



# 2016 Report



Welcome to the 2016 Annual Report of Environmental Biotechnology & Bioenergy Laboratory (EBBL).

In the past year, we added several new members: two PhD students, six MS students and four visiting scholars. We also hosted visiting students from Chile and Spain, and REU students from USC and UT Austin. Our 2016 graduates included two PhD, one MS and three undergraduates. As always, I hope the EBBL experience will benefit their future career and wish them the best luck!

We have had an extremely productive year with publishing 29 journal papers, including 4 papers in *Water Research*. That's a new record for EBBL. Another new record: two undergraduate researchers (Hayden Tse and Michelle Xiang) published their first journal paper as the first author! Several research projects are highlighted at the end of this report.

Syed Md Iskander, a PhD student of EBBL, has received several scholarships in 2016, including a full scholarship of the 2015-2016 SWIS-ISWA Competition on Sustainable Waste Management Essay, the Jaqueline Shields Memorial Scholarship from Air and Waste Management Association, and a 2016 EREF Doctoral Scholarship from Environmental Research and Education Foundation. He was also a member of our ECi competition team that won the 2<sup>nd</sup> place (other members were Akshay Jain and Shiqiang Zou).

EBBL dominated the student competition at the 2016 WaterJAM in Virginia Beach. Our members have won the first places in all the categories: 1<sup>st</sup> place of oral presentation in Water (Qingyun Ping), 1<sup>st</sup> place of oral presentation in Wastewater (Mohan Qin), 1<sup>st</sup> place of poster competition in Water (Qingyun Ping), 1<sup>st</sup> place of poster competition in Wastewater (Shiqiang Zou), and 1<sup>st</sup> place of student design competition (the team members included Katherine Olso, Ke Li, and Pranav Sai Shanker Sampara).

I am excited about what we have accomplished in 2016 and look forward to working with all of you in 2017!



A handwritten signature in black ink, which appears to read "Zhen He".

Zhen (Jason) He  
Associate Professor  
Director of EBBL  
Virginia Tech

**2016 New Members**

**Lu Guan** joined EBBL as a MS student. She came from Michigan State University, where she obtained her BS degree in environmental engineering. She is working on nitrate removal in microbial fuel cells.



**Akshay Jain** joined EBBL as a MS student first and then converted to a PhD student in fall 2016. He is working on bioenergy production from food wastes supported by VT ICTAS Energy and Material Initiative.



**Dr. Weizhou Jiao**, a Professor of Chemical Engineering at North University of China, joined us as a visiting scholar. Dr. Jiao's work focuses on high gravity technology for wastewater treatment.



**Ke Li** joined EBBL as a MS student. Prior to VT, she completed her undergraduate study in Environmental Science at Nankai University. She is working on desalination using microbial fuel cells.



**Xingjian Liu** started his study as a PhD student in August, 2016. Previously he completed a MS degree in Civil Engineering at Virginia Tech and a BS degree in Civil Engineering at Georgia Tech. He is working on anammox treating recalcitrant wastewater such as landfill leachate.



**Pranav Sai Shanker Sampara** joined EBBL as a MS student after completing his undergraduate study in civil engineering at Jawaharlal Nehru Technological University – Hyderabad. He is working on algal-MFC systems.



**Dr. Tongchai Sriwiriyarat**, Associate Professor of Environmental Engineering at Burapha University, Thailand, joined us as a visiting scholar. Tongchai is a Hokie alumnus and works on wastewater treatment.



**Jing Wang** joined EBBL as a MS student. She received her BS degree in Environmental Engineering from Nanjing University of Technology. She is working on new draw solutes for forward osmosis.



**Zhenyu Wu** joined EBBL as a MS student. He received his BS degree in New Energy Engineering and Science from Zhejiang University. He is working on microbial desalination cells and phosphorus recovery.



**Pengyu Yan** joined EBBL as a MS student. He received his BS degree in Environment Science from Tianjin University. He is working on new catalysts for microbial fuel cells.



