OCEESA Profile

Overseas Chinese Environmental Engineers & Scientists Association (OCEESA) is a non-profit organization incorporated in the State of Ohio in 1980, it holds tax exempt status under sec 501(c)(3) of IRS Code. OCEESA is devoted to promote academic and professional excellence and networking in environmental science. OCEESA members work and reside throughout the USA, Canada and in many countries of Asia. In 1988, OCEESA became a chapter of the Chinese Institute of Engineers/USA to affiliate with other Chinese American professional organizations.

OCEESA Officers & Board of Directors

President    Mr. Edward T. Chen  Houston Dept. of Solid Waste Management
Vice President             Dr. Chein-Chi Chang  District of Columbia Water and Sewer Authority
Secretary/Treasurer   Dr. Yung-Sung Cheng  Lovelace Respiratory Research Institute

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

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Dr. Pao-Chaing Yuan  Jackson State University
Dr. Junn-Ling Chao  Montgomery Watson Harza

Ex-Officio:                   Mr. Anmin Liu   AML Environmental Engineering Consultants
Permanent Executive Director: Dr. Yung-Tse Hung  Cleveland State University
Assistant Executive Director: Dr. Howard H. Lo  Cleveland State University

Advisors:     Dr. Shou-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

Membership: Regular members $25/year, Student members $15/year, Corporate members $100/year.

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Permanent Editor-in-Chief
Prof. Yung-Tse Hung
16945 Deerfield Dr. , Strongsville, Ohio 44136-6214 USA
Tel: O: 216-687-2596  Tel: H: (440) 238-0407 Fax: 216-687-5395 Email: y.hung@csuohio.edu

Associate Editors
Prof. Howard H. Lo, Cleveland State University
Dr. Don Tsye-Lang Tang, U. S. Environmental Protection Agency

News Editors
Officers & Directors of the Board

OCEESA Headquarter Office:
c/o Prof. Yung-Tse Hung
16945 Deerfield Dr., Strongsville, Ohio 44136-6214 USA
Tel: O: 216-687-2596 Tel: H: (440) 238-0407 Fax:216-687-5395 Email: y.hung@csuohio.edu

OCEESA World Wide Web Homepage: http://www.oceesa.org
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October 2003

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OVERSEAS CHINESE
ENVIRONMENTAL ENGINEERS & SCIENTISTS
ASSOCIATION

CHINESE INSTITUTE OF ENGINEERS CIE/USA
CLEVELAND, OHIO, USA

OCEESA World Wide Web Homepage: http://www.oceesa.org
OCEESA MEMBER NEWS (October 2003)

1. We welcome Dr. Charles Chi-Su Chou, who was our OCEESA President during the period of June 1, 1986 to May 31, 1987, to re-join our OCEESA. Dr. Chou is professional environmental consultant in Houston, Texas. Email: chisuchou@aol.com

2. Congratulations and many thanks to Mr. Edward T. Chen, our OCEESA President, for excellent job in sponsoring and organizing the 2003 Environmental Summit & Expo, Houston, Texas, September 5-6, 2003. The conference has 250 attendees including 12 OCEESA members.

3. OCEESA annual meeting was held in Houston, Texas, on September 6, 2003, and was chaired by Mr. Edward T. Chen, our OCEESA President, during the 2003 Environmental Summit & Expo. 12 OCEESA members and 5 guests attended the meeting.

4. Mr. Edward T. Chen has appointed the following to the 2003 Nomination Committee.
   - Mr. Edward T. Chen, Chair
   - Dr. Chein-Chi Chang, Vice Chair
   - Dr. Yung-Sung Cheng
   - Dr. Yung-Tse Hung, Secretary
   - Mr. Anmin Liu
   - Dr. John Chao-Oiao Huang

5. Congratulations to Dr. Francis Hun-I Chang, our OCEESA member and Director, who taken early retirement, and has started his own consulting services, FC Consulting, with main expertise in green energy and energy from waste technologies. Dr. Chang’s email: FCConsulting@rogers.com

6. The 9th MTEPC will be held in Xian, China, May 10-14, 2004. The conference is co-sponsored by Xian Jiao-Tong University, Xian, China, Jiao-Tong University, Hsin-Chu, Taiwan, and OCEESA. If you are interested in submitting papers for presentation or interested in attending the conference, please contact Dr. Chein-Chi Chang, OCEESA Vice President, or Dr. Yung-Tse Hung, OCEESA Executive Director. Dr. Chang’s email: chein-chi_chang@dcwasa.com Dr. Hung’s email: y.hung@csuohio.edu

EDITOR’S NOTE

The editors of this issue of OCEESA Journal are Mr. Edward T. Chen, Dr. Francis Hun-I Chang, Dr. Jing-Yuan Wang, Dr. Yei-Shong Shieh, Dr. Pao-Chiang Yuan. The editors for the next issue, February 15, 2004 are Mr. Edward T. Chen, Dr. Chein-Chi Chang, Mr. An-Min Liu, Dr. Junn-Ling Chao, and Mr. Anmin Liu. OCEESA members are encouraged to submit before February 1, 2004 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, 16945 Deerfield Dr., Strongsville, Ohio 44136-6214 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
Dear OCEESA Members:

What a good time we had this month! For those who attended the 2003 Environmental Summit & Expo and OCEESA annual meeting you know what I mean. For those who did not join us, let me share with you the events of September 5 and 6.

For the first time ever, the OCEESA members (members who attended the Summit – please see attachment) mingled with mainstream corporations to co-host an environmental conference in Houston, Texas and over 250 attendees witnessed an overwhelming and successful event.

The Friday morning conference program offered three distinct forums, industry, government and innovation in environmental technology, each with six speakers.

In the Industrial Forum the topics ranged from wood waste recycling to recycling and mining C&D waste. Speakers from various governmental entities lectured on clean fuels, air quality, wastewater processing and policies relating to waste disposal and treatment in Taiwan. The innovation forum touted fresh topics such as water and sewer infrastructure rehabilitation, sediment and erosion control, and environmental venture capital. More than sixty conference participants attended each forum and after the morning break one forum had an overflow crowd. The OCEESA had four (4) speakers attend these forums. The speakers are: Dr. Shou-Yuh Chang of North Carolina; Dr. Harvey Houng, Ph.D. of Taiwan; Mr. Ben H. Chen of Florida; and Dr. John C. P. Huang, Ph.D. of Minnesota.

The highlight of the conference was the luncheon saluting the Environmental Professionals and Environmental Sanitarians of the Year. The goal of this conference was to recognize front line workers and environmental professionals in the environmental industry. As OCEESA president, I acknowledged the nearly 20 corporate mainstream and Asian American sponsors, and numerous volunteers that made the conference a success. Gordon Quan, Council Member and Mayor Pro-Tem of the City of Houston, delivered the welcome remarks. Commissioner Ralph Marquez of the Texas Commission on Environmental Quality was the keynote speaker. Afterward, the award ceremony began.

The Board of Directors and past presidents of OCEESA honored Lee P. Brown, Mayor of the City of Houston, with its Environmental Leadership Award. Mayor Brown was chosen for his environmental leadership and vision. Mayor Pro-Tem Quan accepted the award on behalf of Mayor Brown who was absent due to travel outside the United States.

The gathering of family, friends and co-workers listened as the master of ceremonies, an anchor from Fox TV, read aloud the bases for which the awardees were chosen. Commissioner Marquez presented the Environmental Professional of the Year Award to five industry experts deserving of the recognition. Mayor Pro-Tem Quan presented plaques to the five environmental sanitarians chosen by the Selection Committee to receive their award. One award recipient was so emotional that he was unable to speak when he approached the microphone to accept his award. Awards for environmental team, environmental humanitarian, and lifetime achievement were also given at the luncheon.
Although less than 50 people actually pre-registered for the technical tour, surprisingly more than 70 conference attendees took advantage of the tour featuring the City of Houston’s Westpark Consumer Recycling Center and ReStore, and Environmental Service Center.

Friday concluded with a dinner reception for OCEESA members and local Chinese-American environmental professionals and my staff (who helped put together this event), sponsored by the Science Division of the Taipei Economic Culture Office in Houston.

On Saturday, September 6, 2003, OCEESA held its Annual Meeting/Houston Chinese-American Environmental Professionals joint meeting. The meeting opened with the president’s remarks and the vice president and treasurer’s reports. Dr. Rubin Yu, Dr. John Huang, Dr. Ben Chen, Dr. Karen Liu, Dr. Harvey Huang from Taiwan EPA, and others made presentations to the joint group. A one-hour open discussion followed the morning break.

At noon, the meeting adjourned and the group went to lunch at a local restaurant. When lunch concluded, the group took a boat tour of the Port of Houston. The group got a first hand look at the world’s sixth largest port on this two hour round trip boat ride. After the boat trip, we toured the world famous Texas Medical Center and one of the richest neighborhoods in Houston – River Oaks.

Later in the evening, many of OCEESA’s members attended the Chinese-American Mid-Autumn Celebration Festival in nearby Sugarland where they were free to visit food stands at the festival or have dinner at area restaurants. We left the festival around 7:30 p.m. Then my wife and I invited the group to my house to taste the Moon Cake. Around 9:00 p.m. they returned to the hotel.

Since the conference, I have had feedback from several conference attendees who expressed their delight and appreciation for the two days of activity. For those who were not able to attend this year, I hope this summary provides a glimpse of this memorable event. I hope everyone will have the opportunity to meet the next time we come together for this or similar events.

By the way, please take a minute to see some photographs from the conference. If you would like the Public Information Officer’s photo album please let me know.

Sincerely,

Ed Chen, President
OCEESA

Attachment: Attendees List; Photographs

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**OCEESA Annual Meeting**
**September 6, 2003**

**Attendees List (OCEESA Members and Guests*)**

<table>
<thead>
<tr>
<th>Name</th>
<th>City, State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helen Wang Hsu</td>
<td>New York, New York</td>
</tr>
<tr>
<td>Edward T. Chen</td>
<td>Houston, Texas</td>
</tr>
<tr>
<td>Francis Hun-I Chang</td>
<td>Toronto, Ontario, Canada</td>
</tr>
<tr>
<td>Pao-Chiang Yuan</td>
<td>Brandon, Mississippi</td>
</tr>
<tr>
<td>*Humbert Chu</td>
<td>Houston, Texas</td>
</tr>
<tr>
<td>Karen Chu-Lan Lee Liu</td>
<td>Washington, DC</td>
</tr>
<tr>
<td>Yung-Sung Cheng</td>
<td>Albuquerque, New Mexico</td>
</tr>
<tr>
<td>*Tom Chiang</td>
<td>Houston, Texas</td>
</tr>
<tr>
<td>*James Chen</td>
<td>Houston, Texas</td>
</tr>
<tr>
<td>Ning-Wu Chang</td>
<td>Los Angeles, California</td>
</tr>
</tbody>
</table>
Shoou-Yuh Chang  Greensboro, North Carolina
John Chao-Piao Huang  Cupertino, California
*Susan Chen  Plantation, Florida
Ben H. Chen  Plantation, Florida
Rubin Hu  Seattle, Washington
*Harvey Houng  Taiwan

Note: 12 OCEESA members and 5 guests attended OCEESA annual meeting
Photographs Taken During 2003 Environmental Summit and Expo and OCEESA Annual Meeting
September 5-6, 2003

Page 4
1) Overseas Chinese Environmental Engineers and Scientists Association (OCEESA) past presidents and Board Members presenting award for Environmental Leadership to Mayor Lee P. Brown. Mayor Pro-Temp Gordon Quan accepting the Environmental Leadership Award on behalf of Mayor Brown
2) Reporters from Chinese paper
3) Master of Ceremonies, Jose Griñan, introducing Keynote Speaker, Texas Commission on Environment Commissioner (TCEQ) Ralph Marquez
4) Andrew Contreras receiving award for Environmental Professional of the Year from Commissioner Marquez
5) Director of the Solid Waste Management Department, Thomas “Buck” Buchanan, introducing Mayor Pro-Temp Quan
6) Roger Jones receiving Environmental Sanitarian of the Year Award from Mayor Pro-Temp Quan
7) George Brodie, Environmental Humanitarian Award recipient, with Mayor Pro-Temp Quan
8) Gay Donehoo accepting Environmental Humanitarian Award

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9) OCEESA members at annual Meeting
10) Attendees in one of three environmental sessions.
11) Staff member
12) Jose Griñan, Master of Ceremonies, Anchor from Fox 26 News in Houston, TX
13) Gary Readore, accepting the Lifetime Achievement Award for Charles Sennett, award recipient

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14) Master of Ceremonies, TCEQ Commissioner and wife, and award recipient and wife
15) Master of Ceremonies and staff member
16) Master of Ceremonies
17) Staff Members
18) Director of Solid Waste Management

Page 7
19) Dr. Harvey Huang Ph.D., Advisor to the Environmental Protection Administration in Taiwan, Republic of China
20) Speakers in one of three environmental sessions
21) Attendees in one of three environmental sessions
22) Edward Chen, Deputy Director, Solid Waste Management, OCEESA president and conference organizer, with staff members
23) Edward Chen, Deputy Director, acknowledging sponsors and volunteers for their support of the Summit
24) Mayor Pro-Temp Quan, Master of Ceremonies Jose Griñan, Commissioner Marquez and wife, Edward Chen and Buck Buchanan of the Solid Waste Management Department

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25) Master of Ceremonies, award recipient and wife, and Commissioner and wife
26) Conference attendees
27) OCEESA members at Annual Meeting
28) Staff members and Master of Ceremonies
29) Master of Ceremonies closing the Award Luncheon
PROGRAM AGENDA FOR OCEESA MEMBERS
2003 Environmental Summit & Expo, September 5-6, 2003,
Intercontinental Hotel, Houston Texas

FRIDAY, SEPTEMBER 5, 2003

9:00 a.m. - Noon

INDUSTRIAL FORUM (Ballroom I)
Moderator: Jacinta Hamersley, Houston-Galveston Area Council

- Wood Waste Recycling and Market Development
  Bill Winters, President and CEO, Novus Wood Group

- Scrap Metal Recycling
  Emanuel Bodner, President and CEO, Bodner Metal and Iron Corporation

- Paper Recycling Markets
  Ben Walker, Director of Government Affairs, Abitibi Consolidated

- Glass Recycling Markets
  Steve Russell, Strategic Materials

- Recycling and Mining of C&D Waste
  Dr. Shou-Yuh Chang, Samuel Massie Professor, Civil and Environmental Engineering, North Carolina A&T State University

- Environmental Policies for the Port of Houston
  Laura Fifick, Port of Houston Authority

GOVERNMENT FORUM (Ballroom II)
Moderator: Alan Watts, Texas Commission on Environmental Quality

- Integrating Environmental Principles into the Planning Process
  Jeff Taebel, Manager, Houston-Galveston Area Council

- Use of Recycled Content Materials in Road Construction
  Greg Ransil, Texas Department of Transportation

- Clean Fuels Program
  Vic Ayers, City of Houston, Mayor’s Office

- Air Quality and Regional Transportation
  Beth Whitehead, Transportation Planning Manager, Houston-Galveston Area Council

- Waste Water Processing
  Jeff Taylor, Deputy Director, Public Works and Engineering, City of Houston

- Policies and Measures of Waste Disposal and Treatment in Taiwan
  Dr. Harvey Houng, Ph.D., Advisor to the Environmental Protection Administration in Taiwan, Republic of China
INNOVATION IN ENVIRONMENTAL TECHNOLOGY FORUM (Ballroom III)
Moderator: Dawn Moses, City of Houston, Mayor’s Office

- Experience in Water and Sewer Infrastructure Rehabilitation
  Ben H. Chen, President, Chen and Associates

- Sensible Sediment and Erosion Control
  Carolyn J. LaFleur, P.E., Principal, Sustainable Systems Engineering

- Air Quality in Houston
  Dr. Pamela Berger, Director of Environmental Policy, City of Houston, Mayor’s Office

- Processing of Recycled Glass into Beach Sand
  J. D. Porter, President and CEO, Andela Products

- Brownfields Development
  Dawn Moses, City of Houston, Mayor’s Office

- High Tech and Environmental Venture Capital
  Dr. John C. P. Huang, PhD., President, Focus Venture, Inc.

Noon - 2:00 p.m.

Award Luncheon to Salute the Environmental Professional and Sanitarian of the Year (Registration Fee Required)

2:00 p.m. – 4:00 p.m.

Technical Tour: 1) City of Houston Westpark Consumer Recycling Center
2) City of Houston Environmental Service Center
3) Abitibi Paper Recycling Facility

6:00 p.m. – 9:00 p.m.

OCEESA Members Dinner Reception (Dinner covered by OCEESA) – East Ocean Seafood Chinese Restaurant,
10830 Bellaire, Houston  281-568-2288

SATURDAY, SEPTEMBER 6, 2003

8:30 a.m. – Noon
InterContinental Hotel (Ballroom I) [Continental Breakfast Provided]

OCEESA Annual Meeting/Houston Chinese-American Environmental Professionals Joint Meeting

8:30 a.m. – OCEESA’s President Remarks
Board Reports

9:00 a.m. – Presentations (Limited to 10 minutes per person)
Technology and Experience Sharing
Speakers TBD

10:30 a.m. – Coffee Break

11:00 a.m. – Open Discussion
12:00 Noon – Meeting Adjourn

12:00 Noon – 2:00 p.m.
Luncheon – (Luncheon covered by OCEESA.) Canton Chinese Seafood Restaurant, 2649 Richmond, Houston
713-526-1688

2:00 p.m. – 5:00 p.m.
Port of Houston Boat Tour--The Port of Houston is a 25-mile-long complex of diversified public and private facilities located just a few hours' sailing time from the Gulf of Mexico. The port is ranked first in the United States in foreign waterborne commerce, second in total tonnage, and sixth in the world. Approximately 194 million tons of cargo moved through the Port of Houston in 2001. A total of 6,613 vessel calls were recorded at the Port of Houston during the year 2001.

6:00 p.m. – 9:00 p.m.
Attend Chinese-American Mid-Autumn Celebration Festival in Sugarland, Texas
(Dinner on your own, free to visit area restaurants and food stands in festival)

9:00 p.m. – Bus Returns to Hotel
MINUTES OF OCEESA ANNUAL GENERAL MEETING, SEPTEMBER 6, 2003, HOUSTON, TEXAS
OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS AND SCIENTISTS ASSOCIATION (OCEESA)

Date: September 6, 2003
Time: 9:00 PM-12:00 PM
Place InterContinental Hotel, Houston

Present in the tele-conference

Mr. Edward T. Chen President
Dr. Yung Sung Cheng Secretary/Treasurer
Mr. Anmin Liu Ex-Officio
Dr. Ning-Wu Chang Director of Board
Dr. Francis Hun-I Chang Director of Board
Dr. Pao-Chang Yuan Director of Board
Dr. John Huang
Dr. Rubin Yu
Dr. Shou-Yuh Chang
Dr. Ben Chen
Dr. Karen Liu
Mrs. Helen Wang Hsu
Dr. Humber Chu
Dr. Tom Chiang
Dr. James Chen
Dr. Susan Chen

I. President Edward Chen called the meeting to order at 9:00 AM, Central Standard Time. He mentioned that the Environmental Summit was a huge success with about 250 attendees. This conference offered an opportunity for OCESSA to work with mainstream environmental community.

