

**Water Resources Center
Annual Technical Report
FY 2017**

Introduction

The Rhode Island Water Resources Center supported several activities in research and outreach. The Center supported two research grants to study the impacts of chlorine disinfection on water quality and the investigation of a novel water treatment process. The two outreach projects included a Water Symposium and a Summer Water Academy for high school STEM students.

Research Program Introduction

The first of two research projects that were submitted was entitled "Detection and formation of nitrogenous disinfection byproducts (N-DBPs) in Rhode Island source waters" by Soni M. Pradhanang, Thomas B. Boving, Maxwell C. Meadows, Hichem Hadjeres had three goals: I. To conduct a synoptic study for assessing N-DBPs precursors such as Total Nitrogen, (TN), nitrate (NO₃⁻-N), nitrite (NO₂⁻-N), and ammonium (NH₄⁺-N) in RI drinking water, II. To develop a method for nitrosamine detection using Gas Chromatography – Mass Spectrometry (GC-MS) and III. To perform bench-top experiments that mimic typical WTP operations to understand effects of chloramine disinfection on N-DBPs formation. The second research project was entitled, "Water Purification via Hydrogels with Voltage-Controlled Electrodynamic Properties," by Samantha Meenach and Stephen Kennedy There is a strong demand for new water pre-treatment strategies for removing heavy metal ions, organics, metals, solvents, and oils. To accomplish this the project leaders focused on the development of graphene oxide (GO)-loaded hydrogels capable of sequestering cationic model dyes as a preliminary step.

Water Purification via Hydrogels with Voltage-Controlled Electrodynamic Properties

Basic Information

Title:	Water Purification via Hydrogels with Voltage-Controlled Electrodynamic Properties
Project Number:	2017RI127B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	RI-002
Research Category:	Engineering
Focus Categories:	Wastewater, Treatment, Groundwater
Descriptors:	None
Principal Investigators:	Samantha Ann Meenach, Stephen M Kennedy

Publications

There are no publications.

Water Purification via Hydrogels with Voltage-Controlled Electrodynamic Properties

Research Overview

Rhode Island's industrial and commercial bases present high potentials for water contamination. Accordingly, many municipalities have strict restrictions on the types and amount of contaminants that can be discharged to wastewater treatment facilities. These include restrictions on heavy metal ions, organics, metals, solvents, and oils (Cong, Ren et al. 2012, Chen, Chen et al. 2013). Therefore, there is a strong demand for new water pre-treatment strategies. These strategies must be capable of selectively sequestering specific contaminants, safely retaining contaminants during transport, and releasing contaminants when required to do so (after safe transport) (Crini 2006). Additionally, renewability (i.e., reuse of these materials after transport and release) is highly desirable for environmental and economic reasons. These limitations have driven the search for materials more effective in adsorbing harmful water pollutants and have included many newly developed and evaluated types of polymer-based materials such as hydrogels. Hydrogels are networks of cross-linked hydrophilic polymer (Pan 2012) that are able to absorb and retain water and water-soluble molecules (Naficy 2012, Kearney 2013). Thus, they are ideal materials for absorbing and transporting aqueous materials. While hydrogel-based water treatment strategies are promising in that they are capable of retaining and transporting high concentrations of water-carried contaminants, there are a number of aspects requiring improvement for these particular applications. Namely, hydrogel-based strategies for removing specific contaminants must be developed (i.e., not just the removal of contaminants with positive or negative charges, but with specific charge polarities and densities). Furthermore, enhanced strategies must be developed for removing contaminants from hydrogels (for reuse) in an on-demand, inexpensive, and simple manner. The original proposed project involved a novel hydrogel material capable of presenting variable electrical charge in a voltage-controlled manner for the sequestration and removal of model contaminants. Due to unforeseen challenges with this material, the project leaders instead focused on the development of graphene oxide (GO)-loaded hydrogels capable of sequestering cationic model dyes.

Detailed Project Overview

Since the dawn of the industrial revolution indiscriminate dumping of wastewater from textile mills, metallurgical factories, and other manufacturing facilities have contaminated our waterways with toxic dyes and heavy metal ions. The removal of contaminants from wastewater has been successfully achieved using carbon-based materials such as C₁₈ silica and activated carbon but these materials often suffer from low adsorption capacities and lack of reusability. Graphene oxide (GO) has recently been investigated as a solution to these problems. GO is a single atom thick nanomaterial with functionalized oxygen groups on its basal plane (Dreyer, Park et al. 2010). Since GO is a flat sheet, there is tremendous surface area for interaction with other particles. The issue with GO is it tends to aggregate, however, incorporating GO into a hydrogel matrix can overcome this limitation. In this study, the hydrogel matrix was comprised of poly(acrylamide) (PAAm) and the gels were made at room and cryogenic temperatures resulting in nanoporous (N) and macroporous (M) hydrogels, respectively. The difference in polymerization temperatures caused a variation in pore size where cryogenic hydrogels formed a macroporous structure due to the freezing of water molecules and formation of ice crystals during polymerization. GO was added to the hydrogels and swelling and adsorption tests were conducted. For the adsorption experiments, two model contaminants were tested; methylene blue (MB) and eosin Y (EY). The compounds were chosen to represent cationic and anionic molecules respectively. Adsorption experiments were conducted where gel samples were placed into a solution of each contaminant.

Hydrogel Nanocomposite Synthesis and Swelling

Materials and Methods. Acrylamide (AAm) was used as the polymeric backbone of the hydrogel whereas nanosized graphene oxide (GO) was added to the hydrogel nanocomposites because of its large surface area and chemical nature allowing for the attraction of positively charged organic compounds that are potential wastewater contaminants. The hydrogel nanocomposites were chemically crosslinked using ammonium persulfate (APS, free radical initiator) and tetramethylethylenediamine (TEMED, initiator) into 1 mm thick sheets between glass plates. Macroporous gels (M) were created by immediately placing the hydrogel

systems in the freezer immediately following the addition of APS and TEMED but before hydrogel polymerization to allow for the formation of crystals in the systems. Structures of the involved chemicals can be seen in **Figure 1** whereas actual hydrogel structures can be seen in **Figure 2**. Following gel formation, 1 cm circles were cut from the hydrogel sheets for the evaluation of hydrogel swelling. Hydrated gels were weighed (M_{wet}) after equilibrating in water at different temperatures and the freeze-dried then reweighed (M_{dry}) and their mass swelling ratio was calculated using:

