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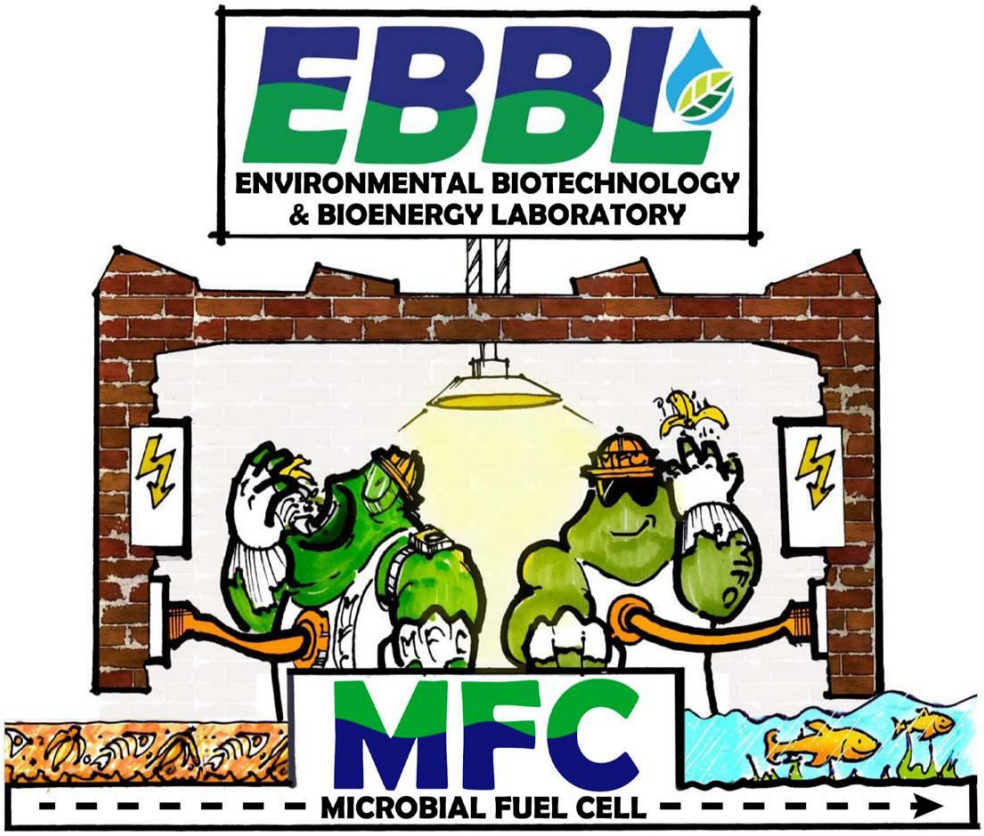
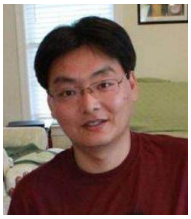


2015 Report



If you are wondering what those fingers on my right shoulder are …. They are from my boy Kevin.

Welcome to the first annual report of the Environmental Biotechnology & Bioenergy Laboratory (EBBL)!

The idea behind creating such a report is to better communicate with the EBBL members, alumni, collaborators, and friends, for what's going on in the EBBL. The core value of the EBBL is its people. In 2015, we had several new members including two PhD students, three undergraduate researchers and one visiting PhD student. Three special new members arrived in 2015, Jim Li's daughter – Anna Li, Ping's daughter – Charlotte Li, and my son – Hovin He. Welcome! We also had a few alumni: one PhD and three MS students graduated, one undergraduate researcher completed her REU, and one postdoc concluded his research. I hope the EBBL experience will benefit their future career, and best luck to their next step!

We have had a very productive year with publishing 25 journal papers, which place us among the most active research teams in microbial electrochemistry and technology. Several research projects are highlighted at the end of this report.

