent was recycled back to dilute the raceway influent. This was done to prevent the NH₄-N exceeding the 80 mg/liter threshold that inhibits mixed bacteria growth. The raceway dissolved oxygen was maintained above 1 mg/liter by surface rotor aeration, compressed air injection (.5 liter air/liter wastewater per hour) and algal metabolic generation of oxygen. The raceway removed 90% of the NH₄-N and 87% of the COD. The quality of the raceway effluent was judged sufficient for pigpen flushing, agricultural use or discharge to domestic sewers.

(B)Integrating Anaerobic Digestion & Algal-Biomass Treatment [9]

A pilot plant consisting of a 20 m³ anaerobic digester and a 120 m³ algal-biomass raceway was tested. Ambient temperature was 22-25 C. The anaerobic digester HRT was varied from 9 to 15 days. The sludge recycle was 2.5 based on flow and was 2 to 4 based on total volatile solids. The gas yield and gas production rate at HRT=1.5 hours (SRT of 2.67 hours) was clearly degraded from the results with longer HRT. The best combination of gas production and sedimentation efficiency occurred at HRT4 hours (SRT = 6.76 hours). The HRT=2.0 hours test had lower sedimentation efficiency than the HRT4 hour run (SRT = 3.25 hours). The author indicated that to avoid washout of
bacteria exceeding their reproduction rate, the SRT for anaerobic systems should not be less than 2 to 6 days. The algal-biomass raceway had the goal of reducing soluble COD and soluble NH$_4$-N. The raceway perforated disk oxygen transfer rate was found to be 1.66 Kg O$_2$/hour @ 20 C. This is close to the 1.61 to 1.65 Kg O$_2$/hour @ 20 C rates expected for perforated disks. This data was used to predict that sufficient raceway oxygen was present to handle the incoming SCOD with 8 hours of aeration per day and the incoming TCOD with 10 hours of aeration per day.

Four different aerobic stabilization processes are compared in Table 1. The algal-biomass raceway is a very competitive process if land is limited. The methane produced is sufficient to drive the perforated disks that supply oxygen and promote mixing. The overall proposed swine waste management system is shown in Fig. 3. This process is judged to be technically and economically feasible by the authors.

**Table 1  Aerobic Stabilization Processes**

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>BOD$_5$ REMOVAL (%)</th>
<th>ENERGY CONSUMPTION (KWH/Kg BOD$_5$)</th>
<th>LAND AREA (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raceway</td>
<td>97</td>
<td>0.49</td>
<td>0.09</td>
</tr>
<tr>
<td>Aerated Lagoon</td>
<td>80-90</td>
<td>1.16</td>
<td>0.13</td>
</tr>
<tr>
<td>Oxidation Ditch</td>
<td>80-93</td>
<td>5.60</td>
<td>0.04</td>
</tr>
<tr>
<td>Oxidation Pond</td>
<td>70-97</td>
<td>0</td>
<td>0.90</td>
</tr>
</tbody>
</table>

(C) Intermittently Aerated Biocarousel Reactor (IABR) [7]

In warm climates the 20 to 40 liters of water per pig per day used by hog producers dilutes the pig wastewater treated in the past by anaerobic lagoons. To solve these problems posed by the lagoons and to recover energy and nutrients, anaerobic digesters have been proposed to replace the lagoons. However, the dilution of the pig wastewater decreases the anaerobic digester performance. First settling the wastewater and then pumping the settled sludge to an anaerobic digester solves the dilution problem. This leaves the supernatant or diluted swine wastewater containing much organic to be treated. Treatment of this supernatant is the function of the IABR.

The IABR consists of a long tank with a central baffle that permits “racetrack” flow. Two perforated disks rotate at 87.5 rpm on one side of the racetrack oval to facilitate mixing, provide aeration and cause flow around the oval. Tests proved that the IABR increased SRT and allowed a l-EDT decrease. Greater than 90% removal of influent COD and TKN was achieved. Loading rates were 0.2 g COD/ g MLSS/ day and 0.02 g TKN/ g MLSS/ day.

(D) Horizontal-Baffled Anaerobic Reactor (HBAR) [8]

A 20 liter horizontal-baffled anaerobic reactor was used in a 30 C room to treat the supernatant of settled swine wastewater (with total volatile solids, TVS, less than 2 g/ liter. Steady state tests were run at various HRT and SRT values. This reactor achieved high SRT (3 to 60 days) in spite of low HRT (0.25 to 5 days). A maximum TCOD removal of 81% was achieved.

(E) PEMMC Process [6]

PEMMC (packed-entrapped-mixed-microbial cells process) consists of trapping or encapsulation of microbial cells into the porous matrices of polymeric carriers. The porous structures allow organic substrate and nitrate to diffuse into the internal pores where entrapped methanogenic bacteria do denitrification. The polymeric carrier develops surface gradients that protect the bacteria from low pH and toxic materials. The gradients probably account for the denitrification superiority of this process to that of the upflow sludge blanket process (USB).
The PEMMC process has a long SRT (solids retention time) to encourage slow-growing microorganisms and a short HDT (hydraulic detention time) that minimizes land requirements. The long SRT explains the process high nitrification efficiency. The PEMMC process is seen as a polishing step after anaerobic treatment or settling screening pig wastewater. For anaerobically treated pig wastewater, nitrification Efficiency ranged from 80 to 92%, and 95 to 97%, for HRT of 5, and 10 hours, respectively. For settled-screened pig wastewater with a ratio of aeration and non-aeration of 1:1 and HRT of 30 hours, TCOD removal efficiency was 81%, and total N removal efficiency of 90% were obtained.

CONCLUSIONS

The advantages of fixed and suspended media as biomass holders over free-floating biomass is shown for anaerobic fermentation of pig wastewater. Intermittent aeration improves nitrogen removal from pig wastewater over continuous aeration by providing successive aerobic and anaerobic periods. The anaerobic digester with sludge recycle combined with anaerobic algal-biomass raceway with water dilution is shown to be a practical process. The PEMMC (packed-entrapped-mixed-microbial cell) process provides good treatment of anaerobically treated pig wastewater and settled-screened pig wastewater. Both the HEAR (Horizontal Baffled Anaerobic Reactor), and IABR (Intermittently Aerated Bio-carousel Reactor) processes also provided good treatment of settled-screened pig wastewater.

REFERENCES