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USGS 104b
Grant
Program:
Kentucky's
Annual
Report

FY 2019



Kentucky Water
Resources Research
Institute

Title: USGS 104b Grant Program: Kentucky's Annual Report FY 2019

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Cover Picture:

- Caption: Eastern Kentucky University Senior Environmental Health Science Student Lana Sexton pipets standard solutions and lake water samples to a 96-well plate that is part of a kit that detects one of the cyanotoxins measured in Dr. Jason Marion's 104b funded project.
- Photo Credit: Dr. Jason Marion, Eastern Kentucky University.

Note:

The findings and conclusions in this document are those of the authors and do not necessarily represent the views of the University of Kentucky, the National Institutes for Water Resources, or the United States Geological Survey.

Table of Contents

Executive Summary.....	5
Causes and Extent of Elevated Groundwater Methane Concentrations in Eastern Kentucky6	
Technical Report.....	6
Problem and Research Objectives.....	6
Methodology.....	7
Principal Findings and Significance.....	7
References.....	9
Publications and Products	9
Student Support	9
Quantifying the Source of Dissolved Reactive Phosphate in Karst Drainage of the Inner- Bluegrass using Oxygen Isotopes	11
Technical Report.....	11
Problem and Research Objectives.....	11
Methodology.....	12
Principal Findings and Significance.....	14
References.....	16
Publications and Products	18
Student Support	18
Predicting Harmful Cyanobacteria Blooms in Central Kentucky Lakes.....	19
Technical Report.....	19
Problem and Research Objectives.....	19
Methodology.....	19
Principal Findings and Significance.....	19
References.....	22
Publications and Products	23
Student Support	23
Development of Buoyant Photocatalysts for Cleaning Contaminated Streams and Water Bodies	25
Technical Report.....	25
Problem and Research Objectives.....	25
Methodology.....	26
Principal Findings and Significance.....	26

References.....	27
Publications and Products	27
Student Support	28
Comparison of Water Loss Audit Methodologies in High Loss Kentucky Utilities	29
Technical Report.....	29
Problem and Research Objectives.....	29
Methodology.....	29
Principal Findings and Significance.....	30
Publications and Products	32
Student Support	33
Information Transfer Program.....	34

Executive Summary

The Kentucky Water Resources Research Institute (KWRRRI) is one of 54 Water Resource Research Institutes or Centers located throughout the United States and its territories. The state water resources research institutes are authorized by the Water Resources Research Act of 1964 (P.L. 88-379 codified at 42 U.S.C. 10301 et seq.) through the Water Resources Research Institutes Program administered by the United States Geological Survey (USGS) and organized as the National Institutes for Water Resources (NIWR). NIWR cooperates with the US Geological Survey (USGS) to support, coordinate and facilitate research.

The KWRRRI administers several state-level USGS grant programs for water research including the Annual Base Grants (104b) and National Competitive Grants (104g). The annual base grant program is authorized by the provisions of section 104b of the Water Resources Research Act. Under Section 104b, annual base grants are awarded to serve the needs of the state, region and nation by supporting and encouraging research and technology transfer in the area of water resources. KWRRRI's annual base grant program supports the following objectives specified in the Water Resources Research Act:

1. Plan, conduct, or otherwise arrange for competent applied and peer reviewed research that fosters:
 - a. improvements in water supply reliability;
 - b. the exploration of new ideas that address water problems and/or expand understanding of water and water-related phenomena;
 - c. the entry of new research scientists into water resources fields; and
 - d. the dissemination of research results to water managers and the public.
2. Cooperate closely with other colleges and universities from the State that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designated to resolve State and regional water and related land problems.
3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the institutes and for the purpose of promoting regional coordination.

