Water Resources Research Institute of the University of North Carolina
North Carolina State University

Annual Technical Report
2018

General Information

Products

1. Bowen, J. and N. Harrigan. 2018. Water Quality Model Calibration via a Full-Factorial Analysis of Algal Growth Kinetic Parameters. Journal of Marine Science and Engineering. 6 (4), 137

2. Brandt, J.E., N.E. Lauer, A. Vengosh, E.S. Bernhardt, and R.T. Di Giulio. 2018. Strontium isotope ratios in fish otoliths as biogenic tracers of coal combustion residual inputs to freshwater ecosystems. Environmental Science and Technology Letters. 5:718-723.

3. Brandt, J.E., M. Simonin, R.T. Di Giulio, and E.S. Bernhardt. 2019. Beyond selenium: coal combustion residuals lead to multi-element enrichment in receiving lake food webs. Environmental Science and Technology. 58:4119-4127

4. Gibson, N.E., Sun, G., Nichols, E.G. Impacts of Municipal Wastewater Irrigation to the Water Balance in a Forested Water Reuse System. In Review. Ecohydrology. 2019.

5. Han, Y., J. Smithheart, T.N. Aziz, R.L. Smyth, and D.R. Obenour. 2019. Assessing vertical diffusion and cyanobacteria bloom potential in a shallow eutrophic reservoir. In Review. Lake and Reservoir Management. Submitted 3/20/2019

6. Holcomb, D., K. Messier, M. Serre, J. Rowny and J. Stewart. 2018. Geostatistical prediction of microbial water quality throughout a stream network using meteorology, land cover, and spatiotemporal autocorrelation. Environmental Science & Technology. 52(14): 7775-7784. doi: 10.1021/acs.est.8b01178

7. McElroy, A.C., M.R. Hyman, and D.R.U. Knappe. 2019. 1,4-Dioxane in drinking water: Emerging for forty years and still unregulated. Current Opinion in Environmental Science & Health. 7: 117-125.

8. Paerl, H.W., J.R. Crosswell, B.Van Dam, N.S. Hall, K.L. Rossignol, C.L. Osburn, A.G. Hounshell, R.S. Sloup, and LW. Harding Jr. 2018. Two decades of tropical cyclone impacts on North Carolina's estuarine carbon, nutrient and phytoplankton dynamics: Implications for biogeochemical cycling and water quality in a stormier world. Biogeochemistry. 141:307–332. DOI: 10.1007/s10533-018-0438-x.

9. Van Dam, B.R., J.R. Crosswell, I.C. Anderson and H.W. Paerl. 2018. Watershed-scale drivers of air-water CO2 exchanges in two lagoonal North Carolina (USA) estuaries. Journal of Geophysical Research: Biogeosciences. 123. https://doi.org/10.1002/ 2017JG004243.

Information Transfer Program

Through a total of 18 training, education and outreach events, NC WRRI reached 1062 water professionals, students and citizens. Among others, these events include the statewide annual WRRI conference, rain garden plantings, webinars, community group presentations, and themed lunch forums.

WRRI researchers and their students delivered 63 presentations at conferences, stakeholder meetings, workshops and other events this fiscal year, including 4 poster presentations and 12 oral presentations at the NC WRRI annual conference.

NC WRRI's leadership in watershed management efforts is represented by its co-coordination of the NC Watershed Stewardship Network (WSN), which engages students, citizens and local governments. Four grants, totaling $37,500, were received by WRRI's WSN coordinator to support community watershed restoration and education efforts. 104 K-12 students were engaged in related activities.

NC WRRI received $33,274 from the NC Department of Environmental Quality to support training for 53 local government programs on erosion and sediment control research and best practices.

The NC Division of Water Infrastructure awarded $500,000 to NC WRRI to facilitate a statewide water loss control

pilot program for 10 small water utilities across the state.

NC WRRI's communication program was boosted this reporting cycle with the addition of a FTE whose portfolio includes WRRI communications responsibilities. This investment provided immediate payoffs including the largest ever annual conference registrant list resulting from enhanced news releases, a dramatic increase in traffic on our website and social media accounts, and revamped outreach materials highlighting WRRI funded research results.

Student Support

18 graduate students (4 master's and 14 PhD)
4 undergraduates
1 post doc

Notable Achievements and Awards

Seven students received awards for their WRRI-supported research, including: the first place and people's choice award for UNC-Charlotte's Three Minute Thesis competition; third place for a research poster presentation at NC State University's Environmental, Water Resources, and Coastal Engineering Symposium; third place in the NC WRRI annual conference student poster competition; a Natural, Physical, and Mathematical Sciences award at UNC-Greensboro's 7th annual Graduate Research Expo; a 2019 Impact Award from UNC-Chapel Hill's Graduate School; an Outstanding Graduate Research Assistant award in the Civil and Environmental Engineering Department at UNC-Charlotte; and a 2018 Environmental Health Scholars award issued by the Duke University Environmental Health Scholars Program.

