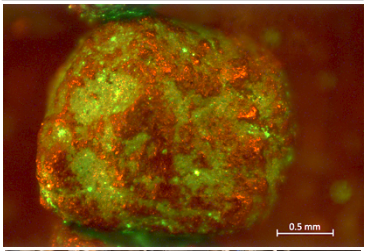
VIRGINIA TECH

2018 Research at SERL

The Charles E. Via, Jr. Department of Civil and Environmental Engineering
National Capital Region (NCR) Campus

2018 Highlights:

- Discoveries
- Projects
- Publications
- Enrollment
- Graduation
- Partners



Dear Friends,

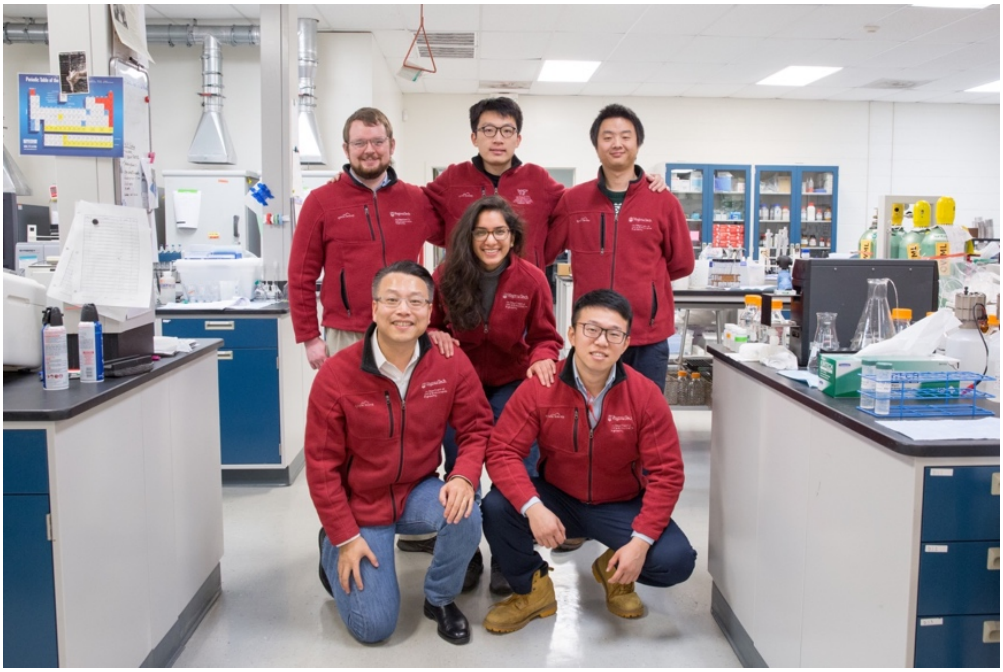
I am pleased to present you the 2018 annual report of the Sustainable Environment Research Laboratory (SERL), a thriving component of the Occoquan Watershed Monitoring Laboratory (OWML) located in Manassas, Virginia. 2018 was another year of accomplishment with steady growth across all areas, including publication of transformative research, recruitment and graduation of our talented students, exploration of unprecedented research directions, acquisition of new funding sources and more collaborators, and significant research contributions in areas ranging from continuous flow aerobic granulation to biofuel fermentation, O_3/BAC for potable water reuse, partial nitritation, digital PCR analysis, temperate phased anaerobic digestion, thermal hydrolysis pretreatment, and point-of-use filter safety.

All of this progress was focused on one goal, i.e., educate and train next-generation scientists and engineers capable of advanced research and technologies for improving the efficiency of water and wastewater treatment as well as the valuable resources recovery.

I am looking forward to making even more progress with you in 2019!

Regards,

Zhiwu Wang



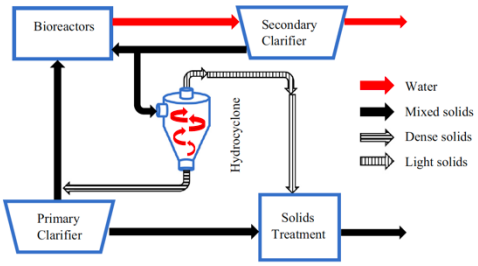
Discoveries in 2018

The spent and regenerated GAC removes trace organic pollutants with different mechanisms