$$\text{Swelling Ratio (SR)} = \frac{M_{wet}}{M_{dry}}$$

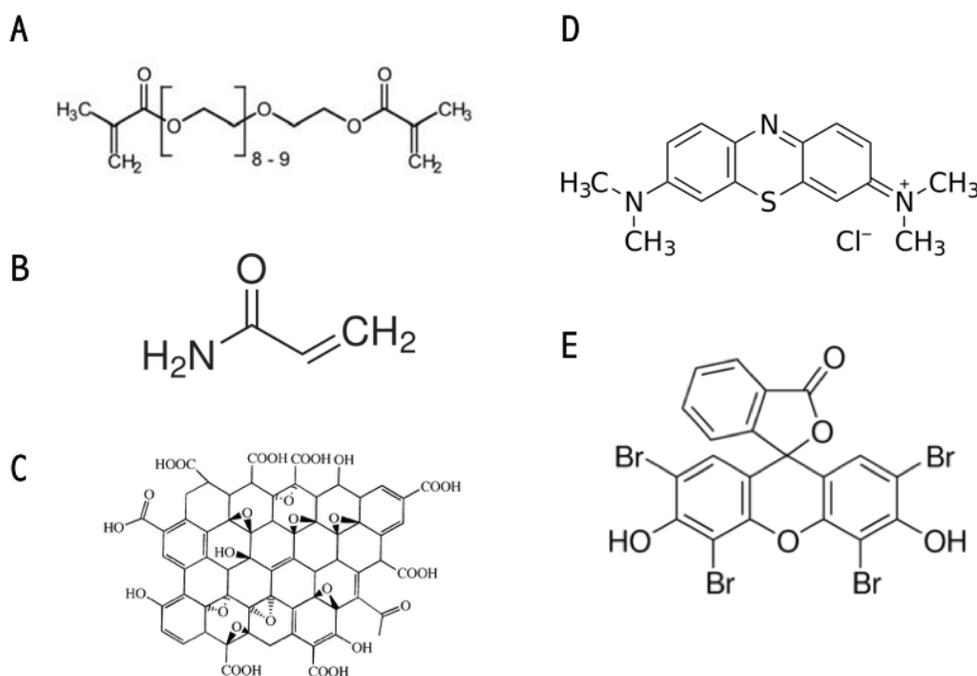


Figure 1. Chemical structures of hydrogel components including: A) poly(ethylene glycol) (PEG MW = 400) dimethacrylate (PEG400DMA), B) acrylamide (AAM), C) graphene oxide (GO) and structures of model wastewater contaminants including: D) methylene blue, E) eosin Y.

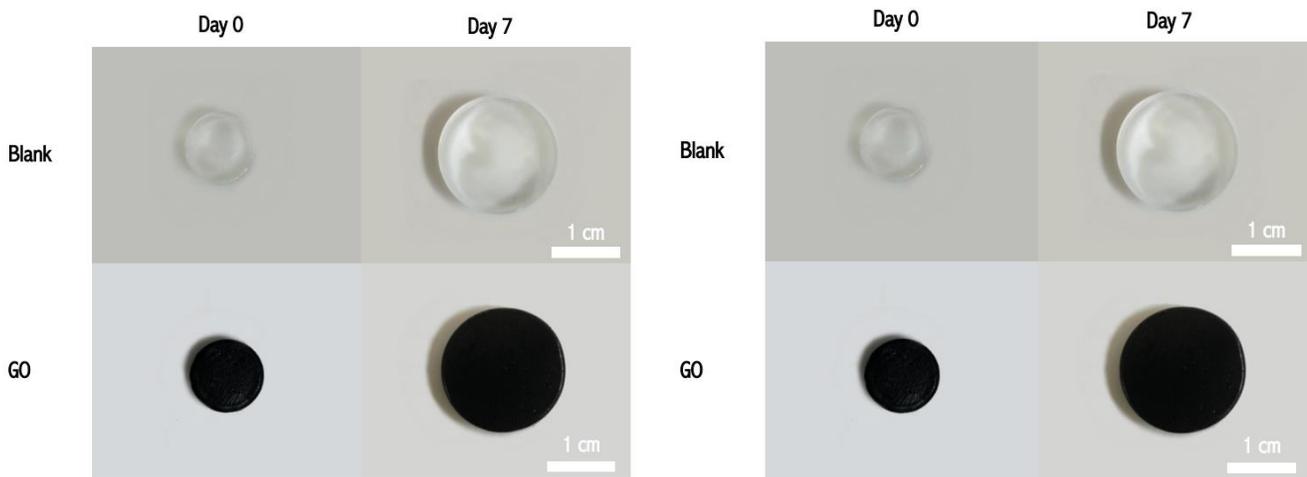


Figure 2. Images of (left) nanoporous (N) and (right) macroporous (hydrogels).

Results. The images in **Figure 2** show the successful formation of hydrogels both with and without GO at their initial synthesis (Day 0) and after 7 days of swelling in DI water. As seen in **Figure 3**, there were minimal differences between the swelling ratios of blank nano- and macroporous gels or GO-loaded gels. There was, however, a difference between blank and GO-loaded gels, likely due to the interaction between the AAm and crosslinker and GO.

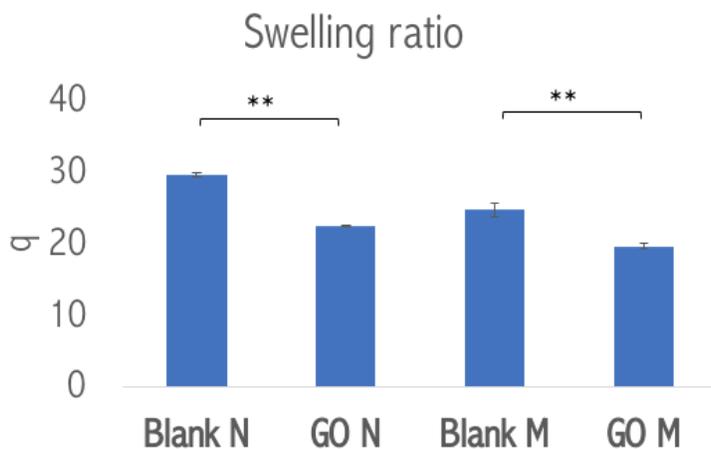


Figure 3. Swelling ratios of nanoporous (N) and macroporous (M) hydrogels with (Blank) and without graphene oxide (GO).

Adsorption Experiments

Materials and Methods: Adsorption studies were completed by taking a swollen hydrogel and placing it into a solution of the model contaminant. At given times, the absorbance of the remaining contaminant was measured to evaluate the amount of contaminant taken up into the hydrogel system. Calibration curves of known contaminant concentration versus absorption were used to evaluate the concentration of the solution at a given time. The adsorption (q) of the contaminant was calculated from:

$$\text{Adsorption, } q \text{ (mg contaminant * g}^{-1}\text{GO)} = \frac{(C_0 - C_t) * V}{M_{GO}}$$

where C_0 is the initial contaminant concentration, C_t is the contaminant concentration at time t , and V is the volume of the solution.

Results: The absorption of both methylene blue (MB) and eosin y (EY) were evaluated in macro- and nanoporous gels, both with and without GO as seen in **Figures 4-7**. MB was successfully absorbed by macro and nanoporous gels containing GO but not in blank gels (without GO) owing to the interaction between GO and MB. EY was not absorbed by any of the hydrogel systems, owing to the similar charge between EY and GO.

