

2020 Research at SERL

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



2020 Highlights:

- **Grants**
- **Alumni**
- **Enrollment**
- **Innovation**
- **Publication**
- **Relocation**

Dear Friends,

I intentionally held off this report until the last day of the year to make sure there were no more misfortunes in 2020. Now I can speak with confidence that we all have survived 2020 with success. It was an unusual year, taking all of us by surprise. When the University labs and offices were locked down, I was so worried about students' livelihoods and study. When God closes a door, he also opens a window for us. Looking back at 2020, I found it was an unfortunate year but with so many fortunate opportunities for us. The research grants we received in 2020 actually doubled that in 2019. We also published more peer-reviewed journal papers than any preceding years. Most importantly, two outstanding graduate students from my lab were awarded Ph.D. degrees and started their new careers in 2020. Moreover, as detailed in this report, our Sustainable Environment Research Laboratory (SERL) was also relocated to new spaces kindly provided by Loudoun Water for easy access to real wastewater samples and in-situ data. With such a strong research team tried and true in 2020, I am optimistic about our 2021 ahead!

Thank you all for your trust and persistence in 2020! Let's embrace 2021 with added confidence and resolution. The world will become better because of your and my unremitting efforts!

Regards,

Zhiwu Wang



2020 Research Grants

2020 was a devastating year for our society. Despite the lockdowns across the world, researchers like us are up to the challenge and ready to win the fight. With strong collaborators, transformative ideas, and supportive funding agencies, we successfully solicited \$857,051 research dollars in 2020 to sustain our research effort in years to come. These funded researches will create innovative solutions to protecting the health of living organisms and improving the quality of the environment. Briefly, in collaboration with researchers from Kansas State University and Old Dominion University, we won a research grant from National Science Foundation (NSF) to develop cutting-edge technology capable of harnessing ocean protist for toxic hydrothermal liquefaction wastewater treatment. In a broader collaboration with researchers from University of Maryland, Naval Research Laboratory, Idaho National Laboratory, and Quasar Energy Group, we won an even larger funding support from the Department of Energy (DOE) for the development of a novel technology to convert food waste to renewable bioplastics. Besides these federal grants, we also received grant support from new industrial sponsors such as Fairfax County and Hazen & Sawyer for the development of a partial denitrification-anammox bioprocess for saving the energy and chemicals in the course of biological nitrogen removal. Gratefully, we received continued funding support from AlexRenew, Arlington County, ICTAS, Loudoun Water, WSSC, and UOSA for continuous flow aerobic granulation, thermal hydrolysis/anaerobic digestion, biosolids management, and odor control.

New Grants in 2020 (\$857,051)

- Title: *Innovative Polyhydroxyalkanoates (PHA) Production with Microbial Electrochemical Technology (MET) Incorporation for Community-Scale Waste Valorization*. Sponsor: Department of Energy. Duration (DE-EE0009268): 10/1/2020-9/30/2023
- Title: *Effects of Carbon Source and C:N Ratio on Partial Denitrification/Anammox in MBBR*. Sponsor: Hazen & Sawyer. Duration: 9/1/2020-8/31/2021
Title: *Continuous Flow Aerobic Granulation Phase III study*. Sponsor: Upper Occoquan Service Authority. Duration: 8/1/2020-12/31/2020
- Title: *A Novel Biological Valorization of Hydrothermal Liquefaction Wastewater with Marine Protist and its Granulated Phenotype*. Sponsor: National Science Foundation-PRM (2001568). Duration: 7/1/2020-6/30/2023
- Title: *Effect of polymer addition on anaerobic digestion of high solids biosolids pretreated with thermohydrolysis (Phase II)*. Sponsor: Washington Suburban Sanitary Commission and Arlington County. Duration: 1/1/2021-12/31/2021
- Title: *Sustainable urban farming system*. Sponsor: Alexandria Renew Enterprises. Duration: 1/1/2021-12/31/2021
- Title: *Evaluating the impact of thermal hydrolysis on dissolved organic nutrient formation at the Broad Run Water Reclamation Facility*. Sponsor: Loudoun Water. Duration 1/1/2021-12/31/2021



