



บันทึกข้อความ

ส่วนราชการ ภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์ มหาวิทยาลัยอุบลราชธานี โทร.3343

ที่ ศธ 0529.8.3/ พิเศษ

วันที่ 6 กันยายน พ.ศ. 2555

เรื่อง ขออนุมัติเงินสนับสนุนเพื่อนำเสนอบทความทางวิชาการในระดับนานาชาติ

เรียน รองคณบดีฝ่ายวิจัยและบริการวิชาการ ผ่านหัวหน้าภาควิชาวิศวกรรมเคมี

ด้วยดิฉัน ผศ.ดร.สุมนา สิริพัฒนานกุล อาจารย์ประจำภาควิชาวิศวกรรมเคมี ได้ส่งผลงานวิจัยและได้รับการตอบรับให้นำเสนอบทความ "Municipal Wastewater Treatment Using Barium Alginate Entrapped Activated Sludge: Adjustment of Utilization Conditions" ด้วยวาจา (Oral Presentation) ในการประชุมทางวิชาการ 2012 3rd International Conference on Chemical Engineering and Applications-CCEA 2012 ในระหว่างวันที่ 27 ถึง 28 ตุลาคม 2555 ณ Regal Riverside Hotel เมืองฮ่องกง ประเทศจีน

ดิฉันมีความประสงค์ขออนุมัติเงินสนับสนุน เพื่อนำเสนอบทความทางวิชาการดังกล่าวเป็นจำนวนเงินตามที่จ่ายจริงแต่ไม่เกิน 40,000 บาท (สี่หมื่นบาทถ้วน) ซึ่งดิฉันได้แนบเอกสารประกอบการพิจารณาโดย ได้แก่ 1) โครงการประชุมวิชาการระดับนานาชาติเพื่อเสนอผลงานวิจัย 2) จดหมายตอบรับร่วมประชุม 3) รายละเอียดของการประชุม และ 4) บทความฉบับสมบูรณ์ มาพร้อมกันนี้

จึงเรียนมาเพื่อโปรดพิจารณา

(ผศ.ดร.สุมนา สิริพัฒนานกุล)

อาจารย์ประจำภาควิชาวิศวกรรมเคมี

เรียน รองคณบดีฝ่ายวิจัย

เรียน คณบดี

เรียน รองคณบดี

เรียน รองคณบดีฝ่ายกิจการพิเศษ

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

เรียน ผศ.ดร.สุมนา สิริพัฒนานกุล

โครงการประชุมวิชาการระดับนานาชาติเพื่อเสนอผลงานวิจัย

1. ชื่องานประชุม 2012 3rd International Conference on Chemical Engineering and Applications (27 ถึง 28 ตุลาคม 2555)
2. สถานที่ เมืองฮ่องกง ประเทศจีน
3. ผู้ขอรับทุน ผศ.ดร.สุมนา สิริพัฒนานุกุล อาจารย์ประจำภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์

4. หลักการและเหตุผล

ตามที่ Asia-Pacific Chemical, Biological & Environmental Engineering Society (APCBEES) ได้จัดการประชุมทางวิชาการ ได้จัดการประชุมทางวิชาการ 2012 3rd International Conference on Chemical Engineering and Applications ในระหว่างวันที่ 27 ถึง 28 ตุลาคม 2555 ณ Regal Riverside Hotel เมืองฮ่องกง ประเทศจีน ผศ.ดร.สุมนา สิริพัฒนานุกุล ได้ส่งผลงานวิจัยและได้รับการตอบรับให้นำเสนอบทความ “Municipal Wastewater Treatment Using Barium Alginate Entrapped Activated Sludge: Adjustment of Utilization Conditions” ด้วยวจา การนำเสนอผลงานดังกล่าวเป็นการเผยแพร่ความรู้ทางด้านการพัฒนานวัตกรรมทางด้านวิศวกรรมสิ่งแวดล้อมเพื่อการบำบัดน้ำเสีย รวมทั้งเป็นการแลกเปลี่ยนความรู้และสร้างเครือข่ายนักวิจัยในระดับนานาชาติ ตลอดจนเป็นการสร้างชื่อเสียงให้กับมหาวิทยาลัยและประเทศไทย

5. วัตถุประสงค์ของโครงการ

- เพื่อเผยแพร่ผลงานวิจัยเรื่อง Municipal Wastewater Treatment Using Barium Alginate Entrapped Activated Sludge: Adjustment of Utilization Conditions
- เพื่อเข้าร่วมแลกเปลี่ยนความรู้จากวิทยากรผู้เชี่ยวชาญอื่น เพื่อส่งเสริมพัฒนาผลงานวิจัย
- เพื่อศึกษาเรียนรู้วิทยาการสมัยใหม่ เพื่อใช้พัฒนาศักยภาพงานวิจัยและงานสอนต่อไป

6. ระยะเวลาดำเนินงาน

ระยะเวลารวม 6 วัน (รวมวันเดินทางตั้งแต่มหาวิทยาลัยอุบลราชธานี) ระหว่างวันที่ 25 ตุลาคม พ.ศ. 2555 ถึง 30 ตุลาคม พ.ศ. 2555