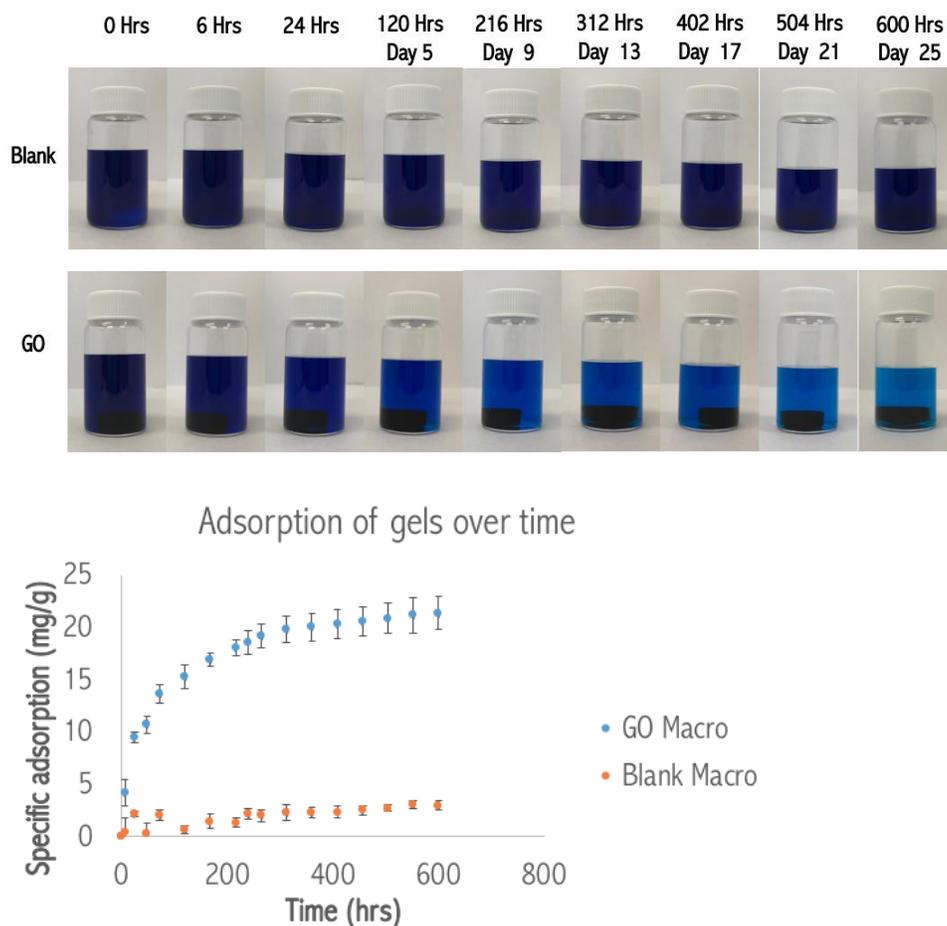
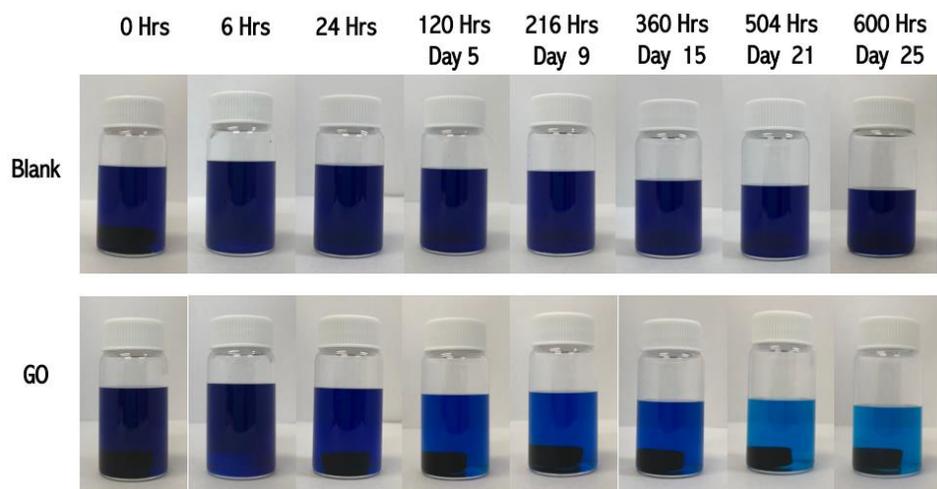


Figure 4. (Top) Vials containing methylene blue (MB) and gels and the resulting adsorption over time. (Bottom) Specific adsorption of MB in GO-loaded and blank macroporous gels.



Adsorption of gels over time

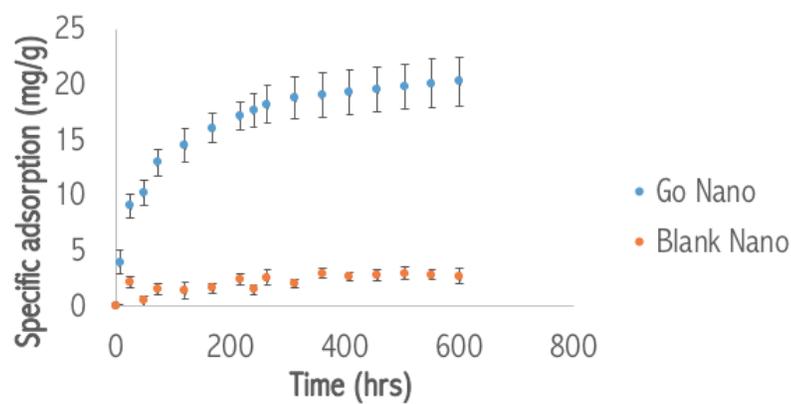
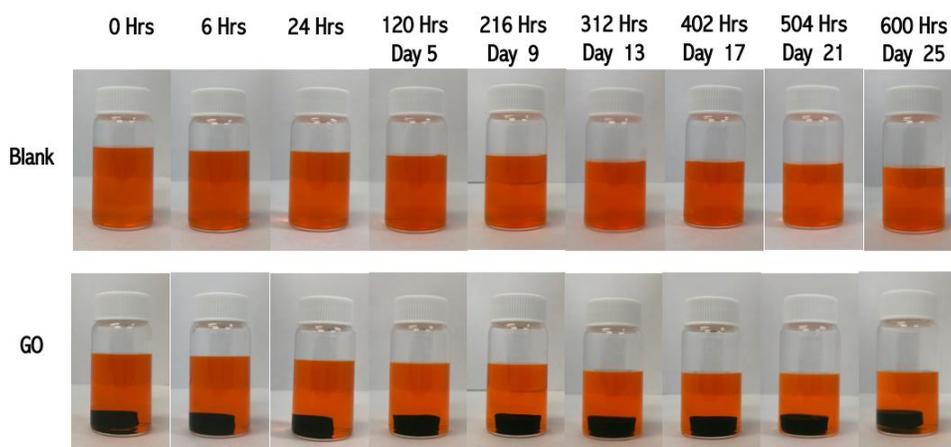


Figure 5. (Top) Vials containing methylene blue (MB) and gels and the resulting adsorption over time. (Bottom) Specific absorption of MB in GO-loaded and blank nanoporous gels.



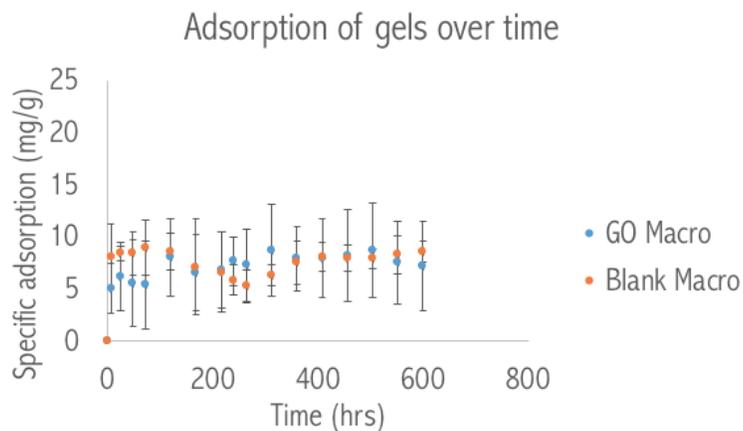


Figure 6. (Top) Vials containing eosin Y (EY) and gels and the resulting adsorption over time. (Bottom) Specific absorption of EY in GO-loaded and blank macroporous gels.