II Vice President Report (prepared by Chein-Chi Chang and presented by Y.S. Cheng)
(1) 9th Mainland-Taiwan Environmental Protection Conference
   - Xian, China, May 10-14, 2004
   - Call for Papers (Oct. 31, 2003 deadline)
   - Suggestions for sessions, programs, and tours

(2) 20th Modern Engineering Technology Seminar
   - November 10-17, 2004, Taipei
   - Chung-Ding Company is the organizer
   - 12 Sessions proposed:
     - Biotechnology & Pharmaceutical
     - Environmental Protection
     - Water Resources
     - Energy
     - Nano and MEMS Technology
     - System Integration
     - Broadband Network and Communication
     - Human Resources Management
     - Medical Emergency Responses and Technology
     - Optical Electronics and Display Technologies
     - E-Technologies
     - Industrial Transformation and Transition

(3) Other items in the report were in the discussion section

III Treasurer Report
IV Technology and Experience Sharing

(1) Dr. Rubin Yu who is the president of International Chinese Environmental Alliance, reported on the activities of ICEA. The future of the organization is pending on the decision of the EPA of Taiwan.

(2) Dr. John Huang talked about his view of the future of OCEESA and what should we do to recruit younger members

(3) Dr. Ben Chen talked about his experience of recruiting new members and improving financial situation.

(4) Dr. Karen talked of forest management within the US Department of Agriculture

V. Discussion

(A) By-Law Revisions
Edward Chen and Chein-Chi Chang explained the needs to consider revision of our current By-laws.

(1) We need more affiliate and student members to actively involve in the OCEESA. One consideration is to reduce their annual fees and change the privileges of affiliated members.

(2) Expand the Board to include presidents of local chapters and affiliate members.

(3) Create Life Membership

We agreed to consider these issues in details at the committee level and consider to have local chapter president as board member but not to change the member classification and privileges.

(B) Web Site

The website should be more accessible. We agreed that it would be good to remove the restrictions to get to some contents.

(C) Journal
The issue is whether we should have hard copies of OCEESA journal. The main issue is the cost, which is quite substantial for hard copies including printing and mailing costs. However, the hard copy is something we could show and display.

(D) Financial Accounts
We have two financial accounts (by executive secretary and treasurer). We discussed the need to have separate accounts.

VI The meeting was adjourned at 12:30 PM, 9-6-03, Central Standard Time.

Submitted by: Dr. Yung-Sung Cheng, Secretary/Treasurer   Date: September 6, 2003
OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS AND SCIENTISTS ASSOCIATION (OCEESA)  
MINUTES OF BOARD OF DIRECTORS MEETING  
MAY 9, 2003  
TELECONFERENCE  

Date: May 9, 2003 (W), 11:30 to 12:30 Central Standard Time (CST)  

Present in the tele-conference  
Mr. Edward T. Chen President  
Dr. Chein-Chi Chang Vice President  
Dr. Yung Sung Cheng Secretary/Treasurer  
Mr. Anmin Liu Ex-Officio  
Dr. Ning-Wu Chang Director of Board  

Other Directors who were called but could not get on the conference lines because of the lines exceeded its capacity.  
Dr. Yung -Tse Hung Executive Director  
Dr. Francis Hun-I Chang Director of Board  
Dr. Yei-Shong Shieh Director of Board  
Dr. Junn-Ling Chao Director of Board  

II. President Edward Chen called the meeting to order at 10:30 AM, 5-9-03, Central Standard Time.  

II 2003 Environmental Summit and Expo to Salute Sanitarians  
(1) Contribution from the corporate sponsors is lower than expected because of slow economy. President Chen will continue to work on this area and need help from all of us.  
(2) Because of budget and SARS epidemic, there will be very few participants from China and Taiwan. Therefore, the focus of the Summit and Expo will be on Friday (September 5). There may not be technical sessions or workshops on Saturday. We still will have OCEESA business meeting and other programs.  
(3) The estimated number of attendees will be between 150 and 250 mostly from corporate sponsors. The number of attendees for 9/6 is uncertain but would likely be around 25-30.  

III. MTETS  
Dr. Chein-Chi Chang reported that the sponsoring organization, Xian Jiao Tong University submitted the application to host the conference to the Chinese Ministry of Education. Because of SARS epidemic, the decision would likely be delayed. Dr. Chang proposed three possible dates (late May, late June and early September 2004) based on the responses of our membership.  

IV Committees  
(1) There is little response from the survey of our memberships on committee volunteers. We decided to establish two committees, the Web/IT and Bylaws. The third committee, Corporate Sponsor, will be considered after the September conference.  
(2) Chein-Chi Chang will chair the Web/IT committee. We need other member of board for volunteers.  
(3) Yung Sung Cheng will chair the By-Law Committee. We need other members of board for volunteers.  

V. By-Law Revisions  
Edward Chen and Chein-Chi Chang explained the needs to consider revision of our current By-laws.  
(4) We need more affiliate and student members to actively involve in the OCEESA. One consideration is to reduce their annual fees.  
(5) Expand the Board to include presidents of local chapters and affiliate members.  
(6) Create Life Membership
We agreed to consider these issues in details at the committee level.

VI The meeting was adjourned at 12:30 PM, 5-9-03, Central Standard Time.

Submitted by: Dr. Yung-Sung Cheng, Secretary/Treasurer  Date: May 9, 2003
EVALUATION OF LIVESTOCK WASTE BY-PRODUCTS

Francis H. Chang, Ph.D., PEng
Principal, FC Consulting
Toronto, Ontario, M1C 3C6 Canada
Email: FCCConsulting@rogers.com

ABSTRACT

The farming community should regard agricultural wastes as a valuable resource. In addition to utilizing the nutrient content as fertilizer, green energy production is a well-known by-product. Examples include: anaerobic digestion (AD) of livestock manure to produce biogas for use as fuel for stove, boiler, combined heat and power (CHP) generation or even as vehicle fuel; and gasification of relatively dry wastes such as poultry manure, wood chips, and saw dust for power generation.

Besides green energy, processing of agricultural waste can provide many more beneficial byproducts. Utilization of carbon dioxide from combustion exhaust in greenhouses is less commonly known, and the environmental benefits such as the reduction of pathogens, odour, greenhouse gas emissions and water contamination are difficult to quantify as byproducts. These benefits are discussed in greater detail in this paper, and quantification methods are proposed. The overall cost of agricultural waste management can be significantly reduced when “full-benefit” accounting is applied, and the cost of implementing advanced technologies can be justified. An integrated solution to alleviate the concerns of agriculture, environment, public health and energy can be developed by fully utilizing the by-product values.

KEYWORDS. Agricultural waste, by-products, manure, biodigestion, biogas, compost, green energy, combined heat and power, cogeneration, integrated solution.

INTRODUCTION

With the recent advent in green energy technology and their favourable impact on global warming, agricultural waste material is increasingly being recognized as a valuable source of biomass renewable energy. The ethanol production from potato and corn wastes (Mann 2002, Kadam, 2002); combustion, gasification and co-firing of poultry manure, plant stems and straw for fuel gas (Tschanum 2001, Morris 2002, Rizeq 2002, Smeenk 2002, Zygarlicke 2002); and manufacture of biodiesel from vegetable oil (Cruz 2002, Worgetter 2002) are some examples.

Livestock manure has always been regarded as a resource on farms. As wet sludge, it is simply land applied for its nutrient value. In remote areas of India, dried dung is being burned for energy even today. However, without the guidance of science and technology, such simplistic approaches are not sustainable. The adverse effects of nutrient saturation and pathogens on soil and water; and the deterioration of air quality owing to emissions of particulates and products of incomplete combustion such as carbon monoxide are causing major environmental and health concerns in both industrialized and developing countries (Overend 2002)

As well developed green technologies are becoming increasingly affordable, and by-product recovery techniques are becoming more fully developed, an integrated solution can often be assembled to utilize the full potential of agricultural wastes. One example of such a solution is the integrated process of anaerobic digestion and biogas cogeneration of electricity and heat, and the proper management of the digestate.

This paper presents a detailed consideration of the various by-product recovery options, and, using anaerobic digestion (AD) technology as an example, the full potential value of the integrated solution.

ANAEROBIC DIGESTION (AD) WITH FULL BY-PRODUCTS RECOVERY
Organic wastes can be processed by anaerobic digestion (AD) reactions, which can be simply defined as the decomposition of organic matter in the absence of oxygen, to produce methane. The basic reaction steps of the conversion are summarized in Figure 1.

**Figure 1. Biochemical Reactions of Anaerobic Digestion (AD) Process**

Figure 2 illustrates the overall concept of applying the AD technology to develop an integrated solution for livestock manure management.
Figure 2. Anaerobic Digestion of Manure with Full By-products Recovery
PRIMARY PRODUCT AND BY-PRODUCTS

Primary Product: It must be recognized that the primary product of using AD technology as a solution to livestock manure management should be considered to be the disposal of livestock manure in a sustainable manner. The single most important benefit is that the livestock industry can continue to operate and the potential bottlenecks to the industry’s expansion and growth can be removed.

By-products: Referring to Figure 2, it can be recognized that, in addition to the Primary Product as defined above, the following by-products are derivable from this process:

A. Tangible Benefits

(1) Energy

Biogas: The primary energy by-product is the methane (CH$_4$) reactant of the bacterial reactions. When diluted by the carbon dioxide (CO$_2$) produced simultaneously from the reaction, a mixture product containing about 55-70% CH$_4$ and 30-45% CO$_2$ with some other gaseous inerts and contaminants is formed which is commonly called biogas. It has between 55-70% the heating value of natural gas. It can be used as a medium value fuel gas, or be purified by a suitable separation method to become a natural gas substitute. Sweden is already using upgraded biogas for vehicle fuel and plans to permit purified biogas into their natural gas grid system (Jonsson 2000).

Electricity: The energy content of the biogas can be converted to electrical energy using one of several conversion technologies: gas engine generator, gas turbine or microturbine generator, and fuel cell. But practically, gas engine generator is a more feasible technology from reliability and economic points of consideration.

Heat: Heat can be generated from combustion of the biogas, or can be generated as by-product of the electricity generation. The engine block heat and the waste heat in the engine exhaust can both be recovered by a waste heat recovery system for desired application.

(2) Nutrients

Nutrients in substrate: Livestock manure contains nutrients that are essential to plant and crop growth. Only the macro nutrients, nitrogen (N), phosphorus (P) and potassium (K) are considered here and the nutrient contents in the manure substrate and their values are based on documents from American Society of Agricultural Engineers, ASAE, and Ontario Ministry of Agriculture and Food, OMAF (ASAE 1998, OMAF 1999).

Nutrients in digestate: The process of anaerobic digestion only removes carbon for conversion to methane and carbon dioxide. Some nitrogen in the form of ammonia may be lost from the digestate during storage unless the storage facility is well covered. Other nonvolatile nutrients are maintained in the digestate.

Nutrients after solid/liquid separation: If the digestate is separated into two component streams, solids and liquid, the nutrients will be distributed between these two phases. The liquid phase can be land applied as is on crop farms or be further processed. The nitrogen, phosphorus and potassium elements in the liquid stream can be processed by struvite crystallization to produce fertilizer solids. The much diluted liquid can be processed until it becomes reusable water (Li 2002).

Compost: The solid component after solid/liquid separation with the absorbed nutrients can be composted to provide soil amendment material for farmland conditioning or landscape use.
Fertilizer crystal: The struvite granules produced by crystallization can be transported in concentrated form and marketed as a valuable fertilizer.

(3) Gaseous Emissions:

Carbon dioxide: Carbon dioxide is a major component of the biogas, and can be a source of industrial gas if available in sufficiently large quantity. A proven application related to agriculture is for CO₂ enhancement in greenhouse operation. It is desirable to raise the CO₂ concentration in greenhouse from about 300 ppm to about 800 ppm to enhance plant growth. The CO₂ gas from biogas and from combustion product are both passed through a selective catalytic reduction process to remove the NOx and unburnt hydrocarbons that are harmful to greenhouse plants before they are used in the greenhouse. Rosa Flora Ltd. Of Ontario, Canada, has implemented successfully such a technology and found the application profitable (Bulk 2000).

Greenhouse gas emission reduction credits: Reductions of greenhouse gases (GHG) such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) are awarded with credits, which can be traded for monetary values if the credits can be certified by the authorized certifying government agencies (e.g. the Clean Air Canada Inc.). The values are assigned on the basis of dollars per ton of CO₂ mitigated or off-set. For CH₄ the value is based on equivalent of tons of CO₂. Since the global warming potential of CH₄ is 21 times that of CO₂, the reduction of methane release could result in a significant value.

B. Intangible Benefits

In addition to the tangible benefits described above, the by-products also include several intangible benefits, which are listed here but will not be discussed in detail due to the limited scope of this paper. Quantification of such benefits such as pathogen destruction, odour reduction, ground and surface water protection, and rural hygiene improvement is being studied, and will be the subject of a separate paper in the future.

BY-PRODUCT VALUES

The values of the various tangible by-products listed above will be assessed to provide data that can be used to conduct an overall evaluation of the integrated solution

The amount of biogas yield is based on 340 m³ per ton of volatile solids for the quantity of hog manure produced in an average 2000-head hog farm. The hog manure production is estimated from ASAE Standards 1998 (ASAE 1998). Approximately 84 kg of manure and 39 kg urine are produced per 1000 kg of live weight of hog, based on an average 52 kg hog. Similar tables can be calculated for other types of livestock manure.

A. Values of the Tangible Benefits

(1) Energy

The unit value of biogas is based on 65% methane content with a 20% discount in price for adulteration by CO₂. Methane price is set at that of December, 2002 contract price of natural gas of $5 U.S. per MMBTU (exchange rate of $1.0 CDN at $0.64 U.S. per Revenue Canada 2002 average).

The price of electricity in Ontario, Canada is currently capped at 4.3¢/kWh which may be artificially low.

Heat value is based on production from natural gas with a boiler of about 80% efficiency.

<table>
<thead>
<tr>
<th></th>
<th>Unit Value</th>
<th>Availability (2000 Hog per Year)</th>
<th>Total Value (2000 Hog per Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
<td>12¢ per m³</td>
<td>93,200 m³</td>
<td>$7,600</td>
</tr>
<tr>
<td>Purified biogas</td>
<td>22¢ per m³</td>
<td>60,600 m³</td>
<td>$14,700</td>
</tr>
<tr>
<td>Electricity</td>
<td>4.3¢ per kWh</td>
<td>275,200 kWh</td>
<td>$7,500</td>
</tr>
</tbody>
</table>
23

(2) Nutrients

Only the macro nutrients; nitrogen, phosphorus and potassium, are considered. The unit values assigned are the values suggested by OMAF (OMAF, 1999) to represent the purchase price of an equivalent amount of available nutrient as mineral fertilizer.

<table>
<thead>
<tr>
<th>Nutrients (N, P₂O₅, K₂O)</th>
<th>Unit Value</th>
<th>Availability (2000 Hog per Year)</th>
<th>Total Value (2000 Hog per Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value in Manure*</td>
<td>$10.5/tonne</td>
<td>3,190 tonnes</td>
<td>$33,500*</td>
</tr>
<tr>
<td>Value in Urine*</td>
<td>$17.2/1000 Imp. Gallon</td>
<td>329,000 Imp. Gallon</td>
<td>$5,660*</td>
</tr>
<tr>
<td>Nutrients (N, P₂O₅, K₂O)</td>
<td>Ave. $8.9/tonne</td>
<td>4,395 tonnes</td>
<td>$39,160</td>
</tr>
</tbody>
</table>

| Nutrients after          | Unit Value | Availability (2000 Hog per Year) | Total Value (2000 Hog per Year) |
| Solid/Liquid Separat.    | Ave. $11.2/tonne | 300 tonnes                      | $3,360                           |
|                         | Ave. $8.7/tonne | 4,095 tonnes                   | $35,800                          |

| Compost                 | $15/tonne   | 270 tonnes                      | $4,050                           |
| Fertilizer crystals     | N/A         | N/A                             | N/A                              |

*Usually mixed, and thus values can be totaled.

The process of producing high value fertilizer by crystallization is being studied by Li et.al. (Li 2002), but the price information is not yet available.

(3) Gaseous Emissions

The unit value of CO₂ is the current market price provided by industrial gas supplier. An alternative method for providing CO₂ to greenhouse is by natural gas burner. The cost of the alternative method has yet to be assessed. The value of emission reduction credit is based on $5 U.S. per tonne of CO₂ (exchange rate based on $1 CDN = $0.64 U.S. per Revenue Canada 2002 average).

<table>
<thead>
<tr>
<th>Unit Value</th>
<th>Availability (2000 Hog per Year)</th>
<th>Total Value (2000 Hog per Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide for Greenhouse</td>
<td>$65 per Size 1-A Bottle of 27.22 kg</td>
<td>54,920 kg**</td>
</tr>
<tr>
<td>GHG Emission Reduction Credit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity Off-Set</td>
<td>$7.8 /tonne CO₂</td>
<td>175 tonnes</td>
</tr>
<tr>
<td>Heat Off-Set</td>
<td>$7.8 /tonne CO₂</td>
<td>580 tonnes</td>
</tr>
<tr>
<td>Methane Mitigation</td>
<td>$7.8 /tonne CO₂</td>
<td>1,330 tonnes</td>
</tr>
</tbody>
</table>

** Sufficient for 20 acres of 20-ft high greenhouse with an air displacement of 0.3 per day.

B. Values of Intangible Benefits

As a by-product of applying the AD/Biogas Cogen technology, the pathogen count of the digestate can be significantly reduced. Thermophilic process with one hour pasteurization at elevated temperature of 70°C is claimed to achieve over 90% pathogen reduction.
The odour of the digestate is considerably less than that of the raw manure because the sulphurous compounds can be removed. The totally enclosed biodigester provides better protection against accidental spills and run-off, and offers better means to achieve water quality protection and rural hygiene. However, the quantification of these intangible benefits remains a challenge. Some evaluation methods are being developed by the author and will be the subject of a future paper.

It must be emphasized that these values only provide an understanding of the theoretical potential. In reality the operating costs, marketing costs and negotiated market values can be quite different. In Table 1, only electricity price is confirmed because currently the price is capped by the Ontario government at 4.3 cents per kWh. All other by-products that have not yet located a committed purchaser are indicated with an “Intrinsic Value” until purchasers can be located and negotiated market value and operating costs can be assigned.

CONCLUSIONS

Many by-products can be derived from an AD/Biogas Cogeneration process for manure management. It is seen that some by-products have very high intrinsic values. These provide opportunities to lower the cost of manure management, or even to generate profit. However, there will be operating costs and investments required for each revenue stream, an understanding of the potential of each by-product will assist the selection of an optimum combination of byproducts that will yield the best overall return.

REFERENCES

American Society of Agricultural Engineers: ASAE D384.1 Dec. 1998
Bulk, Otto. Rosa Flora Ltd. 756 Diltz Road, Dunnville, Ontario N1A 2W2, Canada


This study is an attempt to introduce the State of Washington environmental permit system. It is focused on the major elements and their functions of the environmental permit system in the State of Washington.