**Simiao Wu** joined EBBL as a visiting PhD student supported by CSC. She is currently a PhD student in Municipal Engineering at Shanghai University (China). Her research interest is in resource recovery from landfill leachate.



**Dr. Changqing Liu**, Associate Professor of Chemical Engineering at Fujian Normal University, China, joined us as a visiting scholar. Dr. Liu is interested in research of microbial electrolysis cells.

**Short-term Members (< 6 months)**

**Anibal Aguilera** is a MS student at Austral University of Chile and has spent four months at EBBL working on microbial fuel cells treating salmon wastes. He was also involved in building a new design of MECs.



**Erin Hynes** came from University of Texas Austin and participated in a 10-week NSF REU program at Virginia Tech. She worked with Mohan on resource recovery.



**Elena Lopez** came from University of Southern California and participated in a 10-week NSF REU program at Virginia Tech. She worked with Heyang on resource recovery.



**Isabel San Martín** is a PhD student the University of León, Spain, and has spent three months with us working on microbial electrolysis cells.



**Xiaoran Ma** is a CEE undergraduate student and spent one semester at EBBL working on anammox. She was also a member of our team that won the 3<sup>rd</sup> place on NEWT Water Technology competition at Rice University.

**2016 Alumni**

**Jian Li** completed his PhD study at EBBL and graduated in May 2016 with a thesis on membrane bioelectrochemical reactors. He is a postdoc at Rice University now. He just got married! Congrats!



**Qingyun Ping** completed her PhD study at EBBL and graduated in December 2016. She was working on microbial desalination cells. She is relocated to Charlotte for reunion with her husband.



**Hayden Tse** completed his research work on membrane photobioreactor as an undergraduate researcher. He has published one journal article as the first author and was an active member in several competitions.



**Xiaoxue (Michelle) Xiang** completed her research work on forward osmosis as an undergraduate researcher. She has published one journal article as the first author, and is preparing for application to graduate schools.

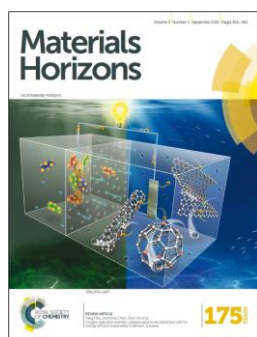
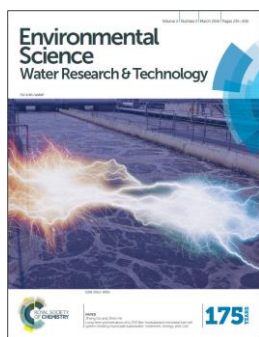


**Xuhui Zeng** received his MS degree in May 2016. He was working on nutrient removal from animal wastewater. He is working as a part time engineer in wastewater treatment at a consulting company.



**Qingying Zha** completed her research work on nitrification of leachate as an undergraduate researcher. She was also a member of our team that won the 3<sup>rd</sup> place on NEWT Water Technology competition at Rice University.