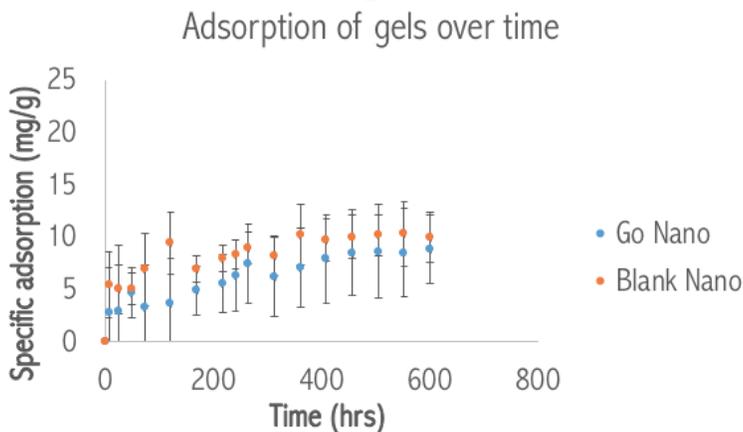
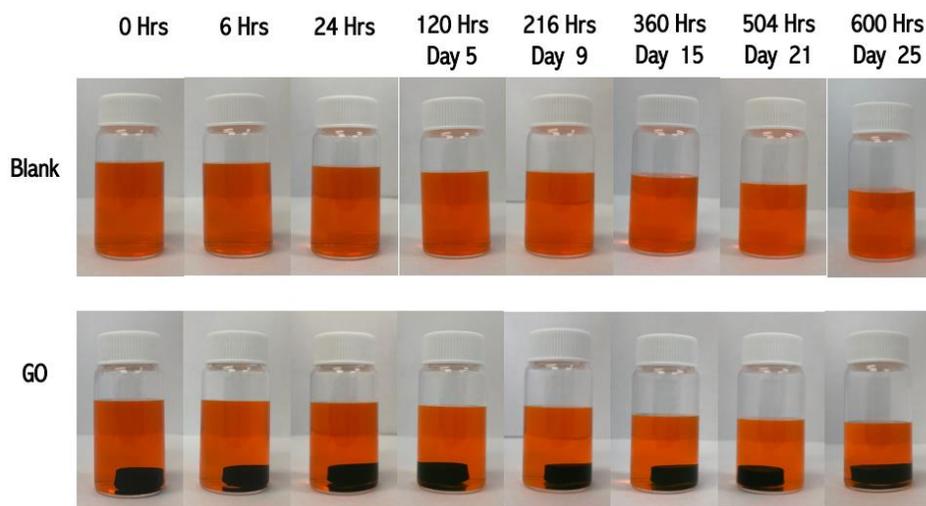


Figure 7. (Top) Vials containing eosin Y (EY) and gels and the resulting adsorption over time. (Bottom) Specific absorption of EY in GO-loaded and blank nanoporous gels.

Summary

Overall, we have successfully loaded GO into macroporous and nanoporous hydrogels comprised of AAm and this is the first time this has been done using these particular compounds. The GO-loaded hydrogel systems

exhibited excellent adsorption toward a cationic dye. These hydrogels systems show great promise to be used in the design of adsorbents for the removal of unwanted contaminants in water systems.

Future Work

Studies that will be need to be complete for this project include:

- Compression testing of hydrogels to determine modulus
- Thermalgravimetric analysis (TGA) to determine actual GO loading
- Completion of isotherms
- Writing and submission of manuscript

Student Impact

An undergraduate student (Elena Rittling) and two graduate students (Elisa Torrico Guzmán and Tania Emi) in chemical engineering oversaw the described project and benefited from the work undertaken. Elisa will be presenting this work at the 2018 American Institute of Chemical Engineers (AIChE) conference in October.

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Occurrence and formation of N-DBPs in source waters of Rhode Island

Basic Information

Title:	Occurrence and formation of N-DBPs in source waters of Rhode Island
Project Number:	2017RI129B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Categories:	Water Quality, Treatment, Surface Water
Descriptors:	None
Principal Investigators:	Soni M Pradhanang, Tom Boving, David A. Reckhow

Publication

1. Meadows, M., Pradhanang S. M., Boving, T.B., Hadjeres, H., 2018. Occurrence of N-DBPs in Drinking Water Sources of Rhode Island. 2018 Graduate Students Conference at the University of Rhode Island, April 7, 2018. Kingston, RI. USA

Detection and formation of nitrogenous disinfection byproducts (N-DBPs) in Rhode Island source waters

Soni M. Pradhanang, Thomas B. Boving, Maxwell C. Meadows, Hichem Hadjeres

University of Rhode Island, Department of Geosciences

Introduction

Nitrogenous disinfection byproducts (N-DBPs) are toxic byproducts of emerging concern that may be present in source waters from industrial or wastewater discharge, septic systems, or as byproducts of water treatment plant (WTP) operations. Specifically, N-DBPs such as nitrosamines can be formed from reaction of precursors within a treatment plant or distribution system (Schreiber & Mitch, 2006). Many nitrosamines that have been studied are potent carcinogens. Nitrosamines are formed by reaction of nitrite with certain organic nitrogen containing compounds (Wolff & Wasserman, 1972); however, the exact environments and processes leading to nitrosamine formation are still not well understood. Mitch & Sedlack, (2002), and Schreiber & Mitch (2006) documented the reactions of chloramines with organic nitrogen precursors as the primary mechanism responsible for N-DBP formation in WTPs. These precursors to nitrosamine formation are abundant in many drinking water sources throughout Rhode Island, and can be formed in the distribution systems, making these supplies particularly susceptible to nitrosamine formation.

The objectives of this study are to:

- I. Conduct a synoptic study for assessing N-DBPs precursors such as Total Nitrogen, (TN), nitrate (NO_3^- -N), nitrite (NO_2^- -N), and ammonium (NH_4^+ -N) in RI drinking water.

- II. Develop method for nitrosamine detection using Gas Chromatography – Mass Spectrometry (GC-MS).
- III. Perform bench-top experiments that mimic typical WTP operations to understand effects of chloramine disinfection on N-DBPs formation.

This report presents the findings of objective I and will address improvised methods for the laboratory analysis of N-DBPs. The information obtained in this study will be used to propose strategies to minimize exposure such as improvising treatment, changing source water, or possibly instituting waste and agricultural management practices. This will allow Rhode Island water supply systems to consider their potential compliance with guidelines and regulations that are anticipated for N-DBPs in the near future.

Methods

Removal of precursors is the most assured way to limit N-DBP formation potential; however, WTP processes may limit effectiveness for precursor removal. For this reason, more recently researchers have emphasized exploring the origin and nature of the precursors that would form N-DBPs (Leavey-Roback et al., 2016; Chu et al., 2013; Krasner et al., 2013; Bond et al., 2011; Chu et al., 2011).

The first phase of this study addresses Objective I. Ten drinking water samples were collected from different places within RI to represent spatial heterogeneity (Fig. 1). Water sources being supplied by WTPs were of particular interest, as there is potential for nitrosamine formation in these operations. Seven of the chosen locations are supplied with treated drinking water from nearby WTPs and the remaining 3 locations are supplied with natural groundwater (GW).

Samples used for TN, NO₃⁻-N, NO₂⁻-N, and NH₄⁺-N analysis were collected in clean 40 mL amber glass vials with Teflon lined screw caps. The samples used for nitrosamine detection were collected in dichloromethane rinsed 1 L amber bottles with Teflon lined screw caps. Prior to storage, 80 mg sodium thiosulfate was added to 1 L samples to quench residual chlorine. All field samples were kept in 4°C cold storage until it was time for extraction or analysis (APHA, 1999). TN analysis was performed using a Shimadzu TOC-L equipped with a TNM-L (Shimadzu, 2014). NO₃⁻-N, NO₂⁻-N, and NH₄⁺-N analysis was completed using a Thermo Fisher Dionex ICS – 5000 DC (APHA, 1992).

Phase two of this study consists of N-DBP method development and formation potential tests using a benchtop experiment and is a part of Objectives II and III. Nitrosamine analysis typically follows methods requiring gas chromatography - tandem mass spectrometry (GC-MS/MS), however the Hydrology and Water Quality Lab at URI is not equipped with this technology. To complete this research, a nitrosamine detection method which required GC-MS was developed. Extraction of field samples followed procedures listed in Standard Methods for the Examination of Water and Wastewater: Method 6410 (APHA, 1999). Figure 2 shows liquid-liquid extraction between collected samples and dichloromethane (DCM) solvent. Following triple extraction, the samples were rinsed through anhydrous sodium sulfate (Na₂SO₄) and collected in a Kuderna-Danish apparatus for concentration (Fig. 3). Figure 4 shows concentration of samples using a hot water bath to finalize extraction procedure. To analyze extractions using GC-MS, operating parameters were setup based on EPA method 521 (USEPA, 2004), but were adjusted to account for expected nitrosamine concentrations after synoptic samples were extracted.

