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Overseas Chinese Environmental Engineers and Scientists Association (OCEESA) Report, Regular Issue, February 2020

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OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS AND SCIENTISTS ASSOCIATION (OCEESA) REPORT

February 2020

OCEESA Report Number: OCEESA/JL-2020/3701

OCEESA Journal Volume 37 Number 1

Dr. Yung-Tse Hung
Permanent Executive Director, OCEESA

海外華人環境保護學會

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This OCEESA report, which is regular issue of OCEESA Journal (Overseas Chinese Environmental Engineers and Scientists Association Journal). This report is OCEESA report number: OCEESA/JL-2020/3701, February 2020, ISSN 1072 -7248. This report is also OCEESA Journal, Volume 37, Number 1, February 2020. Yung-Tse Hung, Permanent Executive Director, OCEESA, is editor of this report. This issue includes 1.OCEESA Profile, 2. Report submission form NTIS, 3. OCEESA Officers and Directors, 4. Overseas Chinese Environmental Engineers and Scientist Association (OCEESA) Presidents List, 5.OCCESA President's Message, 6. OCCESA Past President's Report, 7. Call for Papers, 19th Mainland-Taiwan Environmental Protection Conference (MPEPC), Tianjin University, Tianjin, China, May 17-21, 2019, 8. Kuo-Kuang Hsu, Report on the 19th Mainland-Taiwan Environmental Protection Conference (MPEPC), Tianjin University, Tianjin, China, May 17-21, 2019, 9. 10 OCEESA Best Papers at the 19th Mainland-Taiwan Environmental Protection Conference (MPEPC), Tianjin University, Tianjin, China, May 17-21, 2019, 10. Li Zai-xing, Sun Yue, Zhang Yi-ran, Zhou Shi-lei, Water Pollution Characteristics and Water Quality Evaluation During the Freezing Period in Baiyangdian Lake, 11. Zhang Yi-ran, LI Zai-xing, SUN Yue, ZHOU Shi-lei, Nitrogen removal characteristics of a novel cold-resistant heterotrophic nitrification and aerobic denitrification bacterium, Pseudononas candensisi SY21, 12. 梁银秀, 翟洪艳, 季民, 刘伯约, 植物根系对微生物电化学系统产电和阳极微生物的影响, 13. 胡美艳, 周培疆, 江汉平原东北部浅层地下水化学成分演化规律研究, 14.黄梦露, 杨永奎, 李净宸, 赵林, 潮汐流人工湿地中全程自养生物脱氮作用的强化及其稳定性, 15. 劉乃綾, 侯嘉洪, 以靜電紡絲製備活性碳纖維電極與其於電容去離子技術之應用, 16. 李昱瑾, 駱尚廉, 以過硫酸鹽輔助超聲波增加水中異丙醇之降解, 17.許桓瑜, 廖子賢, 闕蓓德, 食物供應生命週期之衝擊分析與最佳化減量策略, 18. 陳則綸, 黃子郝, 許景翔, 陳奕宏, 蔣本基, 利用超重力旋轉填充床於電子廢棄物回收制程之懸浮微粒 去除效益評估, 19. 顏柏軒, 袁中新, 鄭柏宏, 吳建興, 高污染日不同高程 PM2.5物化特性及污染源解析, 20. 5 OCEESA papers at the 19th Mainland-Taiwan Environmental Protection Conference (MPEPC), Tianjin University, Tianjin, China, May 17-21, 2009, 21.Zhang-Zhi Charlie Huang 黄长志 , Implementing Compensation System for Environmental Damages: Challenges and Solutions, 22. Hanlu Yan, Kaimin Shih施凱閔 , Quantitative X-Ray Diffraction for Characterizing P Recovery Products from Wastewater, 23. Kaimin Shih 施凱閔 , Material Mineralogical Technology for Pollution Prevention and Resource Recovery材料礦物學技術於污染防治與資源回收的應用, 24. Kuo-Kunag Hsu 許國光 , Cleanup of MSW-Gasified Synthesis Gas, 25. Pao-Chiang Yuan 袁保強 , End of Useful Life Computer Recycling Program at Jackson State University, Jackson, Mississippi, USA, 26. Qin Qian钱琴, Bo Sun, Xianchang Li, Frank Sun, Che-Jen Lin, Water quality modeling with data collected by wireless sensor networks (WSNs) in an experimental pond: A case study, 27.Technical papers, 28. Abdulkarim Alorayfij, Yung-Tse Hung, Anaerobic digestion of agricultural waste, 29. Abdullah Alshati, Yung-Tse Hung, Methane Gas Production from Animal Waste, 30. Abdulmajeed Alshatti, Yung-Tse Hung, Treatment of Timber Industry Wastes, 31. OCEESA Constitutions By-Laws (5 November 2000 edition), 32. OCEESA Constitutions By-Laws (14 February 2006 edition), 33. OCEESA Constitutions By-Laws (27 October 2013 edition), 34. Lawrence Kong-Pu Wang letter of support Yung-Tse Hung Permanent Executive Director OCEESA12-30-20, 35. Wen-Chi Ku letter of support Yung-Tse Hung Permanent Executive Director OCEESA12-03-20, 36. OCEESA Member Application Form and Information, 37. Mailing Address Page.

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Overseas Chinese Environmental Engineers and Scientists Association (OCEESA) Profile

海外華人環境保護學會

Overseas Chinese Environmental Engineers and Scientists Association (OCEESA) 海外華人環境保護學會 is a non-profit organization incorporated in the State of Ohio in 1985, 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.

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Permanent Executive Director:	Dr. Yung-Tse Hung 洪永哲	Cleveland State University, Ohio

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LIST OF OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS AND SCIENTIST ASSOCIATION (OCEESA) PRESIDENTS

海外華人環境保護學會　會長

1	1980-81 (6-1-80 to 5-31-81)	Dr. Robert Hsi-Lin Howe (Deceased) 侯希 臨
2	1981-82 (6-1-81 to 5-31-82)	Dr. Howard Ju-Chang Huang (Deceased 1-16-18)黃汝常
3	1982-83 (6-1-82 to 5-31-83)	Dr. Edward Shing-Ke Chian 錢興格
4	1983-84 (6-1-83 to 5-31-84)	Mr. Eugene Y. Hsi (Deceased) 席與錚
5	1984-85 (6-1-84 to 5-31-85)	Dr. Allen Chia-Chen Chao 趙家珍
6	1985-86 (6-1-85 to 5-31-86)	Dr. Yung-Tse Hung 洪永哲
		(Also Executive Director 6-1-86 to present)
7	1986-87 (6-1-86 to 5-31-87)	Dr. Charles Chi-Su Chou 周基樹
8	1987-88 (6-1-87 to 5-31-88)	Dr. James Wen-Chi Ku 谷文琦
9	1988-89 (6-1-88 to 5-31-89)	Dr. Wei-Chi Ying 應維琪
10	1989-90 (6-1-89 to 12-31-90)	Dr. Lawrence Kong-Pu Wang 王抗曝
11	1991 (1-1-91 to 12-31-91)	Dr. Don Tsye-Lang Tang 唐次朗
12	1992	Dr. Chin-Pao Huang 黃金寶
13	1993	Dr. Thomas To Shen (Deceased 3-26-05) 沈鐸
14	1994	Dr. James Shia-Pin Whang 黃夏平
15	1995	Dr. Ching-Tzone Tien 田慶宗
16	1996	Dr. Jen-Tai Yang 楊仁泰
17	1997	Dr. Shoou-Yuh Chang 張守玉
18	1998	Dr. John Chao-Piao Huang 黃肇鑣
19	1999	Dr. Oliver Jing-Ching Hao 郝晶瑾
20	2000	Dr. Chang-Lu Lin 林昌爐
21	2001	Dr. Tsen-Cheng Wang 王增辰
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23	2003	Mr. Edward T. Chen 陳天生
24	2004	Dr. Chein-Chi Chang 張建祺
25	2005	Dr. Yung-Sung Cheng 鄭永松
26	2006	Dr. Francis Hun-I Chang 張恆一
27	2007	Dr. Pao-Chiang Yuan 袁保強
28	2008	Dr. Clark Chen-Kun Liu 劉成均

29	2009	Dr. Wei-Yin Chen 陳惟寅
30	2010	Dr. Wei-Ping Pan 潘偉平
31	2011	Dr. Charles Qun Cheng 程群
32	2012	Dr. David Tai-Ko Shaw 蕭台戈
33	2013	Dr. Jeff Jih-Fen Kuo 郭繼汾
34	2014	Dr. Jason Jun-Shan Wen 温俊山
35	2015	Dr. Kaimin Shih 施 凱 閔
36	2016	Dr. Pao-Chiang Yuan 袁保強
37	2017	Dr. Jy-Shing Wu 吳知行
38	2018	Dr. Qin Qian 錢琴
39	2019	Dr. Ning-Wu Chang 張寧武
40	2020	Dr. Wei-Ping Pan 潘偉平

2020 OCEESA President Message

Dear OCEESA members:

This message comes somewhat later than previous years, but I intend to use the opportunity to wish all OCEESA members and their families a happy, healthy and prosperous New Year.

I would like to congratulate Dr. Ning-Wu Chang, 2019 OCEESA President, for his excellent leadership, culminating to a successful year for our Association during his presidency. Under his leadership, OCEESA successfully completed the 19 th MTEPC in Tianjin in May 17-22, 2019 and has upgraded the OCEESA web site (http://oceesa.org/), which now has more capabilities and is compatible with mobile device viewing. Dr. Chang's dedication and contribution has led our Association toward a stronger and more vibrant organization that we will all benefit from for the years to come. Dr. Chang has agreed to continue to lead the committee of the 2021 AAEOY event tasks.

My heartfelt congratulations to the newly elected officers and board members. Our executive committee and the board this year have diversified expertise. Moreover, several relatively new, enthusiastic members of OCEESA will mingle with the veterans. We believe that this balanced team will lead to fresh ideas that will produce lasting impacts for OCEESA.

Looking ahead, we have the following activities planned for this year, and I strongly encourage each member to participate and support these events to the fullest extent you are able to:

- We plan to celebrate OCEESA's 40 th anniversary in 2020 (OCESSA was established in 1980) along with the 20 th MTEPC event. Dr. Chang is working with Taipei University of Technology to initiate the planning activities. We hope that everyone can participate in this upcoming event and celebrate OCEESA's 40 th anniversary. It most likely will be in October/November of 2020.
- The 28 th METS (Modern Engineering Technology Seminar) event will be held in Taipei between October 25 and 28, 2020, including four major topics (AI manufacturing, Finance, Medical and Transportation). Call for abstract for this meeting will be sent very soon.

- The 2020 AAEOY will be from 5/1-2 at the Santa Clara Convention Center and the current event information is on their website: http://2020.aaeoy.org/index.php.
- OCEESA and CIE-SoCal will co-host the 2021 AAEOY in the Los Angeles area. Dr. Ning-Wu Chang is the co-chair for this event. We do need volunteers to support this event.

I will devote my leadership to showcase OCEESA and its capabilities in addressing significant environmental issues in both mainland China and Taiwan. OCEESA has many experienced environmental engineers, scientist, planners and professors. These members are highly regarded treasures for OCEESA and for mainland China and Taiwan. As OCEESA President, I will work hard and promote our resources and their expertise in solving environmental problems facing mainland China and Taiwan through workshops and conferences.

Best Regards,

Wei-Ping Pan
2020 OCEESA President

Sumpter Professor Emeritus of Chemistry
Western Kentucky University
Phone: (270) 792-3776
E-mail: wei-ping.pan@wku.edu

2019 OCEESA President Report

Dear OCEESA Members:
Happy Chinese New Year and Lantern Festival! As the OCEESA 2019 President, I like to take this opportunity to report OCEESA's 2019 activities and also look for your continuous support for the upcoming activities.

2019 Activities:

1. During CIE-NC (Chinese Institute of Engineer – National Council) Fall Meeting on 10/14/18, OCEESA was on rotation to plan the 2019 Spring Meeting. OCEESA joined CIE-SFB Chapter to co-host the CIE-NC Spring Meeting on 2/14/19, the day after CIE-SFB 40th anniversary event on 2/23/19.

2. OCEESA members – Ning-Wu Chang （张宁武）, Jason Wen（温俊山）, Anmin Liu （劉安民）, John C P Huang（黄肇镳）, and George Tsung-Chu Chien （钱宗驹） (representing OCEESA), and Yung-Sung Cheng （郑永松）(representing CIE-NM) attended CIE-NC 2019 Spring Meeting on 2/24/19 in Santa Clara, CA. By rotation, OCCESA and CIE-SoCal are scheduled to co-host the 2021 AAEOY (Asian American Engineer of the Year) event. It was agreed to have CIE-SoCal taking the lead for the 2021 event this time. The 2021 AAEOY proposal to have the event co-hosted by OCEESA and CIE-SoCal in the Los Angeles area was well received and approved by the CIE-NC.

3. The 19th MTEPC (Mainland-Taiwan Environmental Protection Conference) was Held from May 17 – 22, 2019, in Tianjin （天津）, China. OCEESA members – Qin Qian (錢琴), Pao-Chiang Yuan (袁保強), Kaimin Shih (施凱閔), and Kuo-Kuang Hsu (許國光) attended this successful and most attended event. The MTEPC Consultative Committee meeting held on May18, 2019, during this conference, selected Taipei University of Technology (臺北科技大學, abbreviated as 北科大), assisted by Tianjin University (天津大學), to host the 20th MTEPC in Taipei in late 2020. A full report on this event has been distributed.

4. OCEESA members – Ning-Wu Chang, Jason Wen, and Yung-Sung Cheng attended CIE-NC 2019 Fall Meeting on 8/18/19 in Dallas, TX, following the 2019 AAEOY event hosted by CIE-Dallas on August 16-17, 2019. To be ready for the upcoming 2021 AAEOY event, members from OCEESA and CIE-SoCal exchanged information during this event with other CIE chapters.

5. We have upgraded the OCEESA web site (http://oceesa.org/) and the new web site was launched in December 2019. The new web site has more capabilities and is now compatible with mobile device viewing. The new web site also allows member to update their information and pay their membership due or donation on-line. With the upgraded web site, we hope to expand our social media capability (OCEESA has a Face Book page OCEESA Overseas Chinese Environmental Engineers and Scientists Association and WeChat group already), and to have

better communication with members and future activities, such as podcasting, as well as to recruit new members. Ultimately, we hope this web site upgrade would improve OCEESA sustainability and succession issues. At the meantime, please use these new features on the web site to update your information as appropriate with the link Membership Application – Overseas Chinese Environmental Engineers & Scientists Association.

Other Activities:

1. To co-host the 2021 AAEOY, Ning-Wu Chang from OCEESA and Chuching Wang（王竹青）from CIE-SoCal will be the co-chairs of the CIE event committee. The preparation work for the 2021 AAEOY already began in 2019. Ning-Wu Chang, Jason Wen, and Anmin Liu from OCEESA attended various meetings with CIE-SoCal on 1/13/19, 2/17/19, and 11/24/19 to coordinate the 2021 AAEOY event tasks. We do need volunteers to support the event. Please let us know if you would like to help.

2. We plan to celebrate OCEESA's 40th anniversary in 2020 (OCEESA established in 1980) along with the 20th MTEPC event in Taipei. Ning-Wu Chang from OCEESA met with the representative from Taipei University of Technology in Taipei in October 2019 to initiate the planning activities. Based on the discussion, the event date will be further coordinated between the 20th MTEPC and CIE's 28th METS (Modern Engineering and Technology Seminar) to be held in Taiwan in 2020. We hope you all can participate this upcoming event and celebrate OCEESA's 40th anniversary. We will let you know once the event date is selected, most likely in October/November of 2020.

3. We also like to improve our future social media communication and implement the podcasting activity. We certainly like to have your supports and participation on the activities in the future.

We always welcome inputs and volunteers to help OCEESA activities. Please let us know if you like to get involved in these activities.

Thank you for your supports in 2019.

Ning-Wu Chang
OCEESA 2019 President

February 5, 2020

Call for Papers

论文征稿

第十九届海峡两岸环境保护研讨会

The 19th Mainland-Taiwan Environmental Protection Conference (MPEPC)

Tianjin University, Tianjin, China

May 17 – 21, 2019

议题：科技创新及生态环境可持续发展

Theme: Technological innovation and Sustainable development of Ecological environment

2019 年 5 月 17 日～21 日

Conference Organizers: Tianjin University, Taiwan University, OCEESA

主办单位

大陆：天津大学 （天津）
台湾：台湾大学 （台北）
海外华人环境保护学会（**OCEESA**）

缘起：

“**海峡两岸环境保护研讨会**”为海峡两岸环境保护领域有识之士与“海外华人环保学会（OCEESA）”共同发起的会议，迄今已成功举办了十八届。研讨会涉及环境污染治理、可持续生态环境管理、环境经济及政策、环保产业等领域。第十九届海峡两岸环境保护研讨会将于**2019年5月17日～21日**在**天津大学**举办。

天津，是我国四大直辖市之一，环渤海地区经济中心、首批沿海开放城市，先进制造研发基地、北方国际航运核心区、金融创新运营示范区。天津位于华北平原海河五大支流汇流处，东临渤海，北依燕山，海河在城中蜿蜒而过。经历600余年的沧海桑田，特别是近代百年，造就了天津中西合璧、古今兼容的独特城市风貌，形成“近代百年看天津”共识。

天津大学是教育部直属重点大学，其前身为北洋大学，始建于1895年，是我国第一所现代大学，素以“实事求是”的校训、“严谨治学”的校风和“爱国奉献”的传统享誉海内外。1951年经国家院系调整定名为天津大学，是1959年我国首批确定的16所国家重点大学之一，是“211工程”、“985工程”首批重点建设的大学，入选国家“世界一流大学建设”A 类高校。

本次会议，汇聚两岸及海外地区环保专家学者，讨论环保议题、考察实际环境、落实环保执行，是海峡两岸及海外华人环保专家之珍贵交流机会。**主办单位诚恳期待大家踊跃参与，共创两岸经济发展与环境保护的永续之路**。

会议咨议委员会（按照笔画排序）

海外华人环境保护学会

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施凯闵	（Kaimin Shih）	张宁武	（Ning-Wu Chang）
吴知行	（Jy-Shing Wu）		

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康世芳	（淡江大学）	张章堂	（宜兰大学）

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会议主题：科技创新及生态环境可持续发展

征文议题

（1）海岸带环境污染控制与管理

（2）土壤和地下水污染修复技术

（3）城市绿色基础设施与海绵城市

（4）废水废物处理与资源化技术

（5）大气污染防治与质量管理

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（7）地球关键带生态系统服务

（8）区域环境治理及生态安全

（9）环境规划、管理及政策

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（13）环境污染治理新技术、新设备

（14）工业园区环境管理

会议议程：包括研讨会、环保设施及生态考察。

征文办法

请于 **2018 年 12 月 31 日**前将一页中文或英文论文摘要表（500 字以内）并注明通讯作者姓名及地址发邮件至**筹备委员会联络人**。论文摘要经审查通过后，于 2019 年 1 月 15 日前通知接受及发表方式。被接受之论文请于 2019 年 2 月 10 日前邮件发中文或英文论文全文。

将邀请相关领域重要期刊主编、副主编与参会者面对面讨论，并组织相关期刊专刊。

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1. 论文摘要截止日期：　2018年12月31日

2. 论文接收通知日期：　2019年1月15日

3. 论文全文截止日期：　2019年2月10日

4. 会议报道注册日期：　2019年5月17日

4. 研讨会会期：　2019年5月18-19日

5. 环保设施、环境生态保护区之参观考察（自由参加）：2019年5月20-21日

研讨会正式语言、文字及原则

1. 中文简体、繁体或英文均视为正式文字。

2. 大会正式语言为汉语。

3. 研讨会任何场合不展示有政治性标志，不发表或传播有政治性言论、主张或音像制品。

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摘要范本

滨海地区土壤盐分空间分布预测方法比较研究

陈三[1]、许四[1]、李五[2]

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以天津滨海地区为例,利用4种确定性方法(反距离权重、径向基函数、全局多项式、局部多项式)和5种地统计方法(普通克里格、协同克里格、泛克里格、指示克里格、序贯高斯模拟)对典型样区进行土壤盐分空间分布估计、土壤盐渍化风险区域识别及其不确定性评价,并针对不同方法的预测效果进行了综合对比分析.结果表明:地统计方法的插值精度整体上优于确定性方法,序贯高斯模拟具有相对最高的预测精度;模拟结果的统计特征与实测数据的一致性较高,预测表面对局部细节的反映能力较强;在以含盐量0.6%,为阈值的土壤盐分含量不确定性评估中,序贯高斯模拟可通过多次模拟实现将环境风险性定量化,是科学管理滨海地区盐渍化土壤资源的有效手段.

关键词：土壤盐分; 空间分布; 序贯高斯模拟; 不确定性评价

Report on the 19th Mainland-Taiwan Environmental Protection Conference (MPEPC), Tianjin University, Tianjin, China, May 17-21, 2009

Dr. Kuo-Kuang Hsu 許國光
CIE/USA National Council Chair 1997
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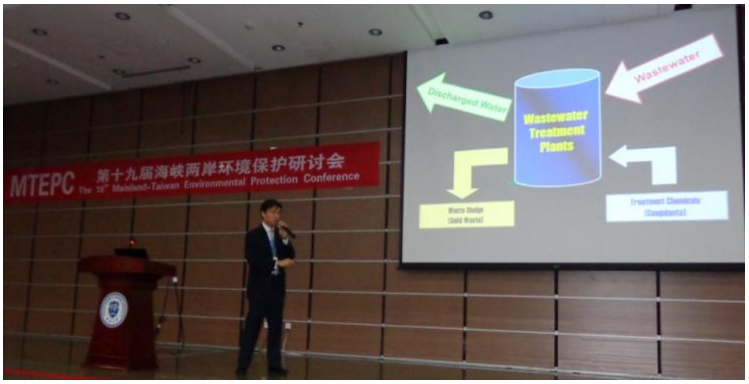
The 19th Mainland-Taiwan Environmental Protection Conference (MTEPC) was held from May 17 to 21, 2019 in Tianjin (天津). Two hundred and eighty-five Chinese environmental scientists, engineers and graduate students from Mainland, Taiwan, and Overseas attended the conference. A total of 176 technical papers were presented in eight concurrent technical sessions, including 38 technical papers presented by graduate students working on their master or doctoral degrees. All of the technical papers were edited and published by the conference organizing committee in conference proceedings (digitized in a USB card). In addition, there were 32 posters of research studies by graduate students displayed during the Conference.

At the opening ceremony representatives from the three organizing bodies addressed the audience; they were Vice Secretary of Tianjin University, the past president of Overseas Chinese Environmental Engineers and Scientists Association (OCEESA), professor Qin Qian (錢琴) (photo 1), and professor Shang-Liang Lo (骆尚廉) of Taiwan University from Taipei. After the opening ceremony all the participants were invited to take a group picture (photo 2).

Photo 1: Prof. Qian addressing the audience at the opening ceremony

Photo 2: Group photo following the opening ceremony

In the plenary session six invited speakers spoke over a wide spectrum of topics with respect to latest advances in environmental protection science and technology, directions of future water-management-mined city design and endeavors of China’s environmental protection businesses. Professor Kai-Min Shih representing OCEESA was one of the six invited speakers and made a presentation entitled “材料礦物學技術於汙染防治與資源回收的應用” (photo 3). Different from the previous conferences was invitation of a non-Chinese speaking scholar – Professor John Crittenden of George Tech, with a presentation title of “The Application of Advanced Oxidation Processes (AOPs) and Development of Electrochemical Advanced Oxidation Processes (EOPs)”



Four OCEESA members attended the conference - Professors Qin Qian (錢琴), Kaimin Shih, (施凱閔), Pao-Chiang Yuan（袁保強）and Dr. Kuo-Kuang (許國光). They were actively involved in the conference and interacted with other participants. Their activities during the conference are to be reported below.

In this summary report, a few highlights of the 19th MTEPC are provided below.

1. Highlights of the 19th MTEPC

The conference was second most attended only next to the one held at Wuhan (武漢). All sessions proceeded on schedule, and facilities and convenience were adequately provided for interaction among attendees. From the arrival of guest attendees in Tianjin till departure, reception, registration, dining, etc. were all arranged diligently with genuine hospitality by Tianjin University – we appreciated.

In addition to the traditional organizing trio (Environmental Protection professionals in Mainland, Taiwan and Overseas), for this conference, from Tianjin and Beijing three institutes joined as assisting organizations and three companies and one institute as supporting organizations. Such addition demonstrates a successful expansion of the conference to reach into industry/businesses.

An MTEPC Consultative Committee meeting was held on the evening of May18, 2019. The committee made the following important resolutions.

(1) The next MTEPC will be hosted by Taipei University of Technology (臺北科技大學, abbreviated as 北科大)[1], assisted by Tianjin University (天津大學). Conference timing is tentatively set in November, 2020.

(2) Qingdao University of Technology (青島理工大學) expressed strong interest in hosting the 21th MTEPC and the Consultative meeting welcomed the intention with tentative decision on the conference at such location.

(3) The Consultative committee will establish two awards to be presented at the 20th MTEPC: Life-time Achieve Award (終身成就獎) and Extraordinary Contribution Award (卓越貢獻獎).[2]

(4) With the existing platform of the Consultative Committee, some senior committee members propose to further promote interactions in such scopes as environmental protection education, science and technology and industry/business both in Mainland and in Taiwan.

On the fourth day of the conference (May 20, 2019), some conference participants went for site visits to (Tianjin) Limutai (梨木臺) (photo 4), where Tianjin University conducts extensive geological ecology studies. On the return, the team stopped by Eastern Royal Tombs of the Qing Dynasty (清東陵) briefly to view the commingling of nature and history.

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[1] Contact : Prof. Tien-Chin Chang (張添晉教授 – 北科大), tcchang@ntut.edu.tw.

[2] Extraordinary Award is to be presented to those who will have made outstanding contribution to the establishment and continuing support of the MTEPC (Mainland-Taiwan Environmental Protection Conference).

Photo 4: A natural scene of Limutai in Tianjin

2. OCEESA Participation in the 19th MTEPC

Activities of OCEESA's attendees can be summarized in a few occasions:

- The past President, Professor Qin Qian (錢琴), addressed at the opening ceremony.
- Professor Kaimin Shih delivered a keynote speech entitled "材料礦物學計術於汙染防治與資源回收的應用" in the plenary session.
- In addition to the keynote by Prof. Kaimin Shih, four papers were presented by the four OCEESA attendees.

1. *Water quality modeling with data collected by wireless sensor networks (WSNs) in an experimental pond: A case study*
   Presenter: Professor Qin Qian (錢琴)

2. *End of Useful Life Computer Recycling Program at Jackson State University, Jackson, Mississippi, USA*
   Presenter: Professor Pao-Chiang Yuan（袁保強）(photo 5)

3. *Qualitative X-Ray Diffraction for Characterizing P Recovery Products from Wastewater*
   Presenter: Professor Kaimin Shih (施凱閔）

4. *Cleanup of MSW-Gasified Synthesis Gas*
   Presenter: Dr. Kuo-Kuang Hsu（許國光）(photo 6)

Photos 5 and 6: Prof. Yuan (l) and Dr. Hsu (r) made presentations in the session of "Solid Waste Management and Reutilization)

- At the closing ceremony, Professor Qin Qian presented special awards to outstanding conference contributors in recognition of their superb support to the conference over the past years. (photo 7)

Photo 7: Awards presented to outstanding conference organizers. Left to right: Kuo-Kuang Hsu (OCEESA), HongBo Liu (Tianjin U.), Pen-Chi Chiang (Taiwan U.), Wan-Fa Yang (Taiwan U.), Qin Qian (OCEESA), (to be identified), Shang-Liang Lo (Taiwan U.) and Pao-Chiang Yuan (OCEESA).

- At the closing ceremony, Professor Qin Qian presented OCEESA's Best Paper Awards, which was a great encouragement to graduate students. The presentation was a highlight to and brought a delightful moment at the closing ceremony. Nine awards were given with OCEESA certificates and a $100 cash award each. (see Photo 8)

Photo 8: Best Paper Awards presented by OCEESA

- All four OCEESA participants attended the organizers' Consultative meeting and engaged in active discussion regarding future directions of the conference, in particular, at the time in preparation for the 20th MTEPC, a major milestone of the Conference.
- Off the formal conference sessions, OCEESA members actively interacted with Tianda（天大）helping graduate students providing advices on career, new development directions in Environmental Protection domain, or even discussion of fundamental methodology of research, etc.
- Dr. Kuo-Kuang Hsu attended the ecological site visit (on May 20).

During the 19th MTEPC, all the four attending OCEESA members exchanged views informally concerning involvement of the organization in the future MTEPCs. General consensus is (a) to encourage more members to attend the conference, (b) to encourage members to be more engaged in the conference in a more meaningful fashion, and (c) to recruit more environmental protection professional (outside the mainland and Taiwan) to join the OCEESA organization.

白洋淀冰封期水污染特征及水质评价[1]

李再兴，孙悦，张艺冉，周石磊*
（河北科技大学环境科学与工程学院 河北省污染防治生物技术实验室）

摘要：为明确白洋淀冬季水污染特征，于 2019 年 1 月对白洋淀旅游区、原始区、生活区、养殖区和入淀区 5 个监测断面 25 个表层水样采集，选取 pH、氨氮(NH_4^+-N)、总氮(TN)、总磷(TP)、高锰酸盐指数、溶解氧(DO)作为评价因子，并采用单因子评价法、综合污染指数(K)法和主成分分析法对水质进行综合评价。结果表明：白洋淀水体呈碱性，TN 和 TP 含量较高。单因子评价表明，TN 和 TP 为白洋淀水质主要限制因子，TN 参与评价时，25 个采样点中，Ⅲ类水体占 28%，其余为Ⅳ类、Ⅴ类和劣Ⅴ类；TP 参与评价时，Ⅲ类水体占 20%，其余为Ⅱ类和Ⅴ类，综合看，白洋淀水质受 TN 影响更大；综合污染指数法表明，白沟引河、府河和瀑河三条入淀口河流水质状况最差，为重度污染，主要污染物为 NH_4^+-N、TN、TP；主成分分析法表明，原始区及旅游区水质较好，生活区水质次之，养殖区及入淀区水质较差，主要受 TN、TP 的影响。通过 3 种评价方法定性定量的有机结合，为全面评价白洋淀污染特征和水质状况奠定基础，也为治理和修复淀区污染提供指导意义。

关键词：白洋淀；冰封期；水污染特征；水质评价

Water Pollution Characteristics and Water Quality Evaluation During the Freezing Period in Baiyangdian Lake[1]

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Abstract: In order to clarify the winter water pollution characteristics of Baiyangdian Lake, In January 2019, 25 surface water samples were collected from five monitoring sections of Baiyangdian Tourist Area, Original Area, Living Area, Breeding Area and Entering Area. pH, ammonia nitrogen (NH_4^+-N), total nitrogen (TN), total phosphorus (TP), permanganate index, dissolved oxygen (DO) were selected as evaluation factors,and single factor evaluation method and comprehensive pollution index (K) were adopted. Comprehensive evaluation of water quality by method and principal component analysis. The results show that the water quality of Baiyangdian Lake is alkaline and the content of TN and TP are high. The single factor evaluation showed that TN and TP were the main limiting factors for Baiyangdian water quality. When TN participated in

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the evaluation, among the 25 sampling points, Class III water bodies accounted for 28%, and the rest were Class IV, Class V and inferior Class V. When TP participated in the evaluation, Class III water bodies account for 20%, and the rest are Class II and Class V. In general, the water quality of Baiyangdian Lake is more affected by TN; the comprehensive pollution index method shows that the water quality of the rivers in Baigou River, Fuhe River and Puhe River are the worst. For heavy pollution, the main pollutants are NH_4^+-N, TN, TP. Principal component analysis shows that the water quality in the original area and tourist area are good, the water quality in the living area is second, and the water quality in the culture area and the entering area are poor, mainly by TN. and TP. The qualitative and quantitative organic combination of the three evaluation methods lays a foundation for comprehensive evaluation of the pollution characteristics and water quality of Baiyangdian, and also provides guidance for the treatment and restoration of pollution in the sedimentary area.

Key words: Baiyangdian Lake; freezing period water ; pollution characteristics ; water quality evaluation

1 引言

人类活动和全球气候变化引起了水质恶化、湖泊富营养化、水生态环境破坏等一系列的水环境问题，如何改善水污染现状已成为区域水环境研究中迫切需要解决的问题[1, 2]，而河流水质因子众多，受地理环境、气候因素、以及人类活动的影响使得流域水质在时空上呈现较大的异质性[3, 4]。因此在对水环境治理前，对水质状况进行合理且准确的分析评价，可为水环境治理提供准确信息。

白洋淀作为华北平原最大的淡水湖泊，对维护华北地区生态系统平衡、调节华北平原乃至京津地区气候、补充地下水源、调蓄洪水以及保护生物多样性和珍稀物种资源等方面发挥重要作用[5]。随着雄安新区的设立，白洋淀的生态环境越来越受到重视，因此采用合适的方法对白洋淀水质现状进行科学评价和揭示其污染特征具有十分重要的意义。目前，常用的水质评价方法主要有单因子评价法[6]、综合污染指数法[6, 7]、综合水质标识指数法[8]、模糊综合评价法[6]、主成分分析法[9, 10]等，这些评价方法各有优缺点，侧重点也不同，因此，将多种评价方法有机结合更能科学合理地评价白洋淀的水质状况。

白洋淀总面积达 362.8km^2，淀内主要由大小不等的 143 个淀泊和 3700 多条沟壕组成，以水体为主，水域间有苇田、台地、村庄[11]。迄今为止，针对白洋淀的水质评价主要选取部分河流或部分淀区为主且评价方法单一，例如王瑜等[12]利用应用修正的卡尔森营养指数和优势种评价法对对枣林庄、端村的营养状态进行评价，结果显示两个淀区的水体处于中度富营养状态。王朝华等[13]对府河水质进行评价，结果表明府河水质污染严重，应加紧对府河水质的治理。为明确白洋淀整体水质情况，对白洋淀各淀区、河流的水质进行客观评价，本研究根据各淀区的承载功能，将白洋淀分为五个功能区[14, 15]，每个功能分区选择具有代表性的采样点进行水样的采集和分析，采用单因子评价法、综合污染指数法和主成分分

析法进行定性和定量评价，探究白洋淀的主要污染因子，以期为治理和修复淀区污染提供参考依据。

2 材料与方法

2.1 样品采集

根据白洋淀各淀区承载功能不同，将白洋淀分为原始区、旅游区、生活区、养殖区、入淀区五个监测断面（图 1a），原始区包括藻苲淀 1#（S1）、藻苲淀 2#（S2）、藻苲淀 3#（S3）3 个采样点，旅游区包括烧车淀（旅游码头）（S4）、鸳鸯岛-旅游区（S5）、文化苑西门（S6）3 个采样点、生活区包括枣林庄（S7）、平阳淀（S8）、小麦淀（S9）、北田庄西淀（S10）、涝王淀（S11）、采蒲台北（S12）、范峪淀（S13）7 个采样点，养殖区包括前塘（S14）、后塘（S15）、端村 1#（S16）、端村 2#（S17）、泛鱼淀（S18）、鲥鯸淀（S19）6 个采样点，入淀区包括白沟引河（S20）、萍河藻苲淀入淀口（S21）、瀑河藻苲淀入淀口（S22）、唐河端村入淀口（S23）、南刘庄府河入淀口（S24）、猪笼河入淀口（S25）6 个采样点。于 2019 年 1 月对 25 个采样点采集表层（0.5m）水样。（图 1b）

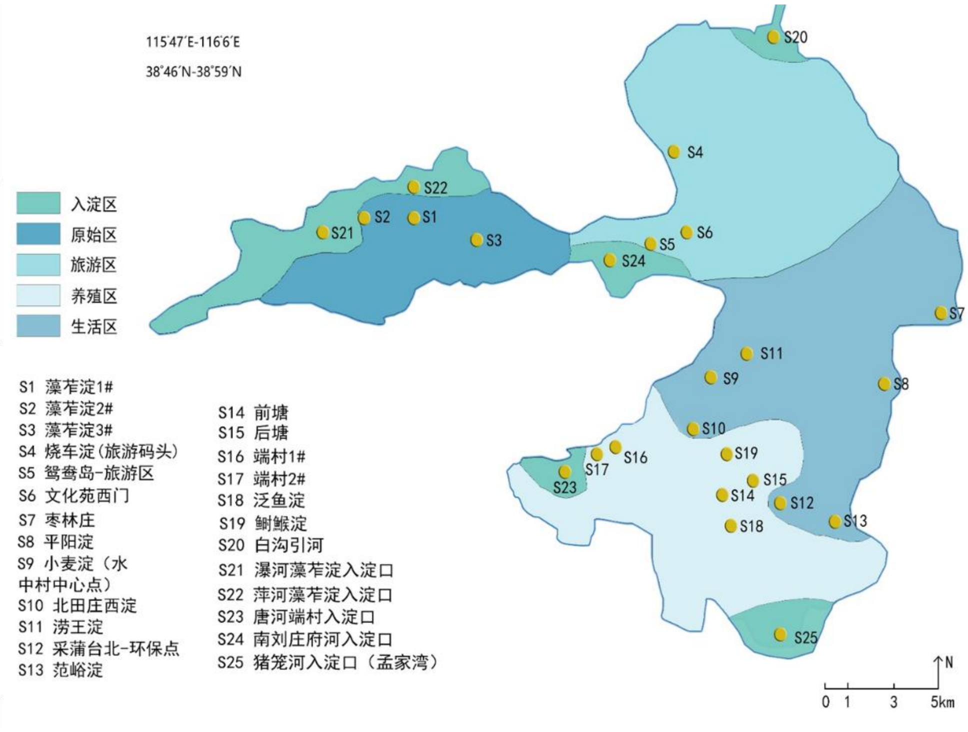

图 1 白洋淀采样断面图

2. 2 测定方法

本研究测定了白洋淀 5 个监测断面 25 个水样的 6 个水质指标，其中 pH、溶解氧（DO）利用多参数水质分析仪现场测定，高锰酸盐指数采用酸性法测定，氨氮(NH_4^+-N)采用纳氏试剂光度法测定，总氮（TN）采用过硫酸钾氧化－紫外分光光度法测定，总磷（TP）采用钼锑抗分光光度计法测定。

2. 3 数据处理与评价方法

采用 IBM SPASS17.0 软件对数据进行统计分析，为确保结论的准确性，本研究中单因子评价法、综合污染指数法、主成分分析法均采用 6 个水质指标进行

评价。

2.3.1 单因子评价法

单因子评价法采用一票否决法原则，即根据评价时段内该断面参评的指标中类别最高的一项来确定该断面水质类别。在所有参评水质指标中，如有一项指标超标，则所属水域不符合相应的水质标准[16]。

2.3.2 综合污染指数（K）法

综合污染指数（K）法是我国第一个综合表示水质污染情况及综合评价水污染的指数，它企图用一种最简单的，可以进行统计的数值来评价水质污染情况。它在空间上可以对比不同河段水体的水质污染程度，便于分级分类；在时间上可以表示一个河段，一个地区水质污染的总的变化趋势，其表达式是：

$$K=\sum Ci*Ck/Coi$$

式中：Ci 指各类污染物的实测浓度（mg·L^{-1}）；Coi 指各类污染物评价标准值；Ck 指地表水各类污染物的统一标准值，此值为 0.1。综合污染指数法评价分级标准见表 1[17]。

表 1 综合污染指数法评价分类标准

K 值	K＜0.1	0.1＜K＜0.2	0.2＜K＜0.5	0.5＜K＜1.0	K＞1.0	K＞5
污染程度	一般或未受污染水体	微度污染水体	轻度污染水体	中度污染水体	重度污染水体	严重污染水体

2.3.3 主成分分析法

主成分分析法是通过原有变量的线性组合以及各个主成分的求解来实现变量降维。它的主要目的不是将那些不太重要的指标去掉，而是通过全面分析各项指标所携带的信息，筛选出比原始指标少，但能解释大部分资料的综合性指标[18]。

3 结果与讨论

3.1 水质因子特征

3.1.1 理化和营养盐指标

图 2 显示了白洋淀冰封期各采样断面的理化和营养盐水质指标情况，由图 2 可知，白洋淀各采样点的 pH 范围为 9.13-10.2，呈碱性，pH 值最高的区域出现在了原始区的 S3 采样点，最大值为 10.2，其余各采样点的 pH 数值变化不大，均在 9-10 之间；NH_4^+-N 的范围为 0.009-0.736mg·L^{-1}，水中氨氮的来源主要为生活污水中含氮有机物受微生物作用的分解产物，其中 S20 是白沟引河采样点，白沟引河处设立了防洪闸，承担了白洋淀抗洪蓄水的责任[19]，随着时间的积累，此采样点受到外源性污染物较多，氨氮值最高为 0.736mg·L^{-1}，旅游区的 S4 和 S6 采样点氨氮值最低为 0.009mg·L^{-1}，该淀区的功能是承接游客，周边无居民居住，没有生活垃圾排入水中，因此水质中氨氮含量较低；TN 的变化范围在 0.837-8.131mg·L^{-1} 之间，各功能区水质的 TN 含量变化范围较大，入淀区 6 个采样点的 TN 值均较高，S24 的 TN 值达到了 8.131mg·L^{-1}，污染最为严重，根据功能分区进行数据分析可知 6 条入淀区不仅承载了白洋淀淀区自身的水体，还承接了大清

河流域水系，因此汇入河流中的污染物较多；TP 的变化范围在 0.043-1.620mg·L^{-1}之间，通过数据可以得出 TP 的变化趋势和 TN 类似，入淀区河流的值偏高，可能是输入入淀区河流的污染物较多，导致入淀区河流水质较差。因此在对白洋淀水质进行治理时，入淀区河流的水质应进行重点治理，水质中的氮磷污染物应成为重点去除污染物质。

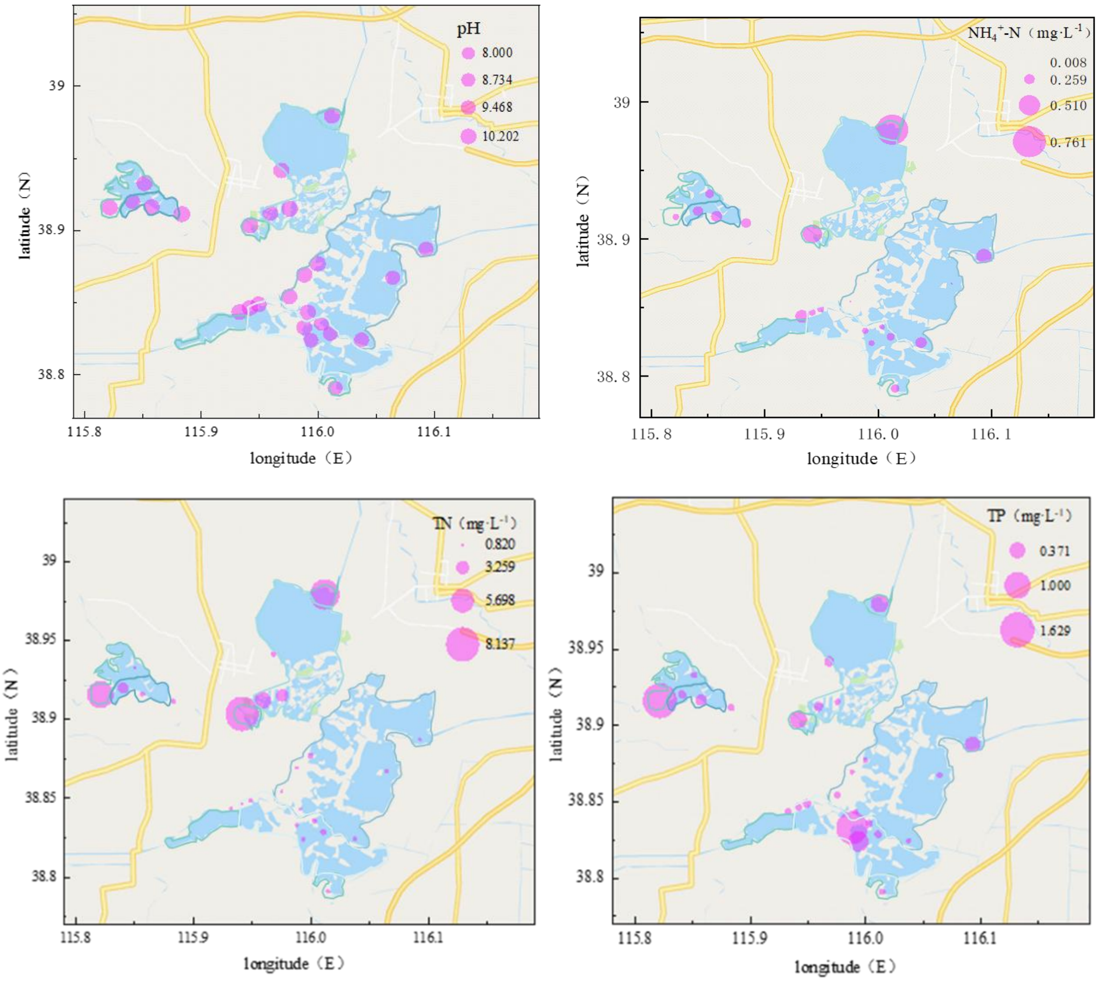

图 2 白洋淀采样点理化和营养盐指标

3.1.2 有机污染指标

由图 3 可知，DO 在各个采样点之间的数值相差较大，其中原始区的 S2 采样点溶解氧为 9.82mg·L^{-1}，高于地表水质量标准□类限值（7.5mg·L^{-1}），水体以呈现了过饱和状态，这可能与原始区内芦苇、藻类物质生长过盛，导致水体状态达到过饱和状态，位于生活区的 S8 采样点溶解氧最低为 0.53mg·L^{-1}，可能是当地居民的生活垃圾、日常废水排放入淀区，导致淀区的水体受到有机与无机还原性物质的污染，使得淀区中溶解氧含量降低。高锰酸盐指数常被作为地表水体受有机污染物和还原性无机物质污染程度的综合指标，数据显示高锰酸盐指数的变化范围在 4.738-8.755mg·L^{-1}之间，80%的采样点高于 6mg·L^{-1}（□类水质标准限值），位于养殖区的 S15 采样点高锰酸盐指数值最高，为 8.755mg·L^{-1}，可能是养殖区水域大面积发展养鱼蟹，水中投放的大量饵料除被鱼蟹食用外，大部分的饵料沉

积水中，污染淀区水质。

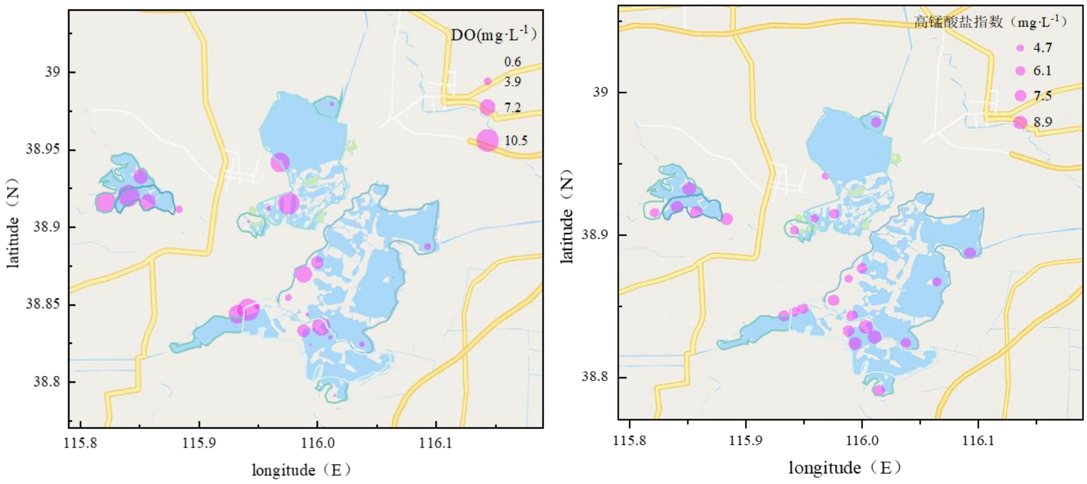

图 3 白洋淀采样点有机污染指标

综合图 2 图 3 显示出的数据可知，白洋淀水体呈碱性，各采样点中 TN 和 TP 的水质指标变化幅度较大且大多数采样点 TN 和 TP 含量较高，超过了□类水体的限值，淀区中的污染主要来源于居民生活和养殖面源污染，这与阳小兰[20]得出的总氮总磷是白洋淀的主要污染物的结论相一致。

根据文献发现，我国淡水湖的主要污染指标均为 TN、TP，与其他淡水湖相比（表 2）[21-24]，太湖的 TN 变化范围较小，水质指标均超过了地表水□类限值，巢湖、小兴凯湖、鄱阳湖 TN 指标变化幅度较大，湖泊水质污染程度差异大，根据数据显示可得白洋淀淀区水体 TN 含量与小兴凯湖的 TN 含量变化范围最为接近，最小值均未超过地表水□类限值（1mg·L^{-1}），但最小和最大值的变化幅度较大，这说明白洋淀和小兴凯湖内部的水质污染程度差异较大，治理时应针对具体区域采取相应的办法；太湖、巢湖、小兴凯湖、鄱阳湖的 TP 含量与白洋淀相比含量较低，这说明白洋淀水体不仅受 TN 影响较大，TP 对其的影响也较为显著，在对水质进行治理时，应重点关注对 TN、TP 的降解。

表 2 白洋淀主要污染指标与国内其他淡水湖的比较

研究区域	TN（mg·L^{-1}）	TP（mg·L^{-1}）	主要污染指标
白洋淀	0.837-8.131	0.043-1.62	TN、TP
太湖	3.06-4.9	0.1-0.27	TN、TP
巢湖	1.07-10.22	0.06-0.47	TN、TP
小兴凯湖	0.49-8.35	0.011-0.382	TN、TP
鄱阳湖	0.48-4.13	0.01-0.61	TN、TP

3.2 单因子评价结果

采用单因子评价法对各采样点的水质类别进行评价时，当定类项目为 TP，TN 不参与评价时，25 个采样点中，S3、S6、S8、S9、S10、S11、S12、S13、S15、S16、S17、S19、S21、S25 达到□类水水质标准，占到 25 个采样点的 56%，比例最大；S1、S2、S4、S5、S23 达到□类水标准，占总采样点的 20%；其中 S7、S14、S18、S20、S22、S24 为□类水质，占 24%。当定类项目为 TN，TP 不参与

评价时，采样点中 S7、S9、S10、S16、S17、S19、S21 达到□类水质的标准，占比 28%；S1、S3、S4、S8、S13、S14、S15、S18、S23、S25 共 10 个采样点为□类水质，占到的比例最大，为 40%；S11、S12 采样点的水质为□类水质，占比 8%；其中以 TN 作为参考项目时，S2、S5、S6、S20、S22、S24 这 6 个采样点的水质达到了劣□类水质标准，占到总采样点的 24%，这 6 个采样点中，入淀区河流占到了一半，这说明入淀区河流不仅要承担白洋淀自身的内源污染物，还要接纳外界河流汇入的外源污染物，这与张铁坚[25]对于入淀区河流的研究结果相一致。

根据以上分析结果，可以得出在用单因子评价方法对白洋淀水质进行评价时，TN 和 TP 是白洋淀冰封期水质的限制因子，因此在水质治理时，对氮磷污染物的去除将成为治理重点，同时也要对入淀区河流水质的治理给予重点关注，只有有效改善入淀区河流的水质，才是净化白洋淀水体的关键。

3.3 综合污染指数评价结果

采用综合污染指数法对白洋淀冰封期 25 个采样点的综合污染指数进行计算，结果见图 3（a），原始区、旅游区、生活区、养殖区、入淀区的综合污染指数范围分别是 0.389-0.66、0.463-0.635、0.257-0.425、0.264-1.047、0.292-1.77，根据图中的功能分区，对 25 个采样点进行分析可知，16 个采样点的水质级别是轻度污染，5 个采样点水质是中度污染，其中 S14、S20、S22、S24 这四个采样点的水质到了重度污染的级别，这四个采样点中，S14 后塘位于养殖区，养殖区水质除接纳淀区其它水质的污染外，自身承担白洋淀水产业的养殖，受人类活动影响频繁，受到的外源污染物较多，这与王亚琼对于白洋淀养殖区水体污染的研究结果一致；其余三个采样点均属于入淀区河流，白洋淀的防洪闸位于 S20 这一采样点中，随着时间的积累，防洪泄闸时期可能汇聚了较多的污染物，导致白沟引河的水质质量下降，S22 位于原始区，可能是原始区内芦苇等水生植物较多，植物腐烂产生的污染物质进入水体导致水质较差，保定污水处理厂位于 S24 南刘庄府河入淀口的上游，保定市居民的生活污水经由污水厂处理后直接汇入府河，导致府河水质受到严重污染，进而污染其它入淀区河流水质，对白洋淀整体水质造成巨大的威胁，这与龙幸幸的研究结果相一致[26]。

图 3（b）为五个功能区的综合污染指数平均值，根据数值分析，生活区水质较好，内部采样点的综合污染指数均小于 0.5，水质为轻度污染；入淀区的水质最差，因入淀区河流起到白洋淀与外界河流沟通的作用，汇入的污染源较多，水体自净能力较弱，因此入淀区河流的水质相较其它功能区较差，在对白洋淀水质进行治理时，入淀区河流水质将成为治理重点。

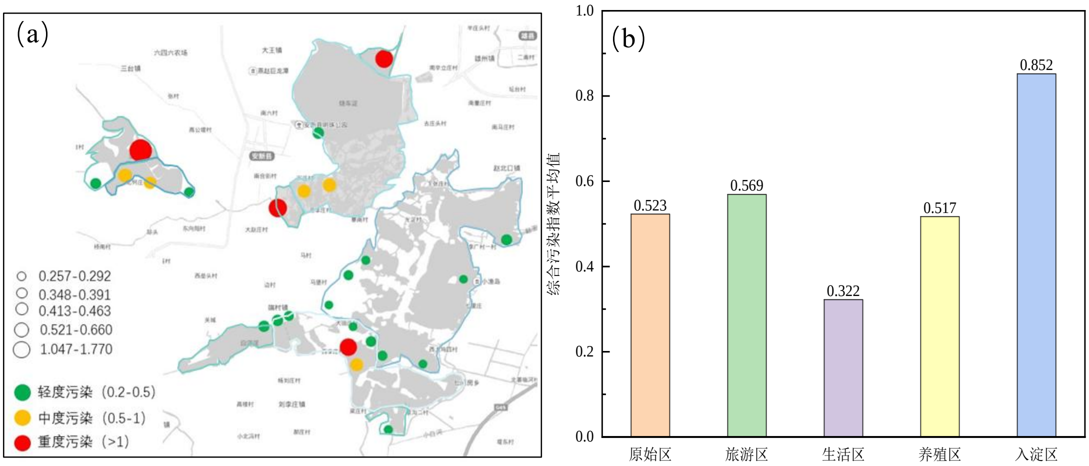

图 3 白洋淀综合污染指数

3.4 主成分分析评价结果

白洋淀冰封期 25 个采样点的理化参数主成分分析见图 4，由图 4 可以看出，不仅不同功能区的水质存在一定差异，即使相同功能区的水质存在的差异也很明显，入淀区中 5 个采样点的水质差异最为明显，彼此间偏离较大，出现这种情况的原因可能是每条入淀区河流承接的上游水系不同，各项水质因子含量存在差异，因此水质差异较为明显，养殖区、原始区、旅游区三个功能区的水质根据图形显示偏离较小，证明各功能区内部水质的影响因子偏差不大，生活区的各采样点间距离是最小的，证明内部水质差异不大。PC1 和 PC2 分别描述了 42.6%和 15.5%的水质差异，与第一主成分高度相关的理化指标是 TN，达到了 0.44，与第二主成分高度相关的理化指标是 TP，因子负载达到了 0.55，通过这两个数值也可以反映出白洋淀冰封期水质主要受到了 TN 和 TP 的影响，较高的 N、P 值也将成为白洋淀水体富营养化的潜在风险，这一结果与王亚琼对于入淀区和养殖区水体受 N、P 影响较大的污染结果相一致。

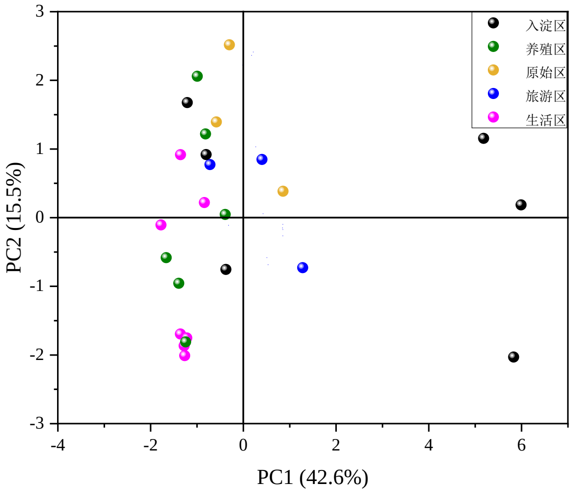

图 4 白洋淀冰封期采样点主成分分析

根据成分得分系数矩阵等相关方程和公式得出 25 个采样点的主成分综合得分，即能定量描述各断面水质的污染程度，综合得分越高，水质越差，结果见图 4，从得分情况可知，水质较差的采样点为 S22 和 S24，水质较好的采样点为 S8；

S22 和 S24 采样点分别为瀑河藻苲淀入淀口和南刘庄府河入淀口，这两条入淀河流都属于大清河南支河流，瀑河藻苲淀入淀口位于白洋淀的西部，为季节性泄洪河道，南刘庄府河入淀口是上游保定市排放生活污水、工农业生产污水的排泄通道，受人类活动影响较频繁，汇入的外源污染物较多，致使水质较差。S8 平阳淀位于整个淀区的东部，远离入淀区河流的污染，淀区水体受到的污染较小，因此水质较好。从淀区的 5 个功能分区分析，入淀区的水质是最差的，生活区的水质较好。通过数据分析可知，白洋淀各淀区水质存在一定差异，一方面与水体在淀区的迁移流向有关，另一方面与淀区及淀区周边的污染物排放有关，白洋淀是封闭性湖泊，淀区地势起伏不大，淀区内水体流动不明显，因此位于西部的入淀区河流在接纳外源和内源污染物时，由于水体流动较慢，自净能力较弱，水质相较其它功能区较差，位于中部和东部的生活区因远离入淀区河流的污染以及政府对于白洋淀水体的治理，水质相对较好。

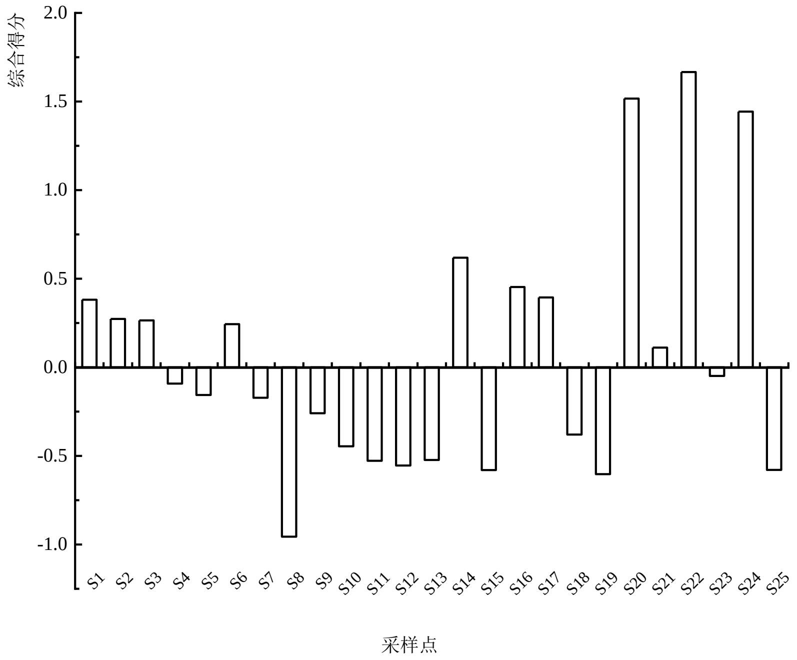

图5 采样点主成分综合得分

3.5 三种评价方法的对比

运用单因子评价法、综合污染指数法、主成分分析法三种评价方法对白洋淀水质进行评价。单因子评价法简单直观，能够对白洋淀水质进行定性评价，利用数据判定各采样点的水质等级，得出TN和TP是白洋淀水质的限制因子，但单因子评价法不能对同一等级的水质断面进行更详细的优劣排序；综合污染指数法和主成分分析计算相对复杂，能对水质进行定量分析，能对各采样点的水质情况进行优劣排序，对五个功能区的水质进行整体分析，通过这两种方法的分析，25个采样点中，S22和S24的水质是最差的，S8平阳淀因远离入淀区河流的影响，水质较好。按功能区分析，入淀区河流不仅要承载白洋淀自身水质的污染源，还要承载外界河流汇入的污染物质，因此水质最差；养殖区、生活区和旅游区的水质由于受到人类活动和淀区自身水生植物腐烂产生的污染物质的

影响，水质次之；原始区因属于未开发区域，人类活动干预较少，因此水质较好，虽然两种评价方法的计算方法和原理不一样，但最终得出的结果是一致的。这三种方法各有其优缺点，可以从不同角度评价白洋淀各淀区水质的污染状况，故运用多种评价方法能更客观全面的反映白洋淀水质的状况与污染特征。

4 结论

（1）白洋淀水体呈碱性，25个采样点中TN、TP含量变化幅度较大且含量较高；各淀区水质的溶解氧含量变化幅度较大，原始区内溶解氧处于过饱和状态；养殖区水质的高锰酸盐指数较高，可能是淀内剩余饵料沉入水中产生了较高的污染。

（2）单因子评价结果显示，TN参与评价时，□类和劣□类水质占到了总采样点的8%河24%；TP参与评价时，□类水质占到了总采样点的24%，说明TN、TP是白洋淀冰封期水质的限制因子。

（3）白洋淀各采样断面的水质综合污染指数在0.257-1.77范围间，各断面水体的污染程度集中在轻度污染-重度污染间，入淀区河流的水质是最差的，在对白洋淀水质进行治理时，入淀区河流水质将成为治理重点。

（4）主成分分析结果显示入淀区河流水质差异性最为明显，水质主要受TN、TP两个水质指标的影响较大，较高的N、P值可能会引起水体的富营养化，因此应加紧对白洋淀水体的治理。

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一株耐冷好氧反硝化菌 pseudomonas candensisi SY21 的鉴定及脱氮特性研究

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摘要：采用氨氮和硝氮为氮源的富集驯化方式，从石家庄市景观水体沉积物中分离出 1 株异养硝化-好氧反硝化菌株 SY21，通过形态观察、生理生化特性以及 16S rRNA 基因序列分析，对该菌株进行鉴定；并且在硝氮浓度 30.9mg·L-1 下，考察了该菌株的脱氮效果，探究了好氧反硝化特性及影响因素。结果表明，SY21 呈短杆状、具有粘性、边缘整齐无鞭毛的白色菌落，生理生化试验结果为革兰氏阴性菌，过氧化氢酶和淀粉酶均呈阴性，并鉴定为假单胞菌属 pseudomonas sp.，GenBank 登录号为(MH388423)；在 10℃硝酸盐反硝化体系中，72h 内菌株 SY21 对硝氮的去除率为 78.5%，反硝化速率为 0.34mg·(L·h)-1，同时亚硝氮积累达 0.46mg·L-1；影响因素结果显示菌株最适 C/N=12，最适初始 pH=7，最适接种量为培养基体积的 3%，在该条件下，硝氮和总氮去除率分别为 85.5%和 32.6%，溶解性总氮去除率达 52.4%。综上表明该细菌具有耐冷，可实现好氧反硝化的特点，这对北方地区冬季景观水体的修复具有潜在实际应用价值。

关键词：耐冷；景观水体；异养硝化-好氧反硝化；16S rRNA；影响因素

Nitrogen removal characteristics of a novel cold-resistant heterotrophic nitrification and aerobic denitrification bacterium, *Pseudononas candensisi* SY21

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Abstract: A heterotrophic nitrification-aerobic denitrification strain SY21 was isolated from the landscape water sediments of Shijiazhuang city by the enrichment and domestication of ammonia nitrogen and nitrate nitrogen as nitrogen sources. The strain was identified by morphological observation, physiological and biochemical characteristics and 16S rRNA gene sequence analysis. The influencing factors and characteristics of heterotrophic nitrification-aerobic denitrification were investigated. The results showed that the strain was identified as *pseudomonas* sp., and the GenBank login number was MH388423. In 10□ nitrate denitrification system, factors affecting the results showed that optimum C/N = 10 strains, the optimal initial pH =7 ~ 8, the optimal quantity of 2% of the volume of medium, in this condition, the only nitrogen source test showed that ammonia nitrogen, nitrate nitrogen and the nitrate nitrogen removal rate were 74.5%, 71.1% and 63.2%, ammonia nitrogen and nitrate nitrogen removal rates were 85.5% and 40.3% respectively under nitrogen source. To sum up, this bacteria has the characteristics of cold resistance and simultaneous nitrification and denitrification, which has potential practical value for the restoration of winter landscape water bodies in northern China.