The Washington environmental permit system is centered in the State Environmental Policy Act (SEPA). SEPA is designed to evaluate the environmental impacts of a proposed project and identify methods to reduce the impacts. SEPA is being implemented in conjunction with other environmental and land use/development laws of the federal, state and local governments.

Therefore, the state environmental permit system is a network for implementation of federal, state, and local environmental laws and land use/development regulations. Most of the environmental permits are related to local comprehensive planning, land use, development and building activities. Consequently, local governments (counties and cities) play a major role in the environmental permit system in the State of Washington.

The first part of this paper highlights the major federal environmental legislations and regulations which require implementation by the state and local governments, such as the National Environmental Policy Act, the Clean Air Act and Clean Water Act. The second part is an introduction of the State of Washington environmental laws and permits. The last part reveals the local environmental and land use/development regulations in relation to the federal and state environmental laws and permit system.

PART I. FEDERAL LEGISLATION AND REQUIREMENTS

The State of Washington permit system is a tool for the implementation of the federal legislations and requirements. The major federal environmental laws and regulations involved in the state environmental permit system are the National Environmental Policy Act (NEPA), Clean Air Act, and Clean Water Act. The state is also required to meet a number of federal environmental requirements, such as: the requirements of the United States Army Corps of Engineers (CORPS) and the Federal Energy Regulatory Commission (FERC).

PART II. STATE OF WASHINGTON ENVIRONMENTAL LEGISLATION

In the last decades, the State of Washington has enacted a number of environmental laws. These laws, such as the State Environmental Policy Act (SEPA), Shoreline Management Act, Washington Clean Air Act, and Growth Management Act are the foundations for the environmental permit system in the state.

A. WASHINGTON STATE ENVIRONMENTAL POLICY ACT (SEPA)

The State Environmental Policy Act (SEPA) was first adopted in 1971. It is intended to ensure that environmental values are considered by state and local government officials when making decisions.

The SEPA process starts when someone submits a permit application to an agency (city or county) or when an agency proposes to take some official action. Prior to taking any action (issuing permits, approvals, etc.) on a nonexempt project, agencies must follow specific procedures to assure that appropriate consideration has been given to the environment.
The severity of potential environmental impacts associated with a proposed project will determine whether an environmental impact statement (EIS) is required. If an environmental impact statement is not issued, a determination of nonsignificance must be issued.

After completion of the EIS or determination of nonsignificance, agencies may act upon the permit application or other approval required for the project. Administrative or legal appeals and challenges concerning SEPA compliance must be linked to specific governmental action (e.g., permit) and be brought in a timely manner.

B. STATE OF WASHINGTON SHORELINE MANAGEMENT ACT OF 1971

The basic intent of this Act is to protect the public interest in the state's shorelines and, at the same time, to recognize and protect private property rights consistent with the public interest. The Act's policies are directed toward the enhancement of public use and enjoyment of shorelines rather than restriction of their use. The law provides for both the state and local governments to engage in a coordinated effort for the planning and administration of the Act.

C. STATE OF WASHINGTON GROWTH MANAGEMENT ACT OF 1990

In 1990, the State of Washington enacted the Growth Management Act (GMA) to address growth and environmental problems. The Act requires all cities and counties in the state to develop a comprehensive plan for land use, transportation, and environmental protection.

D. STATE OF WASHINGTON CLEAN AIR ACT

The 1991 State of Washington Clean Air Act provides fundamental authority to implement federal law and carry out state clean air initiatives. The Washington State Clean Air Act covers the following major provisions:

1. Strengthened Vehicle Emissions Testing
2. Fuel Efficiency and Alternative Fuels
3. Conformity
4. Transportation Demand Management (TDM)
5. Operating Permits

E. STATE ENVIRONMENTAL PERMITS FOR WASHINGTON

The Washington state government has regulatory jurisdiction related to the following environmental permits:

1. Water Resources
   a. Water Right Permit
   b. Public Water Supply Approval
   c. Water Well Construction and Operator's License
   d. Reservoir Permit

2. Water Quality
   a. State Waste Discharge Permit
   b. National Pollutant Discharge Elimination System (NPDES) Permit
   c. Wastewater Plant Operator's Certificate
   d. Temporary Modification of Water Quality Criteria (Water Quality Modification)
   e. On-Site Sewage Disposal Permit (Septic System)
   f. Accreditation of Environmental Laboratories

3. Aquatic Resources
   a. Coastal Zone Management Certification
   b. Hydraulic Project Approval (HPA)
   c. Fish Screen Requirements
4. Wetlands
   a. Federal Regulations
      The principal federal laws that regulate activities in wetlands are Sections 404 and 401 of the Clean Water Act and Section 10 of the River and Harbor Act. Other federal laws include the National Environmental Policy Act, the Federal Water Pollution Control Act, the Coastal Zone Management Act, and provision of the 1985 Food Security Act known as "Swampbuster".
   b. State Regulations
      The primary state regulations that affect development activities in and near wetlands include the Shoreline Management Act, the Hydraulic Project Approval, the State Water Pollution Control Act, the State Environmental Act, and the Floodplain Management program.
   c. Local Regulations
      Many local jurisdictions also have laws that may affect projects in or adjacent to wetlands. The most common local means of regulating development in wetlands areas is the local Shoreline Master Program.

5. Land Resources
   The State Department of Natural Resources, under the direction of the Commissioner of Public Lands, administers many permits regulating the use of over 12.5 million acres of state and private land. Forest practices enforcement, surface mine regulation, and administration of other land resource permits, are among the Department's responsibilities.
   a. Forest Practices Approval
   b. Surface Mine Permit

6. Air Quality
   Air pollution control in Washington is based upon a set of local, state and federal laws and regulations involving three levels of government.
   a. New Source Construction Approval
   b. Air Contaminant Source Registration
   c. Prevention of Significant Deterioration (PSD)
   d. Air Quality Permit (Open Burning)
   e. Solid Fuel Burning Device Standards (Wood Stoves, Inserts)

7. Hazardous and Dangerous Solid Waste
   The State Department of Ecology has several programs devoted to managing waste to protect public health and the environment, and to promote waste reduction and recycling. The following provisions cover the state's regulations dealing with hazardous, dangerous, and solid waste.
   a. Hazardous Waste Release Notification (Spills or Release)
   b. Dangerous Waste Designation
   c. Dangerous Waste Permit(s) (treatment, storage, disposal)
   d. Underground Storage Tank Notification Requirement
   e. Certification of Operators of Solid Waste Incinerator and Landfill Facilities

8. Pesticides
   Anyone interested in starting a business that involves selling or using pesticides may be required to obtain a license.
   a. Commercial Pesticide Applicator's License
   b. Private Commercial Applicator's License
   c. Public Pesticide Operator's License

9. Livestock
   a. Public Livestock Market License
   b. Animal Feeding Operations - NPDES and State Wide Discharge Permits

PART III. LOCAL ENVIRONMENTAL REVIEW AND PERMITS
In Washington, as well as other states in the United States, local governments play a major role in land use and development control. This includes comprehensive planning, zoning, subdivision, building, and other types of control. All the local zoning, subdivision and building permits are subject to SEPA compliance. The local governments are responsible for SEPA and NEPA reviews and holding public hearings.

A. SEPA REVIEW

The State Environmental Policy Act (SEPA) is intended to ensure that environmental values are considered by state and local government officials when making decisions about projects. The SEPA process starts when a permit application is submitted to an agency (city, county, school or utility district). If the agency finds there will be a significant impact(s) of a project, an environmental impact statement shall be prepared. The agency shall hold public hearings on the proposal(s).

B. NEPA REVIEW

The National Environmental Policy Act (NEPA). NEPA requirements are very similar to those of SEPA. An environmental assessment is used by the lead agency to determine the extent of environmental impacts associated with the project (with federal funds). Though the lead agency is responsible for the content of the assessment, the permit applicant may be asked to contribute extensive information. If the project is determined to be environmentally significant, an environmental impact statement (EIS) is required.

C. LAND USE AND DEVELOPMENT CONTROL

County and city governments are responsible for regulating land use, development, and building activities. The local requirements include:

1. Shoreline Management Act Permits
2. Floodplain and Wetlands Development Permits
3. Building Permits
4. Subdivision Approvals
5. Zoning and Conditional Use Permit
6. On-site Sewage Disposal Permit
7. Tree Cutting Permit
8. Noise Control

CONCLUSION

The Washington State environmental permit system covers a wide range of elements in the environment, such as water resources, water quality, aquatic resources, wetlands, land resources, air quality, hazardous waste, pesticides, and livestock. The Washington environmental permit system reflects a well coordinated effort with federal and local agencies. Although most of the environmental permits are issued at the state level, the process begins with local cities and counties. The local land use and development control system, including such elements as comprehensive planning, zoning, subdivision and building regulations, environmental review process, shoreline management regulations, and noise ordinances, has reinforced the state environmental permit system.

The environmental permit system of the State of Washington reveals three important characteristics: 1. the environmental laws must be implemented in conjunction with local land use and development regulations, 2. the environmental review process provides a tool for prevention of significant environmental impacts which is more important than mitigation, 3. local governments and the people are the major players in environmental protection and the environmental permit system.

REFERENCE

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7. Washington State Land Use Regulatory Reform Bill (ESHB)
I. Introduction

County, state, and federal agencies in the United States are currently requiring solid waste recovery and recycling. The Department of Environmental Protection (DEP or equivalent) from several states have set forth guidelines for waste reduction and separation with the objective of achieving reduction in solid waste streams via the removal of recyclable materials under the provision known as the Solid Waste Management Act. As available local landfill space becomes increasingly difficult to find, the associated increase in tipping fees at these landfills for the disposal of solid waste, including construction and demolition debris (referred to herein as C&D material), has imposed a significant economic burden on the carting industry and the sectors they serve. The limited number of local sites approved by the State DEP for the landfilling and disposal of solid wastes and C&D material, and the restrictions placed on those sites often dictate careful separation of the waste stream prior to disposal.

As more states and provinces adopt landfill bans and restrictive actions in North America, and as the cost of landfill disposal continues to increase, beneficial uses of C&D material will become a profitable reality. Other key non-hazardous materials for beneficial uses include sewage sludge, water treatment sludge, dredge spoils, drill cuttings, industrial by-products, petroleum-contaminated soils, animal wastes, yard wastes and other recyclable matters.

Material recovery and transfer facilities have been constructed and operated in the Northeast United States to recycle and beneficially reuse components of C&D material. This is often due to the high cost of disposal, which is currently greater than $60/ton. The reclaimed waste streams include ferrous metal, non-ferrous metals, plastic, wood, rock, brick, stone, and C&D screenings. Gypsum wallboard can be segregated and processed into gypsum and paper for recycling. Gypsum can be recycled back to wallboard plants, cement kilns, and used in the agricultural market. Paper can be used as animal bedding material.

The beneficial uses of these waste materials have reduced the waste disposal problems and the associated environmental impacts.

II. Construction and Demolition Wastes

Construction and Demolition (C&D) Debris is waste material that is produced in the process of construction, renovation, or demolition of structures. The Composition of C&D material is highly variable and depends on the type of construction activity involved. The material typically includes concrete, asphalt, wood, metals, gypsum wallboard, and roofing, and is normally non-hazardous based on USEPA standards. An estimated 136 million tons of building-related C&D debris was generated in 1996 in the US. The estimated per capita generation rate in 1996 was 2.8 pounds per person per day. Forty-three percent of the waste (58 million tons per year) is generated from residential sources and 57 percent (78 million tons per year) is from nonresidential sources. Building demolitions account for 48 percent of the waste stream, or 65 million tons per year; renovations account for 44 percent, or 60 million tons per year; and 8 percent, or 11 million tons per year, is generated at construction sites.

The most common management practice for C&D material is landfilling. An estimated 35 to 45 percent was disposed in C&D landfills in 1996. An estimated 30 to 40 percent of C&D material is managed on-site, at Municipal Solid Waste (MSW) landfills, or at unpermitted landfills. There is a trend toward increasing recovery and recycling of C&D debris in the United States. An estimated 20-30 percent of building-related C&D debris was recovered for processing and recycling in 1996. The materials most frequently recovered and recycled are concrete, asphalt, metals, and wood. Metals have the highest recycling rates among the materials recovered from C&D sites. The Steel
Recycling Institute estimates that the recycling rate for C&D steel is about 85 percent (18.2 million tons out of 21.4 million tons generated). These numbers include not only scrap steel from buildings but also from roads and bridges.

The Florida Center for Solid and Hazardous Waste Management [2] in the State University System of Florida has conducted extensive research on C&D material to quantify the generation rate, characterize the material and determine the environmental impact of its disposal and reuse. Based on the study conducted by the Florida Center, Florida Department of Environmental Protection has established Guidelines for the management of recovered C&D screening material [3]. Under certain guidelines, C&D screenings are allowed to be used at a permitted landfill as subsurface construction material or as initial and intermediate cover.

Before components of C&D material can be recycled, processing is required to separate these components into individual recyclable streams. USEPA estimates that there is about 3,500 operating facilities that process C&D material in the United States for recycling.

### III. C&D Material Recycling Facility

In the Northeast United States, a recycling facility for C&D material is normally located in an urban/industrial area with convenient access to major highways. Part of the facility encompasses a truck depot that includes light truck maintenance. An office facility, storage area, maintenance area, and elevated observation room to inspect incoming wastes are normally located in the main facility building.

Based on observations at several operating facilities in New York, New Jersey and Pennsylvania [4], the property typically contains a C&D material processing facility and transfer station consisting of a clean fill tipping and storage area, a C&D material tipping and sorting area, screening systems, and a truck loading area.

Waste is received and stored in an open area or covered facility, depending on the facility design. Front-end loaders are used to move the material around the facility for appropriate material management. The processing equipment is typically located in a covered facility and includes feeding conveyors, rotating trommel screens and a picking/sorting system. All equipment is normally located on ground level, but in some cases it is elevated to permit gravity feeding of the recycled components into storage bins or containers. Various types of material handling equipment are used to move and feed material including a grapple, front end loader, and trucks.

The facility receives C&D materials from major metropolitan areas for a material recovery and recycling operation. The materials are generated by new construction and demolition projects performed by home repair, renovation and remodeling contracting firms.

Liquid wastes, friable asbestos, regulated medical waste, putrescible waste and other hazardous wastes are not accepted at this type of facility. Employees have been trained in the identification of potentially hazardous materials that may be encountered on the tipping floor. Any material inadvertently shipped from a hazardous waste site or a Superfund site must be on a hazardous waste manifest, and these shipments will be rejected.

### IV. C&D Material Processing and Production

Incoming material is weighed and visually inspected from the indoor inspection room located in the main facility building. The material is then moved to the covered facility where it is dumped into a stockpile. The incoming material consists of non-hazardous, asbestos free construction and demolition (C&D) material with no free liquids. After appropriate inspection any visible large materials are manually removed from the pile via a grapple. The large materials are stored in a separate pile and later loaded for disposal off site at a landfill. The remaining material is then fed via grapple to the conveyor attached to the trommel screen.

As the material passes through the rotating trommel screen, the smaller particles (90% minus 2") drop through the screen to another conveyor where it is then stockpiled. After inspection and analytical testing, this material is loaded via front-end loader onto trucks for offsite disposition as a beneficial reuse product. The larger particles fall onto a discharge conveyor where various materials (wood, rocks, metals, etc.) are manually removed and placed into storage containers. The remaining material is discharged to containers and shipped off site for landfill disposal.
The facility is typically permitted to process up to 2,500 cubic yards/day of C&D material. Approximately 200-500 tons/day of C&D screenings are produced at each facility. The facility normally operates 24 hours/day, 6 days/week.

V. Beneficial Uses of C&D Material

C&D material processing produces recyclables and beneficial use materials. This reduces the material disposal at landfills. Recyclable materials include aluminum, ferrous metal, wood, brick and stone. These recyclable materials from several manual picking/sorting stations are recycled as follows:

- Scrap aluminum – sell to scrap market
- Scrap iron/steel – sell to scrap market
- Wood – shredded on site for potential use as mulch
- Concrete, stone and brick – crushed to the required sizes for use as aggregates

The smaller particles of the C&D material drop through the rotating trommel screens and are known as C&D screenings. The screenings can be recycled as alternative landfill cover, interim landfill cover and structural fill (ALC material). The material has been extensively utilized in New York, New Jersey, Massachusetts and Delaware. This ALC stream accounts for approximately 20-50% of the incoming wastes. The ALC material consists of processed construction and demolition wastes that include wood products, wallboard, ferrous and nonferrous metals, bricks, stone, roofing materials and paper products. The trommel screen produces a uniform product with sizing to meet the specifications for the ALC material. The consistency and uniformity of the ALC product is critical to its intended application. A quality assurance and quality control (QA/QC) program is required to ensure the consistency of the ALC material.

The economics of recycling depends on landfill tipping fees, transportation cost, reuse options, and the cost of collecting and processing. Several commercial C&D material recycling facilities have been in operation for more than 10 years in New York City, Northern New Jersey, and Philadelphia areas. The recycling facility receives the C&D material at the facility in truck loads. The tipping fees can be $70/ton or higher. After processing, the segregated materials such as aluminum, ferrous metal, concrete, stone and bricks are sold to recover the processing costs. The 10-15% oversized material will be disposed at a landfill. The remaining C&D screenings are recycled as landfill cover and structural fill materials at a cost of $20-50/ton including tipping fees and transportation.

Envir-O-Process Technologies, Inc. has worked with four (4) recycling and processing facilities in the last two years to characterize the C&D screenings, and to develop beneficial use alternatives. Detailed analytical testing was performed on the screenings over a year spanning multiple runs. In all cases, the material tested to be asbestos free and non-hazardous based on USEPA standards. A detailed quality control program was implemented and 1” and 2” screenings were produced and tested for interim daily cover at municipal landfills. The C&D screenings performed well as a daily cover material. The lightweight material was easy to spread with a bulldozer and drained well in wet weather.

Several commercial projects in New Jersey have used C&D screenings as structural fill to remediate major Brownfield sites. For example, Jersey Gardens Mall in Elizabeth, NJ, was a 165-acre former landfill that was redeveloped into a highly successful retail outlet center opening in October 1999 [3]. This project has received the National Phoenix Award for the best Brownfield development project in USEPA Region II for 2001. 300,000 cubic yards of C&D screenings and other construction materials were placed at this site. In Bayonne, NJ, a former landfill has used approximately one million cubic yards C&D screenings to recontour the site for the development of Bayonne Golf Course project. In East Rutherford, NJ, several landfills in Hackensack Meadowlands are being redeveloped for multiple commercial uses.

VI. Gypsum Recycling

California [6] and Vermont [7] have published extensive information on the recycling of gypsum wallboard (also known as drywall). The United States Geological Survey [8] web site also contains good mineral information including sources, production and application. According to these publications, The U.S. produces approximately 15 million tons of new drywall per year. Approximately 5% of the gypsum used in wallboard manufacturing emerges as wastes and 12% of new construction drywall during installation ends up as scrap. Therefore, 2.55 million tons per
year of gypsum used in the wallboard market is potentially available for recycling. In the United States, an average new home contains more than 8 tons of gypsum requiring more than 6,144 square feet of gypsum wallboard. At new home construction sites, approximately one ton of gypsum is wasted as scrap for each house built.