The benchtop experiment models a typical WTP chloramine disinfection procedure in a laboratory bench-scale apparatus. Completion of this stage provides greater understanding to which factors contribute the most to N-DBP formation, and how removal of precursors translates to a decrease in N-DBP formation during chloramine disinfection. There have been no systematic studies in Rhode Island which have considered potential for formation of N-DBPs and the relationship of nitrosamine formation to disinfection.

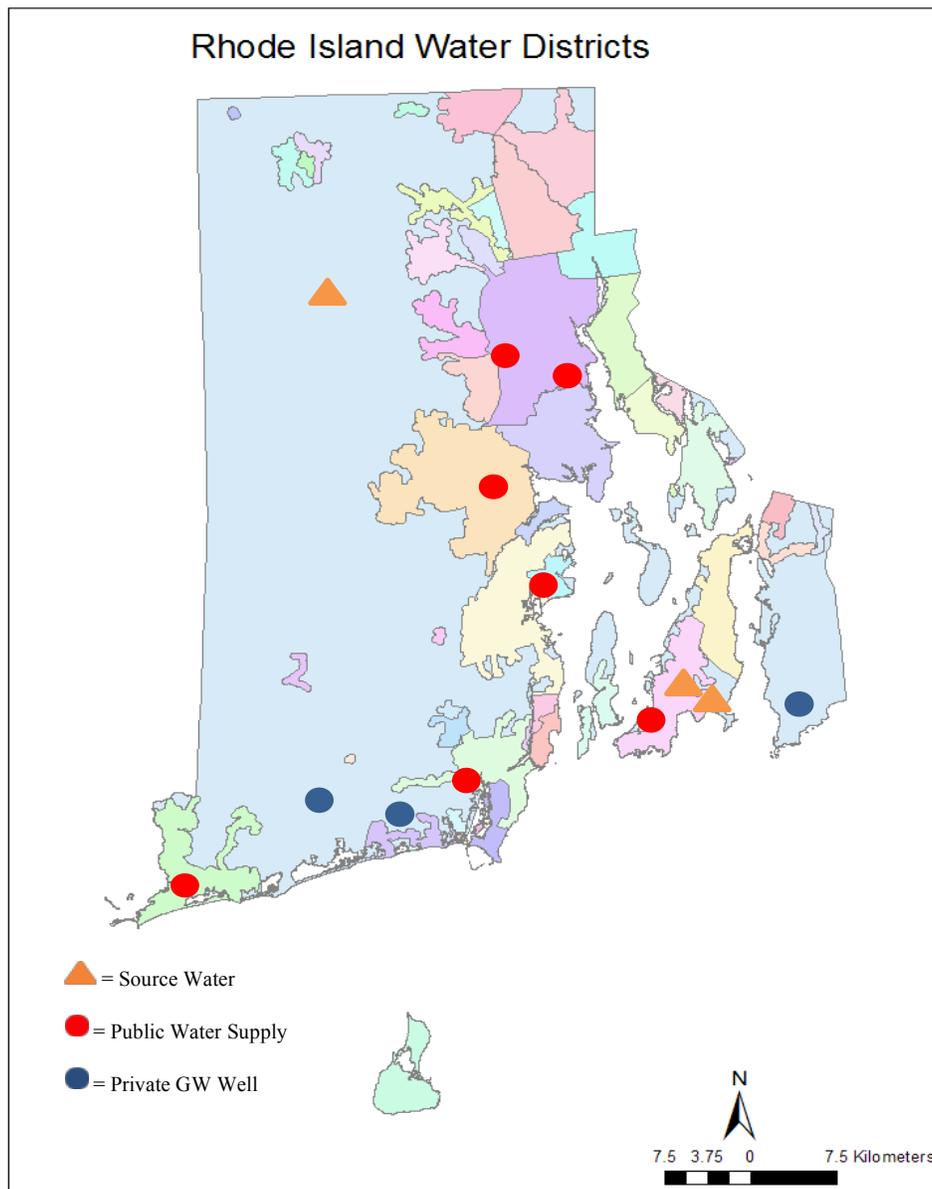


Figure 1. Synoptic sampling and source water locations

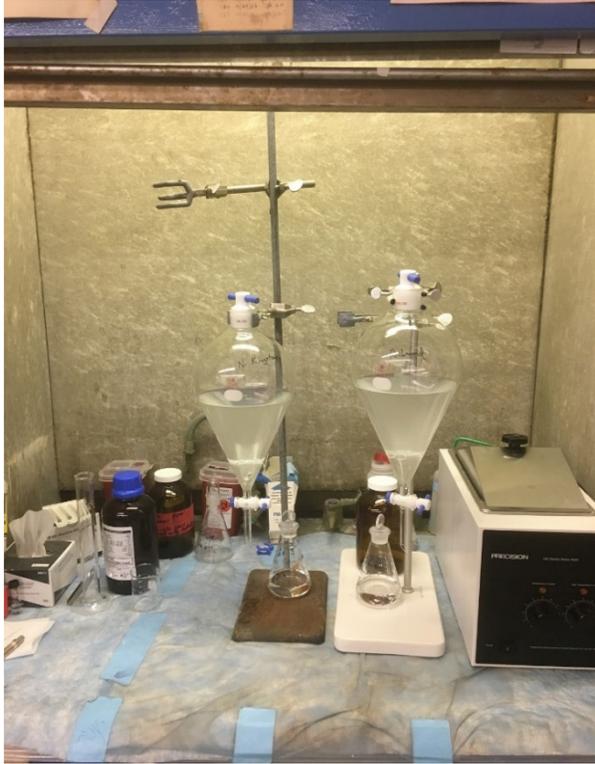


Figure 2. Liquid-liquid extraction of samples



Figure 3. Extract rinsing and collection



Figure 4. Extract concentration

The bench scale WTP was previously developed based on Figure 5, to assess carbon-based disinfection byproducts (DBPs) precursor removal, and how it relates to DBP formation during traditional chlorine disinfection. The same bench scale experiment was altered to study removal rates of N-DBP precursors. Figure 6 shows the flocculator that has been customized for rapid mixing, coagulation, flocculation, and sedimentation occur during the benchtop water treatment experiment. For better demonstration of precursor removal processes, Figures 7 & 8 were included to show coagulation, flocculation, and sedimentation. After allowing sample to settle for a minimum of 1 hour, a peristaltic pump was used to pump water through a dual-media column filter, then through a Granular Activated Carbon (GAC) filter (Figure 9) to optimize precursor removal before chloramine disinfection. Raw sample, and effluents collected following sedimentation, dual media filtration, and GAC filtration will be disinfected using chloramines, then extracted by following developed method procedures. Extractions will be analyzed using GC-MS to quantify N-DBP formation potential during each phase of the bench scale WTP experiment.