U.S. DEPARTMENT OF
ENERGY



Hazen



2020 Alumni and Enrollment

While the whole world paused in 2020, we had two new Doctors of Philosophy born in our team. I can proudly call Yewei and Dian Dr. Sun and Dr. Zhang now. Right before the campus shutdown, Yewei and Dian successfully defended their dissertations. With the large number of peer-reviewed papers published by each of them in renowned international journals, I am not surprised that their degree committees unanimously approved their dissertations titled “[Advanced Biofilm and Aerobic Granulation Technologies for Water and Wastewater Treatment](#)” and “[Effects of process intensification techniques on biosolids management](#)”. Of course, only virtual commencement was provided in this special year. Hopefully, they can have opportunities to walk in doctoral gowns and have tassels flipped when the pandemic is behind us. Right after their graduation, Yewei joined Hazen & Sawyer as a Scientist, and Dian became an Engineer in Stantec. Let’s wish them the best in their continued endeavors in the field of wastewater treatment.



2020 was also a hard year for new student recruitment when so many international airlines were grounded and overseas embassies were closed. Fortunately, we have two outstanding new students joining our team to carry on our research success. Mr. Rafael Iboleon received his B.S. in Environmental Science from Virginia Tech and joined us as a M.S. student when we were shorthanded in Fall 2020. He will deepen Dr. Dian Zhang’s recalcitrant nitrogen research in the field of thermal hydrolysis pretreated anaerobic digestion. Ms. Xueyao Zhang received her B.S. from Beijing University of Civil Engineering and Architecture and her M.S. from University of Southern California in 2020. She flew to Virginia right before the new year to get ready for her Ph.D. study starting in Spring 2021. She will open up a new research direction into the domain of pure culture biogranulation.



Dr. Yewei Sun received his Ph.D. degree in May 2020



Dr. Dian Zhang received his Ph.D. degree in May 2020



Mr. Rafael (Rocky) Iboleon joined Dr. Wang’s team as an Environmental Engineering M.S. student in Fall 2020

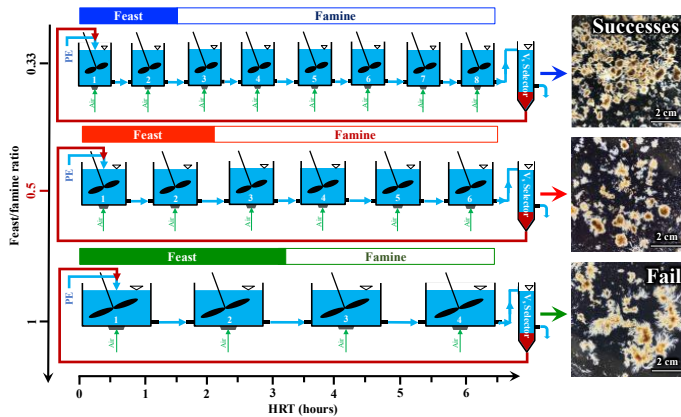


Ms. Xueyao Zhang accepted offer to join Dr. Wang’s team in Spring 2021



2020 Research Highlights

Feast/Famine conditions required for continuous flow aerobic granulation are better understood



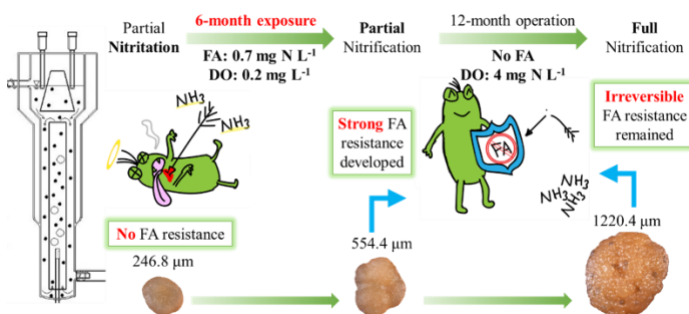
We successively published three papers in series in 2020 to evaluate, define, and predict the essential roles of feast and famine conditions in driving aerobic granulation and also proposed engineering guidelines for utilities to adopt for retrofitting existing tankage for sludge densification. Briefly, it was concluded in these studies that a feast/famine ratio <0.5 is required. The sludge morphology can quickly respond to the feast/famine conditions. A mathematical modeling framework was also put forward to design the number of tanks required at a given F/M ratio and influent loading for ensuring successful aerobic granulation.