The EBBL sent a large team consisting of nine people to the 2015 WaterJAM in Virginia Beach, and helped create a great presence of Virginia Tech in this important water event of Virginia. We have also presented on the major conferences such as WEFTEC, ISMET 2015, and AEESP meeting. Jian Li made a trip to Israel in summer and met with our collaborators at Israel Technion.

Our work and people have been well recognized. Mohan Qin, a PhD student of the EBBL, received 2015 Innovation Award for Best Technological Advancement from the ISEMT. The award was based on her work and publication that created synergy between microbial electrolysis cells and forward osmosis through ammonia recovery and application as a draw solute. Several other EBBL members received awards/fellowships, and the story of our participation in the Big Pitch competition was reported by the campus newspaper Collegiate Times.

I am thrilled to have had a great 2015 and would like to continue working with all of you in the coming year. I wish evervone a wonderful 2016!

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

2015 New Members

Yu Dong joined in the EBBL as an undergraduate student researcher. He is a junior in Civil Engineering at Virginia Tech, and will be working with Jim Li on anammox.

Syeed MD Iskander, a PhD student starting in August 2015, came from Washington State University, where he obtained his MS degree in Environmental Engineering. Prior to that, he completed his undergraduate study in Civil Engineering at Bangladesh University of Engineering and Technology. He will work on resource recovery from landfill leachate.

Hannah Molitor participated in a NSF REU program at Virginia Tech and conducted her summer research with Mohan on resource recovery from landfill leachate using microbial electrolysis cells and forward osmosis. She is an undergraduate student in Environmental Engineering at University of Wisconsin – Platteville.

Xiaoxue (Michelle) Xiang joined in the EBBL as an undergraduate student researcher. She is a junior in Civil Engineering at Virginia Tech, and will be working with Shiqiang Zou on forward osmosis.

Yuli Yang joined the EBBL as a visiting PhD student in September, 2016. She is currently a PhD student in Municipal Engineering at Southeast University (China). Her research interest lies in nitrogen removal via biological treatment such as nitrification/denitrification and anammox. She will work on anammox – related research in the EBBL.

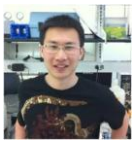
Shiqiang Zou started his study as a PhD student in August, 2015. Previously he completed a MS degree in Chemistry at National University of Singapore and a MS degree in Environmental Engineering at Peking University. His undergraduate study was in Environmental Engineering at Beijing Institute of Technology. At EBBL, he will work on membrane bioreactors for sustainable wastewater treatment.

Special New Members

The EBBL welcome three newborns in 2015: Anna Qianhe Li (left), Hovin Yushi He (middle), and Charlotte X. Li (right).

2015 Alumni

Abdullah Alammar received his MS degree in May 2015. He was working on MDC technology and economical analysis of microbial desalination. After MS study, he continues to work as an engineer at Saudi Arabian Oil Company.

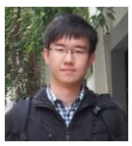


Zheng Ge completed his PhD study in the EBBL and graduated in December 2015. He was working on microbial fuel cell technology with a focus on system scaling up. He has published seven first-author journal papers and coauthored a few other papers. He plans to be an engineer in wastewater industry.

Kaivalya Kulkarni received his MS degree in May 2015. He was working on chromium removal using microbial desalination cells. He is actively searching a position in water/wastewater treatment and environmental consulting.

Dr. Yaobin Lu completed his postdoc work in the EBBL and returned to China in May 2015. He then joined in Sun Yat-Sen University as a research fellow. While in the EBBL, Dr. Lu was working on several projects including osmotic MBR and MDCs. He published four journal papers as first or co-first authors in journals such as *ES&T* and *JMS*.

Hannah Molitor completed her REU program and returned to University of Wisconsin – Platteville. Although her research stay was short, she has made great progress and participated in a journal paper published in *Bioresource Technology* as the second author. We hope to see her again at Virginia Tech.



Bojun Xu received his MS degree in May 2015. He was working on constructed wetland – microbial fuel cell system for sustainable wastewater treatment. He published one journal paper as the first author during his MS study. He is currently an intern at Suez Environment, Richmond, VA.