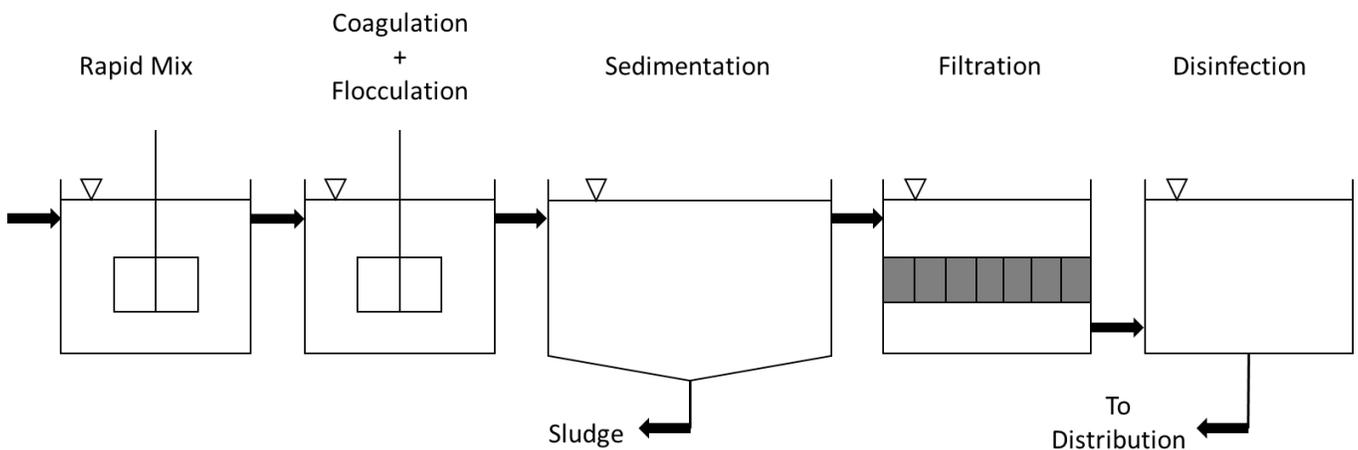


Figure 5. Traditional water treatment protocol used by WTPs

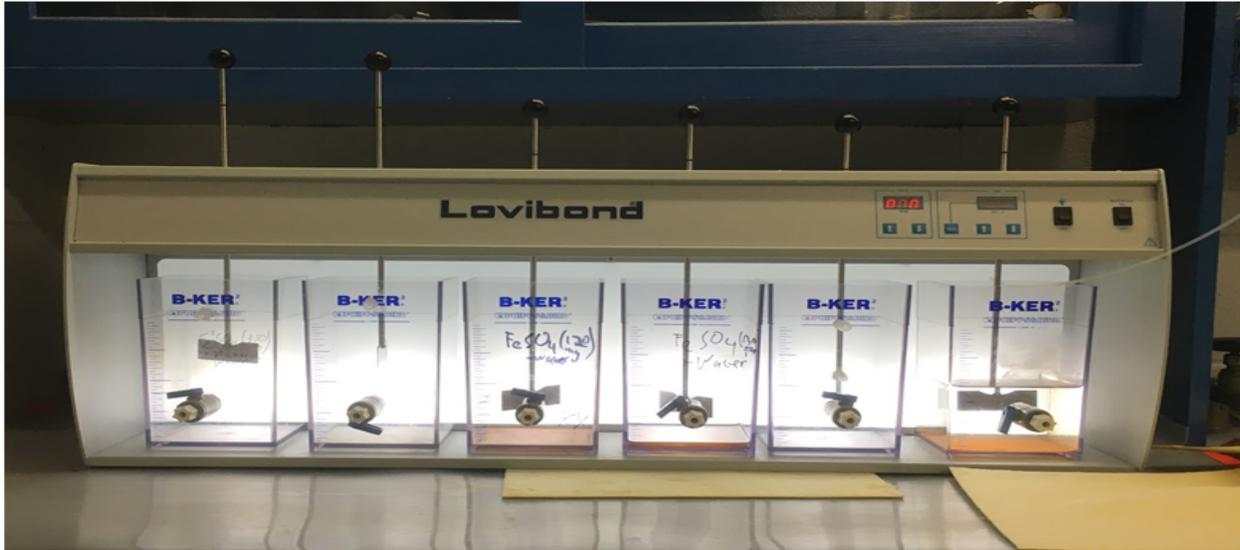


Figure 6. Flocculator used for flocculation, coagulation, and sedimentation steps of bench scale water treatment experiment

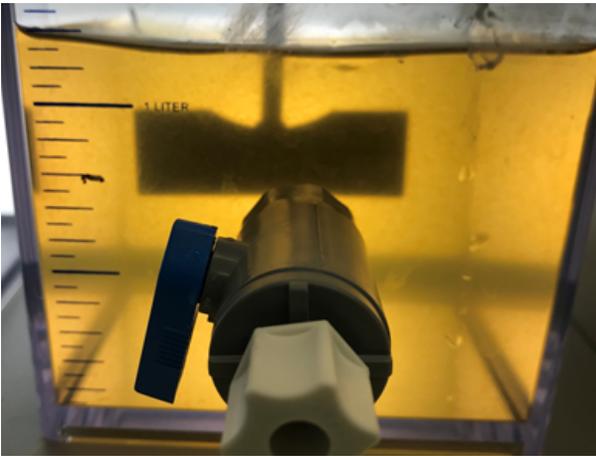


Figure 7. Rapid mixing of coagulant into sample

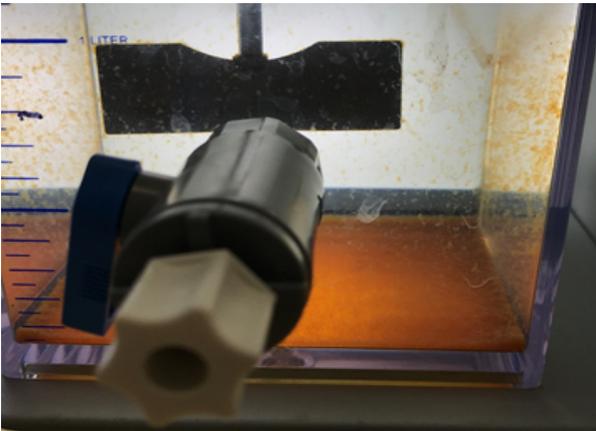


Figure 8. Settled flocculate



Figure 9. Dual media filter (top column) with GAC filter (bottom column)

Results and Discussion

The results presented in this report pertain to the laboratory analysis conducted in the Hydrology and Water Quality Lab at the University of Rhode Island. Figure 10 shows the analysis of TN and Total Organic Carbon (TOC) from synoptic sampling locations. A poor correlation exists between TOC and N-DBP formation potential (Uzun et al., 2015). For this research, TOC was measured to show variation between humic and nitrogenous precursors among sample locations. It is important to note that locations supplied by private GW wells had TN levels ranging from 0 to 0.5 mg/L, therefore, N-DBP formation potential is less in private GW wells than in locations supplied by public water systems. Contributors to TN in both private and public water supplies vary depending on source water type. Typically, GW wells are protected from surface influences like agricultural or urban runoff and industrial discharges, however, well depth plays a critical role in the interaction between surface influences and water quality. A public distribution system may obtain water from GW aquifers, or surface water reservoirs, resulting in precursor concentration variance.