Pilot-scale comparisons of spent and regenerated granular activated carbon (GAC) were carried out in Upper Occoquan Service Authority. Yewei found that the biodegradation by microbial population on spent or regenerated GAC can remove NDMA and 22 pharmaceuticals and personal care products (PPCPs), while the adsorption by regenerated GAC can remove chlorinated THM and HAA precursors, PFAS, flame retardants, and 27 PPCPs. ***Source: Chemosphere, 210:539-549***

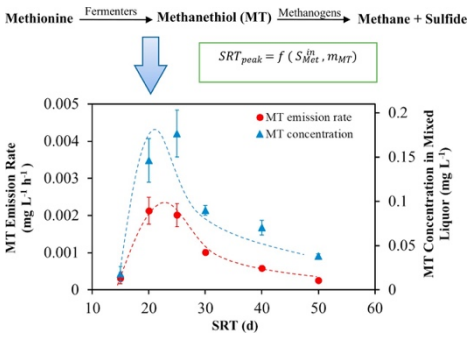
Continuous flow aerobic granulation is the future

Tim reported that applying a selection pressure, based on differences in either settling velocity or the size of the biomass, is essential for successful granulation in continuous flow reactors (CFRs). Besides the formation of aerobic granules, long-term stability of aerobic granules is also a critical issue to be addressed. Accumulated studies demonstrate that aerobic granulation in CFRs is capable of removing a wide spectrum of contaminants. Despite the research progress made toward successful aerobic granulation in lab-scale CFRs, there are only three full-scale tests of the technique. ***Source: Journal of Biotechnology Advances, 36(4): 1139-1166***



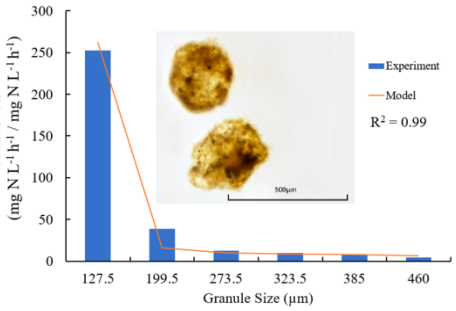
Solids retention time governs odor formation kinetics

The highly volatile methanethiol (MT) with an extremely low odor threshold and distinctive putrid smell is often identified as a major odorous compound generated under anaerobic conditions. Dian's experimental results demonstrated a bell-shaped curve of MT emission versus SRT with a peak around 20 days SRT. His kinetic model simulation revealed that the high protein content in the feed sludge together with the large maintenance coefficient of MT fermenters are responsible for the peak MT emission emergence in the range of typical SRT used for anaerobic digestion. ***Source: Water Research,138, 301-311***



NOB Suppression by free ammonia in small granules

When dissolved oxygen limitation is the only mechanism for NOB suppression, AOB:NOB ratio was usually found to increase with the granule size. However, the trend is reversed when free ammonia has an inhibitory effect on NOB, as was observed in Tim's study. The decrease in AOB:NOB ratio indicates that the resistance to the diffusion of free ammonia along the granule radius limited its ability to inhibit NOB. This means smaller granules, e.g. diameter < 150µm, are preferred for nitrite accumulation when high free ammonia is present, e.g. in the partial nitritation-anammox process. ***Source: M.S. thesis by Kent T.R. (2018).***



dPCR can be used for the quantification of soil nitrogen turnover bacteria in wetland mesocosms

The chip-based QuantStudio 3D digital PCR system was used by Parita to quantify ammonia-oxidizing bacteria, nitrite-oxidizing bacteria, comammox, anammox, and denitrifiers. Results indicated that fertilization or season, which was convolved with fertilization, was the dominant factor influencing the microbial community in the studied environment. ***Source: M.S. thesis by Shah P.R. (2018)***

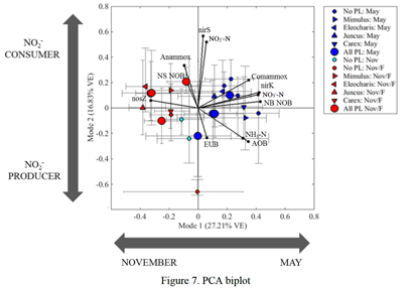


Figure 7. PCA biplot

Point-Of-Use filters led to nitrification

Jie's study revealed that the installation of Point-Of-Use filters led to nitrification, an increase in microbial growth, and a shift of the community distribution of bacteria. ***Source: M.S. thesis by Lin J. (2018)***