Each year, proposals are submitted to further these objectives and promote the national mission and objectives of the USGS, which are focused on providing water quality and quantity information, understanding water availability, addressing the influence of climate on water resources, and responding to water-related emerging needs. This report summarizes the projects funded in FY 2019 through the section 104(b) annual base grant program. The technical reports and supporting information for each project are authored by the project's PI. In FY 2019, five research projects were funded, three at the University of Kentucky, one at Eastern Kentucky University, and one at Western Kentucky University. An information transfer project managed by KWRRRI was also funded in FY 2019. The current focus of the program is to support water-related research efforts in a wide range of disciplines conducted by students at universities and colleges in Kentucky. In FY2019, 11 undergraduate and 3 graduate students were supported through Kentucky's 104b program.

Causes and Extent of Elevated Groundwater Methane Concentrations in Eastern Kentucky

Grant Number: 2019KY287B

PI (Primary): Dr. Andrea Erhardt, Assistant Professor
Department of Earth and Environmental Sciences, University of Kentucky

PI (Secondary): Dr. Thomas Parris, Geologist
Kentucky Geological Survey, University of Kentucky

Co-PI: Cristopher Alvarez Villa, MS Student
Department of Earth and Environmental Sciences, University of Kentucky

TECHNICAL REPORT

Problem and Research Objectives

Methane dissolved in groundwater is an important health and safety concern. Elevated concentrations of methane in groundwater can lead to accumulation of methane in enclosed areas and result in explosive environments (Eltschlager et al., 2001). Elevated dissolved methane concentrations (> 1 mg/L) have been associated with proximity to UOG development and stray gas, but also with natural microbial activity. Methane concentrations in eastern Kentucky groundwater are above the “immediate action” level in some private/domestic water wells, show wide variations over small distances, and have been hypothesized to have different relationships to mining.

This study aimed to: 1) identify the spatial distribution of groundwater with elevated methane concentrations; 2) analyze the geochemical conditions possibly influencing that distribution; and 3) assess any influence from coal mining and oil and gas development in methane occurrence. To meet these objectives, bulk chemistry and isotopic composition of water from 24 private wells in eastern Kentucky have been analyzed. Methane isotopic composition is particularly investigated in relation to methanogenesis, methane oxidation, and bacterial sulfate reduction (BSR). Floyd, Knott, and Magoffin Counties in Kentucky were targeted for sampling to fill a geographic data gap of dissolved methane concentrations in groundwater, where no background/baseline data have been reported for dissolved gases.

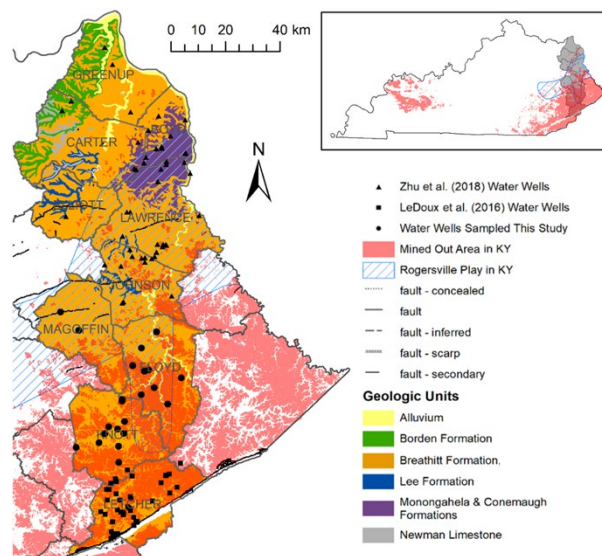


Figure 1. Map of eastern Kentucky with the locations of the 24 water wells in this study and wells in Zhu et al. (2018) and LeDoux et al. (2016). The outline of the Rogersville play, mined-out areas, surficial geology, and faults are shown.