Alumni updates

Dr. Fei Zhang, the first PhD graduate of the EBBL, has accepted a position of engineer at AO Smith and relocated to Milwaukee to start his new career and life.

* Corresponding author
# Equal contribution

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2. Xiao, L., Young, E. B., Grothjan, J. J., Lyon, S., Zhang, H. and He, Z.* (2015) Wastewater treatment and microbial community in an integrated photo-bioelectrochemical system affected by different wastewater algal inocula. ***Algal Research***. Vol 12, pp 446-454.
3. Li, X.,# Lu, Y.# and He, Z.* (2015) Removal of reverse-fluxed ammonium by anammox in a forward osmosis system using ammonium bicarbonate as a draw solute. ***Journal of Membrane Science***. Vol 495, pp 424-430.
4. Ping, Q., Abu-Reesh, I. and He, Z.* (2015) Boron removal from saline water by a microbial desalination cell integrated with Donnan dialysis. ***Desalination***. Vol 376, pp 55-61.
5. Lu, Y. and He, Z.* (2015) Mitigation of salinity buildup and recovery of wasted salts in a hybrid osmotic membrane bioreactor - electrodialysis system. ***Environmental Science & Technology***. Vol 49, pp 10529-10535.
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7. Yuan, H.,# Lu, Y.,# Abu-Reesh, I. and He, Z.* (2015) Bioelectrochemical production of hydrogen in an innovative pressure retarded osmosis - microbial electrolysis cell system: experiments and modeling. ***Biotechnology for Biofuels***. 8: 116.
8. Ge, Z.,# Wu, L.,# Zhang, F. and He, Z.* (2015) Energy extraction from a large-scale microbial fuel cell system treating municipal wastewater. ***Journal of Power Sources***. Vol 297, pp 260-264.
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11. Surajbhan, S., Yuan, H., He, Z. and Abu-Reesh, I.* (2015) Microbial desalination cells as a versatile technology: functions, optimization and perspective. ***Desalination***. Vol 371, pp 9-17.
12. Li, J., Zhu, Y., Zhuang, L., Otsuka, Y., Nakamura, M., Goodell, B.,* Sonoki, T.* and He, Z.* (2015) A novel approach to recycle bacterial cultural waste for fermentation reuse via a microbial fuel cell - membrane bioreactor system. ***Bioprocess and Biosystems Engineering***. Vol 38, pp 1795-1802.
13. Yuan, H. and He, Z.* (2015) Integrated membrane filtration into bioelectrochemical systems as next generation energy-efficient wastewater treatment technologies for water reclamation: a review. ***Bioresource Technology***. Vol 195, pp 202-209.
14. Ci, S., Wen, Z., Mao, S., Hou, Y., Cui, S., He, Z. and Chen, J.* (2015) One pot synthesis of high-performance Co/graphene electrocatalysts for glucose fuel cells free of enzymes and precious metals. ***Chemical Communications***. Vol 51, pp 9354-9357.
15. Guo, W.,# Luo, S.,# He, Z.* and Feng, X.* (2015) 13C pathway analysis of biofilm metabolism of Shewanella oneidensis MR-1. ***RSC Advances***. Vol 5, pp 39840-39843.
16. Ge, Z. and He, Z.* (2015) An effective dipping method for coating activated carbon catalysts on the cathode electrodes of microbial fuel cells. ***RSC Advances***. Vol 5, pp 36933-36937.
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19. Li, J. and He, Z.* (2015) Optimizing a membrane bioelectrochemical reactor using anion exchange membrane for wastewater treatment. ***Environmental Science: Water Research & Technology***. Vol 1, pp 355-362.
20. Yuan, H., Abu-Reesh, I. and He, Z.* (2015) Enhancing desalination and wastewater treatment by coupling microbial desalination cells with forward osmosis. ***Chemical Engineering Journal***. Vol 270, pp 437-443.
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23. Yuan, H. and He, Z.* (2015) Graphene-modified electrodes for enhancing the performance of microbial fuel cells. ***Nanoscale***. Vol 7, pp 7022-7029.
24. Song, Y., Xiao, L., Jayamani, I., He, Z. and Cupples, A.M.* (2015) A novel method to characterize bacterial communities affected by carbon source and electricity generation in microbial fuel cells using stable isotope probing and illumina sequencing. ***Journal of Microbiological Methods***. Vol 108, pp 4-11.
25. Jacobson, K. S., Kelly, P. and He, Z.* (2015) Energy balance affected electrolyte recirculation and operating modes in microbial fuel cells. ***Water Environment Research***. Vol 87, pp 252-257.