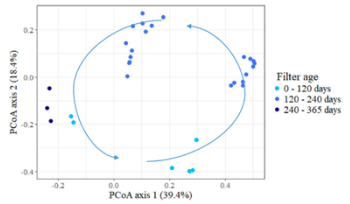


Figure 3-22 Effect of filter age on the morphology fingerprints of effluent live cells in school No. 2 as determined by PCoA analysis

Enrollment and Graduation in 2018

New Enrollment

Zhaohui An started his Ph.D. candidacy in SERL in fall 2018. He received his B.E. in Environmental Engineering from Tongji University in 2017 and M.S. in Civil Engineering from University of Illinois at Urbana Champaign in 2018. Zhaohui's research focuses on a culture-controlled biogranulation technique for high throughput value-added bioproduct fermentation and nitrogen pollution removal.

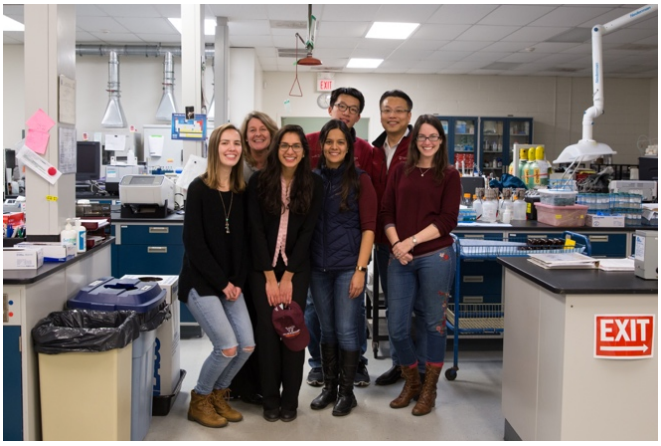
New Graduation

Congratulation to the three M.S. students who successfully defended their theses in 2018. From now on, you are the ambassadors of SERL. Please represent us well. Your career success is SERL's success!

Jie Lin wrapped up her two-year field study in DCWater and successfully defended her thesis on the topic of "*Statistical Evaluation of the Factors causing Microbial Growth in Point-of-use Filters"*. Her outstanding statistical skills and hard-working attitude led to her project success. Jie is now further developing and exercising her statistical expertise in the Operations Research program of Columbia University in the City of New York.

Tim Kent concluded his M.S. study with an excellent defense of his M.S. thesis on the topic of "*Mechanistic Understanding of the NOB Suppression by Free Ammonia Inhibition in Continuous Flow Aerobic Granulation Bioreactors*". Tim only had one year to do his experiment in SERL after completing all his course work in the Blacksburg campus. Within this short period of time, he not only completed all his thesis research work but also published a research paper in a high impact factor (11.452) journal, which is indeed outstanding and rare among M.S. students. Tim is working as a Civil Engineer for AECOM in Roanoke office.

Parita Raj Shah opened a new research avenue in SERL by showcasing how digital PCR can be applied in the field of Environmental Engineering as an alternate tool to conventional real-time quantitative PCR for absolute quantification with high precision and sensitivity. Her thesis titled *"Evaluation of digital PCR (dPCR) for the quantification of soil nitrogen turnover bacteria in wetland mesocosms in response to season, fertilization, and plant species richness"* is the result of her hard field- and lab-work in the past year. Parita, thank you for bringing molecular biology research capacity to SERL!



Research projects started in 2018

Continuous Flow Aerobic Granulation Study at Upper Occoquan Service Authority

The primary goal of this project is to promote continuous flow sludge granulation within the secondary treatment process by using hydrocyclones to improve sludge settleability. Outcome form this study holds promise to increase treatment capacity and postpone future capital costs associated with nutrient removal upgrades at UOSA. Both full- and pilot-scale studies are being carried out to approach the proposed research goal.

Optimizing Treatment and Assessing Aquifer Impact of Ozone/Biologically-Active Filtration for Potable Water Reuse

HRSD is in need of water reuse technologies that allow for the return of highly treated wastewater to the groundwater in order to reverse settlement of the Potomac Aquifer System in the Hampton Roads region. BAC/GAC treatment is an attractive alternative to reverse osmosis which is very costly and will produce a water that is not suitable for the needs for recharge of the local Potomac aquifer. The primary goal of this project is to ensure that the treated wastewater meets water quality requirement and is compatible with the local groundwater, while minimizing costs. Computational model will be used to improve understanding of key factors influencing O_3/BAC/GAC performance and optimize future design.