Methodology

A total of 24 private water wells were sampled in 2019; 13 wells are in Knott County, nine wells in Floyd County, and two wells in Magoffin County. Field parameters (oxidation-reduction potential (ORP), dissolved oxygen (DO), specific conductance (SC), pH, and temperature) were monitored using a YSI multiparameter. Additionally, alkalinity, ferrous iron, sulfide, and sulfate were measured in the field using CHEMetrics test kits. Concentrations of total metals were measured by inductively coupled plasma optical emission spectrometry (ICP-OES) at the Kentucky Geologic Survey (KGS). Concentrations of inorganic anions (Br^- , Cl^- , F^- , NO_3^- -N, and SO_4^{2-}) were measured by ion chromatography at KGS. A subset of samples was also analyzed for some inorganic (F^- , NO_3^- , PO_4^{3-} , SO_4^{2-}) and organic (acetate, formate and oxalate) anions in the University of Kentucky Department of Plant and Soil Sciences. DIC concentration was measured at KGS. Alkalinity was measured by acid titration in the lab following method EPA 310.1. Dissolved methane, ethane and propane concentrations were measured using an SRI 8610C gas chromatograph (GC) equipped with a flame ionization detector (FID) at KGS.

The $\delta^{13}\text{C}$ and $\delta^2\text{H}$ of dissolved CH_4 were determined using a Thermo Trace GC IsoLink interfaced with a Thermo MAT 253 isotope ratio mass spectrometer (IRMS). To measure $\delta^{34}\text{S}$ - SO_4 and $\delta^{18}\text{O}$ - SO_4 , barite was precipitated from collected waters and analyzed for $\delta^{18}\text{O}$ - SO_4 (using a Thermo TC/EA and DELTA^{plus} XP isotope-ratio mass spectrometer [IRMS]) and $\delta^{34}\text{S}$ - SO_4 (using a Thermo EA Isolink and MAT 253) at the Kentucky Stable Isotope Geochemistry Laboratory (KSIIGL). $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in water were measured by isotope-ratio infrared spectroscopy using a Los Gatos Research T-LWIA-45-EP at KSIIGL. Finally, $\delta^{13}\text{C}$ -DIC and $\delta^{13}\text{C}$ -DOC were analyzed using a Thermo Finnigan GasBench II and DELTA^{plus} XP IRMS at KSIIGL.

Principal Findings and Significance

This study identifies how the distribution of methane and sulfate in groundwater and the geochemical processes affecting their distribution relate to the spatial distribution of mining and oil and gas development in eastern Kentucky. Derived primarily from microbial sources, methane in groundwater is a common occurrence. However, methane can be oxidized in sulfate-reducing conditions where mining has created sulfate-rich waters. The oxidation of methane is perhaps most evident in southeastern Kentucky, an area with high mining influence, where methane concentrations are < 10 mg/L (LeDoux et al., 2016). In contrast, northeastern Kentucky has limited mining and methane concentrations can be up to 78 mg/L (Zhu et al., 2018). The study area for this project encompasses zones with different degrees of mining influence, and methane concentrations were up to 50 mg/L. Areas with a high mining influence have low methane concentrations and geochemical processes similar to the ones identified in LeDoux et al. (2016). On the other hand, areas with a low mining influence have high methane concentrations controlled by CO_2 -reduction methanogenesis, and resemble observations in Zhu et al. (2018).

Geochemical conditions for methanogenesis and sulfate reduction appear to be prevalent and interconnected in eastern Kentucky groundwater. High methane concentrations (> 1 mg/L) were detected in 12 out of 24 wells sampled, and the main methane source has been identified as CO_2 -reduction methanogenesis by using bivariate plots with $\delta^{13}\text{C-CH}_4$, $\delta^2\text{H-CH}_4$, $\delta^{13}\text{C-CO}_2$, and gas ratios $\text{C}_1/(\text{C}_2+\text{C}_3)$ as variables (Figure 2). Methane concentrations are reduced in areas with high sulfate concentrations, which are associated with pyrite oxidation. Decreasing sulfate concentrations associated with more positive $\delta^{34}\text{S-SO}_4$ and $\delta^{18}\text{O-SO}_4$ values in groundwater provide evidence of sulfate-reducing conditions in some areas. One well with a high methane concentration (1.9 mg/L) and some sulfate (5.8 mg/L) shows evidence of both sulfate reduction and methane oxidation. Additionally, at least two wells appear to have a thermogenic influence on top of microbial methanogenesis due to methane concentrations exceeding concentrations expected from a methanogenesis-only trend when compared with $\delta^{13}\text{C-CO}_2$ values. Figure 3 illustrates the potential migration pathways leading to the methane compositions observed in this area.