In Canada, there are concerns of producing hydrogen sulfide gas from landfilling gypsum wallboard. The Greater Vancouver Regional District (GVRD) has banned the placement of gypsum wastes in its landfills since 1985 [9]. It is known that hydrogen sulfide gas generation requires several conditions in combination, including a moist, anaerobic environment and low pH. There is no regulation to ban gypsum wallboard from landfills in the United States. Some of the landfills do not accept gypsum wallboard. But, most of them do receive wallboard wastes as C&D material.

Gypsum wallboard can be segregated and processed into gypsum and paper for recycling. The processing plant normally includes an impact crusher, magnetic separator (optional), trommel screen, feed and discharge conveyors and baghouse for dust collection. The crusher removes paper facing and reduces the gypsum core into fine particles. The system produces gypsum and paper in separate piles for recycling at a typical processing rate of 10-20 tons/hour.

Gypsum (approximately 90% of the feed) can be recycled for use in agricultural markets and new wallboard. Other potential markets include construction site reuse, cement production as a retardant, stucco additive, sludge drying, and water treatment. Paper (approximately 10% of the feed) can be used as animal bedding material. Key reuse options are as follows:

- **Animal farming** – Gypsum can absorb moisture much greater than lime, regulate phosphorous by converting it to a complex phosphate, and lock up ammonia as ammonia sulfate in manure, therefore reduce odor. This will preserve the nitrogen value in the manure for use as fertilizer. The value of the recycled gypsum is greater than $30/ton.
- **Animal bedding** – The paper can be recycled for uses in animal bedding, pulp mill, and composting. The value of the recycled paper is greater than $30/ton.
- **New drywall** – Gypsum can be recycled back into wallboard production. The paper content (up to 3%) limits the amount of recycled gypsum to 15-20% of the feed. The value of the product can be lower than the price of virgin gypsum depending on the location of the wallboard plant. Virgin gypsum can be delivered in barge loads at less than $10/ton.
- **Portland cement production** – Gypsum can be added as a retardant to cement clinker to control the setting time in warm weather construction. Additional screening to reduce the paper content in the recycled gypsum to less than 1% may be required. Most of the cement plants are away from major waterways. The value of the recycled gypsum is typically greater than $5-$10/ton.
- **Soil amendment** – New construction wallboard waste is recycled as a soil amendment in general agriculture and composting. Gypsum can improve water penetration, soften soil with high clay content, neutralize soil acidity and provide calcium and sulfur. The value of the products varies widely depending on the end uses.
- **Construction site reuse** – Drywall scrap can be donated and resold for other construction purposes. Ground gypsum wallboard can be applied to the surrounding land area. Normally, there is minimal value for these applications.

The economics of recycling depends on landfill tipping fees, transportation cost, wallboard source, reuse options, and the cost of collecting and processing. Commercial scale wallboard recycling is concentrated in major metropolitan areas where tipping fees are higher than $60/ton or where gypsum wallboard is banned from landfills. Most of the recycling is limited to material from new construction. Wallboard from demolition and renovation projects is difficult to separate. They may only be recycled for non-agricultural uses due to impurities in the waste stream such as nails and paint cover.

The landfill ban of gypsum waste in Vancouver had allowed New West Gypsum Recycling Inc. (NWGR) to commercialize a gypsum wallboard recycling operation in Vancouver since 1985. The tipping fees are reported to be in the $70-80/ton range. The recycled gypsum is sold back to the wallboard manufacturer at a price below that of virgin gypsum. NWGR also operates two other plants in Seattle, WA and Toronto, Ontario.

In New York and Philadelphia areas, most of the landfills accept gypsum wallboard for disposal as C&D wastes. The tipping fees and transportation for the C&D wastes are higher than $60/ton. The collection and transportation of
Wallboard material for recycling can be inconvenient and expensive. The quantity of recyclable gypsum at each construction site is an issue. Each new house construction generates approximately one ton of scrap. This makes the sources of the material very fragmented and very costly to segregate and collect.

One company has successfully commercialized a gypsum wallboard recycling business in Pennsylvania with two operating sites since 2000 [10]. The company has focused on waste collection efforts and developing high value end use markets. Due to the lack of a strong recycling program for the gypsum wastes in this region, the market is currently supply limited. A tipping fee as low as $15-20/ton was necessary to compensate for high costs of waste collection and transportation to the recycling facility. The products are mainly used in animal farming, animal bedding, as soil amendment, and in Portland cement production.

A statewide recycling program similar to other household waste recycling programs (e.g., paper, plastics and metals) is needed to increase the availability of the gypsum wallboard material for recycling.

References

4. Site visits and communication with C&D recycling facility operation managers at Cooper (Brooklyn, NY), IESI (Brooklyn, NY), Astoria (Brooklyn, NY), Cardella (North Bergen, NJ) and Champion (Downingtown, PA).
CELLULAR PHONE E-WASTE

Pao-Chiang Yuan, Ph.D., CHMM
Doris McPherson, Doctoral Student

Hazardous Materials Management Program
Jackson State University
Jackson, Mississippi 39217
Email: pcyuan@yahoo.com

Abstract

I flew from Jackson, Mississippi to Orlando, Florida for the E-Scrap Conference. When I walked into the concourse waiting area, I saw a lot of people talking to themselves. No, actually they were using their cellular phones communicating with their businesses or families. When I landed in Atlanta, one of the largest airports in the world, there were different scenes when compared to few years ago. No long lines waiting to use the public phones, and stores that sell accessories for cellular phones. Several times, as I walked through the campus, I thought someone was talking to me. Actually they were talking on the phone. We are trying to solve the problem caused by millions of obsolete computers. We must not forget this small device that’s growing as faster as end-of-life computers. Up to now, 65,000 tons of hazardous metals and toxic material were dumped into our municipal landfills or burned by incinerators in three years by cellular phone only. Eventually, they may pollute the ground water and generate cancer-causing materials like dioxin in the air. The cellular phone weighs less than a quarter of a pound. Nowadays, the phone is smaller and weighs even less. According to the Association of Wireless Professionals (AOWP), there are more than 145 million cellular phones currently being used in United Sates. Consumers replace most of phones within 18 month. A standard handheld device is equipped with 1) Printed Circuit Board (PCB), 2) Liquid Crystal Display (LCD), 3) keypad, 4) Antenna, 5) microphone, 6) battery and other accessories such as carrying case, and extra adapters. Except for the carrying case made of leather, none of the materials are biodegradable. PCB boards are the same as a PWB (Printed Wiring Board) to distinguish it from the Polychlorinated Biphenyl (PCB), one of the famous toxin; most people prefer to use PWB. This paper will discuss the trend of legislation, hazardous materials involved in them and a recommendation for proper management.

Introduction

In the past three decades, new technologies developed so fast one can hardly understand one when a new one is already on the market. E-kids probably never played marbles, they sit in front of television, a computer monitor, with a hand-held game player in their hand, carrying a portable CD player with ear phones or talking when walking with their fancy cellular phones. They look like something from out of space if you’re not equipped with them also. They never thought about this equipment end-of-useful life or upgrades. Where are they going to be? None of this equipment made by biodegradable materials. Only solution is stored somewhere or put in the trash. Twenty years ago, we have problem with White Goods Waste”, because the refrigerator, washing machine and dryer are white and steel is used, although they cause landfill problem but not like the E-Waste. “E” may stand for electrical or electronic, we may classify them into a) electric house wares such as bread makers, boilers, clocks and so on b) Consumer Electronic will cover CD player, computers, printers, copiers, cellular phones and others

The EPA (Environmental Protection Agency) estimates that electronics make up only 1% of the country’s 210 million tons municipal waste stream each year, it will continue to grow and grow fast. Research conducted in Europe shows that electronic waste is growing at three times rate of other municipal waste. The EPA reports on products thrown away including computers, cell telephones, and fax machines, that make up 42% of total E-waste. The total E-waste created in 1999 in the USA is 1.8 million tons. Of the 756,000 tons of information waste dumped into the country’s 2,200 landfills. Cellular phones first became available in 1984. According to Australia news in year 2000 said approximate 10 millions mobile phones outdated, each million could fill one standard Olympic swimming pools. Cellular phones are typically used for only one and half years, for Service Provider(s) price competition or other reasons. Most cell phones will initially be stored in closets and drawers. Annually, 130 million cell phones will be discarded in the US by 2005. Up to now, there are five ways to treat this waste a) Land-filling, b) Incineration, c) Recycle and Reuse, 4)
Export to third world country 5) Donate to Charity for Emergency use. Another problem is flame retardants used on cellular phones, which may cause health problems.

**Major Cell Phone Manufactures in USA**

The majority of cell phone manufacturers in the world are NOKIA, Motorola, Samsung, Siemens, and Ericsson. They occupy 72% of the market. The major parts of a mobile cell phone includes a) The printed wire board (PWB), b) A Liquid Crystal Display (LCD) panel, c) The key pad, antenna, speakers and microphone, d) the power source/batteries, e) An adapter to charge the batteries, and f) others, such as carrying case. The cell phone is less complicated when compared to computers. Figure 1. show the US subscribers increased since 1985, the prediction will be 200 million according INFORM, Inc. study. They also predict 1 billion users in 2005.

![Cellphone Subscribers by Year](image)

**Figure 1: Cellular Phones subscribers by year. (Data Sources: INFORM, Inc)**

**Regulation Concerning E-Waste**

In the United States only State of California and Massachusetts passed the law prohibited disposal the CRT monitors into landfills. Almost all state focus on CRT. In August 2004,a) all European Union member countries will adopt the following two laws into their own national status. Under the electrical and electronic waste law (WEEE: Waste Electrical and Electronic Equipment), to introduce free take-back of waste goods by final owners and to ensure that equipment producers are responsible for financing the collection, treatment, recovery and disposal of all waste. Consumer will be able to return their equipment free of charge. b) Under the hazardous substances in manufactured equipment (Rosh) law, manufactures will have to cease using, lead, mercury, cadmium, and hexavalent chromium, or the brominated flame retardants PBDE and PBB, in products marketed from July 1, 2006.

**Health Effects by Cellular Phone**

Cellular phones similar to computers contain a number of hazardous substances and others may cause health problem. Table 1 shows the typical contents of NOKIA cell phone.
Table 1. Major Organic and Inorganic Compositions in NOKIA Cell Phone

<table>
<thead>
<tr>
<th>Name</th>
<th>%</th>
<th>Name</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS/PC (Acrylonitrile Butadiene Styrene/Polycarbonate)</td>
<td>20</td>
<td>SiO₂</td>
<td>5</td>
</tr>
<tr>
<td>PMMA (Polymethyl methacrylate)</td>
<td>6</td>
<td>Fe</td>
<td>8</td>
</tr>
<tr>
<td>POM (Polyoxymethylene)</td>
<td>2</td>
<td>Al</td>
<td>9</td>
</tr>
<tr>
<td>TBBA (Tetrabromobisphenol A)</td>
<td>2</td>
<td>Cu</td>
<td>19</td>
</tr>
<tr>
<td>PS (Polystyrene)</td>
<td>2</td>
<td>Ni</td>
<td>1</td>
</tr>
<tr>
<td>Epoxy</td>
<td>5</td>
<td>Sn</td>
<td>1</td>
</tr>
<tr>
<td>LCP (Liquid Crystal Polymer)</td>
<td>1</td>
<td>Glass</td>
<td>11</td>
</tr>
<tr>
<td>PC (Polycarbonate)</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Toxins in Cellular Phone

a. Antimony (Sb): CAS# 7440-36-0, the metal is suspected of causing cancer on both humans and animals. Exposure to antimony occurs in the workplace. Breathing high levels of antimony for a long time can irritate the eyes and lungs, and can cause problems with the lungs, heart, and stomach.

b. Lead (Pb): CAS# 7439-92-1, Most solder in PWB board. The USEPA determined possibly lead leached from devices in landfill. Lead is toxic to the kidneys, blood system, and nervous and reproductive systems & inhibits mental development of young children and fetuses. Consumer electronics constitute 40% of lead found in landfills. Lead and its compound suspected causing cancer on humans but sufficient causing cancer on animals.

c. Beryllium (Be): CAS# 7440-41-7, Beryllium is commonly found on PWB board. The metal has recently been classified as a human carcinogen. Beryllium and its compound suspected of causing cancer on humans but sufficient proof of causing cancer on animals.

d. Mercury (Hg): CAS# 7439-97-6, Sensors, Switches, PWB all contains mercury. High level of exposures contribute to brain and kidney damage, harm the developing fetus and can be passed down through breast milk. Mercury is found in the fat of animals. It is estimated 22% of yearly world consumption is used in electrical and electronic equipment.

e. Nickel (Ni): CAS# 7440-02-0, Nickel is a hard, silver-white metal used to make stainless steel and metal alloys. Skin effects are the most common effects in the people who are sensitive to nickel. Workers who breathed very large amounts of nickel compounds have developed lung and sinus cancers.

f. Cadmium (Cd): CAS# 7440-43-9, Surface Mount Device chip resistors, and infrared detectors containing cadmium. Cadmium is also used as a plastic stabilizer high concentration in the body and can cause kidney damage and harm to fragile bones. Cadmium shows a danger of cumulative effects in the environment due to its acute and chronic toxicity. Cadmium and its compound are sufficient proof of causing cancer on humans and animals.

g. Zinc (Zn): CAS # 7440-66-6, Zinc has many commercial uses as coatings to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass and bronze. The zinc chloride is suspected cancer causing on both humans and animals.
h. Brominated Flame Retardants (BFR): Polybrominated Diphenylethers (PBDE) is frequently used flame-retardants and likely endocrine disrupters. Research has revealed that levels of PBDE, like many halogenated organics, reduce levels of the hormone thyroxin in exposed animals can potentially harm the developing fetus. Thyroxins are an essential hormone needed to regulate the normal development of all animal species, include humans.

i. Plastic (PVC): Dioxin and furan can be formed when PVC (polyvinyl chloride) is burned. Combination of plastics is used in PWB board, cove and keypad. Vinyl chloride is sufficient proof causing cancer for both animals and humans.

Environmental Program in Major Cellular Phones Manufactures’ Company

The majority of cell phone manufacturers in the world are NOKIA, Motorola, Samsung, Siemens, and Ericsson. They occupy 72% of the market. The major parts of a mobile cell phone includes a) The printed wire board (PWB), b) A Liquid Crystal Display (LCD) panel, c) The key pad, antenna, speakers and microphone, d) the power source/batteries, e) An adapter to charge the batteries, and f) others, such as carrying case. The cell phone is less complicated when compared to computers. will be 200 million in 2005, according to INFORM, Inc. study. They also predict 1 billion worldwide users in 2005.

NOKIA: The company focus areas on their End-of-Life (EOL) practice development, work are a) maximizing the recyclability of their product through Design for the Environment, b) Monitoring, comparing and developing take-back and recycling systems in cooperation with recyclers and other stakeholders, c) Actively reducing the use of potentially harmful substances during the design phase, and d) Proper treatment of harmful substances. http://www.nokia.com

Ericsson: Banned and restricted substances to meet laws and legislation requirement or expected new laws and legislation due to the strong trends in the countries. Substances banned includes, the use of Cadmium and its compounds, and mercury in their pigments. They also restricted the use of Arsenic, Beryllium, and Cadmium in batteries and lead and its compound. http://www.ericsson.com

Motorola: Is a funding member of Waste Wise, a voluntary USEPA Program through which organizations eliminate costly municipal solid waste. The company seeks to design their products with upgrade capability wherever possible. This extends the product life and conserves natural resources. Take back programs recover consumer’s products at the end of their useful life. The company has launched programs to take-back and recycle used batteries in the United Kingdom, Australia, Brazil, Malaysia, Japan and China. The company participated in launching Take Back, a national campaign to take-back and recycle cellular phones and accessories at the end of their useful life. In 1995, they had the first national take-back program for cellular base station products. Motorola is a participating member of the Consumer Education Initiative Program developed by the Electronic Industry Alliance. The purpose of this program is to inform consumer about recycling and reuse opportunities for used electronics. http://www.motorola.com/ehs/environment/products/

Siemens: To ease the reuse and the procurement of used parts, the company has proposed a standard for grading their quality. The purpose of this standard is to resolve legal issues associated with the reuse of components and to offer consumers the same degree of dependability and the same guarantees as with entirely new goods. In Siemens, they pursue a number of initiatives for taking back, remanufacturing and remarketing of used products and systems, including medical equipment, computers, and manufacturing machinery. http://www.siemens.com

Samsung: In June of 1992, the company announced its "Environmental Policy,” which aimed at building an Environmental Management System to prevent pollution-causing accidents and continuously improving the environment. This was followed by the announcement of “Green Management” in May 1996. The Green Management philosophy indicated their commitment to take part in the global effort to enrich human lives and preserve the environment by recognizing and actively promoting environment. http://www.samsung.com/aboutsamsung/socialcommitment
Of the above, five cell phone manufacturers are ISO14001 certified companies. They all have Environmental Management Programs but are not very clear on how they will implement the cell phone recycling program. In the United States, AT&T, Cingular Wireless, Nextel, Sprint PCS, Voicestream and Verizon are major cell providers. Except for AT&T, the others companies do not have any information on their web sites that describe their recycling program. In late 1998, AT&T ‘s Environmental Health and Safety Organization began to put the pieces of the recycling puzzle together and centralized information with three goals in mind; 1) establish metrics, 2) review take-back programs, and 3) establish routes of communication with those responsibility for recycling in far-flung parts of the company. In the year of 2002, AT&T had net revenues from recycling of $7.9 million dollars. AT&T was able to avoid $ 3.9 million in potential costs. AT&T donates desktop equipment to various organizations, reuses some equipment, and recycles others. http://www.att.com/ehs/annual_reports/ehs_reports.

In actuality, none of the provider promotes used cell phone take-back programs. Some companies provide users new cell phone every year. You could imagine how many used cell phones in the USA.

**Recommendation and Further Study**

We all understand obsolete cellular phones should not be disposed of in landfills since they contain many toxic materials that harmful to our environment. How do we face this growing problem?

a. In United States, we have too many providers. We need unified the products, easy to recycle, reuse and demanufacturing.

b. Persuade legislature established the law, require the manufactures use the non-hazardous materials in their product. Ex. Use none-lead solder. Establish the laws require the manufactures established The take-back program.

c. Educate people proper disposal of cellular, volunteer set up drop-off center, collected phones donated to emergency services, charities or shipped to third countries to reuse them again. broken phones send to recycler

There is not enough information about flame retardants from incineration process. There is no data after the cellular phone disposal at landfill, we are not sure they will passed the EPA required TCLP (Toxic Characteristic Leaching Procedure) test, classified as Hazardous Waste or general solid waste.