7. ประโยชน์ที่คาดว่าจะได้รับ

- ได้มีโอกาสเผยแพร่ผลงานวิจัย คณะวิศวกรรมศาสตร์ และมหาวิทยาลัยต่อนักวิชาการจากนานาชาติ
- ได้มีโอกาสเผยแพร่ผลงานวิจัยและแลกเปลี่ยนองค์ความรู้ระหว่างนักวิจัยจากประเทศต่าง ๆ
- ได้มีโอกาสเพิ่มพูนความรู้ทางด้านการจัดการสิ่งแวดล้อมจากงานประชุมนี้

8. สรุปกำหนดการเดินทาง

วัน/เดือน/ปี	กำหนดการ
25/10/2555	เดินทางออกจาก ม.อบ. ถึง กรุงเทพฯโดยรถทัวร์
26/10/2555	เดินทางออกจาก กรุงเทพฯ ถึง ชื่องกง
27-28/10/2555	เข้าร่วมการประชุมและนำเสนอผลงาน
29/10/2555	เดินทางออกจาก ชื่องกง ถึง กรุงเทพฯ
30/10/2555	เดินทางออกจาก กรุงเทพฯ ถึง ม.อบ.โดยรถทัวร์

9. งบประมาณ

ประมาณการค่าใช้จ่ายการนำเสนอผลงานวิจัย

รายการ	จำนวนเงิน (บาท)
1. ค่าเดินทาง	
1.1 ค่ารถไฟเส้นทางในประเทศ อบ.-กท.-อบ.	1,500
1.2 ค่าเครื่องบินเส้นทางระหว่างประเทศ กท.-ชื่องกง-กท.	10,000
1.3 ค่าเดินทางภายในต่างประเทศ (ตามที่จ่ายจริง)	3,000
1.4 ค่าเดินทางระหว่างบ้านพักถึงสนามบินในประเทศ	600
2. ค่าลงทะเบียนประชุม (480 USD)	15,360
3. ค่าที่พักในต่างประเทศ (3 วัน) (ตามที่จ่ายจริง)	15,000
4. ค่าเบี้ยเลี้ยง	
4.1 ค่าเบี้ยเลี้ยงในประเทศ (2 วัน, 25 และ 30 ตุลาคม 2555)	480
4.2 ค่าเบี้ยเลี้ยงระหว่างวันที่ 26-29 ตุลาคม 2555 (4 วัน)	8,400
รวม	54,340

อัตราแลกเปลี่ยน 1USD = 32 บาท

ทั้งนี้อาจเดินทางด้วยสายการบินอื่นหากมีราคาต่ำกว่าการบินไทยมากกว่าร้อยละ 30

(ศ.ดร.สุมนา สิริพัฒนากุล)

อาจารย์ประจำภาควิชาวิศวกรรมเคมี
คณะวิศวกรรมศาสตร์ มหาวิทยาลัยอุบลราชธานี



Address: Room5, 6/F., Shun On Commercial Building, 112-114 Des Voeux Road, Central, Hong Kong, Email: admin@cbees.org
Tel: 00852-30697291

Notification of Acceptance of the CCEA 2012 (Round III)

27-28, October, 2012, Hong Kong

<http://www.cbees.org/ccea/>



Paper ID : E00013

Paper Title : Municipal Wastewater Treatment Using Barium Alginate Entrapped Activated Sludge:
Adjustment of Utilization Conditions

Dear Sumana Siripattanakul-Ratpukdi and Thitiporn Tongkliang,

First of all, thank you for your concern. 2012 3rd International Conference on Chemical Engineering and Applications – CCEA 2012 (Round I) review procedure has been finished. We are delighted to inform you that your manuscript has been accepted for presentation at International Conference on Chemical Engineering and Applications – CCEA 2012, Hong Kong. Your paper was tripling blind-reviewed and, based on the evaluations. The reviewers' comments are enclosed.

The conference received papers from about 8 different countries and regions during the submission period. And there are about 94 papers accepted by our reviewers who are the international experts from all over the world. The selected papers could be published in our conference proceeding with high quality. According to the recommendations from reviewers and technical program committees, we are glad to inform you that your paper identified above have been selected for publication and oral presentation. You are invited to present your paper and studies during our CCEA 2012 conference that would be held on 27-28, October, 2012, Hong Kong.

The CCEA 2012 is sponsored by Asia-Pacific Chemical, Biological & Environmental Engineering Society (APCBEES), so it has been listed in the APCBEES Conference Calendar.

APCBEES was founded in 2007. Asia-Pacific Chemical, Biological & Environmental Engineering Society is an independent, nonprofit research and development organization. Its previous name of APCBEES was Asia-Pacific Environmental Consulting Center. The Service can be traced back to the first work in 1999. Every year, APCBEES will Co-organize several important conferences with other universities, organizations all over the world, the conference proceedings of these conferences will be indexed top indexing services, and the selected papers will be published in the Journals. APCBEES is also involved in two International Journals with International Association of Computer Science and Information Technology (IACSIT). More information and conferences please browse the website: www.cbees.org.



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The CCEA 2012 papers will be published in proceedings, and all the papers will be published in the International Journal of Chemical Engineering and Applications (IJCEA, ISSN:2010-0221), and all papers will be included in the Engineering & Technology Digital Library, and indexed by EBSCO, WorldCat, Google Scholar, and sent to be reviewed by Ei Compendex and ISI Proceedings.

One Excellent Paper will be selected from each oral session. The Certificate for Excellent Papers will be awarded in the Welcome Banquet on October 28, 2012.