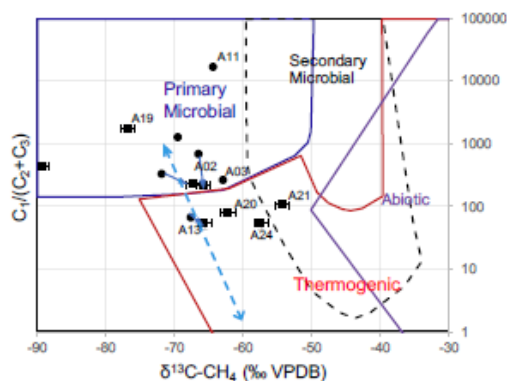


Figure 2. Genetic diagram of $\delta^{13}\text{C-CH}_4$ vs $\text{C}_1/(\text{C}_2+\text{C}_3)$ for fourteen samples from eleven wells, including data for three wells sampled in two sampling events. Blue dashed line represents microbial-thermogenic transition/mixing.

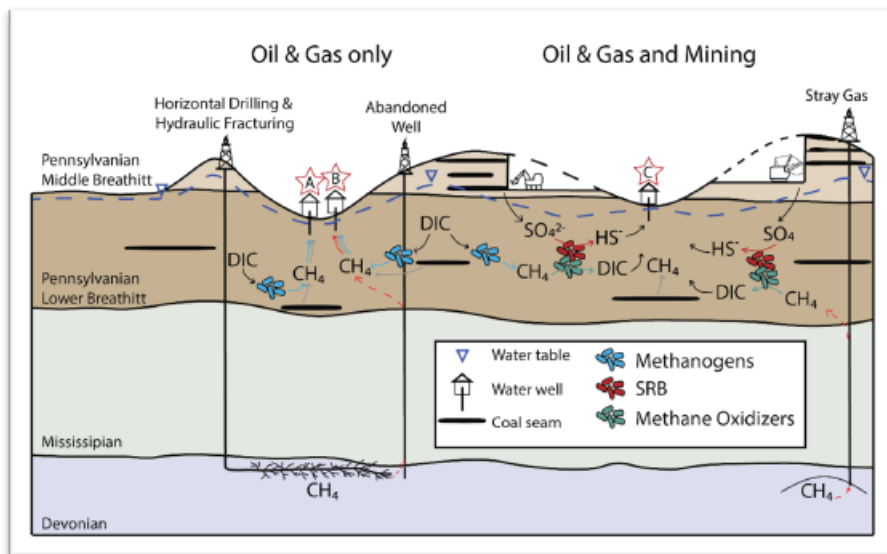


Figure 3. Schematic cross-section of the geochemical processes most relevant to methane in eastern Kentucky in relation to fossil fuel development influences. Methane pathways are indicated by arrows and color indicates source, where blue is microbial, red is thermogenic, and gray is other. Blue dashed line represents groundwater table. Well A shows CR methanogenesis, and it also considers a secondary source from coal. Well B shows a mixture of CR methanogenesis and thermogenic sources. Well C shows no methane in the well, while BSR and methane oxidation can occur nearby.