## Journal Papers



\* Corresponding author  
# Equal contribution

- Luo, S. and He, Z.\* (2016) Ni-coated carbon fiber as an alternative cathode electrode material to improve cost efficiency of microbial fuel cells. *Electrochimica Acta*. Vol 222, pp 338-346.
- Zhao, L.,# Li, J.,# Battaglia, F.\* and He, Z.\* (2016) Computational investigation of the flow field contribution to improve electricity generation in granular activated carbon - assisted microbial fuel cells. *Journal of Power Sources*. Vol 333, pp 83-87.
- Qin, M., Abu-Reesh, I.M. and He, Z.\* (2016) Effects of current generation and electrolyte pH on reverse salt flux across thin film composite membrane in osmotic microbial fuel cells. *Water Research*. Vol 105, pp 583-590.
- Ping, Q., Abu-Reesh, I.M. and He, Z.\* (2016) Enhanced boron removal by electricity generation in a microbial fuel cell. *Desalination*. Vol 398, pp 165-170.
- Yuan, H., Miller, J.H., Abu-Reesh, I.M., Pruden, A. and He, Z.\* (2016) Effects of electron acceptors on removal of antibiotic resistant *Escherichia coli*, resistance genes and class 1 integrons under anaerobic conditions. *Science of the Total Environment*. Vol 569-570, pp 1587-1594.
- Ping, Q., Abu-Reesh, I.M. and He, Z.\* (2016) Mathematical modeling based evaluation and simulation of boron removal in bioelectrochemical systems. *Science of the Total Environment*. Vol 569-570, pp 1380-1389.
- Zou, S., Yuan, H., Childress, A.\* and He, Z.\* (2016) Energy consumption by recirculation: a missing parameter when evaluating forward osmosis. *Environmental Science & Technology*. Vol 50, pp 6827-6829. (Viewpoint)
- Tse, H., Luo, S., Li, J. and He, Z.\* (2016) Coupling microbial fuel cells with a membrane photobioreactor for wastewater treatment and bioenergy production. *Bioprocess and Biosystems Engineering*. Vol 39, pp 1703-1710.
- Li, J., Luo, S. and He, Z.\* (2016) Cathodic fluidized granular activated carbon assisted-membrane bioelectrochemical reactor for wastewater treatment. *Separation and Purification Technology*. Vol 169, pp 241-246.
- Lu, Y., Abu-Reesh, I.M. and He, Z.\* (2016) Treatment and desalination of domestic wastewater for water reuse in a four-chamber microbial desalination cell. *Environmental Science and Pollution Research*. Vol 23, pp 17236-17245.
- Yang, Y., Li, X., Yang, X. and He, Z.\* (2016) Membrane aeration as an energy-efficient method for supplying oxygen to microbial fuel cells. *RSC Advances*. Vol 6, pp 49787-49791.
- Rao, G., Brastad, K.S., Zhang, Q., Robinson, R., He, Z. and Li, Y. \* (2016) Enhanced disinfection of *E. coli* and bacteriophage MS 2 in water using a silver and copper loaded titanium dioxide nanowire membrane. *Frontiers of Environmental Science and Engineering*. 10(4):11.
- Yuan, H., Hou, Y.,\* Abu-Reesh, I.M., Chen, J.\* and He, Z.\* (2016) Oxygen reduction reaction catalysts in microbial fuel cells for energy-efficient wastewater treatment: a review. *Materials Horizons*. Vol 3, pp 382-401. (Inside Front Cover)
- Zou, S. and He, Z.\* (2016) Enhancing wastewater reuse by forward osmosis with self-diluted commercial fertilizers as draw solutes. *Water Research*. Vol 99, pp 234-243.
- Li, X., Sun, S., Badgley, B.D. and He, Z.\* (2016) Long-term performance and microbial community characterization of an osmotic anammox system for removing reverse-fluxed ammonium. *Bioresource Technology*. Vol 211, pp 628-635.
- Zhao, L.,# Li, J.,# Battaglia, F.\* and He, Z.\* (2016) Investigation of multiphysics in tubular microbial fuel cells by coupled computational fluid dynamics with multi-order Butler-Volmer reactions. *Chemical Engineering Journal*. Vol 296, pp 377-385.
- Liu, Y.,# Qin, M.,# Luo, S., He, Z.\* and Qiao, R.\* (2016) Understanding ammonium transport in bioelectrochemical systems towards its recovery. *Scientific Reports*. 6: 22547.
- Li, X., Sun, S., Badgley, B.D., Sung, S., Zhang, H. and He, Z.\* (2016) Nitrogen removal by granular nitrification - anammox in an upflow membrane-aerated biofilm reactor. *Water Research*. Vol 94, pp 23-31.
- Ge, Z. and He, Z.\* (2016) Long-term performance of a 200-L modularized microbial fuel cell system treating municipal wastewater: treatment, energy and cost. *Environmental Science: Water Research & Technology*. Vol 2, pp 274-281. (Inside Front Cover)
- Qin, M., Maza, W.A., Stratakes, B., Ahrenholtz, S.R., Morris, A.J.\* and He, Z.\* (2016) Nanoparticulate Ni(OH)<sub>2</sub> films synthesized from macrocyclic nickel(III) cyclam for hydrogen production in microbial electrolysis cells. *Journal of The Electrochemical Society*. Vol 163, pp F437-F442.