DOI: <https://doi.org/10.1016/j.scitotenv.2020.144155>

DOI: <https://doi.org/10.1016/j.jwpe.2020.101800>

DOI: <https://doi.org/10.1016/j.scitotenv.2020.141467>

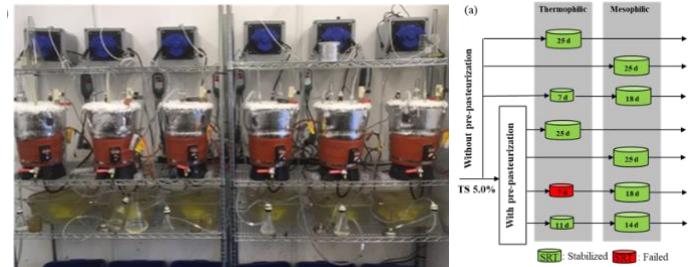
Free ammonia resistance can be developed in aerobic granular sludge cultivated in continuous upflow airlift reactors



The extent of nitrite-oxidizing bacteria (NOB) resistance to free ammonia (FA) inhibition was quantified based on the kinetic response of NOB to various FA concentrations in the form of an uncompetitive inhibition coefficient. It was confirmed that the NOB immobilized in larger granules under longer term exposure to FA tend to become more resistant to FA. Thereby, it was concluded that NOB can develop strong resistance to FA after continuous exposure, and thus FA inhibition is not a reliable strategy

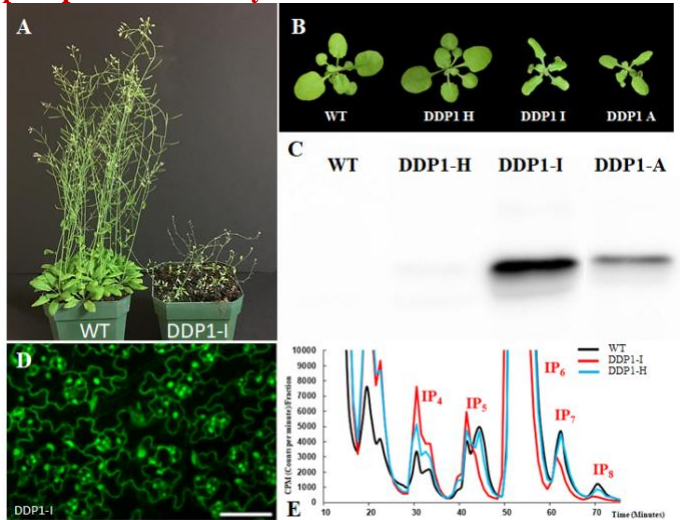
to achieve partial nitrification in mainstream wastewater treatment. DOI: <https://doi.org/10.1002/wer.1440>

Existing pre-pasteurization facility can be repurposed as an in-situ thermal hydrolysis pretreatment process for enhancing anaerobic digestion of municipal sludge



This study found that existing pre-pasteurization system installed in utilities for the purpose of pathogen reduction actually functioned in a similar way as the thermal hydrolysis pretreatment being implemented across the world for anaerobic digestion (AD) process intensification. Because of the sludge biodegradability improvement by pre-pasteurization, high-rate AD such as the thermophilic AD can be subjected to extensive souring problems during startup. DOI: <https://doi.org/10.1039/D0EW00633E>

Genetically modified plants can be harnessed for phosphorus recovery from surface runoff