Areas with higher oil and gas development appear to be more likely to introduce thermogenic methane and stimulate mixing with microbial methane. This is consistent with observations of increased methane concentrations close to oil and gas development in the Marcellus Shale (Jackson et al., 2013; Osborn et al., 2011). Therefore, future fossil fuel development in eastern Kentucky should record pre-

drilling concentrations of dissolved gases and their isotopic composition ($\delta^{13}\text{C-CH}_4$, $\delta^2\text{H-CH}_4$, $\delta^{13}\text{C-CO}_2$) to investigate possible methane leakage. In addition, the record of mining and oil and gas development should be considered, as it appears to have a significant effect on the active geochemical and redox processes affecting environmental conditions.

References

- Eltschlager, K. K., Hawkins, J. W., Ehler, W. C., and Baldassare, F. (2001). *Technical measures for the investigation and mitigation of fugitive methane hazards in areas of coal mining*. Office of Surface Mining Reclamation and Enforcement, Appalachian Regional Coordinating Center, 125 p.
- Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., Osborn, S. G., Zhao, K., and Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences*, 110(28), p. 11250-11255.
- LeDoux, S. M., Szykiewicz, A., Faiia, A. M., Mayes, M. A., McKinney, M. L., and Dean, W. G. (2016). Chemical and isotope compositions of shallow groundwater in areas impacted by hydraulic fracturing and surface mining in the Central Appalachian Basin, Eastern United States. *Applied Geochemistry*, 71: 73-85.
- Zhu, J. F., Parris, T. M., Taylor, C. J., Webb, S. E., Davidson, B., Smath, R., Richardson, S. D., Molofsky, L. J., Kromann, J. S., and Smith, A. P. (2018). Assessing Methane in Shallow Groundwater in Unconventional Oil and Gas Play Areas, Eastern Kentucky. *Groundwater*, 56(3): 413-424.

PUBLICATIONS AND PRODUCTS

- Alvarez Villa, Christopher. (2020). *Identification of the Causes and Extent of Elevated Methane Concentrations in the Groundwater of Eastern Kentucky*. Master's Thesis, Department of Earth and Environmental Sciences, University of Kentucky. <https://doi.org/10.13023/etd.2020.486>
- Alvarez Villa, C. (2020, May). *Geochemical Conditions of Methane Occurrence in Areas of Fossil Fuel Development, Eastern Kentucky*. Kentucky Geological Survey Annual Meeting.
- Alvarez Villa, C., Erhardt, A.M., Fryar, A., Parris, T.M., Zhu, J., and Webb, S.E. (2019). *Identification of the causes and extent of elevated methane concentrations in the groundwater of Eastern Kentucky*. Poster Presentation at the Geological Society of America Annual Meeting.
- Alvarez Villa, C., Erhardt, A.M., Fryar, A., Parris, T.M., Zhu, J., and Webb, S.E. (2019). *Identification of the causes and extent of elevated methane concentrations in the groundwater of Eastern Kentucky*. Poster Presentation at the Eastern Section American Association of Petroleum Geologists.
- Alvarez Villa, C. (2019, October). *Geochemical Conditions of Methane Occurrence in Areas of Fossil Fuel Development, Eastern Kentucky*. Earth and Environmental Sciences Alumni Symposium.

STUDENT SUPPORT

- Cristopher S. Alvarez Villa, MS Student, Department of Earth and Environmental Sciences, University of Kentucky.
- Felicity Shirkey, Undergraduate Student, Department of Earth and Environmental Sciences, University of Kentucky.

Lucy Steiner, Undergraduate Student Department of Earth and Environmental Sciences, University of Kentucky.



MS Student Cris Alvarez field sampling for methane, trace metals, alkalinity, sulfide, sulfate, ferrous iron, and water quality parameters. Wells were sampled directly from the pressure tank before any filtration system or submersible pump. Many groundwater samples had visible degassing of methane.