**Bibliography**


[8] Silicon Valley Toxic Coalition, www.SVTC.org, Excellent site for Electronic waste Information


BIOCONVERSION OF SEWAGE SLUDGE AND FOOD WASTE INTO FERTILIZER

Jing-Yuan Wang, Olena Stabnikova, Joo-Hwa Tay
School of Civil and Environmental Engineering
Nanyang Technological University
50 Nanyang Avenue, Singapore 639798
Email: jywang@ntu.edu.sg

Abstract

Biotechnology for intensive aerobic bioconversion of sewage sludge into fertilizer was developed in this study. The addition of food vegetable waste to sewage sludge, with the ratio of 1:1 by total solids, was made to improve C/N ratio in initial material for bioconversion, to increase the potassium content, to dilute the content of heavy meals, and to reduce the viscosity of sludge. The wastes were treated in a closed reactor under controlled aeration, stirring, pH, and temperature at 60°C, after addition of starter bacterial culture Bacillus thermoamylolovorans. The biodegradation of sewage sludge was studied by decrease of volatile solids (VS) and fluorescence of coenzyme F420. The reduction of volatile solids during bioconversion was 74% from initial quantity. The fertilizer was a powder with 5% moisture content and stability index of 1.3 mg CO2 g⁻¹ OM d⁻¹. Addition of 1.0 to 1.5% of this fertilizer to the subsoil increased the growth of tomato by 130%. The biotechnology can be applied in large scale for the recycling of sewage sludge and food wastes in Singapore.

Keywords: Aerobic bioconversion; fertilizer; food waste; sewage sludge; thermophilic bacteria

INTRODUCTION

Sewage sludge is a general term used to describe the solids produced during the wastewater treatment process at a municipal sewage plant, including sludge removed from an aerobic or anaerobic digester. Dewatered sewage sludge has been applied on land as fertilizer for years as the essential nutrients contained in sludge, such as nitrogen and phosphorus, can enhance the soil fertility and are useful for plant growth. However, lack of potassium and other nutrients in sludge makes it incompatible to the commercial grade fertilizer. Applying sludge directly on land was also of a concern because the heavy metals or chemical pollutants present in sludge may eventually contaminate the soil and aquifer. There is a trend to increase the use of sludge in agriculture. Utilization of sewage sludge in agriculture of USA was 20% in 1972 and 55% in 1997, while utilization of sewage sludge in agriculture of European countries in 1990 varied from 10% in Greece to 80% in Portugal and Luxembourg. In Japan, 2.3 million cubic meters of sewage sludge are produced annually from sewage treatment plants and 24% have been reused on agricultural lands as a fertilizer after composting. However, sewage sludge in other Asian countries is usually disposed of, not utilized. For example, more than 50,000 tonnes of sewage sludge are disposed of in landfill and incineration plants in Singapore annually. Due to the proper planning of the industrial and municipal zones, the municipal wastewater and sewage sludge in Singapore have low content of heavy metals and could be converted for agriculture use.

A popular way of sewage sludge utilization is composting. Composting of sewage sludge can enhance the stability of organic matter and provide the inactivation of pathogens and parasites. In conventional composting the material is aerobically or anaerobically treated for one month, then “cured” and “maturated” in piles or windrows for some months. Starter cultures are rarely used in the composting. The aeration is usually provided only by periodical turning of the composting material. Composting of sewage sludge occupied large space of land and is not suitable for application in large scale in a country with a shortage of land such as Singapore.
The aim of this research was to develop an intensive in-vessel bioconversion of sewage sludge under controlled aeration, stirring, pH, and temperature at 60°C. Such intensive bioconversion system requires small space and minimizes odour problems. Sewage sludge is not easily utilized by microorganisms (Fang et al., 2001). It is accepted that the best ratio of carbon to nitrogen (C/N) in composting material is the range from 20:1 to 30:1, whereas the C/N ratio in sewage sludge is approximately 7:1. In addition, the texture of the composting material must allow effective oxygen transfer into the bulk of the compost, but it is difficult due to the viscous texture of sewage sludge. An approach, which was used in this research, was to mix sewage sludge with solid food waste to allow simultaneous bioconversion in the compost. Due to the mixing, both the C/N ratio and potassium content in the raw material could be increased and the texture of the mixture is made less viscous than if sewage sludge alone was used. To enhance the intensive bioconversion, the starter culture was selected, identified and used; plastic rings were also added to the treated matter to improve its aeration; and pH of the treated material was buffered by CaCO₃.

MATERIALS AND METHODS

Dewatered anaerobic sludge was acquired from a local municipal water reclamation plant. Vegetable food waste was collected from a university canteen. Bioconversion of the mixture of sewage sludge and solid food waste was carried out in a polyacrylic cylinder reactor having a volume of 3.6 l. The contents were stirred at 10 rpm and air was supplied at 0.3 l/min. The temperature of the mixture was maintained at 60°C. Sewage sludge was first pre-treated at 100°C for 15 minutes to inactivate the pathogens and parasites. The thermal pre-treatment was also designed to enhance the sludge cell disruption and the hydrolysis of insoluble macromolecules so as to increase the efficiency of the subsequent process. Food waste was mixed with sewage sludge in the ratio of total solids 1:1. To improve aeration of the mixture, plastic rings with diameter of 10 mm and width of 8 mm were added as artificial bulking agent to give a weight of the rings/total solids (TS) of 25%. Water was added to the reactor daily to maintain the moisture content approximately at the 75 – 80% level except during the last two days of the process. This was to dry the final product, which was a grey powder with a moisture content of approximately 5%.

Biomass of the thermophilic bacterial strain *Bacillus thermoamylovorans* SW25, which was isolated from sludge compost, was used as the starter culture for the bioconversion (Wang et al., 2003). The bacterial strains were grown on tryptic soy broth (Difco, USA) in a shaker at 130 rpm for 24 hours at 60°C. Biomass was recovered by centrifugation at 4000 rpm for 20 min in Eppendorf centrifuge 5810R and added into the reactor. The bioconversion was carried out for 10 days. The enumeration of thermophilic bacteria on tryptic soy agar (Difco, USA) was carried out by a spread-plate method from a serial ten-fold dilution of the suspension produced by vortexing 1 g of mixture in 9 ml of phosphate-buffered saline (PBS). The Petri dishes were incubated at 60°C for one day.

The pH of the samples was measured in a suspension of 1 g of the matter in 10 ml of distilled water. The content of dry matter and organic matter was determined by standard methods (Standard Methods, 1998). The contents of carbon and nitrogen in the samples were determined using an Elemental Analyzer CHNS/O 2400 (Perkin Elmer, USA). The content of K and P was determined using an Inductively Coupled Plasma Atomic Emission Spectrometer (Perkin-Elmer ICP-AES). Measurement of co-enzyme F₄₂₀ was made using a Luminescence Spectrometer LS-50B (Perkin Elmer, UK). Stability of the fertilizer was measured by the carbon dioxide evolution rate (Test methods for the examination of composting and compost materials, 2001). Tomato was used to study the effects of the fertilizer on plant growth in the pots. Two kilograms of fresh subsoil with moisture of 14% were placed in every pot. No fertilizer was added to the control. The fertilizer was added in the experimental pots at an application rate of 0.2, 0.5, 1.0, 1.5, and 1.75% (weight of dry matter/ weight of soil). Each mixture was incubated one week prior to plant growth experiments for the release of nutrients. The growth of the tomato was observed and measured over a period of 5 weeks.

RESULTS AND DISCUSSION

The addition of vegetable waste to sewage sludge, with the ratio of 1:1 by total solids was made. The characteristics of the raw materials (mean ± standard deviation for three independent measurements) are shown in Table 1.

Table 1. Characteristics of the raw materials, initial matter and final product of bioconversion

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Raw materials</th>
<th>Bioconversion</th>
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The data show that the mixing of sewage sludge and food waste could improve the quality of the raw material and the end product. The nitrogen content is high in sewage sludge (5.5%) and C/N ratio is low (6.8). An addition of food waste with high content of carbon (44%), low content of nitrogen (2.2%), and C/N ratio of 18.3 could improve the initial C/N of the mixture. The content of phosphorus is low (0.1%) in food waste, but high in sludge (1.8%). The content of potassium is low in sludge (0.2%), but high in the food waste (4.5%). Therefore, addition of food waste to sewage sludge improves the chemical characteristics of the initial matter for the bioconversion and the end product of bioconversion.

A study of the content of the main heavy metals in sewage sludge from Singapore municipal water reclamation plant showed that their content was generally lower than the US and EU limits for the biosolids (Matthews, 2001). Food waste addition to sewage sludge provides higher quality of final product (Figure 1). The content of heavy metals in fertilizer produced from the mixture of sewage sludge and food waste in ratio 1:1 by TS was lower than EU limits for the biosolids: 52 % of the limit for Cu; 39% of the limit for Ni; 27 % of the limit for Zn; 13% of the limit for Cd; and 4% of the limit for Pb.

The inoculation of composting organic waste by starter cultures is not practically used at present. Usually, finished compost, or compost from the thermophilic phase, is used as an inoculum to speed up the process (Furhacker and Habel 1995; Beffa et al. 1996). The use of a pure starter culture gives control over desirable processes and lower risk of accumulation of harmful microorganisms in the final product of the bioconversion. Thermophilic bacterial strain SW25, identified from partial sequences of 16S rRNA gene as Bacillus thermoamylovorans, with high digestion activity of sewage sludge, was selected and used as starter culture to enhance bioconversion of sewage sludge and food waste (Wang et al., 2003). The biomass of the starter culture was added to the reactor for initial content of the cells 4.2x10^7 to 6.0x10^8 c.f.u./g dry matter. The starter culture was only applied in the beginning of the bioconversion process. Similar maxima in the range 10^8- 10^9 cells/g of the composted matter have been found during composting of anaerobic sewage sludge mixed with wood chips in a closed 300 m³ bioreactor using aeration and temperature control from 65°C to 82°C (Beffa et al., 1996). Samples of

![Figure 1. The content of heavy metals in sewage sludge and fertilizer, % of EU limits.](image-url)
sewage sludge and food waste during bioconversion process were examined by scanning electron microscope (SEM) LEICA (Cambridge Ltd., UK) at a magnification of 5000 (Figure 2).

Figure 2. SEM image of the mixture of sewage sludge and food waste after six days of bioconversion carried out with addition of Bacillus thermoamylolvorans.

Drop of pH from 7.3 – 7.5 to 5.3 – 6.1 was observed during the bioconversion process. To maintain a neutral pH, the buffering substance, such as chalk, was added to adjust pH. Chalk was added at the beginning of bioconversion in a quantity of 5% by total solids to ensure pH stability. The best fertilizer was obtained when the ratio of sewage sludge and food waste was 1:1 by total solids with sewage sludge thermally pre-treated. The content of volatile solids decreased by 24.8% of total solids after 10 days of bioconversion (Table 1, Figure 3). It is commonly agreed that the fluorescence of coenzyme F420 can be used for the conventional measurement of methanogenic biomass, which is the main component of sewage sludge from anaerobic digester. The fluorescence of F420 decreased during the bioconversion of sewage sludge and food wastes, which demonstrated the degradation of methanogens in anaerobic sludge. It was correlated also with the decrease of volatile solids content in the treated matter (Figure 3).

Figure 3. The changes in the content of volatile solids and autofluorescence F420 in relative units, during the bioconversions of sewage sludge and food wastes.

The final product of bioconversion was a grey powder with moisture content of 5%. The product was confirmed as a stable and non-toxic matter for the plants tested based on the results of the phytotoxicity test. The stability index was 1.3 mg CO2 g^1 of organic matter d^1 (considered as “very stable”). The quality of fertilizer, determined in germination and root elongation test, was almost the same and better than the quality of commercial organic fertilizer.
The plant tests indicated that the produced fertilizer can be considered as good as a commercial-grade fertilizer. Addition of 1.0% to 1.5% of fertilizer to the subsoil tested showed that the yield and growth of tomato increased by 130% (Figure 4).

The fertilizer produced by the bioconversion of sewage sludge and food waste was compared with that of raw sewage sludge, dried sewage sludge, and commercial organic fertilizer. The fertilizer, raw sludge and dried sludge were added to the subsoil in dosage of 1% (weight of dry matter/weight of soil). Commercial organic fertilizer was added to the subsoil in quantity 0.7% (weight of dry matter/weight of soil) to equalize the content of nitrogen in the fertilizer and in commercial organic fertilizer. Best growth of the tomato was obtained when fertilizer was applied. The lengths of stems and roots of tomato grown in soil with fertilizer were bigger than those of tomato grown in soil with raw sludge, dry sludge and commercial organic fertilizer by 146, 136, 141, and 121, 113, 196%, respectively.

**CONCLUSIONS**

A new biotechnology for intensive aerobic bioconversion of the mixture of sewage sludge and vegetable food waste into fertilizer was developed. The fertilizer obtained from the mixture of pre-treated sewage sludge and vegetable food waste with a ratio of 1:1 by TS was non-toxic, stable, and its application to the soil resulted in faster growth and development of agricultural plants.

The proposed bioconversion technology appears to be promising to resolve the sludge disposal problem in the populated metropolitans or those countries that are short of land resources, such as Singapore, while the produced fertilizer can be used in urban landscaping and agriculture.

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Abstract

Environmental management strategies have been and are gradually transforming. Traditionally, we have been controlling releases of pollutants in wastes and neglecting the environmentally harmful products and services that also cause pollution. This paper explains the difference between waste management strategy and pollution management strategy. It explains what is pollution management and why? The purpose is to suggest understanding the three principles of environmental pollution and upgrading beyond waste management to pollution management to meet the goals for sustainable development.

Introduction

The environmental profession is undergoing a dramatic change. Let there be a new beginning, but let us also learn from the lessons of the past. Traditionally, environmental management strategies focused primarily on the control of medium-specific pollutants in the wastes as evidenced by our environmental laws, regulations, and management strategies. Many environmental professionals in government and industry were trained to apply end-of-pipe controls appropriate for the specific media. They have not had the opportunity to see environmental problems from more than one perspective. Only in the last two decades, we have begun to realize that certain environmentally harmful products and services can cause even greater pollution in terms of risks to human health and the environment. Pollution sources stretch far beyond the boundaries of traditional waste management that controls the release of pollutants and wastes from power plants, motor vehicle, and various industrial facilities.

Civilization will continue to require economic development by increasing to use amounts of fossil fuels, transport vehicles, industrial chemicals, fertilizers, pesticides, and countless other products. Such development will continue to produce more waste products of all kinds. Environmental management strategies are in a state of transition. The decisions of our leaders for changing focus of environmental management strategies today will determine whether we leave more or less pollution to future generations.

Economic development has the financial and technological resources necessary for environmental enhancement. But such development must be sustainable. Sustainable development requires our recognizing the inter-relationship between economic and environmental goals. In this 21st century of advanced information and technology, it is no longer sufficient for environmental professionals to have only knowledge of waste management strategies that apply media-specific, end-of-pipe, and command-and-control technologies. We need pollution management strategies for sustainable development.

Changing Environmental Pollution Problems

We learned in universities that environmental pollution problem is caused by pollutants in the waste, releasing from various sources into the environment beyond the assimilation capacity of the environment. After graduation, we have been learning from researchers and fellow practitioners as well as various publications that pollution problems are created not only by pollutants and wastes, but also by environmentally harmful products and services. All sectors of our society generate waste, not only industrial and domestic sectors, but also commerce, agriculture, mining, energy, transportation, construction, government activities, and consumers' behavior.

Environmentally harmful products such as DDTs, PCBs, CFCs, asbestos, leaded gasoline; certain kinds of plastics, solvents, disposal diapers, medicines, cosmetics, fertilizers, pesticides, and herbicides; as well as discarded by-products and used products are known to cause environmental and health problems. Environmental harmful services refer to activities such as unintentional government policies, regulations, implementation plans; consulting
services in management, product and process design, equipment manufacturing and supply; and education and training that result in adverse impacts of the environmental quality.

The author has addressed environmental pollution from a philosophic or theoretical point of view and drawn the following three pollution principles.

**The first principle -- Pollution from human activities is unavoidable.**

Pollution is created by releasing pollutants and wastes into the environment as well as by producing certain environmental harmful products and services as a result of unintentional human activities related to social and economic development.

**The second principle -- Prevent pollution whenever possible.**

As a result of the first principle, pollution needs to be managed cost-effectively. Pollution can be prevented or minimized, but not completely eliminated. The remaining residual pollution from human activities must be properly treated and disposed of in order to protect human health and the environment.

**The third principle -- Minimal pollution is acceptable.**

Ecosystems can safely handle and assimilate minimal amounts of pollution. If pollution is within the environmental standards of quality, 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 wise and economically feasible fashion.

**Note:**

1. Human activities cover construction, transportation, production, combustion, distribution, storage, consumption, and services, etc.
2. The word “products” can be chemical, food, plastic, process, facility, building, equipment, instrument, airplane, automobile, bridge, park, city-plan, etc.
3. The word “services” can be governmental, non-governmental, professional, technical and non-technical services such as management, education, design, operation, repair, and maintenance activities, etc.

**Changing Environmental Management Strategy**

The objective of environmental management strategy is to establish a society-oriented approach towards sustainable development and to live in a stable, fruitful, peaceful, and healthy existence on this earth. To achieve this objective, environmental professionals are challenged to understand the sources and causes of all pollution, and then to plan management strategies, which create a society that does not waste our natural resources and a society that exists in harmony with nature. However, economic, social, and political forces can influence environmental policies, regulations and programs.

Environmental management strategies must follow the three principles of pollution as described previously. It can generally be divided into two approaches: *waste management* and *pollution management*. Waste management strategies deal mostly with physical and biological spheres; while pollution management strategies deal with all types of spheres in the environmental system. Both approaches are essential, but “prevention management first” particularly for new development programs. The major difference between the two approaches is that waste management emphasizes control of wastes and pollutants from the sources, while pollution management is not only to control wastes and pollutant, but also searching for better answers to produce and consume environmentally friendly products as well as to provide technical and non-technical “green” services. However, the changing management strategy emphasis from waste control to pollution prevention will require courageous leadership of governments and industries (Shen, 2002).
Waste management strategy focuses on waste control – waste removal, treatment and disposal technologies. It applies end-of-pipe, media-specific, command-and-control technologies and short-term abatement approaches. Waste control has improved environmental quality to a certain extent, but in general, it not only fails to eliminate a pollutant but also often transfers it from one medium to another. Waste treatment processes have produced a large amount of sludge and residue that need to be treated again prior to disposal so that they will not create secondary pollution.

Waste control is now technically possible to greatly reduce or entirely eliminate discharges of certain major pollutants. However, this approach is yielding decreasing benefits per unit of expenditure. At the same time, most companies fear that waste control is an expensive luxury that will divert resources (manpower and finance) from more productive uses. Therefore, for new development programs, industries can no longer afford to continue managing waste by various control technologies only using costly treatment and disposal methods.

In the developed countries, the major focus of environmental management as of today has been on hazardous waste and toxic chemicals. Consequently, there have been impressive reductions in these areas and for both the regulators and the regulated community. However, we need to look to the products services for a couple of reasons. Pollution management requires waste reduction and cleaner production, which will drive clean technologies that reduce wastes by recycling and reuse. Pollution management also requires environmentally friendly products and services. If our environmental management strategies focus expands to address both products and wastes, the leaders of environmental protection will not be environmental protection agencies, but also other connected government agencies. Pollution management faces with the continuing challenge of maintaining a high profile for the movement that can incorporate it into all sectors of the society. Therefore, environmental management strategy needs to upgrade beyond waste management to a broad approach of pollution management (Shen, 1999).