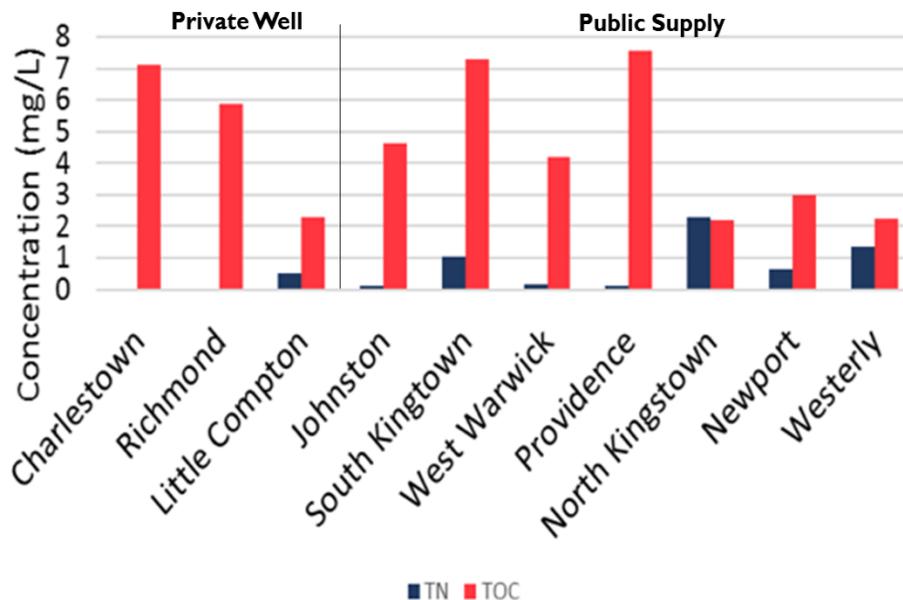


Figure 10. Synoptic sampling precursor concentrations

Traditional WTPs use dual media as a filtration system before the water is disinfected and sent to distribution. In the benchtop experiment, a GAC filter was added as a secondary filter to sorb any particles that may have passed through the dual media filter. One main goal of water treatment is to reduce byproduct precursors before water is disinfected, since disinfecting water with high concentrations of precursors results in formation of high concentrations of by-products. Figure 11 shows the result of using a GAC filter after dual media filtration. By completely removing TN before disinfection, there is low likelihood of N-DBP formation. Krasner et al. (2013) also stated waters exposed to GAC saw reduction in N-Nitrosodimethylamine (NDMA) formation potential.

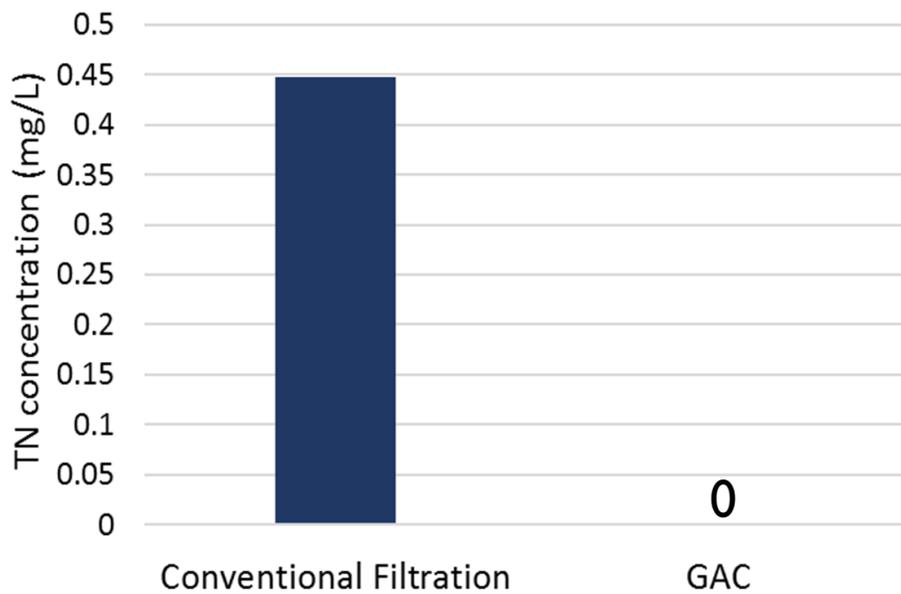


Figure 11. TN concentrations following dual media and GAC filtration

By quantifying nitrogenous precursor concentrations in different source water types, predictions can be made about N-DBP formation potential during disinfection. Standard WTP disinfection procedures could be altered or improvised to accommodate for precursors removal.

Due to the unavailability of GC-MS/MS on site, an integrated method for N-DBP analysis was established. Method development followed sample extraction procedures from Method 6410 (APHA, 1999), and GC-MS operating parameters based on Method 521 (USEPA, 2004). Figure 12 shows the precision of the calibration curve for the integrated method. Following calibration, sample analysis will take place.

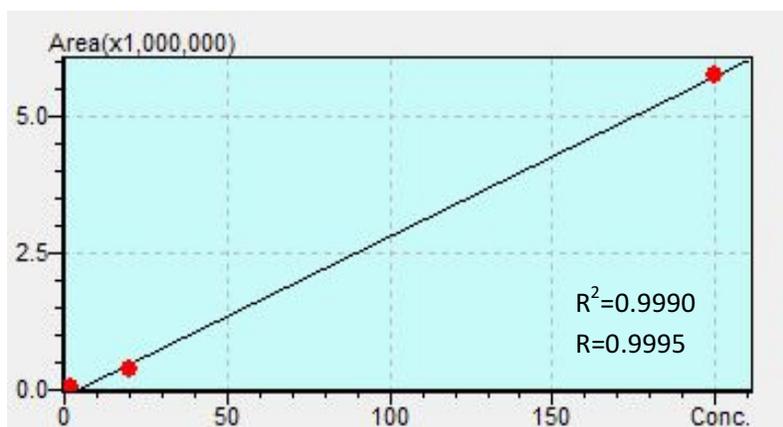


Figure 12. GC-MS calibration curve using nitrosamine standards

Conclusion

Results from precursor analysis showed no correlation between TOC and TN concentrations in both private GW, and public water supplies. GW sources contained some of the lowest TN concentrations compared to some locations supplied by surface water. N-DBP formation potential is predicted to be greater locations where TN concentrations are highest. To reduce N-DBP formation potential during water treatment, TN precursors should be removed prior to chloramine disinfection. GAC filtration was highly effective in the complete removal of TN concentrations following dual media filtration. APHA (1999) liquid-liquid extraction procedures were integrated with USEPA (2004) analysis parameters to create a method that can detect N-DBP concentrations in water. Future work includes continuing assessment of N-DBP

concentrations in RI drinking water. Additional locations will be chosen to extend the spatial distribution of sampling. Seasonal variability and extreme weather events will also be considered when examining source water quality, as it relates to N-DBP precursor loading.

Acknowledgements

We kindly thank the USGS-NIWR and Rhode Island Water Resources Center for granting the opportunity to complete this research. We also acknowledge S-1063 USDA Multistate Hatch Grant for further assistance.

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Students that were supported from this research

This project supported one graduate student. Maxwell Meadows is a graduate student who was supported funding for two semesters from this grant, where he conducted laboratory experiments to develop an N-DBP analysis method and studied precursor involvement in the formation potential of N-DBPs using a benchtop water treatment system. Keeley Lievesley, an undergraduate has also greatly benefitted from this research project. She primarily worked in the lab to analyze TN precursors using a TNM-L analyzer and assisted Maxwell in performing sample extractions. Hichem Hadjeres, a BES graduate student was involved in setting up the benchtop experiment.

Publication:

Meadows, M., Pradhanang S. M., Boving, T.B., Hadjeres, H., 2018. Occurrence of N-DBPs in Drinking Water Sources of Rhode Island. 2018 Graduate Students Conference at the University of Rhode Island, April 7, 2018. Kingston, RI. USA

Information Transfer Program Introduction

There were two information transfer projects funded. One project was a Clean Water Symposium and the other was a Summer Clean Water Academy.

Clean Drinking Water in Rhode Island

Basic Information

Title:	Clean Drinking Water in Rhode Island
Project Number:	2017RI133B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	2
Research Category:	Not Applicable
Focus Categories:	Treatment, Water Quality, Education
Descriptors:	None
Principal Investigators:	Christopher Dickerson Hunter

Publications

There are no publications.