(Important Steps for your registratoion): Please do finish all the 6 steps on time to guarantee the paper published in the proceeding successfully:

1. Revise your paper according to the Review Comments in the attachment carefully. (Five authors at most each paper)

2. Format your paper according to the Template carefully.

http://www.cbees.org/ccea/IJCEA_template.doc (DOC Format)

3. Download and complete the Registration Form.

<http://www.cbees.org/ccea/IJCEA.Reg.doc> (English)

4. Finish the payment of Registration fee. (The detailed information can be found in the Registration form)

<http://www.cbees.org/ccea/IJCEA.Reg.doc> (English)

5. Finish the Copyright Form

<http://www.cbees.org/ccea/IJCEA.Copyright.doc>

6. Send your final papers (both .doc and .pdf format), filled registration form (.doc format), and copyright form (.jpg format) to us at ccea@cbees.org (Before September 15, 2012) (Very important)

CCEA 2012 will check the format of all the registered papers first, so the authors don't need to upload the paper to the system. After the registration, we will send all qualified papers to the publish house and index organization for publishing directly.

We are looking forward to meet all the authors in our conference. But if you and your co-author(s) could not attend CCEA 2012 to present your paper for some reasons, please inform us. And we will send you the official receipt of registration fee, proceedings and/or other materials after CCEA 2012 free of charge.

Please strictly adhere to the format specified in the conference template while preparing your final paper. If you have any problem, please feel free to contact us via ccea@cbees.org. For the most updated information on the conference, please check the conference website at <http://www.cbees.org/ccea/>. The Conference Program will be available at the website in Late September, 2012.

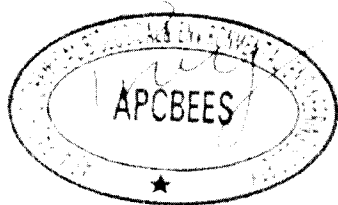


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Again, congratulations. I look forward to seeing you in Hong Kong.

Yours sincerely,

CCEA 2012 Organizing Committees



<http://www.cbees.org/ccea/>
Hong Kong


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CCEA 2012

2012 3rd International Conference on Chemical Engineering and Applications

October 27-28, 2012 Hong Kong



Homepage

Call For Papers

The 2012 3rd International Conference on Chemical Engineering and Applications (CCEA 2012) is the premier forum for the presentation of technological advances and research results in the fields of Chemical Engineering and Applications. CCEA 2012 will bring together leading engineers and scientists in Chemical Engineering and Applications from around the world.

Important Dates

Paper Submission

Deadline: August 5, 2012

CCEA 2012 has been listed in the CBEES Conference Calendar. ([Click](#))

Venue

Topics of interest for submission include, but are not limited to:

Chemical, Environmental, and Process Engineering

Environmental engineering and sustainable development

Process design and optimization

Product innovation, development and economics

Process intensification

Nanotechnology

New materials & structured products

Intelligent polymers

Green organic synthesis routes

Process integration

Environmental engineering & management

Sustainable & clean technologies

Sponsors

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Proceedings

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Tech. Sponsorship



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SCF as solvent substitutes

Chemistry and Chemical Engineering Fundamentals

Chemical engineering fundamentals

Physical, Theoretical and Computational Chemistry

Chemical engineering educational challenges and development

Chemical reaction engineering

Chemical engineering equipment design and process design

Thermodynamics

Catalysis & reaction engineering

Particulate systems

Rheology

Multifase flows

Interfacial & colloidal phenomena

Transport phenomena in porous/granular media

Membranes and membrane science

Crystallization

Distillation, absorption and extraction

Ionic liquids/electrolyte solutions

Multi-scale and/or Multi-disciplinary Approaches

Process system, instrumentation and control

Product engineering and product development

Product design & innovation

Nanomanufacturing

Controlled release of the active ingredient

Energy & nuclear sciences

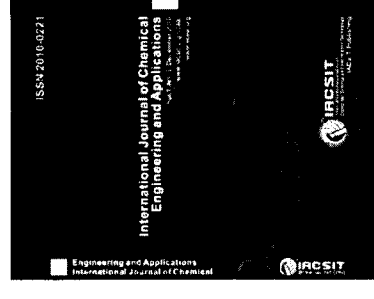
Energy and environment

CFD & chemical engineering

Food engineering

Nanomaterials

Particle technology



International Journal of
Chemical Engineering and
Applications

(IJCEA, ISSN:2010-0221)

Proceedings indexed by



Mathematical modeling in chemical engineering
Macromolecular Science and Engineering
Advanced materials processing

Systematic Methods and Tools for Managing the Complexity

Multiscale modeling
Process synthesis & design
Process control & operations
Process Safety Management
Supply chain management & business decision support
Advances in computational & numerical methods
Safety & risk management systems
Systems biology
Economics and Business Management
Process Analytical Technology - PAT
Software architecture, standards and interfaces

Integration of Life Sciences & Engineering

Biochemical Engineering
Biotechnology
Product Engineering in the Bio Industries
Self-organisation in the Bio-sciences and elsewhere
Delivery of the final product
Biotechnology applied to production of new and better quality food
Physical chemistry and thermodynamics for life sciences and biotechnology
Improvement of environmental remediation processes
Food process technology and engineering
The impact of bio-based polymeric materials
Biochemical and bio-molecular engineering
Bioengineering and biomedical engineering
Biological and Medicinal Chemistry
Energy and environment

Forest product processing
Milk product processing

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One Excellent Paper will be selected from each oral session. The Certificate for Excellent Papers will be awarded in the Welcome Banquet on October 28, 2012.