21. Luo, S.,# Sun, H.,# Ping, Q., Jin, R.\* and He, Z.\* (2016) A review of modeling bioelectrochemical systems: engineering and statistical aspects. *Energies*. 9: 111.
22. Luo, S.,# Guo, W.,# Neelson, K.H., Feng, X.\* and He, Z.\* (2016) 13C pathway analysis for the role of formate in electricity generation by *Shewanella Oneidensis* MR-1 using lactate in microbial fuel cells. *Scientific Reports*. 6: 20941.
23. Hou, Y.,# Yuan, H.,# Wen, Z., Cui, S.,Guo, X., He, Z.\* and Chen, J.\* (2016) Nitrogen-doped graphene/CoNi alloy encased within bamboo-like carbon nanotube hybrids as cathode catalysts in microbial fuel cells. *Journal of Power Sources*. Vol 307, pp 561-568.
24. Yuan, H., Abu-Reesh, I.M. and He, Z.\* (2016) Mathematical modeling assisted investigation of forward osmosis as pretreatment for microbial desalination cells to achieve continuous water desalination and wastewater treatment. *Journal of Membrane Science*. Vol 502, pp 116-123.
25. Iskander, S., Brazil, B., Novak, J. and He, Z.\* (2016) Resource recovery from landfill leachate using bioelectrochemical systems: opportunities, challenges, and perspectives. *Bioresource Technology*. Vol 201, pp 347-354.
26. Li, J., Rosenberger, G. and He, Z.\* (2016) Integrated experimental investigation and mathematical modeling of a membrane bioelectrochemical reactor with an external membrane module. *Chemical Engineering Journal*. Vol 287, pp 321-328.
27. Li, J. and He, Z.\* (2016) Development of a dynamic mathematical model for membrane bioelectrochemical reactors with different configurations. *Environmental Science and Pollution Research*. Vol 23, pp 3897-3906.
28. Qin, M., Molitor, H., Brazil, B., Novak, J. and He, Z.\* (2016) Recovery of nitrogen and water from landfill leachate by a microbial electrolysis cell - forward osmosis system. *Bioresource Technology*. Vol 200, pp 485-492.
29. Ping, Q., Porat, O., Dosoretz, C.\* and He, Z.\* (2016) Bioelectricity inhibits back diffusion from the anolyte into the desalinated streams in microbial desalination cells. *Water Research*. Vol 88, pp 266-273.
- Flux across Thin Film Composite Membrane in Osmotic Microbial Fuel Cells. 3rd Meeting of the North American branch of the ISMET. October 5-7, 2016, Stanford, CA.
3. Heyang Yuan\*, Jennifer H. Miller, Ibrahim M. Abu-Reesh, Amy Pruden, and Zhen He. Effects of Electron Acceptors on the Removal of Antibiotic Resistant Bacteria and Resistance Genes in Bioelectrochemical Systems. 3rd Meeting of the North American branch of the ISMET. October 5-7, 2016, Stanford, CA.
4. Mohan Qin\* and Zhen He. Osmotic Microbial Fuel Cells: A New Approach to for Wastewater Treatment, Clean Water Extraction and Bioelectricity Generation. 2016 WaterJAM. September 12-15, 2016, Virginia Beach, VA.
5. Qingyun Ping\* and Zhen He. Sustainable brackish water desalination and wastewater treatment in microbial desalination cells: experimental investigation and mathematical modeling. . 2016 WaterJAM. September 12-15, 2016, Virginia Beach, VA.
6. Mohan Qin and Zhen He.\* Sustainable Ammonia Recovery from Wastewater by Using Bioelectrochemical Systems. Residuals and Biosolids Conference. April 3-6, 2016, Milwaukee, WI.
7. Hayden Tse\*, Shuai Luo and Zhen He. Development of an Algal-membrane Reactor as Post-treatment for Microbial Fuel Cells Treating Municipal Wastewater. The 30th Anniversary National Conference on Undergraduate Research. April 4-7, 2016, Asheville, NC.