What is Pollution Management and Why?

Pollution management applies pollution prevention (P2) technologies, which is a continual refinement of the knowledge and skills that can provide people the tools and experience they need to understand, process, and use information about P2. It can help everyone in their roles as workers, consumers, investors, and concerned citizens. P2 seeks more lasting and cost-effective reduction of environmental pollution problems. P2 is one of the most interdisciplinary tools of waste management, affecting all current and proposed operations of various governmental agencies. P2 is also one of the most cost-effective tools to achieve sustainable development. It can be applied to all pollution-generating activities (USEPA, 1997).

P2 technologies are not just individual technologies, but total systems that include know-how, equipment, procedures, goods and services as well as organizational and managerial procedures. During the last 15 years, new knowledge and ideas of P2 have been advanced and implemented to differing degrees. For the past decade, new preventive technologies have been directed to cope with changing waste characteristics. Major new and innovative technologies mostly focus on industrial toxics by increasing knowledge of chemicals, improving information, and substituting toxic chemicals with less toxic ones. The systematic approach of preventive technologies, which embraces total management system, life cycle assessment, design for environment and cleaner production, are necessary as part of the approach, but also on the internal consistent as a whole.

In practice, pollution prevention uses less raw materials, energy, and natural resources; substitute nontoxic chemicals for the hazardous or toxic materials currently used in the process; and redesign a manufacturing line to take advantage of newer and cleaner technologies and process equipment. While cleaner production involves only industrial manufacturing plants, pollution prevention is a very broad term and applies beyond industrial sector to a variety of economic sectors and institutional settings. Many organizations and institutions can apply pollution prevention concept that not only reduces the generation of waste materials, but also avoids the environmental harmful products and services. During past few years, considerable progress and success have been made in attaining pollution prevention in various sectors of society in developed countries.

Pollution prevention can help national environmental goals and coincides with industry’s interests. Businesses will have strong economic incentives to reduce the toxicity and volume of the waste they generate.
Reducing waste provides upstream benefits because it reduces ecological damage and pollutants releasing during the production process and during waste recycling, treatment, and disposal operations. A company with effective and ongoing pollution prevention plan, would be the lowest-cost producer, and as a result, have a significant competitive edge. Costs per unit produced will drop as pollution prevention measures reduce liability risks and operating costs. Cost savings from prevention come not only from avoiding environmental costs like hazardous waste disposal fees, but also from avoiding costs that are often more challenging to count, like those resulting from injuries to workers and ensuing losses in productivity. In that sense, prevention is not only an environmental activity, but also a tool to promote worker health and safety. Furthermore, pollution prevention measures will enhance the company’s public image and public health. Among all the benefits, the economic benefits of pollution prevention have proven to be the most compelling argument for industry and business to undertake prevention concept and practices (Shen, 1999).

**Conclusions**

The understanding of changing environmental pollution problems and management strategies needs to stretch far beyond the boundaries of traditional waste management to a broader approach of pollution management. We must realize that environmentally harmful products and services can create serious pollution. Pollution management strategy can broadly be applied to all human activities of all sectors in our society.

Pollution prevention can help achieve national environmental goals and coincides with industry’s interests. It seeks more cost-effective reduction of pollution and more lasting and complete solution to environmental pollution problems from all sources of pollution in all environmental media. The main benefits of pollution prevention include waste reduction, designing and manufacturing environmentally friendly products, greater production efficiency and reduced health risks, environmental compliance costs, and resource conservation.

**References**


**About the Author**

Thomas T. Shen, Ph.D., is an international environmental advisor with more than 40 years of environmental research and teaching experiences. He worked as a senior research scientist with New York State and taught graduate courses at Columbia University. He served as a member of the USEPA’s Science Advisory Board and as a consultant to the United Nations, World Bank and USAEP. Dr. Shen has been active in several environmental professional associations and has lectured at over 30 universities and research institutes as well as conducted seminars in the United States, Asia and Europe. Dr. Shen has published numerous books, technical papers and reports. His recent book, the second edition *Industrial Pollution Prevention* was published in 1999.
SUSTAINABLE DEVELOPMENT STRATEGY AND TECHNOLOGY

Thomas T. Shen, Ph.D., P.E., DEE
Independent Environmental Advisor
Delmar, New York 12054
Email: cs.tt.shen@worldnet.att.net

(Presented to the Albany Torch Club of Albany, New York on April 7, 2003)
The author highlights the importance of environmental strategy and pollution prevention technologies, which are tools to achieve the sustainable development goals.

Sustainable development is a complex and challenging subject that involves challenging of environmental, economic, and social process. The different development objectives need to be integrated where possible, and traded-off where they are incompatible. Institutional and individual roles and responsibilities have to change, so that new patterns of behavior will foster sustainable development. The principle of sustainability must be incorporated into everyday activities of all sectors of society, illustrated by real-life examples. For technologies, this means profound change in thinking and action.

Industry can no longer afford to ignore environmental needs. If prevention is to prevail over environmental cure, we must rapidly develop and deploy a wide array of new, more efficient, and sustainable technologies. This need for new technology is particularly acute in the realms of energy, transportation, and industrial production, because these activities currently account for so much environmental degradation. This paper highlights the background of the United Nations’ Forum and my speech at the Forum, emphasizing on environmental management strategy, pollution prevention technology and practices.

Background of the United Nations’ Forum

The United Nations Forum on “New and Emerging Technologies and Sustainable Development” was sponsored by the UN Department of Economic and Social Affairs and hosted by the Chinese Ministry of Science and Technology in Beijing, China, April 2002. As one of the keynote speakers, my presentation topic is “Sustainable Development: Environmental Strategy and Technology.” High-ranking delegates and representatives from 54 countries participated the Forum. The purpose of the Forum is to enhance exchanges and cooperation between business-science partnerships in utilizing new and emerging technology for sustainable development. The two essential missions are: (1) bring together leaders from academia, the scientific community, professional institutions, industry, business and government to harnessing the potential of new and emerging technologies for promoting technological cooperation and local capacity building through international partnerships, and (2) find a way for developing countries to either acquire or develop, and apply new and emerging technologies.

The action plan of sustainable development requires the application of sound science and technology to eliminating poverty, sustaining economic development, advancing social priorities, and protecting the environment. Most delegates felt that the current gap between “developed countries and developing countries” in the generation of new and emerging technologies and their application to practical problems constitutes a “technological divide.” The technical gap and division must be bridged if developing countries are to participate effectively in achieving the goals of sustainable development.

As of today, the progresses of sustainable development have been considered inadequate. The challenge is to find new and innovative ways of (a) ensuring a more effective cooperation and transfer of technology and knowledge, and (b) building and strengthening of science and technology capacities in developing countries. The new and emerging technologies have the potential to play an important role in achieving sustainable development goals. In order for developing countries to meet their sustainable development goals, they must have access to environmentally sound technologies. Such access requires technology transfer, technical cooperation, and building science and technology capacity to participate in the development and adaptation of these technologies to local conditions.
Today’s global economy has reinforced the geographic separation among resource extraction, production, and consumption. Unfortunately, those who reap the economic benefits of using natural resources often do not bear the environmental pollution costs. Industry is the engine of economic growth, but this engine of growth is highly polluting the environment and eco-system. Many of pollution management technologies are available in most developed countries, such as pollution prevention, clean production, design for the environment, eco-design, environment management system, life-cycle assessment, total cost analysis and others, but not in developing countries (1).

The economic development, social growth, and environmental protection are three pillars that provide the base for understanding the achieving the goals of sustainable development. Science and technology have had a profound impact on economic development. The developing countries generally do not have access to the most effective and economical technologies and know-how to achieve sustainable development in many critical areas. With the ownership of most of the technologies in corporate hands, international partnerships are needed between scientific and technological institutions in developing countries and international corporations. Partnerships offer an important way for developing countries to participate in the development and acquisition of those technologies needed for achieving sustainable development. However, in order for this to happen, certain conditions are essential to attract international corporations. One set of conditions concerns political stability, fiscal regulations, currency convertibility, and business laws as they pertain to foreign-owned enterprises. Another set of conditions concerns the scientific and technological capacity of the host country in terms of its human resources, infrastructure equipment, and institutions.

**Major Areas of Forum Discussion**

Discussions in my group focused on: (1) new and emerging technologies, (2) building local scientific and technological capacity, and (3) international business community and capacity building. Emphasis was given to production, energy, transportation, agriculture, food, as well as national capacity building and international technology transfer.

1. New and emerging technologies
   - What new technologies are needed for sustainable development?
   - What modifications are needed to better adapt existing technologies to local conditions in developing countries?

2. Building local scientific and technological capacity
   - What local skills and infrastructure are needed for the development of such technologies?
   - What mechanisms can harness the potential of the private sector to assist in the development of this capacity?
   - How might partnerships be forged for research and development projects that focus on seeking technological solutions to the problems of developing countries?

3. International Business Community and Capacity Building
   - What local scientific and technological capacity is needed to attract industries to developing countries?
   - How could international partnerships be used to promote new approaches to technology enterprises?
   - What role could the international business community play in helping developing countries participate in global scientific and technological development?

Some delegates suggested that new innovations in renewable energy offer opportunities and challenges for development and application in developing countries. Fuel cell technology, for example, offers promise as an emerging technology for sustainable development. Questions rose about renewable energy by delegates from developed countries mostly related to economy. For instance, are there economic advantages for a company working in the energy and transportation technologies to undertake research and development, and product manufacture in developing countries? International enterprises considering investment in new and emerging technologies in developing countries are attracted most to those countries with scientific and technological capacity.
Environmentally Sound Strategy and Technology

Strategy means a sense of knowing where we want to go and how we want to get there. It is difficult to make real progress without a good plan, without spelling out the exact objectives to be met and the means to be used in the process. Environmental protection from pollution has suffered because nearly all of our actions have been reactive, ad hoc, uncoordinated, and often contradictory. Without a finely sharpened strategy such as prevention, success is not only unlikely; it is difficult even to assess what success is. Developing a strategy would do more than resolve the relative priorities of protecting human health versus protecting natural resources. It would also help establish priorities among different environmental problems. A lack of strategy, for example, may benefit politicians and bureaucrats, who can claim success for nearly all results.

Governments in most developing countries have minimum accountability because lack of sound strategy that means an absence of cost-effective programs and criteria by which the public can judge the worth of actions. Without a strategy, human, financial, and technical resources are not allocated to a clear path, and the environmental protection results are uneven. Sadly, sustainable development programs in developing countries have been unable to establish the relative priorities of socio-economic development and protection of public health and natural resources. Developing an environmental sound strategy provides many opportunities, especially for bringing a pollution prevention program to the attention of decision-makers in industry/business and government for sustainable development.

Environmentally sound strategy needs to be based on pollution prevention principles and practices rather than on taking care of it after the pollution problem has been created (2). Current regulations and standards established mostly focus on media-specific and command-and-control solutions and emphasize end-of-pipe treating and removing pollutants from air emissions or wastewater releases, rather than addressing the causes of the pollution problems. Such technologies have helped solve only short-term problems, rather than eliminate pollution. Especially those traditional small- and medium-sized industries need to be reformed or upgraded to practice the three pollution principles (see Appendix A).

Sustainable production technology calls for minimizing undesirable effluents, emissions, and wastes from processes design, operation, maintenance and equipment modification as well as improving products and services. Sustainable technology focuses on pollution prevention, which requires a total system approach that prevents pollutants from being created in the first place or minimizes undesirable wastes and prevents the need for treatment and control. A preventive approach involves using fewer or nonpolluting materials, designing processes that minimize waste products and pollutants or that direct them to other useful purposes, and creating recyclable products.

Following a pollution prevention concept, human intelligence and creativity can focus on prevention, elimination, or minimizing the production of all kinds of wastes and pollutants as well as all harmful products and services. That is the prime objective of prevention. Improving environmental quality requires that economic growth be contingent on producing less environmental waste per unit of economic activity. Producing less environmental waste and harmful product is equivalent to using less natural resources and reducing the traditionally hidden environmental costs of making and consuming goods and services. Environmental efficiency must become as compelling as energy efficiency.

Adoption of a new technology often depends on whether the potential adopters use and trust sources of information on the new technology. To make policies more effective, governments need to disseminate accurate information to potential adopters of technologies from sources that companies trust and in forms that they find useful.

Environmental Pollution Management

In general, pollution management could be divided into two strategies: pollution prevention and pollution control. Their major differences are that pollution control focuses on wastes and pollutants from various sources, while pollution prevention not only minimizes wastes and pollutants but also prevents certain environmentally harmful products and services.
Pollution control applies end-of-pipe waste treatment and disposal technologies that have produced substantial improvement in the quality of the air, water and soil by waste management practices, but costly. In recent years, costs of waste treatment and disposal, waste cleanup, and liability insurance have risen, while costs of resource input, energy and raw materials have also risen. A waste treatment system requires investment in design, installation, operation and maintenance, but the system has no financial benefit to the industrial production. Pollution control technologies may also transfer pollutants from one environmental medium (air, water, or land) to another, causing potential secondary pollution problems that require further treatment and disposal. In fact, more attention has been given generally to recycling than to preventing waste generation. Pollution control technologies helped solving only short-term problems, rather than eliminating pollutants and wastes (3).

Pollution prevention is a step forward by searching for alternative solutions and logical extensions of pollution control. Pollution prevention is not just individual technology, but total systems that include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures. The process of pollution prevention in a system approach is very much in line with other technologies such as eco-design, clean production or design for the environment. New knowledge and ideas of pollution prevention have advanced and implemented to differing degrees:

- The best waste management approach should be applied to prevent waste from all sources (industry, energy, transportation, mining, government and non-government organizations, commercial establishments, and individual homes).
- If waste cannot be prevented, then try to recover, reuse, or recycle prior to treatment.
- Residues and sludge from the treatment process must be disposed safely.

Pollution prevention for industrial manufacturing facilities can be understood by observing the path of material as it passes through an industrial site. Even before materials arrive at the site, we can avoid toxic materials when less toxic substitutes exist. Pollution prevention technologies begin with life-cycle assessment, analyzing all aspects of product manufacturing, use, reuse, and disposal of that should be carried out in such a way that future generations are not impacted negatively. This implies that there will be no overuse of raw materials that cannot be regenerated and that no portion of the environment (air, water, or land) will be degraded.

A manufacturing facility that starts and continually improves a pollution prevention program will contribute to achieving sustainable development. Pollution prevention technology in manufacturing plants can be generalized into six groups:

- Improved plant operations
- In-process recycling
- Process modification
- Materials and product substitutions
- Materials separations
- A system approach.

Note: Accepting the primacy of pollution prevention does not mean abandoning traditional pollution control of end-of-pipe technologies or the government regulatory and legal systems designed to ensure their implementation. In fact, not all waste and pollution can be eliminated or prevented, either immediately or in the long run. The remaining waste that cannot be prevented needs to be adequately treated and disposed of. What is absolutely crucial, however, is to recognize the importance of pollution prevention in the hierarchy of environmental options.

Education and Training

Investments in education and training are indispensable for sustainable development in design and manufacturing and production as well as in services and construction, and much more. Environmental professionals, government officials and industry/business managers need to understand changing needs of environmental management programs and new technologies to meet the needs of the changing characteristics of waste, pollutant, harmful product and service problems. The environmental future must apply “anticipation and prevention” as the very first step in the environmental management programs for sustainable development. Critical environmental
issues and problems must be the priority of environmental management, such as the changing needs to prevent risks, and potential impact of toxic chemicals and hazardous wastes associated with people’s daily decisions.

Government officials and industrial/business managers cannot protect the environment without adequate knowledge and information of changing environmental pollution issues. All environmental programs require more practitioners with adequate education and training in current environmental science, technology and management skills. Such education and training are critical for setting environmental policies and regulations as well as ensuring that environmental policies and programs are managed effectively and efficiently. Various education and training materials are available in various publications or on Internet websites. Electronic information sources through the Internet and the World Wide Website are becoming increasingly common and more helpful to search for information.

Conclusion

Sustainable development is a long-term goal. Achieving the goal requires technical tools that pursuit economic prosperity, environment quality, and social equality. Pollution control technologies helped solving only short-term problems rather than eliminating pollutants and wastes. Pollution prevention technology minimizes not only pollutants and wastes, but also prevents certain environmentally harmful products and services. Pollution prevention searches for alternative solutions and logical extensions of pollution control. Pollution prevention is not just individual technology, but total systems that include know-how, procedures, production and services, and equipment as well as organizational and management procedures. Investments in education and training are indispensable for sustainable development.

References


Appendix A. Shen’s Three Principles of Environmental Pollution

| The first principle -- Pollution from human activities is unavoidable. |
| 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. |

| The second principle -- Prevent pollution whenever possible. |
| 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. |

| The third principle -- Minimal pollution is acceptable. |
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.

About the Author

Thomas Shen received his Ph.D. degree from Rensselaer Polytechnic Institute in Troy, New York. He is a Diplomate of the American Academy of Environmental Engineers and an independent environmental advisor to the United Nations. Dr. Shen was president of the Phi Tau Phi Scholastic Honor Society, East American Chapter. He served as a Senior Researcher with the New York State Health Department and the Department of Environmental Conservation for 26 years, and taught graduate courses at the Columbia University for 11 years. He has lectured in more than 40 universities and research institutes in America, Asian and European countries. He authored and co-authored four books, three handbook chapters, and many technical papers. The Springer-Verlag International in Heidelberg of Germany published his second edition book of “Industrial Pollution Prevention Book” in 1999.
DESIGN AND APPLICATION OF VERMICOMPOSTING PROCESS

Lawrence K. Wang*, Yung-Tse Hung**, Howard H. Lo****, Constantine Yapijakis****, J. Paul Chen*****

*Zorex Corporation, Newtonville, New York 12128-0405
Email: larrykwang@juno.com
**Department of Civil and Environmental Engineering
Cleveland State University, Cleveland, Ohio 44115-2214
***Department of Biological, Geological and Environmental Sciences
Cleveland State University, Cleveland, Ohio 44115-2214
****Civil Engineering Department
Cooper Union, New York, New York 10003
*****Department of Chemical and Environmental Engineering
National University of Singapore, Singapore 129791

1. Process Description

Vermicomposting process is a novel municipal wastewater sludge treatment process which uses earthworms (Oligochaete annelids). This system is often called earthworm conversion, vermicomposting, vermistabilization, or annelidic consumption. Vermicomposting is different from the conventional composting of wastewater treatment plant sludge. In the vermicomposting (earthworm conversion) process, the worms are provided an optimum environment to consume or metabolize the sludge and produce feces or castings. These castings may be used as a soil conditioner. (1-16, 30-32)

2. Vermicomposting Process Arrangement and Applications

Vermicomposting process (Figure 1; Source: US EPA) is basically a simple earthworm conversion process (30, 32). The process requires worm beds and a supply of worms. Generally, digested and dewatered sludge is put into the beds, although experiments are underway, where raw liquid sludge is placed in beds. If anaerobic digestion is used prior to earthworm conversion, additional pretreatment may be needed. A bulking agent such as wood chips may be useful in some cases for keeping the bed porous and aerobic, especially if moisture is high. Sludge is, however, generally applied without any bulking agent. A worm bed may take the form of a simple tray. Windrows similar to those for composting may also be used. After the worms have consumed the sludge, they must be separated from the castings. This may be done with an earthworm harvester, a drum screen that rotates on a nearly horizontal axis. Castings fall through the screen openings while worms tumble through the length of the drum. Section 6 contains some critical operational parameters for the earthworm conversion process.