- Dr. He was invited to attend a workshop organized by Department of Energy in Washington D.C., March 2015, and presented "Synergy between membranes and microbial fuel cells".
- Dr. He presented "Recovering ammonium bicarbonate to achieve wastewater treatment and reuse in a microbial electrolysis cell – forward osmosis coupled system" on 2015 Water and Energy in Washington D.C., June 2015.
- Dr. He was invited to participate in the Intensification of Resource Recovery (IR^2) Forum in August 2015 at Manhattan College, New York City.
- Dr. He presented "Improving wastewater reuse using self-supplied ammonium draw solute in a coupled microbial electrolysis cell forward osmosis system" on the 2015 WEFTEC in Chicago, September 2015.
- Dr. He presented "When bioelectrochemical systems meet forward osmosis: accomplish wastewater treatment and reuse through synergy" on the 5th ISMET meeting at Arizona State University, October 2015.
- Dr. He was invited to attend the 4th International Conference on Environmental Simulation and Pollution Control at Tsinghua University, Beijing, November 2015.
- Dr. He visited Renmin University of China and North University of China in November, 2015.




Jian (Jim) Li visited Israel Institute of Technology (Technion) in August 2015, as a part of our collaborative MDC project funded by Binational Agricultural Research and Development Fund (BARD).

The EBBL members attended 2015 WaterJAM in Virginia Beach. We had great presence on the meeting with four oral presentations, seven poster presentations, and one participant in the Student Water Challenge. The presentations covered a wide range of the research subjects in the EBBL, including anammox, microbial fuel cells, microbial desalination cells, membrane bioreactors, and forward osmosis.

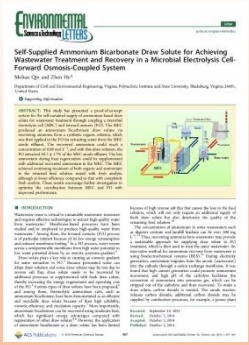

Four EBBL members, Mohan, Shuai, Katherine and Hayden, participated in BIG Pitch Competition organized by Ocean Exchange in Savannah, GA. They were competing with the teams from Stanford, Georgia Tech, Cornell, and CU Boulder. They entry was about resource recovery from sustainable wastewater treatment through cooperation between microbial electrolysis cells and forward osmosis.


- Mohan Qin and Heyang Yuan delivered oral presentations about ammonia recovery and osmotic bioelectrochemical systems on the 2015 AEESP conference at Yale University.
- Shuai Luo presented a poster of algal bioreactors integrated with microbial fuel cells on 2015 Water Resources Conference of the Virginias in West Virginia.
- Qingyun Ping presented a poster about brackish water desalination in MDCs on the 2015 NC-AWWA-WA meeting in Raleigh, NC.

2015 Innovation Award for Best Technological Advancement

Mohan Qin received 2015 Innovation Award for Best Technological Advancement from the International Society for Microbial Electrochemistry and Technology (ISMET). Her award was based on a paper published in 2014:

Qin, M. and He, Z.* (2014) Self-supplied ammonium bicarbonate draw solute for achieving wastewater treatment and recovery in a microbial electrolysis cell - forward osmosis coupled system. ***Environmental Science & Technology Letters.*** Vol 1, pp 437-441.