Important Date

Last Round

Paper Submission (Full Paper)	Before August 5, 2012
Notification of Acceptance	On August 25, 2012
Final Paper Submission	Before September 15, 2012
Authors' Registration	Before September 15, 2012
CCEA 2012 Conference Dates	October 27-28, 2012

SUBMISSION METHODS:

Formatting Instructions (DOC)

1. Electronic Submission System; (.pdf)

If you can't login the submission system, please try to submit through method 2.

2. Email: ccea@cbees.org (.pdf and .doc)



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2012 3rd International Conference on Chemical Engineering and Applications October 27-28, 2012 Hong Kong



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Committees

Conference Chairs

Senior Environmental Scientist, Mr. Saji Baby, Wataniya Environmental Services, Kuwait
Parvinder Singh Sandhu, Rayat & Bahra Institute of Engineering & Bio-Technology, India

Technical Program Chairs

Emine Seydametova, Faculty of Chemical and Natural Resources Engineering, University Malaysia
Anoop Singh, Technical University of Denmark

Eblisam Kamal Mohamed Heikel, Egyptian Petroleum research institute, Egypt

Steering Chairs

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Xiaoxia Yin, The University of Adelaide, Australia
Wu Chunliang, Guangdong Ocean University, China

Technical Committee

Paper Submission

Deadline: August, 5, 2012

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Calendar. (Click)

Tech. Sponsorship



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 Nguyen Phuc Thanh, Solid Waste Management Research Center, Okayama University,
 Japan

Other Conferences

Mir Mehrdad Mirsanjari, Malayer University, Malayer, Iran

Saji George, Piramal life science, India

Aparna Kalawate, Indian Plywood Industries Research & Training Institute, India

Zeeshan Nawaz, FLOTU, Tsinghua University, Beijing 100086, China

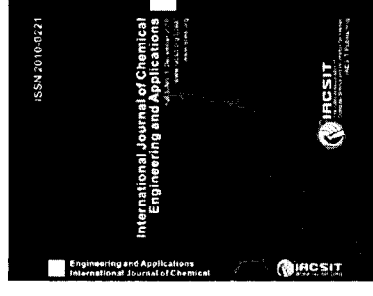
Asim Kumar Jana, Department of Biotechnology, National Institute of Technology, India

Falode Olugbenga Adebajo, University of Ibadan, Nigeria

Mukul Chandra Bora, Dibrugarh Polytechnic, India

Farhad Nejadkoorki, Yazd University, Iran

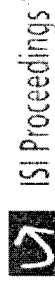
Vijay kumar singh, Department of Zoology, Agra College, Agra, India

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	Registration Fee
Authors (CCEA Reviewers)*	400USD
Authors (APCBEES Member) *:	430 USD
Authors (Student)*	430 USD
Authors (Non Member)*	480 USD
Listeners:	300 USD
Invited Speaker	Free

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Additional Paper (s)**	320 USD
Additional Page	60 USD/ One Page
Extra Proceeding	50 USD

* One regular registration can cover a paper within FIVE pages, including all figures, tables, and references.

** One regular registration with one or more additional papers has only one proceeding book.

*** For the authors who have difficulties to pay US Dollars, such as Iran, please pay Euros as: 1 Euro = 1.25 USD

**** If you would like to register the conference and publish your paper as the reviewer, please send email to review@cbees.org. (Only Ph.D holder can apply)

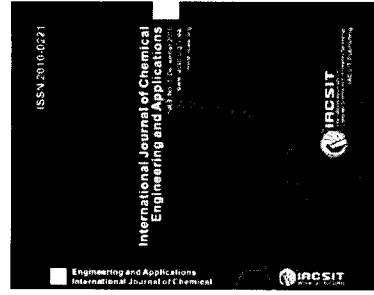
Good News! All authors can join the APCBEES for free right now, then you can register the conference as "CBEES Member"(430 USD). Please visit the following website for more information. (<http://www.cbees.org/member.htm>)

AUTHORS REGISTRATION FEE INCLUDES:

- Participation in the technical program
- Lunch
- Dinner
- Badge
- Conference bag and/or conference accessories
- Conference document (proceedings on book)
- Coffee breaks
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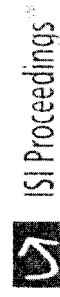
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Municipal Wastewater Treatment Using Barium Alginate Entrapped Activated Sludge: Adjustment of Utilization Conditions

Sumana Siripattanakul-Ratpukdi and Thitiporn Tongkliang

Abstract—The objective of this research is to treat municipal wastewater by barium alginate (BA)-entrapped activated sludge. This study divided into 2 parts including 1) adjustment of operating conditions for municipal wastewater treatment by the BA-entrapped cells in batch experiment and 2) utilization of the BA-entrapped cells in sequencing batch experiment. In the batch experiment, optimization of cell entrapment preparation condition (cell-to-matrix (BA) ratios of 1:5, 1:10, and 1:20 by volume), determination of optimum dissolved oxygen (DO) concentration (DOs of 2, 4, and 6 mg/L), and determination of optimum entrapped cell loading (1,000, 3,000, and 5,000 mg dry cells/L) were performed. The result showed that the cell-to-matrix ratio, DO concentration, and cell loading of 1:10, 6 mg/L, and 1,000 mg/L, respectively performed highest treatability (COD removal of 47-86%). In the sequencing batch mode experiment, the free and BA-entrapped activated sludge reactors operated for 30 runs were performed and microscopically observed. The entrapped cells could treat wastewater for 54% while the free cells treated wastewater of 33%. The micro-structural observation indicated that the BA-entrapped cells slightly damaged after utilization and numerous microbial cells perforated all over the matrix.