Key words: cold resistance; landscape water body; heterotrophic nitrification and aerobic denitrification; 16S rRNA; influence factor

随着我国经济的快速发展，地表水氮素污染作为水体富营养化的主要原因，已成为地表水处理所面临的全球性挑战。而传统生物脱氮技术因其高效经济的优势，成为近年来的研究热点[1, 2]。但是由于传统的生物脱氮是由好氧条件下的自养硝化以及厌氧条件下的异养反硝化来共同完成[3]，而在实际应用中往往由两个反应器组成，且其生物繁殖速率缓慢，难以维持较高的生物量，因而应用传统的生物脱氮技术对于天然水体的氮素去除受到限制。因此，人们将焦点转向能够进行好氧反硝化的微生物上，其可以将氧和硝酸盐氮同时作为电子受体[4]，这位克服传统反硝化的缺点提供了新的思路。但是，在实际应用中，好氧反硝化菌在低温且氮源缺乏的条件下，会对细菌的生长、增殖和代谢有抑制作用[5]。此外，营养的缺乏会抑制耐冷菌的硝化效率，延长硝化过程的时间[6]，因此，在低温好氧条件下研究生物脱氮处理技术成为亟待解决的问题。

20 世纪 80 年代，随着 Robertson 等[7]首次从废水脱硫和反硝化系统中分离出的一株好氧反硝化菌 Thiosphaera pantotropha，其打破了传统的脱氮理论，使脱氮过程在好氧条件下发生，这一研究发现为生物脱氮提供了新的技术可能。同时由于好氧反硝化菌具有生长快速[8]、耐贫营养[9, 10]、耐溶解氧[11]等特点，使其成为当今的研究热点。由于温度是影响微生物活性的主要因素，因此对于北方地区冬季漫长，天气寒冷的气候特征，使得冬季北方地区实现高效稳定的生物脱氮变得很困难，特别是针对天然水体的氮素去除。现在，研究者已经筛选出多株耐冷好氧反硝化细菌，如陈茂霞等[12]筛选出的可以在 5□下生长并适用于高氨氮和高盐的废水处理的 Aeromonas sp. HN-02；郑泽嘉等[13]筛选出在 2□低氮素浓度下表现出好的脱氮能力的一株 Acinetobacter harbinensis HITLi7T，用于寒冷地带的饮用水源地修复；冶清等[14]筛选出一株在 12□下能去除单一和混合型氮源的 Pseudomonas putida Y-12。目前筛选出的耐冷好氧反硝化菌多应用于高浓度废水处理，针对低浓度氮源和低 C/N 下的脱氮特性研究还有所欠缺，因此，开展耐冷好氧反硝化菌的脱氮特性和影响因素研究，可以为将来更好的开展低温下水体治理和生物修复提供必要的技术支持。

本文从石家庄典型景观水体沉积物中分离到一株新的 pseudomonas candensisi SY21 菌株，并对其进行形态观察和生理生化实验。研究了 C/N 比、初始 pH 值和接种量对菌株 SY21 反硝化能力的影响，得出其生长最适条件，同时

对其在以氨氮、亚硝氮、硝氮以及氨氮和硝氮的混合氮源作为氮源时的硝化和反硝化特性。

1. 材料与方法

1.1 富集驯化培养基

硝化培养基(/L)：CH_3COONa 0.2g；NH_4Cl 0.02g；NaH_2PO_4 0.04g；Na_2HPO_4 0.04g；

反硝化培养基(/L)：$Na_2HPO_4\cdot 7H_2O$ 0.316；KH_2PO_4 0.06g；$MgSO_4\cdot 7H_2O$ 0.004g；丁二酸钠 0.188g；KNO_3 0.04g；

微量元素(/L)：EDTA 10g；$ZnSO_4$ 0.44g；$CaCl_2$ 1.1g；$MnCl_2\cdot 4H_2O$ 1.02g；$FeSO_4\cdot 7H_2O$ 1.0g；钼酸铵 0.22g；$CuSO_4\cdot 5H_2O$ 0.32g；$CoCl_2\cdot 6H_2O$ 0.32g；蒸馏水 1000mL；pH 7.0~7.5。

固体培养基是在培养基中以 20g/L 的琼脂的量配制而成。

1.2 氮源试验培养基

以氨氮为唯一氮源培养基(/L)：NH_4Cl 0.02g；丁二酸钠 0.188g；$Na_2HPO_4\cdot 7H_2O$ 0.316g；KH_2PO_4 0.06g；$MgSO_4\cdot 7H_2O$ 0.004g

以硝氮为唯一氮源培养基(/L)：KNO_3 0.04g；丁二酸钠 0.188g；$Na_2HPO_4\cdot 7H_2O$ 0.316g；KH_2PO_4 0.06g；$MgSO_4\cdot 7H_2O$ 0.004g

以亚硝氮为唯一氮源培养基(/L)：$NaNO_2$ 0.0278g；丁二酸钠 0.188g；$Na_2HPO_4\cdot 7H_2O$ 0.316g；KH_2PO_4 0.06g；$MgSO_4\cdot 7H_2O$ 0.004g

以氨氮和硝氮共同作为氮源培养基(/L)：NH_4Cl 0.01g；KNO_3 0.02g；丁二酸钠 0.188g；$Na_2HPO_4\cdot 7H_2O$ 0.316g；KH_2PO_4 0.06g；$MgSO_4\cdot 7H_2O$ 0.004g

1.3 细菌的驯化与分离

本试验所得菌株是在石家庄市景观水体沉积物中分离所得。

取 100mL 新鲜的沉积物放入含有 700mL 反硝化培养基的 1000mL 烧杯中，置于 10□，120rpm 的环境下，每间隔 3d 更换一次培养基。在一次培养结束后，静置 12h，取 3mL 悬浊液转移至含有 150mL 反硝化培养基的 250mL 锥形瓶中，仍置于 10□，120rpm 的震荡培养箱中富集培养。培养基与源水的占比按照 100%、100%、80%、70%、50%配制，每个浓度的培养基分别持续 3d 且经过 120□持续 30min 的灭菌处理。

在 50%的培养基中富集驯化结束后，通过稀释梯度法对菌液稀释，并在琼脂平板上涂布，培养 3d 后，对菌落进行分离。此后将单菌落接种在反硝化培养基中，于 120rpm，10□下振荡培养，通过硝氮和总氮去除率以及亚硝氮的积累情况确定其好氧反硝化能力。最终获得了一株对硝氮和总氮去除效果较好的细菌 SY21，并用 50%的甘油长期贮藏在-80□。

1.4 细菌的鉴定

1.4.1 细菌的形态观察和生理生化实验

将纯化的菌株划线至固体培养基上，10□培养 48h 观察菌株在固体培养基上的菌落特征。通过扫描电镜和革兰氏染色来观察细菌的形态。

1.4.216S rRNA 测序及系统发育分析

首先，采用 DNA 提取试剂盒(Water DNA Kit，Omega，USA)提取细菌的 DNA。通过正向引物 27F：5'-AGAGTTTGATCCTGGCTCAG-3'；反向引物 1492R：5'-GGTTACCTTGTTACGACTT-3'进行 PCR 扩增。扩增体系（20μL）：模板 0.5μL，27F 和 1492R 各 1μL，10×Ex Taq buffer 2μL，5U Ex Taq 0.2μL，2.5mM dNTP Mix1.6μL，ddH_2O 13.7μL。通用引物扩增后，进行电泳检测。电泳条件是 1%琼脂糖凝胶，120V 电压电泳 30 min。PCR 反应程序：95□预变性 5min，95□变性 30s，56□复性 30s，72□延伸 90s，25 个循环，72□延伸 10min。通过上海美吉生物技术公司进行高通量测序，16S rRNA 基因序列通过 BLAST (http://www.ncbi.nlm.nih.gov/BLAST/Blast.cgi)进行同源比对，利用 MEGA7.0 软件，采用 Neighbor-joining 法与 1000 次 Bootstrap 的统计检验构建系统树，以确定新分离菌的系统发育地位。

1.5 菌株的生长及反硝化特性试验

1.5.1C/N 对菌株好氧反硝化能力的影响

将氮素浓度维持在 5mg/L，通过改变碳源丁二酸钠的量，调整 C/N 分别为 4、6、8、10 和 12，配制反硝化培养基，在 120□，30min 下灭菌，待用。再将处于对数期的细菌悬液以 2%的体积分别接种至反硝化培养基中，每个样品设置 3 个平行，置于 120rpm，10□下培养 120h，每间隔 24h 取培养液测定 OD600 和 TN，过滤后测定 NH_4^+-N、NO_2--N、NO_3--N，绘制菌株生长曲线并确定该菌株对硝态氮的去除能力，每个样品设置 3 个平行。

1.5.2 初始 pH 对菌株反硝化能力的影响

将培养基初始 pH 用 5mol/L 的 HCl 和 5mol/L 的 NaOH 分别调整为 6、7、8、9、10，将菌液以 2%的体积接种至适宜 C/N 比的培养基中，置于 120rpm，10□下培养 120h，每个样品设置 3 个平行，取样及指标测定同 1.5.1。

1.5.3 接种量对菌株反硝化能力的影响

将菌液分别以 1%、2%、3%、4%、5%体积的接种量接种至适宜 C/N、初始 pH 的培养基中，置于 120rpm，10□下培养 120h，每个样品设置 3 个平行，取样及指标测定同 1.5.1。

1.5.4 唯一氮源下菌株异养硝化-好氧反硝化能力

分别以氨氮、硝氮、亚硝氮作为唯一氮源以及氨氮和硝氮共同作为氮源，考察菌株硝化、反硝化以及同时硝化反硝化能力，将细菌以 2%的接种量接种至不同类型的培养基中置于 120rpm，10□下培养 120h，每个样品设置 3 个平行，取样及指标测定同 1.5.1。

1.6 测定方法

NH_4^+-N：纳氏试剂分光光度法；NO_2--N：N-(1-萘基)乙二胺光度法；NO_3--N：紫外分光光度法；TN：碱性过硫酸钾分光光度法；菌体生长测定采用 UV-5100 型紫外可见分光光度计于 600nm 处测量吸光度值；形态观察使用 XSP-BM-8C 型光学显微镜；pH 值：采用 pHS-2F 型 pH 计测定。

2. 结果与讨论

2.1 菌株的筛选与分离

通过利用氨氮和硝氮交替提供氮源进行富集驯化和分离纯化，初步筛选到10株细菌，如图1所示，对这10株细菌采用摇瓶培养进行复筛。复筛结果表明，有两株NO_3--N去除率达80%以上，选择其中一株并将其命名为SY21，并进行后续好氧反硝化特性的研究。

2.2 菌株形态特征和生理生化特性

SY21菌株在反硝化培养基上置于10□下培养48h后进行观察，直径大小为2～3 mm，菌落为圆形，表面光滑湿润，边缘整齐，乳白色。革兰氏染色为阴性，其电镜扫描照片如图2所示，菌体细胞呈短杆状，无鞭毛，无芽孢。

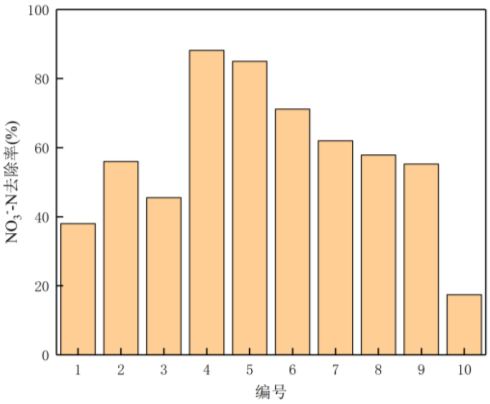


图1 反硝化特性筛选结果

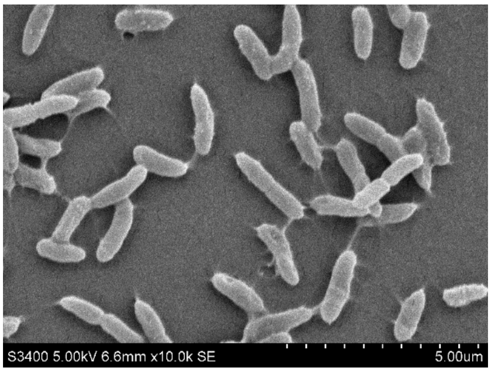


图2 SY21扫描电镜下的形态特征

2.316S rRNA基因序列分析

通过对菌株SY21的16S rRNA基因序列进行PCR扩增，获得1455bp片段。该序列GenBank 序列登录号为MH388423，在NCBI通过Blast同源序列比对，并基于16S rRNA基因序列采用Neighbor-joining法与1000次Bootstrap的统计检验，通过MEGA7.0构建系统发育树。如图3所示，结果表明，SY21与Pseudomonas canadensisi 2-92(AYTD1000015.1)相似性高达99%，结合菌株的形态和生理生化特性，可初步确定菌株SY21为假单胞菌属。

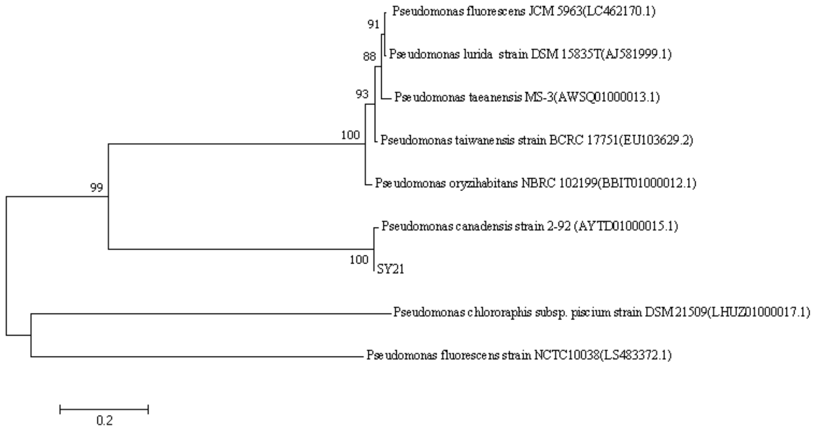


图3 SY21的N-J法系统发育树

2.4 菌株的最适生长条件研究

2.4.1C/N

碳氮比(C/N)对菌株的生长和降解特性有显著影响[15]。通过将 C/N 从 4 调整到 12 来探究该因素对菌株在好氧条件下对反硝化能力的影响。不同 C/N 下菌株 SY21 的生长特性[如图 4(a)]所示，在有氧条件，10□下培养至 24h 后，细菌开始进入对数期，并随着 C/N 的增大，细菌菌体量和增殖速率增大，C/N=4 和 6 维持在较低的菌体值，这是碳源不充足造成的，使菌体的生长受到一定程度的抑制，在 72h 时不同 C/N 的最大值范围为 0.008~0.031，相对应的在细菌快速增长时，NO_3--N 浓度在 C/N=12 时，由 5.36mg·L-1 降至 0.95mg·L^{-1}，最大去除速率为 0.140mg·L^{-1}·h^{-1}[图 4(b)]，这与吕东伟等[16]研究的 Janthinobacterium sp. M-11 得出的高 C/N 能促进细胞的合成和生长的结果相一致。在整个反硝化过程中亚硝氮的积累如图 4(c)，培养至 24h 时，C/N=8、10、12 时积累量达到最大，C/N=4 和 6 积累量最大值出现在 48h，最大积累量为 0.75mg·L-1，然后均在 72h 时下降并最终平稳，且 C/N 越大，积累量也略高。整个反硝化过程中对硝氮的去除率如图 4(d)所示，随 C/N 的增大逐次升高，最大去除率达 82.3%，而总氮的最大去除率出现在 C/N=10，为 51.1%。由硝氮和总氮去除率，并综合考虑实际应用过程中，因此将 C/N=10 作为其最适反应条件。

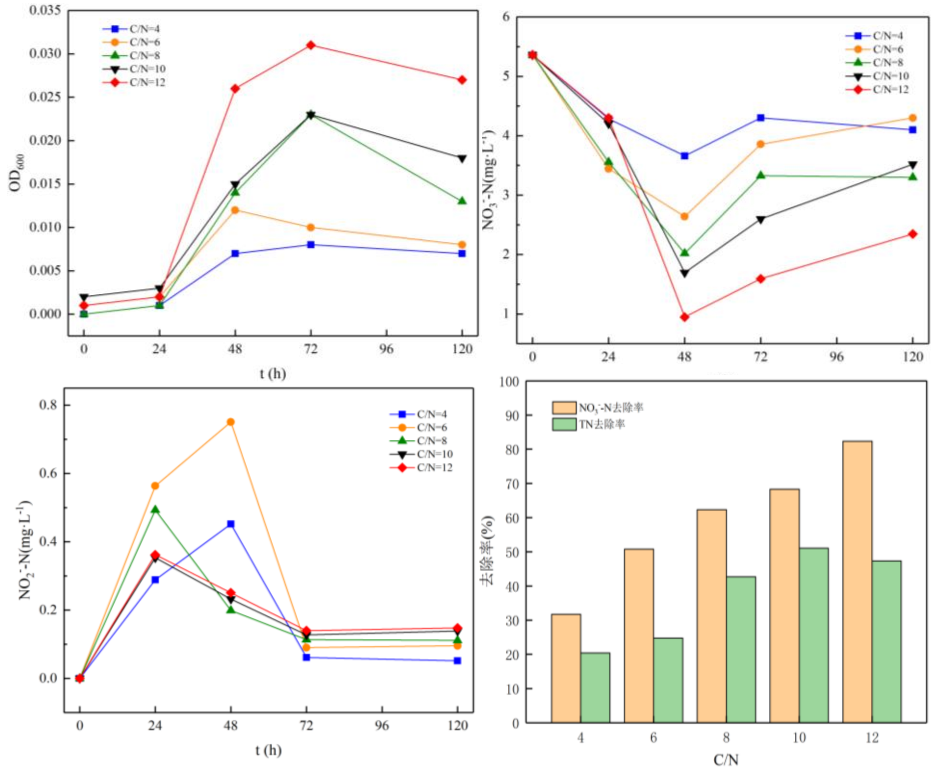


图 4 不同 C/N 对细菌反硝化特性的影响

2.4.2 初始 pH

好氧反硝化菌适应的 pH 范围一般为中性或偏碱性[17]，如图 5(a)所示，初始 pH 从 6 变化到 9，细菌在整个 pH 范围内均可生长，但在 pH=9 时生长缓慢，这是由于极端的 pH 可能破坏了细胞并且对细菌的新陈代谢起到抑制作用[18]。

最大菌体浓度在 pH=6 时，为 0.043。除 pH=9 时，其余 pH 在硝氮去除速率和去除率上无显著差异[图 5(b)，5(d)]，均从 4.18mg·L^{-1} 降至 0.8mg·L^{-1} 左右，当在消耗 NO_3--N 时，NO_2--N 的浓度逐渐增大，最大为 0.122mg·L^{-1} 图 5(c)，主要发生在反硝化过程的快速时期。综合生长特性、NO_3--N 去除和 NO_2--N 积累情况，认为 pH=7~8 为细菌最适生长 pH，这与培养基本底 pH 相一致。

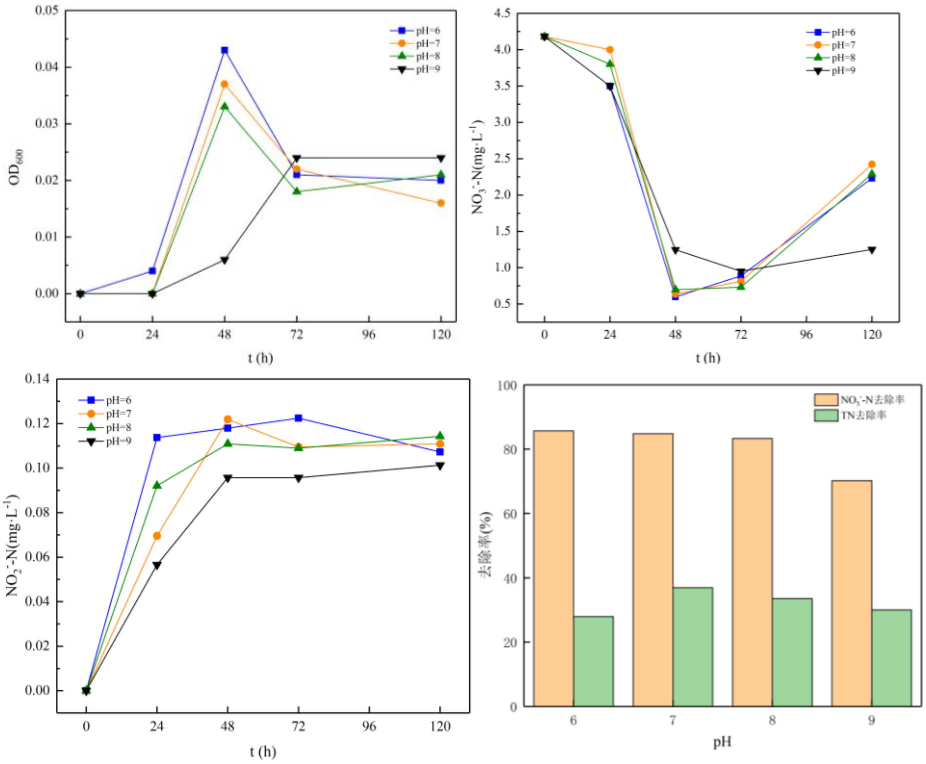


图 5 不同 pH 对细菌反硝化特性的影响

2.4.3 接种量

接种量的多少对于细菌生长特性和脱氮过程具有一定影响，一般来说，在反硝化过程中，若接菌量不足则不能充分发挥微生物生长繁殖的潜力，导致脱氮效果差；而接菌量过多会导致细菌对营养物质的竞争，部分细菌死亡，脱氮率降低[19]。如图 6(a)所示，在接种后的 24h 内 4%的接种量表现出的停滞期较短，菌体生长较快，当接种量较低为 1%和 2%时，细菌生长缓慢需要适应环境，导致达到最大值的时间拉长，在 72h 时接种量菌达最大值并无显著差异，与此相对应的脱氮过程[图 6(b)]，接种量为 5%的细菌在 24h 内脱氮速率较快，而其他接种量的细菌在培养时间为 48h 时起主要作用，最终的 NO_3--N 浓度无明显差异。而对于亚硝氮积累来说[图 6(c)]，积累量最大发生在接种量为 5%时，达 0.39mg·L-1，即在其硝氮降解速率较快的阶段下，亚硝氮转化也越高，在 24h 整体的亚硝氮积累规律同硝氮去除速率相关，培养时间至 48h，不同接种量下的亚硝酸盐浓度已经趋于稳定。再综合 NO_3--N 去除率考虑[图 6(d)]，在 72h 时，不同接种量的硝氮去除率均达 80%以上，这一过程与周石磊等[20]研究的 Zoogloea sp. N299 在 2~10%接种量下无显著差异的结果相一致，并且本研究中接种量为 2%的总氮去

除率最大，为 41.5%，因此认为 2%的接种量为最适接种量。

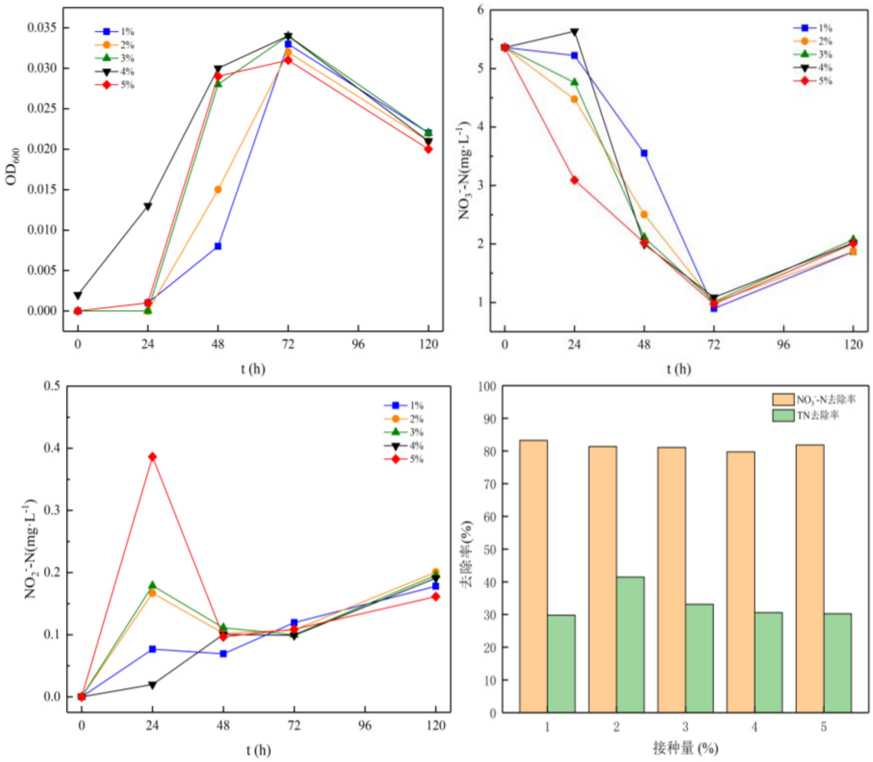


图 6 不同接种量对细菌反硝化特性的影响

2.5.菌株 SY21 的异养硝化-好氧反硝化特性

2.5.1 氨氮为唯一氮源时 SY21 的异养硝化特性

为了研究在氨氮为唯一氮源下细菌 SY21 的异养硝化特性，将菌株 SY21 在氨氮浓度为 5.52mg/L，C/N 为 10 的硝化培养基中培养。如图 7(a)所示，当氨氮浓度为 5.52mg/L 作为唯一氮源时，在细菌对数生长期的前 48h，OD600 增大至 0.039，氨氮由 5.52 mg·L^{-1} 降至 1.41 mg·L^{-1}，去除率为 74.5%，在 24 至 48h 的培养下氨氮去除速率最大，为 0.122 mg·L^{-1}·h^{-1}，这比郑泽嘉等[13]研究的在 2□下的 HITLi7T 去除初始浓度为 5.83 mg·L^{-1} 的氨氮的最大去除速率 0.076 mg·L^{-1}·h^{-1} 还要高，而尽管与王旭明等[21]研究的 SL-205 相比，其氨氮最大去除速率在培养温度为 28□下达 3.32 mg·L^{-1}·h^{-1}，但是本研究所得数值在初始浓度较低且低温的条件下仍具有重要的参考价值。48h 时。反应体系的氮素组成发生了很大的变化，氨氮去除的部分转化成细菌生长繁殖的有机组成，在 60h 时，细菌已经基本达到稳定，氨氮也基本不再变化，这些结果证实了氨氮的去除和细菌的生长是密切相关的，而后体系的氮主要向硝氮转化，达 1.11 mg·L^{-1}，且仅存在 0.14 mg·L^{-1} 的亚硝氮的积累，且最终硝氮亚硝氮的积累量都很低，这说明在氨氮的去除过程中 SY21 将氨氮在 AMO 的存在下氧化为羟胺后又在 HAO 的催化下变为含氮气体从体系中去除。这同倪晋仁等研究的 Acinetobacter sp. HA2 中亚硝氮先积累后去除存在不同，而 Yang 等[22]研究的 Acinetobacter sp. JR1 在反应过程中无硝氮和亚硝氮的积累现象有相似之处。与孙庆华等[23]研究的 Klebsiella sp. y5 的反应过程较为一致。当培养至 60h 时，氨氮浓度有轻微的上升，这可能是因为氮从衰

亡的细菌体中溶出所引起的。

2.5.2 硝氮为唯一氮源时 SY21 的好氧反硝化特性

众所周知，我们将硝酸盐经由亚硝酸盐还原酶还原为亚硝酸盐作为反硝化的第一步[24]，因此将硝氮作为唯一氮源在 10□好养条件下进一步考察 SY21 的好氧反硝化性能。如图 7(b)所示，细菌同氨氮为唯一培养基时相同是在 24h 后也进入对数期，OD600 在 84h 的培养中达到最大值为 0.036，同时硝氮由 6.33 mg·L^{-1} 降至 1.83 mg·L^{-1}，硝氮的最终去除率达 71.1%，并且从 24h 开始亚硝氮开始积累，硝氮一部分用来细菌生长，另一部分积累成亚硝氮，说明 SY21 存在反硝化功能，亚硝氮最终积累 1.37 mg·L^{-1}，但是积累后不在去除而是存在于反硝化体系中。SY21 的硝氮的最大去除速率为 0.128 mg·L^{-1}·h^{-1}，这与氨氮最大去除率相当，结果表明当氨氮和硝氮分别作为唯一氮源时，SY21 的异养硝化和好氧反硝化能力均能发挥作用，但是在硝氮浓度降低到 2 mg·L^{-1} 时，其反硝化能力下降，这种现象可能是由于通过亚硝酸盐还原酶的作用，反硝化进程加快，硝氮快速下降造成的。这与何腾霞等[25]研究的 A. arilaitensisY-10 相比，硝氮在初始浓度为 11.59 mg·L^{-1} 时的去除率为 71.4%，但当硝氮低于 3mg·L^{-1} 时，其反硝化能力变得很弱较为一致。

2.5.3 亚硝氮为唯一氮源时 SY21 的好氧反硝化特性

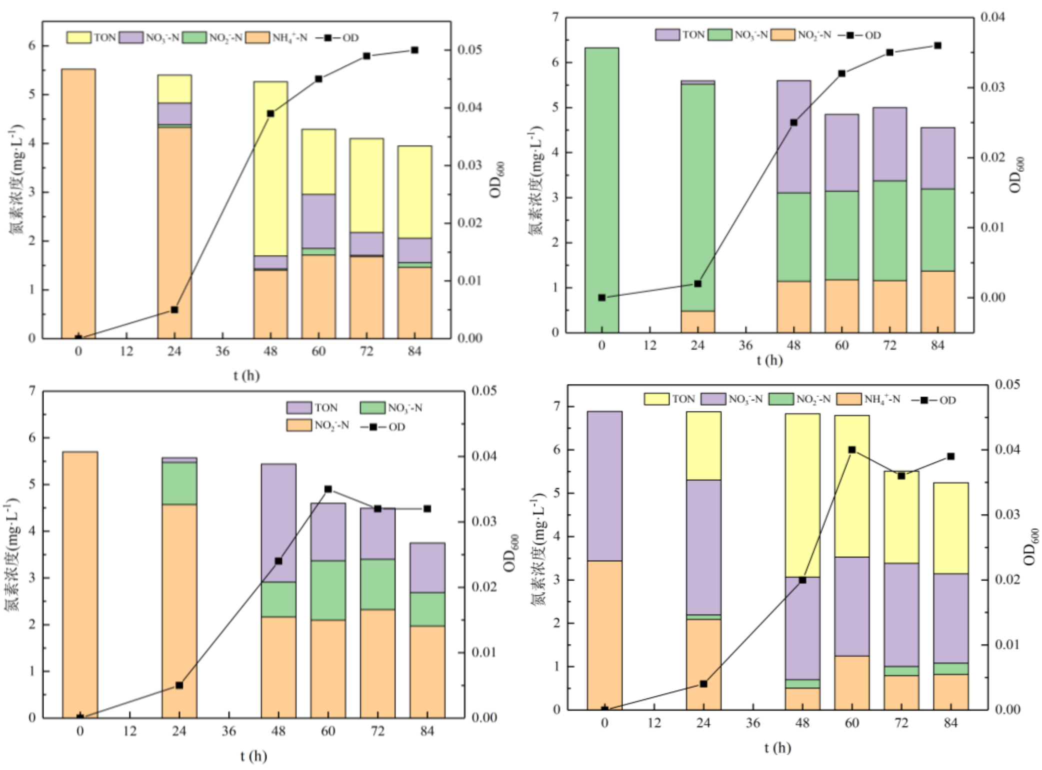
如图7(c)所示，在亚硝氮为唯一氮源时，细菌在24h时进入对数期，这比 *Pseudomonas tolaasii* Y-11[8]的停滞期时间要短，并在60h时OD$_{600}$达到最大值0.035，且平台期较短，在反映开始的24h内，体系19.8%的亚硝氮先转化为硝氮，硝氮达0.9 mg·L^{-1}，亚硝氮最大去除速率为0.1 mg·L^{-1}·h^{-1}，略低于其他两种唯一氮源，随着进入对数期，菌体的生长使得有机氮含量升高，亚硝氮在60h时浓度由5.70 mg·L^{-1}下降到2.10 mg·L^{-1}，去除率为63.2%，硝氮升高至1.27 mg·L^{-1}，最终的积累量为0.72 mg·L^{-1}。在以亚硝氮为氮源时细菌对其的利用率降低，亚硝氮转化为硝氮的最大转化率为22.3%，同样的，当亚硝氮降低至约2 mg·L^{-1}时反应结束，这与硝氮为唯一氮源时亚硝氮的积累量导致反应结束是一致的。

2.5.4 混合氮源下 SY21 的异养硝化-好氧反硝化特性

为在 10℃下研究菌株 SY21 的同时硝化-反硝化能力，将 3.44mg·L^{-1} 的氨氮和 3.45mg·L^{-1} 的硝氮混合作为氮源。如图 7(d)所示，在 24h 内，仅氨氮有明显降低，由 3.44 mg·L^{-1} 降至 2.08 mg·L^{-1}，此时细菌开始生长增殖，随培养时间到 48h，氨氮降至 0.50 mg·L^{-1}，最大去除速率和去除率分别为 0.066 mg·L^{-1}·h^{-1} 和 85.5%，这比单一氨氮为氮源时的去除率有所升高，在 60h 时，OD$_{600}$ 达到最大值 0.040，相较于单一氮源时，没有明显的增长，但是氨氮有升高趋势，但总体氮素无变化，仅在体系内部进行。对于硝氮来说，由 3.45 mg·L^{-1} 最终降至 2.06 mg·L^{-1}，去除率为 40.3%，这比单一硝氮为氮源时的去除率降低约 1.7 倍。这同何腾霞等[25]研究的 *Arthrobacter arilaitensis* Y-10 中由于氨氮的加入会促进硝氮的利用的结果是不同的。氨氮的存在主要用于细菌的生长，硝氮在该条件下进行的反硝化作用中，基本无亚硝氮的积累，可以看出两种并存时，细菌优先利用氨氮，此后再利用硝

氮，这些结果表明，该菌株 SY21 对混合氮源中氨氮的去除效果较好，这可能与氨氧化酶活性高于硝酸还原酶活性有关。相同的结果在 *Acinetobacter* sp. JR1[22] 也有体现。

图7 不同氮源下对细菌异养硝化-好氧反硝化特性的影响



3. 结论

(1) 通过形态学、生理生化和 16SrRNA 基因序列分析，将从景观水体沉积物中分离获得的 SY21 菌株鉴定为假单胞菌属（*pseudomonas candensisi*）。

(2) 通过影响因素试验得出，SY21 最适的 C/N=10，pH=7~8，接种量为 2%时为其最适生长条件，这对应用到半封闭型天然水体有指导意义。

(3) 菌株 SY21 的异养硝化和好氧反硝化作用主要发生在对数增长期，单一氮源下，菌株对氨氮和硝氮的利用结果相似，对亚硝氮利用略差；在氨氮和硝氮混合氮源下，菌株优先利用氨氮进行硝化作用，然后再利用硝氮，且硝氮利用率降低。

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植物根系对微生物电化学系统产电和阳极微生物的影响

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植物微生物电化学系统（PMES）是在传统微生物电化学系统（MES）的基础上发展起来的，该技术利用植物光合作用产生葡萄糖、有机酸等小分子有机物的特点，从而加强 MES 产电。但是，植物普遍具有强大的通气组织，根系处会大量泌氧，而泌氧会改变阳极附近的厌氧环境，从而改变电子受体，影响 MES 产电。本研究设置了三组不同阳极深度的 PMES：较浅深度（S-PMES）、中等深度（M-PMES）和较深深度（D-PMES），用以模拟三种不同阳极和根际位置关系。研究发现根系为 PMES 提供根际分泌物促进产电的同时，根际泌氧对 SMES 产电有明显抑制作用；在 M-PMES 中，植物根际直接接触阳极，其开路电压明显低于无植物组，表明植物根际的泌氧作用降低了阳极电位；D-PMES 的产电能力高于 D-MES，表明 D-PMES 植物根系的促进作用明显大于抑制作用；通过检测沉积物 O_2 浓度梯度，M-PMES 中阳极表面的 O_2 浓度明显升高达到了 23 μmol/l；通过对阳极生物膜多样性分析发现，阳极深度、植物根系、有无电流均对微生物群落产生影响。

关键词：植物微生物电化学系统；根系深度；氧气；产电；微生物多样性

微生物电化学系统（Microbial Electrochemical System, MES）借助特定的微生物可以降解介质的有机污染物，同时将化学能转化为电能，实现“废物利用”和“能量回收”，成为近几年的研究热点。沉积物微生物电化学系统（Sediment Microbial Electrochemical System, SMES）是 MES 的一种重要形式。SMES 的阳极一般放置于沉积物中，阴极放置在自由水面中。SMES 运行机理为：首先，有机物被氧化释放电子，电子或可以通过电子介体、或直接膜接触、或通过纳米线、或尚未发现的其他途径转移到阳极[1, 2]。随后，阳极电子通过外导线到达阴极。在阴极表面，末端电子受体（多为氧气）接受电子被还原。在阳极区有机物被氧化后释放的质子迁移到阴极室，从而使得电子、质子和氧在阴极表面结合形成水[3]。植物微生物电化学系统（PMES）正是基于上述理念而发展的一项新的能源技术，该技术将植物的光合作用与 MES 技术相结合，利用植物的光合作用，为 MES 中的产电微生物源源不断的提供基质，电活性微生物（EAB）在生长的同时产生电流，从而实现了太阳能至电能的转化。

2.材料与方法

本实验采用石墨毡材料作为电极材料，石英砂（≤1 mm）作为沉积物，接种的微生物为二沉池污泥。选取石菖蒲（*Acorus tatarinowii*）这种天津本地常见的根系发达物种作为种植的植物。实验开始时，将重量和生长情况相近（鲜重 9.42 ±1.21 g，高度约 20 cm）的植株移栽至反应器。反应器为直径 7 cm，高 15 cm 的高型烧杯。在反应器中，石英砂高度为 9 cm，水层高度为 5 cm。阴极垂直置于

水层。阳极分别位于距离沙水界面为 2.0 cm （S-PSMES）、5 cm（M-PSMES）、7.5 cm（D-PSMES）处。所有闭路反应器均连接 1000 Ω 的外电阻，并设置开路对照组 S-O-PSMES，M-O-PSMES，D-O-PSMES 和无植物对照组。每组设置 3 个平行实验。

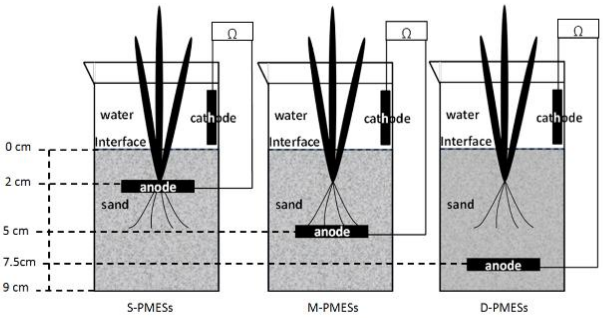

图 1 装置示意图

3. 结果与讨论

3.1 阳极开路电势

阳极电势是影响 SMES 产电的重要因素。如图 2 所示，D-O-PSMES 和 D-O-SMES 有较高的开路电势，在 700-800 mV，并且较为稳定。M-O-PSMES 和 M-O-SMES，S-O-PSMES 和 S-O-SMES 有较大的变化，表面明其确实受到植物的影响。

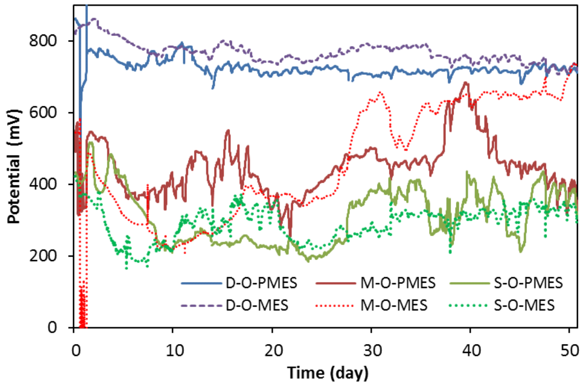

图 2 不同反应器阳极开路电势

3.2 沉积物中氧含量分布

植物根系会释放溶解氧，产生的氧气会向四周扩散，从而根系周围产生微氧环境。在实验运行第 41 天，测定了各个反应装置不同深度沉积物处的氧含量，如图 3 所示。D-PSMES，M-PSMES 和 S-PSMES 的氧气浓度从水沙界面开始明显下降，到-3.5 cm，-4 cm 时候，基本降到 0，然后开始逐渐提高。在 D-PSMES 中，植物根系生长到了约 6 cm 深度，泌氧区域在-5.0 cm 到-7.0 cm，在-5.5 cm 深度时候有最大氧浓度为 10.8 μmol/L。在 M-PSMFCs，根际泌氧区域在-4.0 到-6.0 cm 处，其中最大氧含量达到了 26.5 μmol/L，最大氧含量出现在距离沙水界面-4.5

cm 处。在此深度氧气含量最高的原因是，植物根系生长受到阳极石墨毡的阻碍，在阳极表面聚集。

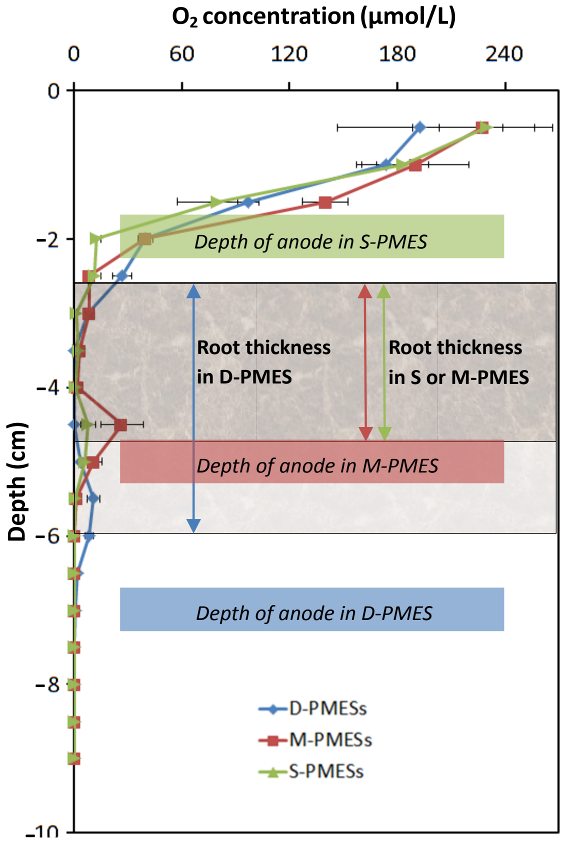

图 3 不同反应器的径向氧浓度分布
注：0 cm 是水-沙界面

3.3 植物对产电的影响

根系影响产电的程度随着阳极深度的不同而改变，如图4所示。在D-PSMES，阳极附近的氧含量大约为 0.23-0.77 μmol/L，其产电电压高于 D-SMES。在反应器开始运行至稳定期（20-51 天），D-PSMES 的平均电压比 D-SMES 高 12.1 mV。这主要是因为根际分泌物和根系脱落组织为产电微生物提供了有机物基质且泌氧没有抑制产电作用。Oh 等人发现[4]，当阳极区域含量低于 0.9 μmol/L 时，MFC 可以有稳定的电能输出。D-PSMES 的阳极区氧含量为 0.23-0.77 μmol /L，低于 0.9 μmol/L，因此植物根系分泌物提供的基质促进产电的作用高于泌氧的抑制作用。因此可得，在 D-PSMFCs 中植物的根系作用有利于系统产电。M-PSMES 降低至与 M-SMES 输出相近的电压，表明植物根系在阳极表面稳定生长后，植物根尖的泌氧作用阻碍了 SMES 的产电。因此，PSMFC 的植物根系紧贴阳极的植物种植方式不利于产电。

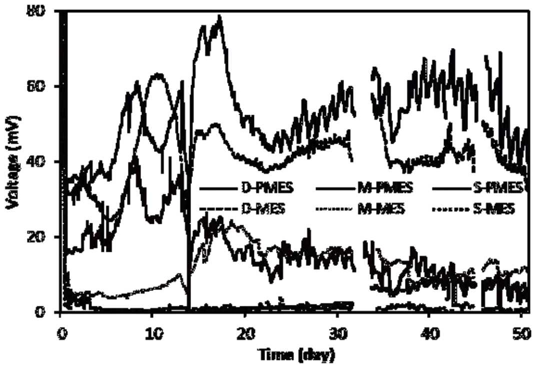

图 4 不同反应器的产电效果

3.4 阳极微生物群落结构

为更加明显区分阳极生物膜的主要菌群分布，本研究对有无植物组反应器中丰度最大的 10 个纲分别进行分析，见图 5。D-PSMES、M-PSMES 和 S-PSMES 比 D-SMES、M-SMES 和 S-SMFES 的分布较为分散，表明植物的存在增大了三种深度阳极反应器微生物的特异性。在所有 PSMES 中，*Betaproteobacteria*，*Deltaproteobacteria*，*Gammaproteobacteria* 占据的丰度最高。*Betaproteobacteria* 在 D-PSMES 中有更高的丰度，*Deltaproteobacteria* 在 M-PSMES 中有更高的丰度。

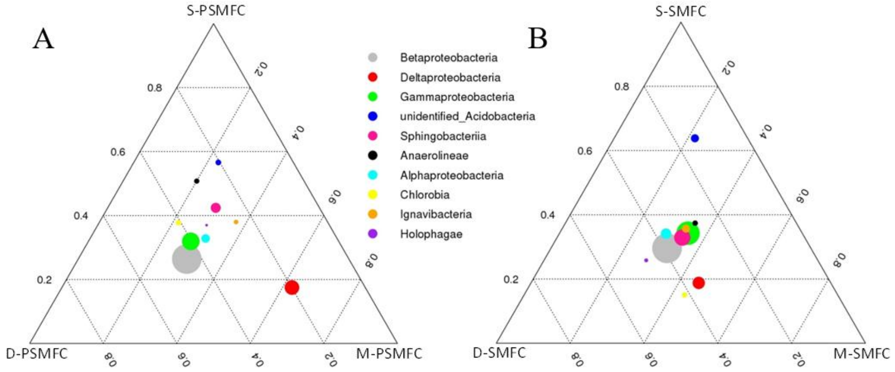

图 5 有无植物组反应器中的微生物分布

由于植物泌氧作用，阳极区出现了部分兼性好氧菌和好氧菌（见图 6），如 *Pseudomonas*、*Hydrogenophaga*、*Massilia*、*Herbaspirillum* 和 *Flavobacterium*。在 M-PSMES 中，*Pseudomonas*、*Hydrogenophaga*、*Massilia*、*Herbaspirillum* 比其他组的相对丰度高，尤其是 *Pseudomonas* 和 *Massil*ia 尤其明显。产电菌和好氧或兼氧菌在基质的利用上具有竞争关系，因此较高丰度的好氧菌和兼氧菌会不利于产电菌的富集。这于上文中 M-PSMES 产电效果差的现象一致。

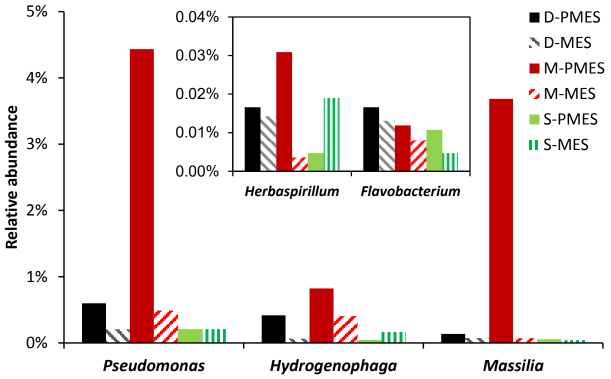

图 6 好氧菌在阳极生物膜上的相对丰度分布

4. 结论

本研究主要得到以下两个结论：

（1）阳极和植物根系的位置关系是 PSMFC 运行的关键，当植物根系位于阳极上表面约 2.5 cm 处时，根系能够为阳极提供产电基质，同时泌氧对阳极影响较小，产电最高；

（2）在 M-PSMFC 组最高泌氧达到了 26.5 μmol/L，植物的根际泌氧提高了阳极的氧含量并富集了一定的好氧或兼氧菌。

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江汉平原东北部浅层地下水化学成分演化规律研究

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摘要：研究地下水化学成分的演化规律和形成机理，为地下水的合理开发利用和地下水污染治理提供科学依据。本文以江汉平原东北部浅层地下水为研究对象，分析了 Qp3al 含水层和 Qhal 含水层浅层地下水化学成分的演化规律和形成机理。通过对地下水化学成分和稳定同位素特征的分析，发现 Qhal 含水层中的地下水向 Ey 含水层和 Qhal 含水层补给，Qhal 含水层中的地下水接受 Qp3al 含水层和 Ey 含水层的侧向径流补给。Qp3al 含水层表现出补给-径流区的特点；Qhal 含水层表现出排泄区的特点，由于径流途中的离子交换作用，导致地下水 Mg2+含量有所增加。不同含水层 δD、δ18O 值的富集程度不同体现了不同水体的水循环条件存在差异性；不同含水层的蒸发线的斜率 K 值不同说明各含水层的蒸发强度不同，整体的蒸发强度与含水层的埋藏深度表现出一致性。

关键词：浅层地下水；演化规律；形成机理；化学成分；稳定同位素

潮汐流人工湿地中全程自养生物脱氮作用的强化及其稳定性

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摘 要：本文探究了分流措施对潮汐流人工湿地（TFCW）系统的脱氮效能与相关微生物特性的影响，以期探寻可有效强化TFCW中基于亚硝化的全程自养脱氮作用(Completely Autotrophic Nitrogen Removal Over Nitrite，CANON)的途径。试验结果表明，分流比可显著影响TFCW系统的脱氮效能，当分流比为1:1时，系统的脱氮效能最佳，其对TN和NH4+-N的去除负荷分别为(127.00±13.78)和(124.77±4.37) mg/(L d)；随着分流比的增大，系统中功能基因anammox 16S rRNA的绝对与相对丰度均有所增加，系统中的厌氧氨氧化作用得以强化，从而有利于TFCW中TN的去除。另外，6种脱氮功能基因(narG、napA、nirS、nirK、qnorB和nosZ)的绝对与相对丰度亦有所增加，但其变化并不显著，系统中的反硝化作用并未得到强化；由逐步线性回归模型可知，TFCW中TN的去除途径主要为CANON作用。而当分流比为1:1时，系统中DO与有机物的浓度分布较为合理，CANON型人工湿地反应体系得以成功构建。

关键词：潮汐流人工湿地(TFCW)；基于亚硝化的全程自养脱氮(CANON)；厌氧氨氧化；分流比；脱氮

当前人工湿地技术广泛地用于处理如垃圾渗滤液、食品废水等低 C/N 废水，然而人工湿地的脱氮性能却受系统氧供应量不足以及缺少有机碳源因素的制约[1, 2]，很难实现人工湿地的高效脱氮。因此，研究者们试图通过一定的技术手段和调控措施来缓解溶解氧和有机碳源对人工湿地系统的制约。

强化人工湿地中基于亚硝化的全程自养脱氮(Completely Autotrophic Nitrogen Removal Over Nitrite，CANON)作用，构建 CANON 型人工湿地反应体系是目前人工湿地强化脱氮的热门研究之一。通常认为,湿地填料层中 DO 浓度与分布的调控是 CANON 型人工湿地在构建过程中的关键参数。通过改进湿地系统运行方式，调控填料层中的 DO 浓度与分布,进而强化人工湿地系统的 CANON 作用。分段进水是强化 CANON 作用的一个重要调控措施。通过在系统中形成限氧环境可减少氮氧化物，提高系统 TN 去除能力。然而，CANON 型潮汐流人工湿地系统对 $NH4^{+}$-N 和 TN 的去除效果还并不理想，分流措施处理低 C/N 污水时对湿地系统脱氮性能的影响机制仍未明晰。因此，评估分流比对人工湿地系统脱氮性能的影响也十分必要。

为此，本研究以潮汐流人工湿地(TFCW)为试验装置，从系统宏观工艺运行性能和微观生物学特征两个方面出发，强化了 TFCW 中的 CANON 作用，并分析了其微生物特性，完成了对单级 CANON 型人工湿地反应装置的优化控制。本研究可为低碳氮比废水的高效、低成本处理与新型人工湿地的工程化应用提供理论依据和数据支持。

1 材料与方法

1.1 试验装置

TFCW 系统位于实验室内，温度维持在(25±2)℃。TFCW 的表面积约为 314 cm2(φ≈20cm)，材质为有机玻璃，湿地填料层高度为 80 cm:下层为 10cm 厚的支撑层，填充粒径为 10~15 mm 的砾石；上层为 70 cm 厚的填料层，填充粒径约 2~5 mm 的海蛎壳。TFCW 总体积为 25.12 L，因填料层孔隙率为 40.30%，其有效体积为 10.12 L。系统顶部设置有“Ω”型穿孔管作为进水管，在距装置底部 5 cm 处安装出水管，底部安装有另一个“Ω”型穿孔管作为分流进水管。在 TFCW 填料层中部安装有垂直的 PVC 管(长 80cm，φ≈3.5cm)，用于原位检测污水的部分理化参数。在 TFCW 装置侧壁的四个不同高度(14，28，42，和 56cm)处设有内径约为 25 mm 的取样管，用于采集填料样品。每个取样管用橡胶塞密封。TFCW 内种植芦苇[3]，种植数量为 4 株(芦苇幼苗高度约为 30cm，保留其主茎和 2~3 个嫩枝)。

1.2 试验条件

1.2.1 进水水质

试验用水为人工配制的模拟污水。其中，进水中化学需氧量(COD)浓度为(79.40±17.72) mg/L，BOD5 浓度为(37.83±12.57) mg/L，NH4+-N 浓度为(35.54±1.80) mg/L，NO2--N 浓度为(2.80±0.57) mg/L，NO3--N 浓度为(1.72±0.18) mg/L，TN 浓度为(42.97±2.85) mg/L，TP 浓度为(13.64±2.39) mg/L，进水 pH 值为(7.74±0.58)。

1.2.2 运行方式

本研究中 TFCW 系统采用分段进水潮汐流模式连续运行，以期最大限度的强化系统中的 CANON 作用。在此模式下，系统每天运行 4 个周期，每个周期 6 h，具体运行方式为(图 1-1)：(a)进水期(t=10 min)：一定体积的污水通过进水管泵入 TFCW 系统中。与此同时，另一部分污水则通过分流管由蠕动泵泵入 TFCW 系统中，为了调节系统填料层中的 DO 浓度，自分流管泵入的污水采用上向流模式；(b)淹水期(t=240min)：进水期结束后，整个填料层保持在浸没状态；(c)排水期(t=10min)：填料层内污水通过系统底部出水管排出系统；(d)闲置期(t=100min)：整个湿地填料层处于闲置阶段。

TFCW 系统每个周期共泵入 10L 污水(包括从分流管泵入的污水)，相应的 HLR 为 1.27m3/(m2·d)。试验设置了 6 种不同的分流比，分别为 0:1、1:4、1:3、1:2、1:1 和 2:1。

试验可划分为 6 个时期：A 期(分流比 0:1，运行 182 个周期)、B 期(1:4，运行 186 个周期)、C 期(1:3，运行 186 个周期)、D 期(1:2，运行 246 个周期)、E 期(1:1，运行 246 个周期)和 F 期(2:1，运行 186 个周期)。实验装置置于室内，进出水温度变化范围为 21~26℃。

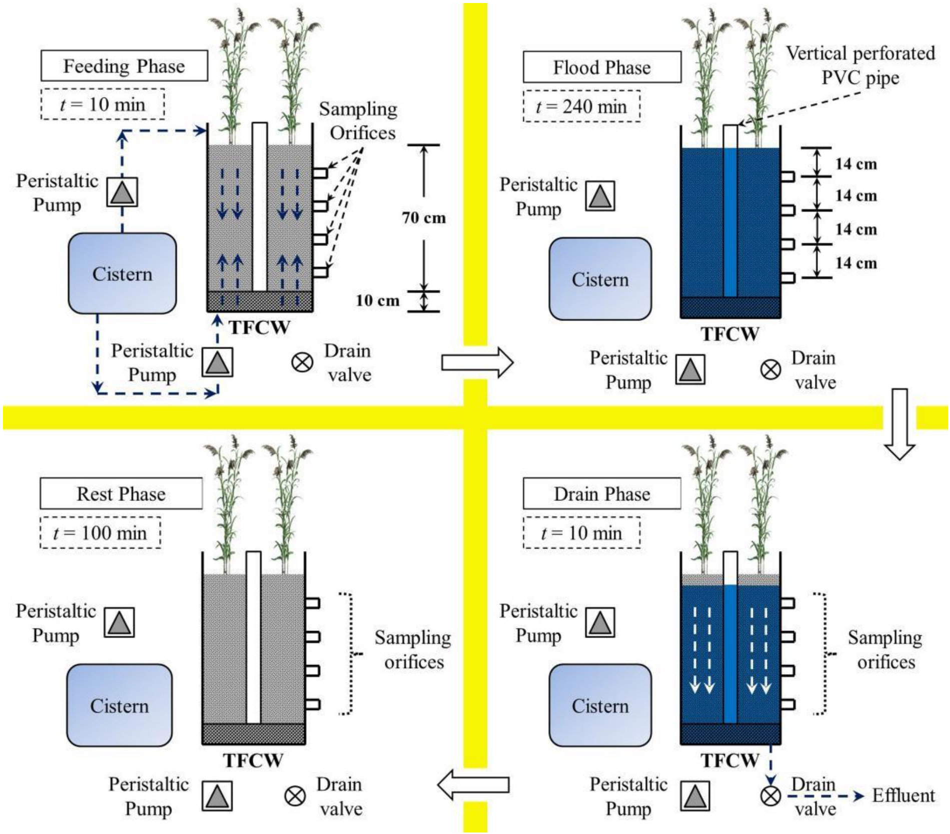


图 1-1 CANON 型 TFCW 系统构建阶段的构型与运行方式

Fig 1-1 Schematic of the modified single-stage TFCW during a typical cycle

1.3 分析方法

定期从 TFCW 系统的进出水管采集水样并进行测定。待各组 TFCW 运行稳定后，在系统淹水期 1 和淹水期 2 两个阶段内每隔 30min 采集填料层中的水样，以期监测典型周期内各系统中污染物的实时变化特征。系统运行稳定后，于各 TFCW 系统中采集填料样品。采集到的填料样品混合均匀后置于冷藏箱中，并尽快送至实验室进行 DNA 提取。此外，每周对 TFCW 系统中植物的平均高度进行测量。