The main product of the vermicomposting (earthworm conversion) process is the worm's castings. In some process arrangements there may be a net earthworm production. The excess earthworms may then be sold for fish bait or animal protein supplement. Earthworm marketing is a complex problem. For municipal sludge applications, surplus earthworms may be considered a by-product; the principal product is the castings, which can be a resource.

Wright-Patterson Air Force Base, Dayton, Ohio, USA, (4) has launched a vermicomposting program in July 2002, using earthworms to consume a daily average of 500 pounds of solid waste. The worms digest vegetable matter and old newspapers. That saves the base about $25 per day on transporting and disposing of waste. As the number of worms grows, so does the amount of waste they consume. The base acquired 250,000 worms and their climate-controlled home (at 70 degree constant temperature) for the environmental project. At Wright-Patterson, which produces more than enough fruit and vegetable waste from its commissary, the earthworms have flourished, now numbering more than 300,000. Their numbers eventually could top 1 million, who are in there eating and multiplying in high efficiency. The worm casings replace chemical fertilizer at the base's golf course, which saves additional money. More successful stories can be found in the literature (1-30).

Vermicomposting has gained popularity in schools and municipalities, according to Stuckey and Hudak (31). In Boston, Massachusetts, Josiah Quincy Elementary School received a grant to build a roof top organic garden. The students maintain garbage eating red wiggler worms to break down fruits and vegetables. Once processed in the bin, the compost is
applied to the garden. A revolutionary worm-use concept has been promoted in Orange County, Florida, where worms stabilize biosolids to a “Class A pathogen standard” substance.

3. Advantages of the Earthworm Conversion Process

When dry, earthworm castings are essentially odorless; when damp, they have a mild odor like a good quality topsoil. Also, the castings have a favorable appearance. When sifted and dry, they are granular, about 0.02 to 0.1 inches (0.5 to 3 mm) in maximum dimension (with some fines); color is brownish gray. In a study where municipal sludge was applied to a wheat crop, it was found that when earthworms were added to the sludge, the germination rate of the wheat was improved (21). The odor, appearance, and soil supplementation advantages of the earthworm conversion process may help in the acceptance of sludge by farmers and householders.

Earthworm conversion affects several other sludge characteristics. The oxygen uptake rate increases (17); the acid-extractable fraction of various nutrients increases (21). The volatile content of the solids drops slightly and humic acid concentrations fluctuate (17). While these effects may be beneficial, there are no data to show how the results affect design or operation of earthworm conversion installations.

The earthworm conversion process would appear to be low in cost, although this cannot be said with certainty, since no cost data are available for full-scale operations on sludge. The process does not require chemicals, high temperatures, or large amounts of electricity. Only a small amount of low-speed mechanical equipment is needed. Significant expenditures may be required to offset the potential operating difficulties discussed below.

4. Troubleshooting Guide for Process Operation

A number of potential operating difficulties and their solutions are listed in below. None of these difficulties are insurmountable. Probably it is most difficult to economically pretreat anaerobically digested sludge so that it is nontoxic to the worms (30, 32).

- **Worm drowning:** Worms must be protected from flooding.
- **Worm loss due to migration from the process:** Caused by flooding, toxic sludge, unpalatable sludge, adjoining areas attractive to worms, lack of artificial lighting on rainy nights.
- **Toxicity of sludge to worms:** Significant for anaerobically digested sludge. However, toxicity is eliminated by exposing the sludge to air for two months (17) or wetting sun-dried sludge daily for 14 days (21). Stabilization by lime or chlorine is not recommended for sludge that will be fed to earthworms. Toxicants such as copper salts might also cause problems. Aerobic digestion is best suited for sludge to be converted by earthworms.
- **Toxicity or unpalatable nature of dewatering chemicals:** Avoided at Hagerstown, Md., by use of food-grade polymer (19). Drying beds may be used; drying beds do not usually require chemicals.
- **Worm shortage in the process, so that worm additions are required:** Worms reproduce via egg capsules. These capsules may be lost from the process in the castings. Also, toxic conditions, drowning, and other problems will cause worm populations to drop. At Hagerstown, Md., a worm raising operation has been proposed to supply the necessary make-up worms to the sludge conversion process (19).
- **Shortage of worms for initial inventory or restart:** To begin operation, a large worm inventory may be needed, so large that local worm suppliers may be unable to fill it. Gradual start-up is therefore desirable, especially for large plants. Also, earthworm exchanges may become available nationwide so that sludge operations can draw on larger numbers of earthworm suppliers.
- **Temperature extremes:** Worm feed most rapidly at 15 to 20 degrees C; about 5 degrees C, feeding is quite slow (17). Freezing will kill worms. High temperatures can also cause problems. It may be necessary to stockpile sludge during the winter or provide a heated building for the conversion process.
- **Shortage of enzymes:** Not a problem, despite claims by marketers of enzyme preparations that these preparations are valuable to the process (23).
- **Exposure to light:** Worms avoid bright light. Some sort of cover or shade should be provided so that worms will convert the top layer of the sludge.
- **Dehydration:** There is a minimum moisture content for the worm bed (23).
• **Salinity in castings**: Under some conditions, castings may have sufficient dissolved salts to inhibit plant growth. This problem may be eliminated by leaching or by mixing the castings with other materials with lower dissolved salts (24, 25).

• **Contamination of castings by heavy metals, motor oil, rags, and similar materials**: Source control may be used, where feasible, as for other processes aimed at reuse of sludge as a soil conditioner.

• **Odors**: The most likely source is raw or aerobically digested sludge, which has been stockpiled to await earthworm conversion.

5. **Process Limitations**

Limitations include, but will not be limited to, the following (30, 32):

- Earthworm conversion decreases the total nitrogen values in the sludge because ammonia nitrogen will be lost to the atmosphere.
- Costs are unpredictable.
- Two common ions in municipal wastewater sludge, ammonium and copper, may be toxic to worms. Studies have found that these ions were lethal at additions equivalent to 180 mg NH₄-N and 2,500 mg Cu per kilogram of wet substrate (26,27). Safe limits for these elements are not known.
- Cadmium accumulates in the worm Eisenia foetida. Zinc apparently does not accumulate in Eisenia foetida but does accumulate in other species (27,28). If the worms are to be used as animal feed, the system must be operated such that cadmium and zinc concentrations in the worms do not exceed recommended levels for animal consumption.
- Space requirements may rule out earthworm conversion at some treatment plants.
- The earthworm business has been afflicted with unsound investments and excessive claims. For example, it has been claimed that earthworm processing is able to reduce concentrations of heavy metals (29). Any such reduction could only be caused by simple dilution with uncontaminated waste or by concentration of the contaminants in the earthworms.
- If a particular sludge is suitable for earthworm conversion, that sludge should also be suitable for reuse as a soil conditioner without being processed by earthworms. However, earthworm conversion reduces odor, improves texture, and may increase germination rate.

These limitations may be significant but not overwhelming. There is considerable research and development underway. It appears that earthworm conversion may have a role in municipal wastewater treatment plant sludge processing.

6. **Process Design Criteria**

Design criteria have been generated by the operators in the field (17-20, 30, 32) for the vermicomposting process.

Species of worm being tested were *Eisenia foetida* (redworm, hybrid redworm, tiger worm, dung worm) (17, 30), *Lumbricus rubellus* (red manure worm, red wiggler worm) (18), and *Lumbricus terrestris* (nightcrawler) (17). The following are the compiled design criteria:

- Detention time of sludge in worm beds = 2 to 32 days (18-19)
- Worm reproductive cycle = 1 to 2 months
- Rate of worm feeding (15°C) = 0.17 to 1.7 grams dry sludge per gram dry worm weight per day (17)
- Optimum temperature = 15 to 20 degrees C
- Dry matter content of worms = 20 to 25 percent (*Eisenia foetida*) (20)
- Minimum solids content of the worm bed mixture = 20 percent; Actual minimum solids content depends on such factors as porosity, type of sludge, ability to keep aerobic. Experiments are being conducted to better define these parameters.

**REFERENCES**


FIGURE 1
DIAGRAM OF AN EARTHWORM CONVERSION PROCESS
1. Introduction

The use of soaps, detergents, and their derivatives in many of the nation’s industries and household make the soap and-detergent manufacturing industry one of most lucrative commercial successes in the USA. American industry consists of approximately 700 plants which produce a total of 34,000 tons of soap and related products per day. A vast portion of these products, or their components will invariably be deposited in the nation's waterways and wastewater treatment facilities from various production plant operations or after actual household use.

Four large companies which dominate the industry own only about 5% of all the plants, yet sell 50% of all soap products, and account for 54% of total industry employment. Of these institutions, three are multinational corporations having individual annual sales over one billion dollars from the sale of household products and health and beauty aids. These large corporations are able to own and economically operate innovative production processes and large, efficient wastewater treatment facilities and other pollution control systems.

The small and medium plant operations that make up the remainder of the industry (approximately 95%), are limited to large population centers and state-of-the-art technology. These plants must, in most cases, use publicly owned treatment facilities and operate with less capital for advanced process technologies and pollution abatement equipment.

The industry is covered under Standard Industrial Classification (SIC) Code 2841 which includes provisions for the manufacture of soap, synthetic organic detergents, and organic alkaline detergents, or any combination of these. SIC Code 2841 also includes the manufacture of crude and refined glycerine from vegetable and animal fats and oils. The US EPA Effluent Guidelines Division, Washington, DC, has devised a sub-categorization of this industry based upon the specific types of manufacturing processes undertaken at a given establishment.

Of all soap and detergent manufacturing plants in the US, 1% of the plants directly discharge wastewaters to receiving waters, 64.8% of the plants indirectly discharge their wastewaters to receiving waters after certain wastewater pretreatment, and remaining 34.2% of the plants adopt the best “Zero Discharge” system which treats wastewater for internal reuse.

There are estimated 1,523 process installations that produce 31,000 tons of soap, detergent, and glycerine per day. Liquid detergent and dry-blended detergent manufacturing account for 47% of this production. Over 75% (124,000 m³/d) of the normalized approximate total wastewater flow (143,000 m³/d) is estimated to come from the 40 glycerine recovery (concentration and distillation) installations.

2. Subcategory Descriptions
The method for subcategorizing the soap and detergent manufacturing industry mentioned above was established to identify potential wastewater sources and controls, provide a permit granting authority with a way to analyze a specific plant regardless of its complexity, and permit monitoring for compliance without undue complication or expense. The categorization consists of 2 major categories and 19 subcategories. The major categories follow the natural division of soap manufacturing (production of, alkaline metal salts and fatty acids derived from natural fats and oils) and detergent manufacturing (production of sulfated and sulfonated cleaning agents from manufactured raw materials, primarily petroleum derivatives). The subcategories are based on discrete manufacturing units employed by the industry for conversion of raw materials to intermediate products and conversion of intermediate products to finished marketed products. A manufacturing unit may contain a single process (e.g., continuous neutralization for production of neat soap by fatty acid neutralization) or a number of processes (e.g., crutching, drying, milling, plodding, stamping, and packaging for production of bar soaps from neat soap).

The following are the subcategory designation:

(a) Subcategory 1: soap manufacture by batch kettle
(b) Subcategory 2: Fatty acid manufacture by fat splitting
(c) Subcategory 3: Soap from fatty *old neutralization
(d) Subcategory 4 and 5 Glycerine concentration and distillation (glycerine recovery)
(e) Subcategory 6: Soap flakes and powders(s)
(f) Subcategory 7: Bar soaps
(g) Subcategory 8: Liquid soaps
(h) Subcategory 9: Oleum Sulfonation and Sulfation(s)
(i) Subcategory 10: Air-SO(3) sulfation and sulfonation(s)
(j) Subcategory 11: SO(3) Solvent and vacuum sulfonation(s)
(k) Subcategory 12: Sulfamic acid sulfation(a)
(l) Subcategory 13: Chlorosulfonic acid sulfation(s)
(m) Subcategory 14: Neutralization of sulfuric acid esters and sulfonic acids
(n) Subcategory 15: Spray dried detergents
(o) Subcategory 16: Liquid detergents
(p) Subcategory 17: Dry detergent blending
(q) Subcategory 18: Drum dried detergents(s)
(r) Subcategory 19: Detergent bar and cakes(s)

3. Waste Characteristics

Major types of wastewater pollutants from the subcategories 1-11 of the soap and detergent manufacturing industry can be found in Table 1 (Source: U.S. EPA). This table shows that resultant wastewaters depend upon process operating parameters and the kind of soap or detergent material produced.

Of these pollutants, several are of particular environmental concern. Synthetic surface active agents not only create BOD and COD, but they cause water to foam and, in high concentrations, they can be toxic to fish and other organisms. Nutrients, particularly phosphate produced in part by liquid detergent manufacture, are of concern because of their contribution to eutrophication of the lake. Soap production leads to wastewaters with high alkalinity, high salt, and high oxygen demand. Spills of raw materials contribute to oil and grease levels. Most of the suspended solids come from organics (i.e., calcium soaps), and many are of the volatile rather than nonvolatile type. Since strong acids and strong alkalis are used in most of these subcategories, pH can be very high or very low in wastewater.

4. Waste Treatment

Pollutants released in the process waters from the soap and detergent industry are generally of a nontoxic nature and can be pretreated, removed, or ultimately disposed of under normal controlled conditions. Treatment techniques currently in use to recover or remove wastewater pollutants at these facilities are standard, well-established processes.
The industry's wastewater pollutants can be greatly reduced by lower process water usage and/or the recycling of process water. In addition, significant recovery of marketable soap products, fats, glycerine, organic surface active agents, etc., can be realized by lower water use, particularly through process redesign or replacement. For example, in the manufacture of liquid detergents, installation of additional water recycle piping and tankage and the use of air (rather than water) to blow out filling lines can substantially reduce water use and minimize loss of the finished products.

4.1 Removal of Free and Emulsified Oils and Greases

The feasible treatment methods and reduction are: (a) gravity separation (90%); (b) coagulation and sedimentation (95%); (c) carbon media filtration (95%); (d) mixed media filtration (95%); (e) flotation (up to 90%); and (f) foam separation (85%)

4.2 Removal of Suspended Solid

The feasible treatment processes and percent removal are: (a) plain sedimentation (50%); (b) coagulation-sedimentation (50-85%); (c) mixed media filtration (70-95%); (d) coagulation-flotation (70-95%); (e) coagulation-physicochemical SBR (85-95%); and (f) coagulation-ultrafiltration (99%)

4.3 Removal of Dispersed Organics

The feasible treatment processes and percent removal are: (a) bioconversion, including activated sludge, trickling, rotating biological reactors, lagoons, oxidation ditch, wetland process, sequencing batch reactors, etc. (60-95%); (b) carbon adsorption (up to 90%); (c) polymeric adsorption or resin adsorption (up to 90%); and (d) membrane bioreactor (85-99%)

4.4 Removal of Dissolved Inorganic Solids

The feasible treatment processes and percent removal are: (a) reverse Osmosis (99%); (b) ion exchange (99%); (c) chemical precipitation-sedimentation (up to 90%); (c) evaporation; (d) chemical precipitation-flotation (up to 95%); (e) chemical reduction-oxidation precipitation (up to 95%); (f) physicochemical SBR (95%); and (g) precipitation-ultrafiltration (95%)

4.5 Reduction of Unacceptable Acidity and Alkalinity

The feasible treatment processes include: (a) neutralization, and (b) recarbonation.

4.6 Reduction of Surfactants

The feasible treatment processes and percent reduction are: (a) ion exchange (99% for ionic surfactants); (b) carbon adsorption (95%); (c) foam separation or dispersed air flotation (85%); (d) reverse Osmosis (99%); (e) bioconversion (60-95%); (f) dissolved air flotation (95% for ionic and nonionic surfactants); and (g) physicochemical SBR (95% for surfactants)

4.7 Treatment and Disposal of Sludges

The feasible treatment processes include: (a) aerobic digestion; (b) incineration; (c) lagooning; (d) gravity thickening; (e) centrifuging; (f) wet oxidation; (g) vacuum filtration; (h) flotation thickening; (i) anaerobic digestion.

REFERENCES
<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Major wastewater pollutants</th>
<th>Source(s) of pollutants in process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soap manufacture by batch kettle</td>
<td>Fats and oils; unrecou-tered NaCl, Na(2)SO(4) and NaOH; spilted and products (glycerine)</td>
<td>Fat refining and bleaching, fat heating, neutralization of batch, fat handling.</td>
</tr>
<tr>
<td>Fatty acid manufacture by fat splitting</td>
<td>Fatty acids, unreacted fats and glycerine; sodium salts and NaOH; zinc and alkaline earth metals, nickel</td>
<td>Fat heating, catalytic splitting, flash hydrogenation, neutralization</td>
</tr>
<tr>
<td>Soap from fatty acid neutralization</td>
<td>Fats and oils; unrecou-tered NaCl, Na(2)SO(4) and NaOH; spilted and lost soaps and by-products (glycerine)</td>
<td>Fat heating, catalytic splitting, flash hydrogenation, neutralization</td>
</tr>
<tr>
<td>Glycerine concentration and distilla-</td>
<td>Glycerine, glycerine polymers, NaCl, and Na(2)SO(4)</td>
<td>Lye treatment, glycerine distillation</td>
</tr>
<tr>
<td>tion (glycerine recovery)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soap flakes and powders(a)</td>
<td>Pure soap, small amount of free fatty material, NaCl from splits and leaks</td>
<td>Skimming, crutching and drying, spray drying, packaging</td>
</tr>
<tr>
<td>Bar soaps</td>
<td>Pure soap, small amount of free fatty material, NaCl from splits and leaks</td>
<td>Soap milling, crutching and drying, packaging</td>
</tr>
<tr>
<td>Liquid soaps</td>
<td>Solvents (alcohols or glycols), builders, dyes, perfumes, and potassium salts</td>
<td>Receiving and storage, blending, packaging</td>
</tr>
<tr>
<td>Glucon Sulfonation and Sulfation(e)</td>
<td>Oily raw materials, sulfuric acid, and surfactant sulfonic acid</td>
<td>Receiving and storage, oleum fume scrubber, cooling water, reactor leaks and spilt, reactor and mixer washouts</td>
</tr>
<tr>
<td>Air-SO(3) sulfation and sulfona-</td>
<td>Oily raw materials, sulfuric acid, and surfactant sulfonic acid</td>
<td>Receiving and storage, vaporizer condensate, dryer and reactor washouts</td>
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<td>tion(e)</td>
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<tr>
<td>SO(3) solvent and vacuum sulfona-</td>
<td>Oily raw materials, sulfuric acid, surfactant sulfonic acid and sulfate</td>
<td>Receiving and storage, vaporizer condensate, scrubber and degasser</td>
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I. Introduction

The purpose of this paper is to examine the effects of shear force on the formation, structure and metabolism of aerobic granules, which will be helpful in understanding the mechanisms that are responsible for aerobic granulation. Wastewater from industrial processes and more recently from households (sewage) may be fed to a suitable distribution system situated at the bottom of the UASB reactor.