Quantifying the Source of Dissolved Reactive Phosphate in Karst Drainage of the Inner-Bluegrass using Oxygen Isotopes

Grant Number: 2019KY288B

PI: Dr. William Ford, Assistant Professor
Department of Biosystems & Agricultural Engineering, University of Kentucky

TECHNICAL REPORT

Problem and Research Objectives

Management of phosphorus (P) in disturbed watersheds is a global issue facing scientists and engineers given its well-recognized linkages to crop productivity and downstream water quality (Jarvie et al., 2013; Jarvie et al., 2015; Sharpley et al., 2015; Smith et al., 2015; Withers et al., 2015; MacDonald et al., 2016; Sharpley, 2016). These issues are particularly relevant in the Midwestern U.S., including the state of Kentucky, as evidenced by the seasonal hypoxia experienced in the Gulf of Mexico and increasing occurrence of harmful algal blooms in inland freshwater ponds, lakes, and rivers in the region that may adversely impact drinking water sources and livestock feeding ponds (Alexander et al., 2008; Smith et al., 2015; Brooks et al., 2016). Of the 31 states that drain to the Gulf, modeling results suggest Kentucky, Tennessee, Ohio, Mississippi, Illinois, Iowa, Indiana, Missouri, and Arkansas contribute approximately 75% of the total nutrient loads, largely stemming from anthropogenic disturbances (Alexander et al., 2008). While targeted conservation strategies to minimize P loading have been effective in some cases, broadly they have led to insufficient water quality improvements (Sharpley et al., 2013; Sharpley et al., 2015). In part, ineffectiveness of conservation strategies stems from poor understanding of P source, fate, and transport in disturbed watersheds.

Karst landscapes have particularly high uncertainty regarding P dynamics due to complexities in flow pathways and highly variable concentrations in surface runoff and spring drainage (Mellander et al., 2013; Hartmann et al., 2014; Jarvie et al., 2014; Husic et al., 2017a). This proposal places emphasis on study of karst landscapes because (1) karst springs serve as a drinking water supply for nearly 25% of the global population (Ford and Williams, 2007; Hartmann et al., 2014), (2) karst geology is prominent in Kentucky, underlying 55% of the terrestrial surface area (Currens, 2002), (3) datasets that can validate physically-based numerical models to describe P source provenance and fate in karst landscapes are lacking and will be necessary for development of sustainable management strategies (Hartmann et al., 2014), and (4) site assessment tools that are used by practitioners and policymakers, such as the Phosphorus site index (P-index), do not currently account for leaching of P in karst landscapes (Bolster et al., 2011; Bolster et al., 2014).

The project research objectives were to 1) collect source samples of orthophosphate and monitor spring and surface water samples across a variety of flow conditions, 2) process and analyze source and mixture samples for isotopic and elemental compositions, and 3) perform analysis of loadings and source contributions of dissolved orthophosphate in Inner-Bluegrass karst watershed. Subsequent to our proposal acceptance, we shifted emphasis from the Cane Run/Royal Spring basin, to the Camden Creek watershed. There are several reasons for the change. First, we have now published a paper using historical data (1996-2006) from Camden Creek that has enhanced our understanding of flow

pathways and fate of DRP (Ford et al., 2019). Further, we have extensive sensing infrastructure at this site, including a YSI EXO2 with pH, DO, temperature, conductivity, depth, turbidity, and fDOM, a SUNA V2 Nitrate/nitrite sensor, and an OTT Hydromet Cycle P orthophosphate sensor. The site is predominantly agricultural (as opposed to the mixed-use Cane Run), so we can more explicitly focus on separating ambient (phosphatic limestone) derived sources and anthropogenic agricultural inputs (e.g., legacy stores in surface soil from chronic organic P applications).