Five WRRI-funded students received professional placements in their respective fields upon graduation in May 2019, including one student who joined the USGS South Atlantic Water Science Center full-time.

Researchers with active projects during this reporting period who were funded through WRRI (including from USGS, state, and research consortia funds) successfully secured a total of $439,375 in external funding for continuation and expansion of the research topics for which their WRRI-supported project served as the foundation.

WRRI renewed the bylaws for its two industry-based research consortia - the Urban Water Consortium representing 12 of the state's largest drinking water and wastewater utilities and the Stormwater Consortium (SWC) representing 9 municipal stormwater programs, whose combined annual membership dues of $165,000 support research on emerging topics in water. WRRI and the SWC co-developed a special RFP to build partnerships and improve engagement between municipal programs and underserved communities.

Projects

A Watershed Model to Understand Groundwater and Surface Water Interactions to Support Sewer Utility Resilience at the Jacksonville N.C. Forest Water Re-Use Facility

Project Type: Annual Base Grant **Project ID:** 2018NC223B

Project Impact: This project developed a hydrologic model to provide the City of Jacksonville (COJ) (NC) with visualizations of how their current municipal wastewater treatment system, a forest land application site (FWR), functions hydrologically and seasonally in response to weather, forest age, and forest management. COJ is exploring strategies to increase FWR capacity for future demand. The model provided insight to management practices that could increase FWR efficiency and flexibility for managing variable weather with climate change. One management option to increase irrigation capacity is to increase irrigation volume earlier in March rather than May. Forest management practices such as bedding for replanting would improve rooting depth of trees, which significantly impacts water use. COJ was excited that project results, shared by student researcher Nancy Gibson, support current operation perspectives that the FWR could treat more wastewater if allowed more flexibility to land apply when conditions are optimal rather than prescribed volumes per week. Model observations that irrigation does not limit FWR evapotranspiration and that rainfall drives FWR export of water were key outcomes that resonated with city officials and operators. Results will be provided as a summary for COJ personnel to use in discussions with NC Department of Environmental Quality as they discuss revised permits to avoid emergency spraying for extreme storms. This study has shown that these unique forest systems offer insights to water balance dynamics in irrigated forests and forest resiliency to extreme hydraulic loading that can be of use to regional wastewater land treatment systems for NC.

Adding Additional Model Years and Other Model Refinements to the Updated Neuse Estuary Eutrophication Model

Project Type: Annual Base Grant **Project ID:** 2018NC220B

Project Impact: The Neuse Estuary Eutrophication Model (NEEM) that is used as the basis of this was originally developed in the early 2000's as part of the North Carolina nutrient TMDL process. In a previous project funded by WRRI, researcher James Bowen created a new model grid, updated the model to run a second time period from 2006 to 2008, and developed a new procedure for calibrating the model that systematically evaluated thousands of potential parameter sets to find a set of them that satisfied multiple calibration criteria. The motivation to extend the model period past 2008 in this most recent project comes from the observation that both the magnitude and composition of incoming nutrients have been continually changing in the Neuse River Estuary. Analysis indicates that over the past ten years, total nitrogen loading to the estuary has continued to increase, with more and more of that load coming from the organic nitrogen portion. Variations in algal responses also motivated the analysis of more recent time periods. PI Bowen serves on the Science Advisory Committee (SAC) for the NC Nutrient Criteria Development Plan, which works to develop appropriate nutrient criteria for waters of the state. The goal of the NC Division of Water Resources (DWR), the state division overseeing the plan, is to develop scientifically defensible criteria based primarily on the linkage between nutrient concentrations and protection of designated uses. Results from this project have been directly transferred to the SAC and DWR's Modeling Unit to help inform nutrient criteria development.

Administration

Project Type: Annual Base Grant **Project ID:** 2018NC-ADMIN

Project Impact: In total, WRRI supported 23 active research projects during this reporting period through funds from the US Geological Survey (USGS), the state and other consortia funds. Twelve of those projects were initiated in this fiscal year, 5 of which were student projects. Researchers across these projects supported a total of 23 students (undergraduate, masters and PhD), delivered 63 presentations, achieved 13 publications, and successfully secured a total of $439,375 in additional funding outside of WRRI for which their WRRI-supported project served as the foundation. A further $570,774 in external grants was secured by WRRI to continue its community-based watershed

management efforts, launch a statewide water loss control pilot program and train local government staff on erosion and sediment control. Twelve students were formally recognized for their work through awards and employment, while many more had significant impacts and accomplishments through their other research and outreach activities.

