# Illinois Water Resources Center

## Annual Technical Report
## 2019

## Products

1. The Role of Floating Gardens to Alter the Water Quality of the Chicago River: Chicago, IL. Spooner, Emmett. 2020 *M.S. Thesis* 55 pages.
2. Supporting data – Floating Gardens, Chicago River, April 29, 2018 to November 19, 2019. Peterson, Eric. 2021 Faculty Publications-- *Geography, Geology, and the Environment*.
3. Biological Nitrate Removal with Emerald Ash Borer-killed Ash and High-tannin Oak Woodchips. Wickramarathne, N., L.E. Christianson, M.E. Foltz, J.L. Zilles, R.D. Christianson, R.A.C. Cooke. 2021. *Frontiers in Environmental Science - Water and Wastewater Management.* Accepted 2/24/2021. DOI pending.
4. A Data-Driven Approach to Quantifying Energy for Residential Water Heating in Urban Areas. Bongungu, Joseph (et al). 2019. *American Geophysical Union 2019 Fall Meeting.* Poster Presentation (https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/551515).
5. The Energy-Water Nexus at Home: Energy and Water in the Residential Environment. Stillwell, Ashlynn. 2021. *AIChE 2nd Annual Food-Energy-Water Conference.* Invited Oral Presentation (https://www.aiche.org/sites/default/files/docs/conferences/foodenergywaternexus_program_updated.pdf).
6. Water We Doing at Home? Water and Energy in the Residential Environment. Stillwell, Ashlynn. 2021. *University of Massachusetts Amherst CEE seminar series.* Invited oral presentation.
7. Estimating residential hot water consumption from smart electricity meter data. Bongungu, Joseph. 2020*. M.S. thesis.* *(*https://www.ideals.illinois.edu/handle/2142/108042).
8. Molecular Tuning of Redox-Copolymers for Selective Electrochemical Remediation. Kim, Kwiyong; Baldaguez Medina, Paola; Elbert, Johannes; Kayiwa, Emmanuel; Cusick, Roland; Men, Yujie; Su, Xiao. 2020. *Advanced Functional Materials* (30) p. 2004635. (https://onlinelibrary.wiley.com/doi/10.1002/adfm.202004635).
9. Electrochemical Platforms for Process Intensification. Cotty , Stephen. 2019. Department Chemical and Biomolecular Engineering Qualifying Exam Report (Passed).

## Information Transfer Program

1. **Project Title:** *Illinois Geothermal Coalition Technical and Education/Outreach Program*

   **IWRC's Role:** Co-Collaborator

   **Award:** $59,543

   **Timeframe:** November 2020 – present

**Overview:** As Illinois moves towards achieving its commitment of converting all energy systems to running on 100% renewable energy by 2050, it is recognized that other renewable energy sources besides solar and wind energy, including geothermal energy, will be needed to meet the State's future energy demands. This project will develop a technical and E&O program that supports wider adoption of geothermal energy systems and disseminates information to decision makers and public stakeholders about the potential economic, energy efficiency, and climate resilience to the residents of Illinois. An interactive dashboard will be developed that provides technical data and explanatory information on the water-energy nexus to the geothermal industry and government organizations. In addition, a decision support tool will be programmed to assist decision makers and public stakeholders in identifying how geothermal energy can be implemented successfully in long-term solutions. The project will involve a coordinated statewide education and outreach program that introduces all aspects of geothermal energy pertinent to Illinois, and provides a venue to discuss potential benefits to the residential, commercial, and industrial sectors.