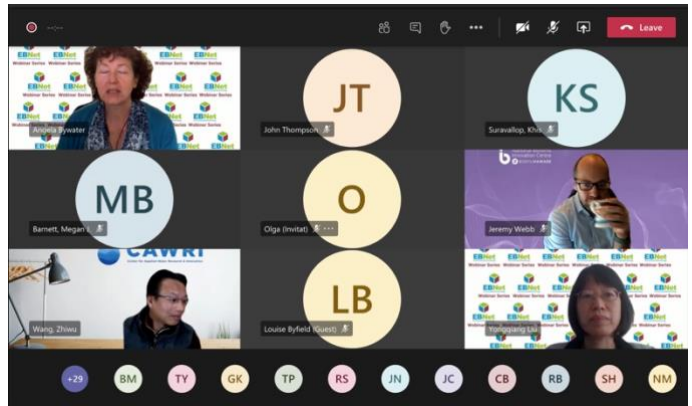


In collaboration with Dr. Glenda Gillaspay from the Biochemistry Department, a patent was filed in 2020 for a technology capable of harnessing genetically modified plants for phytoremediation via bio- or hyper-accumulation of P from specialty crop agricultural tailwater or urban runoff, reducing non-point source pollution and converting P enriched plant biomass byproducts into slow release, non-labile forms of phosphorus that can be used in agricultural or urban areas.

Patent Serial No.: [63/106,408](https://doi.org/10.1002/wer.1440). Filing Date: October 28, 2020

2020 International Outreach

Since all international travel was banned in 2020, we timely resorted to the new norm, namely web-based academic exchange, for international collaboration. I personally fell in love with this new mode of ‘face-to-face’ communication not only because it saved tremendous travel time and money but also I found I can do it in pajamas without jet lag. In a certain sense, I appreciate the pandemic without which I won’t have realized so much can be accomplished with teleworking. I had the opportunity to interact with hundreds of researchers and engineers in the UK and China through invited talks delivered remotely. Although we never met in person, I was able to remotely collaborate with researchers from the University of Calgary in Canada on the publication of a new book chapter titled “*Bioconversion of methane to chemicals and fuels by methane-oxidizing bacteria*” in *Advances in Bioenergy*. My student Yewei even presented his biofiltration work through an online platform provided by “Environmental Perspectives” editorial board in Singapore. It was so nice to receive beautiful cookies made of all parties’ logos from our UK partners. I just still cannot make myself to eat them though. These are fantastic memories of our special 2020!



Tuesday, 3rd November 2020 at 12:00pm - 1:30pm

This event is FREE-TO-MEMBERS. Register through [Eventbrite here](#). Non-members are welcome - join the Network for free prior to registration. Alternatively, email Louise and Angie at EBNet@EBNet.ac.uk.

In place of our Research Colloquium 2021, EBNet will be hosting a series of specialist webinars to support knowledge exchange amongst members. Register now to join the EBNet webinar “**Aerobic granules in wastewater treatment - combining novel molecular techniques and technologies for environmental biotech**”. Hear the latest developments from top speakers and participate in the online chat to engage with questions.

Featuring presentations from:



Assistant Prof Zhiwu (Drew) Wang, Virginia Polytechnic Institute and State University, USA
“Aerobic granules in continuous flow reactors for wastewater treatment”

Biography: Dr. Zhiwu (Drew) Wang is an assistant professor working in the Department of Civil and Environmental Engineering at Virginia Polytechnic Institute and State University (Virginia Tech). As a professional engineer stationed in the national capital region of the U.S, Dr. Wang’s academic footprint is firmly rooted in applied research world with almost all his experiments conducted in wastewater treatment plants. His diverse research portfolio covers continuous flow aerobic granulation, anaerobic digestion, energy and chemical efficient nutrient removal and recovery, as well as innovative methods for valorization of pollutants from the contaminated environments and waste materials such as wastewater, biosolids, food waste, animal manure, or plant biomass. He has been closely worked with utilities, consulting firms, and other research-intensive institutions to promote technology ideation, development, and transfer.



State of the art of aerobic granulation

- First report in 1999
- Only successful in SBRs
- No luck with CSTRs
- The full-scale application is mainly in Nereda’s SBRs.

Why still not popular after 20 years of R&D?