Cometabolic Degradation of 1,4-Dioxane in Biologically Active Carbon Filters with Locally Enriched Biota

Project Type: Annual Base Grant **Project ID:** 2018NC225B

Project Impact: 1,4-Dioxane (14D) is a likely human carcinogen, and it occurs widely in drinking water sources. Some physiochemical treatment processes can control 14D, but treatment costs are high. Cometabolic biological approaches represent a promising treatment alternative. We enriched cultures from North Carolina (NC) rivers and (waste)water treatment plants and demonstrated they cometabolically degrade 14D with isobutane as primary substrate. The overarching goal of this study was to develop an engineered biofiltration system for long-term 14D degradation. Pilot-scale biofilters were designed to identify factors that affect biofilter efficiency (media type, empty bed contact time (EBCT), and primary substrate). Biofilters received coagulated NC surface water supplemented with nutrients and 14D (10 µg/L). Three active columns containing media with different 14D sorption capacities [two granular activated carbons (GACs), one carbonaceous resin] were inoculated and fed with primary substrate (n-butane, PEG400). In two active GAC filters receiving n-butane (1% v/v), 14D removal was maintained for >6 months, while the control GAC filters did not remove 14D after 2-4 weeks of operation. At an EBCT of 30 minutes, 14D degradation averaged 87% at steady state in the most effective GAC filter, and doubling the EBCT increased 14D degradation to >92%. The most effective GAC biofilter contained GAC with a larger grain size (4x12 mesh) and lower adsorption capacity. A lower backwash frequency and greater ability of n-butane to diffuse deeper into the GAC bed containing larger grains are possible explanations. Experiments are ongoing to characterize the spatial distribution of microbial activity in the biofilter.

Electrochemical Mineralization of Perfluorooctanoic Acid and Perfluorooctanesulfonic Acid

Project Type: Annual Base Grant **Project ID:** 2018226B

Project Impact: Per- and polyfluoroalkyl substances (PFASs) have been widely used in lubricants, polyurethane production, inks, varnishes, firefighting foams, food packaging, adhesives, electroplating, textiles, and stain resistant coating in clothing and carpets. PFASs from various sources pose risks to water quality in North Carolina and PFASs are highly recalcitrant to conventional and many advanced treatments practiced in drinking water treatment plants. Perfluorooctanoic acid (PFOA) is one of the most widely used and well-studied PFAS species and it is toxic and carcinogenic for both humans and animals. Ingestion of contaminated drinking water is one of the most important exposure route to PFOA. Although a considerable amount of research has been conducted on PFAS electrochemical degradation, limitations need to be addressed before such treatment can be applied for PFOA removal. The results from this study show that aerosol-based PFOA losses during electrochemical studies can be significant. Capturing such losses is an essential part of achieving complete fluorine mass balance. It is possible that previous studies done on electrochemical oxidation of PFAS compounds were not able to complete the fluorine mass balance due to these aerosol losses. Although this one-year project does not provide a successful treatment approach for PFAS electrochemical mineralization, it opened up other research opportunities and led to findings about important pitfalls from other previous studies. To extend the conclusions from this project to better evaluate the feasibility of PFAS electrochemical mineralization, future studies are being planned by the research team.

Hidden sediment sources: Locating and studying road-draining gullies using a geospatial model and field measurements

Project Type: Annual Base Grant **Project ID:** 2018NC219B

Project Impact: Sedimentation is a major pollution problem in North Carolina. Gullies formed by road drainage are a potentially large source of sediment, especially in the mountainous western portion of the state. The primary impact of the work so far has been on the undergraduate students involved in the analyses. So far, five undergraduate students

have contributed to the project. Three of them have presented related findings at the Southeastern Geological Society of America meeting and at least two will present at the American Geophysical Union fall meeting in San Francisco in December 2019. These experiences will have a profound impact on the students. The research features multiple future potential impacts. First, the state-provided, 1-m resolution DEM appears to be high enough resolution to remotely locate erosional gullies draining roads. Second, our preliminary gully detection model suggests that a simple multivariate logistic regression on 3-4 landscape metrics is capable of automatically detecting these features. Future work will test this model on data set not used in the development of the model. If the success of the model continues, we believe it can be applied widely to detect problem erosional features associated with roads across the mountains of the southeastern United States. Finally, there is preliminary evidence that the 1-m resolution DEM is high enough resolution to detect channel initiation points remotely. If verified, this may be of significant interest to the hydrologists and geomorphologists, and we hope the results will enhance our understanding of human influence over drainage networks and erosion/sedimentation.