## Presentations

### \*Presenter

1. Zhen He\*. Resource Recovery from Wastewater by Using Bioelectrochemical Systems: Status, Perspectives and Challenges. Invited lecture at Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. September 20, 2016, Beijing, China.
2. Mohan Qin\*, Ibrahim M. Abu-Reesh, Zhen He. Effects of Bioelectricity Generation and Electrolyte pH on Reverse Salt



**EBBL Outdoor Research Facility**

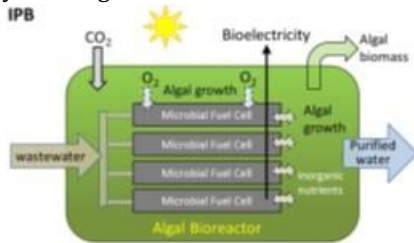
A new research facility has been established at the parking lot of Duck Pond. It was designed for hosting large-scale reactors that can sample the domestic wastewater through the manhole next to it. Several projects are being planned to set up testing systems in this facility, including mainstream anammox, a microbial desalination cell system, and a constructed wetland-algae system.

This facility was made possible with the financial support from ICTAS, CEE department, and Dr. He's startup fund. We appreciate the great help from Julie Petruska and Vickie Mouras!



**New Algal Projects**

We have started a new NSF project aiming to develop an integrated photobioelectrochemical (IPB) through collaboration with Drs. Erica Young and John Berges at University of Wisconsin – Milwaukee. We will also start another collaboration of IPB development with Dr. Samuel Morton of James Madison University, funded by a 4-VA grant.



**Hokies Won!**

Virginia Tech Football team won the ACC Coastal Division Title and the Commonwealth Cup. Let's go Hokies!

Seriously, is this really EBBL progress?



Who cares? We beat UVA for 13 straight years!



**Metabolic Pathway**

We have collaborated with Dr. Xueyang Feng of VT BSE to apply <sup>13</sup>C to study metabolic pathway of *Shewanella Oneidensis* MR-1. Our finding shows that lactate is mainly metabolized to support the cell growth, and formate is oxidized to release electrons for higher electricity generation.



**ICTAS Projects**

Dr. He is leading a research thrust of Food, Energy and Water in the newly formed Energy and Material Initiative supported by ICTAS. The team consists of researchers from CEE, ME, BSE, and FST.

Dr. He is initiating research collaboration with North Carolina Agricultural and Technical State University, a historically black college, supported by an ICTAS Diversity and Inclusion Seed Grant.

### Syed Won Multiple Scholarships!



Syed Md Iskander, a PhD student at EBBL, has won several scholarships in 2016.

- He received a full scholarship of the 2015-2016 SWIS-ISWA Competition on Sustainable Waste Management Essay, and attended the SWIS-ISWA Winter School 2016 in Texas.
- He received the Jaqueline Shields Memorial Scholarship (\$4,000) from Air and Waste Management Association.
- He was selected as a 2016 EREF Doctoral Scholar with a scholarship of \$14,400 per year by Environmental Research and Education Foundation.

He was also a member of the ECi competition team. Congratulations!

Syed Md Iskander, Akshay Jain and Shiqiang Zou, three EBBL PhD students, won the 2nd place (\$3,000) in the 2016 Environmental Challenge International (ECi) competition at the A&WMA conference in New Orleans.