Nereda’s full-scale SBRs (photo from internet)

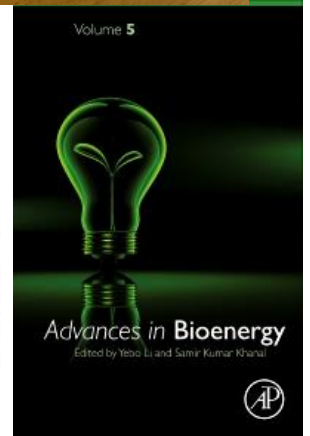
Participants

In this meeting (61)

- Dariusz Watanowski
- Agnes Shen
- Aidan Loughlin (Guest)
- Alexandra Gordon
- An Tran
- Angela Bywater (Guest)
- Anna Alessi BDC (Guest)
- Ariene Ditchfield
- Barnett, Megan J.
- Ben Morris
- Benedict Claxton Stevens
- Charles Banks

小业伟，2016年8月于美国弗吉尼亚理工大学王智武教授课题组攻读博士学位。
 主要研究领域为污水的新型生物处理技术研发以及相关工艺的模型开发。在 *Water Research*, *Environmental International*, *Science of the Total Environment*, *Chemosphere* 等国际期刊发表学术论文8篇。

END



2020 Publications

Journal papers

- Sun Y.W., Gomeiz A.T., Aken B.V., Angelotti B., Brooks M., Wang Z.W. (2020) Dynamic response of aerobic granular sludge to feast and famine conditions in plug flow reactors fed with real domestic wastewater, *Science of the Total Environment*, DOI: <https://doi.org/10.1016/j.scitotenv.2020.144155>
- An Z.H., Sun Y.W., Angelotti B., Brooks M., Wang Z.W. (2020) The feast-to-famine duration ratio dependent aerobic granulation in continuous flow and sequential batch reactors, *Journal of Water Process Engineering*, DOI: <https://doi.org/10.1016/j.jwpe.2020.101800>
- Zhang D., Santha H., Pallanschb K., Novaka J.T., Wang Z.W. (2020) Repurposing pre-pasteurization as an in-situ thermal hydrolysis pretreatment process for enhancing anaerobic digestion of municipal sludge: A horizontal comparison between temperature-phased and standalone thermophilic or mesophilic anaerobic digestion, *Environmental Science: Water Research & Technology*, 6, 3316 - 3325. DOI: <https://doi.org/10.1039/D0EW00633E>
- An Z.H., Kent T.R., Sun Y.W., Charles B., Wang Z.W. (2020) Free ammonia resistance of NOB developed in aerobic granular sludge cultivated in continuous upflow airlift reactors performing partial nitrification, *Water Environment Research*, DOI: <https://doi.org/10.1002/wer.1440>
- Sun Y.W., Angelotti B., Brooks M.A., and Wang Z.W. (2020) Feast/Famine Ratio Determined Continuous Flow Aerobic Granulation, *Science of the Total Environment*, 141467. DOI: <https://doi.org/10.1016/j.scitotenv.2020.141467>
- Jin Q., An Z., Damle A., Poe N., Wu J., Wang H., Wang Z.W., Huang H. (2020) High acetone-butanol-ethanol production from food waste by recombinant *Clostridium saccharoperbutylacetonicum* in batch and continuous immobilized-cell fermentation, *ACS Sustainable Chemistry & Engineering*, 8, 26, 9822–9832. DOI: <https://doi.org/10.1021/acssuschemeng.0c02529>
- Alfredo K., Lin J., Islam A., and Wang Z.W. (2020) Impact of activated carbon-block point-of-use (POU) filters on chloraminated water quality, *AWWA Water Science*, 2(3) e1180. DOI: <https://doi.org/10.1002/awws.1180>
- Zhang D., Strawn M., Broderick T., Novak J.T., Wang Z.W. (2020) Effects of anaerobic digester solids retention time on odor emission and dewaterability of biosolids subjected to various shear intensity, polymer doses, and storage duration, *Environmental Science: Water Research & Technology*, 6, 1588-1596 DOI: <https://doi.org/10.1039/D0EW00028K>
- Zhang D., Sun Y.W., Angelotti B., Wang Z.W. (2020) Understanding the dewaterability of aerobic granular sludge formed in continuous flow bioreactors treating real domestic wastewater: is it really better than that of the activated sludge? *Journal of Water Process Engineering*, 36, 101253 DOI: <https://doi.org/10.1016/j.jwpe.2020.101253>
- Zhang D., Feng Y.M., Huang H.B., Khunjar W.O., Wang Z.W. (2020) Recalcitrant Dissolved Organic Nitrogen Formation in Thermal Hydrolysis Pretreatment of Municipal Sludge, *Environment International*, 138, 105629, DOI: <https://doi.org/10.1016/j.envint.2020.105629>