1.3.1 水样采集及分析方法

对水样的温度，pH，DO，ORP，TSS，COD、BOD、TN、NH_4^+-N、NO_3--N、NO_2--N 和 TP 进行分析。水样中 TSS、COD、BOD、TN、NH_4^+-N、NO_3--N、NO_2--N 和 TP 的测定方法按照《水和废水监测分析方法》[4]的标准方法进行测定。水样 pH 值由数字式 pH 计(PB-10，Sartorius，德国)测定。典型周期内 TFCW 系统填料层中水温、DO 和 ORP 均使用便携式 HACH HQ30d 多参数分析仪进行原位测定。

1.3.2 FISH 荧光原位杂交

采用 FISH 技术对 TFCW 系统各运行阶段填料层中好氧氨氧化菌(AOB)和厌氧氨氧化菌(anammox)的相对数量及分布进行分析。从系统填料层中提取生物膜样品，溶于 4%多聚甲醛溶液。样品的预处理可参照文献[5]中所述方法.，而后进行杂交。杂交方法可参照文献[6]中所述方法，所用探针和杂交条件则如表 1-1 所示，试验中所用到的寡核苷酸探针均由上海生工生物工程技术服务有限公司合成。杂交后的样品通过激

光共聚焦显微镜 LSM 510META(Zeiss, Germany)观察，FISH 图片则使用 Image-Pro Plus 6.0(Media Cybernetics, America)软件进行统计分析。

表 1-1 FISH 分析中所用探针及杂交条件

Tab 1-1 16S rRNA-targeted oligonucleotide probes during the analysis of FISH

探针	特异性	靶位点 (*E.coli*)	甲酰胺 (%)	NaCl(mmol/L)	标记	参考文献
NSO190	AOB in the *β*-*Proteobacteria*	190~208	40	25	Cy3(绿色)	[6]
PLA46	*Planctomycetales*	46~63	30	159	Cy5(红色)	[7]
AMX820	*Cand*. “*Brocadia anammoxidans*” *Cand*. “*Kuenenia Stuttgartiensis*”	820~841	40	56	Cy5(红色)	[7]

1.3.3 脱氮功能基因定量分析

利用土壤 DNA 试剂盒(D5625-01 Omega USA)将采集的生物膜样品进行 DNA 的提取纯化，产物经紫外分光光度计测定核酸浓度以及纯度，并贮存于-20℃的冰箱中保存。随后将提取的 DNA 样品进行荧光定量 PCR 测定测定，即对其中的 bacteria 16S rRNA 和微生物脱氮关键功能基因(包括 amoA、anammox 16S rRNA、nirS、nirK、nxrA、narG、napA、qnorB 和 nosZ)进行测定。试验使用 Applied Biosystems StepOneTM 仪器进行荧光定量 PCR 分析并用 SYBR Green I 荧光染料法进行测试，扩增体系如下：10 μL SYBR Green I PCR master mix (Applied Biosystems, USA)、8 μL DEPC 处理水(Applied Biosystems, USA)、正反向引物各 0.5 μL、DNA 模板 1 μL，共 20 μL 反应混合液，扩增 40 个周期。每种功能基因使用的引物种类和反应所需的条件均参照文献[8]中所述方法。

1.4 试验数据处理

系统中 COD、TN、NH_4^+-N、NO_3--N、NO_2--N 和 TP 的去除率、转化率和积累率均参照文献[9]中所述方法进行计算。试验所得数据均使用 SPSS 21.0 和 Excel 2010 软件进行统计分析。利用 SPSS 21.0 进行单因素(one-way ANOVA)方差分析，显著临界值为 $p<0.05$。使用 Duncan 检测法评估各种方法的区别。Pearson 相关性分析用于鉴定显著性线性关系。运用 SPSS 21.0 软件利用逐步线性回归模型解析 TFCW 系统中氮素转化速率与相关脱氮功能基因的定量响应关系。使用 Origin 8.5 软件绘图，数据采用(平均值±标准差)方式表达。

2 结果与分析

2.1 CANON 型 TFCW 系统的脱氮效果

通过进一步优化分流式 TFCW 系统运行方式，尝试进行 CANON 型 TFCW 系统的构建。由表 2-1 可知，在不同分流比的条件下，虽然进水中 COD 和 BOD 的浓度较低，但 TFCW 系统仍可实现对 BOD、COD 的有效去除(如表 2-1)。此外，不同分流比下，TFCW 系统对 TP 的去除亦呈现出较为理想的效果(如表 2-1)，此试验结果主要

归因于海蛎壳较高的磷素吸附容量[10]。

由图 2-1 可知，分流比可显著影响分流式 TFCW 系统中氮素的迁移转化及其脱氮性能。当分流比为 0:1 时，淹水期伊始系统填料层中的 DO 浓度高达(4.33±0.31) mg/L，系统中大部分溶解氧在此时期消耗。NH4+-N 去除负荷也随之高达(123.68±4.92) mg/(L·d)，而 TN 的去除负荷仅为(8.92±1.07) mg/(L·d)，出水中的氮素多为 NO3--N，其浓度为(32.49±2.49) mg/L，一个典型周期内 NO3--N 的生成量/NH4+-N 的消耗量≈(1.05±0.09)。通常认为，人工湿地的复氧能力显著影响 NH4+-N 的氧化[10-12]。研究表明，潮汐流运行方式下 TFCW 的氧气传递速率可达 450 g/(m2·d)[13]，远高于传统潜流型人工湿地和曝气型人工湿地，由此可获得更高的 NH4+-N 去除率。然而，由于分流式 TFCW 系统缺乏有机碳源且填料层中 DO 浓度过高，致使未能为 NOx--N 还原为 N2 提供适宜条件。通过 FISH 技术也未能在系统中检测到有厌氧氨氧化菌 (数据未列出)。

当分流比由 1:4 增至 1:3 时，淹水期伊始系统填料层中的 DO 浓度由(3.60±0.20)降至(2.97±0.12) mg/L。系统 NH4+-N 去除率在 B、C 期较高，可达(130.14±7.10) mg/(L·d)和(121.79±8.68) mg/(L·d)。而 TN 去除率仍处于较低水平，分别为(12.58±1.34) mg/L 和(15.48±3.57) mg/L。由此可知，此时系统中有少量氨氮通过厌氧氨氧化或反硝化作用转化为气态氮。通过 FISH 技术在 B、C 期并没有发现厌氧氨氧化菌的迹象。在 C 期初亚硝酸盐开始显著积累，这表明由于系统采取分流措施，填料层中的限氧环境会抑制亚硝化细菌(NOB)的活性。通常认为，可采取限制曝气的措施实现对 NOB 的抑制，进而实现系统中的短程硝化作用[15]。当系统在 C 期运行，亚硝酸盐积累率(NAR)达到最高值 77.96%。如图 2-1 所示，当分流比从 0:1 增至 1:3，NO3--N 生成量/NH4+-N 的消耗量范围在(1.05±0.09)到(0.46±0.14)，这与 CANON 作用的化学计量摩尔比率仍存在偏差[16]。

此后，为了在 TFCW 系统中创造更严格的限氧环境，增加分流比从而继续降低系统填料层中的 DO 浓度，使得系统的 TN 去除性能进一步得到提升。D 期开始后，淹水期伊始系统填料层中的 DO 浓度降至(1.69±0.24) mg/L，TN 去除率则开始增加，NH4+-N 去除率仍维持较高水平，可达(118.18±6.69) mg/(L·d)，NAR 开始迅速下降，出水中的亚硝酸盐浓度从第 280 天的 16.49 mg/L 降至第 400 天的 5.25 mg/L。显然，分流式 TFCW 系统在 1:1 分流比下脱氮效果最佳，TN 和 NH4+-N 平均去除率分别为(127.00±13.78)mg/(L·d)和(124.77±4.37) mg/(L·d)，DO 浓度维持在(1.03±0.23) mg/L。Sun[17]等研究发现 TN 去除率最高为 0.279mg/(L·d)，本 TFCW 系统 TN 去除率相较于其他人工湿地而言，其 TN 去除率较高[0.0024~0.084 mg/(L·d)][18-22]，即本试验中的 CANON 型人工湿地系统的脱氮性能较为理想，其 TN 去除负荷与 Third [23]等的研究结果类似[0.120 mg/(L·d)]。如图 2-2 所示，分流式 TFCW 系统在分流比 1:2、1:1、2:1 条件下运行时，FISH 分析结果表明，在生物膜中有 anammox 存在。样品的 CLSM 图像检测出 AOB 和 anammox 共存于生物膜中：聚集在外层的 AOB 为内层 anammox 提供 NO2--N，亦可缓解 O2 对 anammox 的抑制[24]。研究表明，系统以适宜分流比运行时，TFCW 中的 CANON 作用可得到最大限度的强化。当 anammox 出现后(如图

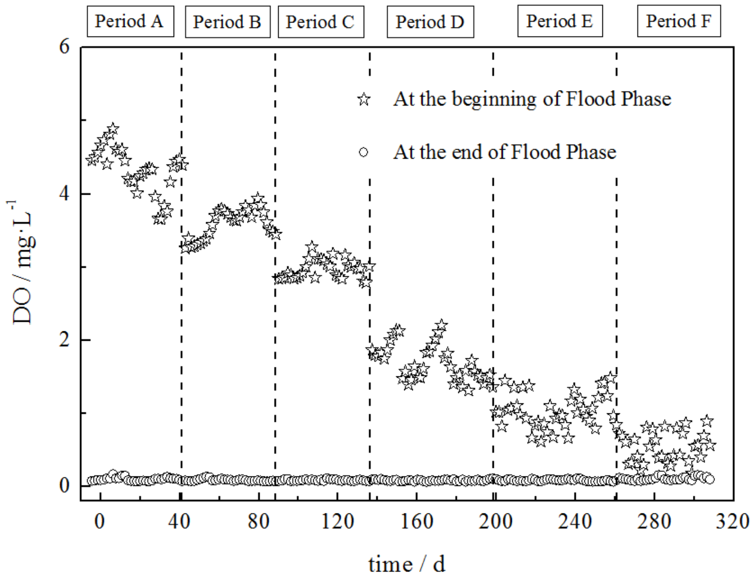
2-1)，E 期之初 NO_3--N 的生成量/NH_4^+-N 的消耗量约为 0.11，符合 CANON 反应的特点，由此表明 TFCW 系统 CANON 反应体系在 E 期得以成功构建。当分流比继续增至 2:1 时，系统 TN 和 NH4+-N 的去除率平均下降至 (99.84±14.51) 和 (84.43±13.76)mg/(L·d)。在 F 期间，淹水期之初系统填料层中的 DO 浓度降至(0.54±0.20) mg/L，NO_3--N 的生成量/NH_4^+-N 的消耗量维持在(0.087±0.054)，这与 CANON 作用中 NO_3--N 的生成量和 NH_4^+-N 的消耗量之比略有差别。这是由于 2:1 的分流比造成系统复氧能力恶化，进而致使淹没期生成的亚硝酸盐不足，随之抑制了 anammox 作用的进行。

综上所述，当系统分流比为 1:1 时，分流式 TFCW 的脱氮性能最佳，CANON 型 TFCW 系统能够得以成功构建。

表 2-1 CANON 型 TFCW 系统构建阶段不同分流比下污染物去除率

Tab 2-1 TSS, COD, BOD, and TP removal of TFCW under shunt ratio constraints.

	进水	出水					
		分流比					
		0:1	1:4	1:3	1:2	1:1	2:1
TSS / mg·L^{-1}	65.12±24.51	3.77±1.01	3.87±0.78	3.80±0.72	4.38±0.84	4.18±1.21	4.70±1.39
COD / mg·L^{-1}	79.40±17.72	20.60±1.23	23.38±3.24	22.28±2.16	25.16±3.71	21.43±1.07	23.94±2.45
BOD / mg·L^{-1}	37.83±12.57	3.26±2.21	4.25±1.28	3.40±1.74	4.10±1.47	3.44±2.06	3.94±2.17
TP / mg·L^{-1}	13.64±2.39	0.74±0.15	0.63±0.11	0.74±0.08	0.70±0.23	0.77±0.14	0.83±0.13



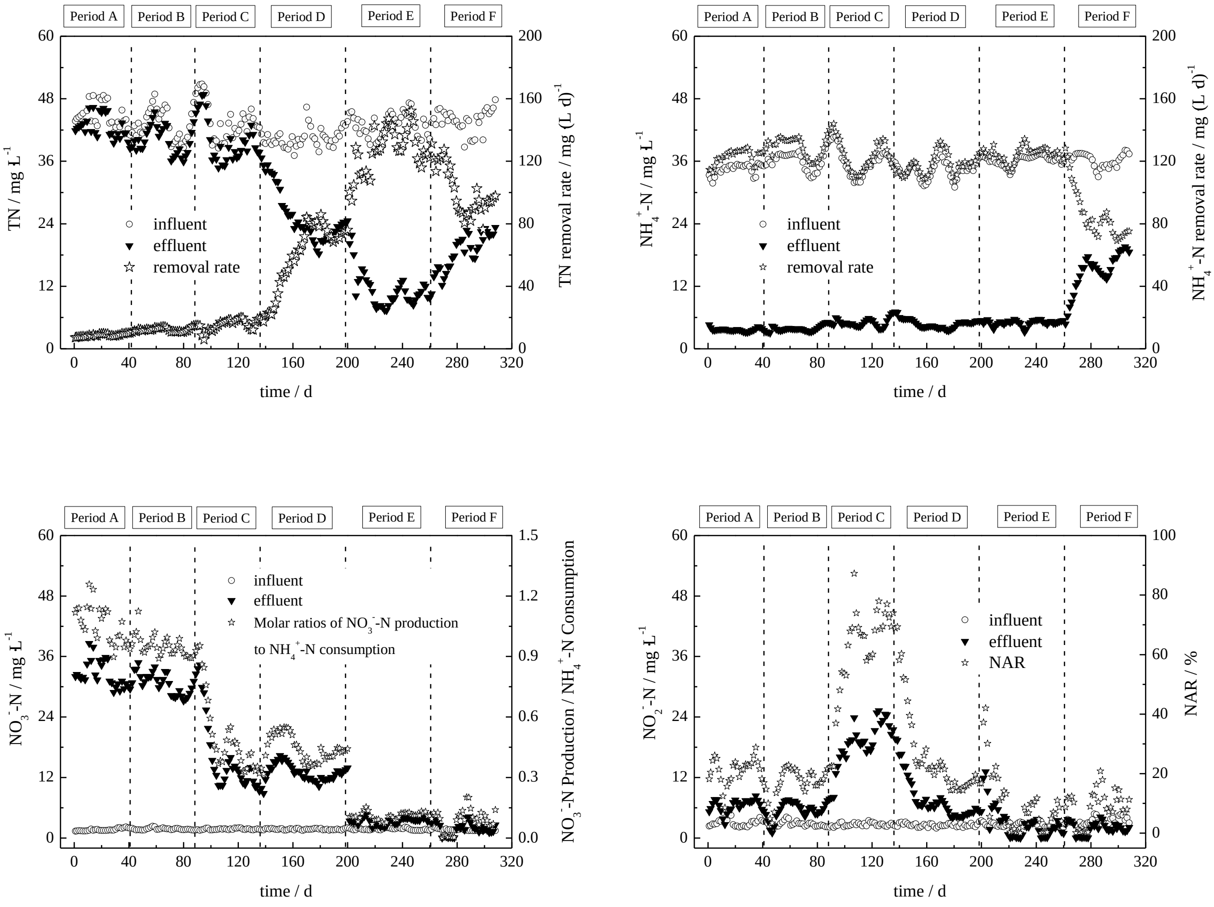


图 2-1 CANON 型 TFCW 系统构建阶段氮素的转化与去除性能

Fig 2-1 Nitrogen transformation and treatment performances of the TFCW under shunt ratio constraints.

(A 期: 分流比为 0:1, B 期:分流比为 1:4, C 期:分流比为 1:3, D 期:分流比为 1:2, E 期: 分流比为 1:1, F 期: 分流比为 2:1).

(Period A: shunt ratio of 0:1, Period B: shunt ratio of 1:4, Period C: shunt ratio of 1:3, Period D: shunt ratio of 1:2, Period E: shunt ratio of 1:1, Period F: shunt ratio of 2:1).

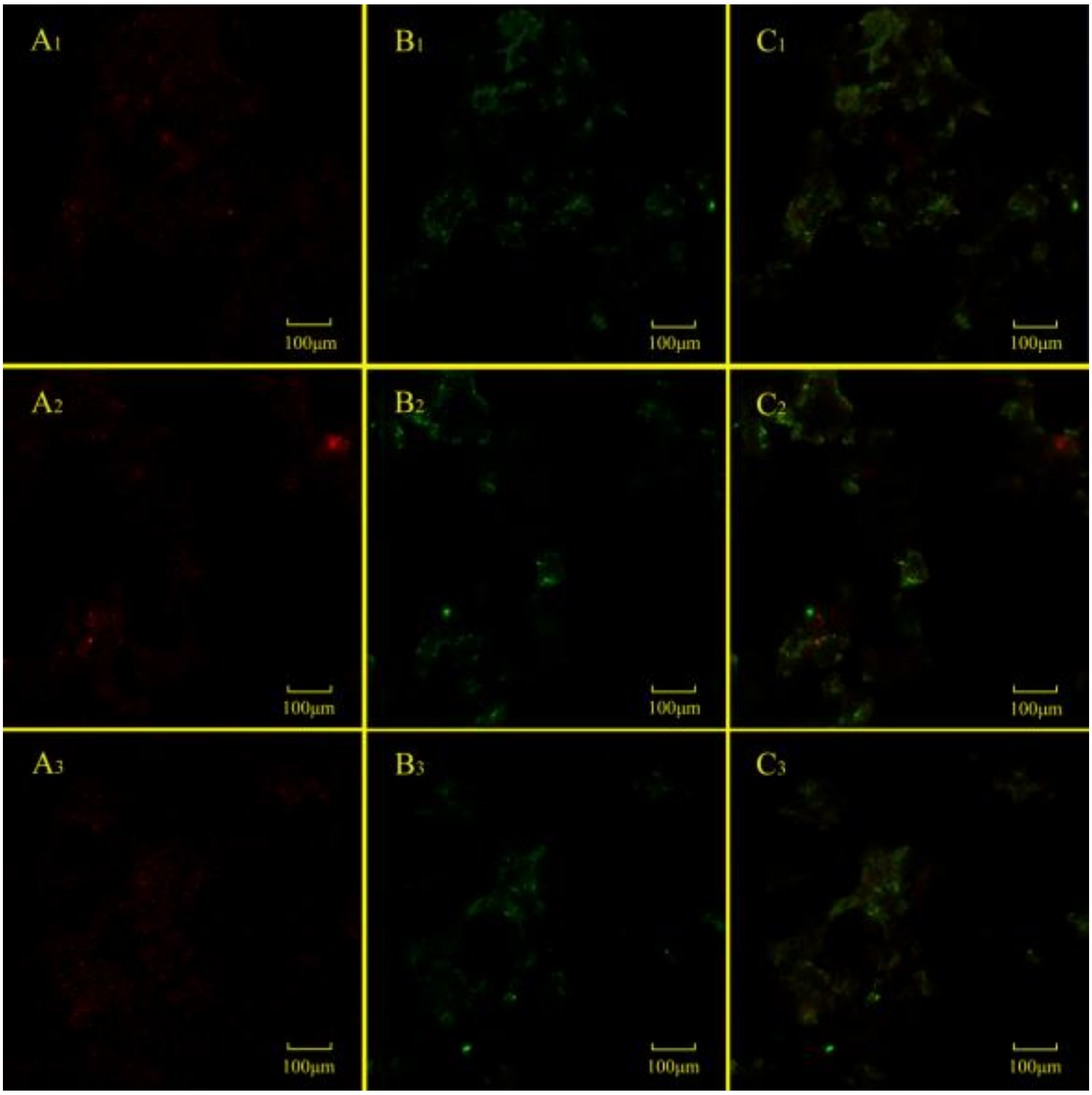


图 2-2 TFCW 系统中填料样品的 FISH 分析结果

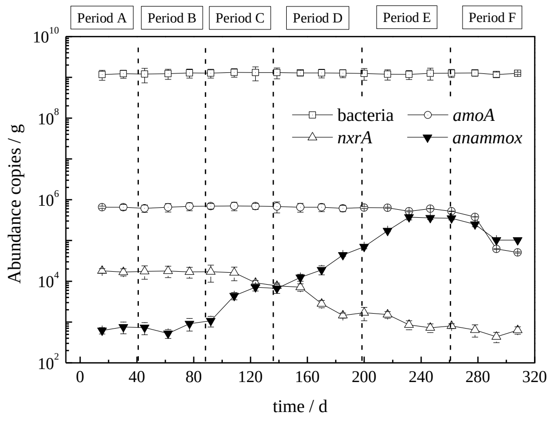
Fig 4-5 FISH analysis of substratum samples from the TFCWs: (A1, A2, A3) hybridization of biomass with Cy5-labelled Amx820 (red) on day 170, day 246, and day 293; (B1, B2, B3) hybridization of the same biomass with FITC-labelled NEU653 (green) on day 170, day 246, and day 293; (C1, C2, C3) simultaneous hybridization of biomass with Cy5-labelled Amx820 (red) and FITC-labelled NEU653 (green) on day 170, day 246, and day 293.

2.2 分流比对 CANON 型 TFCW 系统脱氮功能基因的影响

参与氮素迁移转化的关键功能基因变化情况如图 2-3 所示(bacteria 16S rRNA、anammox 16S rRNA、amoA、nxrA、narG、napA、nirK、nirS、qnorB、nosZ)。TFCW 系统中 bacteria 16S rRNA 基因拷贝数较高，其变化范围为(1.16×109~1.32×109) copies/g，由此可知分流式 TFCW 系统中有充足的微生物量可为强化系统的 CANON 作用提供保证[14]。

如前所述，amoA 是参与 NH4+-N 氧化生成 NO2--N 的关键基因[25]，nxrA 是参与 NO_2--N 氧化生成 NO_3--N 过程的功能基因[26]。Anammox 16S rRNA 是参

与厌氧氨氧化反应的关键基因。由图 2-3 得知，在 TFCW 系统的稳定运行阶段，上述三个功能基因拷贝数较为稳定，A 期时样品中的 amoA、nxrA 和 anammox 16S rRNA 基因拷贝数分别为 6.53×10^5、1.78×10^4copies/g 和 5.26×10^5 copies/g。其中，amoA 和 nxrA 的基因拷贝数显著高于 anammox 16S rRNA 的基因拷贝数，并在 B 期仍保持较高水平。由于 AOB 和 NOB 具有相似的生长环境和生理代谢习性[8]，nxrA 与 amoA 有相似的变化趋势，但 nxrA 基因拷贝数低于 amoA。当分流比由 0:1 增至 1:4，nxrA 的基因拷贝数由 A 期的 1.81×104copies/g 下降至 B 期的 1.72×10^4 copies/g。与 amoA、nxrA 不同，在 B 期结束后，系统中 anammox 16S rRNA 的基因拷贝数维持在一个较低水平。由此可知，在 A、B 期 TFCW 系统中 NH4+-N 的去除途径主要为短程硝化作用，并且有少量 NO_2--N 积累。然而，由于此时填料层中 DO 浓度较高，系统中几乎没有厌氧氨氧化反应的发生[27-28]。随着分流比大于 1:3，由于系统填料层中的限氧环境，使得 nxrA 的基因拷贝数于 D 期阶段开始下降。而 amoA 的基因拷贝数在 D、E 期没有显著变化。此外，anammox 16S rRNA 的基因拷贝数由 C 期的 4.4×10^3copies/g 增至 E 期的 3.74×105copies/g，直到 E 期结束仍维持较高水平。厌氧氨氧化反应进行的必要前提之一是实现稳定的短程硝化反应[29]。结果表明，通过调节系统分流比改变系统填料层中 DO 浓度，可实现短程硝化，也进一步证明低 DO 浓度(1mg/L)是控制亚硝化的关键因素[30]。此外，厌氧氨氧化菌在分流式 TFCW 系统中得到有效富集，表明限氧条件下 CANON 作用在系统中得以强化。当分流比为 1:1 时，CANON 作用逐渐成为分流式 TFCW 系统的主要脱氮途径。分流比继续增至 2:1 时，系统中 amoA 和 anammox 16S rRNA 基因拷贝数呈现显著下降趋势，表明过大的分流比对 CANON 作用会产生抑制作用。这是由于过大分流比会导致系统氧传输能力受阻，系统亚硝化反应随之会受到抑制，anammox 由于其反应底物 NO2--N 不足，其活性会随之降低。



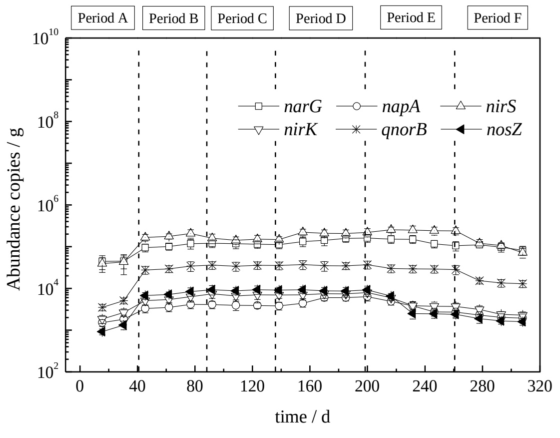


图 2-3 CANON 型 TFCW 系统构建阶段相关脱氮功能基因的变化

Fig 2-3 Absolute abundance of nitrogen transformation functional genes in the TFCW under shunt ratio constraints.

由于系统填料层中限氧环境的加强，参与反硝化的 6 种关键功能基因的拷贝数在 D、E 期略有增加；然而，由于进水中缺乏有机物，其 BOD_5/N(≈0.88)值相对较低，反硝化能力不足，系统反硝化脱氮性能并未显著提高。一般地，为了将 1g NO_3--N 反硝化还原为 N_2，通常需要 2.86g 的 BOD。研究表明，当进水 C/N(BOD5：∑NOx−-N)低于 2.3 时，反硝化能力受阻[31]。因此，通过传统硝化反硝化很难将污水中的氮素去除。当分流比继续增至 2:1 时，由于过大分流比对 TFCW 系统的氮素转化产生不利影响，narG、napA、nirS、nirK、qnorB 和 nosZ 基因拷贝数于 F 期开始降低。

2.3 CANON 型 TFCW 系统氮素转化与脱氮功能基因的响应关系

为探究不同分流比对 CANON 型 TFCW 系统氮素转化率的影响，将 10 个脱氮功能基因作为候选变量利用逐步线性回归模型分析不同阶段各形态氮素转化速率和脱氮功能基因的定量响应关系。功能基因组亦作为逐步回归分析的变量进行系统中氮素迁移转化途径的探究。4 组回归模型的 R2 值范围在 0.913~0.972(如表 2-2)。

由表 2-2 可知，TN 去除速率[v(TN)]受(amoA+anammox 16S rRNA/bacteria 16S rRNA)、(bacteria 16S rRNA)和 nxrA 三个变量的影响。(amoA+anammox 16S rRNA/bacteria 16S rRNA)与[v(TN)]呈显著正相关，表明 CANON 作用是此 TFCW 系统主要的脱氮途径，anammox 16S rRNA 和 amoA 是 TN 去除的关键基因。bacteria 16S rRNA 和 v(TN)呈正相关关系，表明系统中微生物量增加有益于提高系统 TN 去除性能。鉴于 nxrA 功能基因参与 NO_2--N 的氧化，则其表示 NO_3--N 的积累程度，根据结果发现由于 NO_3--N 的积累，使得厌氧氨氧化菌的活性下降[27]。该回归方程表明，CANON 作用是 TFCW 中 TN 去除的主要途径。

NH4+-N 去除速率[v(NH4+-N)]与(amoA/bacteria 16S rRNA)和(amoA+anammox 16S rRNA/bacteria 16S rRNA)显著正相关。amoA 的丰度可在一定程度上反映系统亚硝化过程中 NO_2--N 的积累情况，且 NO_2--N 积累量增加有助于提高 NH_4^+-N 的去除速率。而变量(amoA+anammox 16S rRNA/bacteria 16S rRNA)则说明系统中 NH_4^+-N 去除的主要途径之一为 CANON 作用。因此，由回归方程可知， TFCW 中 NH_4^+-N 去除的主要途径为短程硝化作用和 CANON 作用。

影响 NO_3--N 累积速率[v(NO_3--N)]的 3 个变量为(nxrA/bacteria 16S rRNA)、(nxrA+anammox/bacteria 16S rRNA)和(narG+napA)。其中，前两个变量与 v(NO_3--N)均呈现正相关，反映了 NO_3--N 在系统中的累积程度。nxrA 和 anammox 分别参与硝化反应和 CANON 作用生成 NO_3--N 的过程。narG 和 napA 均是参与反硝化过程中 NO_3--N 还原的功能基因则变量(narG+napA)表明 NO_3--N 可通过反硝化作用去除。该试验结果与 Wang 等[32]的一致。

NO2--N 累积速率[v(NO2--N)]受(amoA/bacteria 16S rRNA)、[(amoA+anammox 16S rRNA/bacteria 16S rRNA)]和(nxrA/bacteria 16S rRNA)3个变量影响。(amoA/bacteria 16S rRNA)可反应 NO2--N 的累积程度。[(amoA+anammox 16S rRNA/bacteria 16S rRNA)]和(nxrA/bacteria 16S rRNA)则分别表明 CANON 作用和硝化反应均可降低系统中 NO_2--N 的浓度。根据方程可知，硝化、CANON 作用是参与系统中 NO_2--N 转化的两种主要途径，亦体现了系统填料层中微生物种群的复杂性。

表 2-2 CANON 型 TFCW 系统构建阶段氮素转化速率与脱氮功能基因的定量响应关系

Tab 2-2 Quantitative response relationships between nitrogen transformation rates and functional genes of the TFCW under shunt ratio constraints. (n = 20).

逐步线性回归方程式	R^2	p
$v(\mathrm{TN})=95.45+13.72\cdot(\text{anammox 16S rRNA}+\mathit{amoA}/\text{bacteria 16S rRNA})+6.10\times10^{-8}\cdot\text{bacteria 16S rRNA}-3.42\times10^{-3}\cdot\mathit{nxrA}$	0.960	0.003
$v(\mathrm{NH_4^+\text{-}N})=71.31+1.04\times10^{5}\cdot(\mathit{amoA}/\text{bacteria 16S rRNA})+7.43\cdot[(\mathit{amoA}+\text{anammox 16S rRNA})/\text{bacteria 16S rRNA}]$	0.972	0.001
$v(\mathrm{NO_3^-\text{-}N})=-19.84+3.18\times10^{6}\cdot(\mathit{nxrA}/\text{bacteria 16S rRNA})+3.34\times10^{2}\cdot[(\mathit{nxrA}+\text{anammox})/\text{bacteria 16S rRNA}]-2.10\times10^{-4}\cdot(\mathit{narG}+\mathit{napA})$	0.913	0.007
$v(\mathrm{NO_2^-\text{-}N})=-1.27+9.89\times10^{5}\cdot(\mathit{amoA}/\text{bacteria 16S rRNA})-29.62\cdot[(\mathit{amoA}+\text{anammox 16S rRNA})/\text{bacteria 16S rRNA}]-1.20\times10^{7}\cdot(\mathit{nxrA}/\text{bacteria 16S rRNA})$	0.969	0.005

3 结 论

本研究从系统宏观工艺运行性能和微观生物学特征两个方面出发，在常温和低 NH4+-N 浓度下开展了 TFCW 中 CANON 作用强化研究，考察了强化 CANON 作用过程中系统的脱氮性能，并分析了系统中微生物的群落特征及其更迭和演替规律，完成了单级自养脱氮型人工湿地系统的构建。具体研究结论如下：

(1)分流比可显著影响 TFCW 系统的脱氮效能，当分流比为 1:1 时，系统的脱氮效能最佳，其对污水中的 TSS、有机物和 TP 等污染物亦具有较高的去除率。此时 TFCW 对 TN 和 NH4+-N 的去除负荷分别为(127.00±13.78)和(124.77±4.37) mg/(L·d)。

(2)随着分流比的增大，系统中功能基因 anammox 16S rRNA 的绝对与相对丰度均有所增加，系统中的厌氧氨氧化作用得以强化，从而有利于 TFCW 中 TN 的去除。另外，6 种脱氮功能基因(narG、napA、nirS、nirK、qnorB 和 nosZ)的绝

对与相对丰度亦有所增加，但其变化并不显著，系统中的反硝化作用并未得到强化。

(3)利用逐步线性回归模型解析了不同分流比条件下湿地系统中各形态氮素的转化速率与相关脱氮微生物功能基因丰度变化的响应关系。试验结果表明，分流比的变化会引起湿地系统中 DO 和有机物浓度及分布的变化，进而导致了系统中部分脱氮功能基因绝对及相对丰度的变化，最终使得不同分流比下系统的脱氮性能发生变化。由回归模型可知，TFCW 中 TN 的去除途径主要为 CANON 作用。而当分流比为 1:1 时，湿地系统中 DO 与有机物的浓度分布较为合理，CANON 型人工湿地反应体系得以成功构建，TN 去除率亦较为理想。

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以靜電紡絲製備活性碳纖維電極與其於電容去離子技術之應用

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近年來，受到氣候變遷的影響，水資源短缺已成為一項重要的議題，發展一項新穎的水中離子分離技術，並同時解決傳統技術所帶來高能耗及二次汙染物的問題，為現階段永續發展與節約能源使用的重點之一。電容去離子技術(Capacitive deionization, CDI)為一項新穎、綠色、低能耗的電化學水處理程序，主要係以奈米多孔碳材為基礎，利用電荷分離與電吸附原理，來移除水體中的鹽類或是帶電荷污染物質。而在電容去離子技術中，材料為控制電容去離子脫鹽效果的一項關鍵因素。在選擇材料時，高比表面積、良好導電性、孔洞性及親水性，為選擇材料時首先需要考量的指標。為製備出具有良好上述指標特性之奈米多孔材料，本研究中使用靜電紡絲(Electrospinning)，配合不同高溫碳化及活化的程序製備出活性碳纖維(Activated carbon fiber, ACF)。傳統製備電極的過程中，均需添加聚合物作為黏著劑，將多孔碳才顆粒聚集成片狀，且聚合物會影響電極表面之導電性，以靜電紡絲製作出之活性碳纖維電極，無須添加任何聚合物即可獲得片狀電極。實驗中，利用不同的活化程序，可同時控制活性碳纖維的比表面積及孔徑分布。實驗結果中，比表面積分布經由不同活化溫度及時間，比表面積分布於450至1300 m2/g間，並將其利用於電容去離子程序中，其吸附容量為4.73 mg/g。

前言

近年來由於工業及科技的蓬勃發展，間接產生許多含有鹽類及重金屬離子的廢污水，使得原已稀少的水資源更顯得珍貴。台灣屬於海島型氣候國家，雖具有豐富的降水量(約 2500 mm/year)，為世界平均降水量之 3 倍，但因山脈陡峭、河川短而急，無法有效的利用降水所提供之水資源。根據經濟部水利署資料指出，台灣在全世界缺水排於第十八，單位人口所可使用到的水資源為世界平均值的六分之一，故發展新穎離子分離技術，解決現有水資源問題，是追求永續發展與節約能源使用的重點之一。

電容去離子技術(capacitive deionization, CDI)為一項新穎的水處理技術，其應用範圍片及生活、工業及科技等，應用範圍廣泛，因此現階段被視為極具有開發潛力之技術。相較於傳統的水處理技術，CDI 具有操作簡便、低壓力、低電壓、高容量及可調控性，可避免傳統薄膜處理程序中，高壓力、高能耗及反沖洗時所產生之二次汙染物對環境所造成的影響。圖 1 為其工作原理示意圖，首先將預處理之水體通入兩片電極間，此時水中的帶電荷離子受到庫倫靜電力的驅使，因而趨向於相反電性之電極表面，此時再以電吸附的方式將離子儲存於電極表面孔洞的電雙層中，以達到淨化水體的目的(Farmer et al., 1996)。

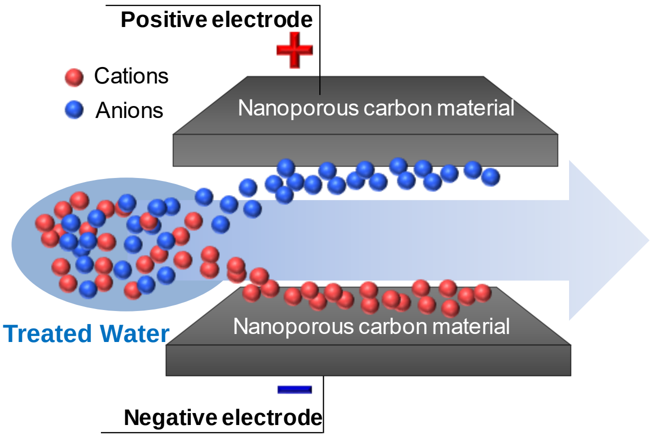

圖 1 電容去離子工作示意圖

在電容去離子技術中，離子的儲存主要是利用電極在經由電場的施加，在電極材料的奈米孔洞中形成電雙層進而儲存離子，因此電極材料中的奈米孔洞被視為電容去離子程序中的一項重要因子。根據國際純粹應用化學聯合會(IUPAC)定義，可分為粗孔(macropore > 50 nm)、中孔(mesopore, 2-50 nm)及微孔(micropore, < 2 nm)。再者，Porada 的研究團隊於 2013 年所發表的文獻中指出，在選擇電吸附實驗電極時，以下幾點為優先考量是否為適合應用於電容去離子技術之參考：1.在進行實驗時，對於離子接受性高的比表面積、2.具有良好的導電性、3.有利於離子擴散進出的孔隙、4.在高 pH 值與高電位下不易發生電化學反應、5.電極

與系統電阻小、6.低成本具實用性、7.親水性良好、8.具有良好的可塑性、9.對於環境影響低、10.高生物惰性。另外，在 2015 年 Yeh 及 2018 年 Liu 等人的研究成果中顯示，奈米孔洞材料中，不同比例的微孔及中孔洞分布與比表面積對於電容去離子中的電吸附效果會有顯著的影響，在選擇材料時，除選擇高比表面積、良好導電性與高機械性等特性外，中孔洞及微孔洞的平均分布，也有利於電吸附程序的進行。

現階段的研究中，多以粉末狀之奈米多孔碳材，並以 5~20%之聚合物作為黏著劑作，製作出奈米多孔碳電極，應用於電容去離子程序中儲存離子。然而，以聚合物作為黏著劑，將奈米多孔碳粉末製作成片狀的過程中，所使用的黏著劑(如：聚偏氟乙烯，polyvinylidene fluoride，PVDF 等)存在以下問題：1.導電性不佳：因黏著劑之導電性差進而影響到電極的整體導電性，造成電子在電極表面傳遞不均。2.疏水性：大多數黏著劑具有疏水的特性，在實驗進行的過程中，因電極親水性不佳，造成故意介面接觸不理想，影響離子於電極表面及孔洞的傳輸。3.電極比表面積變低：在進行成膜的過程中，黏著劑為將碳顆粒進行鏈結，會覆蓋到部分碳顆粒之表面，使得奈米多孔碳材電極之比表面積相較於原始粉末狀之奈米多孔碳材之比表面積較低。4. 奈米多孔碳粉末分布不均：粉末狀的碳顆粒與黏著劑在製作成電極後，無法有效均勻分布。

為解決現階段奈米多孔碳電極所面對的問題，近年來發展出以靜電紡絲(Electrospinning)配合碳化及活化技術，製作出具高比表面積的活性碳纖維，活性碳纖維具有無黏著劑添加、片狀碳電極與比表面積可調控性的優勢，以避免黏著劑對於電極所造成的問題。Wang 等人在 2010 年首先利用聚丙烯腈(polyacrylonitrile，PAN)為電紡原料，製作出片狀纖維，並將電訪分別進行碳化及活化，進而與活性碳及碳氣凝膠等奈米多孔碳電極，於於電容去離子的電吸附效果進行比較，實驗結果中顯示，活性碳之吸附容量約為 0.15 mg/g，碳氣凝膠與活性碳纖維之吸附量約為 3.25 mg/g，顯示以電紡所製備出之活性碳纖維應用於電容去離子技術中之潛力。再者，Wang 等人另於 2010 年，將電紡所製作出之片狀纖維，配合不同的碳化溫度及固定活化參數，以控制活性碳纖維之比表面積，用此方式可將活性碳纖維之比表面積控制在 335 至 712 m^2/g 之間，最後以比表面積 712 m^2/g 之活性碳纖維進行電吸附實驗之電吸附容量為 4.64 mg/g。

本研究目的主要是利用電紡製備出片狀纖維電極，配合不同活化參數製備出具有良好導電性、良好親水性及高比表面積的活性碳纖維，並針對其表面特性及電吸附特性進行研析，了解片狀活性碳纖維對於電容去離子技術改善之效益。

研究方法

電紡絲製備活性碳纖維 以聚丙烯腈(Polyacrylonitrile, PAN)為原料，將其以10%wt與90%wt之二甲基乙烯胺(N,N-dimethylacetamide, DMAc)混合均勻後，以電壓15 kV、流速2 mL/min、距離12公分之參數，製備出片狀纖維。再將片狀纖維至於280°C下進行固定化2小時，再以800°C進行碳化，最後在800及900°C下以二氧化碳之物理活化法，利用不同時間參數對於纖維電極進行活化，以製備出活性碳纖維電極。本研究之材料命名方式如表1所示。

表1 本研究依照不同活化溫度及時間之材料命名

Temperature	CO_2 activated retention time		
	0.5 hr	1 hr	1.5 hr
800°C	ACF805	ACF810	ACF815
900°C	ACF905	ACF910	ACF915

電吸附實驗 本研究中使用批次式實驗，進而了解活性碳纖維於電吸附之效果，實驗中以恆電位儀施加定電壓 1.2 V，並以二極式方式進行，電解質溶液在系統中的總體積為 25 mL，流量則由蠕動幫浦控制在 5 mL/min。並以下列公式計算其電吸附容量。

$$q_e = \frac{(C_0 - C_t)\mathrm{V}}{\mathrm{m}}$$

q_e：電吸附容量(mg/g-carbon)
C_0：初始濃度(mM)
C_t：吸附飽和濃度(mM)
V：溶液體積(L)
m：電極質量(g)

結果與討論

活性碳纖維表面特性分析　圖 2(a)為針對未碳化及活化之片狀纖維之表面觀察，由圖中可看出，利用靜電紡絲所製備出之片狀纖維以交錯的方式形成片狀纖維，結構良好，圖 2(b)為經過碳化及活化程序後之活性碳纖維，圖中可看到纖維在經過活化過後，表面顯示出凹凸不平的型態，可能為活化過程中二氧化碳侵蝕比面所造成。

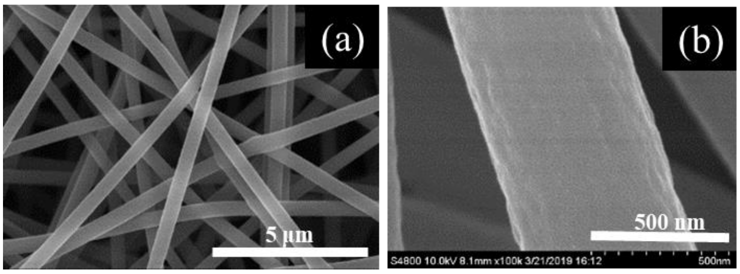

圖 2 (a)未碳化及活化之片狀纖維與(b)活性碳纖維之表面觀察

圖 3(a)為使用拉曼光譜對於活性碳纖維之導電特性分析，於頻率 1350 cm^{-1} 之 D-band 及 1582 cm^{-1} 之 G-band 計算出缺陷程度(I_D/I_G)，缺陷程度越低，表示材料導電性越佳，ACF805 至 ACF915 之缺陷程度界於 1.00 至 0.92，其中 ACF915 具有最低的缺陷程度 0.92，為所有材料中缺陷程度最低者，具有最佳的導電性。

圖 3(b)及表 2 為活性碳纖維 BET 比表面積分析結果，表 2 的結果中可得知，活性碳纖維之比表面積隨著活化溫度及時間的增加而增加，其比表面積大多由微孔洞所貢獻。值得注意的是，在活化溫度為 900^{o}C，活化時間為 1 小時及 1.5 小時的兩組實驗中發現，總比表面積由 1075 m^2/g 增加至 1300 m^2/g，但兩者之微孔洞比表面相近，由此可得知中孔洞比表面積顯著增加，由孔體積量測的結果中，亦得到相同的結果，由此組實驗中可得知，以二氧化碳進行活化的過程中，起先活化以產生微孔洞為主，但在特定時間後，中孔洞會隨著時間增加而增加。

由上述結果中可了解到，活性碳纖維 ACF915 具有最佳的導電性、高比表面積及較多的中孔洞比例，因此本研究後續將以 ACF915 進行電吸附之試驗。

表 2 活性碳纖維 BET 分析結果

Carbon	S_{BET}^{a} (m^2/g)	S_{micro}^{b} (m^2/g)	V_{tot}^{c} (cm^3/g)	V_{micro}^{d} (cm^3/g)
ACF805	468	415	0.25	0.22
ACF810	495	449	0.19	0.17
ACF815	527	488	0.21	0.18
ACF905	846	771	0.34	0.30
ACF910	1075	938	0.45	0.37
ACF915	1300	929	0.66	0.40

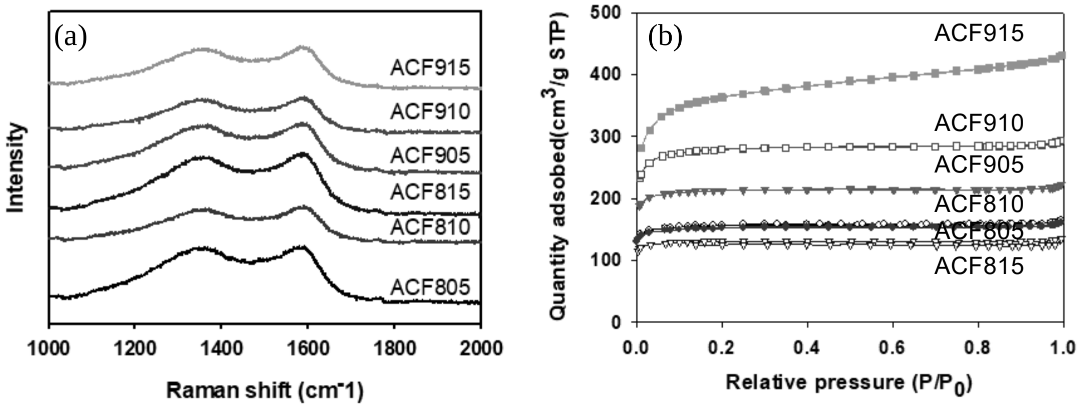

圖 3 (a)拉曼光譜及(b)氮氣吸附及脫附測試

活性碳纖維於電容去離子之應用　　圖 4(a)為 ACF915 活性碳纖維於提供系統電壓 1.2 V 下，於 5 mM 之 NaCl 溶液下進行批次式實驗導電度隨時間的變化。圖中可看到在 CDI 的系統下，ACF915 在施加電壓 15 分鐘時，導電度由初始 580 μS/cm 下降至 525 μS/cm，而在 MCDI(Membrane capacitive deionization)的系統中，導電度則由初始 580 μS/cm 下降至 430 μS/cm，電吸附容量由 4.73 mg/g 提升至 14.49 mg/g。其原因為在電極表面添加陰陽離子交換膜後，可避免系統中同離子效應及法拉第反應的影響，有效將電極的特性展現出來，同時亦可增加系統之穩定性。再者，圖 4(b)中則是將 CDI 及 MCDI 兩者系統於各吸附量下對吸附速率之 Ragone plot，在 Ragone plot 的分析中，好的系統需有良好的電吸附容量及吸附速率，亦及圖形趨勢越偏向右上方越好，於此結果中，MCDI 之曲線圖較 CDI 較偏上右上方，因此可進一步推斷 MCDI 具有較好的電吸附表現。最後，為確保以電紡技術進行碳化活化後的活性碳纖維，為適用於電吸附實驗之電極材料，進行 20 次的連續吸附及脫附測試，如圖 4(c)所示，由此實驗結果中可進一步確認，以電紡技術進行碳化活化後的活性碳纖維，具有良好的電吸附穩定性，適用於電容去離子程序中。

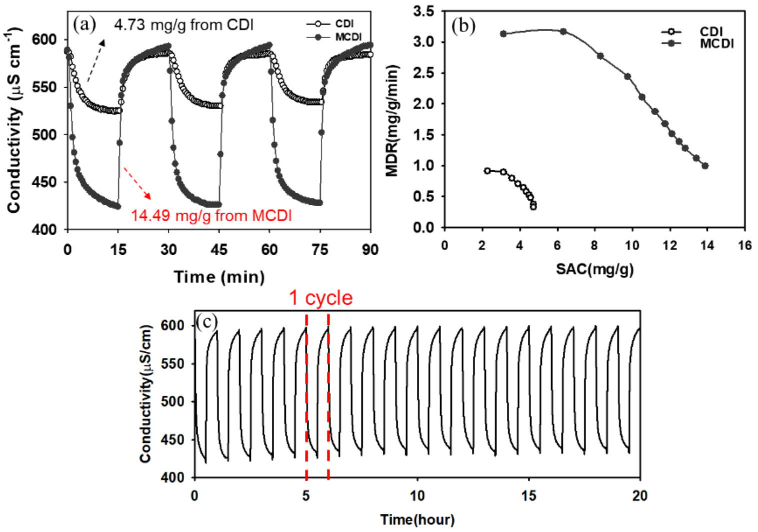

圖 4 (a) ACF915 活性碳纖維於 5 mM 的 NaCl 溶液中進行 CDI 及 MCDI 之測試、(b)CDI 及 MCDI 於 Ragone plot 的分析結果、(c)MCDI 之穩定性測試

結論

本研究以電紡技術製備出片狀纖維，並且經過碳化及活化程序後得到活性碳纖維，並進一步探討材料之表面特性及其於電容去離子技術之應用。在表面特性分析的研究結果中，本研究成工製備出具片狀，且具有良好導電性及高比表面積的活性碳纖維作為電極材料。在電吸附的實驗中，於 5 mM 的 NaCl 溶液中進行 CDI 及 MCDI 的實驗，在 MCDI 系統中，電吸附容量為 14.49 mg/g，為 CDI 系統的三倍，其原因係由於陰陽離子交換膜可避免在進行電吸附程序時可能發生的同離子干擾及法拉第反應，在最後的穩定性實驗中，成功確立以電紡技術進行碳化活化後的活性碳纖維，具有良好的電吸附穩定性，確立其為適用於電容去離子程序中之電極材料。

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以過硫酸鹽輔助超聲波增加水中異丙醇之降解

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隨著台灣科技業的蓬勃發展，有機溶劑的使用量也隨之提高，其中異丙醇(Isopropyl alcohol, IPA)為一種無色、易揮發的液體，半導體業廣泛應用於晶圓清洗、濕蝕刻等製程之乾燥用有機溶劑，對人體也具有吸入、攝入及吸收毒性，成為汙染環境的潛在威脅，因此如何妥善處理廢水、廢氣中的異丙醇便成為目前實廠需面對的問題。

超聲波技術波能夠增加反應中污染物和自由基之碰撞次數，有效降解水中有機汙染物；本研究利用超聲波引發之空蝕效應(Cavitation effect)造成水中過硫酸根離子($S_2O_8^{2-}$)及過氧化氫(H_2O_2)發生熱裂解反應，釋放出高反應性之硫酸根自由基($SO_4^{\cdot -}$)及氫氧自由基($OH^{\cdot}$)，進而促進異丙醇之氧化分解。本研究將探討於不同之過硫酸鹽添加濃度、超聲波輸出功率、初始 pH 值等不同反應條件下水中異丙醇降解效率的變化，可快速且有效地降解水中的異丙醇。

一、 前言

異丙醇(C_3H_8O, isopropyl alcohol)，簡稱 IPA，又名 isopropanol、2-propanol，為常溫常壓下易揮發的有機溶劑，具有些微的臭味，被廣泛應用於藥物、油漆、印刷、橡膠製造工業，主要做為溶劑使用(Raghuvanshi et al. 2012)，常見於 LCD/LED 產業及半導體廠的廢水中(Wu et al. 2008)，在半導體廠中無論是氧化、蝕刻、光微影、塗佈、氣提、切削、礦化噴敷、平面化等大部分製程都會使用到，主要用於晶圓的濕蝕刻、氣提、切割以及清洗製程等的乾燥輔助溶劑(Lin and Tsai 2019)，因此半導體業的廢水中便含有大量的異丙醇(Wu et al. 2008)。IPA 不僅對環境中水及空氣品質造成負面影響，也對大眾健康產生危害(Raghuvanshi et al. 2012)。吸入 IPA 氣體會造成腸胃不適、痙攣、噁心、嘔吐及腹瀉，也會造成眼睛過敏、角膜損傷，慢性暴露則會造成皮膚問題，皮膚病患者、肝腎及肺部功能不良的患者對 IPA 暴露會更加敏感。而暴露於高濃度 IPA 將會抑制中樞神經系統、失去意識甚至是死亡。美國職業安全與健康管理局(OSHA , Occupational Safety and Health Administration)定義 IPA 於工作場所的八小時容許暴露濃度(PEL, permissible exposure limit)為 400mg/ L (Raghuvanshi et al. 2012)。

有鑑於 IPA 對環境及人體的負面影響，我們必須在排放進入環境前妥善去除廢水中的 IPA，因此研究水中 IPA 有效且經濟可行的處理技術便成為目前迫切的需求(Wu et al. 2008, Raghuvanshi et al. 2012)。

二、 研究方法

本研究利用超聲波輔助過硫酸鹽系統降解 IPA，首先配置 50ppmIPA 以及過硫酸鈉標準溶液，定量至 1.5L，倒入雙層玻璃反應槽，經磁石攪拌後以微量吸管取出 2mL 之樣品，並以一次性之 PTFE 過濾頭過濾水樣至樣品瓶中，此時為 IPA 初始濃度 C_0。將反應器接上恒溫水浴槽之冷卻回流水管線，控制系統溫度為 20℃，並將超音波探棒置入於液面下，每次實驗時其深度皆為固定位置，進行超音波裝置之條件設定後便可啟動。反應時間為 120 分鐘，每隔 30 分鐘進行採點。

(1)首先，觀察在超音波單獨作用下對 IPA 之降解效率，利用 GC-FID 分析 IPA 之濃度變化，找出最佳功率條件。

(2)觀察不同濃度之氧化劑過硫酸根離子(1.66mM, 4.16mM, 8.32mM)對 IPA 降解效率之影響。反應溫度為 20℃；溶液初始 pH 值為 5.4。將過硫酸鹽加入反應容器中以磁石攪拌至完全溶解，再定量至 1.5L 進行取樣及分析。利用 GC-FID 分析 IPA 之濃度變化，找出最佳過硫酸鹽添加濃度。

(3)觀察不同初始酸鹼值下(pH5, pH7, pH9)，IPA 之降解效果，利用 GC-FID 分析 IPA 之濃度變化，找出最佳操作參數。

三、　結果與討論

（一）單純施加超聲波對 IPA 降解之影響

圖 1 為 250W 與 500W 之超聲波對初始濃度為 50ppm 之 IPA 溶液進行 120 分鐘反應的實驗結果，可以發現 250W 與 500W 的超聲波對 IPA 的 120 分鐘去除率分別為 13.3%和 17.3%，IPA 濃度隨著時間下降，證明超聲波對於 IPA 確實有降解效果；但提升超聲波功率對於 IPA 降解效果影響並不明顯。

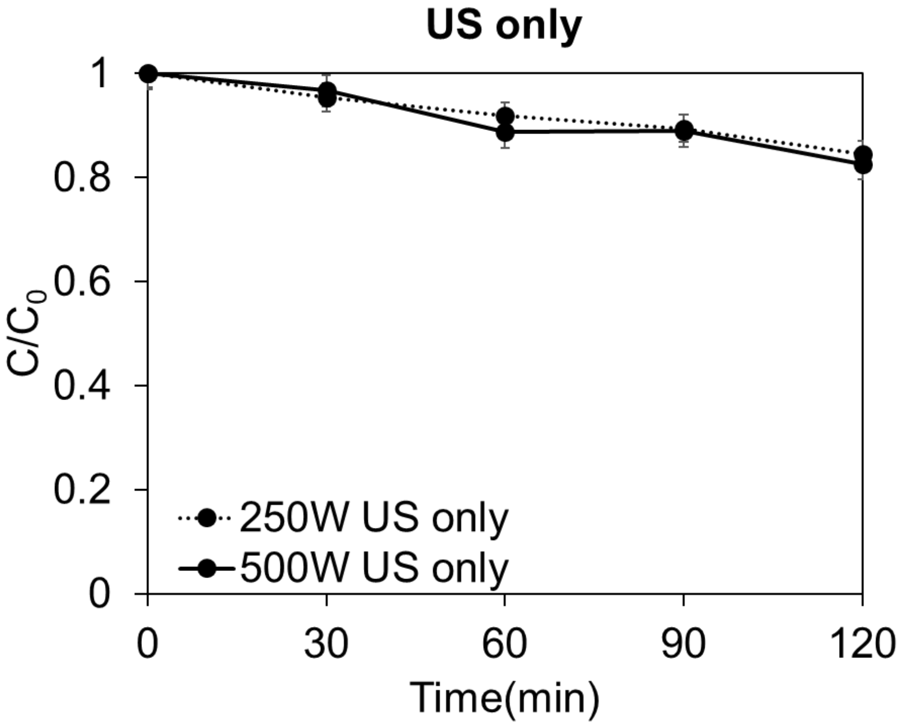

圖 1. 不同超聲波功率對 50ppm IPA 降解之影響

（二）不同過硫酸鹽添加量對 IPA 降解之影響

圖 2 為在 500W 超聲波功率下，分別對系統添加 1.66mM、4.16 mM、8.32 mM 之過硫酸鈉([過硫酸鈉]：[IPA]之比例分別為 2、5、10)，對 IPA 進行 120 分鐘反應的實驗結果。可以發現添加 1.66、4.16 及 8.32mM 過硫酸鈉對 IPA 的 120 分鐘去除率分別為 30.7%、69.8%與 56.2%，去除率隨著添加濃度由 1.66 增加到 4.16mM 提高，卻於增加至 8.32mM 時下降，原因為(式 3-1)及(式 3-2)所示(Huie and Clifton 1989, V. Buxton et al. 1999)，硫酸根自由基隨過硫酸鈉添加量提高，但卻因自由基彼此結合或與過硫酸根反應而形成反應性較低之過硫酸跟以及過硫酸根自由基，因而降低 IPA 去除率(Hao et al. 2014, Lin and Tsai 2019)。

$$SO_4{}^{\cdot -} + S_2O_8{}^{2-} \rightarrow SO_4{}^{2-} + S_2O_8{}^{\cdot -} \quad k = 6.1 \times 10^5 M^{-1}s^{-1} \qquad \text{(式 3-1)}$$

$$SO_4{}^{\cdot -} + SO_4{}^{\cdot -} \rightarrow S_2O_8{}^{2-} \qquad k = 4 \times 10^8 M^{-1}s^{-1} \qquad \text{(式 3-2)}$$