2. **Project Title:** *Integrating Groundwater Resources and Geothermal Energy for Water-Energy Security and Resilience*

   **IWRC's Role:** Lead Collaborator

   **Award:** $30,000

   **Timeframe:** May 2020 – present

   **Overview:** The proposed research is to initiate the development of University of Illinois at Urbana-Champaign campus to be the world class center on groundwater and geothermal integration research. The immediate research activity for this Living Lab is to enhance water and energy security and climate resilience on urban systems, agricultural applications, and military bases by utilizing groundwater resources and geothermal energy as an integrated system. Such interdisciplinary research development is designed to benefit iSEE's five thematic areas of interest. The potential applications will improve the urban resilience to climate change and the military's readiness by providing reliable indoor climate control and water supply. Our group will use currently abundant campus geothermal projects funded by SSC/iSEE and geothermal deep direct use feasibility study funded by DOE, then will expand on these projects by preparing proposals to three potential federal agencies, DOD, DOE and USGS based on current collaborations with these three agencies.

3. IWRC is a founding member of the **Illinois Geothermal Coalition (IGC)** – a group of corporations, non-profits, geothermal professionals, and water-energy nexus researchers seeking to establish Illinois as a leader in geothermal energy. Through sharing experiences with new technology, implementation of existing and future technologies, and support for the various geothermal efforts by members, this coalition will work together to strengthen and advance the implementation and design of geothermal energy systems in the Midwest. (August 2020 – present).

IGC hosted a virtual Low-temperature Geothermal Workshop on November 5, 2020. Over 80 participants attended.

4. Since its inception in 1964, IWRC has been a member of the *Illinois State Water Plan Task Force.* IWRC's most recent involvement includes participation as a voting agency in two of the 13 critical issues determined by the Illinois State Water Plan Task Force – **Climate Change** and **Stream Data Management** – during the 2020/2021 update of the Illinois State Water Plan.
5. **Project Title**: *Partnering to Mitigate Harmful Algal Blooms in the North Central Region of the United States*

   **IWRC's Role:** Co-Lead

   **Award:** $10,000

   **Timeframe:** 2017 – present

   **Overview:** Initiated in 2017 when nine Water Resource Research Institutes (WRRIs) in the Upper Mississippi River Basin aligned their 104B program proposals to include Harmful Algal Blooms (HABs) as a focus area. The intention of this ongoing, regional collaboration is to gain, share, and synthesize knowledge on HABs in order to develop a regional product. With support from the North Central Region Water Network, this regional coordination initiative led to the formation of a twelve-state team (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin) – the Algal Bloom Action Team (ABAT). This team partners WRRIs and Cooperative Extensions at each of the states' land grant institutions to assess current HABs outreach and education efforts and establish uniform recommendations for the North Central Region. Phase 1 of this effort led to a white paper assessing the needs of the region. Currently in phase 2, IWRC is co-leading (with the Iowa Water Center) ABAT's efforts of designing and implementing the recommended messaging from the white paper throughout the region. In 2021, ABAT will host a research symposium, design a website resource page including FAQs, and printable resources for educators such as fact sheets, and coordinate a webinar series hosted by the North Central Region Water Network.
6. IWRC has partnered with the *Discovery Partners Institute's (DPI's) – Center for Urban Resilience and Environmental Sustainability (CURES).* As a Center that aims to address urban sustainable development challenges of the 21st century including climate change, human migration and population growth, disruptive technological change, and increased social inequality and conflict, CURES provides an additional avenue for IWRC to engage with the public. IWRC assists CURES with website and communications design, enabling IWRC to provide consistent, standardized messaging to the public through CURES outreach, events, and research activities. Further, in the fall, CURES has proposed to host a, "Workshop on Interdisciplinary Sustainable Solutions for Small to Medium

Sized Illinois Communities Facing a Changing Climate." IWRC will create the promotional materials for the event as well as provide an additional avenue from which to disseminate the findings. (August 2020 – present).