Index Terms—Barium alginate, cell entrapment, cell-to-matrix ratio, cell loading, dissolved oxygen, municipal wastewater.

I. INTRODUCTION

It is generally known that biological treatment by suspended activated sludge is a basic process for municipal wastewater treatment. The process with the suspended cells is efficient but a few drawbacks of the process are also concerned. Washed-out of the suspended activated sludge during the treatment process was previously reported [1-2]. Also, inactivation of the suspended microbial cells by environmental stresses, such as contamination of toxic substances in the systems was found [3].

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Cell entrapment, cell immobilization in a porous polymeric matrix, has been applied to lessen the problems [4-5]. The cell entrapment technique was successfully applied for both municipal and industrial wastewater treatment applications [3,6]. Typical polymers used as an entrapment matrix including calcium alginate, carragenan, polyvinyl alcohol, and cellulose triacetate were reported [3].

Calcium alginate is the most utilized entrapment matrix in environmental applications [3-4]. This is due to calcium alginate is a natural polymer which is non-toxic to microorganisms and environment. However, based on prior studies, calcium alginate was not durable [3,7]. The matrix produced by calcium alginate likely to break or swell during use affecting lower wastewater treatment performance. Barium alginate (BA) entrapment was developed and applied to solve the problem [8-10]. It was found that the BA-entrapped cells well performed and were durable in environmental pressures. However, most previous studies focused on utilization of the BA-entrapped cells for treating different types of wastewater [8,10]. Thus far, there is no publication emphasizing on operating factors related to performance of the wastewater treatment by the BA-entrapped cells.

The aim of this study is to treat municipal wastewater by the barium alginate (BA)-entrapped activated sludge. The work included determination of optimum wastewater operating condition for the BA-entrapped cells and demonstration of the wastewater treatment by the BA-entrapped cells in sequencing batch reactor (SBR) experiment. In addition, scanning electron microscopic (SEM) observation was performed along with the wastewater treatment for insight information.

II. MATERIALS AND METHODS

A. Wastewater Source and Characteristics

Wastewater from university cafeteria was obtained (Ubon Ratchathani, Thailand). The wastewater characteristics were as shown in Table I.

B. Activated Sludge Cultivation

Activated sludge was cultivated and acclimated using commercial synthetic medium in a 30-L reactor for 2 months before use in the experiments. The reactor was operated in sequencing batch reactor (SBR) mode with hydraulic and solid retention times of 1 and 30 days, respectively. Dissolved oxygen concentration of higher than 1 mg/L was continuously maintained.

TABLE I: WASTEWATER CHARACTERISTICS

Parameter	Range
Biochemical Oxygen Demand	260-760 mg/L
Chemical Oxygen Demand (COD)	360-840 mg/L
Suspended solids (SS)	155-400 mg/L
Total kjeldahl nitrogen	198-243 mg/L
Ammonia-nitrogen (as N)	Not detectable
Nitrate-nitrogen (as N)	0.14-0.58 mg/L
pH	5.53-6.38

C. Free and BA-Entrapped Cell Preparation

To prepare the cell for the experiment, 1,000 mL of the activated sludge from the 30-Liter reactor was centrifuged at 7,000 rpm for 10 min to obtain concentrated cells. The concentrated cells were vigorously re-suspended in 10 mL of sterile de-ionized water (DI). The re-suspended cells were used for the free activated sludge (described below) and also for preparing the entrapped cells.

For the entrapped cell preparation, sodium alginate (Fluka, Singapore) was dissolved into sterile DI to prepare a sodium alginate solution at a concentration of 3% (w/v). The re-suspended activated sludge as prepared above was uniformly mixed with the sodium alginate solution. The cell-matrix mixture contents (cell-to-matrix ratios) are described in Table II. The mixture was manually dropped into a calcium chloride solution of 5% (w/v) using a sterile syringe to form spherical beads with a size of 3-5 mm. The beads remained in the solution for 2 h for hardening.

TABLE II: DESCRIPTIONS OF REACTORS IN BATCH EXPERIMENT

Reactor	Cell-to-matrix ratio*	DO (mg/L)	Final cell loading in reactor (mg SS/L)
<i>Optimization of entrapment matrix preparation</i>			
F-CTM1:00	1:00	6	1,000
E-CTM1:05	1:05	6	1,000
E-CTM1:10	1:10	6	1,000
E-CTM1:20	1:20	6	1,000
<i>Optimization of DO concentration</i>			
E-DO2	Selected ratio	2	1,000
E-DO4	from previous	4	1,000
E-DO6	experiment	6	1,000
<i>Optimization of entrapped cell loading</i>			
E-1000	Selected ratio	Selected	1,000
E-3000	from previous	concentration from	3,000
E-5000	experiment	previous experiment	5,000

* mL of cells : mL of BA

D. Batch Experiment

In the batch experiment, optimization of entrapment preparation condition (cell-to-matrix (BA) ratios of 1:5, 1:10, and 1:20 by volume), determination of optimum dissolved oxygen (DO) concentration (DOs of 2, 4, and 6 mg/L), and determination of optimum entrapped cell loading (1,000, 3,000, and 5,000 mg dry cells/L) were focused. Description of the reactors used in the experiment was as shown in Table II. All experiments were triplicate.