The 2017 University of Rhode Island (URI) Clean Water Science and Engineering Academy

This year's URI Clean Water Science and Engineering Academy occurred on five consecutive Saturdays between September 16 and October 14 with 15 students who were entering 9-12 grades from the Times Squared STEM Academy High School from Providence, RI. All sessions were held at URI, whether they were in classrooms, labs, or capturing data in the field near URI. Students were involved with activities from approximately 9:00AM to 3:30PM each day. The academy was free for the students, and it included a light breakfast, lunch, and snacks.

The week began with a presentation on the impact of water and then the water cycle. This led us into a general discussion session with the students and into the first major activity for the students, "Pop Quiz". Figure 1 gives you an indication of what happens during this game. Students are presented with an answer and a dollar amount, and they must answer in the form of a question.

The academy does spend some time investigating water quality by typically gathering 2 or 3 samples of water from various locations and allowing students to test for pH, hardness, nitrate/nitrite levels, Iron, Copper, Free chlorine, and turbidity. In some instances, we have also tested drinking water from various water fountains around the URI campus. We give the students a map and send them out to gather two samples: one on the initial turn on of the water and then another, 1 minute after the water has been running. Sometimes, we have asked the students to bring samples from home for comparison.

Beyond the various labs on filtration, settling, and flocculation, we exposed the students to some coding through MATLAB software. Teams were given water-based problems to solve and then they were asked to look through data on water quality, pick one or two water quality characteristics and to plot those using MATLAB over the ten sites that were provided.

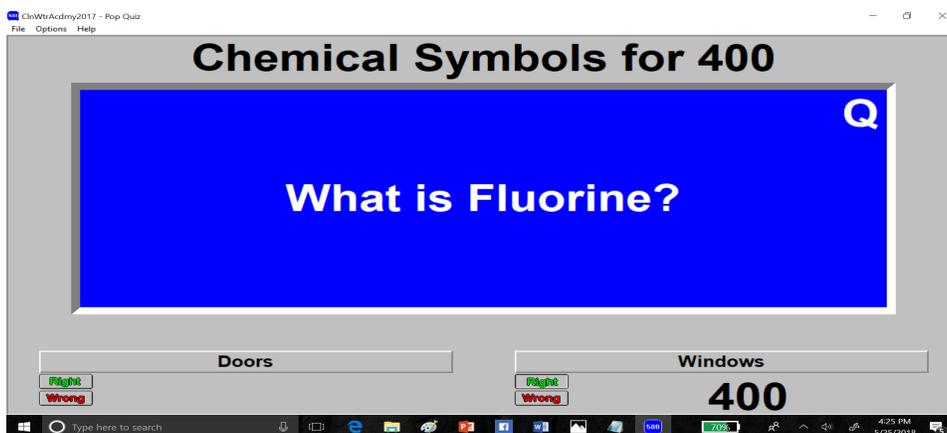
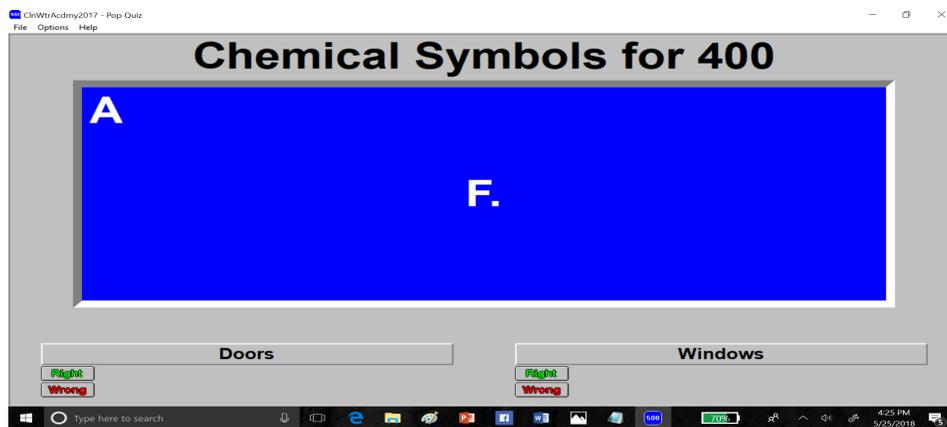
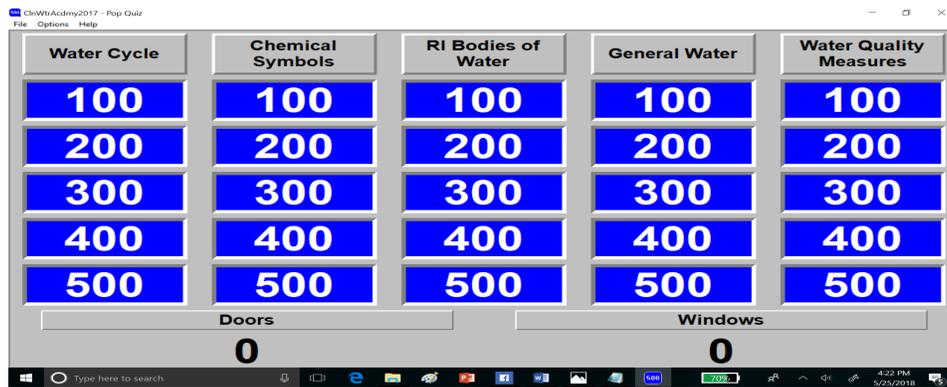


Figure 1. Pop Quiz Activity Example

Overall, activities for the students involved numerous presentations, various laboratory exercises, field data capture, and software applications, including Microsoft Excel and MATLAB. Among the presentations were those on of the water cycle, chemistry of water, water quality and treatment, sewage treatment and biological technology, runoff and storm water, pollution

prevention, etc. Laboratory exercises included water quality sampling and testing, pH and dissolved oxygen measurement, filtration, and settling experiments. Field work included the collection of water samples from various locations, including 30 Acre Pond at URI, where students were allowed to enter into the shallow areas of the pond to sample for macro-invertebrate life in the pond. Students were provided with waders or rubber boots, depending on how far they wished to move about in the water. Some just stood on the bank and captured what they could with a net or a bucket. I was stationed at a point in the pond at the point where no one was to pass. This was one of their favorite activities. See Figures 2 & 3.

Dr. Hunter, from URI, was responsible for most of the presentations and establishing the activities. One external presenter was involved in the process, Mr. Sean Osborne. He had been involved in 2016 and wanted to come back again to share about being the principal in a civil engineering company, OSD, LLC, that focuses on water resources. His interactive style kept the students engaged, and he shared information about one of his recent projects and how he thought through each step, asking students math and basic science questions along the way. He also shared how he was using Apps to help better monitor systems and to get real-time updates.

With regard to laboratory exercises, teams were developed in groups of three to four persons. Some teams were asked to report their findings, while all were asked to write a report on their major activities. One of the favorites from over the years is the development of a small filter system. We then show them a large filter system that we've created for environmental engineering research at URI, which uses similar conceptual "filtration" ideas. See Figure 4.



Figure 2. View of 30 Acre Pond at URI



Figure 3. Sampling from 30 Acre Pond at URI for MacroInvertebrates and Investigating the Health of the Pond.



Figure 4. A small filter that the students create with fine white sand, cotton, powdered charcoal, and aquarium gravel.

The finale for this year's academy involved a two-round "Pop Quiz" that revisited the first day's questions, but then took into account the various labs and experiences of the week. This will probably be revised and taken into account again for the 2018 academy. We will also look to incorporate using MATLAB to help design a water molecule and then hopefully do 3-D printing of each team's molecule.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	2	0	0	0	2
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	6	0	0	0	6

Notable Awards and Achievements

This year the Rhode Island Water Resources Center sponsored a Clean Water Symposium which was jointly sponsored by an NSF faculty grant. The Conference also included a Poster Session which had 25 posters submitted by graduate and undergraduate students.