7. In response to the COVID-19 pandemic in 2020, IWRC immediately sought ways to provide water resources research, information, and education in a primarily virtual world. In 2020, IWRC created a Water Resources for Students webpage intended as a virtual learning hub for students and educators. (March 2020 – present).
8. IWRC, in conjunction with the Department of Geology, initiated campus-wide access to data hosted by Planet as a library service. IWRC's contribution to this service was $1,000 providing IWRC and its affiliated researchers and students access to 1.66TB of data. (August 2020 – present).
9. In 2020, IWRC purchased two remotely accessible workstations. IWRC manages access and provides support to affiliated researchers and students enabling increased computational capacity for data analysis. One workstation, a Dell Precision 5820 Tower is housed in the IWRC Director's on-campus office. The second, a Dell Precision 7750 is a mobile workstation. (February 2020 – present).
10. IWRC recruited 8 potential reviewers for the National Grants Selection Panel 104G of which 4 were selected to assist. (May 2020 – August 2020).
11. **Event:** *CUAHSI-AGU H3S 2020 Spring Cyberseminar Series: Navigating Academic Waters: Essential Skills to Thrive as a Student and Early Career Scientist*

    April 24, 2020 | Managing Manuscripts: Writing Manuscript Reviews and Responding to Reviewers
    - Holly Michael, University of Delaware
    - Yu-Feng Lin, University of Illinois at Urbana-Champaign
    - Barret Kurylyk, Dalhousie University
12. IWRC worked with other institutes in the region to develop research priorities for the $1M in additional appropriations provided by US Congress to fund aquatic invasive species research in the Upper Mississippi Basin. The Program Manager coordinated the call to discuss the direction of the funding, took notes, and compiled research needs for Illinois. The nationally competitive call for proposals was announced in May. Illinois submitted 4 of 12 total proposals. One Illinois proposal was selected for funding ($240,624). Project Title: *Water Quality as a Deterrent to the Movement of Invasive Fishes in the Illinois Waterway: Implications for the Upper Mississippi Basin.* (February 2020 – present).

For more information on IWRC's information transfer activities, we encourage you to visit our website: https://iwrc.illinois.edu/.

## Student Support

104B Undergraduates: 4
104B Masters: 3
104B Graduates: 3
104B Postdocs: 1
Coordination Grant: 0
NIWR-USGS Student Internships: 0
Total: 11

## Notable Achievements and Awards

1. Illinois Lake Management Association Student Research Grant (2019).
2. Wetland Society Student Research Grant (2019).
3. American Chemical Society Viktor K. LaMer Award (2020).
4. University of Illinois at Urbana-Champaign Grainger Small Equipment Award (2019).
5. Developed Flow-Device for E-chem Separation (2019-2020).
6. The Director has been appointed by the Illinois Governor to serve as a Commissioner on the Great Lakes Commission (GLC) (2020-2021).

## Estimating Residential Hot Water Use From Smart Electricity Data

**Project Type:** Annual Base Grant
**Project ID:** 2019IL089B

**Project Impact:**

In this project, we estimate residential hot water use from smart electricity data for areas in greater Chicago. We use a non-intrusive load monitoring (NILM) algorithm to estimate electricity for water heating, as a measure of hot water consumption, using meter-level data for single-family residential homes (with electric space heat) at 30-minute resolution. Results indicate that water heating in the analyzed single-family residential homes accounted for 7-20% of total electricity consumption, representing an average of 40-60 gallons of hot water consumption per day. These results also demonstrated significant spatial variability, such that some areas of Chicago show higher per household hot water use. Our findings reveal that disaggregation of electricity meter data can provide an estimate of water heating; however, those estimates have significant uncertainty due to the temporal resolution of the electricity data. These findings 1) provide estimates (albeit overestimation) of hot water consumption in single-family residential homes; 2) demonstrate spatial variability in water heating and energy load; and 3) emphasize the need for finer temporal resolution electricity data for further study. These results were summarized in Joseph Bongungu's M.S. thesis and are currently being edited for submission to a peer-reviewed journal for publication.