The obtained wastewater of 400 mL and the free or entrapped cells were filled in the reactors. All reactors were aerated for 8 hr. The wastewater samples (10 mL) were taken at one-hour interval for the entire experiment to measure

soluble COD. The wastewater treatment kinetics and the wastewater treatment efficiencies were determined.

E. Sequencing Batch Experiment

Triplicate experiments of SBR for the free and BA-entrapped activated sludge operated for 30 runs was demonstrated. The entrapped cell preparation and operating conditions were followed the optimum conditions based on the results from the batch experiment. Each cycle took 10 hr and included five periods of the traditional SBR cycle: 1) fill of 0.25 hr, 2) react of 8 hr, 3) settle of 1 hr, 4) draw of 0.50 hr, and 5) idle of 0.25 hr. Influent and effluent samples from each cycle were taken for soluble COD measurement. The entrapped cells before used (cycle no. 0) and after used at cycle no. 10 and 30 were observed using SEM.

F. Analytical Procedures

All parameters were measured according to standard methods [11]. After filtering water sample using GF/C filter glass paper, SS (solids retained on the filter paper) was measured. The soluble COD was measured by potassium dichromate digestion method.

For SEM observation, the entrapped cell beads were rinsed in 5% BaCl₂ solution for five times (15 min each) and fixed in a solution containing 2.5% glutaraldehyde at 4°C for 6 d. After that, the samples were rinsed in 5% BaCl₂ solution for three times (20 min each). The beads were undergone dehydration process by storing the beads in five ethanol solutions (30%, 50%, 70%, 90%, and absolute ethanol) for 20 min each, consecutively. The dehydrated beads were critical point dried with liquid carbon dioxide as a transitional fluid (Balzers, CPD 020, Liechtenstein). After that, the beads were cut and coated with gold using a Balzers SCD 040 sputter coater, and examined using a scanning electron microscope (JEOL, JSM-5410LV, Tokyo, Japan).

III. RESULTS AND DISCUSSION

A. Batch Experiment

Optimization of entrapment matrix preparation

Aim of this section is to investigate the optimum condition of cell entrapment preparation. Four reactors with activated sludge prepared differently (free cells and BA-entrapped cells at the cell-to-matrix ratios of 1:5, 1:10, and 1:20 by volume designated F-CTM1:00, E-CTM1:05, E-CTM1:10, and E-CTM1:20, respectively) were tested. Fig. 1 presents the normalized COD remaining of the wastewater during the tests for 8 hr. The COD values continually decreased for entire of the experiment. At the end of the experiments (8 hr), COD remained 45, 25, 18, and 37% in F-CTM1:00, E-CTM1:05, E-CTM1:10, and E-CTM1:20 reactors, respectively. The COD removal kinetics in this case followed the first order kinetic reaction with the rate constants of 0.10-0.22 1/hr (Table III).

During this experiment, control tests which were only the BA matrices (no activated sludge) were also tested. These reactors were performed to determine effect of the BA matrix adsorption. The COD remaining in the control test was quite stable for entire of the experiment (data not shown). This

clearly indicated that COD adsorption onto the BA matrices was not significant. The COD removal in this study was biological removal by activated sludge. This observation was similar to a previous study which reported insignificant adsorption of organic contaminant by the entrapment matrices [12]. The above results suggested that the BA-entrapped cells (COD removal of 63-82%) obviously performed better than the free cells (COD removal of 51%) as presented in Table III. This is because the entrapped cells generally tolerate and acclimate better than the free cells resulting higher wastewater treatment efficiency [4, 12-13].

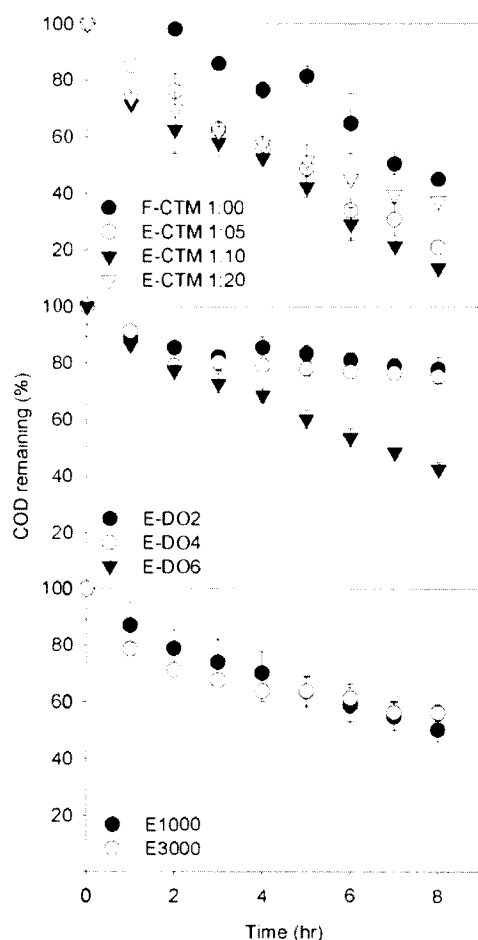


Fig. 1. Normalized COD remaining in the batch experiment.