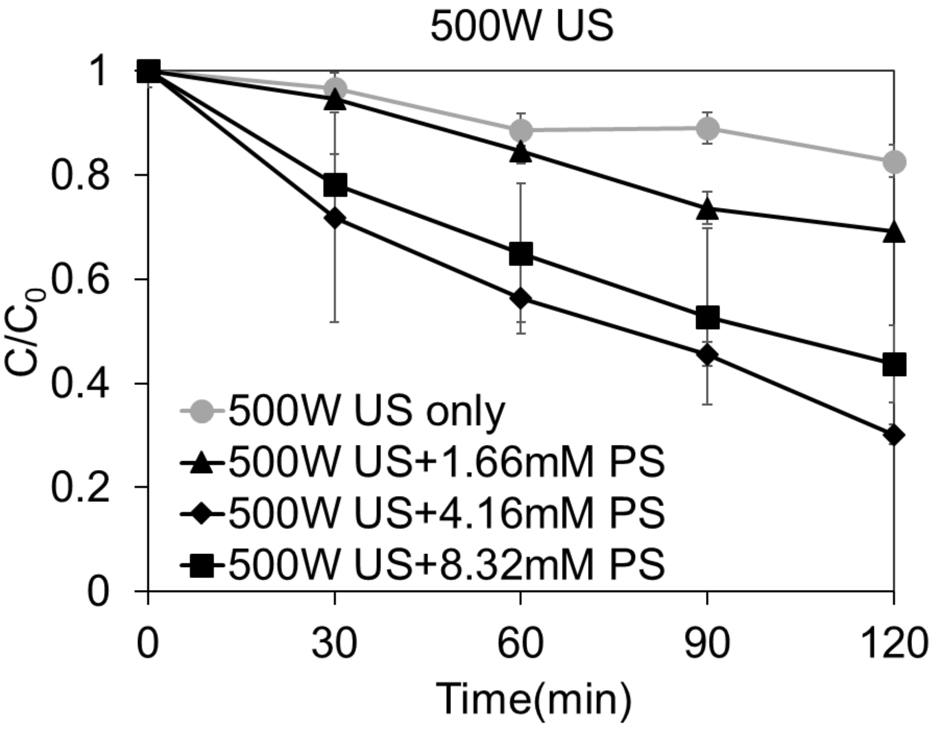

圖 2. 不同過硫酸鹽添加濃度對 50ppm IPA 降解之影響

（三）不同初始酸鹼值對 IPA 降解之影響

圖 3 為在 500W 超聲波功率下，將過硫酸鹽添加濃度為 4.16Mm 之 IPA 溶液分別調整初始酸鹼值至 pH5、pH7 及 pH9 後進行 120 分鐘反應的實驗結果，可以發現 pH5、pH7 及 pH9 對 IPA 的 120 分鐘去除率分別為 49.6%、44.1%與 14.8%，可能是因為在鹼性條件下過硫酸根離子會與水結合形成氫氧根自由基，使得硫酸根自由基減少，因而降低 IPA 去除率。(Hayon et al. 1972)

$$SO_4^{\cdot -} + H_2O \rightarrow SO_4^{2-} + OH^{\cdot} \quad k = (6.5 \pm 1.0) \times 10^{7}\ \mathrm{M^{-1}s^{-1}} \qquad (式\ 3\text{-}3)$$

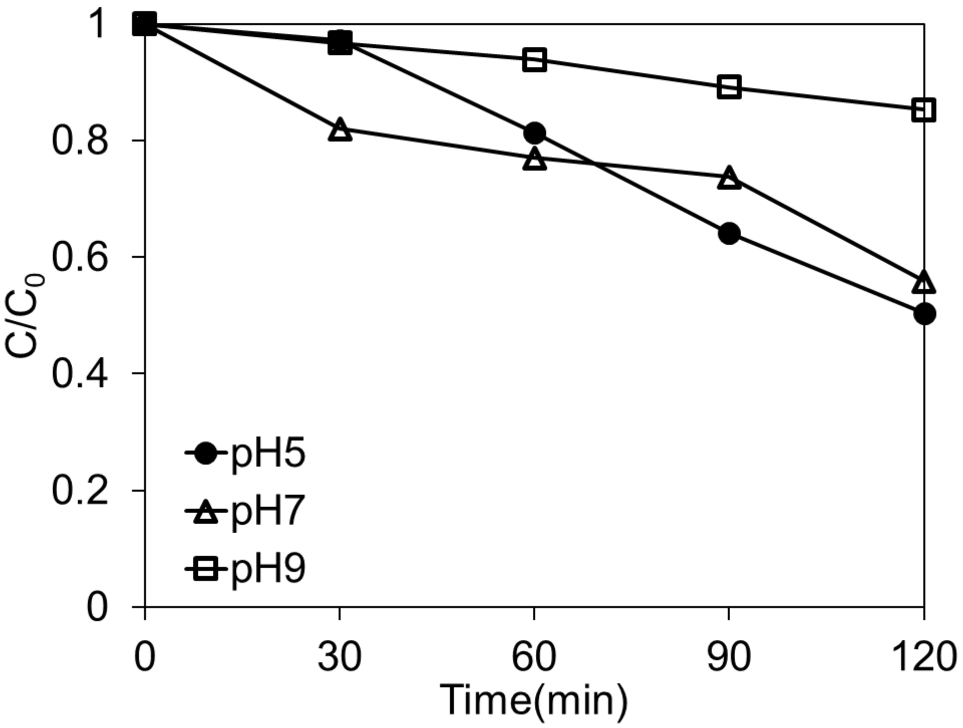

圖 3. 不同初始酸鹼值對 50ppm IPA 降解之影響

四、 結論

1. 添加過硫酸鹽有助於提升超聲波對於 IPA 之去除效果
2. 提高過硫酸鹽添加量能產生更多硫酸根自由基，但自由基會互相結合或是與過硫酸根離子結合，減少自由基的量，因而降低 IPA 去除率，因此

必須透過實驗方能找出最佳添加濃度。

3. 不同 pH 值下的 IPA 降解效果為 pH5>7>9
4. 最佳條件為：$[IPA]_0$=50ppm, US=500W, [PS]=4.16Mm, pH=5

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食物供應生命週期之衝擊分析與最佳化減量策略

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食物供應生命週期所產生之廢棄品，不僅於生產過程中浪費資源，在廢棄物終端也造成巨大的溫室氣體排放與其他環境衝擊。本研究結合環境因子及經濟因子建立在地化食物廢棄物管理輔助工具，以線性規劃建立結合環境因子與經濟因子的食物廢棄物永續管理最佳化模式，包含預防、重複利用與回收再利用等16項配置方案。各類食物生命週期之環境衝擊熱點不同，食物供應鏈上游的環境衝擊分析結果指出，衝擊熱點為生產階段之食物以穀類、肉類及蔬果類為主，衝擊熱點為加工階段之食物為乳類；食物供應鏈下游之最終處置階段，衝擊最大為集中堆肥，其次是厭氧共消化以及動物飼料。最佳化分析結果顯示，消費者教育活動、統一日期標示、產品規格改變、改善存貨管理、冷鏈管理、標準化捐贈規範及捐贈義務教育皆兼具環境效益及經濟有效性，而捐贈倉儲與管理以及集中堆肥處理，則在模擬結果中為環境效益最低之管理方案。本研究建立在地化食物廢棄物管理工具，用以量化食物供應鏈之環境衝擊，並以此作為優先切入點提出最佳化減量策略。

關鍵字：食物廢棄物、永續管理、線性規劃分析、成本效益分析

1. 前言

根據聯合國糧農組織(Food and Agriculture Organization of the United Nations, UNFAO)統計，人類每年扔掉的食物約佔了糧食總產量的三分之一，在全球食物供應鏈上所產出之食物廢棄物總量將近十三億噸(FAO, 2011)。食物供應問題涉及糧食安全、資源分配及社會正義等面向，食物廢棄物對於環境的負荷對人類的影響亦不容忽視，全球食物之碳足跡僅次於大陸或美國，而全球食物水足跡比任何單一國家之耗水更高，全球食物廢棄物所需之土地佔用為14億公頃，相當於世界農地總面積之28%，僅次於俄羅斯之國土面積，因此，食物廢棄物之管理也顯得格外的重要(FAO, 2011)。

食物廢棄物可能來自於食物供應鏈的各個階段，在中高收入之國家中，銷售與消費階段之食物廢棄物產生量佔了總產生量的40%以上；而在中低收入國家則是生產階段與加工階段的食物廢棄物產生量較高，佔總產生量的40%以上。食物廢棄物的廢棄型態因各國而有所差異，美國國家科學基金會(National Science Foundation, NSF)提出國家系統概念圖，將食物系統分為生產、倉儲、加工/包裝、批發/零售、消耗、最終處置/再利用，以及階段與階段間之運輸與交易(NSF, 2015)。而過去的研究多聚焦於食物廢棄物下游處置，在食物廢棄物處理的相關研究中，Khoo et al. (2010)從生命週期評估的角度，評估了新加坡食物廢棄物處理情境，指出厭氧消化所造成的環境影響低於小規模堆肥，而兩者皆優於使用焚化爐處理食物廢棄物。而曾偉倫(2015)指出廚餘堆肥主要衝擊為處理程序之電力消耗，其次為氣體排放，將廚餘轉化成生質酒精的環境衝擊是該研究中衝擊最低的處理情境；若考量各處理情境的替代效益，則以廚餘經高溫蒸煮後堆肥之環境衝擊為最低。

除了環境面進行衝擊量化之外，Angelo et al. (2017)結合了LCA與多準則決策分析(multi-criteria decision analysis, MCDA)，針對巴西里約熱內盧居家食物廢棄物管理提出改善策略，收集20%和50%食物廢棄物進行厭氧消化，而剩餘的食物廢棄物以掩埋處理，並將厭氧消化產生的有機固體作為農場肥料，為MCDA結果中較佳的選擇。De Clercq et al. (2017) 同樣以MCDA進行決策分析的研究，評估三個將有機廢棄物轉化為生質瓦斯於技術、經濟及環境面考量共七個情境之管理策略，提出建議將資本投資補貼轉變為績效的補貼，可提高沼氣生產率以及找到最具經濟效益之沼氣用途。

除了比較終端之食物廢棄物處理情境之外，Eriksson and Spångberg (2017)的研究中也比較食物管理情境(捐贈)的二氧化碳排放及能源使用，結果指出超商食物廢棄物施以捐贈和轉換能有效較低環境衝擊，且對於全球暖化潛勢和優養化的減緩有顯著的影響。Notarnicola et al. (2017)進一步利用了國際參考生命週期資料系統(International Reference Life Cycle Data System , ILCD)對歐洲公民的食物消耗進行環境衝擊評估，研究指出環境影響主要來自於該食物種類對於環境的負擔，以及該食物被攝取的相對量；食物的生命週期評估中，農業活動在大多數的盤查項目中造成了最多的環境負擔，其次為食物的加工及物流，因此建議增加可永續的

農業生產力，降低作物對於土壤、空氣以及水的各類排放，並且推廣民眾改變飲食習慣，減少對環境具有高負擔的食品如牛肉，最後則是降低食品的浪費，並藉由管理提昇食物垃圾的回收率。

以食物供應鏈為範疇，並對地區損耗的型態與尺度做系統性評估，建立在地化之食物廢棄物決策的輔助工具，可提供更全面的食物廢棄物之處置決策。臺灣地區自2005年起推動垃圾分類計畫，2013年食物廢棄物共計有79萬噸，佔垃圾清運量10.8%(環保署，2015)，本研究選定臺灣地區穀類、肉類、蔬果類及奶類食物共四種類別食物，以預防、重複利用及回收再利用3大類共16項食物廢棄物管理方案作為評估對象。考量食物於生產、加工與包裝、運輸與消費各階段，所產生之食物廢棄物進行定量，運用生命週期評估、成本分析，計算4類食物於食物供應鏈各階段之環境衝擊與食物成本，最後以線性規劃建立兩種最佳化模式，結合環境因子與經濟因子，評估16種方案之總環境效益。

2. 研究方法

本研究考量了食物供應鏈，盤點各階段之環境衝擊，並根據美國非營利組織「反思食品浪費」(ReFED)報告書資料，提出了預防、重複利用、回收再利用等 16 項對策，本研究以最佳化模式進行分析，計算出不同預算限制下最具環境效益的組合。

2.1 環境衝擊與效益計算方法

本研究以 ISO14040 規範之生命週期評估方法，依循目標與範疇界定、盤查分析、衝擊評估與結果闡釋四大步驟進行食物廢棄物環境衝擊量化(ISO, 2006)。本研究選定穀類、肉類、蔬果與牛奶共四類食物，將食物供應鏈分為生產、加工與包裝、運輸、消費及廢棄物管理五個階段(圖 1)，計算臺灣食物供應鏈上各階段衝擊。以臺灣地區 2011 年食物於各階段之狀態計量 1 公噸為功能單位，以穀類為例，意即生產、加工與包裝、運輸、消費、廢棄處理 1 公噸穀類食品，以 ReCiPe 混和型衝擊評估模式進行衝擊量化。其中，因為食物廢棄物多為混和處理，因此於廢棄處理階段，本研究計算不同處理方式之衝擊並假設四類作物之衝擊相同。盤點各階段衝擊後，整理食物廢棄物再利用預防、再利用方案可避免之環境衝擊，此避免之衝擊又稱為環境效益；預防類方案假設減少的食物廢棄物從未被生產出來，亦不會到達最終處置，因此這部分效益包含了避免生產食物及最終焚化處置所產生的衝擊；重複利用方案從營養的角度來看，捐贈的食物不必然會符合受贈組織與人們的生理需求，因此無法取代消費階段的食物，此類方案計算避免剩食產生的階段至消費中間階段所產生的衝擊量；回收與再生利用方案的效益計算則相對直觀，計算方式為焚化處理的衝擊量減去這些方案所產生的環境衝擊。

盤查分析則根據範疇詳細盤查生命週期各個階段物質及能源之投入(Input)與產出(Output)資料，進行蒐集與計算，以建立系統的物質和能量流動情況。本研究以臺灣食物供應鏈相關文獻資料為主，以國外食物供應鏈相關文獻資料及 Simapro 8 內建之資料庫 Ecoinvent 為輔，進行研究相關之資料盤查(表 1)。

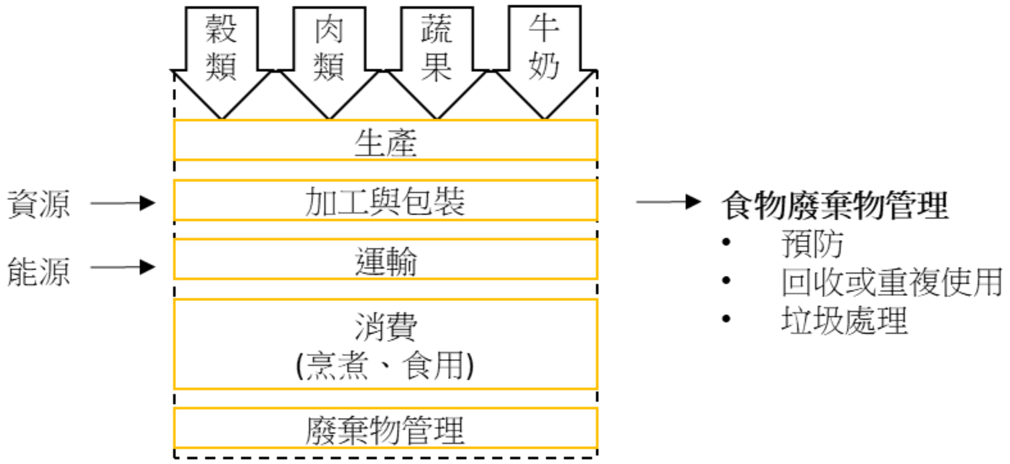


圖 1 系統邊界圖

2.2 經濟成本計算方法

食物廢棄物管理方案之經濟因子時有財務成本、經濟價值或是財務效益等數種經濟指標可以用以量化(ReFed, 2016)，決策者僅有一定的預算(B)來處理食物廢棄物管理問題，無法採取全部可用方案的狀況下，本研究以財務成本為主要之評估方法，包含了初期投資，操作成本、其他支出，同時考量折舊與折現率(r)後計算各行動的淨現值(Net present value, NPV)。各方案之年成本為AFC_i，同時依照模式差異，研究進一步以AFC_i推算出該方案每處理一單位食物廢棄物之年成本支出$UAFC_i$，最後依照模式需求利用AFC_i或$UAFC_i$與方案處理之食物廢棄物量算出執行方案之總年成本TFC，公式以式(1)至式(4)表示。

$$AFC_i = \frac{\sum_t \frac{AC_{t,i}}{(1+r)^r}}{t} \forall i \qquad 式(1)$$

$$UAFC_i = AFC_i / \sum_j Q_{max_{i,j,k=p}} \qquad 式(2)$$

$$TFC = \sum_i AFC_i \qquad 式(3)$$

$$TFC = \sum_i \sum_j \sum_k Q_{prevented_{i,j,k=p}} * UAFC_i \qquad 式(4)$$

本研究參考(ReFED, 2016)中各類處理方案之年成本作為經濟因子資料來源(表 2)，而其中時間週期(t)設定為 10 年，折現率(r)設定為 4%。本研究中之年成本係由報告書中美國各方案之年成本，除以美國各方案之處理量，最後再乘上臺灣地區之處理量，並且乘上匯率 30 倍而得，單位為百萬元臺幣，而單位年成本的計算為年成本除以臺灣地區之處理量所得，單位為百萬元臺幣/公噸。

表 1 四類食物於生產、加工、運輸、消費等階段之盤查項目清單

	穀類(稻米)	**肉類(豬肉)**	**蔬果***	**奶類(牛奶)**
生產階段	● 播種	● 飼料	● 以 Ecoinvent 資料庫選取八項主要蔬果項目	● 飼料
	● 除草	● 能源	● 以該蔬果項目與總量的比例，將蔬果之衝擊分配	● 飲水
	● 施肥	● 飲水		● 包裝耗材
	● 灌溉	● 堆肥(溫室氣體排放與廢水處理)		● 運輸材料
	● 收割			● 牛隻排放之溫室氣體
				● 畜牧廢棄物
	袁光宇(2017)	洪慧娟(2013)	本研究假設	唐維(2012)
加工處理階段	● 濕穀烘乾	● 豬隻屠宰耗水	● 清洗用水	● 鮮乳處理之能源
	● 低溫儲存	● 能源	● 能源	
	● 脫殼	● 淤泥(溫室氣體排放與廢水處理)	● 容器	
	● 包裝			
	鍾明修(2013)	洪慧娟(2013)	鍾明修(2013)	唐維(2012)
運輸階段	● 貨車(以產量最多之彰化縣為出發點)	● 貨車(以產量最多之雲林縣為出發點)	● 貨車(以產量最多之雲林縣為出發點)	● 貨車(以產量最多之彰化縣為出發點)
	Ecoinvent 資料庫	Ecoinvent 資料庫	Ecoinvent 資料庫	Ecoinvent 資料庫
消費階段	● 米飯烹煮	● 豬肉零售	● 冷藏能源	● 冷藏能源
		● 居家冷藏之能源	● 清洗用水	
	鍾明修(2013)	Winkler et al. (2016)	鍾明修(2013)	本研究假設

**八項主要蔬果項目：香蕉、鳳梨、木瓜、葡萄、紅蘿蔔、馬鈴薯、高麗菜、番茄

表 2 方案處理成本

編號	**類別**	**方案**	**美國處理量**	**美國成本**	**臺灣處理量**	**單位成本**	**臺灣成本**
i1	預防	消費者教育活動	584,337.44	21.78	43,549.27	0.0011	48.71
i2		統一日期標示	398,411.89	8.44	26,129.56	0.0006	16.60
i3		產品規格改變	266,244.97	112.29	16,523.85	0.0127	209.08
i4		包裝改善	207,691.19	233.59	32,661.95	0.0337	1,102.06
i5		防腐敗包裝	71,893.68	145.10	4,653.75	0.0605	281.78
i6		改善存貨管理	59,222.54	43.74	2,935.02	0.0222	65.03
i7		冷鏈管理	17,572.30	3.55	1,261.89	0.0061	7.64
i8	重複利用	捐贈租稅誘因	382,500.00	633.01	22,977.54	0.0496	1,140.78
i9		標準化捐贈規範	193,050.00	4.22	9,034.22	0.0007	5.92
i10		捐贈運輸設施	109,980.00	64.94	67,878.39	0.0177	1,202.41
i11		捐贈倉儲與管理	102,960.00	53.43	4,710.11	0.0156	73.32
i12		加值處理	102,330.00	10.48	6,036.47	0.0031	18.54
i13		捐贈義務教育	56,700.00	4.22	3,212.12	0.0022	7.17
i14	回收再利用	集中堆肥	5037,070.15	501.97	228,959.80	0.0030	684.51
i15		厭氧共消化	1637,201.60	150.98	228,959.80	0.0028	633.44
i16		動物飼料	48,807.51	4.49	554,210.80	0.0028	1,528.64

資料來源:ReFed (2016)

2.3 最佳化模式建立

本研究以線性規劃法，結合了環境因子及經濟因子，建立臺灣地區食物廢棄物永續管理最佳化模式，分別為僅考慮選或不選的 MODEL1 模式，及選擇多少處理量的 MODEL2 模式。

於 MODEL1 模式中(式(5)至式(7))，目標函數為最大化總環境效益(TEIA)，而總環境效益由被選上方案依照其分類所計算出之環境效益所加總，在此模式中，各方案處理量為定值，即該方案之處理量($Q_{prevented_{i,j,k}}$)等於最大避免之食物廢棄物量($Q_{max_{i,j,k=p}}$)。設定所採用方案之總年成本小於一定值之年預算(B)為限制式。MODEL1 模式中之目標函數與限制式中設定二元變數 x_i，該變數僅為 0 或 1，其代表意義為在模式中一特定方案之選擇與否。

$Max\ TEIA$

$$TEIA = \sum_{a} \left(\sum_{iprev} \sum_{j} \sum_{k=1}^{k=p} EI_{j,k,a} * x_i * Q_{prevented_{i,j,k=p}} \right. \quad 式(5)$$

$$+ \sum_{iprev} \sum_{j} EI_{j,k=EoL,a} * x_i * Q_{prevented_{i,j,k=p}}$$

$$+ \sum_{ireu} \sum_{j} \sum_{k>p}^{k<4} EI_{j,k,a} * x_i * Q_{prevented_{i,j,k=p}}$$

$$+ \sum_{ireu} \sum_{j} EI_{j,k=EoL,a} * x_i * Q_{prevented_{i,j,k=p}}$$

$$- \sum_{ireu} \sum_{j} EI_{j,k=6} * x_i * Q_{prevented_{i,j,k=p}}$$

$$+ \sum_{irere} \sum_{j} EI_{j,k=EoL,a} * x_i * Q_{prevented_{i,j,k=p}}$$

$$\left. - \sum_{irere} \sum_{j} EI_{j,k=AEoL,a} * x_i * Q_{prevented_{i,j,k=p}} \right)$$

s.t

$$\sum_{i} x_i * AFC_i \leq B \quad 式(6)$$

$$x_i = 0\ or\ 1\ \forall i \quad 式(7)$$

MODEL2 模式中(式(8)至式(12))，目標函數同為最大化總環境效益(TEIA)，而總環境效益為各方案依照其分類及處理量所計算出之環境效益所加總。在此模式中，各方案處理量($Q_{prevented_{i,j,k}}$)為變數，而該變數會受到一些條件限制，首先即該方案之處理量會小於等於最大避免之食物廢棄物量($Q_{max_{i,j,k=p}}$)，第二為在一階段所有方案之處理量總和會小於等於該階段之食物廢棄物產生量($Q_{\mathrm{generated}_{\mathrm{j,k}}}$)，第三係由於 i14 集中堆肥處理與 i15 厭氧共消化之處理目標皆為所回收堆肥廚餘，因此設定此二方案之處理量小於等於所回收之堆肥廚餘量。而最後同樣限制所有處理方案之總年成本小於一定值之年預算(B)。

$Max\ TEIA$

$$
\begin{aligned}
TEIA = \sum_{a}\Bigg(& \sum_{iprev}\sum_{j}\sum_{k=1}^{k=p} EI_{j,k,a} * Q_{prevented_{i,j,k=p}} \\
& + \sum_{iprev}\sum_{j} EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} \\
& + \sum_{ireu}\sum_{j}\sum_{k>p}^{k<4} EI_{j,k,a} * Q_{prevented_{i,j,k=p}} \\
& + \sum_{ireu}\sum_{j} EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} \\
& - \sum_{ireu}\sum_{j} EI_{j,k=6} * Q_{prevented_{i,j,k=p}} \\
& + \sum_{irere}\sum_{j} EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} \\
& - \sum_{irere}\sum_{j} EI_{j,k=AEoL,a} * Q_{prevented_{i,j,k=p}} \Bigg)
\end{aligned}
\qquad 式(8)
$$

s.t

$$\sum_{i}\sum_{j}\sum_{k} Q_{prevented_{i,j,k=p}} * UAFC_{i} \leq B \qquad 式(9)$$

$$Q_{prevented_{i,j,k=p}} \leq Q_{max_{i,j,k=p}} \qquad 式(10)$$

$$\sum_{i} Q_{prevented_{i,j,k=p}} \leq Q_{generated_{j,k=p}} \qquad 式(11)$$

$$Q_{prevented_{i=15,j,k=p}} + Q_{prevented_{i=16,j,k=p}} \leq Q_{max_{i=15,j,k=p}} \qquad 式(12)$$

3. 結果與討論

3.1 食物供應鏈生命週期評估結果

食物供應鏈上游的環境衝擊分析結果如圖2所示，衝擊熱點為生產階段之食物以穀類、肉類及蔬果類為主，衝擊熱點為加工階段之食物則為乳類。衝擊貢獻部分，穀類以生產中對空氣、水體及土壤的排放為最大衝擊貢獻來源，肉類以餵養豬隻的飼料為最大衝擊貢獻來源，蔬果類生產階段則依照各作物的類別而有不同，而奶類則以加工投入之高耗電為最大衝擊貢獻來源。食物供應鏈下游之最終處置階段(考慮替代效益)，衝擊最大為集中堆肥(2.36 Pt)，其次是厭氧共消化(-3.01 Pt)以及動物飼料(-3.01 Pt)。進一步分析各衝擊熱點可以發現，四類食物於熱點所

產生的衝擊類別中皆顯示以氣候變遷對人體健康衝擊、化石燃料耗用及粒狀污染物形成為佔比最大的衝擊類別。

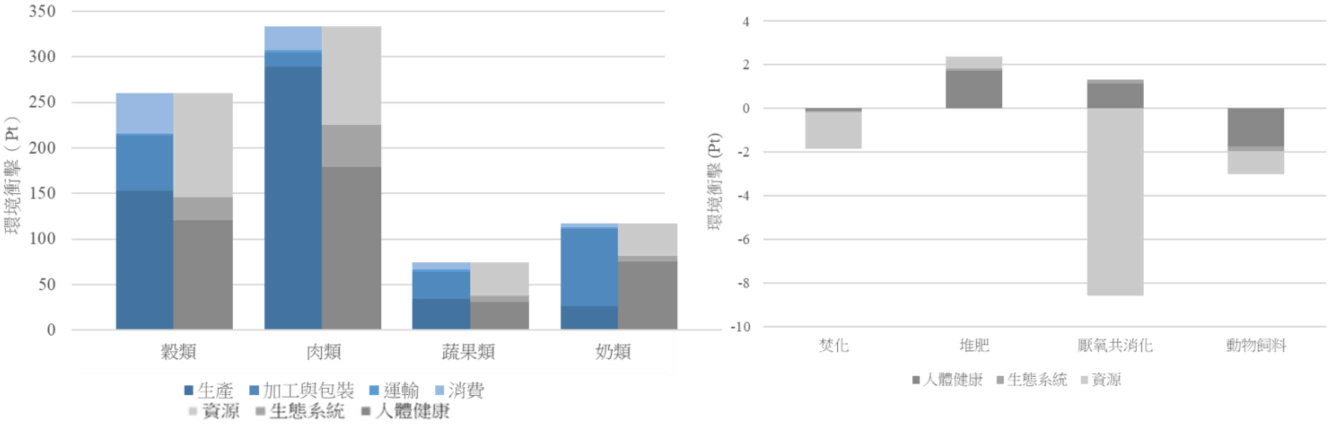


圖2 食物供應鏈各階段衝擊

3.2 決策預算與再利用方案之環境效益

預算與環境效益之關係如圖3所示，MODEL 1和MODEL 2具有相同的趨勢，預算為100億時，環境效益增加幅度最高，邊際環境效益遞減，預算為700億時達到環境效益最大值。

處理率(各類處理量除以食物產生量)在MODEL 1中，在達處理極限時，採用之各方案對於各類別食物廢棄物之最高處理率為：穀類46.9%、肉類38.2%，蔬果類25.8%及奶類111.8%，而總體的食物廢棄物處理率為36.1%，可以看到奶類的處理率超過100%，代表由這些方案所能處理之廢棄物多於產生之廢棄物，因此，由MODEL1所計算出之環境效益可能高於實際上所能得到的環境效益。本研究計算出穀類佔了臺灣食物廢棄物總量之13.0%、肉類為15.0%、蔬果類65.1%及奶類7.0%，由於奶類於整體臺灣食物廢棄物總量低，奶類的處理比率不論是在多少預算下皆是處理率最高者，且處理率隨著預算上升的程度也越大，相反的，蔬果類食物廢棄物佔了臺灣食物廢棄物總量超過六成，其處理率在所有預算下皆為最低者，反應了臺灣蔬果類廢棄物的高產生量，雖然蔬果類廢棄物產生的環境衝擊是四項食物類別中最低的，但如果決策者是以處理量為決策考量點，需納入更多樣化的管理方案才有辦法提高處理率。

在環境效益於廢棄物分層等級的概念中，預防類方案之環境效益相較重複利用類及回收再利用類方案高，然而，在MODEL 1中，考量被啟用的方案就須達到一定數量的處理量時，各方案的效益不全然遵守分層等級的原則，廢棄物分層等級的概念不必然適用。

處理率在MODEL 2中，在達到最大量之處理量時，穀物類處理率為45.6%，肉類處理率為37.8%，蔬果類為25.4%，乳類為100%，而整體食物廢棄物處理率為34.8%，模擬結果中奶類的高處理率，與MODEL 1原因相同。

MODEL 2的模擬結果中，各方案的效益大致符合廢棄物分層等級的原則，預

防的效益大於重複利用，而重複利用的效益大於回收再利用的效益；重複利用類方案運用在生產階段時能夠產生環境效益，然而若將這類方案運用在消費階段，也就是於消費階段捐贈剩食，此類管理方案並無法產生環境效益，反而產生額外的環境衝擊。

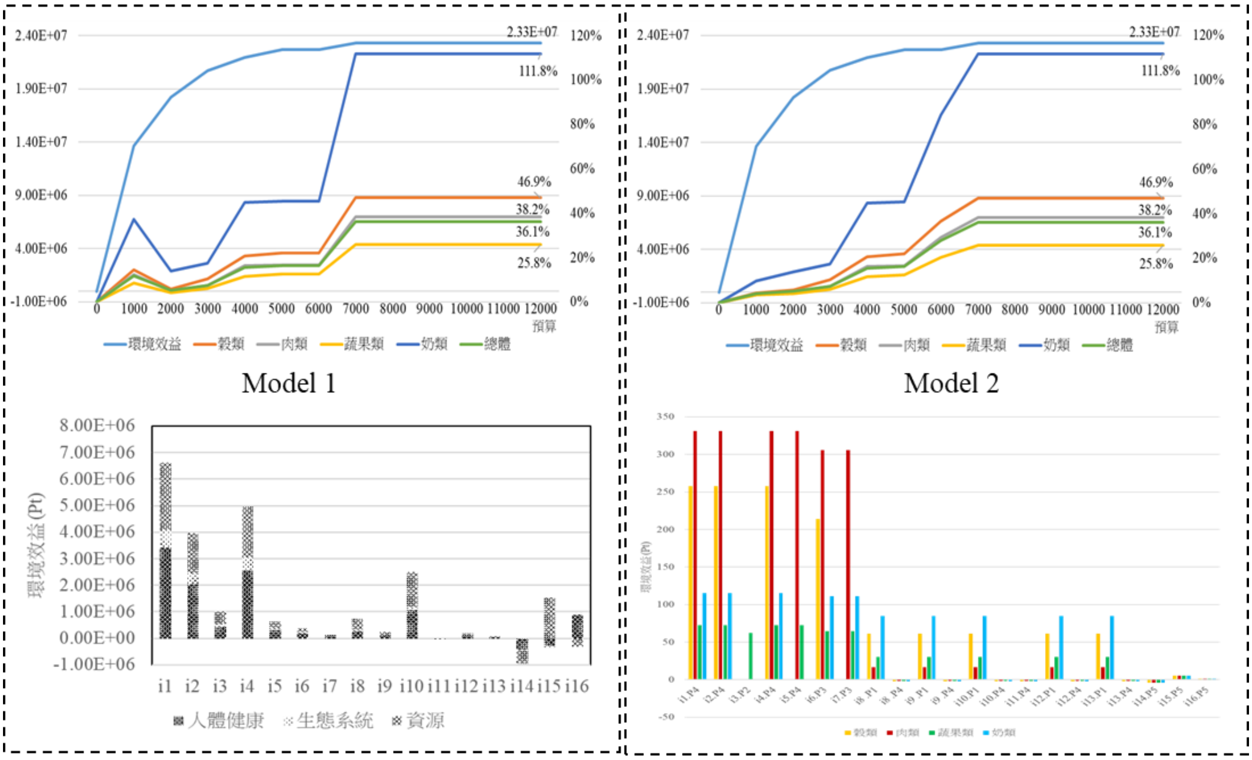


圖 3 不同預算下最佳組合方案之環境效益與食物處理率

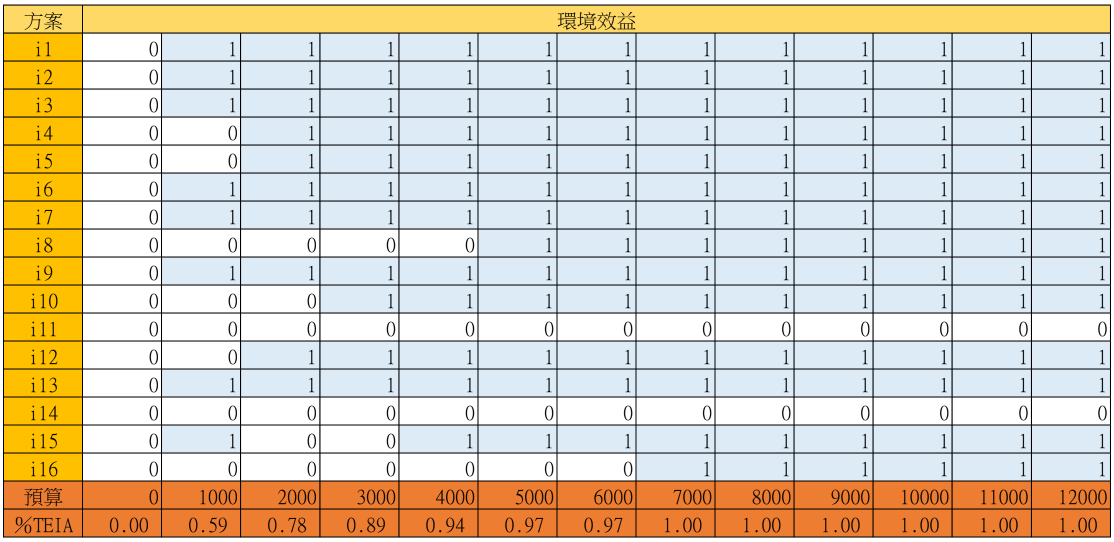
3.3 減少食物廢棄物方案最佳化結果

MODEL 1最佳化分析結果顯示(圖4)，消費者教育活動、統一日期標示、產品規格改變、改善存貨管理、冷鏈管理、標準化捐贈規範及捐贈義務教育皆兼具環境效益及經濟有效性，而捐贈倉儲與管理以及集中堆肥處理，在模擬結果中則為最不具環境效益之管理方案，不管預算多高都不會選擇這兩項管理方案。

MODEL 2最佳化分析結果如表3，各方案的處理量除以各類食物總廢棄物量，可以得到各方案每類食物在不同預算下的處理率，以預算一百億與一千兩百億為例，可發現 i1 消費者教育活動、i2 統一日期標示、i3 產品規格改變及 i12 加值處理在預算為一百億之下處理率就已達極值，顯示這些方案兼具環境效益及經濟可行性，而在不同的預算下對於各方案處理量之分配也有所不同。以穀類為例，於預算為一百億時，i9 標準化捐贈規範的處理率以 0.004 時能達到總體最高效益，然而在預算為極值情況，該方案處理率反而以 0.001 時能達到總體最高效益，顯示了預算對於整體結果的影響性。

最佳化的分析結果中，MODEL1 的輸出結果較簡易直觀，較適合於管理規劃初估階段進行各相近方案之初選，而 MODEL2 的輸出則較為精細但不直觀，較

適合用於規劃後續各管理方案最適處理量之推估。



方案	環境效益												
i1	0	1	1	1	1	1	1	1	1	1	1	1	1
i2	0	1	1	1	1	1	1	1	1	1	1	1	1
i3	0	1	1	1	1	1	1	1	1	1	1	1	1
i4	0	0	1	1	1	1	1	1	1	1	1	1	1
i5	0	0	1	1	1	1	1	1	1	1	1	1	1
i6	0	1	1	1	1	1	1	1	1	1	1	1	1
i7	0	1	1	1	1	1	1	1	1	1	1	1	1
i8	0	0	0	0	0	1	1	1	1	1	1	1	1
i9	0	1	1	1	1	1	1	1	1	1	1	1	1
i10	0	0	0	1	1	1	1	1	1	1	1	1	1
i11	0	0	0	0	0	0	0	0	0	0	0	0	0
i12	0	0	1	1	1	1	1	1	1	1	1	1	1
i13	0	1	1	1	1	1	1	1	1	1	1	1	1
i14	0	0	0	0	0	0	0	0	0	0	0	0	0
i15	0	1	0	0	1	1	1	1	1	1	1	1	1
i16	0	0	0	0	0	0	0	1	1	1	1	1	1
預算	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000
%TEIA	0.00	0.59	0.78	0.89	0.94	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00

圖 4 MODEL 1 不同預算下最佳方案組合

表 3 MODEL 2 於預算一百億與一千兩百億之最佳方案組合

單位:處理率(%)

	預算 1000 百萬				**預算 12000 百萬**			
方案	**穀類**	**肉類**	**蔬果類**	**奶類**	**穀類**	**肉類**	**蔬果類**	**奶類**
i1	0.02	0.017	0.01	0.052	0.02	0.017	0.01	0.052
i2	0.012	0.01	0.006	0.031	0.012	0.01	0.006	0.031
i3	0	0	0.009	0	0	0	0.009	0
i4	0.015	0.013	0	0	0.015	0.013	0.008	0.039
i5	0	0.003	0	0	0	0.003	0.002	0
i6	0.002	0.001	0	0.005	0.002	0.001	0.001	0.005
i7	0	0	0	0.002	0	0	0	0.002
i8	0	0	0	0	0.011	0.002	0.008	0.004
i9	0.004	0.002	0.002	0.003	0.001	0.002	0.002	0.003
i10	0.02	0	0	0.033	0.042	0.023	0.017	0.033
i11	x	x	x	x	x	x	x	x
i12	0.002	0.001	0.002	0.001	0.002	0.001	0.002	0.001
i13	0.001	0.001	0.001	0.001	0	0.001	0.001	0.001
i14	x	x	x	x	x	x	x	x
i15	0	0	0	0	0.103	0.089	0.055	0.275
i16	0	0	0	0	0.249	0.216	0.134	0.553

結論

本研究所建立之在地化食物廢棄物管理工具，量化食物供應鏈之環境衝擊，最後以系統性的觀點評估食物供應鏈上的廢棄物管理，提出最佳化減量策略。首先於環境衝擊之分析結果中指出，穀類、肉類及蔬果類食物皆是以生產階段為衝擊熱點，乳類衝擊熱點則為加工階段；考慮能資源化替代效益的狀況下，各類廚餘能資源化處理方式，以集中堆肥之總環境衝擊最大，其次為厭氧共消化，接著是動物飼料及焚化，且能資源化的替代效益對於整體的總環境衝擊結果影響甚大。

在最佳化分析結果中，若考慮啟用該方案須達到一定額度處理量的因素，各食物廢棄物管理方案的整體效益並不全然遵守廢棄物分層等級原則。此外，模擬結果也顯示了在臺灣進行剩食倉儲管理與廚餘堆肥是較無環境效益的作法，於消費階段進行剩食捐贈也無法產生環境效益；結果亦指出，重複利用方案中，處理消費階段剩食之環境衝擊反而大於進行焚化處理之環境衝擊。

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利用超重力旋轉填充床於電子廢棄物回收制程之懸浮微粒去除效益評估

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摘要：本研究與優勝奈米有限公司進行合作，利用超重力旋轉床進行 IC 碳化制程中產生之懸浮微粒減量去除效益評估。IC 碳化過程中產生大量人體有害之懸浮微粒，超重力旋轉填充床可產生大量小液滴及液膜，可增加對液滴與懸浮微粒之碰撞機率，提升對懸浮微粒之捕捉去除效率。本研究目標包含不同操作條件下對於總懸浮微粒去除效率的影響：研究不同轉速、液體流量與進口濃度對於效率的影響，同時透過反應曲面方法，找出可達之最高效率操作條件，並透過半理論公式進行去除機制分析，同時將實驗結果進行擬合，進行效率預估，最後利用生命週期評估分析整個程式對環境之衝擊。

研究結果發現提高轉速和液體流量皆會對去除效率有很大的提升，提高入口濃度亦可提高效率，但在高轉速與高也體流量下影響並不明顯。利用反應曲面法將轉速與流量進行操作優化，在實驗設備極限中所能達到之最高效率為 99.5%，對應之條件為 1740 rpm、1448 ml/min。透過半理論公式進行超重力旋轉填充床之去除機制進行瞭解，發現填充物與液滴皆對懸浮微粒有顯著的去除效果，低轉速時以填充物去除為主，反之高轉速液滴的去除才較為重要。透過實驗資料進行資料擬合同時也得到良好的相關性進行效率預測。

最後透過生命週期評估進行環境衝擊量化，發現利用超重力旋轉填充床進行懸微粒去除可有效降低環境之衝擊，最低之環境衝擊僅有未經處理的 0.29 倍，證明超重力旋轉填充床不只可達到良好的去除效率，同時也可降低環境衝擊，可視為環境有益之空氣污染處理技術。

關鍵字：細懸浮微粒、超重力旋轉填充床；半理論模式；生命週期評估

高污染日不同高程 $PM_{2.5}$ 物化特性及污染源解析

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長久以來，台灣南部地區空氣污染甚為嚴重，其所在高屏空品區的空氣品質不良率居高不下，尤其對健康危害甚鉅的 $PM_{2.5}$ 濃度明顯高於其他空品區。高屏空品區的 $PM_{2.5}$ 高污染事件好發於每年冬季(約 12-2 月)及春季(約 3-5 月)。高雄地區為台灣重工業最密集之區域，除來自本地排放之大量空氣污染物外，跨境長程傳輸也是空氣品質劣化的重要原因。有鑑於此，本研究選定人為活動頻繁的高雄市區及人為活動較少的北高雄郊區，並分別在夏季(非事件日)和冬季(事件日)於不同高程進行 $PM_{2.5}$ 採樣及分析，藉以瞭解其物理化學特性、污染來源及貢獻量，俾作為擬定空氣污染改善策略之依據。

研究結果顯示，冬季污染事件日期間，$PM_{2.5}$ 平均濃度(49.26 μg/m^3)明顯高於夏季非事件日(10.6 μg/m^3)。另由 $PM_{2.5}$ 的水溶性離子成份得知，水溶性離子成份的佔比呈現事件日(77.5%)明顯高於非事件日(69.7%)的現象。而由碳成份分析結果得知，其佔比呈現事件日(15.33%)高於非事件日(11.94%)，顯示在高污染事件日期間伴隨較多二次有機氣膠的產生。冬季事件日期間衍生性硫酸鹽、衍生性硝酸鹽、衍生性有機碳及衍生性元素碳之貢獻率(34.4%)，均明顯大於夏季非事件日(25.3%)，顯示在高污染事件日期間，衍生性二次氣膠(Secondary aerosols)的貢獻率也隨之上升。

關鍵字：細懸浮微粒($PM_{2.5}$)、高污染事件日、物理化學特性、不同高程、污染源解析

一、 前言

長久以來，台灣南部地區空氣污染甚為嚴重，其所在高屏空品區的空氣品質不良率居高不下，尤其對健康危害甚鉅的 $PM_{2.5}$ 濃度明顯高於其他空品區。高屏空品區的 $PM_{2.5}$ 高污染事件好發於每年冬季(約 12-2 月)及春季(約 3-5 月)。

高雄地區為台灣重工業最密集之區域，根據歷年 $PM_{2.5}$ 監測數據顯示，高雄地區約有 25%以上時間的 $PM_{2.5}$ 濃度高於環境品質標準(35 μg/m^3)，過去文獻證實 $PM_{2.5}$ 相較於 PM_{10} 更容易深入肺部，甚至穿過肺泡而進入血液循環系統，對呼吸系統及心血管系統造成永久性病變，因此環保署已於 2012 年 5 月 14 日發佈 $PM_{2.5}$ 空氣品質標準，其 24 小時平均值為 35 μg/m^3，年平均值為 15 μg/m^3。不良的污染品質，除肇因於氣象條件不利污染物擴散外，本地污染物及境外傳入的空氣污染物，皆容易導致空氣品質不良。

此外，高雄地區因產業分佈密集，不僅傳統工業(如：石化業、鋼鐵業等)密集，同時也有新興的半導體及電子等產業，環境負荷量相當高。若再加上春、冬兩季隨東北季風吹入的大陸灰霾，以及東南亞生質燃燒經由長程傳輸所移入的境外污染物，皆是導致高屏空品區 $PM_{2.5}$ 濃度偏高的重要因素。有鑑於此，本研究選定人為活動頻繁的高雄市區及人煙較為稀少的北高雄郊區，分別在夏季(非事件日)和冬季(事件日)於不同高程進行 $PM_{2.5}$ 採樣及分析，藉以瞭解近地面 $PM_{2.5}$ 濃度之垂直分佈狀況、物理化學特性、污染來源及貢獻量。

二、 研究方法

1. $PM_{2.5}$ 採樣方法

本研究針對前節所述採樣點位分別執行 $PM_{2.5}$ 採樣，每次採樣時間為 24 小時，自早上 8:00 至隔日早上 8:00 止，採樣設備採用 BGI PQ200 型 $PM_{2.5}$ 採樣器。採氣流量為 16.67 L/min，採樣濾紙採用直徑 47 mm 的石英濾紙。採樣前後，先將石英濾紙進行調理(T= 25±2^{o}C 及 RH= 40±5%)至少 24 小時，然後用六位分析天平(精密至 10^{-6} g)加以秤重，再以下式計算 $PM_{2.5}$ 質量濃度。本研究細懸浮微粒採樣及分析作業流程如圖 1 所示。

$$PM_{2.5} = \frac{W_f - W_i}{Q_a \times t} \times 10^6$$

式中 W_f ：採樣後濾紙重量(μg)

W_i ：採樣前濾紙重量(μg)

Q_a ：採氣流量(m^3/min)

t ：採樣時間(min)

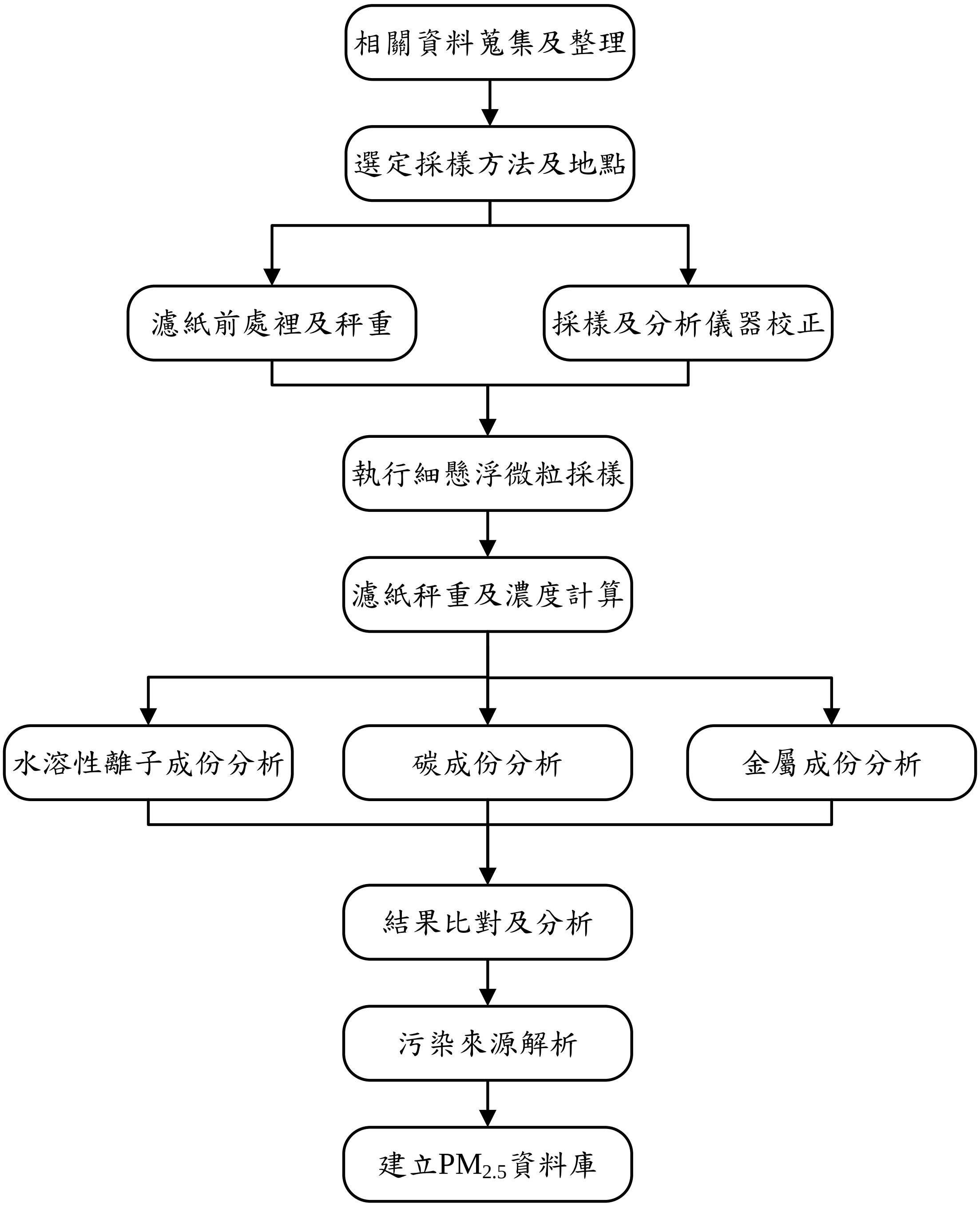


圖 1 細懸浮微粒採樣及分析作業流程圖

2. $PM_{2.5}$化學成份分析

本研究針對所採集之 PM_{10} 樣本進行化學成份分析，分析項目包括水溶性離子成份(F^-、Cl^-、NO_3^-、SO_4^{2-}、NH_4^+、K^+、Na^+、Ca^{2+}、Mg^{2+})、金屬元素成份(Mg、Al、Ca、Ti、V、Mn、Fe、Ni、Zn、Pb、Cr、Cu、Cd、K、As)、碳成份(EC、OC、TC)。上述化學成份分析方法及分析儀器詳見表 1。

(1) 水溶性離子成份分析

水溶性離子成份分析係參照環保署環境檢驗所公告之「空氣粒狀污染物中硫酸鹽、氯鹽、硝酸鹽檢測方法－離子層析法」(NIEA A451.10C)，使用離子層析法(ion chromatography；IC)進行細懸浮微粒之水溶性離子成份分析，分析項目包括 F^-、Cl^-、NO_3^-、SO_4^{2-}、NH_4^+、K^+、Na^+、Ca^{2+}、Mg^{2+}。本研究採用 Thermo Fisher 公司生產的 Dionex ICS-1100 型離子層析儀分析陽離子成份，另採用 Dionex DX-120 型離子層析儀分析陰離子成份。

(2) 金屬元素成份分析

金屬元素成份分析係參照行政院環保署環境檢驗所公告之「空氣粒狀污染物中元素含量檢測方法－感應耦合電漿原子發射光譜法」(NIEA A306.10C)，分析儀器採用 Perkin Elmer 公司生產型號 Optima 2000DV 之感應耦合電漿原子發射光譜儀(ICP-AES)，同步進行 Mg、Al、Ca、Ti、V、Mn、Fe、Ni、Zn、Pb、Cr、Cu、Cd、K、As 等 15 種金屬元素成份之分析。

(3) 碳成份分析

碳成份分析係參照行政院環保署環境檢驗所公告「碳、氫、硫、氧、氮元素含量檢測方法－元素分析儀法」(NIEA M403.00C)，分析儀器採用 Elementar 公司所生產之 Vario EL III 型元素分析儀、AS 200 型自動進樣系統及 DP 700 型積分儀，進行細懸浮微粒中元素碳(EC)及總碳(TC)有機碳則由總碳扣除元素碳而得。

表 1 細懸浮微粒化學成份分析方法及分析儀器彙整表

類別	分析項目	分析方法
水溶性離子成份分析	F^-、Cl^-、NO_3^-、SO_4^{2-}、NH_4^+、K^+、Na^+、Ca^{2+}、Mg^{2+}	空氣粒狀污染物中硫酸鹽、氯鹽、硝酸鹽檢測方法－離子層析法(NIEA A451.10C)，所使用之分析儀為離子層析儀，Dionex ICS-1100
金屬元素成份	Mg、Al、Ca、Ti、V、Mn、Fe、Ni、Zn、Pb、Cr、Cu、Cd、K、As	空氣粒狀污染物中元素含量檢測方法－感應耦合電漿原子發射光譜法(NIEA A306.10C)，所使用之分析儀為感應耦合電漿原子放射光譜儀(ICP-AES)，Perkin Elmer, Optima 2000DV
碳成份	元素碳(EC)、有機碳(OC)、總碳(TC)	碳、氫、硫、氧、氮元素含量檢測方法－元素分析儀法(NIEA M403.00C)，所使用之分析儀為元素分析儀(EA)，Elementar, Vario EL III

3. 細懸浮微粒濃度分佈及污染源解析

本研究之污染源貢獻量解析係採用化學質量平衡法(chemical mass balance，簡稱 CMB)，該方法於 1969 年由 Winchester 與 Nifong 等學者提出，屬於定量分配模式。本研究所採用化學質量平衡模式係利用美國內華達州沙漠研究所(Desert Research Institute；DRI)所發展之 CMB8 軟體，進行污染源種類及貢獻量之推估。

透過上述採樣及分析方法，以利掌握北高雄(湖內區東方設計大學)及市區(三民區長谷世貿大樓或其他市區高樓)的 $PM_{2.5}$ 濃度、水溶性離子成份、金屬元素成份、碳成份，並透過化學質量平衡受體模式(receptor model)，解析污染源種類及貢獻率，俾做為研擬細懸浮微粒管制策略之參考。

三、 結果與討論

1. 採樣期間氣象概況

本研究北高雄採樣點氣象資料取自中央氣象局湖內氣象站，高雄市區取自中央氣象局三民氣象站，分別參考氣溫、相對濕度(RH)、風向、日平均風速及最大陣風等氣象因子。此外，為瞭解非事件日及事件日能見度的差異，本研究亦從長谷世貿大樓拍攝市區照片加以比較，圖 2 為夏季非事件日的能見度照片，而圖 3 為冬季事件日前的能見度照片，圖 4 則為冬季事件日的能見度照片。

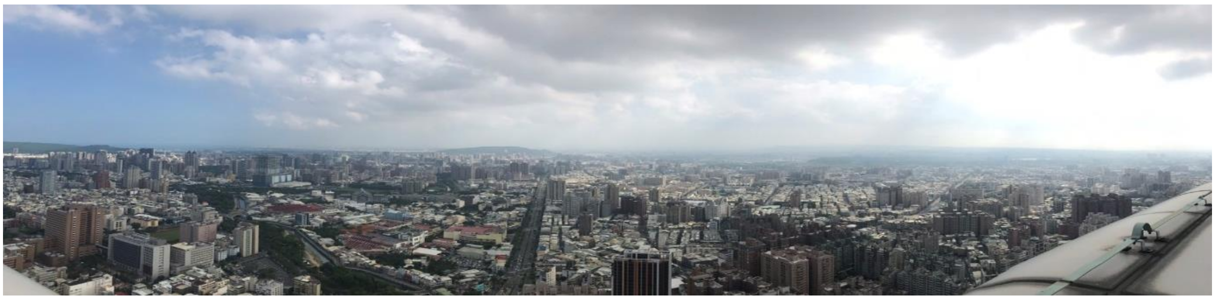


圖 2 夏季市區高程能見度觀測照(非事件日)

圖 3 冬季市區高程能見度觀測照(事件日前)

圖 4 冬季市區高程能見度觀測照(事件日)

本研究夏季採樣期間為 2018 年 7 月 17-19 日(共三天)，北高雄氣溫介於 25-30℃之間，平均相對溼度為 86.5%，盛行風向為西南風，日平均風速為 2.3 m/s，最大陣風介於 8.3-8.7 m/s 之間。高雄市區氣溫介於 25-31℃之間，平均相對濕度為 71.6%，盛行風向為西風，日平均風速為 1.6 m/s，最大陣風介於 7.8-10.9 m/s 之間。

冬季採樣期間為 2018 年 11 月 6-8 日(共三天)，北高雄氣溫介於 24-30℃之間，平均相對濕度為 76.3%，盛行風向為北風，日平均風速為 1.1 m/s，最大陣風介於 4.5-7.5 m/s 之間。高雄市區氣溫介於 21-30℃之間，平均相對濕度為 88.3%，盛行風向為北風，日平均風速為 1.8 m/s，最大陣風介於 6.8-9.9 m/s 之間。

2. 細懸浮微粒濃度變化

本研究於 2018 年 7 月(夏季)及 11 月(冬季)分別在高雄市湖內區、三民區設立四處高低程採樣點，每次採樣時間連續三天，採樣結果分別為夏季(圖 5)及冬季(圖 6)。夏季非事件日 $PM_{2.5}$ 濃度皆未大於 35 μg/m^3，而冬季事件日 $PM_{2.5}$ 濃度均高於 35 μg/m^3。採樣結果顯示，夏季期間北高雄低層 $PM_{2.5}$ 平均濃度(8.3 μg/m^3)略大於高層(8.15 μg/m^3)，高雄市區低層 $PM_{2.5}$ 平均濃度(14.2 μg/m^3)明顯大於高層(11.9 μg/m^3)；北高雄地區(13 μg/m^3)大於高雄市區 $PM_{2.5}$ 平均濃度(8.2 μg/m^3)。冬季北高雄地區低層 $PM_{2.5}$ 平均濃度(55.21 μg/m^3)大於高層(48.9 μg/m^3)，高雄市區低層 $PM_{2.5}$ 平均濃度(48.76 μg/m^3)大於高層(44.1 μg/m^3)，北高雄地區 $PM_{2.5}$ 平均濃度(52.08 μg/m^3)大於高雄市區(46.43 μg/m^3)。整體而言，冬季事件日期間 $PM_{2.5}$ 平均濃度(49.26 μg/m^3)大於夏季非事件日(10.6 μg/m^3)。

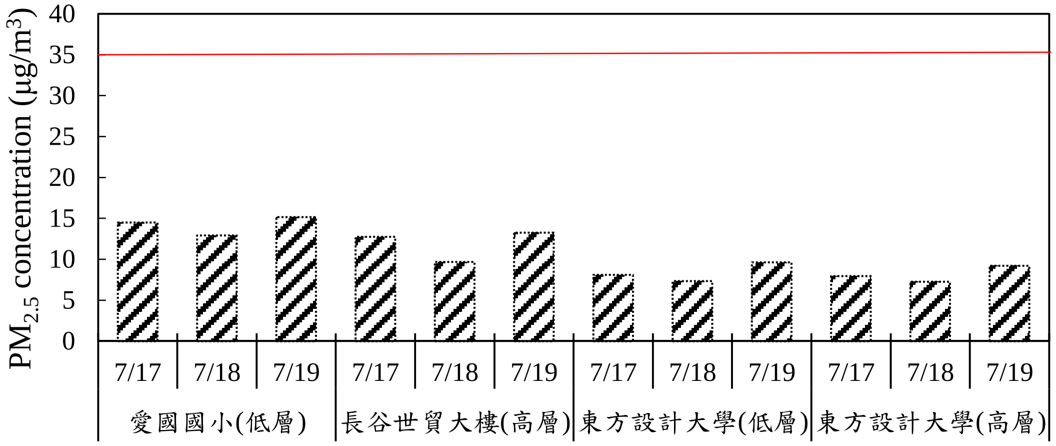


圖 5 夏季期間 $PM_{2.5}$ 濃度變化趨勢

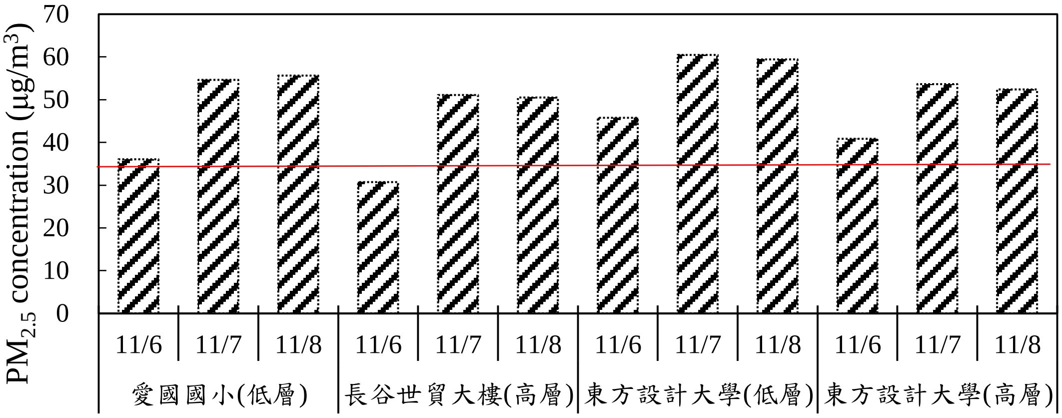


圖 6 冬季期間 $PM_{2.5}$ 濃度變化趨勢

3. 水溶性離子成份分析結果

本研究採用離子層析法針對夏季(非事件日)和冬季(事件日)期間之北高雄及高雄市區不同高度所採集之 $PM_{2.5}$ 樣品，進行水溶性離子(WSI)成份分析，分析項目包括 F^-、Cl^-、Br^-、NO_3^-、SO_4^{2-}、NH_4^+、K^+、Na^+、Ca^{2+}、Mg^{2+}，並分別將夏及冬季 $PM_{2.5}$ 之離子成份分析結果彙整於圖 7 及圖 8。