Synergistic Integration of the Biogranulation Theory into Advanced Membrane Bioreactors for Value-Added Chemicals Production from Food Waste

This USDA project aims to develop an innovative process that converts the food waste into value-added chemicals, e.g., butanol, through an integrated biogranule fermentation-membrane separation system, and the process will reduce food waste, recover resources, and promote sustainable development. A synergistic integration of biogranule fermentation and membrane pervaporation will be carried out and evaluated for efficient, long term, and continuous production and purification of value-added chemicals from food waste. This project will apply engineering principles and tools to food waste to create usable, tangible, and economically viable products.

Turning Phosphorus Pollution into A Marketable Product by Using Fungi

Virginia soils are naturally low in phosphorus and require supplemental phosphorus addition. Meanwhile, Virginia is also the largest contributor of phosphorus pollution to Chesapeake Bay. Fungi hold promise to provide an all-in-one solution to this Virginia phosphorous dilemma. The goal of this study is to turn phosphorus pollutants into a marketable product that not only can be easily transported to those Virginia soils low in phosphorus and but also improve the bioavailability of phosphorus for plant utilization.

Turning Mushrooms into Stormwater Treatment Tools Through 4-VA Collaborative Effort

As stormwater flows across impervious surfaces or farmland, it picks up pollutants such as heavy metals, pathogens, pesticide, fertilizer, etc., and becomes a major contamination contributor to rivers, lakes, estuaries, wetlands, and groundwater. This proposed study will leverage the hyperaccumulation capacity of fungi for *in-situ* heavy metal removal and verify the possibility of fungal predation of bacteria for pathogen control. The project will reinforce collaborative partnerships of the Virginia Tech with the Virginia Commonwealth University, George Mason University, and the Old Dominion University.

Effect of Temperature-Phased Anaerobic Digestion and Thermal Hydrolysis Pretreatment on The Process Intensification of Biosolids Anaerobic Digestion

Process intensification is the technology intended to reduce equipment size, improve reaction kinetics, achieve better energy efficiency, and avoid negative impacts. Both temperature-phased anaerobic digestion (TPAD) and thermal hydrolysis pretreatment (THP) are known to be advanced practices for the process intensification of anaerobic digestion. This project is aimed to evaluate the performance of TPAD and THP in comparison with the conventional anaerobic digestions for treating domestic wastewater sludge produced from the wastewater treatment processes of Alexandria Renew and Arlington County Water Pollution Control Plant, respectively. Of particular interest in the research is a comparison of the systems from the standpoints of biogas production and organic reduction, system stability including inhibition and foaming potential, digested residual quality in terms of dewaterability & odor emission, and coliform reduction.

Publications in 2018

Journal papers

Sun Y.W., Angelotti B., Brooks M., Dowbiggin B., Evans P.J., Devins B., and Wang Z.W. (2018) A Pilot-Scale Investigation of Disinfection By-Product Precursor and Trace Organic Removal Mechanisms in Ozone-Biologically Activated Carbon Treatment for Potable Reuse, ***Chemosphere***, 210:539-549

Kent T.R., Bott, C.B., and Wang Z.W. (2018) State of the Art of Aerobic Granulation in Continuous Flow Bioreactors, ***Biotechnology Advances***, 36(4): 1139-1166

Zhang D., Strawn M., Novak J.T., and Wang Z.W. (2018) Kinetic modeling of the effect of solids retention time on Methanethiol dynamics in Anaerobic Digestion, ***Water Research***,138, 301-311

Conference presentations

Sun Y.W., Khunjar W., Rosenfeldt K., Selbes M., Vaidya R., Wilson C., Bott C.B., Wang Z.W., Mathematical modeling of deep-bed biofiltration to describe contaminant control and headloss development, Weftec 2018, New Orleans, Louisiana, October 1-3

Rosenfeldt K., Sun Y.W., Khunjar W., Selbes M., Vaidya R., Wilson C., Bott C.B., Wang Z.W., Mathematical modeling of deep-bed biofiltration to describe contaminant control and headloss development, WaterJam 2018, Virginia Beach, Virginia, September 10-13

Zhang D., Angelotti B., Schlosser E., and Wang Z.W. (2018) Using cerium salt as an economical precipitant for struvite control and effective dewatering of anaerobic digestate, Chesapeake Tri-Association Conference 2018, Ocean City, Maryland, August 28 – 31

Zhang D. and Wang Z.W. (2018) Using cerium salt as an economical precipitant for complete phosphorus recovery and effective dewatering of anaerobic digestate, ASABE 2018, Detroit, Michigan, July 29- Aug 1.

