PURDUE UNIVERSITY | Environmental and Ecological Engineering

EEE Research Seminar

Date: September 12, 2023, at 10:30 AM
Location: POTR 234 (Fu Room)

April Z. Gu, Ph.D.

Professor
Department of Civil and Environmental Engineering
Cornell University

Towards Phosphorus Sustainability with Circular Economy

Abstract

Within the framework of the renowned P paradox, P is an irreplaceable, scarce element for food security and renewable energy (biofuel) production and, at the same time, its inefficient use and loss to the environment is also the leading cause for widespread eutrophication that threatens global water security. To offer long-term off-site life cycle environmental and health benefits, there is an imperative need of paradigm shift towards a more sustainable regional-scale nutrient management system that incorporates P recycle from P-rich agricultural sources (i.e. dairy wastes, manure) and targets sustainable agricultural intensification with P conservation, water quality protection and energy demand abatement. Our team has been working on addressing the recognized two main challenges that limit the implementation of sustainable P recycling and management system: 1) a lack of cost-effective and environmentally-sound technology for P recovery from high-strength agricultural wastes to enable P recovery, storage, and redistribution; 2) unpredictable plant-bioavailable P and largely unknown impact of biofertilizer application on crop production and long-term soil health. Conventional biological nutrient removal (BNR) processes are usually energy intensive and require sufficient carbon, often additional external carbon, to reliably meet stringent regulatory requirements. Our research group are working towards breakthroughs in theoretical understanding and successful implementation of external carbon-independent, energy-efficient and reliable integrated A-stage carbon capture, enhanced side-stream biological phosphorus removal (S2EBPR) and short-cut N removal for simultaneous P recovery, N removal and carbon energy recovery from various wastewater. The S2EBPR technology creates a better controlled ecological selection condition that involves more favorable and different underlying mechanisms from those in convectional EBPR, thus overcome the challenges in barriers and limitations that preventing its coupling with short-cut N removal processes. We integrate advanced genomics, phenotyping, data analytics and modeling to discover function-targeted and high-resolution ecological-system dynamics and rules. We pioneered the operational phenotypic units (OPUs) concept based on single cell Raman Micro-spectroscopy (SCRS), which enables a novel phenotyping method for profiling the microbial physiological diversities within ecosystems. The outcome revealed the phenotypic heterogeneity and plasticity of the key agent-polyphosphate-accumulating organism (PAO) population, which otherwise could not be disclosed through conventional phylogenetic analysis alone, and showed its complex but potentially crucial association with EBPR process stability. To close the circular economy for P sustainability, we optimize for the value-added product-biofertilizer from the above treatment process, which will alleviate the reliance on inorganic P fertilizers that has negative implications on soil health. In collaboration with the NSF CROPPs center team, we demonstrated the superiority of recycled biosolids on plant growth. We advanced our fundamental understanding of plant P uptake and utilization within the plant-rhizomicrobiome interactions via advanced and new approaches such as Raman activated cell sorting followed by single cell genomics analysis for rhizomicrobiome, combined stable isotope labeling, metabolomics for elucidating the P uptake through plant metabolism pathways, and greenhouse-based platforms for non-invasive phenotyping of root growth. We aim to contribute to the realization of the paradigm shift towards P recycle for advancing food-energy-water sustainability.

Bio

Dr. Gu is a full professor in School of Civil and Environmental Engineering, affiliated field faculty with Department of Microbiology and Department of Biological and Environmental Engineering (BEE) at Cornell University in Ithaca, NY. Dr. Gu received her B.S. in Environmental Engineering and Science from Tsinghua University in Beijing, China and a Ph.D. in Civil and Environmental Engineering, jointly in Microbiology, from the University of Washington, US. She was a visiting professor at University Vienna in 2014 and at University of Oxford in 2018. Her expertise and area of research interest include: 1) biotechnology for water and wastewater treatment and biological nutrient removal; 2) risk-based water quality monitoring and toxicity assessment; 3) global phosphorus cycling and bioavailability of nutrients in natural ecological systems, 4) biosensors and nano-biosensors. She has led and participated over 30 research projects funded by various agencies including NSF, DOE, EPA, WERF, WRF, USDA/NIFA, and NIEHS. She has been a coauthor for over 190 journal, conference and other technical publications and given 280 presentations at conference and workshops, including more than 80 invited talks. She and her team have received a number of national awards including NSF CAREER award, WEF Ralph Fuhrman Medal, CAPEES/Nanova Frontier Research Award, AEESP outstanding service awards, AEESP/Mary Ann Liebert Award for Publication Excellence in Environmental Engineering Science, HDR National Pathfinder Award for Creativity, SETAC Global Best Student Paper Award and, IEEE Yong researchers Forum Award and ACS Outstanding Presentation Merit Award etc. She received the Søren Buus Outstanding Research Award and Excellence in Mentor Award from Northeastern University and elected to be COE faculty Fellow in 2014. She was invited speaker for Gordon Conference-Drinking Water Disinfection Byproducts 2017, Gordon Conference -Environmental Nanotechnology 2013, and Gordon Conference – Water Science in 2012. She has been elected to serve on the Board of Directors for AEESP from 2017 to 2020. Dr. Gu is an elected Fellow of Water Environment Federation.