Anaerobic Biological Treatment (Sludge Bed) – under anaerobic conditions in the reactor (i.e. where no molecular oxygen is present), organics from the wastewater are used by different types of microorganisms as the source of energy for the biological degradation process. These organisms tend to agglomerate into flocs, referred to as sludge. Under certain circumstances the bacteria may even from small roundish pellets, called granules that consist mainly of methanogenic bacteria (1). This granulation had a very strong influence on the increased application of anaerobic treatment to polluted waste waters. The sludge produces gas as a by-product of the degradation process. A small amount of the food is transformed either into free energy and water or cellular material, which is equal to the new growth of bacteria, but a large amount is transferred into gas, which consists mainly of valuable methane and carbon dioxide.

The anaerobic process is a natural one using some of the oldest microorganisms on earth. Through the formulation of granules, the number of bacteria per unit of volume in the reactor is much higher than those reactors being operated with flocculent sludge. Therefore the size of reactor required is much smaller than that required for conventional anaerobic treatment. Anaerobic bacteria keep on working 24 hours a day, as the aerobic bacteria. In contrast to the aerobic biological process where bacteria need to be fed “continuously”, periods with no or low feed do not significantly affect the anaerobic process performance (1).

Aerobic Biological Treatment (Aeration) - In the aeration basin oxygen from the air is used by a mixture of different types of microorganisms as a source of energy for the breakdown of complex organic substances. These microorganisms agglomerate into sludge flocs. The resulting mass of organisms is called activated sludge. Activated sludge uses the organics in wastewater together with nutrients that are available or that have been provided, to feed themselves. The food is transformed either into free energy, carbon dioxide and water or cellular material, which is equal to the new growth of bacteria. The microorganisms of only remove organic materials from the waste water, but also nitrogen and phosphorous. A surplus of sludge is invariably produced and must be removed from the reactor.

The activated sludge process is a natural one, which uses the same type of organisms as, found for example in the soil. The number of bacteria per unit of volume in the reactor, however, us much higher. Therefore the size of reactor required is much smaller than required for natural treatment. These microorganisms work 24 hours a day.

Secondary Clarification (Sedimentation) – In the sedimentation unit the valuable bacteria, in the form of sludge flocs, settle by gravity and can be return to the aeration unit. In the aeration unit small flocs are preferable so that good contact can be achieved between the substrate in the wastewater, the air and the microorganisms which permit rapid uptake of the food available. In contrast, small flocs are not wanted in
the sedimentation tank, because they do not settle as rapidly as sludge comprising large flocs. Large flocs facilitate rapid return of settled sludge to the aeration unit, while at the same time the sedimentation tank volume required for satisfactory separation is at a minimum.

Currently studies are under way concerning granulation and its correlations with liquid surface tension. As well as different properties of the substrate, such as the buffer capacity, the presence of high energy carbohydrates, in the form of food processing waste, and of high levels of free suspended solids, proteins, $\text{NH}_4^+$, sulfates and sulfides are investigated (2).

Distribution of metabolic groups ($\text{SO}_4^{2-}$ - reducers) and extra cellular polysaccharides in granules are current topics of attention. Also a continuous screening is going on for bio-supplements that can be applied in practice to full scale installations in order to enhance granular growth.

The active biomass concentration, the overall biodegradation rates, the reactor configuration and the feeding rates of the pollutants and dissolved oxygen are the driving forces in the performance of an immobilized – cell system for wastewater treatment. An upflow anaerobic sludge blanket (UASB) bioreactor using anaerobic granules is one of the best known self – immobilization processes and has been extensively applied to anaerobic wastewater treatment. In this system granulation by methanogens, acidifying bacteria, nitrifying bacteria, and denitrifying bacteria has been reported (2, 3, 4, 5, 6). The advantages of aerobic granular sludge, as compared with conventional activated sludge flocs, are the regular, dense and strong microbial structure, good settling ability, high biomass retention, and ability to withstand a high organic microbial structure.

There is very little information on the impact of shear force in the formation of aerobic granules. However, since we are provided with research reports stating that shear force may definitely play an important role in anaerobic cell – immobilization systems it can be safe to take this statement a step further and assume that shear force will also play a vital role in the formation of aerobic granules.

In a biological reactor, the shear force caused by hydraulics and or particle – particle collision is a key factor that influences the formation, structure and stability of the cell – immobilization community such as biofilm and anaerobic granules under hydrodynamic conditions. The higher the shearing force is the stronger the biofilm would be. However, on the other hand when the shearing force is weak the biofilm will tend to become a heterogeneous, porous and weaker structure (7, 8). Concluding that shear force plays an important part in cell – immobilization systems.

II. Biological Treatability Testing

The bench-scale laboratory testing of the wastewater is recommended whenever uncertainty exists regarding the composition of the wastewater and its biodegradability. For example, wastewater with high concentrations of sulfur-bearing compounds should be tested in the laboratory as the first step in determining the advisability of proceeding with more detailed pilot studies.

The purpose of a bench test is to gain a first impression of the digestibility of a given wastewater sample. By testing the wastewater under controlled conditions, one can obtain an indication of the sludge activity, the possible COD reduction, possible short term adverse effect of components in the wastewater and sludge adaptation potential.

The wastewater sample is characterized to determine the chemical composition, and then is added to a three liter double-walled batch-vessel having a fixed concentration of anaerobic Biothane sludge. The vessel is maintained at a temperature of 35º C (95º F), and during the test, methane production and COD removal efficiencies are measured. The results gathered from the bench test are forwarded in a brief report which includes the activity curve data together with an interpretation of the test results.

III. In-house Pilot Testing

The Biothane and Biobed pilot plants consist of a reactor vessel, constructed of double walled glass. The reactor is temperature regulated by means of a thermal bath control unit supplied as part of the system. Also supplied with the reactor is a peristaltic feed pump, a gas back pressure vessel (to maintain proper
degassification space within the reactor), a pH controller and probe for the influent and a peristaltic pH control pump. Biogas production is measured by water displacement through the gas receiver.

During the test period the COD (chemical oxygen demand), VFA (volatile fatty acids), alkalinity, TSS, pH, temperature, gas flow, and gas quality (percent CH₄ are monitored routinely. The measurement of BOD₅ (5 day biochemical oxygen demand), TKN (total kjedahl nitrogen), NH₃, and TP (total phosphate) are also analyzed on a periodic basis. The removal efficiencies and volumetric loadings for the full-scale facility are confirmed and “steady-state” operation is demonstrated in this pilot program. For a potentially difficult to treat wastewater, sludge adaptation and ultimate performance is verified.

The results gathered from the pilot test are forwarded in a report which includes discussion and graphs depicting the test results. The amount of wastewater required for the pilot study is dependent upon the COD concentration of the wastewater streams.

IV. Case Study (9, 10)

The Microbial Granulation technology is used for production of anaerobic waste degrading microbial granules. MBI outlicensed this technology to a Korean company for granulation of microorganisms that degrade a variety of non-toxic organic compound found in diverse waste streams into methane, a renewable fuel.

Biofilter- MBI’s biofilters reduce VOCs in gas streams up to 99.9%. The high efficiency engineered biofilter uses microorganisms attached to proprietary for treating VOCs from airborne chemicals and other toxic vapor phase streams. The media contains its own nutrient source and buffering capacity to promote rapid startup and provide protection against system upsets. The nutrient solution used during performance throughout the treatment process. The engineered biofilter is a low cost, high-performance option for treating VOCs (volatile organic compounds) and sulfur-containing compounds to control odor. The technology meets compliance standards set by the Clean Air Amendments Act of 1990, and can be used to: provide up to 99.9% removal of target waste, to treat exhaust gas from soil vapor extraction sites, and to treat vapors from painting and fiberglass molding operations.

Environmental Cleanup Granules – MBI’s dechlorinating granules treat PCBs, CE, TCE and other intermediates. The patented anaerobic microbial consortia can completely dechlorinate even the most highly chlorinated PCB mixtures, including Aroclor 1254. The consortia retain dechlorinating activity event with brief exposure to oxygen and reasonable concentrations of other contaminants and heavy metals. Chlorine is removed from the PCBs and no potentially toxic intermediates accumulate during treatment. MBI’s anaerobic dechlorinating granules can completely dechlorinate PCE, TCE and their partially-chlorinated intermediates – DCE and VC – to non-toxic ethylene and ethane. The consortia and granules are self-immobilized microbial cells that can be mass-produced in upflow anaerobic situ bioremediation of contaminated groundwater, saturated soils, or used in an above-ground reactor to treat contaminated groundwater.

In R1 operated in a superficial air velocity of 0.3 cm/s, aerobic granules did not form during the whole experimental period; and only bioflocs were observed. However, regular-shaped granules were successfully cultivated in R2, R3 and R4, which were operated at a relatively high superficial upflow air velocity. The smooth, dense and stable aerobic granules were formed only under high shear strength. In fact, it has been reported that lower superficial gas velocity did not favor the formation of stable aerobic granules in the same type of reactors (2).

The formation of stable granules was closely correlated with an increase in the hydrophobicity of the cell surface. Hydrophobic binding has a prime importance for cell-to-cell interaction, which may induce the initial self-immobilization of bacteria and further keep the bacteria tightly together. This would serve as the first step towards to microbial granulation. In fact, the surface hydrophobicity of granules is much higher than that of bioflocs. In a thermodynamic sense, increasing the hydrophobicity of cell surfaces causes a decrease in the excess Giggs energy of the surface, which favors solid (cells) – liquid phase separation, that is, microbial aggregation. Therefore, it is reasonable to consider that a higher hydrophobicity of the cell surface would result in a more strengthened cell-to-cell interaction and, further, a dense and stable structure. In fact, the SVI of cells almost linearly decreases with the
increasing hydrophobicity of cell surfaces. It appears that hydrophobicity might be the main inducing force for the initiation of sludge granulation. It is, at least, one of the forces for maintaining the stable microbial structure of granules. In fact, there is strong evidence to show that the hydrophobicity of the cell surface is important affinity force in the self-immobilization and attachment of cells. Previous research indicated that the hydrophobicity of microorganisms would play a crucial role in the formation of anaerobic granules (11, 12). Mahoney reported that the non-granular sludge washed out from UASB reactors was more hydrophilic than the reactor sludge.

It has been generally believed that cell polysaccharides can mediate both cohesion and adhesion of cells and play a crucial role in maintaining the structural integrity of the biofilm and anaerobic granule matrix (1). The PS/PN ratio increases with the shear force, in terms of superficial upflow air velocity, up to a relatively stable value. Also, it is worth noticing that the polysaccharide content of granules is much higher than that of bioflocs. In fact, Vandevivere and Kirchman found that the content of exopolysaccharides was five-fold greater for attached cells than for free-living cell (10). This in turn implies that the polysaccharides would greatly contribute to the self-immobilization process of cells, for example, aerobic/anaerobic granulation. The polysaccharide content of granules is nine-fold higher than the protein content of granules. It is most likely that cell proteins contribute less to the structure and stability of aerobic granules. Higher shear force seems to stimulate the production of cell polysaccharides. In fact, it has been generally observed that high shear force can induce the biofilm to secrete more exopolysaccharides, which in turn results in a balanced biofilm structure under the given hydrodynamic conditions (9). It has been reported that colonic acid, an exopolysaccharides of Escherichia coli K-12, is critical for the formation of the complex three-dimensional structure and depth of E. coli biofilm (13). It seems reasonable to consider that cell exopolysaccharides can play a crucial role in building up and maintaining the architecture of biofilm and granular sludge. Ohashi and Harada observed a proportional relationship between the polysaccharide content of cells and biofilm density (14). Therefore, it explanation for the high gravity of sludge observed at high shear force.

The metabolic network of cells includes interrelated catabolic and anabolic reactions. The catabolic activity of microorganisms is directly correlated with the electron transport system activity, which can be described by the SOUR. The SOUR of cells was stimulated in a significant way by shear force, in terms of superficial upflow air velocity. As pointed out earlier, the shear force may trigger the production of cell polysaccharides. In research on biofilms, the shear force-associated phenomena are usually attributed to a simple physical effect (14). However, the microbial community may respond to shear force by metabolic changes and some biological events should be involved in shear-associated phenomena. The effect of shear force on the ration of polysaccharides to oxygen utilization rate (OUR), in terms of milligrams of oxygen utilized per hour, indicated that this ratio increased with the shear force. Such an observation implies that when the shear force is increased, much more energy generated by catabolism would be used for the production of polysaccharides rather than for growth purposes. It is most likely that when the shear force exerted on granular sludge is high, the granules would have to regulate the metabolic pathway so as to maintain a balance with the external shear force, through consuming non-growth-associated energy. In fact, inhibition of the energy-generating function had found to prevent the development of competence for cell aggregation in many systems. Consequently, the catabolic activity of cells would play a role in the development of granular sludge.

Shear force, in terms of superficial upflow air velocity, is important in the aerobic granulation process. The results show that a superficial air velocity higher than 1.2 cm/s must be satisfied in order to produce aerobic granules. Shear force has significant effects on the microbial structure and metabolism of microorganisms. It was found that high shear stimulates the production of polysaccharides and improves the hydrophobicity of granular sludge. It appears that the compactness and structure of granular sludge are highly dependent on cell hydrophobicity and the polysaccharide content of cells. It is reasonable to consider that hydrophobicity might act as an inducing and further maintaining force for aerobic granulation. The shear-stimulated polysaccharide production may strengthen the structure of aerobic granules and plays an important role in building-up and maintaining architecture of granular sludge. It is expected that this research should be useful for the production of aerobic granules and the development of aerobic granular sludge-based bio-reactors for handling high-strength organic wastewater.

References


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Major Fields of Expertise (list 3 from topics of category in Table 1):
Areas of Specialization (list 5 from 4 digit codes in Table 2):
Additional Areas of Interests (list 3 areas):

Professional Experience:
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Table 1 and Table 2  OCEESA Expertise and Speciality
Note:  Expertise (2 digits)  specialty (4 digits)

1 AIR POLLUTION CONTROL PROCESSES

0101 Absorption
0102 Adsorption
0103 Combustion
0104 Electrostatic precipitation
0105 Particle filtration
0106 Gravity settler
0107 Inertial separator
0108 Scrubbers
0109 Source modification
0110 Biofiltration

02 ANALYTICAL METHODS

0201 Aerosol analysis
0202 Bioassay
0203 Chromatography, gas
0204 Chromatography, liquid
0205 Electron microscopy
0206 Elemental analysis
0207 Inorganic analysis
0208 Mass spectroscopy
0209 Organic analysis
0210 Quality control
0211 Sampling
0212 Solids analysis
0213 Spectrophotometry
0214 Taste and odor
0215 Toxicity

03 ATMOSPHERIC CHEMISTRY AND AIR QUALITY

0301 Acid deposition
0302 Aerosols
0303 Chlorofluorocarbons
0304 Clouds chemistry and physics
0305 Gas-phase reactions
0306 Greenhouse gases
0307 Heterogenous reactions
0308 Indoor air quality
0309 Nitrogen oxides
0310 Ozone
0311 Photochemical reactions
0312 Smog
0313 Sulfur dioxides
0314 Transport
0315 Visibility

04 BIOLOGICAL TREATMENT
Activated sludge
Biofilm process - aerobic
Biofilm process - anaerobic
Composting
Denitrification
Kinetics
Lagoons - aquatic macrophytes
Lagoons - stabilization
Methanogenesis
Nitrification
Phosphorus removal
Septic tanks
Sludge digestion
Sulfate reduction

CHEMICAL AND PHYSICAL TREATMENT PROCESSES FOR WATER AND WASTEWATER

Adsorption
Chlorination and dechlorination
Coagulation/flocculation
Disinfection
Filtration
Flotation
Gas transfer
Ion exchange
Irradiation
Membrane processes
Ozonation
Precipitation
Sedimentation
Mixing

DRINKING WATER QUALITY

Chemicals - inorganic
Chemicals - organic
Disinfection by-products
Disinfection residuals
Microbiological
Stability
Tastes and odors

ECOLOGY

Aquatic
Microbial
Soil
Terrestrial
Toxicology
08 GEOLOGICAL SCIENCES
0801 Erosion
0802 Geology
0803 Geophysics
0804 Hydrogeology
0805 Mineralogy
0806 Sediment transport
0807 Soil classification

09 GROUNDWATER QUALITY
0901 Aquifer restoration
0902 Colloid transport
0903 Inorganic geochemistry
0904 Microbiology
0905 Monitoring
0906 Multiphase systems
0907 Organic geochemistry
0908 Radionuclides
0909 Sorption
0910 Transformation reactions

10 HAZARDOUS MATERIALS
1001 Biological treatment
1002 Characterization
1003 Chemical treatment
1004 Exposure and risk
1005 Incineration
1006 Intermedia transport
1007 Land disposal
1008 Management
1009 Physical treatment
1010 Reuse, recycling, recovery and source reduction
1011 Solidification
1012 Storage and transportation

11 HYDROLOGY
1101 Evaporation/precipitation
1102 Groundwater movement
1103 Groundwater/surface water interactions including recharge
1104 Land use
1105 Meteorology
1106 Seepage
1107 Water circulation
1108 Well analysis and design

12 HYDROMECHANICS
1201 Coastal hydraulics
1202 Cold regions
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1204 Fluid mechanics
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1606 Risk assessment
1607 Viruses

17 RADIOACTIVE MATERIALS

1701 High-level radioactive wastes
1702 Low-level radioactive wastes
1703 Radiation physics
1704 Radiotracers
1705 Radon
1706 Stable radionuclides

18 SLUDGE HANDLING AND DISPOSAL

1801 Aerobic digestion
1802 Anaerobic digestion
1803 Composting
1804 Conditioning
1805 Dewatering, centrifugal
1806 Dewatering, Filtration
1807 Dewatering, evaporative
1808 Incineration
1809 Land disposal and agricultural Use
1810 Marine disposal
1811 Thickening

19 SOLID-WASTE MANAGEMENT

1901 Biological treatment
1902 Co-disposal
1903 Incineration
1904 Landfilling
1905 Recycling and recovery
1906 Volumetric reduction

20 SURFACE-WATER QUALITY

2001 Dissolved oxygen
2002 Drinking-water supply
2003 Eutrophication
2004 Fisheries
2005 Land-use control
2005 Mixing zones
2007 Non-point sources
2008 Pathogens
2009 Photo processes
2010 Recreation
2011 Sedimentation
2012 Waste load allocation

21 WASTEWATER COLLECTION

2101 Characterization of wastewaters
2102 Corrosion control
2103 Maintenance and construction
2104 Odor control
2105 Sewerage systems
2106 Storage or retention

22 WATER CHEMISTRY

2201 Acids and bases
2202 Complexation and chelation
2203 Corrosion and material degradation
2204 Kinetics
2205 Organic transformation
2206 Oxidation/reduction reactions
2207 Photochemistry
2208 Precipitation and dissolution
2209 Sorption
2210 Thermodynamics and Equilibrium

23 WATER DISTRIBUTION

2301 Bacterial growth
2302 Construction and maintenance
2303 Corrosion
2304 Disinfectant residual
2305 Reservoirs and storage tanks
2306 Tastes and odors
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