夏季採樣期間，水溶性離子成份佔 $PM_{2.5}$ 平均濃度比例(WSI / $PM_{2.5}$)，北高雄低層(56.94%)大於高層(51.62%)，高雄市區高層(54.87%)和低層(54.44%)相差不大；高雄市區(54.50%)略大於北高雄郊區(54.28%)。冬季採樣期間。就 WSI/$PM_{2.5}$ 平均比值而言，北高雄高層(59.1%)大於低層(51.72%)，高雄市區低層(57.27%)大於高層(54.04%)；而高雄市區(55.65%)大於北高雄郊區(55.41%)。

針對二次無機氣膠(SIA)佔 $PM_{2.5}$ 濃度的平均比例加以分析比較，夏季

採樣期間，北高雄高層(68.0%)大於低層(66.1%)，高雄市區低層(76.9%)明顯大於高層(67.7%)；高雄市區(72.3%)大於北高雄(67.1 %)。冬季採樣期間SIA/WSI 比例，北高雄高層(78.6%)略大於低層(77.6%)，高雄市區高層(77.8%)大於低層(75.7%)，而北高雄郊區(78.1%)大於高雄市區(76.8%)。

就不同季節比較而言，夏季屬於低污染期間，而冬季則屬高污染期間，由 $PM_{2.5}$ 的水溶性離子成份可發現，水溶性離子成份的平均濃度，事件日明顯高於非事件日，尤其 NO_3^-離子平均濃度升高為 6.04 倍，NH_4^+和 K^+離子平均濃度升高為 5.1 倍，SO_4^{2-}和 Mg^{2+}離子平均濃度升高為 4.6 倍，其他離子平均濃度也有 3.1~3.5 倍的上升。而兩季中 $PM_{2.5}$ 的水溶性離子中皆以 SO_4^{2-} 及 NO_3^-濃度最高，其次為 Cl^-、NH_4^+及 Na^+。其中 SO_4^{2-} 主要來自工業污染排放，NO_3^-則主要來自移動源排放。此結果顯示，$PM_{2.5}$ 濃度超過 20 μg/m^3 時，$PM_{2.5}$ 中以 NO_3^-為主要離子成份，推測主要來源為移動污染源排放所導致。

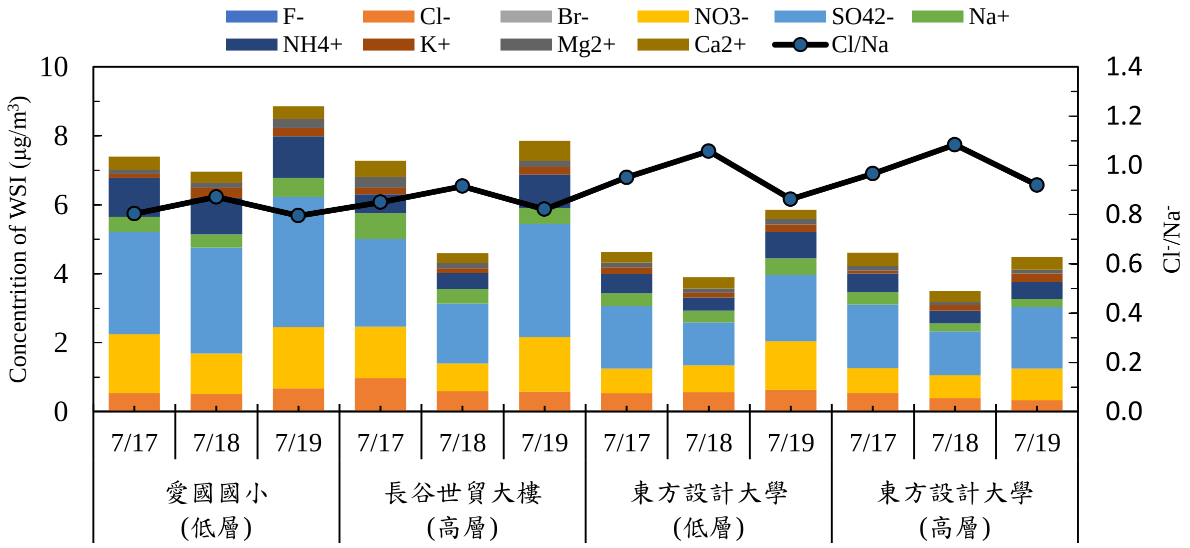


圖 7 夏季採樣期間 $PM_{2.5}$ 中水溶性離子濃度分佈圖

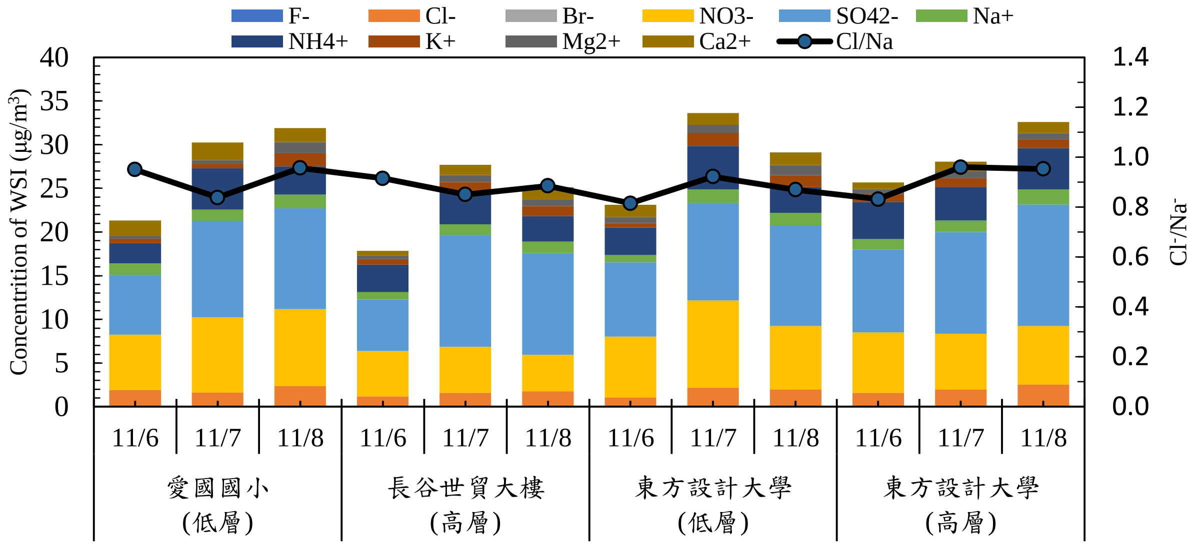


圖 8 冬季採樣期間 $PM_{2.5}$ 中水溶性離子濃度分佈圖

4. 金屬元素成份分析結果

夏季及冬季採樣期間 $PM_{2.5}$ 之金屬元素成份濃度及金屬元素佔 $PM_{2.5}$ 濃度的平均比例彙整於圖 9 及圖 10，金屬元素成份的分析項目包括 Na、Mg、K、Ca、Ti、V、Cr、Mn、Fe、Ni、Cu、Zn、Al、As、Cd 等 15 種金屬元素成份。

夏季非事件日採樣期間，北高雄金屬元素成份佔 $PM_{2.5}$ 平均濃度的比例(14.32%)略高於高雄市區(13.69%)，冬季事件日採樣期間，北高雄金屬元素佔 $PM_{2.5}$ 平均濃度的比例(15.12%)與高雄市區(15.26%)差異不大，然而事件日(15.19%)普遍高於非事件日(14.01%)。金屬元素佔 $PM_{2.5}$ 平均濃度比例顯示高雄市南北差異不大，而事件日與非事件日的差異甚小。

5. 碳成份分析結果

碳成份分析項目包括總碳(TC)、有機碳(OC)、元素碳(EC)，圖 11、圖 12 彙整夏季及冬季採樣期間 $PM_{2.5}$ 之碳成份濃度變化趨勢。夏季非事件日採樣時間碳成份佔 $PM_{2.5}$ 平均濃度比例比較，北高雄高處平均比例(11.13%)高於低處(10.45%)，而高雄市區低處平均比例(13.31%)大於高處(12..86%)，高雄市區平均比例(13.08%)大於北高雄郊區(10.79%)。冬季事件日採樣期間

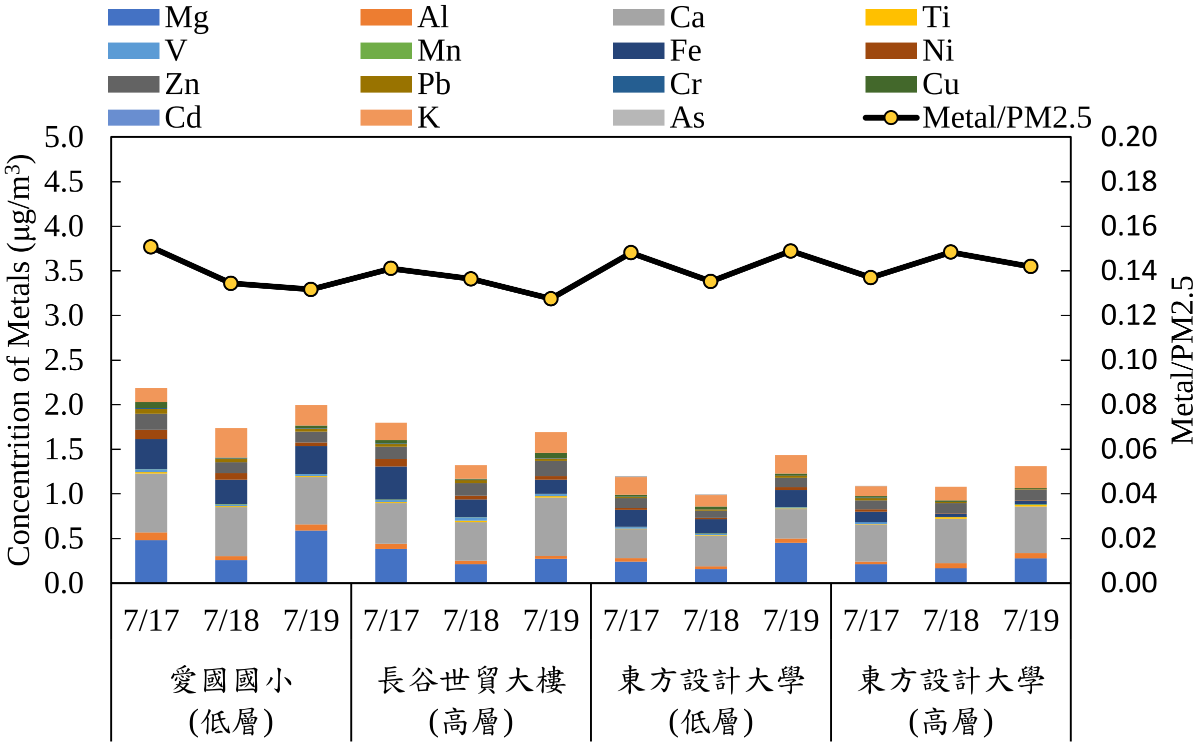


圖 9 夏季採樣期間 $PM_{2.5}$ 中金屬元素濃度分佈圖

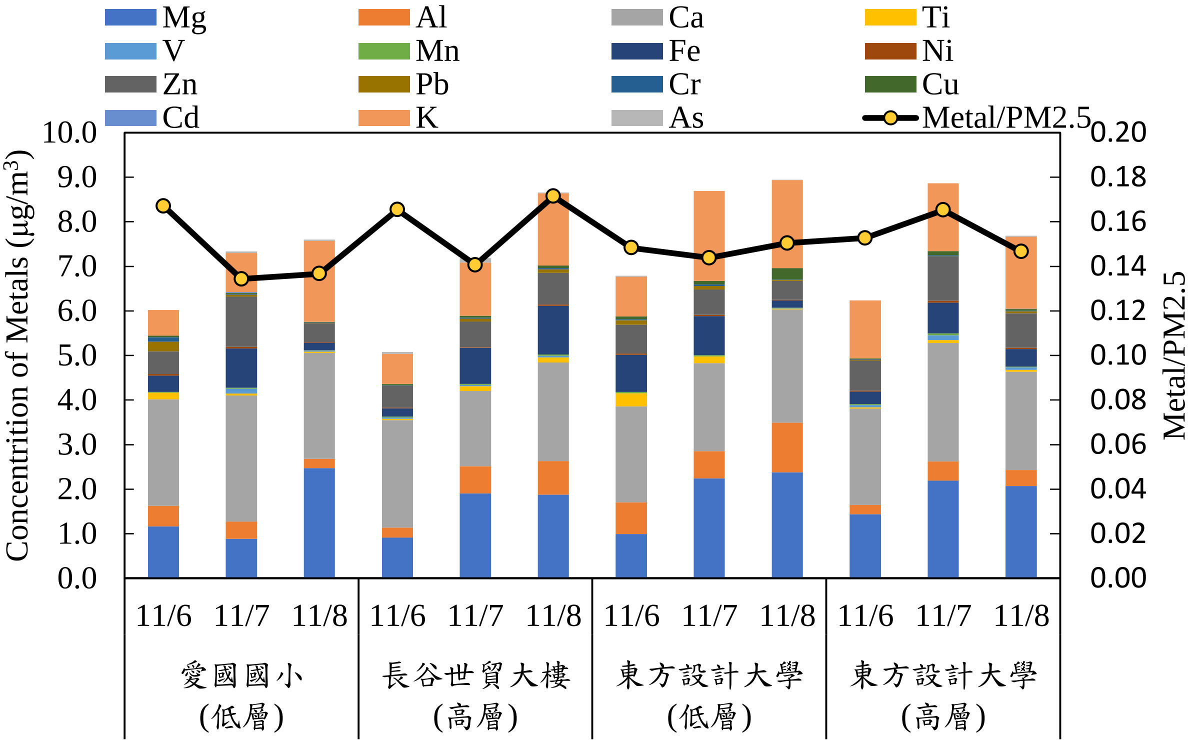


圖 10 冬季 $PM_{2.5}$ 中金屬元素濃度分佈圖

碳成份佔 $PM_{2.5}$ 濃度平均比例比較，北高雄低層平均比例(16.89%)大於高層(14.67%)，高雄市區則為高層的平均比例(15.42%)大於低層(14.33%)，而北高雄地區平均比例(15.78%)大於高雄市區(14.88%)。

針對有機碳與無機碳比值(OC/EC)而言，夏季非事件日採樣期間，北高雄高層的 OC/EC 比值(1.78)略大於低層(1.74)，高雄市區高層 OC/EC 比值(1.60)大於低層(1.48)，而北高雄地區的 OC/EC 比值(1.76)大於高雄市區(1.54%)。冬季事件日採樣期間，北高雄高層的 OC/EC 比值(2.01)大於低層(1.94)，高雄市區高層的 OC/EC 比(2.10)大於低層(1.75)，而北高雄地區的 OC/EC 比值(1.98)略大於高雄市區(1.92)。

就總碳成份佔 $PM_{2.5}$ 濃度平均比例(TC / $PM_{2.5}$)，北高雄的事件日(15.78%)大於非事件日(10.79%)，而高雄市區的事件日(14.88%)大於非事件日(13.08%)；整體而言，事件日(15.33%)大於非事件日(11.94%)。此外，就有機碳與元素碳的比值而言，北高雄的事件日(1.98)大於非事件日(1.76)，而高雄市區事件日(1.92)亦大於非事件日(1.54)；整體而言，事件日的 OC/EC 比(1.95)大於非事件日(1.65)。此結果顯示在高污染事件日期間伴隨較多二次有機氣膠的產生。

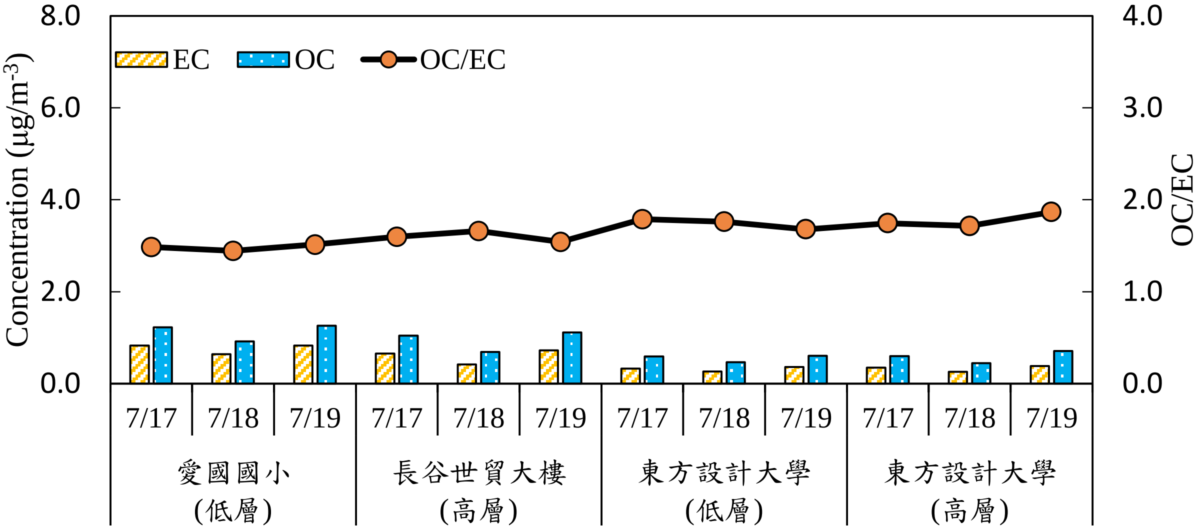
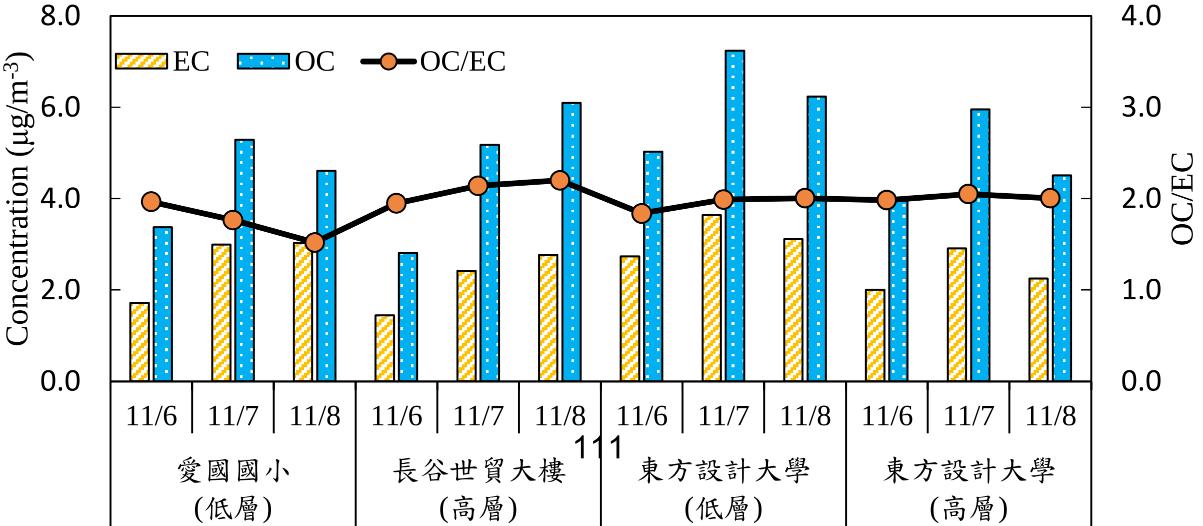


圖 11 夏季採樣期間 $PM_{2.5}$ 之碳成份濃度分佈圖

圖 12 冬季採樣期間 $PM_{2.5}$ 之碳成份濃度分佈圖



6. 細懸浮微粒污染來源解析

本研究利用化學質量平衡受體模式，解析夏季及冬季所採樣 $PM_{2.5}$ 之污染源種類及貢獻率。採用美國內華達州沙漠研究所(DRI)所開發之 CMB8.0 受體模式，搭配國內外專家學者之 $PM_{2.5}$ 排放源指紋資料庫(source profile)，解析 $PM_{2.5}$ 之污染源種類及貢獻率。茲將本研究採樣 $PM_{2.5}$ 之污染源種及貢獻率彙整於圖 15 及圖 16。

夏季非事件日採樣期間，$PM_{2.5}$ 的污染源種類及平均貢獻率由高至低依序為：燃煤鍋爐(15.2%)、鋼鐵廠(11.8%)、逸散揚塵(10.6%)、衍生性硫酸鹽(9.0%)、燃油鍋爐(8.5%)、交通運輸(7.6%)、衍生性硝酸鹽(7.5%)、焚化燃燒(6.8%)、衍生性有機碳(5.6%)、石化業(5.2%)、衍生性元素碳(3.2%)、生質燃燒(3.1%)、海鹽飛沫(3.0%)、水泥業(2.5%)等(見圖 13)。夏季非事件日採樣期間，工業污染(含燃煤鍋爐、鋼鐵廠、燃油鍋爐)為主要貢獻來源，其次為二次氣膠(含衍生性硫酸鹽、衍生性硝酸鹽、衍生性有機碳)，工業污染貢獻率為 35.5%，逸散揚塵及二次氣膠貢獻率為 10.6% & 22.1%。

冬季事件日採樣期間，$PM_{2.5}$ 的污染源種類及貢獻率由高至低依序為：衍生性硫酸鹽(14.1%)、燃煤鍋爐(14.0%)、鋼鐵廠(9.9%)、衍生性硝酸鹽(9.4%)、逸散揚塵(9.3%)、燃油鍋爐(8.4%)、衍生性有機碳(7.2%)、交通運輸(6.8%)、焚化燃燒(6.2%)、石化業(4.9%)、衍生性元素碳(3.7%)、生質燃燒(2.8%)、海鹽飛沫(2.6%)、水泥業(2.4%)等(見圖 14)。冬季事件日採樣期間，工業污染(含燃煤鍋爐、鋼鐵廠、燃油鍋爐)亦為主要貢獻來源，其次為二次氣膠(含衍生性硫酸鹽、衍生性硝酸鹽、衍生性有機碳)，工業污染貢獻率為 32.2%，逸散揚塵及二次氣膠貢獻率為 9.3% & 30.7%。

整體而言，冬季採樣期間衍生性硫酸鹽、衍生性硝酸鹽、衍生性有機碳及衍生性元素碳之貢獻率(34.4%)大於夏季(25.3%)，顯示在高污染事件日期間，二次氣膠的貢獻率也明顯上升

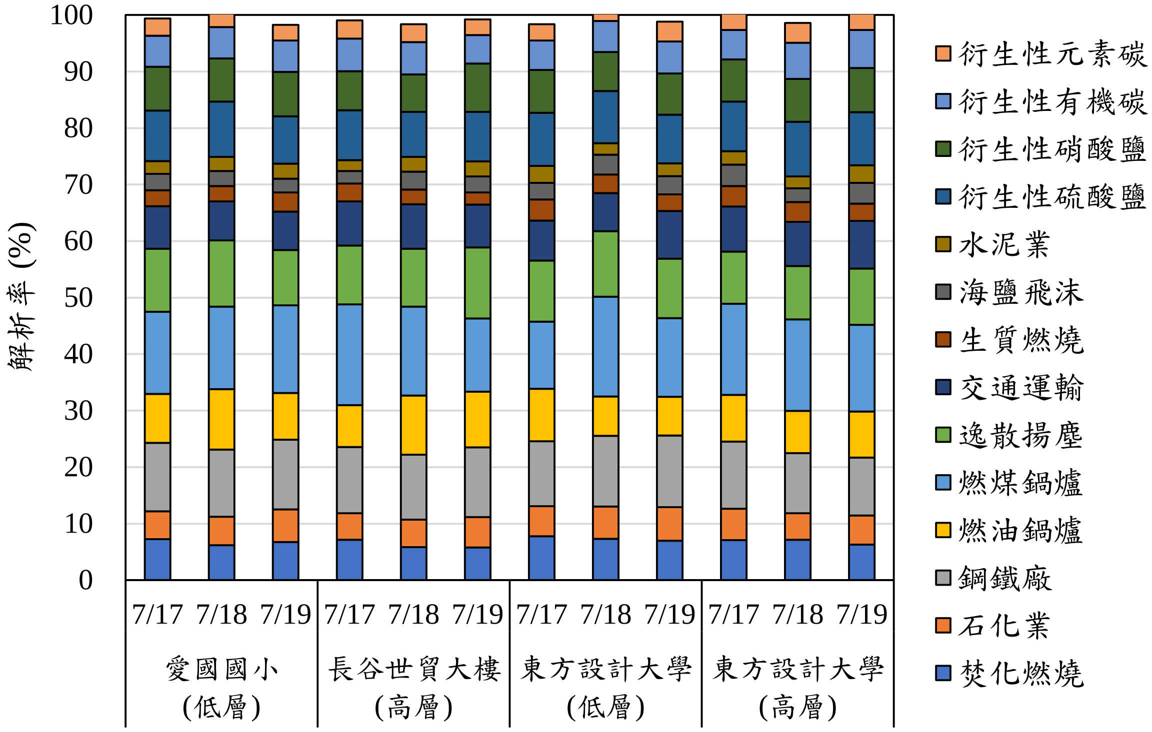


圖 13 夏季 $PM_{2.5}$ 之污染源種類及貢獻率解析圖

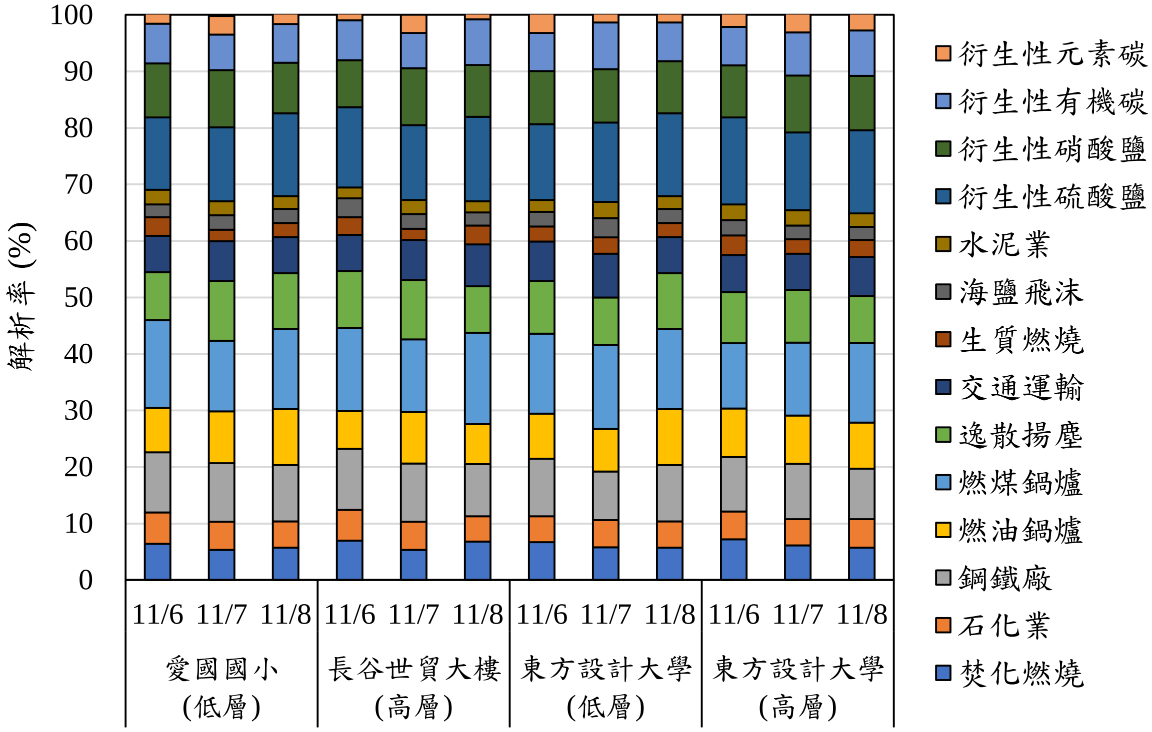


圖 14 冬季 $PM_{2.5}$ 之污染源種類及貢獻率解析圖

四、 結論

以 $PM_{2.5}$ 濃度區域變化比較，兩季北高雄地區皆高於高雄市區，推測夏季時，北高雄地區為下風處，污染物主要來自高雄市區之工業區，但因夏季大氣對流較旺盛，夏季 $PM_{2.5}$ 平均濃度(10.6 μg/m^3)明顯低於冬季平均濃度(49.26 μg/m^3)。冬季時，北高雄地區可能有農作露天燃燒及宗教祭拜習俗，導致其 $PM_{2.5}$ 濃度略大於高雄市區。兩季之 $PM_{2.5}$ 濃度低層皆大於高層，推測是低層有較多的逸散揚塵及交通運輸污染，而高層可能風速較大，因此高層 $PM_{2.5}$ 平均濃度比低層還低。

冬季事件日低層 WSI 平均濃度佔 $PM_{2.5}$ 濃度的 28.2%較高層的 26.1%略高。二次無機氣膠(SIA)為 $PM_{2.5}$ 中水溶性離子成份的主要成份，高層 SIA 佔 WSI 的 78.2%與低層的 76.7%差異不大。而兩季中 $PM_{2.5}$ 的水溶性離子中皆以 SO_4^{2-} 及 NO_3^-濃度最高，其次為 Cl^-、NH_4^+及 Na^+。其中 SO_4^{2-} 主要來自工業污染排放，NO_3^-則主要來自移動源排放。金屬元素佔 $PM_{2.5}$ 平均濃度比例顯示高雄市南北及高低程差異不大，而事件日與非事件日的差異甚小。就總碳成份佔 $PM_{2.5}$ 濃度平均比例(TC / $PM_{2.5}$)，高雄市區的事件日(14.88%)大於非事件日(13.08%)，事件日低層(15.6%)略大於高層(15.0%)，整體而言，事件日(15.33%)大於非高事件日(11.94%)。此外，就有機碳與元素碳的比值(OC/EC)而言，北高雄的事件日(1.98)大於非事件日(1.76)，而高雄市區事件日(1.92)亦大於非事件日(1.54)，事件日高層(2.05)大於低層(1.85)；整體而言，事件日的 OC/EC 比(1.95)大於非事件日(1.65)。此結果顯示在高污染事件日期間伴隨較多二次有機氣膠的產生。

在兩季採樣期間工業排放為主要污染源(33.8%)，其中以燃煤鍋爐與鋼鐵廠排放較高，石化業貢獻則相對較少，交通源佔 $PM_{2.5}$ 之 7.2%，道路揚塵與海鹽則分別佔 10%與 2.8%。事件日期間二次氣膠貢獻率(30.7%)明顯高於非事件日(22.1%)，顯示事件日污染源可能來自境外長程傳輸。

Implementing Compensation System for Environmental Damages:

Challenges and Solutions

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Abstract

Environmental damage assessment includes remediation of contaminated environmental media and restoration of injured natural resources. Site remediation decisions are made by ecological risk assessment (ERA), whereas restoration and compensation decisions are made by the natural resource damage assessment (NRDA) process. Our objectives with this paper are to evaluate the technical underpinnings of to translate natural resource injury into ecosystem service losses and to propose ways to enhance damage assessments using ecosystem service assessment endpoints in the NRDA process. Three aspects are addressed: 1) improving the linkage among assessment endpoints and ecosystem services evaluated in the NRDA process, 2) Using ecosystem service assessment endpoints to improve damage assessments, and 3) highlighting challenges and solutions for an environmental liability and compensation law in China specify the source, the budget and the compensation fund, similar to the US Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund). A thesis central to this paper is that ecosystem services can be a common currency used by both processes to guide environmental decision making. We propose development of generic ecosystem service assessment endpoints for application in hazardous site investigations. From a number of important ecosystem services, we recommend measures of biodiversity be targeted as key measurement endpoints to support the translation between ecosystem service losses and NRDA.

Keywords: Natural resource damage assessment, Ecosystem services, Assessment endpoints, Environmental damage compensation

实施环境损害赔偿制度-挑战和解决方案
挑战和具体建议

摘要

环境损害评估包括污染环境介质的修复和受损自然资源的恢复。现场修复决策由生态风险评估（ecological risk assessment , ERA）决定，而恢复和补偿决策则由自然资源损害评估（natural resource damage assessment, NRDA）过程决定。本文的评估是将自然资源损害转化

为生态系统服务功能损失的基础，并提出在NRDA过程中利用生态系统服务功能评估终点加强损害评估的方法。解决了三个方面：1）改善NRDA过程评估的评估终端和生态系统服务功能之间的联系；2）利用生态系统服务功能评估终点改进损害评估；3）强调中国环境责任和赔偿法的挑战和解决方案指定来源，预算和补偿基金，类似于美国综合环境响应，赔偿和责任法案（CERCLA或Superfund）。本文的核心论点是，生态系统服务功能可以是两个过程用于指导环境决策的通用货币。我们建议开发通用生态系统服务功能评估终端，以应用于危险现场调查。从一些重要的生态系统服务功能中，我们建议将生物多样性的衡量标准作为关键的衡量终点，以支持生态系统服务功能损失与NRDA之间的转换。
关键词：自然资源损害评估，生态系统服务功能，评估终点，环境损害赔偿

前言

近年来，伴随着中国经济的超高速发展，环境事故在中国各地频繁发生。这类事件的破坏范围和影响程度越来越大。。 例如，2015年天津港危险化学品爆炸，2014年甘肃，宁夏，内蒙古自治区交界的腾格里沙漠污染废水，2012年广西龙江镉污染，紫金矿尾矿废水泄漏 2010年金铜矿区等每一次污染事故都在全国范围内引起人们的关注，并对自然资源造成严重破坏，危害公众健康。 这一系列事件迫使政府采取有效行动，制定更详细、量化的环境损害评估准则，以增加环境损害的评估的准确性，威慑环境污染行为，从而减轻自然资源损害事故带来的损失。

1.1 NRDA量化了自然资源和服务功能所造成的伤害程度

中国的环境损害评估涉及两项立法:*环境污染犯罪的解释(*最高人民法院 最高人民检察院，2016*）*和*促进生态进步综合改革计划*(CPCCC and SC, 2015)。污染环境介质的修复，受损自然资源的恢复或补偿以及它们提供的服务功能的损失。受损自然资源的恢复由政府机构通过自然资源损害评估（natural resource damage assessment [NRDA]）过程进行。在NRDA中，环境保护者量化自然资源所承受的伤害（影响）的程度以及由于石油或有害物质的释放而损害的服务功能，并通过补偿系统对损害索赔进行扩展以提供适当数量的恢复。评估过程所需的技术信息包括所关注化学品的分布和浓度，生态受体的实际或潜在暴露程度，以及这些暴露所产生的不利影响的可能性。

1.2环境损害赔偿的必要性

本文的评估是将自然资源损害转化为生态系统服务功能损失的基础，并提出增强NRDA过程中获得的数据有用性的方法。 解决了三个方面：1）改善评估终端与NRDA过程评估的生态系统服务功能之间的联系；2）利用生态系统服务功能评估终点改进损害评估以改进损害评估，3）强调环境责任和环境责任的挑战和解决方案 中国的赔偿法规定了来源，预算和赔偿基金，类似于美国的综合环境响应，赔偿和责任法案（CERCLA或Superfund）。 本文的核心论点是生态系统服务功能可以是两个过程用于指导环境决策的通用货币。

2.生态系统服务功能作为通用货币

2.1提高生态和社会科学界的意识

生态学和社会学界越来越意识到，通过全面考虑环境系统可以实现改善环境管理（Di Giulio and Benson 2002）。这种观点认为，有效的生态系统有助于大环境系统的生态和社会组成部分的健康，并认为人类是该系统的明确部分（Miranda et al. 2002）。在该系统中反映的是，完整生态系统的结构组件和过程在功能上相互作用以提供系统内所有生命所需的支持。从广义上讲，生态系统对人类和非人类物种生命力的贡献可以被视为生态系统服务功能，即从正常运作的生态系统中获得的益处，这些生态系统有助于生物体的健康。该定义通常包括提供食品，纤维，住所和清洁水等商品，以及调节生物生产力，物质循环，气候等的过程。最近人们注意到生态系统服务功能对人类和社会的至关重要性（Daily et al.1997; Millennium Ecosystem Assessment 2005）。虽然在这些话语中所采取的观点确实是人类中心主义，但生态功能产生人类受益的生态系统服务功能这一概念反映了非人类物种也从功能生态系统中获益的考虑。考虑到这种系统观点来管理环境可能会给人类和其他生物带来更大的回报，而不是采用简化方法来关注单个生态受体或与大环境系统隔离的特定结构成分。

2.2 NRDA过程的目标是返回因有害物质释放而受伤的自然资源

NRDA进程的目标是通过直接恢复或更换受伤资源并使公众赔偿，将返回到没有释放有害物质其未受害的基线状态，以恢复受损的自然资源，及受损资源的服务。生态损伤是根据自然资源提供被减少的物理，化学或生物服务的功能来量化的，并且就损害（货币）或直接作为恢复行动而要求赔偿这些损害。损害赔偿是使用各种市场和非市场经济技术计算的，损害赔偿和直接恢复项目都按照损害索赔的规模进行了调整。

2.3利用生物多样性措施作为改进NRDA的关键衡量标准

生物多样性措施经常被纳入NRDA的终点，因为它们对生态系统和社会具有重要意义。 实际上，越来越多的证据表明，生物多样性直接影响着生态系统服务功能，高物种多样性最大化营养水平的资源获取，并降低与环境条件随机变化相关的风险（Chapin et al. 1998）。保护生物学家利用种丰富度（多样性的衡量标准）和生态系统功能之间的积极关系来争取更好的物种保护。多样性与生态系统过程之间的关系正在成为当代生态学的一个基本概念。虽然这种关系的具体形式及其潜在机制各不相同（Hooper et al. 2005），但科学家和政策制定者都认识到物种在提供对人类福祉至关重要的商品和服务功能方面的重要作用。

这里，我们广泛地定义生物多样性，以在分析的空间背景下包括遗传，物种和功能多样性的各个方面。物种多样性与生态系统功能之间的正相关关系已在小规模微宇宙（Heemsbergen et al. 2004），海洋潮汐池（Bracken et al. 2008），大规模田间试验（Tilman et al. 1997; Hector et al. 1999）中，并在大陆全球范围内（Worm et al.2006）得到证实。 支持这种关系的基本论点是，更大的种丰富度增加了功能重要物种在生态系统中存在的可能性。如果我们假设这些物种具有不同的功能作用并且任何单一物种所执行的功能是有限的，那么物种的消除将影响生态系统过程。还有证据表明，更大的多样性增强了生态系统对人为干扰的抵抗力和恢复力（Frost et al. 1999）。关于多样性 - 生态系统功能关系的大多数研究都集中在初级生产力上，并且通常很好地理解负责这种关系的潜在机制。 拥有更多物种的生态系统可能会更有效地利用现有资源，从而提高初级生产力。 除了生产力之外，科学界现在广泛的共识是物种丰富度和功能多样性直接调

节许多其他生态过程（Hooper et al. 2005），包括营养动态，分解，土壤呼吸和授粉（表1）。功能相关组合中的物种损失，例如传粉媒介和开花植物，可以在非常大的空间尺度上影响生态系统服务（Biesmeijer et al. 2006）。

表1.与生态系统服务功能直接相关的种丰富度和多样性的案例。转译结果是根据原始论文中描述的关系的基础上估算的，没有考虑不确定性。

生态系统服务	位置和栖息地类型	关系	转译	参考
初级生产力	明尼苏达州（美国）草原	曲直线	丰富度降低93％ -生物量减少59％	Tillman et al. (1997)
生产力	八种欧洲草原	直线, 对数直线	功能组别减少67％ -生物量减少33％	Hector et al. (1999)
氮摄取	加州（美国）草原	曲直线	功能组别减少67％ -氮吸收量减少50％	Hooper and Vitousek (1997)
分解和土壤呼吸	土壤微宇宙	直线	功能相异性减少67％ 效果降低10％-	Heemsberger et al. (2004)
鱼类生产	开放海域	直线	丰富度降低71％ -平均捕获量减少80％	Worm et al. (2006)
氮吸收	海洋潮池	直线	丰富度降低55％ -氮吸收量减少46％	Bracken et al. (2008)
生物扰动	海洋底栖	直线	密度降低99％ -生物扰动减少99％	Solan et al. (2004)
授粉	英国田间	未知	60％-90％的物种表现出性状减少 -强制性昆虫授粉植物减少22％	Biesmeijer et al. (2006)

调查多样性与生态系统过程之间关系的大多数研究都集中在单一的营养级别上；在具有多个营养级别的系统中，这种关系肯定会更加复杂。 与失去初级消费者相比，去除营养水平较高的物种对生态系统过程的影响将大不相同。例如，种丰富度在较高的营养水平下降低，而顶级捕食者通常更容易受到人为干扰。 因此，了解食物网结构对于预测物种丧失对生态系统功能的影响是必要的（Petchey et al. 2004）。 在由自上而下的营养相互作用调节的系统中，预计在较高营养水平下去除物种会产生更大的影响（Downing and Leibold 2002）。

不考虑有序后果与随机物种损失相比可能会导致分析人员低估物种灭绝对生态系统功能的影响（Zavaleta and Hulvey 2004）。Solan et al.（2004）比较了随机和非随机物种灭绝模型中物种损失对海洋沉积物生态系统过程的影响。 去除丰富，大型和高度流动的海洋无脊椎动物对生态

系统过程的影响要大于去除较小的，较少丰富的物种。基于随机和非随机灭绝情景的模型模拟表明，物种灭绝对碳储存的影响受到物种移除顺序的强烈影响（Bunker et al. 2005）。

我们认为生物多样性措施可提供有关危险场所污染相关服务功能损失的有价值见解。尽管多样性与许多生态系统服务功能之间的具体关系仍有待定量描述，但上述研究中提供的信息可构成补偿的基础。此外，高生物多样性对社会具有固有的审美和文化重要性，有助于量化服务功能损失和收益的价值。因此我们建议注意研究精炼生物多样性的措施及其NRDA标准使用的定量关系。

3.实施补偿的挑战

3.1中国政府正在对环境损害赔偿进行全面改革

为了遏制对自然资源的破坏并弥补损失，中国政府正在对环境损害赔偿进行全面改革。改革的目标有四个：1）明确补偿范围。补偿应包括：应急费用，清理费用，恢复费用，临时损失和调查和评估费用；2）认可责任方和权利方3）规范程序4）明确责任。(最高人民法院 最高人民检察院, 2016; CPCCC and SC, 2015)

3.2补偿的核心问题是量化损害，因为传统的民法在限制公共利益损害方面是有限的。 NRDA采用的两种方法：第一，栖息地等效性分析（habitat equivalency analysis [HEA]）是一种用于确定自然资源栖息地丧失及其提供的生态服务的补偿的适当类型和规模的方法（见Unsworth and Bishop 1994; Dunford et al. 2004; NOAA 2006）。第二，资源等效性分析（resource equivalency analysis [REA]），用于在主要涉及一种或多种自然资源物种而不是栖息地时对伤害进行扩展。在REA中，损伤通常以死亡个体数量或生殖能力丧失来衡量。关于REA在NRDA背景下的开发和应用可以在Donlan et al. (2003), McCayet al. (2004)，以及Luckenbach意外事故的损害评估和恢复计划（CADFG 2006）等文章中找到。

NRDA试图考虑与场地污染相关的全部伤害和服务损失。为了确保全面确定损害赔偿，与多种污染物或涉及多种自然资源相关的损失必须以避免低估或高估这些损害的方式汇总。 聚合方法的选择通常与选择用于将测量端点与服务损失相关联的转换度量或度量相互交织。在这里，描述一个案例研究，其中聚合问题已被成功解决。 这一案例研究还提供了如何将几个测量端点转换为服务损失的示例。

案例研究 - 沉积物污染址

公众信托人使用沉积物质量指南来估算德克萨斯州东南部纠正行动地点多环芳烃和金属在潮间带沉积物中的累积影响造成的生态服务损失。根据Long et al. (1998),开发的模型，损失计算基于对海洋端足类类动物的毒性概率，根据海洋片脚类动物的10天毒性试验结果，评估沉积物中毒性的发生率和程度。通过计算沉积物样品中各个污染物浓度与其各自的ERM值之间的比率的平均值，为每个样品开发平均效应范围中值商mean effects range median quotients (Mean ERM-Qs)（平均ERM-Qs）。 ERM值是数值指导原则，暗示了暴露和生物累积对沉积物栖息生物的不利影响（Long et al.1995）。在ERM以上的污染物浓度下，极有可能产生不利的生物效应。受托人认为沉积物污染物可用于沉积物摄取生物，然后将每个位置的平均ERM-Q值与Long et al. (1998),建立

的预测毒性范围进行比较。对潮间带沉积物提供的生态服务损失与海洋片脚类动物的预测毒性进行了直接翻译。平均ERM-Qs在0.11和0.5之间，在0.51和1.5之间，以及大于1.5的位置的沉积物分别被指定为30％，46％和74％的服务损失，这与Long et al（1998）确定的毒性预测范围一致。。然后计算在每个范围内包含平均ERM-Q的区域的空间范围。

4. 具体建议

我们在此建议：

1）设立独立的第三方评估机构，而政府单位作为监管机构。用生态系统服务功能的评估方法来计算赔偿费,把生物多样性的损害进行量化,避免显得自然资源极其廉价的赔偿费。可参考用在林业系统初现端倪的评估。

2)**目前**，在中国重大环境事故的应急处理中，已经应用无人机航拍了，然而，在非特大环境事故中，一般的民事诉讼中，却鲜有应用。但是无人机航拍对于小尺度的环境损害事件中有着巨大的技术优势和便捷的应用前景。 如果能够全面的运用无人机航拍，不但可以获取精确的破坏面积数据，还可以提供对场地污染相关的全部伤害和服务损失的估计数据，大大减少了人力成本，同时提高了准确性。

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Quantitative X-Ray Diffraction for Characterizing P Recovery Products from Wastewater

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ABSTRACT: The ability to control, manipulate, and design materials to prevent the pollution of our environment and also to recover valuable resources from the waste streams will be a major technological challenge in the 21st century. In this presentation, we will use our quantitative X-ray diffraction (QXRD) work to demonstrate its application potential on evaluating the strategies of recovering phosphorus from wastewater via struvite precipitation and adsorption by layered double hydroxides. Many waste-to-resource strategies can effectively achieve both goals of pollution prevention and resource recovery. However, the generated products should go through a series of detailed material characterizations to ensure the product quality. Particularly, the quality of recycling products generated from complex waste streams needs to be further evaluated. In the development of phosphorus recovery technologies, we have first quantified the struvite content in the recovered products by X-ray diffraction technique and facilitated the development of optimized phosphorus recycling route. With the rapid progress in materials science and characterization techniques, this study demonstrates an example that many new developments of environmental technologies are now spearheaded by the interdisciplinary environmental materials research.

Key Words: QXRD; waste-to-resource; phosphorus; struvite; adsorption

1. INTRODUCTION

The limited availability of phosphorus (P) resource causes the worldwide study of P recovery techniques. Struvite ($MgNH_4PO_4{\cdot}6H_2O$) crystallization is one of the most promising methods, because its products can be directly applied in agriculture as a slow-releasing P fertilizer [1]. Normally, struvite is formed in concentrated P aqueous solutions like sludge liquors and landfill leachates. However, both of the mentioned solutions contain the other metal ions, like Ca^{2+}, Fe^{3+} and Al^{3+}, which are with high affinity to phosphate anions (PO_4^{3-}). Particularly, a high calcium to magnesium molar ratio was reported in the settled sludge liquors, ranging from 1.4 to 3.7 [2]. Previous studies have qualitatively analyzed various characteristics of struvite products derived from a wide variety of solution compositions [2, 3]. However, limited quantitative work has been done to provide information on the phase composition of struvite-containing precipitates. Adsorption is another important nutrient recovery route, and Mg-Al layered double hydroxide (LDH) was reported as an excellent P adsorbent. The elution of P adsorbed Mg-Al LDH via ammonia could transfer the product into a struvite-like fertilizer [4]. Similarly, the P existence form and content in the achieved product need further exploration. In this study, quantitative X-ray diffraction (QXRD) technology was employed to directly identify the P crystallization phase and content in the recovered products from the P enriched solutions. The obtained results were further analyzed to optimize P recycling approaches from wastewater.

2. MATERIALS AND METHODS

2.1 Batch Experiments

Batch experiments of struvite precipitation were performed with analytical grade of magnesium chloride hexahydrate ($MgCl_2{\cdot}6H_2O$), ammonium chloride (NH_4Cl), and potassium dihydrogen phosphate (KH_2PO_4). The molar ratios of Ca to Mg were designated as 1:5, 1:3, 1:2, 1:1, 1.25:1, and 2:1 for the pH 7.5 to pH 11.0 environments. Concentrated NaOH solution was added in the crystallization process to adjust the system pH to the designated values. For adsorption and desorption studies of Mg-Al LDH, 300 °C calcined LDH adsorbent was dispersed in KH_2PO_4 solution with P initial concentration at 500 ppm shaken for 24 hours to prepare Mg-Al LDH with high P uptake level. The obtained adsorbent was filtered, washed by DI water and dried by vacuum drying method. The dry powder samples were subsequently distributed in ammonia solution at 0.5 M with various solid to liquid ratio for 24 hours to examine the desorption properties. Solid and liquid samples were separated by filtration and collected for subsequent quantitative analysis.

2.2 Analytical Methods

A Bruker D8 diffractometer (Bruker Co. Ltd.) equipped with a Cu X-ray tube was used to collect the diffraction patterns in step sizes of 0.02°, ranging from 10° to 110° at a 2θ angle. The obtained XRD patterns were analyzed based on the Rietveld refinement method to quantify the phase compositions of the obtained precipitates. Other characterization technologies (i.e., scanning electron microscopy and Raman spectroscopy) were also adopted to further understand the phase information of achieved products.

3. RESULTS AND DISCUSSION

3.1 Calcium and pH Affecting Struvite Precipitation

The finding of struvite phase in the phosphorus-containing products precipitated at different Ca/Mg molar ratios can be observed from the XRD patterns shown in Figure 1. With more XRD patterns similar to those in Figure 1, the Rietveld refinement method can further quantify the struvite contents in the precipitates with different Ca/Mg molar ratios and at different pH environments (Figure 2). The results showed that the struvite crystallization was significantly inhibited by calcium ions, particularly at high pH (i.e., pH ≥ 10.0). The struvite contents in the precipitates were generally below 50 wt.% when the Ca/Mg molar ratio was 1:1 or higher. Moreover, a good linear correlation was found between the struvite content and the Ca/Mg molar ratio. The line for pH 9.0 was found to have the smallest negative slope (absolute value). This finding indicates that the pH 9.0 may provide the most favorable environment for struvite crystallization, since struvite has the lowest solubility under this condition, even under the adverse influence of calcium ions.

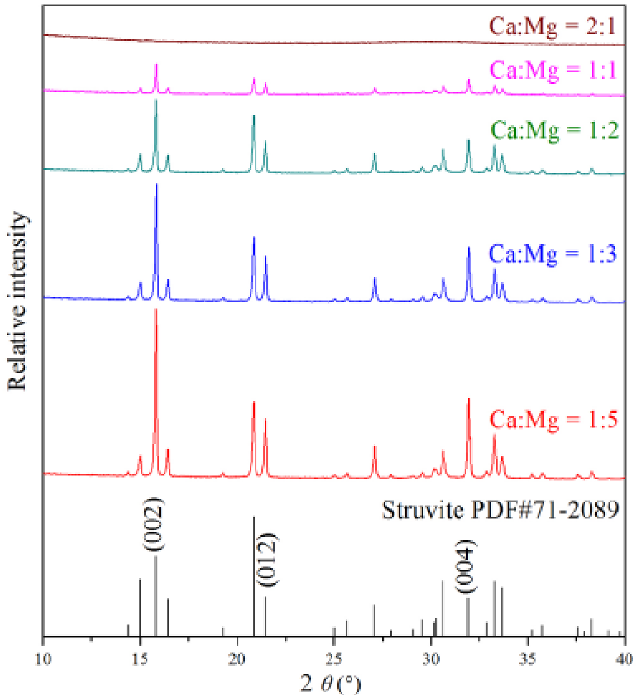

Figure 1. XRD patterns of samples precipitated at pH 10.0 with different Ca/Mg molar ratios showing the struvite formation.

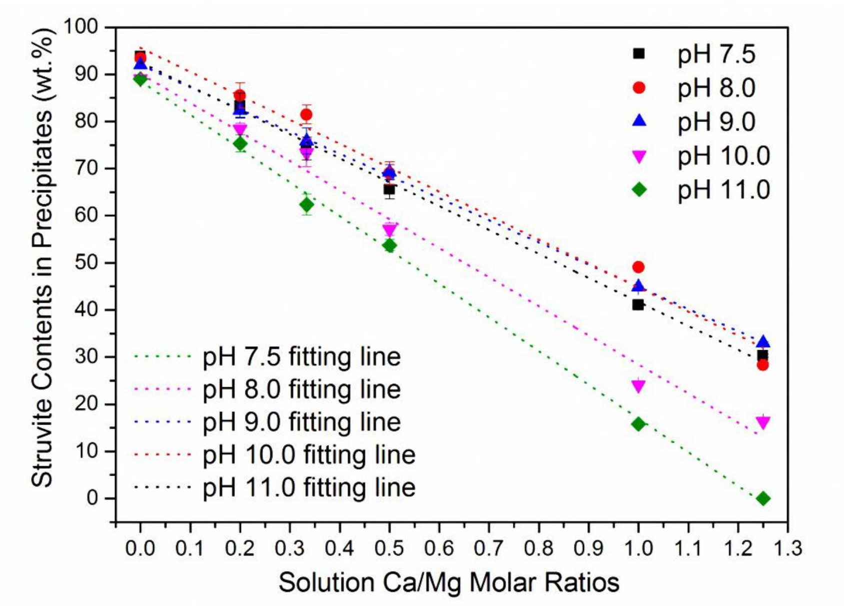

Figure 2. Struvite contents in the samples precipitated from different solution Ca/Mg molar ratios and pH conditions. The results were obtained by the Rietveld method.

3.2 Characterization of Ammonia Treated Mg-Al LDH

The P adsorbed Mg-Al LDH was eluted by 0.5 M of ammonia solution at different solid to liquid ratios, and the achieved products were quantitively identified by the Rietveld refinement technique, providing the weight percentage information of including phases. Mg-Al LDH and struvite are the only two detectable phases in solid samples. Using CaF_2 as the internal standard, the weight percentages of containing phases together with the amorphous content can be obtained. On the basis of results from quantitative XRD analysis, the P distribution in different media can be calculated through the following formula:

$$R_l(\%) = \frac{c \times V}{M_P} \times 100\% \qquad (1)$$

$$R_S(\%) = \frac{12.64\% \times (wt.percentage\ of\ struvite) \times M_d}{M_P} \times 100\% \qquad (2)$$

$$R_a(\%) = 100\% - R_l - R_S \qquad (3)$$

where R_l (%) is the ratio of adsorbed P released into liquid solution, c (mg/L) is measured concentration of P in elution solution, V (L) is the volume of elution solution, M_P (mg) is the P loading amount in adsorbent. R_S (%) is the ratio of adsorbed P existed in struvite phase and M_d (mg) is the mass of dry solid obtained from desorption solution. R_a (%) is the ratio of adsorbed P retained in LDH adsorbent or amorphous solid. During the experiments, it was found that there was a marginal change of the solid mass before and after desorption by NH_4OH, hence M_d was valued by the solid dosage for desorption. Fig. 3a summarizes the relative distribution of P by three forms (R_l, R_S, R_a) at solid/liquid ratios of 1 g/0.1 L, 1 g/0.25 L, 1 g/0.5 L, 1 g/0.75 L and 1 g/1 L. The P amount reserved in LDH and/or amorphous solid (R_a) remained stable and accounted for the major part of totally adsorbed P, ranging from wt. 55% to wt. 65%. More P was released into the liquid phase as the solid/liquid ratio decreased, whereas the corresponding P concentration in solutions declined, indicating that higher solid/liquid ratio achieves better accumulation effect. The decreased phosphate concentration resulted in lower supersaturation, and thus was with less struvite production. Moreover, the comparison of P releasing rate between ammonia treated Mg-Al LDH and struvite was shown in Fig. 3b. Basically, the P leaching behavior of Mg-Al LDH is similar with that of struvite including the releasing amount and speed. Without considering the initial dissolution, P was released from LDH and struvite at an extremely slow speed. The P distribution analysis together with leaching experiment results suggest that P-loaded Mg-Al LDH might be transferred into a slow-releasing fertilizer with ammonia treatment.

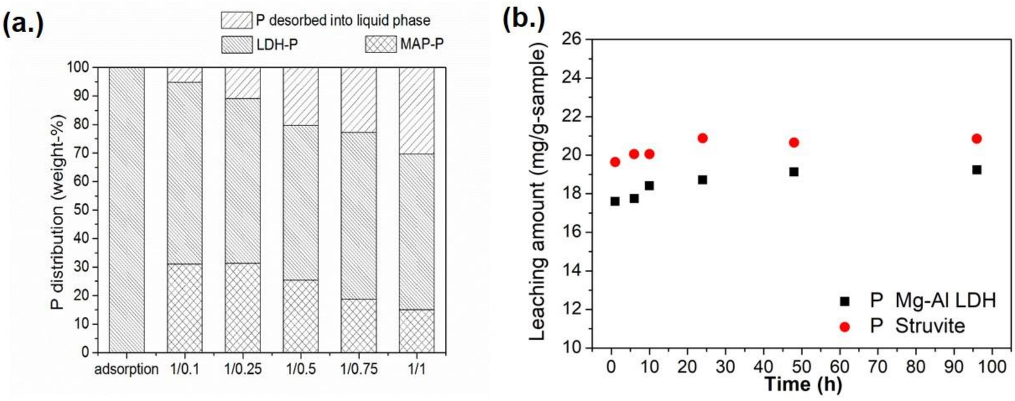

Fig. 3 (a) Effect of solid to liquid ratio (adsorbent-g/ammonia solution-L) on phosphorus distribution in possible media - desorbing solution, struvite and LDH adsorbent including amorphous solid; (b) The change of releasing amount of phosphorus per gram of solid sample with contact time in 1 L of deionized water.

4. SUMMARY

This work has successfully quantified the influence of calcium ions on struvite precipitation, as well as identifying the P distribution in ammonia treated Mg-Al LDH. The outcome demonstrated that the struvite crystallization was significantly inhibited by the co-existence of calcium ions, under different pH environments, which significantly limits its application in P recovery field. On the other hand, ammonia eluted Mg-Al LDH was observed with struvite crystallization as well due to struvite has a higher precipitation tendency than LDH with adequate existence of NH_4^+ ions. Though the major fraction of P reserved in adsorbent, ammonia treated Mg-Al LDH showed similar P releasing behavior with struvite. The results indicated that P-loaded Mg-Al LDH with further treatment might be transferred into struvite-like fertilizer, providing a novel P recovery route from waste streams.

5. ACKNOWLEDGEMENTS

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Material Mineralogical Technology for Pollution Prevention and Resource Recovery
(材料礦物學技術於污染防治與資源回收的應用)

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ABSTRACT: A major challenge for the 21st century environmental technologies is their capabilities to prevent the pollution of our environment and at the same time recover valuable resources from the waste streams. In this presentation, we will demonstrate the examples of utilizing material mineralogical information to assist the stabilization of hazardous metals in ceramic products, recovery of metallic lead from waste electronics, and the fate and transport investigation of fluorine in perfluorochemicals (PFCs) in wastewater sludge. With the quantitative X-ray diffraction (QXRD) technique, the feasibility of stabilizing metal-laden waste sludge/ash by a wide variety of aluminum-/iron-rich ceramic precursors is reflected by the high metal transformation efficiency and the significant reduction of metal pollution potential. As an example of metal recovery, our work on transforming the lead in waste cathode ray tube (CRT) glass to metallic lead shows how the quantitative mineralogical phase analysis can assist the development of a new waste-to-resource method. By reductively transforming the lead in CRT glass into its metallic form through the reactive sintering with zero-valent iron, the QXRD results successfully produced the optimized parameters to guide the implementation of this operation. QXRD was also first used for analyzing the fate and transport of fluorine when thermally treating the lime-conditioned wastewater sludge containing PFCs. Two fluorine mineralization mechanisms were found to form CaF_2 and $Ca_5(PO_4)_3F$ in the thermally treated products, contributing to the reduction of potent greenhouse gases (fluorocarbons). With the rapid progresses in materials science and characterization techniques, this presentation reflects the strong potential of developing new and quality environmental technologies guided by the interdisciplinary environmental materials research.