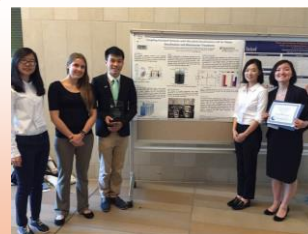
Hayden Tse, an undergraduate researcher, won the 3rd place in the Undergraduate Research poster on the 6th CEE Research Day. He also published a first-author journal paper, creating a record for EBBL as the first “undergraduate first author”.



### EBBL Dominated 2016 WaterJAM

The EBBL members have won the first place in all the student competitions at WaterJAM 2016, Virginia Beach:

- Qingyun Ping, an EBBL PhD student, won the poster competition in Water category (\$1,000) and will represent VA section on ACE 2017. She also won the first place in oral presentation in Water category (\$500);
- Shiqiang Zou, an EBBL PhD student, won the poster competition in Wastewater category (\$1,000);
- Mohan Qin, an EBBL PhD student, won the first place in oral presentation in Wastewater category (\$500);
- The VT team, consisting of three EBBL students (Katherine Olson, Ke Li, and Pranav Sai Shanker Sampara), won the first place in the Water Challenge.



Five EBBL undergraduate researchers won the 3rd place and People's Choice Award on NEWT Global Water Technologies Competition at Rice University, Houston, TX.

The iWaste team by four EBBL members competed on the 8th annual Global Entrepreneurship Challenge Semifinals organized by VT KnowledgeWorks.

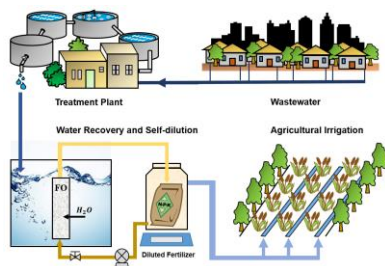


Dr. He and Shiqiang were featured as the Inventors of the Month by VT Intellectual Properties.

Dr. He was selected as one of Top 10 reviewers in 2016 for *Environmental Science: Water Research & Technology*.

### Fertilizer Draw Solute for FO

Using fertilizers as draw solutes in forward osmosis (FO) can accomplish wastewater reuse with elimination of recycling draw solute. In this study, three commercial fast-release all-purpose solid fertilizers (F1, F2 and F3) were examined as draw solutes in a submerged FO system for water extraction from either deionized (DI) water or the treated wastewater. Systematic optimizations were conducted to enhance water extraction performance, including operation modes, initial draw concentrations and in-situ chemical fouling control. Under the active layer facing the feed (AL-F or FO) mode, a maximum of 324 mL

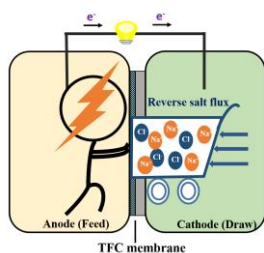


water was harvested using 1-M F1, which provided 41% of the water need for fertilizer dilution for irrigation. Among the three fertilizers, F1 containing less urea content was the most favored because of a higher water extraction and a lower reverse solute flux (RSF) of major nutrients. Using the treated wastewater as a feed solution resulted in a comparable water extraction performance (317 mL) to that of DI water in 72 h and a maximum water flux of 4.2 LMH. Phosphorus accumulation on the feed side was mainly due to the FO membrane solute rejection while total nitrogen and potassium accumulation was mainly due to RSF from the draw solute. Reducing recirculation intensity from 100 to 10 mL min<sup>-1</sup> did not obviously decrease water flux but significantly reduced the energy consumption from 1.86 to 0.02 kWh m<sup>-3</sup>. These results have demonstrated the feasibility of using commercial solid fertilizers as draw solutes for extracting reusable water from wastewater, and challenges such as reverse solute flux will need to be further addressed.

Further reading: Zou, S. and He, Z.\* (2016) Enhancing wastewater reuse by forward osmosis with self-diluted commercial fertilizers as draw solutes. *Water Research*. Vol 99, pp 234-243.