Book chapter

- Wang S., Zhaohui An, Wang Z.W. (2020) Bioconversion of methane to chemicals and fuels by methane oxidizing bacteria. In: “Advances in Bioenergy, volume 5”, Elsevier Inc., Cambridge, MA. DOI: <https://doi.org/10.1016/bs.aibe.2020.04.005>

Patent

- Gillapsy G., ; Freed C., Williams S.P., Wang Z.W. (2020) Utilizing slow-releasing fertilizer processed from phosphate-hyperaccumulating plants to remediate phosphate pollution. Serial No.: 63/106,408. Filing Date: October 28, 2020

Dissertations

- Sun Y.W. (2020) Advanced biofilm and aerobic granulation technologies for water and wastewater Treatment, Ph.D. Dissertation, Blacksburg, Virginia Tech, USA
- Zhang D. (2020) Effects of process intensification techniques on biosolids management, Ph.D. Dissertation, Blacksburg, Virginia Tech, USA

Invited talks

- Wang Z.W. (2020) Aerobic Granules in continuous flow reactors for wastewater treatment, Webinar Talk invited by UK Environmental Biotechnology Network, Nov 3rd
- Wang Z.W. (2020) Aerobic granules in continuous flow reactors for upgrading wastewater treatment capacities. Webinar Talk invited by Beijing University of Technology

Conference Oral Presentation

- An Z.H., Bott C., Wang Z.W. (2020) The feast-to-famine duration ratio dependent aerobic granulation in continuous flow and sequential batch reactors. *WaterJAM 2020*, Virtual, September 14-October 2
- Luo H., Taylor M., Nguyen C., Quansah S., Wang Z.W. (2020) Identification of the Source, Cause, and Aeration of sludge holding as an economical means for biosolids odor control, *WaterJAM 2020*, Virtual, September 14-October 2

Technical Reports

- Luo H. and Wang Z.W. (2020) Turning phosphorus pollution from digested dairy manure into a marketable product by using fungi, Submitted to Virginia Department of Agriculture and Consumer Services, Mar
- Luo H., Zhang D., and Wang Z.W. (2020) Identification of the Source, Cause, and Solution of the Biosolids Odor Emission in Western Branch Water Resource Recovery Facility, Submitted to Washington Suburban Sanitary Commission, Mar 4
- Zhang D. and Wang Z.W. (2020) Effect of temperature-phased anaerobic digestion and thermal hydrolysis pretreatment on the process intensification of anaerobic digestion, Submitted to Arlington County Water Pollution Control Plant and Alexandria Renew Enterprises, Jan 10.

2020 Laboratory Expansion

With the rapid expansion of our research portfolio, the availability of wet-lab spaces, especially the ones suitable for wastewater research, has become a limiting factor constraining SERL development. This urgent lab space need became intensified in 2020 when the grants we received doubled previous year while most university facilities were shut down in the mid of the pandemic. In order to upgrade the SERL capacity, minimize the pandemic impact, and better serve the demand-oriented research needs at water industry frontiers, we moved SERL out of the Occoquan Watershed Monitoring Lab into transitional spaces before we can make our final move to a permanent space kindly provided by Loudoun Water. During this transitional phase, we also overflow many of our most needed research works into other local water reclamation facilities where we can tap in valuable resources such as laboratory, real samples, and upscaled bioreactor setup in close proximity. By placing and leveraging these in-situ research platforms, we were able to deliver high-impact real-world research beyond the reach of conventional university setup. We are confident that this laboratory expansion in 2020 will open a new era of wastewater treatment research for SERL, and SERL will soon become a leader for Industry-University collaborative research in the U.S. and even the world.



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