Sun Y.W.* and Wang Z.W. (2018) Fast-growing can be taken as an alternative strategy to fast-settling by microorganism to survive extreme selection pressures in aerobic granulation reactors, ASABE 2018, Detroit, Michigan, July 29- Aug 1.

Theses

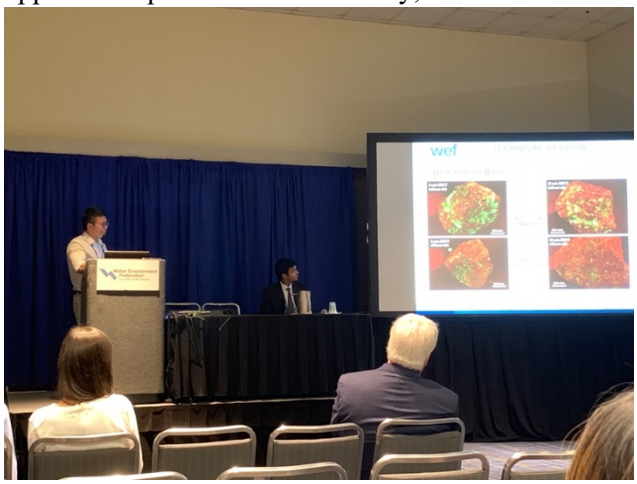
Lin J. (2018) Statistical Evaluation of the Factors causing Microbial Growth in Point-of-use Filters, Master thesis, Blacksburg, Virginia Polytechnic Institute and State University

Kent T.R. (2018) Mechanistic Understanding of the NOB Suppression by Free Ammonia Inhibition in Continuous Flow Aerobic Granulation Bioreactors, Master thesis, Blacksburg, Virginia Polytechnic Institute and State University

Shah P.R. (2018) Evaluation of digital PCR (dPCR) for the quantification of soil nitrogen turnover bacteria in wetland mesocosms in response to season, fertilization, and plant species richness, Master thesis, Blacksburg, Virginia Polytechnic Institute and State University

Project Reports

Zhang D. and Wang Z.W. (2018) Effect of cerium chloride addition on sludge dewatering through centrifugation, Upper Occoquan Service Authority, Mar 1.



University-Industry collaborative partnerships in 2018

Virginia Tech's environmental engineering program has a long tradition of excellence in conducting applied water/wastewater research. The station of Dr. Wang's SERL in northern Virginia is aimed to serve industrial research needs in close distance and promote VT-Industry collaborative relationship. Highlights of collaborative activities with industrial partners in 2018 include:

- Published a research paper in ***Water Research*** with **Arlington County** on the topic of odor control in the processes of anaerobic digestion and sludge dewatering.
- Published a research paper in ***Chemosphere*** with **UOSA** and **CDM Smith** about the performance of pilot-scale O_3/BAC treatment trains for potable reuse water generation.
- Published a review paper in ***Biotechnology Advances*** with **HRSD** summarizing the state-of-the-art of continuous flow aerobic granulation.
- Presented biofiltration modeling work with **Hazen & Sawyer** and **HRSD** in ***Weftec 2018*** and ***WaterJam 2018.***
- Presented phosphorus removal research with **UOSA** in ***Tri-Association Conference 2018*** and ***ASABE 2018.***
- Presented aerobic granulation research in collaboration with **UOSA** in ***ASABE 2018***
- Started temperature-phased anaerobic digestion (TPAD) and thermal hydrolysis pretreatment (THP) research with **AlexRenew** and **Arlington County.**
- Started fermentative bio-P research with **WSSC** and **Black & Veatch**.
- Submitted NSF proposals in collaboration with **WSSC**, **Black & Veatch**, **UOSA**, **DCWater**, **Arlington County**, and **HRSD.**
- Graduated a M.S. student (Jie Lin) with her thesis written on Point-Of-Use data collected from a project in collaboration with **DCWater.**
- Graduated another M.S. student (Tim Kent) with his thesis written on research supported by **HRSD** about partial nitritation of mainstream aerobic granules.
- Started both pilot- and full-scale continuous flow aerobic granulation research with **UOSA** and **Jacobs**
- Hosted **HRSD**, **UOSA**, **WSSC**, **AlexRenew**, **Loudoun Water**, **Fauquier County**, and **Arlington County** in the board meetings of Center for Applied Water Research and Innovation (CAWRI).

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