### Bioelectricity Inhibits RSF

Osmotic microbial fuel cells (OsMFCs) take advantages of synergy between forward osmosis (FO) and microbial fuel cells (MFCs) to accomplish wastewater treatment, current generation, and high-quality water extraction. As an FO based technology, OsMFCs also encounter reverse salt flux (RSF) that is the backward transport of salt ions across the FO membrane into the treated wastewater. This RSF can reduce water flux, contaminate the treated wastewater, and increase the operational expense, and thus must be properly addressed before any possible applications. In this study, we aimed to understand the effects of current generation and electrolyte pH

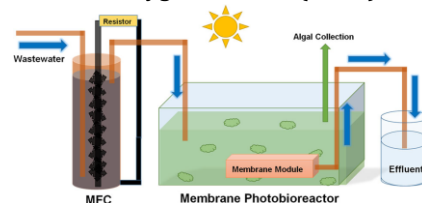


on RSF in an OsMFC. It was found that electricity generation could greatly inhibit RSF, which decreased from  $16.3 \pm 2.8$  to  $3.9 \pm 0.7$  gMH when the total Coulomb production increased from 0 to 311 C. The OsMFC exhibited  $45.9 \pm 28.4\%$  lower RSF at the catholyte pH of 3 than that at pH 11 when  $40 \Omega$  external resistance was connected. The amount of sodium ions transported across the FO membrane was 18.3-40.7% more than that of chloride ions. Ion transport was accomplished via diffusion and electrically-driven migration, and the theoretical analysis showed that the inhibited electrically-driven migration should be responsible for the reduced RSF. These findings are potentially important to control and reduce RSF in OsMFCs or other osmotic-driven processes.

Further reading: Qin, M., Abu-Reesh, I.M. and He, Z.\* (2016) Effects of current generation and electrolyte pH on reverse salt flux across thin film composite membrane in osmotic microbial fuel cells. *Water Research*. Vol 105, pp 583-590.

### Photo-Membrane Bioreactor + MFCs

Microbial fuel cells (MFCs) and membrane photobioreactors are two emerging technologies for simultaneous wastewater treatment and bioenergy production. In this study, those two technologies were coupled to form an integrated treatment system, whose performance was examined under different operating conditions. The coupled system could achieve 92-97% removal of soluble chemical oxygen demand (SCOD), and nearly 100% removal of ammonia. Extending the hydraulic retention time (HRT) of the membrane photobioreactor to



3.0 d improved the production of algal biomass from  $44.4 \pm 23.8$  mg L<sup>-1</sup> to  $133.7 \pm 12.9$  mg L<sup>-1</sup> (based on the volume of the treated water). When the MFCs were operated in a loop mode, their effluent (which was the influent to the algal reactor) contained nitrate and had a high pH, leading to the decreased algal production in the membrane photobioreactor. Energy analysis showed that the energy consumption was mainly due to the recirculation of the anolyte and the catholyte in the MFCs, and decreasing the recirculation rates could significantly reduce energy consumption. The energy production was dominated by indirect electricity generation from algal biomass. The highest energy production of 0.205 kWh m<sup>-3</sup> was obtained with the highest algal biomass production, resulting in a theoretically positive energy balance of 0.033 kWh m<sup>-3</sup>. Those results have demonstrated that the coupled system could be an alternative approach for energy-efficient wastewater treatment and using wastewater effluent for algal production.

Further reading: Tse, H., Luo, S., Li, J. and He, Z.\* (2016) Coupling microbial fuel cells with a membrane photobioreactor for wastewater treatment and bioenergy production. *Bioprocess and Biosystems Engineering*. Vol 39, pp 1703-1710.



Dr. Zhen (Jason) He  
Durham Hall, RM 403  
1145 Perry St.  
Blacksburg, VA 24060  
Office phone: 540-231-1346  
Email: [zhenhe@vt.edu](mailto:zhenhe@vt.edu)

EBBL  
Hancock Hall, RM 204 & 206  
490 Old Turner St.  
Blacksburg, VA 26040  
Lab webpage: [www.ebbl.cce.vt.edu](http://www.ebbl.cce.vt.edu)