Key Words: Hazardous metals; Quantitative X-ray diffraction; Waste electronics; Perfluorochemicals

1. INTRODUCTION

Despite of a long history of environmental technology development, both inorganic and organic pollutants continuously threaten our living environment and ecosystem, if not also the human health. Traditional environmental treatment strategies for inorganic pollutants mainly aim at separating the pollutants from environmental matrices. However, the properties of the pollutant hosts and the opportunities of beneficially using those inorganic substances attracted much less attention. The fate and transport of many organic pollutants in the environmental treatment processes were studied, but with an astonishing rate of introducing new organic compounds into our daily life the available studies are far from sufficient. For example, hazardous metals, such as nickel, copper, zinc and lead, are inorganic pollutants and are not biodegradable. Therefore, they can accumulate in nature, causing various diseases and disorders when exceeding specific limits (1). The spread of such hazardous metals from mining operations or by the use of agrochemicals, can contaminate the soil of surrounding areas (2,3). This work will demonstrate how the addition of aluminum- and iron-rich materials into hazardous metal waste can reliably stabilize the hazardous metals in spinel structures through well-controlled thermal treatment schemes. Over 98% of lead is found in cathode ray tube (CRT) glass (4), which is derived from a type of metal-laden waste electrical and electronic equipment (WEEE). This study will report how the lead ion can be reductively transformed by zero-valent iron to form metallic lead for metal recovery.

As an example of new environmental organic pollutant, perfluorochemicals (PFCs) are with high-energy carbon-fluorine (C-F) bonds that make them structurally persistent, and the most common PFC in our environment is perfluorooctanesulfonate (PFOS) (5). Direct emission from PFOS-derived products, such as stain repellent treated carpets, waterproof apparel, and aqueous fire-fighting foams, has resulted in the release of 450-2700 tons of PFOS into wastewater streams. Studies (6,7) have shown that wastewater treatment sludge is a sink for environmental PFCs. Thus, the waste sewage sludge treatment plays an important role in determining the subsequent fate and transport of PFC pollutants in the environment. Thermal treatment (such as incineration) is a strategy offering a very effective mechanism to break the robust halogen-carbon bonds in PFCs. A study by Yamada and Taylor (8) demonstrated that PFOS can be thermally decomposed at temperatures above 600 °C, and tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) were the main final products. However, CF_4 and C_2F_6 compounds were found to be potent greenhouse gases, and their global warming effects of are 6,500 and 9,200 times higher than that of CO_2 with atmospheric lifespans of 50,000 years and 10,000 years, respectively (9). Therefore, a suitable treatment method for PFC-containing sewage sludge that can effectively decompose the PFC structures and also reduce the subsequent emission of CF_4 and C_2F_6 gases is required. Our experimental work will point out how the fate and transport of fluorine in PFOS can be controlled, when the sewage sludge is subject to different PFOS contents and thermal treatment methods.

2. MATERIALS AND METHODS

2.1 Material Syntheses and Experiments

To study the metal incorporation mechanism, experiments were conducted with samples prepared by firing MO (M denotes hazardous metals like Ni, Cu, Zn, etc.) with ceramic precursors (aluminum-rich or iron-rich). A short sintering scheme with a 3-h dwelling time at the targeted temperature was used for temperatures ranging from 650 to 1450 ºC. For lead recovery from CRT glass, funnel glass from color computer monitors was collected and crushed. The obtained powder was dried at 105°C for 24 h and mixed with zero-valent ion powder at different weight fractions. The mixtures were homogenized by ball milling and pressed into pellets under a pressure of 650 MPa to ensure the consistent compaction of the samples. The pellets were then transferred into a muffle furnace preheated at the target temperatures (600-950°C) and thermally treated with a dwell time ranging from 3 to 180 min in air. In the investigation of thermally treating PFOS and $Ca(OH)_2$ in sludge, a sludge sample collected from municipal sewage (wastewater) treatment plant was dried at 105 ºC for 24 h, and then ground to homogenous fine particles by ball milling. To observe the thermal mineralization behavior of PFOS in lime-conditioned sludge, 0.70 g fine sludge particles and 0.30 g $Ca(OH)_2$ with different PFOS contents (0.016-0.256 g) were mixed in a muffle furnace preheated to targeted temperatures (300-900 °C). The period of thermal treatment ranged from 1-30 min, and the samples were then air-quenched, weighted, and ground (to particle size <10 μm) before XRD analysis.

2.2 Analytical Methods

For quantitative X-ray diffraction (QXRD) analysis, a Bruker D8 diffractometer (Bruker Co. Ltd.) equipped with a Cu X-ray tube was used to collect the diffraction patterns in step sizes of 0.02°, ranging from 10° to 110° at a 2θ angle. The obtained XRD patterns were analyzed based on the Rietveld refinement method to quantify the phase compositions of the obtained solid samples. Other characterization technologies (i.e., electron microscopies and elemental analyses) were also used for analyzing solid and solution samples produced from the experiments.

3. RESULTS AND DISCUSSION

3.1 Stabilization of Hazardous Metals in Ceramic Products

Taking copper in the aluminum-rich matrix as an example, XRD patterns in Figure 1a demonstrate the phase transformation at temperatures ranging from 650 to 1150 ºC in a 3-h sintering scheme. The peaks of $CuAl_2O_4$ phase were first observed in the 650 ºC sintered sample. The increased peak intensity was found in the sample sintered at 850 ºC for 3 h. However, the substantial development of the $CuAl_2O_4$ spinel phase occurred when the sample was sintered at 1000 ºC. The signal of $CuAl_2O_4$ spinel phase continued until the temperature reached 1150 ºC. Further heating will cause the generation of other copper-containing phases, i.e. $CuAlO_2$, Cu_2O and CuO. According to the database of the $CuAl_2O_4$ XRD pattern (PDF#78-1605), its major peak is located at $2\theta=36.868$. Therefore, the 2θ range of 36.5-37.2º was selected to observe the variation of $CuAl_2O_4$ spinel with the elevated temperature (Figure 1b). The substantial increase of $CuAl_2O_4$ peak intensity occurred at 950 ºC, and similar peak intensities within the temperature range of 950-1050 ºC were observed. The decomposition of $CuAl_2O_4$ spinel was observed with the decrease of $CuAl_2O_4$ peak intensity.

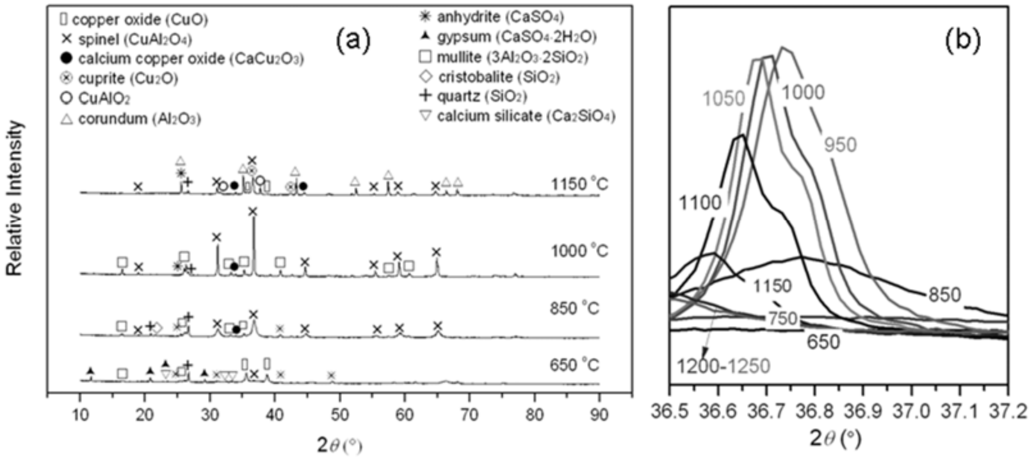


Figure 1. The (a) overall XRD patterns and (b) the growth of $CuAl_2O_4$ peak within 2θ of 36.6 - 37.2º for Cu-electroplating sludge + waterworks sludge ash sintered at 650 - 1250 ºC for 3 h.

When incorporating copper in sewage sludge ash (containing iron in the matrix), strong peaks of $CuFe_2O_4$ spinel phase were observed when the sample was sintered at 650 ºC for 3 h (Figure 2a). Further increase of sintering temperature increases the intensity of spinel phase signal in the sintered samples. According to the standard diffraction pattern of $CuFe_2O_4$ spinel (PDF#77-0010), the major peak at $2\theta \sim 35.5^o$ was overlapped by the major peaks of the other phases. Therefore, the second highest peak at $2\theta \sim 62.7^o$ was selected to further observe the formation of $CuFe_2O_4$ spinel in the sintered products as shown in Figure 2b. The peak intensity of the $CuFe_2O_4$ spinel increased after its first appearance and reached the maximum value at 950 ºC. It then kept relatively stable with a further increase of sintering temperature.

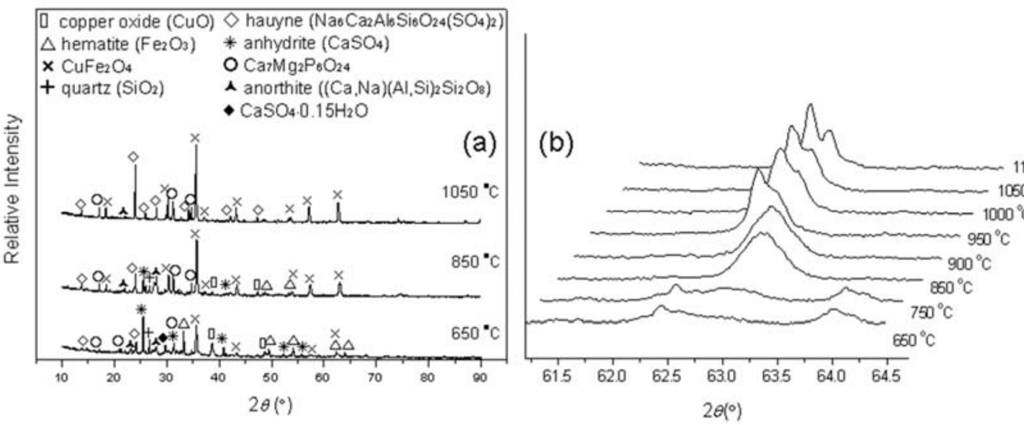


Figure 2. The (a) overall XRD patterns and (b) the growth of $CuFe_2O_4$ spinel peak within 2θ of 61.5 - 64.5° for Cu-electroplating sludge + sewage sludge ash sintered at 650 - 1250 °C for 3 h.

3.2 Recovery of Metallic Lead from CRT Glass

The reaction between Fe and Pb-glass was investigated under various thermal treatment temperature, time and Fe/Pb-glass ratios. The Pb extraction ratio (ER) values of Fe+Pb-glass under different recovery conditions were shown in Figure 3. Figure 3a summarizes the observed ER index values over the temperature range of 600-950 °C for the samples with Fe/ Pb-glass mass ratios of 0.1/1 and 0.75/1. At temperatures of 600-700 °C, substantial increases in the Pb extraction efficiency were observed for both mass ratios, and the lead extraction ratios increased significantly to 33% (Fe/Pb-glass of 0.1/1) and 54% (Fe/Pb-glass of 0.75/1). However, the curves also reflect a dramatic decrease in the lead extraction efficacy at higher temperatures (750-950 °C) for both the 0.1/1 system (a decrease from 33% to 0%) and the 0.75/1 system (a decrease from 54% to 12%). This finding clearly demonstrates a particular condition for initiating the phase transformation of lead, and the results of the quantitative X-ray diffraction reveal 700 °C to be the most effective temperature for extracting the lead from glassy networks. In Figure 5b, the ER increases with the ratio increase up to 1, and then maintains the ratio of 1.5/1. Therefore, the use of a Fe/Pb-glass mass ratio of close to 1/1 results in a more effective and economical extraction operation. In Figure 5c, the ratio of metallic lead extraction was enhanced by the use of prolonged heating time (180 min) to 37% at 600 °C. At 700 °C, the lead extraction efficiency first exhibited a significant increase to 58% after 30 min of heating, but then gradually decreased with prolonged heating time, dropping to 39% after 180 min of treatment. In contrast, a negative relationship between the lead extraction efficiency and thermal treatment time was found at 950 °C. The lead extraction ratio quickly reached 24% after 3 min of heating at 950 °C, but the extraction efficiency decreased continuously with prolonged heating. Therefore, the recovered Pb can be re-oxidized and over 30 min at 700 °C or over 3 min at 950 °C.

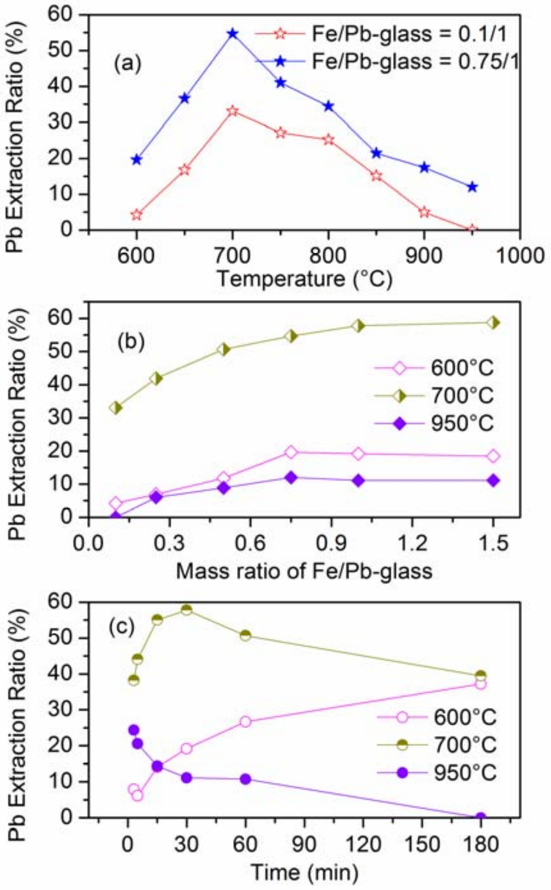
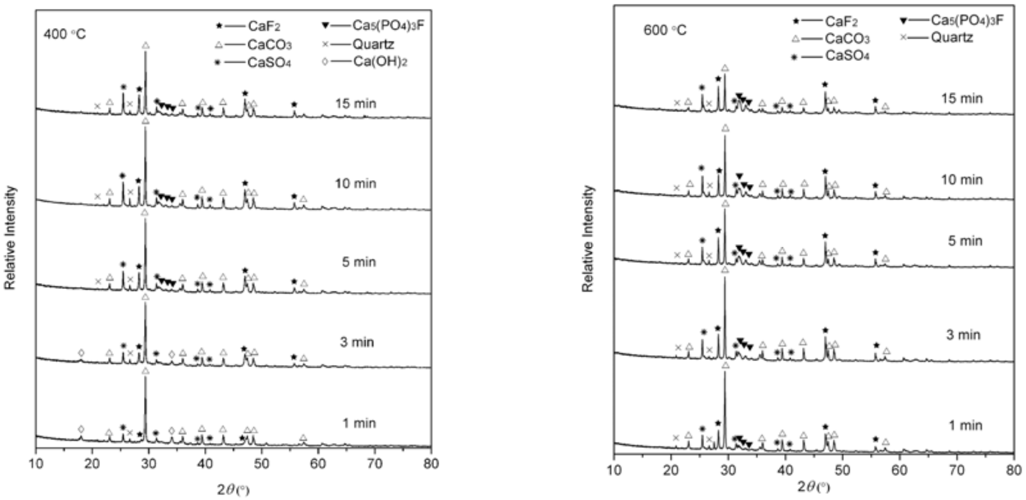


Figure 3. Extraction ratio (ER) values of Fe+Pb-glass (a) with the mass ratios of Fe/Pb-glass at 0.1/1 and 0.75/1 thermally treated at 600-950 °C for 30 min; (b) with different Fe/glass mass ratios treated at 600, 700, and 950 °C for 30 min; (c) with the mass ratio of Fe/Pb-glass at 1/1 treated at 600, 700, and 950 °C for 3-180 min.

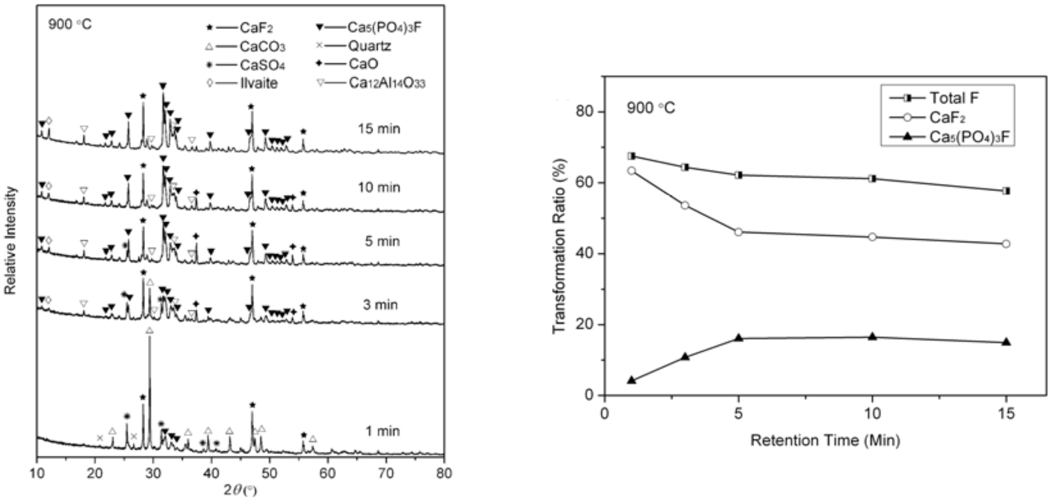
3.3 Fate and Transport of Fluorine in Thermally Treating PFOS in Wastewater Sludge

When treating the sludge mixtures at a relatively low temperature (400 °C), substantial growth of the CaF_2 phase was found after a treatment time of 3 min (Figure 4a). At higher temperatures of 600 °C and 900 °C, the formation of CaF_2 and $Ca_5(PO_4)_3F$ was observed immediately after 1 min of thermal treatment (Figures 4b and 5a). This result indicates that both heating time and temperature are important factors in promoting the fluorine mineralization in the system. To better depict the fluorine transformation process, the mineralization efficiencies during the 15 min treatment at 400 °C, 600 °C, and 900 °C treatments were quantitatively evaluated. The results of 900 °C treatment were selected to be plotted and demonstrated in Figure 5b. The mineralization products at 400 °C and 600 °C were mostly CaF_2; only a little $Ca_5(PO_4)_3F$ was formed during the heating period. However, a significant increase of the $Ca_5(PO_4)_3F$ phase was observed at 900 °C, indicating that $Ca_5(PO_4)_3F$ is a more favorable product phase at higher temperatures. Furthermore, the increase of $Ca_5(PO_4)_3F$ was accompanied by the simultaneous decrease of CaF_2, strongly suggesting the presence of an interaction between CaF_2 and phosphorus compounds at 900 °C. When the heating time at 900 °C increased from 5 to 15 min, the formation of $Ca_5(PO_4)_3F$ was limited and the decrease of CaF_2 ceased. As the conversion of CaF_2 to $Ca_5(PO_4)_3F$ requires phosphorus and abundant calcium in the system, the conversion process will stop when either calcium or phosphorus is depleted.



(a) (b)

Figure 4. The XRD results of (a) Sludge + $Ca(OH)_2$+ PFOS samples (Ca/F molar ratio of 2/1) heated at 400 °C for different treatment time periods, and (b) Sludge + $Ca(OH)_2$+ PFOS samples (Ca/F molar ratio of 2/1) heated at 600 °C for different treatment time periods.



(a) (b)

Figure 5. The XRD results of (a) Sludge + Ca(OH)2+ PFOS samples (Ca/F molar ratio of 2/1) heated at 900 °C for different treatment time periods, and (b) Transformation Ratio (TR) values for the Sludge + PFOS + $Ca(OH)_2$ samples (Ca/F molar ratio of 2:1) obtained by heating samples at 900 °C for different treatment time periods.

4. SUMMARY

This work has successfully demonstrated the use of QXRD technique in stabilizing metal-laden waste sludge/ash by a wide variety of aluminum-/iron-rich ceramic precursors, transforming the lead in waste CRT glass to metallic lead as a new waste-to-resource method, and analyzing the fate and transport of fluorine when thermally treating the lime-conditioned wastewater sludge containing PFCs. These examples are just the very small parts of the many application opportunities in environmental treatment industry. However, they have already indicated the importance of possessing in-depth understanding in the materials used in and produced from the environmental treatment processes. Current movement in nanomaterials research has substantially supplied the state-of-the-art characterization techniques for environmental research. This new and interdisciplinary environmental materials research direction requires its next-generation scientists to be solidly trained by the fundamentals in both environmental chemistry and materials science to explore new development opportunities in the 21st century environmental treatment industry.

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Cleanup of MSW-Gasified Synthesis Gas

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ABSTRACT: Gasification of municipal solid waste (MSW) to produce synthesis gas (abbreviated as syngas) has been practiced in commercial operation for years. Currently the generated syngas is combusted immediately after gasification for power and/or heat generation. It can be better used with improved efficiency (e.g. combustion in a gas turbine for electricity) or higher economic return (via chemical reactions for chemicals) if the syngas can be first treated with detrimental species and particulate matter removed. However, treatment of the raw syngas is a daunting technical challenge and yet to be developed.

In this paper, the author will start with an over-all strategic consideration for potential recovery of the sensible heat stored in the hot syngas exiting a gasifier before hitting the clean-up train. Main focus is on removal of such contaminants as particulates, sulfur compounds, halides, nitrogen compounds and mercury. Characteristics of these contaminants produced in the reducing (gasification) environment will be addressed. Currently available technologies to remove these contaminants will be introduced. Comparisons of different technologies will be made in the considerations of compliance with environmental requirement, equipment integrity, interference with chemical synthesis, etc.

Key words: gasification, MSW, contaminant, particulate, hydrogen chloride, sulfur, nitrogen, mercury, heat recovery

Introduction

Although gasification of wastes, including biomass, sludge, MSW, etc, has been in operation for decades, treatment of its crude syngas still remains an area yet to be explored. Laurence and Ashenafi addressed removing tarry products and particulates in the syngas.[1] Sawyer [2] and Tsangaris and Swain [3] proposed cleanup processes, but did not elucidate characteristics of those species intended to remove in the context of selecting a suitable technology for removal.

In this paper, the author is attempting to illustrate commercially available technologies that are applicable to cleanup of MSW-gasified syngas stream. For each targeted species, the author will address its origin, approximate concentration, commercially available technologies for removal and their suitability in exemplary process conditions. Before designing the cleanup process, one may wonder if it is worthwhile to recover some of the sensible heat contained in the hot syngas just exiting a gasifier.

Considerations of Recovering Syngas Heat

Temperature for MSW gasification is bracketed between 500 and 900 °C (in air gasification) and 1000 – 1600 °C by Arena. [5] A typical operating temperature of 900 °C is reported by Willis et al.[6] Considering relatively high moisture and ash content of MSW, a temperature range of 800 – 1200 °C is probably practical for gasification with enriched oxygen and thus the resulted syngas contains a significant amount of sensible heat. Report on heat recovery from MSW-gasified syngas is essentially non-existent in the public domain. Nevertheless, knowledge in this regard can be borrowed from experiences in coal gasification.

Zhu [7] conducted a research on heat recovery from coal-gasified syngas. It reportedly contains 5 ~ 25% of the energy in the feed (coal) as sensible heat and 5 percentage points of efficiency improvement can possibly be realized via effective heat recovery. From the report it clearly suggests convective type exchangers fit better for the temperate range of MSW-gasified syngas. However, convective type exchanges were prone to plugging and fouling, which led to plant outages and increased maintenance costs.

In the author's opinion one can consider implementing heat recovery coolers only if he has (i) acquired good operating experience in MSW gasification, (ii) obtained good knowledge in the characteristics of the MSW to be gasified and complete analyses of the resulted syngas stream, including particulates and (iii) allotted resources for a project to cover sufficient time length for technology development and verification.

Cleanup of MSW-Gasified Syngas

Overview

MSW-gasified syngas contains mainly three categories of species: intended products or environmentally accepted species like H_2, CO, Ar (inherently present with oxygen in the oxidant used for gasification); environmentally unacceptable ones like HCN, HCl; and non-gaseous species such as particulates, tars, low boiling point metals such as mercury. The latter two categories are the targets for removal, which include halides (mainly chlorides), nitrogen compounds (mainly NH_3), sulfur compounds, particulates and tars (if present). Two questions need to be addressed first – (1) what is the sequence of the identified species to be removed? And (2) how clean does the syngas need to be?

Most commercially proven technologies operate effectively at relatively low temperatures, generally less than 300 °C. Syngas cooling thus becomes the first step in the cleanup train. Afterwards, removal will be arranged generally by the order of severity and breadth of damage of a species to the downstream equipments and operation. Figure 4 of Reference 4 is to be used as a go-by for the sake of discussion (copied in Figure 1), and by no means is the most efficient sequence.

As for "cleanness", the requirement is usually dictated by a few factors. Material compatibility is the first to consider, in terms of potential chemical reaction, e.g., corrosion with the downstream equipment or interference with a catalytic reaction. Solid particulates cause erosion in rotating equipments or potentially plugging in a packed bed and need to be controlled. If the syngas is to be combusted, the resulted flue gas will be released to the atmosphere and its pollutants have to comply with environmental regulations.

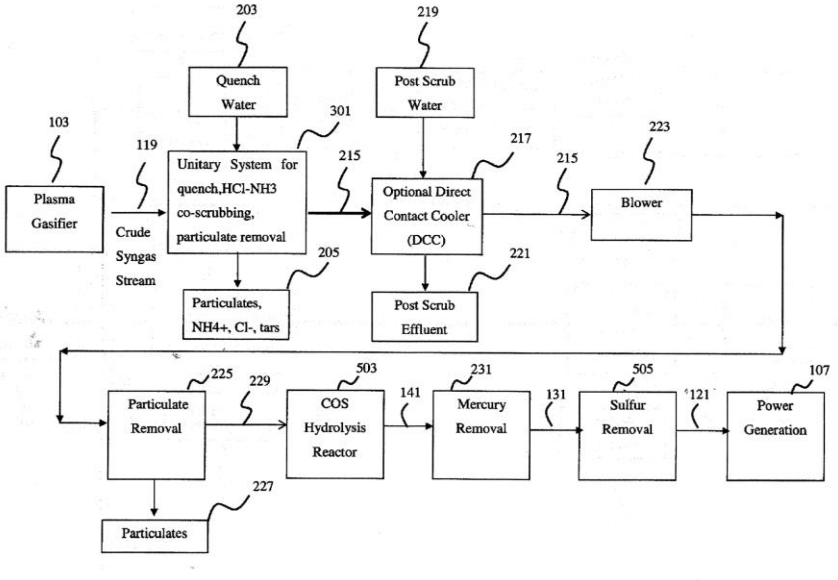

Figure 1 Syngas cleanup process flow copied from Reference 4.

Removing Particulates

Particulates may result from incomplete gasification of hydrocarbons, disintegration of large particles in the waste, or even suspected "evaporation" of some low boiling point oxides later solidifying into solid form. Depth of removal depends on the uses of the syngas and the rotating machine that transports the syngas. Combustion in a gas turbine yields higher power efficiency; however, it demands very low content (or loading in particulate technology jargon), as low as 5 mg/Nm^3(dry). It is less stringent for a gas engine and ~50 mg/Nm^3 is acceptable.[5] Combustion in a furnace to generate steam generally imposes no limit; in this case the rotating machines and local environmental regulation on the flue gas would set the limits. Cleanness for a packed bed (e.g. catalyst bed) is usually surpassed by the requirement of rotating machines.

Equipment design requires knowledge of the characteristics of the particulates to be removed; among many the most important are particle size distribution (PSD) and particulate loading. The former most likely determines the separation technology or combination of technologies to do the cleaning. Reference 8 reveals very fine particles exhibited in MSW gasification pilot tests - about 50% in mass are smaller than one micron. A comparison is made in Figure 2 against PSD for flue gas of a coal-fired power plant. In combustion of coal, sub-micron particles only account for less than 10%. Besides "fineness", the pilot tests disclosed significant quantity of particulates, as high as 26,800 mg/Nm^3(dry) post first quench. It can be safely say that the number would exceed 30,000 at the outlet of the gasifier.

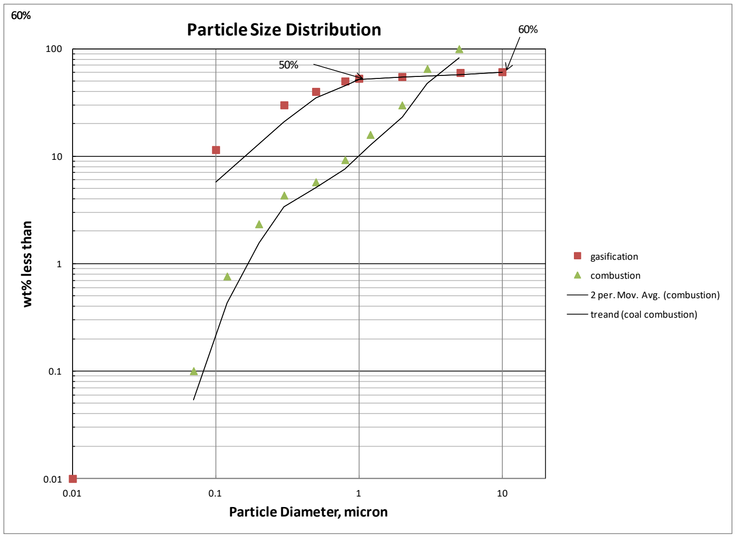

Figure 2: PSD Comparison of raw MSW-gasified syngas[8] with coal-fired flue gas[9].

A few particulate separation technologies have long been extensively practiced. Their operating principles can be classified by (1) mechanical force, e.g. cyclone, (2) filtering, e.g. bag houses, (3) mechanical impacting by small water droplets, e.g. venturi scrubber or spraying tower, and (4) electrostatic forces, e.g. ESP or WESP (wet electrostatic precipitator).[1] A comparison of these technologies is provided in Table 1. Because of considerable amount of particulates observed in the sub-micron range in the pilot tests, cyclone can be first excluded from consideration, so is bag house filtration for pressure drop reasons and material compatibility. ESP is effective in polishing instead of bulk separation. Venturi scrubbing seems a good choice for a broad range of particle size. There is an additional important benefit. As the first cleanup unit (when heat recovery is not considered), Venturi scrubber can effectively quench the hot syngas to a temperature below 100 °C (without heat recovery) over a short distance. Transient transition greatly reduces the probability of chemical reactions among the syngas species to form undesired larger molecules or even dioxins and furans if unreacted oxygen is left in the stream.

[1] New technologies are being developed, such as ceramic filters for high temperature applications, but its reliability against fouling in MSW syngas environment needs to be examined.

Type of Device	Separation Principle	Eff. size for Capture (μ)	Efficiency (%)	Use as	Equip. cost	Pres Drop	notes
Cyclone	Centrifugal	> 5 ~ 10	depends	Coarse separation	low	Small	
Baghouse	Filtering	> 0.1	> 99	Bulk - fine	Med.	Rel. high	Safety with flammable gas Gas corrosive on bag material
Water spraying	Water droplet impacting	> 1	~ 85	Bulk – fine	Med.	Small	Water treatment required
Venturi	Water droplet impacting	> 0.5	~ 90	Bulk –fine	Low	Rel. high	Water treatment required
Electrostatic precipitator	Electrostatic force	> 0.01	> 80	fine	high	Small	Safety with flammable gas

Table 1: Comparison of various particulate removing technologies.

Venturi scrubbing alone is not able to wash out all fine dusts or tars. For applications requiring very low particulate loading in the syngas a polishing step is needed. As suggested in Reference 4, an option like wet electrostatic device can be added downstream to achieve the cleanness. The overall design of particulate removal should include the outlet(s) of the recovered particulates. Composition analysis is required for the decision. If significant amount of unreacted carbon exists, the particulates may worth being recycled into the gasifier for further conversion. If the particulates are environmentally neutral, landfill is the most economic solution; otherwise more elaborate treatment may be required.

Removing Halides

Chlorine is omnipresent in all MSW constituents[2], of which the highest percentage is in plastic wastes while lowest in biogenic wastes. Chlorine is liberated during gasification and reacts quickly, almost exclusively with hydrogen to form hydrogen chloride (HCl). Relative to coal, MSW contains much higher chlorine content. Table 4.20 of Reference 10 shows a C-to-Cl mass ratio of 78 to 0.08 (= 975) for coal and 40 to 0.75 (= 53) for refuse[3]. As a result, HCl is present in MSW-gasified syngas at a much higher concentration than that in coal-gasified syngas. For design purposes, one can safely assume all chlorine in the waste is reacted to form HCl. Fluorine also exists in MSW, but at a much lower level, roughly an order of magnitude lower. Other elements in the halogen group can be ignored from engineering point of view.

HCl is chemically very active and causes corrosion problems almost in any kind of material of process equipment, piping, fittings, instrumentation etc. It is poisonous to most catalysts. Under adequate conditions it reacts with ammonia, which is sure to be present in MSW-gasified syngas, to form a salt, ammonium chloride (NH_4Cl), causing plugging problems. Problems caused by HCl are broad and severe and needs to be removed as early as possible in the cleanup train. Fortunately, HCl is very soluble in water and can be easily removed in water. The water cooling step such as venturi scrubber discussed above can serve the purpose in addition to quenching and particulate removal. Hydrogen chloride is a strong acid and an alkaline is to be added in the cooling water prior to entering the quenching equipment to neutralize the acidity. As the syngas exits the equipment free of chloride, the effluent cooling water becomes chloride-loaded. Likely it needs treatment to remove the chlorides; then the question is who is going to do it. The designer needs to clarify at the battery limit with the owner of the downstream processer. HCl removal should be complete as long as sufficient contact between the syngas and water is ensured and pH of the incoming cooling water is controlled. For full protection of a particular downstream process unit, a guard bed in front of it may be installed with adsorbents designed specifically to capture chlorides.

[2] Constituents mean "visually definable" categories in MSW, such as "paper and cardboard", "glass", "wood", etc.

[3] Mechanically processed MSW without altering its chemical composition except moisture content

Hydrogen fluoride (HF) should be present at a much lower level than HCl as said above. It causes a great concern to some materials, in particular FRP (fiberglass reinforced plastic). If such a material is used, one should clarify with the FRP equipment supplier on HF tolerance.

Removing Mercury

Mercury exists across most constituents of MSW in minute quantity, on the ppb level. But when fluorescent tubes or thermometers are present in the waste feed, mercury content spikes. Mercury removal is required mainly for environmental reasons after the syngas is combusted. The removal also protects the downstream equipment containing aluminum since it is known to be metallurgically reactive with aluminum leading to corrosion or changing its metallurgy weakening its mechanical strength.

In a reducing environment of gasification, we can fairly assume mercury in the syngas exists in the elemental form. Adsorption is an effective means to remove mercury; activated carbon and sulfur-impregnated activated carbon are commonly used. Adhesion of mercury on activated carbon is physical sorption while sulfur-impregnated carbon is chemical sorption on the sulfur sites plus physic-sorption on the base carbon. Design of an adsorption packed bed is fairly straightforward, but one should consider disposal of the mercury-laden adsorbent. Mercury recovery from the spent sulfur-impregnated adsorbent is possible; for example in Europe there are qualified companies that are specialized in mercury recovery from adsorbents. Changeover of the adsorbent involves removal of the spent adsorbent. Care should be taken that the spent adsorbent may have co-adsorbed poisonous chemical species, e.g. H_2S, which can be possibly released into the atmosphere by replacement due to exposure to excessive amount of moisture.

Removing Sulfur

All of the constituents of a municipal solid waste contain sulfur and it is a building block of matter. Its content is reported in an ultimate analysis along with C, H, O and N. Sulfur content in MSW is on a par with that in coal as demonstrated in C to S mass ratio of 78/0.45 (= 173) for coal and 40/0.22 (= 182) for refuse given in Table 4.20 of Reference 10. Rubber is high in energy content and is attempting to blend in the MSW feed to enhance BTU values of the resulted syngas. But, it should be noted that its sulfur content is at a much higher (C/S) level, 64.4/1.5 (= 43). Gasification converts sulfur to mainly hydrogen sulfide and carbonyl sulfide (COS) possibly plus trace of carbon sulfide. Relative content of the two major species is roughly 10 to 1, but the ratio is reported over a wide range in open literature probably due to variations in sampling and analysis techniques, gasification temperature and composition of the feedstock. Incomplete gasification or gasification at low temperatures may result in sulfur compounds of larger molecules, such as thiophenes and thiols, etc. [11]

Sulfur compounds cause corrosion in some materials and are poisonous to some catalysts. Combustion of sulfur-contained syngas produces sulfur oxides, which are strictly regulated by environmental requirement. Hydrogen sulfide is lethal at low concentrations with threshold being even lower than that for carbon monoxide[4]. Technologies for removing hydrogen sulfide from a gas stream have been well developed and widely practiced. As for removal of carbonyl sulfides, it is not so readily available.[5] When low sulfur is required, a hydrolysis step will be needed to convert COS to H_2S first, followed by a bulk removal of hydrogen sulfide.

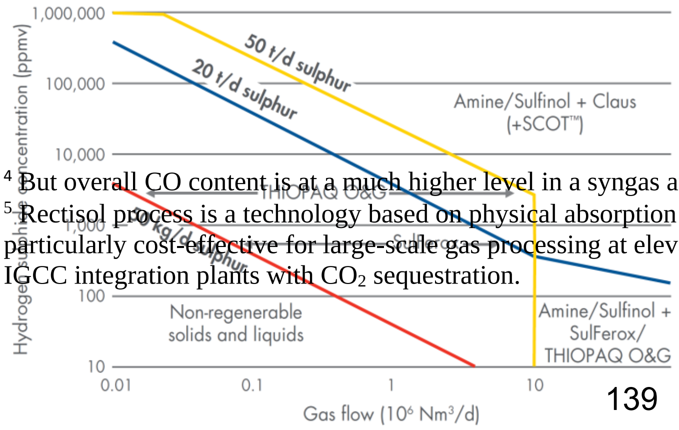

Figure 3: Technology selection for sulfur removal [12]

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[4] But overall CO content is at a much higher level in a syngas and still a main concern in managing safety.

[5] Rectisol process is a technology based on physical absorption into methanol. It absorbs both H_2S and COS. It's particularly cost-effective for large-scale gas processing at elevated pressures, e.g. treating coal-gasified syngas for IGCC integration plants with CO_2 sequestration.

Technologies for hydrogen sulfide removal are generally classified in two categories: wet and dry. In each category there are various technologies available. Shell published a map (copied in Figure **3**) that shows boundaries for different technologies to best fit per flow rate, H_2S concentration of the gas to be treated, and total quantity of sulfur to be removed. It is absolutely not the author's intention to promote Shell's products. It is intended to help the readers to home in a rightful technology for particular process conditions.[6] Actually against all the Shell's processes in the map there are licensors that offer equivalent and equally effective technologies.

An MSW gasification facility usually falls, at most, in the mid-size range, relative to coal gasification plants. A wet process in application that best fits will most likely employs circulation of a solution with chemical agent(s) that preferentially absorbs H_2S. In the absorption unit H_2S is absorbed and sulfur is oxidized to elemental sulfur. The solution then enters a regeneration unit where sulfur is separated out and the absorption agent is regenerated to be returned to the absorption unit for reuse. Wet process is complex, involves many equipment such as vessels, pumps, pressure regulators and chemicals to control the process conditions at a prescribed sweet spot for effectiveness. Figure 3 rightfully indicates that the wet processes does not fit for small-scale plant for economical and operational reasons. For smaller-scale plants a dry process fits best with adsorbents commercially available. Table **2** shows typical operating temperatures and extent for which the adsorbents are able to remove hydrogen sulfide down to. It is obvious that these adsorbents can be used in a stand-alone step for desulfurization or a polishing or guard bed in conjunction with a wet process that does the bulk separation.

	Amb. to Med. Temp. (< 200 °C)		Med. Temp. (200 – 400 °C)	
	temperature	exit H_2S	temperature	exit H_2S
iron oxides	up to 140 °C	~ 1 ppm	up to 450 °C	< 3 ppm
zinc oxides	up to 150 °C	~ 0.1 ppm	up to 450 °C	< 1 ppm

Table 2: Iron oxide and zinc oxide adsorbents for desulfurization (inlet H_2S in the range of hundred ppm)

CONCLUSION

MSW-gasified syngas can be treated with existing proven technologies to achieve cleanness in compliance with process and environmental requirements as illustrated in this paper. Challenges do exist in safety, reliability, operability, variability of the MSW feed, costs **-** just to name a few. Air Products built a MSW gasification facility at Tees Valley in United Kingdom with "the syngas…treated, cleaned, and used in a combustion gas turbine to generate electricity". [13] Although the project was suspended, benefits of a cleaned syngas have already been grasped by industry.

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[6] Processes in the Shell chart: Sulfinol – absorption by a solvent Sulfinol; SCOT – Shell Claus Off-gas Treating process to deep conversion of sulfur compound by catalyst; THIOPAQ – biological absorption process; SULFEROX – redox-based absorption process. Equivalents of these processes are offered in the market by other licensors.

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End of Useful Life Computer Recycling Program at Jackson State University, Jackson, Mississippi, USA

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Abstract For two decades, Dr. Pao-Chiang Yuan has overseen the Computer Recycling Program at Jackson State University. To date, this project has collected the following: 13,934 desktop personal computers; 6,024 mice; 14,407 monitors; 8,437 keyboards; 4,821 printers; 2,131 laptops. Overall, the program received more items than anticipated. These items included servers, cables, televisions, radios and office furniture. The program has refurbished 5,276 computer systems and returned them back to the community. Many of the places that received donations were daycare centers, low-income families, libraries, and churches. Over 100 non-profit organizations have received more than five computer systems each. By giving computers a second life, the project not only saved raw materials but also minimized landfill spaces. In 2001, a proposal was submitted to the Mississippi Department of Environmental Quality (MDEQ) through the Hinds County Board of Supervisor and Planning Department. Dr. Yuan was awarded $75,000 in grant funds, which were collected by the city through waste tire collection fees. The goals for this grant were to: (a) collect computers from private homes, businesses, and government agencies, (b) training high school dropouts and/or high risk groups, (c) refurbish computers and return them back to families and communities in need. Since 1999, the MDEQ has supported the Hinds County Obsolete Computer Recycling and Training. The Hazardous Materials Management Program of the Department of Technology at Jackson State University led this project. This paper describes the experiences and trends for the future.

Keywords: Refurbish, Recycling, PC, MDEQ

Introduction

In 1999, Dr. Pao-Chiang Yuan submitted a request for grant funds to Hinds County[1] in Mississippi on behalf of Jackson State University's (JSU) computer recycling program. The grant was successfully accepted and JSU became a subcontractor for this award. The main objective of the JSU Recycling Program is to train and educate JSU students about preserving the environment, extending the shelf life of computers systems, and giving back to the community.

The guidelines set forth in this grant to JSU's Computer Recycling Program are the following:

a) To collaborate with Stewpot Community Service[2] to receive donations, specifically computer equipment and office supplies (i.e. file cabinets, printers, and chairs).
b) To refurbish computers and redistribute them back to low-income families, non-profit organizations, churches, and daycare centers within Hinds County.

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[1] Hinds County is located in the State of Mississippi. As of 2015, the population was estimated at 242,891. "State and County Quick Facts." United States Census Bureau, http://quickfacts.census.gov, (January 17, 2019).

[2] Stewpot Community Service is a nonprofit organization located in Jackson, Mississippi. It serves hot meals, groceries, shelter, childcare and mentoring to people in need. "Stewpot Community Service," Stewpot, www.stewpot.org, (January 17, 2019).

c) To receive and house the donated computers and accessories.
d) To provide receipts to donors, if requested, for tax purposes. Stewpot Community Services, Inc. would provide a 501(c) letter if needed.
e) Will not receive computer systems from JSU.
f) Will not receive any monetary payments for the refurbished computers, and/or donated items.

Most computers that were donated are outdated and have little or no value. Majority were approximately six years or older. JSU students were hired through the work-study or work-aid program to sort and test all donations received. These students were responsible for accepting and making telephone calls to donation recipients within Hinds County. The calls were documented to determine if the donor was eligible. Students also assisted in obtaining and collecting donations from various locations within Hinds County. While most of the employees were JSU students, other students were also hired to receive community-service hours that were not employed by the JSU Recycling Program.

On any given day, the JSU Recycling Center maintained approximately 100 to 150 families and 25 to 30 non-profit organizations on the waiting list. The distribution process was as followed:

a) When approximately 10 to 20 computers have been refurbished, the student will contact the recipients on the waiting list to schedule a pick-up time and date.
b) The recipients must complete a form to include their name, date, address, telephone number, status (i.e. church, non-profit organization) and signature. If there was a request for more than three computers, documentation must be provided by the organizations letterhead.
c) If computer accessories were requested, they were distributed upon availability. This included monitors, power cords, laptop chargers, and batteries.
d) Items that were not used by the JSU Recycling Center were sent to Allen's Recycling in Canton, Mississippi.

The program reported quarterly to MDEQ on the amounts of computers, computer accessories and other item received from Hinds County, Madison County, and Rankin County.[3]

The main purpose of the project was to:

a) Train high risk groups in Hinds County;
b) Create jobs for low-income families;
c) Educate the public on the proper disposal of useful computers and their peripheries;
d) Prevent dumping of obsolete computers into the landfills;
e) Save previous land space; and
f) Conserve natural resources and our living environment.

This program was extremely successful and it was widely recognized across the United States. In 2004, the Environmental Protection Agency (EPA) awarded the program with its WasteWise Award. Overall, the program received 10 awards and 2 citations. Locally, the program was well known in the tri-county area of Mississippi.[4] Even the local newspaper published an article with questions and answers for readers on how to properly dispose of computers. As a result of the popularity of the program, there were daily phone calls and emails requesting to participate in the program. Thousands of pieces of non-biodegradable item were collected and reused or properly disposed. The successful work also led the program to collaborate with Earth911 and be recognized as a Community Microsoft Authorized Refurbisher.[5]

[3] These are respective counties within the State of Mississippi. In 2005, the Southeast part of the United States suffered a catastrophic storm known as Hurricane Katrina. There were requests made from neighboring counties for assistance.

[4] Specifically, Hinds, Rankin and Madison Counties.

[5] This program was later to renamed "Microsoft Registered Refurbisher Program ("RPP") in May 10, 2010.

Due to budget constraints, the training high school dropouts and/or high-risk groups training portion had to be suspended during the project; however, Stewpot Community Services, Inc. continued to support the program. With their collaboration, we were able to continue offering our donors tax write-off for their donations. [6]

Methodology

The process used in the program were as follows (Figure 1):

1) Notice
    a. Program receives a notice to pick-up/drop-off computers by
        i. Telephone calls
        ii. E-mails
        iii. Faxes
2) Collecting
    a. Donations were collected from donor’s homes, agencies and/or business.
    b. Donation were dropped-off at JSU recycling office
3) Sorting
    a. Computers were separated into those that can be refurbished.
        i. Unwanted items were placed on the pallet or gallows box
    b. Policy on items
        i. Computers below Pentium Core-2 systems would not be refurbished
        ii. Monitors manufactured before 2000 or Cathode Ray Tube (“CRT”) were placed on the pallet
        iii. Cords/Cables were separated into boxes and drawers
            1. Power cables, printers, internet devices, monitors, special cords/cables
        iv. Due to the current trend, white color computers were generally stripped for parts and their monitors were placed pallet
        v. Apple computers-Because the program did not own their legal operation system, apple computers were either placed on the pallet or donated as is.
4) Refurbishing
    a. As a member of RRP, all refurbished desktop computers would installed with a minimum of Windows 7 Operating System and Microsoft Office 2010. Prior to participating in the RRP Program, the existing operating systems on the machines were typically used and donors passed along the original software with a CD/DVD.[7] The program cost was $6.00 for each operating system and Microsoft Office to RRP. Most computer systems that were donated did not come with an operating system or any software. If for some reason the software could not be loaded, the computers were placed on the pallet to be recycled. When operating systems were relocated, they were generally reformatted and all of the old data was erased. Some donors also requested “DBAN”[8] to be used to remove the original data, which would add additional time to the refurbishing process.
    b. Speakers were also retested with the matching power supply and stereo wires.
    c. Printers with ink cartridges that are mostly out-of-date were typically not tested. Instead, they were placed on the pallet to be disposed. Laser printers were tested and if they were operable they were provided to donors.
5) Returning Computer Systems to the Community
    a. “Community” is defined as anyone who will not use the computer system for profit.

[6] This service ended in 2010.

[7] Although these often did not contain proper registration numbers.

[8] Refers to “Darik’s Boot and Nuke” is a program that erases a hard drive until everything is deleted and unrecoverable.

    b. Members of the community who desired a computer most commonly made requests through a phone call. Their personal information (name, address, and phone number) was recorded and they were placed on a waiting list.
    c. When the request was from a non-profit organization and they requested more than three computers, they were required to provide a written request on their organizations letterhead. After the systems have been refurbished, the student employee will reach out to the organization to schedule a pick-up time.
6) Computer Systems Post Delivery Issues
    a. If a system stopped working after three months, recipients may return the computer to the Recycling Center and they were placed back on the waiting list for another system.
    b. If the system stops working after three months, they were given a replacement system.
    c. If the computer system is no longer needed, they were returned or collected by the recycling center.
7) Registered Recycler
    a. Registered recyclers collected unwanted computer systems materials.

Collection Results

The collection efforts from 2003-2018 can be found in Table 1. The table breaks down the major parts collected. .

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Desk PC	636	422	1007	648	965	966	1471	1929	869	945	472	1301	647	604	639	533	115	13934
Mice	305	156	364	199	424	330	713	452	400	530	175	726	182	354	300	283	67	6024
Monitors	1020	630	917	686	608	834	914	1743	730	837	444	602	404	319	644	345	55	14407
Keyboard	510	443	633	458	422	200	858	1696	524	645	245	770	242	230	284	326	41	8437
Printers	72	97	412	163	201	198	453	476	310	506	296	334	246	330	425	198	61	4821
Laptops	24	39	38	46	173	28	65	64	78	32	48	295	211	322	260	248	88	2131
Donation	22	83	269	293	506	320	443	640	315	373	196	329	376	269	447	306	99	5276

Table 1-Collection Efforts from 2002-2018

As part of the study, the type of computer systems was evaluated. At the beginning of the collection years, white monitors were donated more than black ones. To date, most monitors that are collected are black. Liquid Crystal Display (LCD) was collected, mostly in rectangular sizes approximately 17 inches to 19 inches. The brands that were collected predominately came from IBM, Pentium I-IV, Xeon, i3, i5 and i7. Mice, wireless mice and keyboards collected that have AT and PS2 mouse type adapters are deemed obsolete and placed in recycling. Instead, current computer systems use Universal Serial Bus (USB) adapters.

Similarly, printers these days have USB adapters rather than parallel ports. Unfortunately, printers often end up in the waste stream because printer ink is expensive and most vendors promote printers by selling their systems with an accompanying ink cartridge printer rather than laser ink. Sometimes there were DOT matrix printers[9] in the waste but surprisingly some companies actually came to the recycling center to see if the program had any.

Finding

In this past two decade, the program saw many successes but there were some issues within the program. Without question, there was and is a digital divide that exist in the community. Majority of recipients were from low-income families who simply do not have the resources to purchase a computer system. The next

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[9] Dot matrix printing is a type of printing where the computer prints from a collection of dot matrix data.

largest groups of recipients were from local churches. They used the donations for their youth programs or after school programs.

1) Advantages
    a. Grant funds were distributed by the university accounting office
    b. The ability to train our own students with plenty of hand-on experiences in refurbishing computers. Students played a large part in collecting, sorting, loading and unloading materials. It taught them the importance of community service.
    c. The program was able to provide systems and part to the campus community.
    d. MDEQ donated two vehicles to the program to be used for picking up and delivering computer systems. A number of our clients were elderly and physically challenged.
2) Disadvantages
    a. When the computer systems were being given away, it was a difficult for JSU campus security to allow recipients to come onto campus without proper identification. As a result, many of our pick-ups were on a Saturday, which proved difficult for students to be present.
    b. Although the university itself had a large end-of-life computer system, they could not sent it to us due to the state regulations, which mandated that they be sent to the state surplus center for disposal.
    c. At times, it was difficult to verify the recipients as low income.
    d. It was difficult to refuse the donor to from asking for other items such as network frame, plotters, and office furniture.

Conclusion

The program goal was to refurbish computers and return them back to the community. There was a clear trend of clients preferring to have a laptops over desktops. Because larger businesses and banks nowadays rent computers rather than purchasing them, there was a growing concern that the collection of computer systems will decrease.

The program offered computer training to special groups but that was difficult to control as participation from the attendees were not consistent and sometimes even after some basic computer training attendees still were not able to operate the system. What was eventually offered was computer training on a case-by-case to those who made a request.

As the project continued, donors were often removing the hard drive and the memory chips. Another problem was that many laptops often were donated without power adapters so the program had to purchase generic adapters.

Overall, the program was very successful. We know that landfill space was saved and computers were given a second life. The program was done with the support of MDEQ Chief of Waste Division Mark Williams, Hinds County Board President of Supervisor George Smith, Hinds County Planning Director James A. Barker, and Director of Human Capital Development Clarence Williams. At JSU, the program was supported by Lavon Magee, Program Coordinator Paulette Bridges and the students at JSU.

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Water quality modeling with data collected by wireless sensor networks (WSNs) in an experimental pond: A case study

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Abstract: Sound decisions on sustainable water management require data support from real-time water quality monitoring data and water quality modeling at fine temporal and spatial resolutions. Recent development of Wireless Sensor Networks (WSNs) promises potential to revolutionize acquisition of water quality monitoring data. A case study on the experimental pond in Beaumont, TX, USA is conducted to demonstrate real-time data assessment and model develop processes with the monitoring data measured by WSNs. The objective of this study is to demonstrate a water quality model utilizing the real-time and *in-situ* water temperature (*T*) and dissolved oxygen (*DO*) data collected with deployment of wireless sensor networks (WSNs). WSNs from *National Instruments (NI)*, eKo Pro Environmental Monitoring System from *Memsic* and STORM 3 data loggers have been developed to collect data successfully under large scale, real world, and long-lived outdoor environment. A two-dimensional computational fluid dynamics (CFD) model is developed using finite volume numerical solver in ANSYS/Fluent to simulate flow field and water temperature affected by the weather condition in an experimental pond. The results indicate that the thermal pollution and anaerobic conditions are the main causes of the eutrophication. A surface aerator has been installed to improve the water circulation, which in turn to increase DO to be more than 4 ppm and diminish the harmful algal. The case study demonstrates an improved decision-making as a result of the WSN measurements and the model development, and provides a better practice tool for water resource management in a retention pond.

Keywords: wireless sensor networks (WSNs); water quality modeling; computational fluid dynamics (CFD); Temperature; Dissolved Oxygen (DO)

Introduction

It is well known that retention ponds have been constructed to store stormwater and allowed for the settling of sediment and biological uptake, adsorption and ion exchange of dissolved pollutions, reducing nonpoint pollutant loads for surface water (Urbonas 1995). Inappropriate design and postponed maintenance often leads to water quality issues (Sample et al. 2012), such as thermal pollution (Jones and Hunt 2010), anaerobic condition (WEF and EWRI

2012). The water quality model can be an effective tool of predicting water transport and treatment processes, and provides an important component of environmental impact assessment for natural waterbodies (Edinger 2002; Ji 2008; Qian 2016). Due to the function and size of the retention pond, hydrodynamic and water quality models have not been widely used to evaluate water quality of retention ponds (Beener et al. 2011). In addition, although a significant progress has been made for water quality modeling with advances in computer technology, the differences in predictions among models sometime are large due to a lack of adequate field monitoring data for calibration to reduce the uncertainty of predictions and validation to predict future conditions (Moriasi et al. 2015).

Recently, deployments of distributed wireless sensor networks (WSNs) and associated data measurement technologies may fill the gap (Jiang et al. 2015; Jin et al. 2010; Xiao et al. 2011; Xiao et al. 2012; Sun et al. 2015; Sun et al. 2016). Considerable efforts have been devoted to various aspects of WSN applications on water monitoring, for example, water distribution system monitoring (Lin et al. 2008), agriculture and water monitoring on a river basin (Kotamaki et al. 2009), seawater depth monitoring (Yang et al. 2007), environment observation and forecast system (CORIE) (Dang et al. 2007), groundwater transport models (Barnhart et al. 2010), and ecology (Porter et al. 2005). However, previous studies have demonstrated that a fully developed prototype system in the lab could experience various difficulties in bridging the gap to address large scale, real world, and long-lived outdoor WSNs. Most WSN deployments are designed for short-term experiments or proof-of-concept demonstrations, instead of long-term operations. When applying WSNs to water quality monitoring systems, there are still significant practical challenges, including sensor and wireless module deployment architectures, instability of the system caused by inclement or even under normal weather conditions, and loss of communication and data (Jiang et al. 2015; Jin et al. 2010; Sun et al. 2015; Sun et al. 2016; Lin et al. 2008; Kotamaki et al. 2009). Therefore, a robust multi-hop connectivity is necessary to improve communication for collecting sensor probe data (Xiao et al. 2011; Xiao et al. 2012). Besides fundamental challenges, WSNs also need to be tailored to integrate third-party sensors for various water quality parameter measurements. These sensor probes require continuous calibration and verification in order to ensure the data accuracy. The real-time and in-situ data collected with WSNs provide a great water quality monitoring system, but such data have finer temporal scale than the data for water quality model calibration and validation. It is required significant data assessment to utilize WSNs' data for a water quality model development.

The objective of this study was to evaluate and enhance water quality in an experimental retention pond utilizing the real-time and in-situ water temperature (T) and dissolved oxygen (DO) data collected by the deployment of WSNs along with hydrodynamic and water temperature model. Three suitable WSN products, including WSNs from the NI (http://www.ni.com), eKo Pro Environmental Monitoring Systems from Memsic and the STORM 3 data loggers from YSI have been explored. Deployment of different WSNs with sensor probes were conducted and compared to demonstrate potential applications in other bigger water bodies, i.e. rivers and lakes. With the available data from field and WSNs, a two-dimensional computational fluid dynamics (CFD) model was developed using a finite volume numerical solver in ANSYS/Fluent to simulate flow field and water temperature on a daily scale of typical weather conditions. Finally, an evaluation of the available water quality enhancement solutions was conducted based on the monitoring data and model predictions.

Materials and Methods

Description of study case

The experimental retention pond located at Lamar University, Beaumont, Texas, USA was constructed in 1982 and has the total volume of 6235 m^3, a surface area of 2861 m^2 (30,798 ft^2) with a perimeter of 274 meters, and 5.18 m (17 ft) in elevation from the pond bottom to the bank according to the original construction plan provided by the facility management of Lamar University. It was experiencing a serious eutrophication problem due to an algae bloom, and excessive sediment and algae buildup along the shorelines (Figure 1, sensor location). These issues may be caused in part by poor water currents and/or nutrient contamination from the stormwater runoff over the time (Sample et al. 2012). Another concern pertaining to eutrophication is the thermal pollution due to long residence times and large surface areas (Sample et al. 2012; Jones and Hunt 2010). Due to significant solar energy absorption at the water surface, the vertical temperature stratification due to the water density changing with temperature causes the vertical DO concentration distribution. Higher T and DO concentration on water surface and lower T and DO near the bottom has been a potential stress for sensitive organisms in lakes and ponds (Sample et al. 2012; Jones and Hunt 2010; WEF & EWRI 2012; Beenen et al. 2011).

To evaluate the cause of eutrophication, T, pH and DO sensor probes were selected to deploy in designing the WSN system in the pond starting 12/19/2013. The better wireless communication system requires an open area and enough sunlight to produce electricity through the solar panel. To facilitate wireless communication infrastructure, a steel pole was installed on the grass field with the wireless modules connected to the sensor probes in the water (Figure 1, left panel). Two sensors were mounted on the PVC pipes to suspend securely one close to the water surface (Figure 1) and another one close to the sediment. Two locations (X1 and X2 in Figure 1) have been selected to install the sensor probes. The depth between two probes at the X1 is about 20 cm, while widens to 50 cm at the X2. The temperature sensors WaterLOG H377 were configured with the STORM3 and installed in the X1 and X2. The sensor was also configured with the NI WSN and installed in the X2. The temperature sensor probes from Sensorex (eS1201) was configured with the eKo Pro and installed in the X1. The S8000 pH Sensor and DO 6400 Dissolved Oxygen Sensor Probe were configured with the NI WSN and installed in the X2 to collect hourly continuous data from 12/19/2013 to 04/10/2014 for DO and pH measurements as demonstrated in our previous study (Sun et al. 2016). The real-time WSN's data for pH were close to 8 at two depths, which consistent to the field measurement. The DO data close to the sediment were lower than 2 mg/L, while more than 8 mg/L at the water surface(Sun et al. 2016) indicated that the low DO anaerobic condition in the pond (Jones and Hunt 2010; Michaud 1991). In addition, an abnormal drop in DO levels from daytime to nighttime was also noted, which may demonstrate the possible thermal pollution due to solar energy absorption (Sample et al. 2012; Jones and Hunt 2010; WEF & EWRI 2012).