For comparison of the cell entrapment preparation conditions, the cell-to-matrix ratios apparently influenced the treatment performance. In this study, the entrapped cells prepared at the cell-to-matrix ratio of 1:10 provided the best COD removal. Too high ratio (1:5) could lead to too high cell density inside the matrices resulting in not enough space for cells to grow. On the other hand, too low ratio (1:20) could limit substrate diffusion through the matrices. This result was similar to prior works which the entrapped cell preparation condition affecting wastewater treatment was stated [12-13]. However, the optimum entrapped cell preparation condition may not conclude for all cases since there are co-factors influencing wastewater treatment performance, such as wastewater characteristics, microbial species, and reactor operations. The precise entrapped cell preparation condition

should be carried out for case by case.

TABLE III: COD REMOVAL KINETICS

Reactor	COD removal (%)	COD removal kinetics		
		Equation*	R ²	Rate constant (hr ⁻¹)
<i>Optimization of entrapment matrix preparation</i>				
F-CTM1:00	54.90	Y = -0.10X+4.75	0.90	0.10
E-CTM1:05	75.07	Y = -0.19X+4.68	0.97	0.19
E-CTM1:10	82.38	Y = -0.22X+4.65	0.94	0.22
E-CTM1:20	62.75	Y = -0.11X+4.50	0.97	0.11
<i>Optimization of DO concentration</i>				
E-DO2	22.22	Y = -0.02X+4.54	0.78	0.02
E-DO4	24.71	Y = -0.03X+4.52	0.71	0.03
E-DO6	57.60	Y = -0.10X+4.59	0.99	0.10
<i>Optimization of entrapped cell loading</i>				
E-1000	46.81	Y = -0.08X+4.56	0.99	0.08
E-3000	43.78	Y = -0.06X+4.46	0.85	0.06

* Y = ln COD and X = time (hr)

Optimization of DO concentration

This section is to investigate the optimum DO concentration for wastewater treatment by the BA-entrapped cells (at the ratio of 1:10). Three reactors designated E-DO2, E-DO4, and E-DO6 (DOs of 2.1-2.3, 3.7-4.5, and 6.0-6.6 mg/L, respectively) were tested. Fig. 1 presents the normalized COD remaining of the wastewater during the tests for 8 hr. The COD values continually decreased for entire of the experiment. At the end of the experiments (8 hr), COD remained 88, 75, and 43% in E-DO2, E-DO4, and E-DO6 reactors, respectively. The COD removal kinetics followed the first order kinetic reaction with the rate constants of 0.02-0.10 1/hr (Table III).

The results clearly indicated that DO played an important role on wastewater treatment by the BA-entrapped cells. Based on the results of E-DO2 and E-DO4, the COD removal efficiencies (22-25%) were similar whereas the COD removal efficiency of almost 60% was found in E-DO6. The result suggested that optimum DO concentration for wastewater treatment by the BA-entrapped cells were 6 mg/L.

It is known that DO is a major factor influencing wastewater treatment performance by suspended activated sludge. In traditional (suspended) activated sludge, DO of 2 mg/L is sufficient. For the entrapped cells, structure of the cells is dense net of matrices. This limits the oxygen diffusion resulting in higher DO concentration required.

Optimization of entrapped cell loading

This section is to investigate the optimum BA-entrapped cell loading for wastewater treatment. Three reactors designated E-1000, E-3000, and E-5000 (which represented the reactors with cell masses of 1,000, 3,000, and 5,000 mg dry cells/L, respectively) were tested. Note that the E-5000 reactor contained too much of the BA-entrapped cells which caused the mixing and aeration problems. The E-5000 reactor was not continued for the experiment.

Fig. 1 presents the normalized COD remaining of the wastewater during the tests for 8 hr. The COD values continually decreased for entire of the experiment. At the end of the experiments (8 hr), COD remained 55 and 54% in E-1000 and E-3000 reactors, respectively. The COD removal kinetics followed the first order kinetic reaction with the rate

constants of 0.06–0.08 1/hr (Table III).

The results showed that BA-entrapped cell loading slightly influenced wastewater treatment. Normally, the cell loading should obviously affect the treatment efficiency. Higher cell loading should provide better wastewater treatment efficiency. But in this study, E-1000 performed slight better than E-3000. This could be because the reactors contained a number of the BA-entrapped cells (also a number of the matrices) had mixing and aeration problems decreasing the treatment performance. The result suggested that the optimum BA-entrapped cell loading for the wastewater treatment were 1,000 mg/L.

B. Sequencing Batch Experiment

Performance of entrapped and free cell systems

In this section, the experiment was conducted to compare long term performance (30 cycles) between the BA-entrapped and free cells in SBR. Fig. 2 presents the COD remaining in the systems (FC_{inf} and EC_{inf} are the influent of the free and entrapped cell reactors while FC_{eff} and EC_{eff} are the effluent of the free and entrapped cell reactors). Average COD of the influent of the reactor was 612 ± 18 mg/L (average \pm standard deviation). The treatment efficiencies by both systems were quite stable. The BA-entrapped cells could remove COD for $54 \pm 2\%$ while the free cells treated COD of $33 \pm 2\%$.

The results showed that the BA-entrapped cells had higher treatment performance compared to those of the free cells. Moreover, the BA-entrapped cell system was stable. Therefore, the BA-entrapped cells are promising to apply for municipal wastewater treatment.