Improving performance and examining expansion of constructed wetlands for tertiary treatment of nitrogen from domestic and municipal wastewater

Project Type: Annual Base Grant **Project ID:** 2018NC221B

Project Impact: Shifting to smaller wastewater treatment systems such as constructed wetlands offers a solution for reducing N pollution in streams and rivers in rural communities. These systems have been successful in NC; however, few are in operation, performance data are limited, and some older systems show signs of decreased N removal. Monitoring stations were installed at the inlet and outlet of two older wetland cells. Water quality samples indicated that the wetlands provided limited treatment. However, 72% of inlet TN was the form of NH4+. Treatment wetlands are anaerobic environments designed to remove NO3- via denitrification. Tracer tests indicated the cells were operating at 20 to 25% design volume with residence times of ~1 day. Restricted storage was the result of roughly 20 years of detrital build-up as vegetation is not harvested after the growing season. A clean out of one cell improved storage to 69% of design volume and reduced NH4+ export by removing a portion of the internal ammonium source. As the project progresses, increased nitrification in the upstream treatment system to provide NO3- enriched water to the wetlands will be a focus. By better utilizing the denitrification process, removing the internal source of NH4+, and increasing residence times, we hypothesize that the wetlands can be rejuvenated and provide improved N removal. We hope that the site can demonstrate to other minor wastewater treatment plants in NC how wetlands can be a low energy, long-lasting, environmentally-friendly way to reduce N loading to surface waters.

Occurrence of pesticides in North Carolina private drinking water wells and identification of point-of-use treatment options

Project Type: Annual Base Grant **Project ID:** 2018NC218B

Project Impact: In North Carolina, nearly 30% of residents rely on private well water as their primary drinking water source. There is little information on the occurrence of pesticides and other pollutants in private wells because they fall outside the purview of the Safe Drinking Water Act. The first goal of this research is to assess pesticide occurrence in private well water across North Carolina. The second goal is to evaluate the effectiveness of point-of-use (POU) treatment options for well users affected by pesticide contamination. To accomplish the first goal, 150 private wells in five North Carolina counties will be sampled and analyzed for a suite of contaminants including pesticides, volatile organic contaminants, and total coliforms. To date we have sampled 35 wells in Guilford county and are currently recruiting participants in Wake county. To identify a wide range of pesticides we have developed a new analytical method using high-resolution mass spectrometry to identify a more comprehensive suite of pesticides using nontarget analysis. For the second goal, a range of POU treatment devices will be tested to identify those effective in removing pesticides and other contaminants identified in objective one. The proposed research will benefit the public in North Carolina by introducing a new analytical approach to more comprehensively assess the quality of private wells. Furthermore, the obtained water quality data will support private well users' assurance that their drinking water is safe or it will enable them to make informed decisions about treatment options to reduce human exposure.

Phytoplankton Nutritional Ecology and the Eutrophication Trajectory in a Piedmont Reservoir with Elevated Ammonium

Project Type: Annual Base Grant **Project ID:** 2018NC224B

Project Impact: Potable source waters across the U.S. are sustaining cultural eutrophication, and rising water demands following population growth further stress these systems. Reservoirs in the Southeast are characterized as nutrient over-enriched, turbid, and shallow with recurrent algal blooms that are increasing in frequency and duration, but there is little information about the phytoplankton ecology and response to escalating eutrophication. Falls Lake, near Raleigh N.C., is a representative drinking water reservoir in a rapidly urbanizing watershed. We completed two objectives to examine the Falls Lake phytoplankton response to shifting nutrient regimes. First, we data-mined a long-term dataset on Falls Lake (from the Center for Applied Aquatic Ecology [CAAE]) for water quality and algal assemblage dynamics. Second, we conducted microcosm experiments in situ to assess the phytoplankton assemblage response to elevated concentrations of N forms (NH4+ or NO3-), with or without P and to shifts in inorganic nitrogen-to-phosphorus (Ni:Pi) ratios. Falls Lake had the greatest increase in algal biomass (as chla) to both N and P additions. Cyanobacteria dominate the phytoplankton assemblage, and are expected to persist if nutrient inputs continue or increase with forecasted watershed urbanization. Cyanobacteria are high-nutrient and low-light adapted, suggesting that they have an advantage in turbid, increasingly eutrophic aquatic systems, such as Falls Lake. This work underscores the importance of routine water quality and phytoplankton monitoring of drinking source-waters, to better understand the responses of these systems. Co-managed major reductions in both N and P inputs are recommended to reduce harmful cyanobacterial growth and, overall, improve reservoir health.