A topographical surveying indicted that the current volume of the pond decreased to 5071 m^3 with 4.97 m in elevation from the pond bottom to the bank due to the sediment buildup. As indicated in Figure 1, the overflow weirs (X3) discharge 7.95 m^3/hour flow to the pond, and then water cascades over the concrete step (X4) under the bridge to the other side of the pond (X5). Therefore, residence time was calculated to be 26.6 days. A total of 48 water samplers at the X1 to the X6 (eight samples per each location, Figure 1) were collected from October to December, 2015 to measure chemical oxygen demand (COD), ammonia, nitrogen, phosphorus, total suspended solids (TSS), volatile suspended solids (VSS), biochemical oxygen demand (BOD_5)

and alkalinity in the lab. The field DO, pH and T were also measured while taking water samples. As shown in Appendix Table 1, no evidence of nutrient pollution was presented and higher TSS and organic matter contents demonstrated a stressful environment for inhabits. An average pH value of above 8 which consistent to the WSN measurement was demonstrated the presence of algae consuming the available CO_2. The results indicated an average DO level of 9.38 mg/L at the water surface was being supplied by the massive algae content at the water surface. Lower DO level at the bottom were obtained at location X1, X2 and X6 due to algae creating a blanket that blocked sunlight eventually killing the aquatic plants and eliminating oxygen supplies for aquatic animals living in the pond. In summary, the field measurements confirmed the anaerobic condition as indicated from WSN's data.

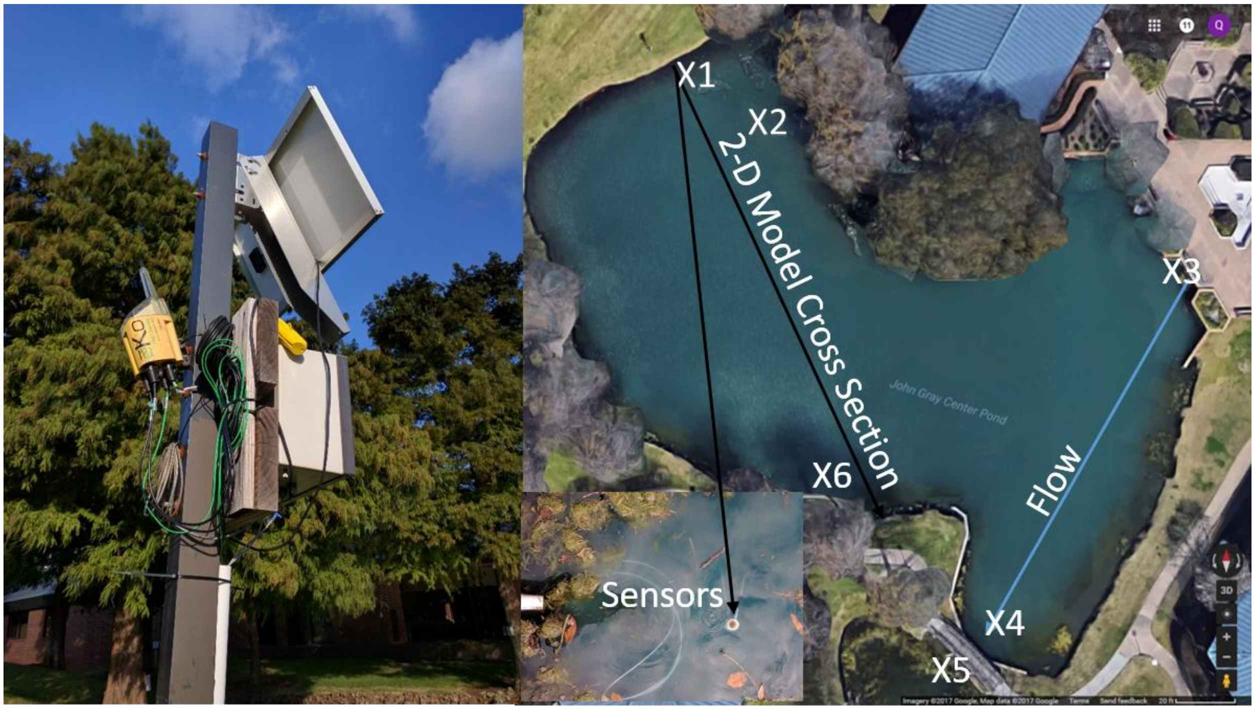
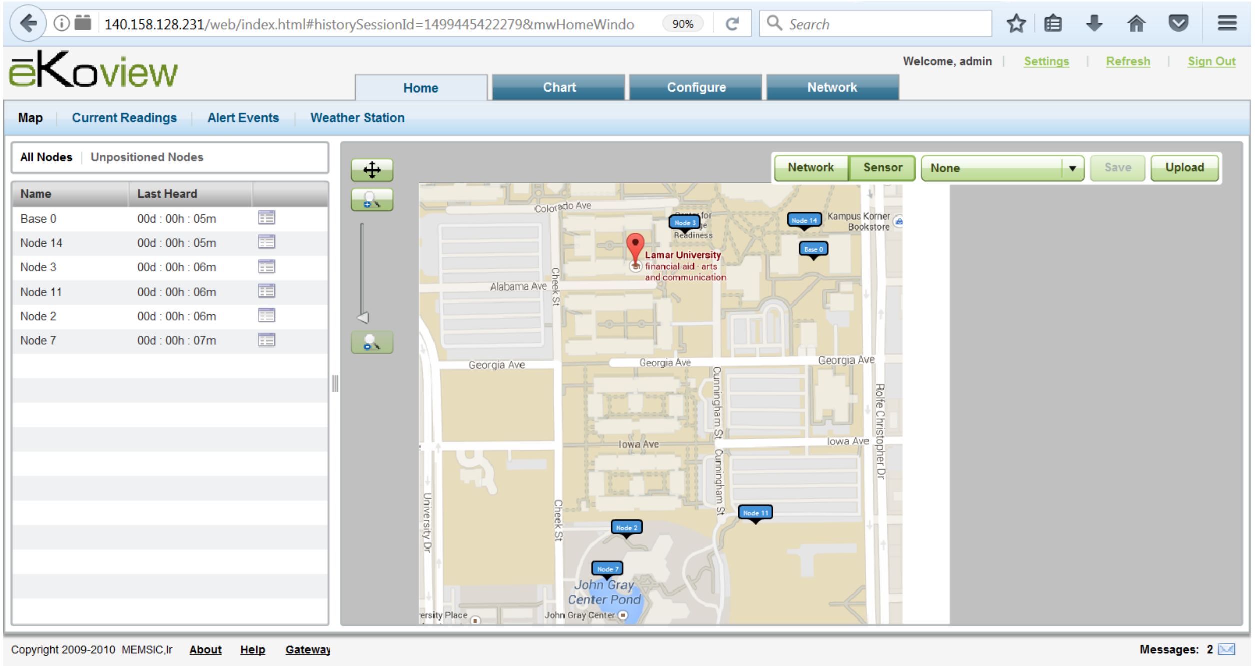


Figure 1: Close view of Wireless Sensor Networking (WSNs) and field measurement locations in the John Gray Pond.

WSNs system design and deployment

To utilize wireless communication technology for collection of water quality data, the main research effort is to connect third-party sensor probes to wireless communication infrastructure modules for transmitting collected data to a control station. Three WSN products, including STORM3, NI WSN, and eKo Pro were utilized with different third-party sensor probes. The WSN module of the STORM 3 system is very different from that of the NI WSN or the eKo Pro. It is solar powered and properly sealed with corrosion-resistant enclosures, which make it desirable for deployment at a field with unpredictable environmental condition. YSI provides a reliable data acquisition probe, which is calibration free (Sun et al. 2016). However, it is much more expensive compared to WSNs from others. WSNs from the NI and the eKo Pro have the similar network architecture. However, the communication range of the NI is not as strong as the eKo Pro (Sun et al. 2016). The eKo Pro wireless modules may self-organize to form a wireless mesh network. Each wireless module is solar powered, which can alleviate the power issues faced by the NI. It is straightforward to set up a multi-hop WSN utilizing the eKo Pro to the gateway. Each node can be used as a router to relay data for other nodes. Therefore, it is easy to use the eKo Pro for covering a wide area. An eK2120 has 4 sensor ports that can support 4 eKo compatible sensor probes. As shown in Figure 2, one eK2120 (Node 14) was deployed right next to the MAES building to improve reliability, the Base 0 was utilized to provide the connection between the eK2120 and the gateway, one eK2120 (Node 7) was deployed to monitor the sensor probe eS1101 – Soil Moisture and Temperature Sensors at the X1 in the pond (Figure 1), and additional three eK2120s (Node 11, 2, and 3) were utilized as relay nodes to relay data packets to the Base 0. Temperature data were collected and transmitted in multiple hops from Node 7 in the pond to the based station (Node 0 in Figure 2). Software eKoView was then installed on a laptop and provided a web browser based interface to visualize the deployed WSN. The eKoView makes it convenient for end users to manage, monitor, and access data anywhere and anytime with an internet connection. End users can also monitor the packet yield, network health, server health, etc.



Name	Last Heard
Base 0	00d : 00h : 05m
Node 14	00d : 00h : 05m
Node 3	00d : 00h : 06m
Node 11	00d : 00h : 06m
Node 2	00d : 00h : 06m
Node 7	00d : 00h : 07m

Figure 2: Deployment of eK2120 wireless modules for temperature measurement on campus.

Water quality model development

To understand the hydrodynamics in the pond, an Aquadopp Profiler from Nortek) was used to measure 3-D flow velocity fields on April 14, 2016 to determine currents due to inflow, outflow, and the wind. The wind with speed of 2.46 m/s (5.5 mile per hour) was measured by a portable handheld anemometer and direction of 149^0 was determined by the compass. Along the X3 to X4 in Figure 1, the flow velocity was less than 0.1 m/s at the water surface, and diminished to 0.05 m/s at 30 cm below and less than 0.005 m/s close to the sediment. The inflow only circulates in the very small area on the northeast side. Along the X1 to X6 in Figure 1, the surface wave velocity was around 0.06 m/s caused by wind and diminished to close to 0 m/s close to the sediment. Therefore, the main driving force to develop current is the wind over the main part of the pond. To fulfill the objectives and meet the available budget for data collection and analysis, a two-dimensional (x-z direction, x-wind direction) models was chosen.

To understand the thermal pollution and weak currents, the hydrodynamic and heat transport model is need to demonstrate flow field and the variation of temperature due to wind and solar radiation. A two-dimensional (2D) computation fluid dynamics (CFD) model was developed using a finite volume numerical solver in the ANSYS/Fluent software to simulate flow fields and water temperatures. The 2D Navier-Stokes equations and the equations for mass conservation and energy transport of a fluid need to be solved (Batchelor 1967). The mass, momentum and energy conservation equations can be written as follows:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}\, \rho(u_i) = S_m \tag{1}$$

where ρ is density, u_i represents the velocity components in different directions, and S_m is the source term. The symbols t and x_i are for time and coordinates.

$$\frac{\partial}{\partial t}\left(\rho u_j\right) + \frac{\partial}{\partial x_i}\left(\rho u_i u_j\right) = \rho g_j - \frac{\partial P}{\partial x_j} + \frac{\partial \tau_{ij}}{\partial x_i} + F_j \tag{2}$$

where P is the pressure and g_j is the component of the gravitational vector in the j^{th} direction. F_j is the source term and τ_{ij} is the symmetric stress tensor.

$$\frac{\partial}{\partial t}\left(\rho c_p T\right) \frac{\partial}{\partial x_i}\left(\rho c_p u_i T\right) = \frac{\partial}{\partial x_i}\left(\lambda_{eff}\, \frac{\partial T}{\partial x_i}\right) + \varphi + S_h \tag{3}$$

where T is temperature, c_p is the specific heat, φ is the viscous dissipation (related to the velocity gradients) and λ_{eff} is the effective heat conductivity. S_m and S_h are for any extra contributions or source terms for mass and energy, and in this study they were set to be zero because there was no mass and energy source inside the water body. The source term in the momentum equations, F_j, was zero in the horizontal direction because there is no extra body force in this direction. In the vertical direction, the buoyancy force is included. To consider the buoyancy effect on the circulation, density is taken as a function of temperature although it does not vary with the pressure. τ_{ij} is the symmetric stress tensor defined as:

$$\tau_{ij} = \mu\left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j} - \frac{2}{3}\,\delta_{ij}\,\frac{\partial u_k}{\partial x_k}\right) \tag{4}$$

Because the time-averaged Navier-Stokes equations cannot take into account the turbulence fluctuation directly, a turbulent model is needed. One of popular and robust turbulence models is the standard k-ε model (Launder and Spalding 1974). The k-ε model consists of two transport equations with two transport variables, turbulent kinetic energy (k) and turbulent dissipation (ϵ). The transport equations can be written as:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right] + P_k + P_b + S_k \tag{5}$$

$$\frac{\partial}{\partial t}(\rho \epsilon) + \frac{\partial}{\partial x_i}(\rho \epsilon u_i) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial \epsilon}{\partial x_i}\right] + C_{1\epsilon}\,\frac{\epsilon}{k}\left(P_k + C_{3\epsilon} P_b\right) - C_{2\epsilon}\,\rho\,\frac{\epsilon^2}{k} + S_\epsilon \tag{6}$$

where μ is the fluid viscosity and the turbulent viscosity μ_t can be given by,

$$\mu_t = \rho C_\mu \frac{k^2}{\epsilon} \tag{7}$$

The production of turbulent kinetic energy is taken into the term, P_k, and the buoyancy effect is included in the term, P_b.

$$P_b = \beta g_i \frac{\mu_t}{P_{r_t}} \frac{\partial T}{\partial x_i} \tag{8}$$

where P_{r_t} is the turbulent Prandtl number which is set to 0.85 (Batchelor 1967). β is the coefficient of thermal expansion and g_i is the component of the gravitational vector in the ith direction. The source terms S_k and S_ϵ can be set to zero if there is no additional effect included.

Note that the terms (S_k and S_ϵ) are designed to count any extra source, and therefore a fixed definition cannot be given. Other model constants are $C_{1\epsilon} = 1.44$, $C_{2\epsilon} = 1.92$, $C_\mu = 0.09$, $\sigma_k = 1.0$ and $\sigma_\epsilon = 1.3$ (Launder and Spalding 1974).

The average wind speed of 2.59 m/s (5.8 mph) with a direction of 149^o and the average daily solar radiation of 337 Langley/day were considered as the weather conditions in April and October to develop the 2D CFD model. The 2D plane was chosen to align with but opposite to the wind direction (X1 to X6) as shown in Figure 1. No flow boundary condition was applied on the side and bottom. A shear stress calculated from the wind and the average daytime solar radiation was applied as boundary condition on the water surface. A constant temperature of 20^oC was assigned as an initial condition based on the WSN's data in April and October.

Results and Discussion

Data Assessment on WSNs measurements

Water temperature data were collected by the deployed eKo Pro system starting on 09/29/2015 and by the STORM 3 system starting on 10/01/2015 at location X1 (Figure 1). As shown in Figure 3, temperature fluctuates with time as the eKo Pro system collects the instantaneous temperature value every 60 minutes. In Figure 3, some data losses were observed due to the harsh outdoor environment and inclement weather. For example, long rainy days from 16:00 pm Oct. 14 to 20:00 pm Oct. 21 led to insufficient charge of the solar cells in wireless sensor modules and bursts of packet losses as energy depleted. When solar cells became charged again, wireless modules could be turned on automatically, and self-organized and collaborated to form a new network for the packet transmission. In this process, no human efforts were required and the system could report the network health condition to remind the user. To compare the eKo Pro and STORM 3, the hourly average temperature was calculated with data collected by the eKo Pro system and plotted with the STORM3 data as shown in Figure 4. Differences between them are below 0.5 $^\circ$C, which demonstrates a good agreement between two systems. Therefore, the eKo Pro was capable to measure accurate water temperature and easy to set up with multiply hops to cover a relatively wider area although the deployed eKo Pro system was more fragile and needed constant effort to maintain. It can be considered as an alternative to replace the expensive STORM3 system in the field.

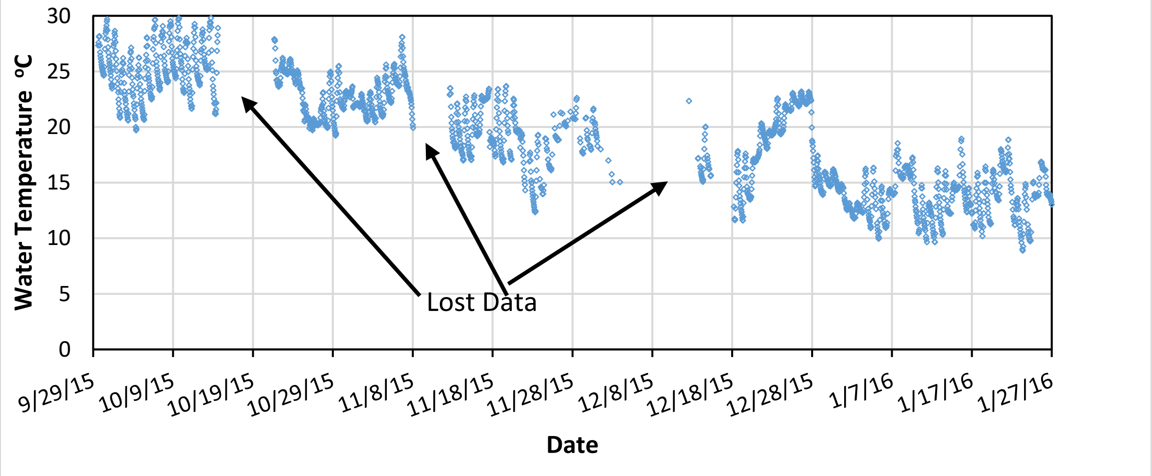


Figure 3: Water temperatures change over four months (September 29, 2015 to January 27, 2016) measured using the eKo Pro system.

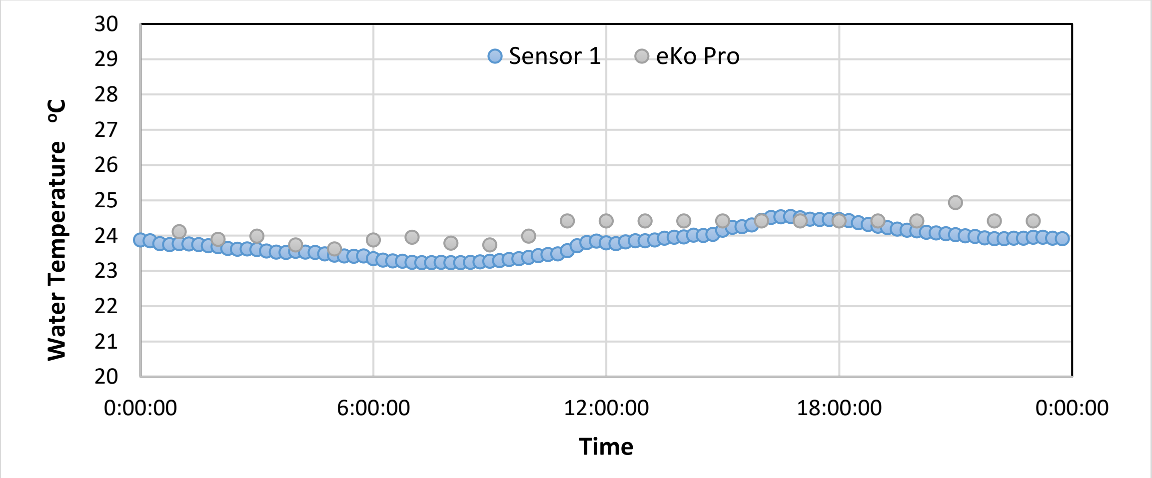


Figure 4: A daily temperature change in the pond on 10/22/2015 measured from eKo Pro and STORM3.

The 15-minute average water temperatures close to the water surface at sensor 1 and above the sediment at sensor, 2 by the STORM 3 were plotted in Figure 5. It is obvious that the temperature difference in Figure 5 were not the common thermal stratification as occurring in the summer, because such discrepancy has not been observed in the area with enough current mixing (X2) as indicated in Sun et al. (2016). Due to long residence times and large surface areas, significant solar energy absorption at the water surface only heats up the water surface and the limited current mixing at this location cannot transport the heat to deep-water layers to cause the thermal pollution. Such vertical temperature stratification may in turn to cause the vertical DO concentration distribution for eutrophication as observed from DO data measured by WSNs (Sun et al. 2016).

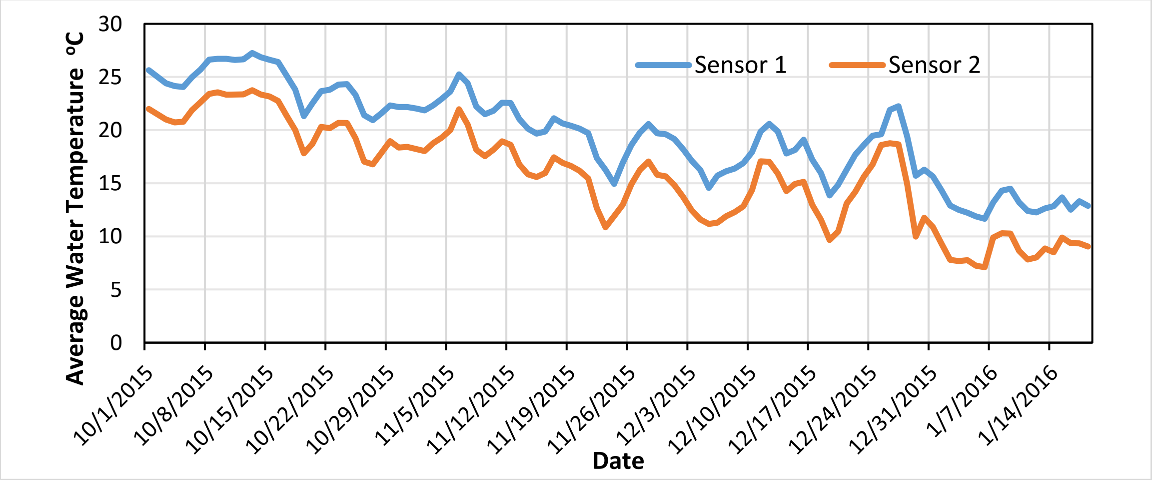


Figure 5: Average water temperatures change over four months (October 1, 2015 to January 26, 2016) measured by STORM 3.

Model results

The geometry of the 2D CFD model with a width of 52 m (171 ft) and a depth of 3.05 m (10 ft), and the mesh about 9000 cells were presented in Figure 6. A finer mesh was generated in the regions located close to the free water surface and the bank to capture the large gradient of velocity and temperature.

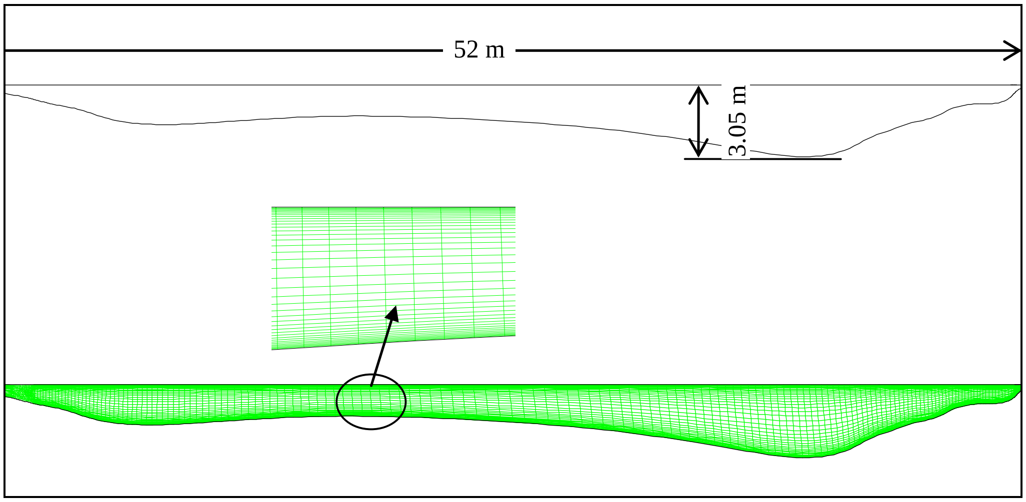


Figure 6: Geometry of the 2D modeling and its mesh

Figure 7 presents the temperature contour and streamlines 5 hours after the initial conditions were given. It can clearly be observed that the water temperature is layered due to buoyancy forces, which makes mixing in the vertical direction less effective. Streamlines show a complete flow pattern, although the maximum velocity in this case is only 0.06 m/s (Figure 8), which is consistent with the field flow measurement at a wind speed of 2.46 m/s (5.5 mph) on April 14, 2016. Note that the color of streamlines represents different values of the stream functions with a fixed interval. The streamlines are used to show the flow pattern and the value of the steam function itself is not important. The uncertainty of numerical results may come from different ways such as the physical modeling and meshing, and therefore there is not a procedure to evaluate it. By using different turbulence models with grid independence study, it is estimated that the uncertainty is less than 10%. Detailed distributions of temperature and flow velocity at the vertical direction 5 meters away from the X1 (Figure 1) is shown in Figure 8. This indicates the temperature difference of 6 °C along the depth, which is close to the WSNs' measurement as in Figure 5. The water flowing from right to left at the surface due to wind, diminished along the depth, and became left to right due to buoyance. In addition, the different wind speeds and solar radiations have applied to indicate that better mixing occurs with higher wind speed, while less mixing occurs with higher solar radiation, as expected.

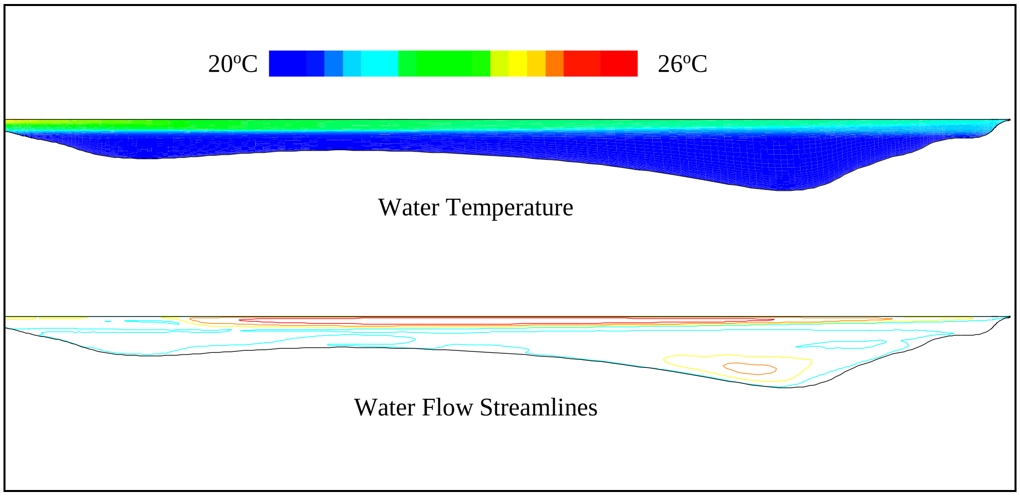


Figure 7: Temperature contour and streamlines derived from the 2D CFD modeling

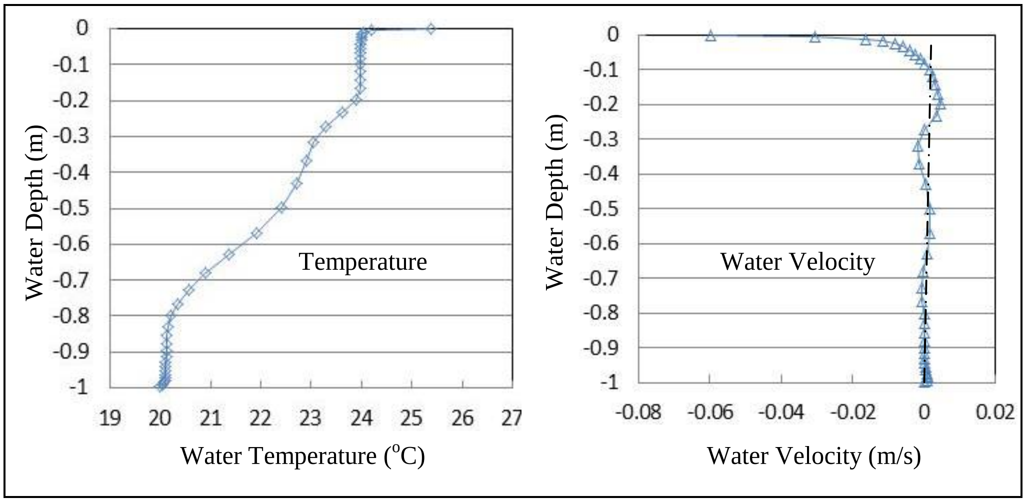


Figure 8: Distributions of temperature and velocity along the vertical direction 5 meters away from the left.

Evaluation on the possible engineering approaches

In summary, the eutrophication in the pond was caused by poor water currents and thermal pollution. To retrofit eutophication, the DO concentration variation in the pond is most likely the single important water quality factor in the pond (Sample et al. 2012). The possible engineering approaches include improving water circulation by a sump pump with flow routings, increasing DO with surface aerator, decreasing sediment load by installing a filtration tank, destroying algae with chemical solution, dredging and cleaning sediments, or their combinations (WEF&EWRI 2012; EPA833-B-09-001 2009). To avoid extra pollution from chemical solutions, only a sump pump with flow routing system, filtration tank, dredging and aerator were considered with decision matrix based on improving circulation and DO, decreasing turbidity, aesthetics and sustainability of design, equipment cost, construction time and cost, and operation and maintenance cost. A completed study has been conducted by a group of undergraduate students as a senior design project in 2016 and the final decision matrix table is attached in Appendix Table 2. The aerator from living water aeration (www.livingwateraeration.com) with 746 J/s (1 horsepower) floating fountain pump was recommend to satisfy the recirculation time of 2.17 day and 100% required DO. A surface aerator was installed close to the middle point of the 2-D model cross section (Figure 1) in summer 2016 to increase the circulation and DO concentration in the pond. The algae bloom did not occur in spring 2017. To evaluate the outcome of the aerator, the DO were measured on every Tuesday at noon from Sept 19 to Oct 9, 2017 with the YSI field DO sensor at the original six locations and two more locations close to the aerator. The range of DO was between 4.5 mg/L and 8.7 mg/L. It reached 100% saturation at the water surface and was lower under shade area at the X2 (6.0 mg/L to 7.1 mg/L). The DO at the bottom was between 4.5 mg/L to 5.6 mg/L. The higher DO was found in area with higher currents. The field DO measurements demonstrated that the aerator was a successful approach for enhancing the water quality caused by weak circulation and thermal pollution in the pond. Therefore, the hydrodynamic and water quality model can be considered in the retention pond design to understand the hydrodynamics and evaluate the possible water quality issue due to future hydrological change and/or sediment buildup. Another option to consider is to construct a vegetation buffer around the pond, which catches sediment from the runoff before it runs into the pond (EPA833-B-09-001 2009).

Conclusions

To collect the real-time and in-situ water quality monitoring data with deployment of wireless sensor networks (WSNs), three WSN systems including STORM 3 data loggers from YSI, eKo Pro Environmental Monitoring System from Memsic, and National Instruments (NI) were investigated in the experimental pond, Beaumont, TX, USA. The setup and maintenance of STORM 3 systems did not need much effort. The data collected from STORM 3 sensor probes were ready to use and accurate. However, it was much more expensive than the other WSNs. The eKo Pro could cover a relatively wider area and easy to set up. Their wireless modules were deployed at many locations for monitoring purposes. However, the deployed eKo Pro system was more fragile and required constant effort to maintain. The NI WSN system, much like the eKo Pro in terms of WSN architecture, is a popular WSN system for various research disciplines. Its wireless communication is very reliable. However, it is nontrivial to integrate third-party sensor probes to NI WSN systems and enable a multi-hop connection in the field, limiting its applications. The more practical solution to monitor water quality data with WSNs was to combine the eKo Pro with the STORM3 in the field. The eKo Pro provided water quality monitoring data at fine temporal and spatial granularities for a large area, and the STORM3 provided accurate water monitoring data at one location with the same fine temporal granularity as the eKo Pro. Such systems have been successfully installed in the 1000 m long river reach upstream of the Salt Water Barrier on Neches River, Beaumont, Texas, USA. One STORM3 system located in the front of the barrier has collected the water quality data including conductivity/temperature, dissolved oxygen, turbidity, total algae, pH, and water depth. The eKo Pro has been installed to collect accurate temperature data at 20 locations on both sides along the reach since March 3, 2016. The data from both systems assist our ongoing efforts on the non-point source assessment from runoff.

The real-time in-situ water temperature and dissolved oxygen data collected by the deployment of WSNs demonstrated that the thermal pollution and anaerobic conditions cause eutrophication in the pond. A topographical surveying of the bathymetric data has been conducted and 48 water samples have been collected to measure suspended solids concentrations, total dissolved solids, phosphorus, BOD to evaluate water quality. The Secchi depth (SD) and the 3-D flow velocity field in the pond at the different locations and depths with the Aquadopp Profiler from Nortek were also measured. A two-dimensional CFD model was developed using finite volume numerical solver in ANSYS/Fluent to simulate the flow field and water temperature variation affected by wind and solar radiation. Results indicated that the thermal pollution and anaerobic condition along shoreline due to weak circulation were the main causes of the lower T and DO at the bottom of the pond, and an engineering approach to increase circulation was needed to improve DO concentration. After evaluation of different possible approaches, a surface aerator was installed in summer 2016 and the notable water quality improvement was reported. The study demonstrated a decision making with WSNs' measurements and model developments, and provided a better practice tool for water resource management in retention pond.

Appendix

Table 1: Water sample results

	X1	X2	X3	X4	X5	X6

	mean	stedv	mean	stedv	mean	stedv	mean	stedv	mean	stedv	mean	stedv
DO at surface (mg/L)	9.40	0.50	9.26	0.7	8.86	0.89	10.85	1.31	10.36	1.3	11.28	1.3
DO at bottom (mg/L)	2.28	0.34	2.62	0.42	7.72	0.69	8.01	1.21	8.21	1.3	3.63	0.65
pH	7.64	0.65	7.75	0.61	7.21	0.45	8	0.67	8.13	0.74	8.06	0.45
Temp (^{o}C)	18.63	4.48	18.58	4.2	18.88	3.84	18.45	3.97	18.35	4.05	18.1	4.58
COD(mg/L)	43.15	3.42	46.2	4.32	52.75	14.73	45.43	6.16	43.08	2.81	48.13	7.49
Ammonia (mg/L)	0.02	0.01	0.03	0.01	0.04	0.02	0.02	0.01	0.02	0.01	0.04	0.03
Nitrogen (mg/L)	1.1	0	1.3	0.00	<1	0.00	1.22	0.08	1.51	0.5	1.5	0.26
Phosphorus (mg/L)	0.08	0.03	<0.05	0.00	0.23	0.19	0.05	0	0.08	0	0.07	0.02
TSS (mg/L)	14.00	5.83	7.25	4.99	10.75	3.3	12.25	5.85	9	2.94	12.5	5.45
VSS (mg/L)	7.75	2.22	5.75	0.96	4	1.41	4.75	4.5	6.75	0.96	7.25	2.63
VSS/TSS	0.58	0.11	0.64	0.20	0.38	0.12	0.37	0.25	0.87	0.5	0.64	0.23
BOD_5 (mg/L)	3.65	0.95	2.57	1.48	4.11	1.88	3.87	1.13	4.33	0.72	3.74	1.33
BOD_5/COD	9%	0.03	6%	0.03	8%	0.06	9%	0.03	10%	0.02	8%	0.03
Alkalinity (mg/L as $CaCO_3$)	116.00	10.97	116	11.24	125.30	14.22	127	17.93	127	16.17	119	10.44

Table 2: Decision matrix

Decision Matrix of Approaches	**Decision Matrix Parameters**										**Total Score**
	Pond Parameters					**Construction & Operation**					
	Stagnation	Turbidity	Oxygen Demand	Aesthetics	Sustainability	System Equipment Cost	Build Time	Construction & Labor Cost	Operational Requirements	Maintenance Cost	
Adjustment factor (f)	2	1.5	1.5	1.25	1.25	1.25	1.25	1	1	1	
Flow Routing	1	3	4	4	4	1	2	3	4	1	34.25
Aeration	3	3	1	1	1	5	1	1	1	2	26
Filtration	3	1	4	2	1	4	3	3	3	4	36
Dredging	4	4	2	2	4	0	5	5	0	0	35.75

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Anaerobic Digestion of Agricultural Waste

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Abstract

Agricultural waste is one of the industrial waste, in the form of liquid or solid which are produced by agricultural practices, such as, pesticides, fertilizers, crop residue and cattle manure. The present study is focused on turning the agricultural waste into renewable energy resources through Anaerobic Digestion technology (AD). AD is one of the promising technology, which converts these agricultural waste into renewable energy as biogas that containing methane-rich mix gas and digestate as a fertilizer. In this study, basic principles and advancement in AD, types of reactors, operating parameters, merits and demerits of AD are reviewed. Operating parameters such as pH, Hydraulic Retention Time (HRT), temperature, C/N ratio, loading rate, substrate, F/I ratio, TS and ammonia concentration that are involved in biogas production is also analyzed. Direct comparison on the application of hybrid anaerobic digester (wet/ dry; single/multistage) is done at various types of agricultural wastes such as crop wastes, fruits and vegetable wastes, food processing residues and manure digestion.

Keywords: Agricultural Waste; Anaerobic Digestion; Biogas; Methane; Hybrid Reactors; Optimization.

Introduction

Agricultural activities done industrially or locally produce some left over in which case it is treated as waste. Different agricultural set ups produce different kinds of wastes in their day to day activities. These unused left over from agricultural plants may be in the form of solid waste as well as liquid waste. Solid waste may come in the form of plant residue that is not mainly utilized by farmers for example maize stalks while things like insecticides as well as manure are treated as liquid waste (Durán-Escribano & Cuadrado-Esclapez, 2017).

In modern times agricultural waste has been growing concern since such waste has the ability to create substantial environmental hitches. On the other hand, agricultural waste has numerous benefits to people as a source of energy (Zhang et al., 2012). In the Asian region, countries like India enjoy enormous prosperity in livestock and have an increasing rate of about 6% every year. Effective exploitation of waste products brings a direct impression on the economy as well as matters of ecological conservation in the country. Whenever there is underutilization of waste products, prospective income is lost as well as a swelling budget of discarding the waste products.

In many developed countries, swine droppings create the main fragment of animal agricultural waste. Developing countries on the other hand, rely mainly on cattle waste as a major source of their agricultural waste (Robinson et al., 2014). Anaerobic digesters can convert these waste products into biogas as renewable energy.

Of the methane that is available in the thermosphere, more than half of it is produced by Agricultural waste. Through anaerobic digestion agricultural waste is converted into renewable sources of energy. Anaerobic Digestion produces at the bare minimum, 50% of Methane while the remaining solid deposits are used as manure and composts that are highly rich in nutrients.

Anaerobic digestion is a very capable valorization tool since it has the ability to transform nearly all sources of biomass to energy, anaerobic digestion has the capacity of converting different kinds of organic waste into energy, biogas is made out of such waste that would otherwise be misused (Madsen et al., 2011).

Basic Principles and Advancement in AD

Co-digestion which also means anaerobic digestion is a very operational and amazing practice in the reutilization of agricultural waste. Most agricultural waste has extraordinary levels of decomposable constituents.

Placing both aerobic and anaerobic digestion back to back, the later saves enough energy that will be required for the ventilation procedure. Aerobic digestion has proved to produce way less mud that is about 50 times less and in return makes biogas that is rich in energy which contains at the very least 50% of methane gas.

Three major steps are involved in the digestion of anaerobic matter. Archaea bacterial class and bacteria are the major players in the entire process of degradation.

The first step involves the breakdown of hydrolytic bacteria breaking down polymeric carbon-based matter into monomers; best example is that of amino acids and sugars. Going down further, the second step in this degradation process involves the breaking down of monomers created in the first step into volatile fatty acids; best example is acetate. The third and final stage of bio-degradation involves the breakdown of acetic acid and hydrogen to gas such as methane and carbon dioxide. The bacteria involved in this chemical reaction are mainly, acetotrophs, methylotrophs and hydrogenotrophs.

Anaerobic reactions that lead to conversion of biomass and degradation can as well be sub-divided into four different phases. These four phases are sequential hydrolysis, acidogenesis, acetogenesis, and methanogenesis.

Operating Parameters of Aerobic Digesters

For the production of biogas, a number of parameters need to be in play for optimal biodegradation. Factors like, temperature, PH, the rate of loading, substrate, hydraulic retention time (HRT), mixing and C/N ratio are the most basic parameters' to ensure any biodegradable waste is digested properly. There need to be specific optimal environmental conditions to ensure complete degradation (Serna et al., 2016).

Bio-degradation in itself is a very slow process which in optimal conditions may take up to three weeks for the microbes to adjust to different budding conditions due to changes in substrate composition as well as the new temperature levels (Serna et al., 2016).

The most important parameter of them all is temperature. Any changes in temperature are recorded and affect the changes in the bio-digestion process in the affirmative. The most sensitive bacteria involved in bio-degradation process like the methanogens bacteria are quite sensitive to any thermal changes.

Studies have proven that enormous proportions of NaOH have been quite in the lead in the maintenance of the right PH value of the influent digester to the tune of 6.8 averagely. A daily average consumption of 42Kg of the NaOH which translates to (0.105 m3 .d-1 of 30.5% NaOH water solution) is used in the digester. The abnormal consumption of NaOH is directly proportional to temperatures in the digester. This means that for as long there are low temperatures in the digester, there will be need of immense supply of NaOH. A drop is registered in the rates of production of biogas every time there is a decrease in temperature. Bacterial activity in the digester largely depends on favorable temperature for multiplication and activity Kumar et al., 2017).

The pH values of the digester are dependent on the fermentation process. The rate at which fermentation takes place during anaerobic digestion will create variance and changes in the pH values of the digester. The rate at which intermediates are formed throughout the fermentation procedure creates the pH scale of the digester. The sensitivity of this aerobic fermentation is dependent totally on the PH scale of the digester. For a good digester to function properly a PH scale that ranges from 6.8 to 7.2 should be maintained for the reasons of converting those fatty acids to carbon dioxide gas and methane (Saikaew, Kaewsarn & Saikaew, 2009).

C/N Ratio and F/I Ratio

The optimal conditions for microbial digestions and breakdown of biomass in aqueous conditions rely on the co-operation of the most important microbial community. That kind of cooperation will ensure the optimization of the PH in the digest and thus will increase performance in double fold (Wu et al., 2020).

Keeping a relatively appropriate carbon to nitrogen ratio is very vital for good ecological digestion. A C/N value that is not below 25/1 is recommended for optimum production gas Animal waste, especially cow dung averagely has a C/N ratio of close to 24.0. Botanical constituents for example straw from cereals and sawdust have a relatively advanced amount of carbon. Constituents that have high C/N ratio can be mixed with those of low C/N ratio constituents (Belhamdi et al., 2016).

The composition of feed material affect the yield of biogas produced in the eventuality. Biomass comprising of protein, fat and carbohydrates yield better biogas since its biochemical composition are pro methane. This is illustrated in the equations below:

Carbohydrates:

$(CH_2O)_n \rightarrow 0.5\, n\, CH_4 + 0.5\, n\, CO_2$, $Y_{CH_4} = 0.37\ Nm^3 .kg^{-1}$Sugar

Proteins:

$C_{3.12}H_{4.94}ON_{0.82}S_{0.03} + 2\, H_2O \rightarrow 1.61\, CH_4 + 1.51\, CO_2 + 0.82\, NH_3 + 0.03\, H_2S$; $Y_{CH_4} = 0.51\ Nm^3 .kg^{-1}$ protein

Lipids:

$5.62\, CH_4 + 2.38\, CO_2$; $Y_{CH_4} = 1\ Nm^3 .kg^{-1}$ fat (eq.3)

Biomass:

C5H9O2.5NS0.025 + 2.26 H2O → 2.62 CH4 + 2.38 CO2 + NH3 + 0.025 H2S ; YCH4 = 0.48 Nm3 .kg-1 VS

Therefore; the general formular to be used is;
C1HaObNc+(1-0.25a-0.5b+0.75c)H20→ (0.5+0.125a-0.25b+0.75c)CO2+(0.5+0.125a-0.25b+0.75c)CH4 + cNH3
CcHhOoNnSs + 1/4 (4c - h -2o + 3n + 2s)H2O → 1/8(4c – h -2o - 3n - 2s)CO2 + 1/8(4c - h -2o - 3n - 2s)CH4 + nNH3 + sH2S (Dai et al., 2018).

The CH4 can be predicted from calculating the ratio of substrate used with biological compounds that are not known the chemical oxygen demand (COD) and total organic carbon (TOC); the following equation demonstrates the calculations.
CH4 in % = 18.75 COD/TOC (Dai et al., 2018).
The complexities in bacterial trails are a serious merit when compared to any other form of biological fuel creation. The complexities here in the conversion of energy improve the outcome of biogas to biomass (Dai et al., 2018).

Loading Rate and Substrate

The content of water in the substrate is supposed to constitute close to 90% of the total weight of the substrate. The raw materials used affect the amount of water to be used in the decomposition process. In the case of freshly collected cow dung, then the amount of water that should be used in the substrate shall be in the ratio of one unit each just (1/1, water /dung). These volumes of mixture should be prepared beforehand.

The organic loading rate (OLR) is well-defined by the volume of the content fed to the digester every single day in terms of the quantity of unstable solids or chemical oxygen demand (COD). In the case of dairy manure, there is need to fill in a solid concentration of up to 15.2% for reasons of gaining the maximum harvests in gas production. On the other hand, in the case of freshly collected dairy fertilizer, a range of 13.0% to 15.0% of solid biomass will be substancial in yielding high gas (Meng et al.,2017).

Crops Waste Digestion

Inedible parts of crops such as waste from vegetables as well as leaves, maize straws and wheat straws make very important part of biomass. The potential of these crop wastes in anaerobic digestion can produce quite impressive yields of gas. The composition of plant biomass is mainly linear polysaccharide polymer of glucose (~ 1.4-glucan). These polysaccharides contain more sugars compared to glucose molecules. There are about 7,000-15,000 glucose molecules per polymer seen in cellulose as compared to Hemicellulose that have about 3,000-5000 glucose molecules (Zang et al.,2018).

Fruits and Vegetables

The characteristic of waste biomass digested from vegetable and fruit waste is always filled with moisture content of over 80%. Their organic compositions are valued at over 95% of unstable molecules and are easily biodegraded. These characteristics match the amount of yield that comes from their composition. Aerobic digestion of such material degrades very fast and can be digested along other biomass (Plazzotta et al., 2017).

Biomass from waste vegetable cannot be used solely in decomposition to create gas, there is need for other matching compositions that will create supplementation of elements in the digester and create a balanced biochemical reaction

Food Processing Residues

Industries that operate in food processing make a very good source of biomass richly concentrated with so much sugars, oils as well as greases, proteins and water. The biomass effluent from such places has a great combination in terms of their biochemical composition and can make very good yields in terms of biogas. The type of lipids that are found in food waste is consisting of mainly triacylglycerides as well as long-chain fatty acids.

This kind of fatty acids can be converted through the process of hydrolysis and broken down by extracellular lipases to glycerol. The glycerol is then broken down to acetate by the acidogenesis progression while LCVFA are consecutively broken down through ß-oxidation pathway to acetate and hydrogen, which eventually are transformed to methane gas (Kovshov & Skamyin, 2017).

Manure Digestion

Organic components that are present in human waste (feaces plus urine) added together with pieces of straw that is used in making material for bedding when put together in decomposing condition can yield good amounts of methane gas (Kovshov & Skamyin, 2017).

Conclusions

In conclusion, the best option to make easy the management of waste products and to as well to cut the costs that are related to the production of biogas is to do a replacement of all the dedicated crops with the waste from vegetables. The most prospective yield of biogas from biological waste can be assessed with a number of parameters and conditions to ensure that you harvest the most from your combination.

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Methane Gas Production from Animal Waste

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Abstract

Recent energy scarcity has led to the fact that total dependency on energy generated from fossil fuels may not turned out to be an effective policy for a longer run. Methane production using the waste from animals has become an economically viable process for animal production procedures on intermediate to large scale. Expansion and development of the livestock industry has not yet introduced options for proper dumping of the waste generated in surplus quantity at poultry, dairy farms, and swine. Pollutants generated out of irregular livestock waste destroys the environment and contribute to global environment change. Interest in conversion of this waste into useful gas mainly methane has aroused. In this paper we will discuss few currently present opportunities for producing methane gas from the waste of animal and its contribution for the betterment of environmental quality and sustainability.

Keywords: Methane gas, pollution prevention, sustainability, environmental quality, Animal waste.

Introduction

The progression in the economy of the world, the uninterrupted progress of human requirements, and technological and industrial development have contributed to amplified demand for the intake of fossil fuels and energy. Since fossil fuel resources are depleting, there is a high demand for the evolution of the economy to attain Sustainable Development, endorsed by the predominant management of waste, restricting consumption of non-renewable energy resources, plus the enhanced production of renewable energy. This research for finding new resources of sustainable energy has resulted in due to the never-ending demand for energy by the human population for growth, as well as depletion of non-renewable energy resources. Furthermore, the enhanced intake of fossil fuels is considered to be the key reason contributing to air pollution and global warming. Consequently, the intake of waste for the production of energy resources such as biogas production is one of the best alternatives to meet the global need for energy intake. Biogas, among different types of renewable energy alternatives, is favored since it can be easily produced and directly utilized in numerous applications such as fuel cells, micro-turbines, fuels, and in combustion generators for electricity, etc. Since the solid by-product produced as a result of the digestion process, the production of biogas is always preferred and can be used as an organic substrate or fertilizer in the cultivation of a greenhouse. This society is mainly concerned with the implications generated by the production and intake of fossil fuels on our environment (Khalil et al., 2019), such as global warming and the enhanced use of fossil-based fuels plus, recognizing options to find replacements in form of renewable resources, the decline in the intake of energy, limiting carbon emission, recycling of waste, and use of the field of biotechnology. Millions of tons of animal waste are produced annually, and its disposal has turned out to be a global issue.

Biogas is considered as an eco-friendly source of energy. Composition of biogas include almost 60% of methane and 35 to 40% carbon dioxide. Small portion of different gases including hydrogen (H), nitrogen(N_2), oxygen (O_2), carbon monoxide (CO), sulfide (H_2S), and ammonia (NH_3) is also contained in biogas. Biogas is usually evolved in a process called as anaerobic digestion (AD). In this process organic compounds are degraded by bacteria into simpler substances in the absence of oxygen and biogas is then released as syntropy. It is basically a biological phenomenon used for transforming waste into various useful energy resources including food waste, sewage waste, municipal waste, agriculture waste and animal waste. However, our prime concern is the treatment of animal waste for the production methane gas. Treatment of animal waste produces a biogas which is comprised of significant portion of methane gas. From this biogas useful product methane is extracted to use for plenty of purposes. Anaerobic digestion not only produces useful product but also advantageous for reducing several problems including release of odor. The waste then treated can also be used as an organic fertilizer in a place of mineral fertilizers for agriculture purposes as well as for cultivating greenhouse.

An anaerobic digester with a bio gas plant converts large proportion of animal waste in to methane gas and it is an extremely reliable technology and resulting products can be use directly as an energy resource (Esfandiari et al., 2011). According to an estimate animal waste adds approximately 240 million metric tons of methane-equivalent carbon dioxide to the environment and biggest representor of methane anthropogenic resources. Considering the fact that methane is second largest global warming contributor after CO_2, it is a need of hour to finds ways to seize anthropogenic methane as much as possible. The major advantage associated with the capturing of methane is that it is utilize as energy source which in terms of cleanness is equivalent to natural gas.

Methane Generation Process

If waste of animal is not collected and processed properly in a gas generation system methane will naturally produce and release in to the atmosphere which ultimately can impact environment in various ways (Abdeshahian et al., 2016). Waste of animal consist of large amount of organic matter. If this waste is processed under controlled condition in an anaerobic digestion it has potential of producing significant amount of methane gas. The anaerobic digestion process is used significantly for the stabilization of sludge and treatment of domestic waste. Converting animal manure to biogas mainly methane via anaerobic digestion enhance the value of waste as a source of energy and significantly reduces the environmental impacts concerned with animal manure. This process is mainly applied in countries having warm climate for producing methane gas as a source of energy, though economic and technical feasibility to produce methane gas in colder regions through anaerobic digestion is still not established. The idea of producing methane gas from animal waste and heaps has substantial scope because it offers solution of two most demanding problems: the shortage of energy and the resource conservation (Tauseef et al., 2013).

Waste from animals usually contain organic (volatile) solids which includes carbohydrates, fats, proteins, and nutrients which are available as energy and food for reproduction and the growth of bacteria in anaerobic digestion. Production of methane is achieved by the biological oxidation of plant refuse and animal waste (organic substances) in the absence of oxygen (anaerobic digestion).

The process of anaerobic digestion occurs mainly in two steps. Initially, volatile solids present in waste is broken down in fatty acids. This stage is also called as "acid-forming" stage and this step is carried out by particular type of bacteria knowns as acid formers. Then in the next step acids are converted into carbon dioxide and methane by a specialized class of bacteria known as "methane formers". Methane formers as compared to acid formers are more adaptative towards environment and the process of anaerobic digestion depends mostly on methane formers. Methane forming bacteria are anaerobes and oxygen is strictly prohibited in their region. Such bacteria function best at temperature 95^oF so in order to achieve maximum production of gas, heat must be supplied to an anaerobic digestor. The growth of methane forming bacteria is relatively slower than acid-bacteria and work at optimum pH of 6.7-7.5 (pH sensitive) (Fulhage, et al., 2018). Providing sufficient amount of in a digester can enhance the growth of acid formers which in turn produces volatile acids in excess amount. This growth will inhibit the methane forming bacteria, lower pH, and stops the production of gas. In order to prohibit the increase of acid growth alkalinity should be high. Further to maintain the control of pH lime is added in the digestor during initial stages. Following materials are also proven toxic for proper working of anaerobic bacteria: heavy metals, salts, antibiotics, and ammonia. Minimum amount of salt is required for the optimum growth of bacteria. But if salts are accumulated above requirement then it can inhibit anaerobic digestion. Heavy metals such as nickel, zinc, copper can also prove toxic for digester. Though mostly heavy metals precipitate out along with sulfides causing no damage to the sludge still special attention should be given to the animal waste containing heavy metals. The gas then produced is biogas which is a composition of methane gas, carbon dioxide and other trace gases. There exist two distance ranges of temperature; the cryophilic range and the mesophilic range. The temperature of cryophilic range 120-140^oF is and mesophilic range is 90-110^oF. In both temperature ranges bacteria produces large quantities of methane gas. The successful operation of anaerobic digestion depends on the control of following factors; loading rate, temperature, retention times, concentration of volatile acids, pH, alkalinity, concentration of total solids, extent of mixing, and nutrient balance.

Biogas produce in a digester is 60-70% methane, 30-40% carbon dioxide, and contain small quantity of Hydrogen Sulphide, and other trace gases (ammonia, nitrogen oxide, hydrogen). Methane produce in a digester is also called as "permanent gas" as it doesn't liquify when pressure is applied at normal temperatures. This poses a specific storage challenge, especially when use in power units of mobile. For effective utilization and production of methane gas standard methods and procedures must be installed for purification, handling, and storage of methane gas.

Safety measures must also be taken during utilization and production as methane gas is an explosive gas when it contacts with air in a ratio of between 5% to 15%. Most animal wastes (particularly poultry or swine) contain considerable quantities of nitrogen gas. This nitrogen gas is converted into ammonia gas in the anaerobic digester. If this ammonia is not mange on time, it will accrue in the tank and become toxic. Toxicity of ammonia is a major issue in an anaerobic digestion process. This problem can be solved by effectively controlling the loading rates in the digester (Abouelenien et al., 2014).

Economic, Social, and Environmental Benefits

There are plenty of social, economic, and environmental benefits concerned with producing of methane gas from animal waste. Methane production by treating the waste of animal is an effective way to meet the energy challenges of the world. Since methane gas is generated locally and across national boundaries, its usage significantly reduces local communities' dependency on the fuels imported from other countries and significantly increases the supply of energy locally. Further it reduces the quantity of waste produce in environment and cost used to disposed off this waste. Using and producing methane gas from animal waste helps in achieving following three important target: renewable production of energy from resources, sustainable management of waste, and reduction in Greenhouse gas emissions. Very low amount of water is used in an anaerobic digester which is reminiscent of water scarcity in the world. To transport and collect raw materials for the production of biogas and to construct, operate, maintain, and manufacture equipment for biogas plant require a lot of staff which ultimately opens the job opportunities in the area. Anaerobic digestion is an enclosed phenomena and there are no chances of emission of any toxic chemical to the environment which can affect weather or air and effluents form in the biogas digester are stable. In addition, odor produce during the process is controlled as all the gasses present in the tank are burned before releasing.

Procedures of Anaerobic digestion contribute to source power reduction by transforming organic substances to carbon dioxide, methane, and minute quantities of microbial biomass; weed seedlings and pathogens are annihilated; and the smell is reduced. The total amount of phosphorus, nitrogen, and other minerals remain unaffected; therefore, waste from a digester should be reserved in a pond and utilized for irrigation purposes and as reprocessed flush water. The probable nonpoint source pollution resulted in due to heavy rain is reduced since the influent to the pond would have undergone a complete process of digestion. There is almost no net production of Greenhouse fumes which is another environmental advantage of employing biogas as a supplier of energy (Molino et al., 2013). The amount of carbon dioxide discharged off during the combustion of biogas was an organic plant originally and therefore, is completing a round from the atmosphere to plant materials to animals and then back to the atmosphere. Methane gas has turned out to be a more harmful gas as compared to carbon dioxide and the confinement of biogas as a fuel resource inhibits the discharge of methane directly into the atmosphere. Anaerobic inlet treatment of fluid effluents and ground application of solids discharges a significant quantity of methane gas into the atmosphere. The confinement of methane gas to be used as a fuel would substantially decline the net release of greenhouse gases resulting from waste, debris and heaps of animals.

Utilization of Methane Gas Produce from Animal Waste

Methane gas produce from animal manure either upgraded or raw cab be used for various purposes.it can be applied directly in various heating systems and industries to save the consumption of oil and natural gas as a valuable and exportable resource of fossil fuel which can help in reducing air pollution. Many countries use methane gas for lightening and cooking. To utilize this gas, it has to be drained, dried, and cooled and it should be free from Hydrogen Sulphide (H_2S) content. High level of H_2S for instance 300–500 ppm can damage the technique of energy conversion (Holm-Nielsen et al., 2004). Now a days biological cleaning can reduce Hydrogen Sulphide content to level 100ppm or below.

Various applications of methane are as follows:

- For producing heat or steam
- Production of electricity along with the production of power and heat
- Upgradation to use as a fuel for vehicles
- Source of energy in industries for heating, cooling, electricity, and steam
- For producing proteins and various chemicals
- Utilization as fuel for several fuel cells
- Injection and upgraded in the grids of natural gas

The demand of production of methane from animal waste is rising exponentially. A noteworthy example of the production of methane and the usage of methane for fuel of vehicles is in Sweden. In Sweden currently more than15,000 vehicles are working on methane gas modified from biogas (Persson et al., 2006).

Further treating waste of animal by anaerobic digestion technology can contribute potentially to the production of enormous quantities of renewable energy. Additionally, organic matters treated can also be used as fertilizers and biochemicals in agriculture purposes for crop cultivation. It is estimated that the production of methane gas will have greater influence on the water, agricultural, electrical and soil sectors in future because the demand of management and utilization of animal waste for promoting the use of sustainable energy is increasing (Esfandiari et al., 2011).

Methane Gas– Flexible and Reliable, Renewable Source of Energy

Methane gas penetration on market of energy will accelerate probably, as market and economics acceptability problems are resolved. There are so many advantages of methane production as compared to the other renewable alternatives of energy. Firstly, methane gas can be produced any time depending upon the need and can be stored for future uses. Secondly, it is easy to distribute the gas from the existing infrastructure of natural gas and can be used in many applications in place of natural gas. Thirdly, apart from using methane gas in heat and energy production it can be utilize in a place of fossil fuels in transport sector thus decreasing the dependency on fossil fuels. Managing cost and reducing cost are the upcoming targets for yielding large quantities of biogas in future. Online measurements have been defined in this regard for effectively and carefully monitoring the process to optimize the yield of gas.

The development of biogas in future from waste include the use of feedstock of new type such as bio-slurries resulting from biofuel industries, by-products resulting from food industries, and pharmaceutical industries.