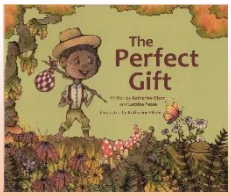
Dr. He accepted this award on behalf of her (and also a plaque for the adviser) on the 2015 ISMET meeting at Arizona State University in October, 2015.

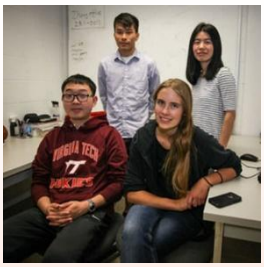
- Syeed Iskander received the Pratt Fellowship from Department of Civil and Environmental Engineering.
- Shiqiang Zou received the Curry Fellowship from Department of Civil and Environmental Engineering.
- Xuhui Zeng participated in a team winning the 2nd place in Water Competition on 2015 WaterJAM.
- Zheng Ge received a Sussman Award for supporting his summer intern at CHA consulting company.
- Xiaoxue (Michelle) Xiang received a Stantec Award for Excellence in Engineering.

Heyang Yuan received the award of poster competition in the category of wastewater on 2015 WaterJAM and a $1,000 prize. This is recognition for his great work in the EBBL and an outstanding productivity with six first-author journal papers in his first year and half of the PhD study.

Hayden Tse received the Undergraduate Student Award from Division of Environmental Chemistry of the American Chemical Society. He also won the 2015 VWEA Undergraduate Scholarship with a $2,000 prize.

Katherine Olson published a children's story book. This is an unusual achievement for a science student. She is working towards her first journal publication as the first author.



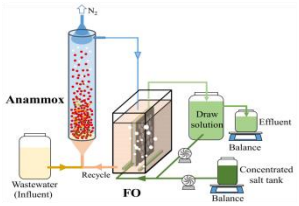


Our team of the four, Mohan, Katherine, Shuai, and Hayden, participated in a "Reclaim is…" video competition organized by University of South Florida, and won the 3rd runner up with their entry "Reclaiming is to recover nutrient, energy and water: All in One by MEC-FO". Their video can be accessed on Youtube: https://www.youtube.com/watch?v=4ks8ZWLAZEc

This team of the four also made into the finalist of the BIG Pitch Competition, hosted by Georgia Southern University's Business Innovation Group. Although they didn't get the grant prize of $10,000, their work received a wide attention. Their story was reported by Virginia Tech campus newspaper "Collegiate Times": http://www.collegiatetimes.com/news/tech-researchers-compete-for-in-the-big-pitch-competition/article_b039e9e4-7054-11e5-ac44-a72dadfe787d.html

Osmotic Anammox

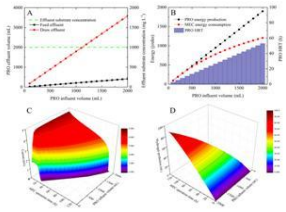
Reverse flux of ammonium draw solute is a serious problem for applying forward osmosis (FO) in water/wastewater treatment. In this study, anaerobic ammonium oxidization (anammox) was synergistically linked to FO for removal of reverse-fluxed ammonium, thereby creating an osmotic anammox system. The feasibility of this system was demonstrated through both batch and continuous operation, and the anammox process was developed in two stages: sole anammox and nitritation-anammox. With addition of nitrite, the sole anammox process achieved an effluent ammonium concentration of at 9.9 ± 9.5 mg N L^{-1}. The nitritation-anammox process exhibited advantages over anammox process in assisting the FO with respect to water flux improvement and chemical savings. The results encourage further investigation of this system for effect of organic residues, decreasing nitrate accumulation, understanding biofilm on the FO membrane, and long-term performance with actual waste.



Further reading: Li, X.,# Lu, Y.# and He, Z.* (2015) Removal of reverse-fluxed ammonium by anammox in a forward osmosis system using ammonium bicarbonate as a draw solute. ***Journal of Membrane Science***. Vol 495, pp 424-430.