# Electrochemically-mediated Adsorption Systems For Selective Nitrate Recovery: Agriculture And The Water-energy Nexus

**Project Type:** Annual Base Grant
**Project ID:** 2019IL090B

**Project Impact:**

We developed a hybrid structure which consists of an electrically-conductive support framework (carbon black and carbon nanotubes (CNTs)) with the coating of redox-responsive polymeric films (polyvinylferrocene (PVF), poly-TEMPO-methacrylate (PTMA), polypyrrole (PPy), polyaniline (PANI), Poly(3-hexylthiophene-2,5-diyl) (P3HT). In our preliminary result using density-functional theory (DFT), it was shown that nitrate binds strongly to oxidized ferrocene group. In our lab-scale preliminary tests, PVF-CNT electrode showed fast adsorption kinetics (reaching equilibrium within 1 h), and the highest uptake up to 200 mg/g. This model polymer allowed electrochemically-controlled capture and release of nitrate, like on/off switches, exhibiting >95 % regeneration efficiencies and thus demonstrating fully reversible, electrochemically modulated nature of our process. In addition, we found that PANI revealed the higher adsorption uptake than any other materials tested (45 mg/g for PANI and 10 mg/g PVF at 1 mM nitrate). We hypothesize that hydrogen bonding with protonated amine group (-NH2+) site is responsible for selective separation. Redox-mediated operation allows adsorption and desorption via simple electrical swings with minimal pH, temperature or other changes in solution conditions, and combines the inherent advantages of electrochemical methods, including high capacity, fast kinetics and modularity, without the selectivity limitations present in traditional capacitive deionization. Thus, this energetically-efficient, point-of-source system for nitrate recovery will be expected to strongly increase community resilience to nutrient problems, and provide a techno-economic motivation to agricultural stakeholders to employ these technologies on the long-term. Continuation of the efforts are being pursued by PI Su and co-PI Cotty.

# Improving Denitrifying Woodchip Bioreactor Design And Management Through Denitrification Potential Testing

**Project Type:** Annual Base Grant
**Project ID:** 2019IL091B

**Project Impact:**

Denitrifying woodchip bioreactors promote biological removal of nitrate to prevent negative environmental consequences of nitrate loading to downstream waters. Bioreactor media should promote complete denitrification while maintaining high rates favorable for nitrate removal. Considering woodchip type, oak had the highest denitrification potential, which also corresponded to the most nitrate removal in lab studies. The overall proportion as N2O was low for all submerged woodchips (<14%), suggesting that woodchips generally have high potential for complete denitrification. There were higher denitrification potentials when carbon was added, suggesting that some bioreactors may experience carbon limitations. Without exposure to drainage water, fresh woodchips were capable of denitrification, albeit at a much lower rate than active or spent woodchips harvest from an operational bioreactor in the field. This demonstrates that denitrifying organisms are present in woodchip media prior to installation in bioreactors. Overall, woodchip type and properties should be an additional consideration for bioreactor design and construction, but this needs to be contextualized within practical factors such as woodchip availability and cost. In addition, field conditions are known to influence performance and N2O proportions should be monitored over time to ensure bioreactors are reaching optimal performance. Key findings of this work were presented to scientific communities through a presentation at an international meeting and inclusion in manuscripts: one recently accepted and one in preparation.

# Assessment Of Floating Gardens To Improve The Water Quality Of The Chicago River

**Project Type:** Annual Base Grant
**Project ID:** 2019IL092B

**Project Impact:**

The work was a pilot study investigating the potential of floating gardens to improve the water quality of an urban stream, the Chicago River. The results showed that concentrations of nitrate as nitrogen in the waters were lower after flowing past the floating garden. Statistical differences were noted in the surface concentrations during both the growing season ($t(22) = 1.9$, $p = 0.03$) and the dormant season ($t(18) = 4.1$, $p < 0.001$) at the surface. The 0.3 m depth says statistically significant lower concentrations in the dormant season ($t(11) = 2.1$, $p = 0.03$). During the non-growing season, which aligns with periods of highest chloride concentrations, the 0.3 m depth say a significant decrease in chloride concentrations after the water flowed under the garden ($t(11) = 2.1$, $p = 0.03$). The pilot project shows that floating gardens have the ability to improve the water quality of river systems.