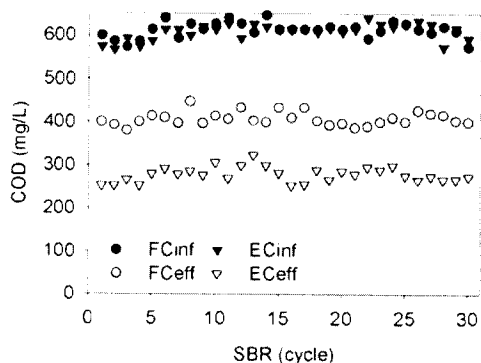


Fig. 2. COD of influents (FC_{inf} and EC_{inf}) and effluents (FC_{eff} and EC_{eff}) in the SBR experiment.

Microscopic observation of the entrapped cells

The microstructures of the BA-entrapped cells were investigated by SEM (Fig. 3). In Fig. 3a, the BA-entrapped cells before use, a dense network contained abundant fine pores was observed. The dense cross-linking was network of barium and alginate. The SEM image supported the results in earlier sections. Numerous pores could limit DO diffusion resulting high required DO in the system with the entrapped cells.

After use, the SEM images indicated that the BA-entrapped cells were slight abrasion during use (Fig. 3b

and Fig. 3c). The macro-pores inside the matrices were observed. This could be from gases produced from the aerobic wastewater treatment process, such as carbon dioxide. Moreover, the macro-pores locating at the center of the entrapped cells were noticed. This should be from inner layer of the entrapped cells are not as strong as the outer layer resulting in damage (pore) taking place at the inner layer. Basically, barium and alginate cross-linking reaction begins at the outer layer of the entrapped cell droplets to form beads. Then, barium ion passes through the beads. The limitation of diffusion may cause the difficulty of barium transport which results in lower reaction and bead strength at the inner layer of the beads. However, based on the SEM image of the entrapped cells after use for up to 30 cycles, the outer layer of the entrapped cells was not damaged. Therefore, this indicated that the BA-entrapped cells were durable.

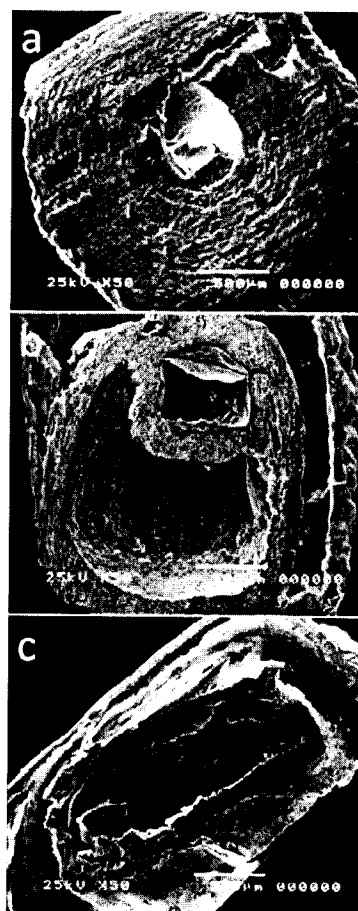


Fig. 3. SEM images of the cross-sectional BA-entrapped cells at $50\times$ (a) before use, (b) after use for 10 cycles, and (c) after use for 30 cycles.

Wastewater treatment by the calcium alginate-entrapped cells was previously reported [7]. In the previous study, the entrapped cells used for only 4 cycles were obviously damaged. This indicated that the BA-entrapped cells were much stronger than the calcium alginate-entrapped cells.

Fig. 4a presents the cells occupied inside the BA matrix at the beginning (before use). After use, numerous cells proliferated in the alginate matrices (Fig. 4b). These SEM results suggested that the BA matrices were durable and the cells inside the matrices well grew and successfully performed wastewater treatment. Hence, the BA-entrapped

cells are potential for real wastewater treatment applications.

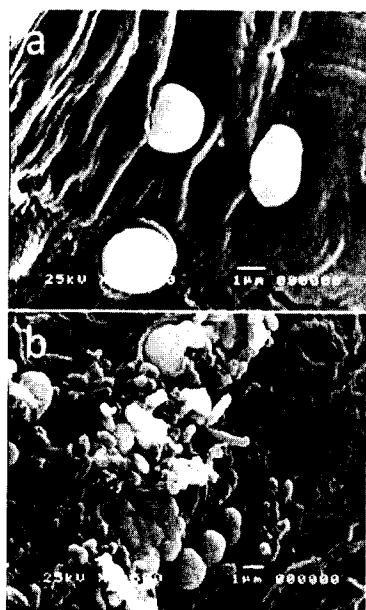


Fig. 4. SEM images of the microbial cells at 7,500 \times (a) before use, (b) after use for 10 cycles.

IV. CONCLUSION

The BA-entrapped cells are potential for treating municipal wastewater. The entrapped cell preparation condition, DO, and cell loading affected the treatment performance. The wastewater treatment kinetics followed the first-order reaction mechanism. In sequencing batch mode, the BA-entrapped cells (COD removal of 54%) performed better than the free cells (COD removal of 33%). After use for 30 cycles, the BA-entrapped cells were slightly damaged. For future work, change of microbial community of the entrapped cells during wastewater treatment should be performed.

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BIOGRAPHIES



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