Hydrogen Production by PRO Energy

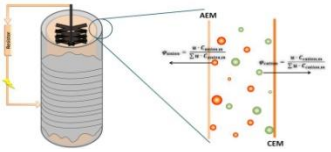
This study presents a proof-of-concept system in which hydrogen can be produced in an MEC powered by theoretically predicated energy by PRO (pressure retarded osmosis); in that way, both osmotic energy and chemical energy in wastewater is mimicked to be used for accomplishing hydrogen production and wastewater treatment. The system consists of a PRO unit that extracts high-quality water and generates electricity from water osmosis, and an MEC for organic removal and hydrogen production. The feasibility of the system was demonstrated using simulated PRO performance (in terms of energy production and effluent quality) and experimental MEC results (e.g., hydrogen production and organic removal). The system is potentially advantageous: (1) the PRO unit can reduce the volume of wastewater and extract clean water; (2) the PRO effluents can be further treated by the MEC; (3) the osmotic energy harvested from the PRO unit can be applied to the MEC for sustainable bioelectrochemical hydrogen production.



Further reading: Yuan, H.,# Lu, Y.,# Abu-Reesh, I. and He, Z.* (2015) Bioelectrochemical production of hydrogen in an innovative pressure retarded osmosis - microbial electrolysis cell system: experiments and modeling. ***Biotechnology for Biofuels***. 8: 116.

Brackish Water Desalination

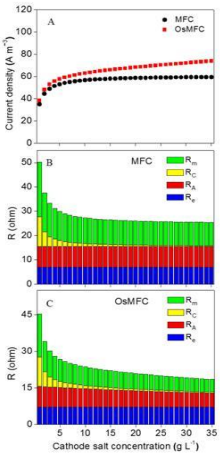
Desalination of brackish water can provide freshwater for potable use or non-potable applications such as agricultural irrigation. Brackish water desalination is especially attractive to microbial desalination cells (MDCs) because of its low salinity, but this has not been well studied before. Herein, three brackish waters prepared according to the compositions of actual brackish water in three locations in Israel were examined with domestic wastewater as an electron source in a bench-scale MDC. All three brackish waters could be effectively desalinated with simultaneous wastewater treatment. The desalinated brackish water could meet the irrigation standard of both salinity (450 mg L^{-1} TDS) and the concentrations of major ionic species, given a sufficient HRT. The MDC also accomplished nearly 70% removal of organic compounds in wastewater with Coulombic efficiency varied between 5-10%. The model also simulated a staged operation mode with improved desalination performance.



Further reading: Ping, Q., Huang, Z., Dosoretz, C. and He, Z.* (2015) Integrated experimental investigation and mathematical modeling of brackish water desalination and wastewater treatment in microbial desalination cells. ***Water Research***. Vol 77, pp 13-23.

Why OsMFCs Generate More Electricity?

Osmotic microbial fuel cells (OsMFCs) are a new type of MFCs with integrating forward osmosis (FO). However, it is not well understood why electricity generation is improved in OsMFCs compared to regular MFCs. Herein, an approach integrating experimental investigation and mathematical model was adopted to address the question. Both an OsMFC and an MFC achieved similar organic removal efficiency, but the OsMFC generated higher current than the MFC with or without water flux, resulting from the lower resistance of FO membrane. Combining NaCl and glucose as a catholyte demonstrated that the catholyte conductivity affected the electricity generation in the OsMFC. A mathematical model predicated the variation of internal resistance with increasing water flux, and confirmed the importance of membrane resistance. Increasing water flux with higher catholyte conductivity could decrease the membrane resistance.



Further reading: Qin, M., Ping, Q., Lu, Y., Abu-Reesh, I. and He, Z.* (2015) Understanding electricity generation in osmotic microbial fuel cells through integrated experimental investigation and mathematical modeling. ***Bioresource Technology***. Vol 195, pp 194-201.

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