Conclusions

Animal waste is the chief contributor of greenhouse gases (GHG) and the anthropogenic sources that causes global warming. Livestock manure is one of the biggest contributors among the anthropogenic sources of the global warming. It is expected that quantity of waste to be handle will increase sharply in the upcoming years. This critical situation, besides high value of methane fuel, require an urgent action globally to discover means and ways for capturing methane derived from waste to use it as a source of energy. The scope of production of methane from animal waste and slurries by process of anaerobic digestion is huge in many countries. Anaerobic digestion process offers so many agricultural, social, economic, and environmental benefits, significant odor reduction, inactivation of number of pathogens, and most important biogas production (mainly methane), as renewable and clean energy source, for utilizing in multiple purposes. Important initiatives have been taken for maturing biogas treatment technologies to enhance economic stability. In this report we demonstrated that treating animal waste is a low-cot, promising and sustainable source of energy and can be utilize efficiently for generating electric power and methane gas. Furthermore, treating waste through anaerobic digestion can reduce the detrimental effects of waste on the environment and enhance the health of public.

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Treatment of Timber Industry Wastes

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Abstract

This paper discussed two stages in the treatment of wood waste in the timber industry, sorting of wood waste and afterward recycling and disposal. The recycling of treated wood waste could include an arranging cycle to isolate treated lumber from untreated wood. A recycling/disposal technology that can cycle both treated and untreated timber would be utilized. Technologies such as PAN stain formulation and X-Ray fluorescence(XRF) are techniques that can be utilized to figure out which sort of treatment has been utilized on the wood. Untreated wood has many recycling choices, and because it has no chemical preservatives, it requires no special processes to prepare for use in other applications. Potential choices incorporate reuse, fiberboard, chipboard, compost, energy/heat recovery, and use in cement kilns. Thermal treatment encompasses incineration, gasification, and pyrolysis. This paper covers a review of research conducted in the treatment of timber industry wastes.

Keywords: PPAN stain formulation, X-Ray fluorescence(XRF), Incineration, Gasification, Pyrolysis, Timber industry wastes

Introduction

The stages to the treatment of wood waste include first sorting of wood waste to recycling and disposal. Before sorting, wood waste is first collected from different sources. One being from household waste recycling centers or through the council's massive waste collection; comprises furniture. After sorting untreated wood waste material, it is then classified based on its quality (Faraca, Boldrin, & Astrup, 2019).

Sorting is based on its different grades; Grade A, goes to sophisticated value markets, for example, animal bedding and panel products. Grade B, its application can be in panel products. Grade C and D can be used in incinerators with grade D termed as hazardous and suitable for landfill. Sorting wood waste in its various grades is a straightforward process and cannot be performed by all producers. The PAS111:2012' is a requirement for producers to take part in the grading of wood waste (Faraca, Boldrin, & Astrup, 2019).

Wood waste treatment is also referred to as recycling, waste from wood is a rich resource that is more at disposal and can be utilized either for material purposes or energy production depending on the grade of the waste. One of an existing phenomenal is chipping and converted to compost. Therefore, it's a process of changing waste into highly competitive market end products. Wood processing industries products are, plywood, wood panel, furniture parts, air-dried lumber, kiln-dried lumber as well as, veneer (Corinaldesi, Mazzoli, & Siddique, 2016).

The quantity of waste generated from processing wood ranges from the type of production to the type of raw material and the end product. The waste thereby is as a result of the size of logs handled, the tool used; type of saw together with the competence of workers. The waste from these industries include; sawdust, wood off-cuts, and wood shavings. Sawdust, in particular, results from slicing, sizing, and edging, on the other hand, trims and shavings result from trimming and smoothening of wood.

A lot of concern has risen through the years about the rapid decrease in natural resources in particular; forest resources. On a scale, wood processing of about 1000 kilograms in the furniture industry will contribute to a waste of about 500 kilograms which is about half the total amount (Kauppi, Sandström, & Lipponen, 2018). The latent was to formulate good forest policy and its implementation quickly to promote sustainable forest administration. This has campaigned through the gradual increase in waste material dumping in conjunction with serious consequences emanating from the environment as a result of the disposal (Simmons, 2018). On a setback, recycling of wood waste cannot be participated by all wood enterprises in the case of small-medium wood enterprises. The biomass wastes are often sold in off-cuts form and cuttings or incinerated for the case of sawdust.

In the recycling process of wood waste, it is performed in a modern formation. Whereby it is important to distinguish between the various wood products to have an efficient recycling process; not all products can be recycled. First is weighing and quality control processes, secondly, sorting concerning the grades follows. Recycled wood grades include; clean recycled wood, industrial feedstock grade suitable for panelboard. Fuel grade and lastly, hazardous waste. Thirdly, is primary shredding, followed by separating the recyclable materials the latter is secondary shredding to achieve fine granules. (Trochu, Chaabane, & Ouhimmou, 2018)

The wastes are used to generate energy as shown in figure 1, which is utilized in the process of drying. Mechanical energy is required, on the other hand, delivered by fuels such as diesel or electric power. The mechanical energy in place ranges in uses from cutting the wastes sawing shaving to pressing. The small-scale industry uses the wastes as fuel and partly for cooking, the reason is the recycling business is more modernized and require more resources (Xu *et.al,* 2017).

The use of waste as fuel is variant depending on the tree species and the parts used; stems and branches. All these factors contribute to what is referred to as the calorific value of the fuel, for example, dry wood has a calorific value of about 99% making it a reliable source of fuel.

1.0 Manufacturing process

In details, processing of timber to processing is made possible by the use of various machines and industrial processes; sawing, drying, machining, gluing, and lastly, finishing. The working environment is hazardous to both the environment and the workers' lifestyle. In the line of machinery, the hazards could be grouped into mechanical; crushing, and shearing. Structural; sharp edges present and obstructions. Physical; noise and vibration. Besides, the operators have to engage with the machinery from, installation, its operation, maintenance, repairs. On the line, they get exposed to hazards (Wang, Zhang, Cao, & Song, 2018). A manufacturing process is as shown in the figure below.

Limiting on wood waste has improved largely on the utilization of wood on a primary level and also on environmental conservation; no more waste disposal. Also, this has helped fulfill the need for timber goods at the same time help in the conservation of forest resources. About 50% of a $1m^3$ of tree excised represents the wood waste. The significant 50% falls as being mainly waste material. In Germany for example, out of the 401 million tonnes of waste, about 11.9 tonnes is waste from wood (Ramage, 2018).

Different types of chemicals are in place during the process of timber production; these chemicals are preservative, adhesives, and coatings. The goal is to increase the lifespan of the products. From misguided disposal plans of such type of product, they can impact largely on the environment.

2.0 Wood treatment

The treatment of wood is an old practice. There are records in ancient Greece that olive oil would be used to treat wooden bridges. In the industrialization period, wood preservation took center stage as far as wood processing is concerned. Wood treatment can either be chemically or through heating. Treated wood has a diverse application in commercial application and domestic applications. Through the years, the industrial treatment of wood has revolutionized. In 2003 December 31st the use of chromated copper arsenate was banned by the US government because of the danger it posed to the public (Choe, Sung, & Kim, 2018)).

2.1 Chemical preservation

According to Gérardin, (2016), It can be grouped into three categories. Oil-based preservatives, water-based, and organic solvent.

2.1.1 Micronized Copper

This technology has been recently introduced in the US. Rather than copper being dissolved the particles are suspended in water. This property makes this system way effective than systems utilizing dissolved copper ions. This system is regarded as being environmentally friendly hence its adoption.

2.1.2 Alkaline Copper Quaternary

Often denoted as ACQ Is a preservative formulated from Copper it acts as a fungicide. The method is widely used over the US continent. Its use is regulated by government standards to prevent posing as a hazard for both the environment and its people.

2.1.3 Copper Azole

The compound is in use in various parts of the world, this is after the US government lifted a ban on the use of Chromated Copper Arsenate. Its use is protected by international standards depending on the end-use of the specific lumber.

2.1.4 Copper Naphthenate

It has gained diverse uses from, treating fence posts, beehives, and also nets. The compound is registered as a non-restricted pesticide, hence its wide use.

2.1.5 Chromated Copper Arsenate

Contains copper and arsenic compounds both acting as fungicides and insecticides. The process is effective in protecting the wood against attack from the atmosphere to the marine environment. The concern about this method of treatment was that the chemicals could leach from the wood and get disposed of in the soil, which posed a hazard. Bans were lifted on the use of these chemicals as a means to preserve the timber.

2.2 Natural preservation

2.2.1 Copper plating

The idea of covering wood using copper metal, a copper plate acts as a shield against toxic fungi as well as termites. Thereby increasing the durability of the lumber (Wang, Feng, Kong, & Wong, 2017).

2.2.2 Naturally rot-resistant woods

Due to high levels of organic chemicals, some tree species are prone to decay. Polyphenols chemicals contain these antimicrobial properties, on the other hand, these species are generally expensive to construct with. For example, the Merbau tree common for decking has had its applications in-ground use but on a limiting side, it is rigid and breakable to work around. Naturally, the ability to refrain from rot and insects in wood is directed to the heartwood. The sapwood on the other side should be regarded as having a shot span if not for the treatment (Reinprecht & Vidholdová, 2019).

2.3 Natural extractives

Substances extracted from trees unaffected with rotting are referred to as natural extractives. These compounds vary from polyphenols, flavonoids, and terpenoids. They are diverse in the heartwood and minimal in the sapwood. Therefore, the treatment of wood with these extracts such as tannins is effective in wood preservation and environmental conservation.

2.4 Heat treatment

Heat treatment is an effective process as long as wood preservation is concerned. Through heating the wood at given temperatures, the wood fiber is no longer rich for the insects such as termites. Heating is also significant in improving the wood quality factoring in moisture content. Where it reduces the amount of mild organic compounds, that possess antimicrobial features.

During heating, the timber is subjected to pressure and heat and nourished with nitrogen gas or steam to help in drying. The process lasts for about a day or two with the temperature being from about 180^0 C to about 230^0 C depending on the species of the plant. The process is important as it adds key characteristics to the wood; they include, stable dimension, toughness, and robustness. The application of this type of wood is mostly in making furniture as well as flooring (Gérardin, 2016).

2.5 Mud treatment

Wood is often buried in mud to it from insects and fungi, the process is vintage. It dates back to Vietnam, where they built a house from wood together with mud mixed with rice hay and was applied to the walls. In a general aspect, whenever the wood is in contact with the soil rotting conditions are favorable unlike with the mud (Wang, 2017).

2.6 New technologies

2.6.1 Biologically modified timber

This mode of timber is subjected to treatment with the help of biopolymers resulting from agricultural waste. Drying and curing are the processes followed to make the untreated timber tough and strong. The agricultural waste used includes bagasse from sugarcane. Furfuryl alcohol is used to soak softwood after which the wood is dried and kilned initiating complex reaction; formation of polymers between the bio-polymer and wood cells. The tough polymer will be impermeable by microorganisms (Dong, 2020).

2.6.2 Wood acetylation

Chemical improvement of wood at the molecular aspect has played a great role in improving the performance properties. Chemical structure of any substantial effects on its physical outlook. Woods have plenty of free hydroxyl chemical groups, which affects the ability of the plant to uptake and release water concerning the climate. Through acetylation, the free hydroxyls in the wood are converted to acetyl groups. Through this, the ability of the wood to uptake water is reduced, consequently, the wood hardens (Rowell, 2020).

3.0 Process of application

Non-pressure ways, commonly is the use of sprays, dipping also soaking. In brushing, a few of the liquid is sucked from the surface of the application. Dipping, wood is completely covered in a bath of creosote and other chemicals.

Treated wood is subjected to Chromated Copper Arsenate. From research, the average lifespan of a deck was about 9 to about 11 years. Esthetics contributed majorly to the removal of the decks, among other factors; wood decay, physical damage, and the structural sanity of the deck. The question raised was as to how much usable lumber being disposed of if beauty took the front stage in the removal of the deck. Therefore, suggesting that some of the deck material can be recovered and reused in a similar application (Mohajerani, Vajna, & Ellcock, 2018).

To establish the efficiency in the reuse of the deck material, various factors were considered, which include; the material need to comprise enough sufficient preservative retention and mechanical characteristics. The physical condition also needed to be acceptable to the end consumer.

Theoretically, the organized and choosy disassembling of decks is termed as deconstruction. A method in which would richly provide materials for the rebuilding of other structures. Before the material could be reused, different parameters could be tested. Chemical retention being one it, sampling of the chemical retention by the treated wood is conducted concerning the American Wood Preserves Association standards. Assuming most of the deck material over 12 years with the lumber thought to be first tested to an in-ground contact holding of 6 kg/m3 (Mohajerani, Vajna, & Ellcock, 2018).

The retention capabilities were different from the wood species. Following was a mechanical test in which pressure was exacted on the sampled treated wood. In return cracking would occur in several aspects on the samples regarding the not suitable for reuse. Once which didn’t crack meant they could be reused in building new decks. The age of the wood was not of significance; in the experiment, wood that was of about 27 years would hold up the pressure as of a recently treated material. This meant that harvesting of the discarded treated wood was key since they could be reused and save on the forest resources of cutting down new trees and treating structure formation purposes.

3.1 Determining the type of wood treatment using XRF technology

During sorting, it is required that the wood waste should be 99% free from chemicals to pass the US environment leaching tests. To achieve the knowledge between chromated copper arsenate from untreated wood, sophisticated technologies are put in place; PAN stain formulation and X-Ray fluorescence(XRF). The XRF has gained its wide use due to its accuracy and promptness. The XRF sensors can be installed in conveyors to aid in its use, nevertheless, despite the condition of the wood be it paint or stained or wet and dry, the technology will effectively distinguish the treated wood from the untreated (Gundupalli, Hait, & Thakur,2017).

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CONSTITUTION AND BY-LAWS OF OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS & SCIENTISTS ASSOCIATION

(5 November 2000 Edition)

VISION

To be a leading resource for fostering global sustainable development, for advancing quality of life and for protecting the environment.

MISSION

To form alliance with other organizations and environmental professionals to:
- Promote state-of-the-art environmental science, technology and management
- Promote opportunities for professional development for members
- Improve greater China environment
- Advocate sustainable environmental policy

CONSTITUTION

ARTICLE I: NAME

The name of this association shall be "Overseas Chinese Environmental Engineers & Scientists Association", hereinafter referred to as "OCEESA".

ARTICLE II: PURPOSE

The objectives of OCEESA shall be:

1. To enhance the advancement of environmental science, technology, and management

2. To provide education, training, and information exchange for members and other environmental professionals

3. To establish data base for environmental resources

4. To assist sustainable environmental trade and business

5. To promote informed environment policy and decision making

ARTICLE III: COMPOSITION OF THE ASSOCIATION

The Association shall be composed of members who in turn may be members of its Chapters, Divisions and/or local Sections. It shall have officers and staff as are necessary to effectuate its purposes.

ARTICLE IV: MEMBERSHIP

Section 1. OCEESA membership shall include regular members, student members, affiliate members, corporate members, honorary members, and life members OCEESA.

Section 2. An Admission Committee shall consist of members of the Executive Council of the Association. This Committee shall admit all new regular and life members, student members, affiliate members, and corporation members and non-resident members. The Committee will also review all honorary member applications and sends the applications to the Board of Directors for approval.

Section 3. Regular members of OCEESA shall be those of Chinese descent who are interested in and supportive of the objectives of the Association, and who are working in environmental engineering and science, and other related professions. Regular members are entitled to all membership privileges. Officers shall be elected among those regular members who are citizens or permanent residents of countries outside of China and Taiwan.

Section 4. Student members shall be students of Chinese descent studying and actively doing research in environmental engineering and science and other related fields at an institution of higher education. Student members shall have voting privileges and shall receive the OCEESA Journal.

Section 5. Affiliate members shall be those, who are not eligible for membership of regular members and student members but who are interested in and supportive of the objectives of OCEESA. An affiliate member shall not vote on OCEESA matters or hold an office of OCEESA; otherwise an affiliate member shall be entitled to all other membership privileges.

Section 6. Any firm, association, corporation, or institution or subdivision thereof desiring to support the objectives and programs of OCEESA may become a corporate member of OCEESA. A corporate member shall be entitled to all membership privileges except voting and being elected as an officer.

Section 7. Honorary members shall be those who are not OCEESA members but has made significant contributions in the improvement of the environment such as, but not limited to environmental engineering, environmental science, humanity, and the growth and development of OCEESA. Honorary members are entitled to all membership privileges except voting and being elected as officers. Honorary members are nominated by OCEESA members and approved by the Board of Directors.

Section 8. Life members shall be those who has paid one lump sum of $250.00 of membership dues at the time of membership application or any time as a regular paying member. Life members are entitled to all membership privileges.

Section 9. All regular members, student members, affiliate members, corporate members, shall pay dues as described in the By-Laws.

Section 10. Voting privileges shall be limited to members in good standing and as described in Article IV with each member having one vote.

ARTICLE V: OFFICERS

Section 1. The officers of OCEESA shall be a President, a Vice President, a Secretary/Treasurer, Directors and Executive Director. The officers, except the Executive Director, shall be elected by the members according to procedures described by the By-Laws. The officers shall make up the Executive Council of the Association, chaired by the President of the Association. Retiring President shall be the ex-officio member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year.

Section 2. The duties of officers of CCEESA are listed below:

1. The President shall be the chief officer of OCEESA, shall have general authority for active management of the business of OCEESA and shall see that all resolutions of the Association are put into effect. The term of presidency shall be one year beginning January 1 of the year.

2. The Vice President, in the absence of the President, performs the duties and exercises the power of the President. The Vice President shall be the President-Elect of OCEESA. The term for Vice President shall be one year beginning January 1 of the year.

3. Under the direction of the President, the Secretary/Treasurer shall be responsible for all official correspondence, admission, finances of OCEESA, shall keep all official files and documents, and shall perform such other duties assigned by the President. The term of the Secretary/Treasurer shall be one year beginning January 1 of the year.

4. The Directors shall be responsible for assisting the President in implementing resolutions, obtaining manuscripts and news items for OCEESA Journal, and nominating candidates for OCEESA officers. The term of the Director shall be two years beginning January 1 of the year. There shall be three (3) Directors elected every year. Total number of Directors shall be six (6) plus the number of local chapter presidents.

5. The Executive Director/Editor-in-Chief of OCEESA Journal is appointed by the President. The terms and conditions for the appointment of new executive director/editor-in-chief of OCEESA Journal shall be set by the President at the time of the appointment. The Executive Director is responsible of the operation of OCEESA headquarters office including publishing of OCEESA Journal and OCEESA Directory, maintenance of OCEESA Directory and Website, receiving membership dues, filing annual tax return, and processing OCEESA Best Paper Awards competition and other publicity events.

Section 3. No officer of OCEESA may serve more than one term of the same office.

ARTICLE VI: COMMITTEES

Section-l. The President shall appoint, as necessary, advisors, chairman and/or members of standing and ad hoc committees on matters such as admission, nomination, publicity, international affairs, and other operations of the programs of OCEESA.

Section 2. Officers of OCEESA may make recommendations to the President for the selection of chairmen and members of subcommittees on matters related to their duties and responsibilities of their offices. The President shall approve or reject the recommendations.

ARTICLE VII: MEETINGS

Section 1. General membership meeting: OCEESA shall hold annual meetings and such other meetings as are necessary to carry out its objectives. The time and place of all meetings shall be selected by the Executive Council as proposed in the By-Laws, and notices thereof shall be sent by the Secretary to each member of OCEESA or shall be published in the OCEESA Journal at least two weeks prior to the date of said meeting.

Section 2. Board meetings: The Board of Directors shall meet at least once a year through telecommunication, video conferencing or physical meeting, at a date to be determined by the Board of Directors. A majority of the Board membership shall constitute a quorum. Special Board meeting can be held at the request of the President or majority of the Board members.

Section 3. At any meeting of OCEESA, 30% of paid member participation shall constitute a quorum.

Section 4. Executive Council meeting: The President shall call Executive Council meetings on a pre-established schedule to conduct association business.

ARTICLE VIII: LOCAL CHAPTERS

Section 1. Upon the request of not fewer than 10 members of OCEESA residing within the area defined in their request, the Executive Council may establish a Local Chapter.

Section 2. Local Chapters shall be governed by the Constitution, By-Laws, Rule, and Policies established by the Executive Council of the Association.

Section 3. A Memorandum of Understanding (MOU) shall be established between the OCESSA Executive Council and the local Chapters.

ARTICLE IX. POLICIES

OCEESA will operate in a non-political, non-partisan, and non-sectarian manner.

Section 1. In the event of dissolution of OCEESA, the Executive Council shall, with the approval of the two-thirds majority of the membership, after paying debts, distribute the remaining assets to any of the organizations with like purposes or to organizations formed and operated exclusively for literary, and educational purposes as shall, at that time, qualify as exempt organizations under Section 501 (c) (3) of the Internal Revenue Code of 1954, or under any section amendatory thereof, supplemental thereto, or substituted therefor. Any such dissolution shall be accomplished pursuant to the laws of the State of Ohio where the OCEESA headquarter is.

ARTICLE XI: BY LAWS

The Executive Council shall make such By-Laws not in conflict with this Constitution as may be necessary for the proper government of the Association. Such By-Laws shall require the approval of the membership by a majority vote.

ARTICLE XII: AMENDMENTS

Section 1. The Constitution and By-Laws may be amended, altered, or repealed at annual meetings of the general membership with quorum by a two-thirds majority of those members present and voting, provided that no amendment is contrary to the provisions set forth in Section 501 (c) (3) of the Internal Revenue Code of 1954, and provided that prior written notice of the proposed changes has been given in the notice of said meeting not less than 30 days prior to the annual meeting of the general membership. The request for the proposed changes with written endorsement of at least ten per cent (10%) of the general membership shall be filed with the Secretary of OCEESA not less than 45 days before the date of said meeting.

Section 2. The Constitution and By-Laws may be amended, altered or repealed, for all practical purposes, may be subject to ratification by majority of membership at large. The procedure of conducting this ratification shall be determined by the Executive Council.

BY-LAWS

BY-LAW 1. MEMBERSHIP DUES

Section 1. The membership year shall be from January 1 to December 31, inclusive.

Section 2. Unless revised by the Executive Council, the dues for various classification of membership are determined by the Executive Council. Presently, the dues are as follows:

Regular Member: $ 25.00 annually
Student Member: $ 15.00 annually
Affiliate Member: $ 25.00 annually
Corporate Member: $100.00 annually
Life Member: $250 (one time)
Honorary Member: Free

Honorary Member Nomination Procedure and Selection Criteria

1. Nomination procedure:

a. A Nomination letter highlighting the significant achievement of the nominee should be submitted to the OCEESA President. The letter has to be signed by at least three OCEESA members in good standing.

b. One page biography of the nominee should be attached with the nomination letter.

c. Nomination material should reach the OCEESA president by August 1 each year and the selection process should be completed within 120 days. The results will be announced on the following year's 1st issue of OCEESA Journal.

d. Election to Honorary Membership shall be at the Board meeting or by mail with secret ballet vote. The ballet shall be based on at least five-sixths of the OCEESA Board of Directors. No less than 80% of votes cast shall be affirmative.

e. The elected Honorary member shall be recognized at the OCEESA annual meeting or other appropriate occasion and publicized in OCEESA Journal and OCEESA Web page.

2. Selection Criteria:

a. "Significant contributions in the improvement of the environment" include but not limited to the following:
· Research: as indicated by referred journals, presentations, patents, etc.
· Design and practices: as demonstrated in the environmental design for achieving substantial efficiency enhancement or cost savings
· Policy and strategies: as demonstrated by environmental quality improvement as the results of implementation of such policy or strategies
· OCEESA development and growth: as demonstrated by extraordinary service to OCEESA or by providing financial or technical support to OCEESA, resulting in significant OCEESA development and growth
· Community service: as demonstrated by exceptional environmental contribution that significantly improves the quality of life of a community.

b. Not more than one Honorary Member can be elected in any calendar year.

c. Unless otherwise noticed by the applicants, applicants not selected will be automatically put in the selection pool for next two years. After that the applicant needs to be renominated.

d. The ratio to membership cannot exceed one Honorary Member to every 20 active OCEESA members.

The fiscal year is from January 1 to December 31.

BY-LAW 2. ELECTION OF OFFICERS

Section 1. Newly elected officers shall take office on January 1. Retiring officers shall leave office on December 31. Retiring President shall be the ex-officio member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year. For operational necessity, the election related deadlines may be adjusted by the Executive council.

Section 2. Nominations Committee shall consist of chairman and other members of Executive Council of OCEESA named by the President. It shall be the duty of this Committee to nominate one or more candidates for each office. The nominations shall be published by mail or announced in the OCEESA Journal, which is sent to its members. All nominees shall be "regular members" in good standing, as described in Article IV of OCEESA Constitution, who have paid their membership dues for the current year.

Section 3. Any additional nominations can be made from the OCEESA members, but each nomination from the members must be seconded by at least ten members, in accordance with the procedure that is used by the Nominations Committee to nominate other candidates.

Section 4. From these nominations the Executive Director of OCEESA shall make up a ballot placing the names of the candidates for each office in alphabetical order on the ballot, which shall be sent by OCEESA office to each paid member no later than December 1. No nominee shall have his/her name placed on the ballot whose consent to serve has not first been obtained by the Nominations Committee or by the Secretary.

Section 5. Members may vote for one candidate for each office for the President, Vice President and Secretary/Treasurer. From the slate of candidates for the offices of Directors, each member may vote for not more than the number of offices to be filled. The Vice President will assume the presidency in the coming year. Unless the Vice President is unable to serve, then the election of the President will be held.

Section 6. All ballots must be returned to the OCEESA office no later than December 24. To be counted, each ballot shall be sealed in an envelope on that shall appear the name of the member, including both signature and the printed or typewritten name. The OCEESA office shall check each name against the membership list and call the attention of the Nominations Committee to any discrepancy. Sealed ballot envelopes, which is to be placed inside the mailing envelope, or ballots bearing the name of the member shall invalidate such ballots.

Section 7. The candidate receiving the highest number of votes for each office shall be declared elected. In case of a tie, a run-off election by mail ballot will be held to elect the winner. In case of an election tie, a special Board meeting shall be called by the president to resolve the issue.

Section 8. The Secretary shall report the election results to the members of OCEESA within the first week of January and in the January issue of OCEESA Journal.

Section 9. Vacancies in office during the year shall be filled by appointment by the Executive Council.

Section 10. Any officer or committee chairperson who shall fail to properly perform the duties of his/her office or shall act in a manner tending to bring discredit to the OCEESA may be removed from office by a two-thirds majority vote of the elected members of the Executive Council. Due notice of the anticipated action shall be given at least one month in advance of this meeting of the Executive Council, at which time the accused shall have full opportunity to be heard. The Secretary of the OCEESA shall conduct the vote by secret ballot. If the President is the officer whose removal is being considered, he/shall not preside over the Executive Council during the consideration of this item of business. Any elected officer removed from office under the provisions of this Section shall have the right to appeal to a duly constituted OCEESA meeting, at which a two-thirds majority vote is required to reverse the decision of the Executive Council.

BY-LAW 3. ANNUAL MEETINGS

The OCEESA annual meetings may be scheduled at the time and place determined by the Executive Council.

BY-LAW 4. OCEESA JOURNAL AND WEBSITE

Section 1. OCEESA Journal shall be the official publication of the Association. It shall be published at least twice a year or quarterly if possible. Journal editor-in-chief is appointed by the President and with the assistance of the associate editors and the editorial board, shall be responsible for the review, editing and publication of the OCEESA Journal. All officers of the Executive Council of the OCEESA shall be responsible for the soliciting and contributing to the writing of manuscripts and OCEESA news items for publication in the OCEESA Journal and Website.

Section 2. OCEESA Journal (ISSN 1072-7248) is deposited in National Technical Information Service (NTIS), U.S. Dept. of Commerce, 5285 Port Royal Rd, Springfield, Virginia 22161, USA (Technical Reports-Project No. L8301001). The order information can be found in the U.S. Government Report Announcement and Index. OCEESA does not accept subscription of OCEESA Journal from non-members.

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

CONSTITUTION AND BY-LAWS OF OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS & SCIENTISTS ASSOCIATION

(14 February 2006 Edition)

ARTICLE I: NAME

The name of this association shall be "overseas Chinese Environmental Engineers & Scientists Association", hereinafter referred to as "OCEESA".

ARTICLE II: PURPOSE

The objectives of OCEESA shall be:

1, To encourage the advancement of environmental engineering in all areas.

2. To promote research in environmental engineering and science.

3. To improve the qualifications and usefulness of OCEESA members.

4. To encourage professional contacts among OCEESA members.

5. To promote interactions with other scientific communities.

6. To strive for international recognition by our professional peers.

7. To assist members in the professional development or educational training.

ARTICLE III: COMPOSITION OF THE ASSOCIATION

The Association shall be composed of members who in turn may be members of its Division and/or its local Sections. It shall have officers and employees as are necessary to effectuate its purposes.

ARTICLE IV: MEMBERSHIP

Section 1. OCEESA membership shall include regular members, student members, affiliate members, corporate members, honorary members and non-resident members of OCEESA.

Section 2. An Admission Committee shall consist of all members of the Executive Council of the Association. This Committee shall admit all new members, student members, affiliate members, and corporation members, and approve all honorary members, and non-resident members of OCEESA.

Section 3. Regular members of OCEESA shall be those of Chinese descent residing in North American Continent, who are interested in the objectives of the Association, and who are working in environmental engineering and science, and other related professions. Regular members are entitled to all membership privileges. Officers shall be elected among those regular members who are citizens or permanent residents of countries in North American Continent.

Section 4. Graduate student members shall be graduate students of Chinese descent studying and actively doing research in environmental engineering and science and other related fields at an institution of higher education in North American Continent. They must have the signature of their major professor to certify membership. Student members shall have voting privileges and shall receive the OCEESA Journal.

Section 5. Affiliate members shall be those, who are not eligible for membership of regular members and student members but who are interested in and supportive of the objectives of OCEESA. An affiliate member shall not vote on OCEESA matters or hold an office of OCEESA; otherwise an affiliate member shall be entitled to all other membership privileges.

Section 6. Any firm, association, corporation, or institution or subdivision thereof desiring to support the objectives and programs of OCEESA may become a corporate member of OCEESA. A corporate member shall be entitled to none of the membership privileges.

Section 7. Honorary life members shall be those of OCEESA members retiring from their regular jobs in environmental engineering and science and other related fields. Honorary life members are entitled to all membership privileges except receiving OCEESA Journal and holding an elected office of OCEESA.

Section 8. Non-resident members shall be OCEESA members of any grade returned to homeland China or their residence outside of North American Continent. Non-resident members shall be entitled to none of the membership privileges. However, a non-resident member is entitled to receiving OCEESA Journal upon payment of regular member dues.

Section 9. All regular members, student members, affiliate members, corporate members, honorary members and non-resident members shall pay dues as described in the By-Laws.

Section 10. Voting privileges shall be limited to members in good standing and as described in Article IV with each member having one vote.

ARTICLE V: OFFICERS

Section 1. The officers of OCEESA shall be a President, a Vice President, a Secretary/Treasurer, Directors and Executive Director. The officers except the Executive Director shall be elected by the members according to procedures described by the By-Laws. The officers shall make up the Executive Council of the Association, chaired by the President of the Association. Retiring President shall be the ex-offico member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year.

Section 2. The duties of officers of CCEESA are listed below:

1. The President shall be the chief officer of OCEESA, shall have general and active management of the business of OCEESA and shall see that all resolutions of the Association are put into effect. The term of presidency shall be one year beginning January 1 of the year.

2. The Vice President, in the absence of the President, performs the duties and exercises the power of the President. The Vice President shall be the President-Elect of OCEESA. The term for Vice President shall be one year beginning January 1 of the year.

3. Under the direction of the President, the Secretary/Treasurer shall be responsible for all official correspondence, admission, the finances of OCEESA, shall keep all official files and documents, and shall perform such other duties assigned by the President. The term of the Secretary/Treasurer shall be one year beginning January 1 of the year.

4. The Directors shall be responsible for assisting the President in implementing resolutions, obtaining manuscripts and news items for OCEESA Journal, and nominating candidates for OCEESA officers. The term of the Director shall be two years beginning January 1 of the year. There shall be three (3) Directors elected every year. There shall be six (6) Directors in total.

5. The Executive Director/Editor-in-Chief of OCEESA Journal is appointed by the President. There is no set term limit for the Executive Director/Editor-in-Chief of OCEESA Journal. The Executive Director is responsible of the operation of OCEESA headquarters office including publishing of OCEESA Journal and OCEESA Directory, receiving membership dues, and processing OCEESA Best Paper Awards competition.

Section 3. No officer of OCEESA may serve more than one term of the same office.

ARTICLE VI: COMMITTEES

Section-l. The President shall appoint chairman and/or members of standing and ad hoc committees on matters such as admission, nomination, publicity, international affairs, and other operations of the programs of OCEESA.

Section 2. Officers of OCEESA may appoint chairmen and members of subcommittees on matters related to their duties and responsibilities of their offices.

ARTICLE VII: MEETINGS

Section 1. OCEESA shall hold annual meetings and such other meetings as are necessary to carry out its objectives. The time and place of all meetings shall be selected by the Executive Council as proposed in the By-Laws, and notices thereof shall be sent by the Secretary to each member of OCEESA or shall be published in the OCEESA Journal at least two weeks prior to the date of said meeting.

Section 2. At any meeting of OCEESA twelve (12) members shall constitute a quorum.

ARTICLE VIII: LOCAL CHAPTERS AND DIVISIONS

Section 1. Upon the request of not fewer than 12 members of OCEESA residing within the area defined in their request, the Executive Council may establish a Local Chapter.

Section 2. Members of OCEESA with a common interest in a particular scientific field of the Association, upon the authorization of Executive Council, may organize a group to be known as a Division of the Association.

Section 3. Local Chapters and Divisions shall be governed by the Constitution, By-Laws, Rule, and Policies established by the Executive Council of the Association.

ARTICLE IX. POLICIES

OCEESA will operate in a non-political, non-partisan, and non-sectarian manner.

Section 1. ln the event of dissolution of OCEESA the Executive Council shall with the approval of the two-thirds majority of the membership, after paying must debts, distribute the remaining assets to any of the organizations with like purposes or to organizations formed and operated exclusively for literary, and educational purposes as shall, at that time, qualify as exempt organizations under Section 501 (c) (3) of the Internal Revenue Code of 1954, or under any section amendatory thereof, supplemental thereto, or substituted therefor. Any such dissolution shall be accomplished pursuant to the laws of the State of Ohio.

Section 2. This Article of Constitution and By-Laws is not amendable during the existence of OCEESA.

ARTICLE XI: BY LAWS

The Executive Council shall make such By-Laws not in conflict with this Constitution as may be necessary for the proper government of the Association. Such By-Laws shall require the approval of the membership by a majority vote.

ARTICLE XII: AMENDMENTS

The Constitution and By-Laws may be amended, altered, or repealed at annual meetings of the general membership with quorum by a two-thirds majority of those members present and voting, provided that no amendment is contrary to the provisions set forth in Section 501 (c) (3) of the Internal Revenue Code of 1954, and provided that prior written notice of the proposed changes has been given in the notice of said meeting not less than 30 days .prior to the annual meeting of the general membership. The request for the proposed changes with written endorsement of at least ten per cent (10%) of the general membership shall be filed with the Secretary of OCEESA not less than 45 days before the date of said meeting.

BY-LAWS

BY-LAW 1. MEMBERSHIP DUES

Section 1. The membership year shall be from January 1 to December 31, inclusive.

Section 2. The dues for various classification of membership are as follows:

Regular Member $ 25.00 annually

Graduate Student Member $ 15.00 annually

Affiliate Member $ 25.00 annually

Corporate Member $100.00 annually

Honorary Life Member Free

Non-Resident Member Free

The fiscal year is from January 1 to December 31.

BY-LAW 2. ELECTION OF OFFICERS

Section 1. Newly elected officers shall take office on January 1. Retiring officers shall leave office on December 31. Retiring President shall be the ex-officio member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year.

Section 2. Nominations Committee shall consist of chairman and other members of Executive Council of OCEESA. It shall be the duty of this Committee to nominate one or more candidates for each office. The nominations shall be published by mail or announced in the OCEESA Journal, which is sent to its members. All nominees shall be "regular members" in good standing, as described in Article IV of OCEESA Constitution, who have paid their membership dues for the current year.

Section 3. Any additional nominations can be made from the OCEESA members, but each nomination from the members must be seconded by at least ten members, in accordance with the procedure that is used by the Nominations Committee to nominate other candidates.

Section 4. From these nominations the Secretary of OCEESA shall make up a ballot placing the names of the candidates for each office in alphabetical order on the ballot, which shall be sent by OCEESA office to each paid member no later than December 1. No nominee shall have his/her name placed on the ballot whose consent to serve has not first been obtained by the Nominations Committee or by the Secretary.

Section 5. Members may vote for one candidate for each office for the President, Vice President and Secretary/Treasurer. From the slate of candidates for the offices of Directors, each member may vote for not more than the number of offices to be filled.

Section 6. All ballot must be returned to the OCEESA office no later than December 31. To be counted, each ballot shall be sealed in an envelope on which shall appear the name of the member, including both signature and the printed or typewritten name. The OCEESA office shall check each name against the membership list and call the attention of the Nominations Committee to any discrepancy. Sealed ballot envelopes, which is to be placed inside the mailing envelope, or ballots bearing the name of the member shall invalidate such ballots.

Section 7. The candidate receiving the highest number of votes for each office shall be declared elected. In case of a tie, a run-off election by mail ballot will be held to elect the winner.

Section 8. The election results shall be reported by the Secretary to the members of OCEESA in the January issue of OCEESA Journal.

Section 9. Vacancies in office during the year shall be filled by appointment by the Executive Council.

Section 10. Any officer or committee chairman who shall fail to properly perform the duties of his/her office or shall act in a manner tending to bring discredit to the OCEESA may be removed from office by a two-thirds majority vote of the elected members of the Executive Council. Due notice of the anticipated action shall be given at least one month in advance of this meeting of the Executive Council, at which time the accused shall have full opportunity to be heard. The Secretary of the OCEESA shall conduct the vote by secret ballot. If the President is the officer whose removal is being considered, he/shall not preside over the Executive Council during the consideration of this item of business. Any elected officer removed from office under the provisions of this Section shall have the right to appeal to a duly constituted OCEESA meeting, at which a two-thirds majority vote is required to reverse the decision of the Executive Council.

BY-LAW 3. ANNUAL MEETINGS

The OCEESA annual meetings may be scheduled to coincide with the annual Purdue Industrial Waste Conference held at Purdue University, West Lafayette, in May of each year, or at the time and place determined by the Executive Council.

BY-LAW 4. OCEESA JOURNAL

Section 1. OCEESA Journal shall be the official publication of the Association. It shall be published at least twice a year or quarterly if possible. Journal editor-in-chief, with the assistance of the associate editors and the editorial board, shall be responsible for the review, editing and publication of the OCEESA Journal. All officers of the Executive Council of the OCEESA shall be responsible for the soliciting and writing of manuscripts and OCEESA news items for publication in the OCEESA Journal. Journal editor-in-chief is appointed by the President.

Section 2. OCEESA Journal (ISSN 1072-7248) is deposited in National Technical Information Service (NTIS), U.S. Dept. of Commerce, 5285 Port Royal Rd, Springfield, Virginia 22161, USA (Technical Reports-Project No. L8301001). The order information can be found in the U.S. Government Report Announcement and Index. OCEESA does not accept subscription of OCEESA Journal from non-members.

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

CONSTITUTION AND BY-LAWS OF OVERSEAS CHINESE ENVIRONMENTAL ENGINEERS & SCIENTISTS ASSOCIATION

(27 October 2013 Edition)

VISION

To be a leading resource for fostering global sustainable development, for advancing quality of life and for protecting the environment.

MISSION

To form alliance with other organizations and environmental professionals to:
· Promote state-of-the-art environmental science, technology and management
· Promote opportunities for professional development for members
· Improve greater China environment
· Advocate sustainable environmental policy

CONSTITUTIONS

ARTICLE I: NAME

The name of this association shall be "Overseas Chinese Environmental Engineers & Scientists Association", hereinafter referred to as "OCEESA".

ARTICLE II: PURPOSE

The objectives of OCEESA shall be:

1. To enhance the advancement of environmental science, technology, and management

2. To provide education, training, and information exchange for members and other environmental professionals

3. To establish data base for environmental resources

4. To assist sustainable environmental trade and business

5. To promote informed environment policy and decision making

ARTICLE III: COMPOSITION OF THE ASSOCIATION

The Association shall be composed of members who in turn may be members of its Chapters, Divisions and/or local Sections. It shall have officers and staff as are necessary to effectuate its purposes.

ARTICLE IV: MEMBERSHIP

Section 1. OCEESA membership shall include regular members, student members, affiliate members, corporate members, honorary members, and life members OCEESA.

Section 2. An Admission Committee shall consist of members of the Executive Council of the Association. This Committee shall admit all new regular and life members, student members, affiliate members, and corporation members and non-resident members. The Committee will also review all honorary member applications and sends the applications to the Board of Directors for approval.

Section 3. Regular members of OCEESA shall be those of Chinese descent who are interested in and supportive of the objectives of the Association, and who are working in environmental engineering and science, and other related professions. Regular members are entitled to all membership privileges. Officers shall be elected among those regular members who are citizens or permanent residents of countries outside of China and Taiwan.

Section 4. Student members shall be students of Chinese descent studying and actively doing research in environmental engineering and science and other related fields at an institution of higher education. Student members shall have voting privileges and shall receive the OCEESA Journal.

Section 5. Affiliate members shall be those, who are not eligible for membership of regular members and student members but who are interested in and supportive of the objectives of OCEESA. An affiliate member shall not vote on OCEESA matters or hold an office of OCEESA; otherwise an affiliate member shall be entitled to all other membership privileges.

Section 6. Any firm, association, corporation, or institution or subdivision thereof desiring to support the objectives and programs of OCEESA may become a corporate member of OCEESA. A corporate member shall be entitled to all membership privileges except voting and being elected as an officer.

Section 7. Honorary members shall be those who are not OCEESA members but has made significant contributions in the improvement of the environment such as, but not limited to environmental engineering, environmental science, humanity, and the growth and development of OCEESA. Honorary members are entitled to all membership privileges except voting and being elected as officers. Honorary members are nominated by OCEESA members and approved by the Board of Directors.

Section 8. Life members shall be those who has paid one lump sum of $250.00 of membership dues at the time of membership application or any time as a regular paying member. Life members are entitled to all membership privileges.

Section 9. All regular members, student members, affiliate members, corporate members, shall pay dues as described in the By-Laws.

Section 10. Voting privileges shall be limited to members in good standing and as described in Article IV with each member having one vote.

ARTICLE V: OFFICERS

Section 1. The officers of OCEESA shall be a President, a Vice President, a Secretary/Treasurer, Directors and Executive Director. The officers, except the Executive Director, shall be elected by the members according to procedures described by the By-Laws. The officers shall make up the Executive Council of the Association, chaired by the President of the Association. Retiring President shall be the ex-officio member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year.

Section 2. The duties of officers of CCEESA are listed below:

1. The President shall be the chief officer of OCEESA, shall have general authority for active management of the business of OCEESA and shall see that all resolutions of the Association are put into effect. The term of presidency shall be one year beginning January 1 of the year.

2. The Vice President, in the absence of the President, performs the duties and exercises the power of the President. The Vice President shall be the President-Elect of OCEESA. The term for Vice President shall be one year beginning January 1 of the year.

3. Under the direction of the President, the Secretary/Treasurer shall be responsible for all official correspondence, admission, finances of OCEESA, shall keep all official files and documents, and shall perform such other duties assigned by the President. The term of the Secretary/Treasurer shall be one year beginning January 1 of the year.

4. The Directors shall be responsible for assisting the President in implementing resolutions, obtaining manuscripts and news items for OCEESA Journal, and nominating candidates for OCEESA officers. The term of the Director shall be three years beginning January 1 of the year. There shall be three (3) Directors elected every year. Total number of Directors shall be nine (9) plus the number of local chapter presidents.

5. The Executive Director/Editor-in-Chief of OCEESA Journal is appointed by the President. The terms and conditions for the appointment of new executive director/editor-in-chief of OCEESA Journal shall be set by the President at the time of the appointment. The Executive Director is responsible of the operation of OCEESA headquarters office including publishing of OCEESA Journal and OCEESA Directory, maintenance of OCEESA Directory and Website, receiving membership dues, filing annual tax return, and processing OCEESA Best Paper Awards competition and other publicity events.

Section 3. No officer of OCEESA may serve more than one term of the same office.

ARTICLE VI: COMMITTEES

Section-l. The President shall appoint, as necessary, advisors, chairman and/or members of standing and ad hoc committees on matters such as admission, nomination, publicity, international affairs, and other operations of the programs of OCEESA.

Section 2. Officers of OCEESA may make recommendations to the President for the selection of chairmen and members of subcommittees on matters related to their duties and responsibilities of their offices. The President shall approve or reject the recommendations.

ARTICLE VII: MEETINGS

Section 1. General membership meeting: OCEESA shall hold annual meetings and such other meetings as are necessary to carry out its objectives. The time and place of all meetings shall be selected by the Executive Council as proposed in the By-Laws, and notices thereof shall be sent by the Secretary to each member of OCEESA or shall be published in the OCEESA Journal at least two weeks prior to the date of said meeting.

Section 2. Board meetings: The Board of Directors shall meet at least once a year through telecommunication, video conferencing or physical meeting, at a date to be determined by the Board of Directors. A majority of the Board membership shall constitute a quorum. Special Board meeting can be held at the request of the President or majority of the Board members.

Section 3. At any meeting of OCEESA, 30% of paid member participation shall constitute a quorum.

Section 4. Executive Council meeting: The President shall call Executive Council meetings on a pre-established schedule to conduct association business.

ARTICLE VIII: LOCAL CHAPTERS

Section 1. Upon the request of not fewer than 10 members of OCEESA residing within the area defined in their request, the Executive Council may establish a Local Chapter.

Section 2. Local Chapters shall be governed by the Constitution, By-Laws, Rule, and Policies established by the Executive Council of the Association.

Section 3. A Memorandum of Understanding (MOU) shall be established between the OCESSA Executive Council and the local Chapters.

ARTICLE IX. POLICIES

OCEESA will operate in a non-political, non-partisan, and non-sectarian manner.

Section 1. In the event of dissolution of OCEESA, the Executive Council shall, with the approval of the two-thirds majority of the membership, after paying debts, distribute the remaining assets to any of the organizations with like purposes or to organizations formed and operated exclusively for literary, and educational purposes as shall, at that time, qualify as exempt organizations under Section 501 (c) (3) of the Internal Revenue Code of 1954, or under any section amendatory thereof, supplemental thereto, or substituted therefor. Any such dissolution shall be accomplished pursuant to the laws of the State of Ohio where the OCEESA headquarter is.

ARTICLE XI: BY LAWS

The Executive Council shall make such By-Laws not in conflict with this Constitution as may be necessary for the proper government of the Association. Such By-Laws shall require the approval of the membership by a majority vote.

ARTICLE XII: AMENDMENTS

Section 1. The Constitution and By-Laws may be amended, altered, or repealed at annual meetings of the general membership with quorum by a two-thirds majority of those members present and voting, provided that no amendment is contrary to the provisions set forth in Section 501 (c) (3) of the Internal Revenue Code of 1954, and provided that prior written notice of the proposed changes has been given in the notice of said meeting not less than 30 days prior to the annual meeting of the general membership. The request for the proposed changes with written endorsement of at least ten per cent (10%) of the general membership shall be filed with the Secretary of OCEESA not less than 45 days before the date of said meeting.

Section 2. The Constitution and By-Laws may be amended, altered or repealed, for all practical purposes, may be subject to ratification by majority of membership at large. The procedure of conducting this ratification shall be determined by the Executive Council.

BY-LAWS

BY-LAW 1. MEMBERSHIP DUES

Section 1. The membership year shall be from January 1 to December 31, inclusive.

Section 2. Unless revised by the Executive Council, the dues for various classification of membership are determined by the Executive Council. Presently, the dues are as follows:

Regular Member: $ 25.00 annually
Student Member: $ 15.00 annually
Affiliate Member: $ 25.00 annually
Corporate Member: $100.00 annually
Life Member: $250 (one time)
Honorary Member: Free

Honorary Member Nomination Procedure and Selection Criteria

1. Nomination procedure:

a. A Nomination letter highlighting the significant achievement of the nominee should be submitted to the OCEESA President. The letter has to be signed by at least three OCEESA members in good standing.
b. One page biography of the nominee should be attached with the nomination letter.
c. Nomination material should reach the OCEESA president by August 1 each year and the selection process should be completed within 120 days. The results will be announced on the following year's 1st issue of OCEESA Journal.
d. Election to Honorary Membership shall be at the Board meeting or by mail with secret ballet vote. The ballet shall be based on at least five-sixths of the OCEESA Board of Directors. No less than 80% of votes cast shall be affirmative.
e. The elected Honorary member shall be recognized at the OCEESA annual meeting or other appropriate occasion and publicized in OCEESA Journal and OCEESA

Web page.

2. Selection Criteria:

a. "Significant contributions in the improvement of the environment" include but not limited to the following:
·

1. Research: as indicated by referred journals, presentations, patents, etc.
2. Design and practices: as demonstrated in the environmental design for achieving substantial efficiency enhancement or cost savings
3. Policy and strategies: as demonstrated by environmental quality improvement as the results of implementation of such policy or strategies
4. OCEESA development and growth: as demonstrated by extraordinary service to OCEESA or by providing financial or technical support to OCEESA, resulting in significant OCEESA development and growth
5. Community service: as demonstrated by exceptional environmental contribution that significantly improves the quality of life of a community.

b. Not more than one Honorary Member can be elected in any calendar year.

c. Unless otherwise noticed by the applicants, applicants not selected will be automatically put in the selection pool for next two years. After that the applicant needs to be renominated.

d. The ratio to membership cannot exceed one Honorary Member to every 20 active OCEESA members.

The fiscal year is from January 1 to December 31.

BY-LAW 2. ELECTION OF OFFICERS

Section 1. Newly elected officers shall take office on January 1. Retiring officers shall leave office on December 31. Retiring President shall be the ex-officio member of the Executive Council following his/her retirement, for a term of one year beginning January 1 of the year. For operational necessity, the election related deadlines may be adjusted by the Executive council.

Section 2. Nominations Committee shall consist of chairman and other members of Executive Council of OCEESA named by the President. It shall be the duty of this Committee to nominate one or more candidates for each office. The nominations shall be published by mail or announced in the OCEESA Journal, which is sent to its members. All nominees shall be "regular members" in good standing, as described in Article IV of OCEESA Constitution, who have paid their membership dues for the current year.

Section 3. Any additional nominations can be made from the OCEESA members, but each nomination from the members must be seconded by at least ten members, in accordance with the procedure that is used by the Nominations Committee to nominate other candidates.

Section 4. From these nominations the Executive Director of OCEESA shall make up a ballot placing the names of the candidates for each office in alphabetical order on the ballot, which shall be sent by OCEESA office to each paid member no later than December 1. No nominee shall have his/her name placed on the ballot whose consent to serve has not first been obtained by the Nominations Committee or by the Secretary.

Section 5. Members may vote for one candidate for each office for the President, Vice President and Secretary/Treasurer. From the slate of candidates for the offices of Directors, each member may vote for not more than the number of offices to be filled. The Vice President will assume the presidency in the coming year. Unless the Vice President is unable to serve, then the election of the President will be held.

Section 6. All ballots must be returned to the OCEESA office no later than December 24. To be counted, each ballot shall be sealed in an envelope on that shall appear the name of the member, including both signature and the printed or typewritten name. The OCEESA office shall check each name against the membership list and call the attention of the Nominations Committee to any discrepancy. Sealed ballot envelopes, which is to be placed inside the mailing envelope, or ballots bearing the name of the member shall invalidate such ballots.

Section 7. The candidate receiving the highest number of votes for each office shall be declared elected. In case of a tie, a run-off election by mail ballot will be held to elect the winner. In case of an election tie, a special Board meeting shall be called by the president to resolve the issue.

Section 8. The Secretary shall report the election results to the members of OCEESA within the first week of January and in the January issue of OCEESA Journal.

Section 9. Vacancies in office during the year shall be filled by appointment by the Executive Council.

Section 10. Any officer or committee chairperson who shall fail to properly perform the duties of his/her office or shall act in a manner tending to bring discredit to the OCEESA may be removed from office by a two-thirds majority vote of the elected members of the Executive Council. Due notice of the anticipated action shall be given at least one month in advance of this meeting of the Executive Council, at which time the accused shall have full opportunity to be heard. The Secretary of the OCEESA shall conduct the vote by secret ballot. If the President is the officer whose removal is being considered, he/shall not preside over the Executive Council during the consideration of this item of business. Any elected officer removed from office under the provisions of this Section shall have the right to appeal to a duly constituted OCEESA meeting, at which a two-thirds majority vote is required to reverse the decision of the Executive Council.

BY-LAW 3. ANNUAL MEETINGS

The OCEESA annual meetings may be scheduled at the time and place determined by the Executive Council.

BY-LAW 4. OCEESA JOURNAL AND WEBSITE

Section 1. OCEESA Journal shall be the official publication of the Association. It shall be published at least twice a year or quarterly if possible. Journal editor-in-chief is appointed by the President and with the assistance of the associate editors and the editorial board, shall be responsible for the review, editing and publication of the OCEESA Journal. All officers of the Executive Council of the OCEESA shall be responsible for the soliciting and contributing to the writing of manuscripts and OCEESA news items for publication in the OCEESA Journal and Website.

Section 2. OCEESA Journal (ISSN 1072-7248) is deposited in National Technical Information Service (NTIS), U.S. Dept. of Commerce, 5285 Port Royal Rd, Springfield, Virginia 22161, USA (Technical Reports-Project No. L8301001). The order information can be found in the U.S. Government Report Announcement and Index. OCEESA does not accept subscription of OCEESA Journal from non-members.

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

Wen Chi (Jim) Ku, Ph.D.
952 Promenade Circle
Cicero, Indiana 46032
Email: wcku89@yahoo.com

December 3, 2020

To Whom It May Concern:

As President of the Overseas Chinese Environmental Engineers and Scientists Association (OCEESA) from June 1, 1987 to May 31, 1988, I would like to inform you the following:

1. Dr. Yung-Tse Hung was appointed as Permanent Executive Director of OCEESA in 1986 and has served in that role for the past 35 years. He is responsible for running OCEESA's Cleveland office located in Cleveland, Ohio, U.S.A.

2. Since 1982, OCEESA's membership dues have been used exclusively for the operation of OCEESA's Cleveland office. This arrangement was made by the late Dr. Howard Ju-Chang Huang, who was President of OCEESA from June 1, 1981 to May 31, 1982.

Dr. Hung has dedicated his entire professional life to establishing OCCESA and nurturing its growth. Dr. Hung was instrumental in founding the OCCESA. He and a group of scholars and environmental engineers and scientists, including me, started the organization in 1980 during the Annual Industrial Wastes Conference held at Purdue University, West Lafayette, Indiana, U.S.A. After serving as its fifth president in 1986, he was appointed as Permanent Executive Director of OCCESA. Through his efforts, OCCESA was incorporated in the State of Ohio, U.S.A., and its headquarters was established in Cleveland, Ohio, U.S.A. Under his skillful management, as well as the leaderships of its many presidents and boards of directors, the organization continued to grow year after year throughout the past 40 years. For many of us, he was, and still is, the face of OCCESA. As I look back at the past 40 years, I can dare say that if it was not for Dr. Hung, OCCESA might not have lasted for so long, letting alone growth and many great accomplishments.

Very truly yours,

Wen Chi (Jim) Ku, Ph.D.
OCCESA President (1987-88)
OCCESA Life Member

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Mailing Address: PO Box 405, Newtonville, NY 12128-0405

December 29, 2020

To Whom It May Concern:

As President of the Overseas Chinese Environmental Engineers and Scientist Association (OCEESA) from June 1, 1989 to December 31, 1990, I would like to inform you the following:

1. Dr. Yung-Tse Hung was appointed as Permanent Executive Director of OCEESA in 1986 and has served in that role for the past 35 years. He has been responsible for the operation of OCEESA's Cleveland office, Cleveland, Ohio, USA, since.

2. OCEESA membership dues have been exclusively used for the operation of OCEESA's Cleveland office since 1982. This arrangement was initially made by the late Dr. Howard Ju-Chang Huang, who was the President of OCEESA from June 1, 1981 to May 31, 1982.

Dr. Hung has dedicated his entire professional life to, first, establish OCCESA and, then, nurture its growth. Dr. Hung was instrumental in establishing the organization of OCCESA. He and a group of environmental scholars, engineers and scientists started the organization in 1980 during the Annual Industrial Wastes Conference held at Purdue University, West Lafayette, Indiana, USA. After serving as the OCEESA's fifth president in 1986, he was appointed as Permanent Executive Director of OCCESA. Through his efforts, OCCESA was incorporated as a non-profit organization in the State of Ohio, and its headquarter was established in Cleveland, Ohio, USA. Under his excellent leadership, OCEESA has been continually growing year after year throughout the past 40 years. If it was not for Dr. Hung, OCCESA might not have survived its long journey, letting alone continuous growth with great accomplishments.

Very Truly Yours,

Prof. Lawrence K. Wang, PhD, PE, DEE
OCCESA President (1989-1990)
Home Address: 1 Dawn Drive, Latham, NY 12110-5305 USA

OCEESA MEMBERSHIP APPLICATION

Name: ____
Last First Middle

Chinese Name (in Chinese):_________________________ Sex: ☐ Male ☐Female
Membership Status: ☐ Regular ☐Student ☐Corporate
Title (Job Title): ____________________________________
Department: ____
Organization: _______________________________________
Business Address:
____
Street City State ZIP
Home Address:
____
Street City State ZIP
Office Phone: ___________________ Office Fax: _________________ Office Email: _________________
Home Phone:____________________Home Fax: __________________ Home Email: _________________

Occupation: ☐Private Practice/Consulting ☐ Educator ☐ Industry ☐ Laboratory
☐ Federal Official ☐State Official ☐ Local Official ☐Retired ☐Other: ___________
Birth Date:____/____/_____ Birth Place: _____________________________-___________________________
Month Day Year City State Country
Professional Engineer License: ___________________ Other License (please specify): ______________________

B.S. Degree: -
____
Degree Major Year Institution
M.S. Degree:
____
Degree Major Year Institution
Ph.D. Degree:
____
Degree Major Year Institution
Member of Associations:
☐AWMA ☐ AlChE ☐APHA ☐APWA ☐ASEE ☐ASCE ☐ ASME ☐AWWA
☐AEESP ☐GRCDA ☐ NSPE ☐WEF ☐ACS ☐Other: ___________
Major Fields of Expertise (list 3 from 2-digit code in Table 1):_________________________
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:____
Signature:____Date:________________

Annual Dues: Regular Member $ 25; Student Member $ 15; Corporate Member $100; Annual membership due on January 31. Please mail this membership form with 1-page resume and payment (payable to OCEESA) to: Dr. Yung-Tse Hung, Professor, 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, yungtsehung@yahoo.com Please note that the dues payment check must be in U.S. dollars and must be drawn from a U.S. bank located in U.S. Please also email your membership form and 1-page resume to Dr. Yung-Tse Hung. OCEESA Web Page: http//:www.oceesa.org Note: Format resume as follows: Name, position, department, employer, complete contact information, education, academic experience, industrial experience, professional engineering registration, professional association, major field of competence, list of publications (incl. presentations).

Table 1 and Table 2 OCEESA Expertise and Specialty

Note: Expertise (2 digits) Specialty (4 digits)

01 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

0401 Activated sludge
0402 Biofilm process - aerobic
0403 Biofilm process - anaerobic
0404 Composting
0405 Denitrification
0406 Kinetics
0407 Lagoons - aquatic macrophytes
0408 Lagoons - stabilization
0409 Methanogenesis
0410 Nitrification
0411 Phosphorus removal
0412 Septic tanks
0413 Sludge digestion
0414 Sulfate reduction

05 CHEMICAL AND PHYSICAL TREATMENT PROCESSES FOR WATER AND WASTEWATER

0501 Adsorption
0502 Chlorination and dechlorination
0503 Coagulation/flocculation
0504 Disinfection
0505 Filtration
0506 Flotation
0507 Gas transfer
0508 Ion exchange
0509 Irradiation
0510 Membrane processes
0511 Ozonation
0512 Precipitation
0513 Sedimentation
0514 Mixing

06 DRINKING WATER QUALITY

0601 Chemicals - inorganic
0602 Chemicals - organic
0603 Disinfection by-products
0604 Disinfection residuals
0605 Microbiological
0606 Stability
0607 Tastes and odors

07 ECOLOGY

0701 Aquatic
0702 Microbial
0703 Soil
0704 Terrestrial
0705 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
1203 Flooding
1204 Fluid mechanics
1205 Hydraulics
1206 Hydromechamics
1207 Open-channel flow
1208 Pumping
1209 Sedimentation
1210 Waves

13 MANAGEMENT/POLICY

1301 Air basins
1302 Economics and finance
1303 Environmental impact Assessment
1304 Laws and regulations
1305 River basins
1300 Utilities
1307 Water allocation
1308 Water conservation
1309 Water-quality standards

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