Methodology

Objective 1: Sample collection methodology

Soil source samples: In May of 2019 soil pits were collected at three different locations within the Camden Creek watershed resulting in a total of 71 samples by Dr. Chris Shepard in the Plant and soil sciences department at UK. Two of the locations where sinkholes located near livestock located on LRC property (one near a horse pasture and the other near cow pasture), while the third location was an actively sinking sinkhole in a cultivated row-crop area. Sample pits were collected at each location along several different slopes to inspect the lateral variation of the soils over a hillslope profile (summit, shoulder, side slope, toe slope, and foot slope) as well as sampled following methods discussed in Schoeneberger et al. (2012) for horizon sampling. This resulted in several soil pits along the slope at each location with each pit containing a soil depth exceeding 100cm to capture the soil horizons. After collection, samples were brought back to the lab, air dried, sieved (2mm mesh), and stored at room temperature in sealed plastic containers until further analysis.

Water sample collection: An ISCO 6712 Avalanche portable refrigerated water sampler (with PVC vinyl tubing) was installed at the watershed outlet stream site, ST1 (see images above). Event-based samples were collected at ST1 via the ISCO 6712 Avalanche sampler. Four events were collected between January 2020 and April 2020. Prior to an event occurring, the avalanche sampler was programmed to sample sequentially in a 14 x 950 ml bottle configuration. All bottles were sanitized in the lab prior to deployment via a phosphate free detergent, 10% HCl acid bath, and DI rinse. Total volume collected for each sample was set to 850 ml to avoid over fill of bottles. Time between individual sample collection was set at either 6-hours (events 1 and 2) or 4-hours (events 3 and 4). Spatial grab samples were collected four times between January 2020 and April 2020 at various spring locations throughout the watershed (SP1, SP11, SP15, SP3, SP4, SP2, SP8, SP6, SP7) as well as the watershed outlet stream site (ST1). Following collection, samples were immediately placed into an iced cooler, and returned to the laboratory where they were filtered using GF/F (0.7 μm pore size) filters and placed in a laboratory refrigerator (maintained at 4°C) where they were stored prior to processing. Filters used during this process would be dried and weighed to determine total suspended solids in each sample following EPA methods (EPA Method 160.2).

Objective 2: Analysis of soil and water samples

Both event-based and spatial water samples were processed similarly for orthophosphate (DRP), nitrate (NO_3^-), $\delta^2\text{H}$, $\delta^{18}\text{O}_{\text{H}_2\text{O}}$, and $\delta^{18}\text{O}_{\text{PO}_4}$. First, stored filtered samples were separated into 4 splits: 1) a 2-ml split (in 2-ml clear glass vials) to be sent off to the Kentucky Stable Isotope Geochemistry laboratory for $\delta^2\text{H}$ and $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ analysis, 2) a 50-ml split (in a 50-ml conical-bottom centrifuge tube) to be sent to the Kentucky Geological Survey laboratory for nitrate analysis, 3) a 50-ml split (in a 50-ml conical-bottom centrifuge tube) to be sent to the Kentucky Geological Survey laboratory for

orthophosphate analysis, and 4) remaining volume split (in a sterilized 4L polypropylene bottle) for $\delta^{18}O_{PO_4}$ analysis preparation that would later be sent off to Nebraska Water Center. The remaining volume split typically contained a volume of 750-3850 ml depending on if it was a spatial grab or event-based sample. Regardless of the volume, these samples were processed the same way.

Each soil sample was analyzed for water-extractable phosphate (WEP) at Kentucky Geological Survey and $\delta^{18}O_{PO_4}$ at the Nebraska Water Center. Water extractable phosphate was chosen because previous studies have expressed it as a direct measure of soil solution P concentration and have found strong correlations between soil WEP and runoff dissolved reactive phosphorus concentration (Ford et al., 2019 and Pote et al., 1996). WEP was determined in each sample following methods discussed in Self-Davis et al. (2000). First 20ml of DI water was added to a 50ml centrifuge tube with 2ml of soil. This mixture was shaken for one hour and then centrifuged at 3500rpm for 30 minutes. Next, the samples were filtered using a GF/F filter (0.4 μ m pore size). Immediately following filtration, filtered water was retained and sent to Kentucky Geological Survey for orthophosphate analysis.

Objective 3: Hydrograph separation and comparison with DRP

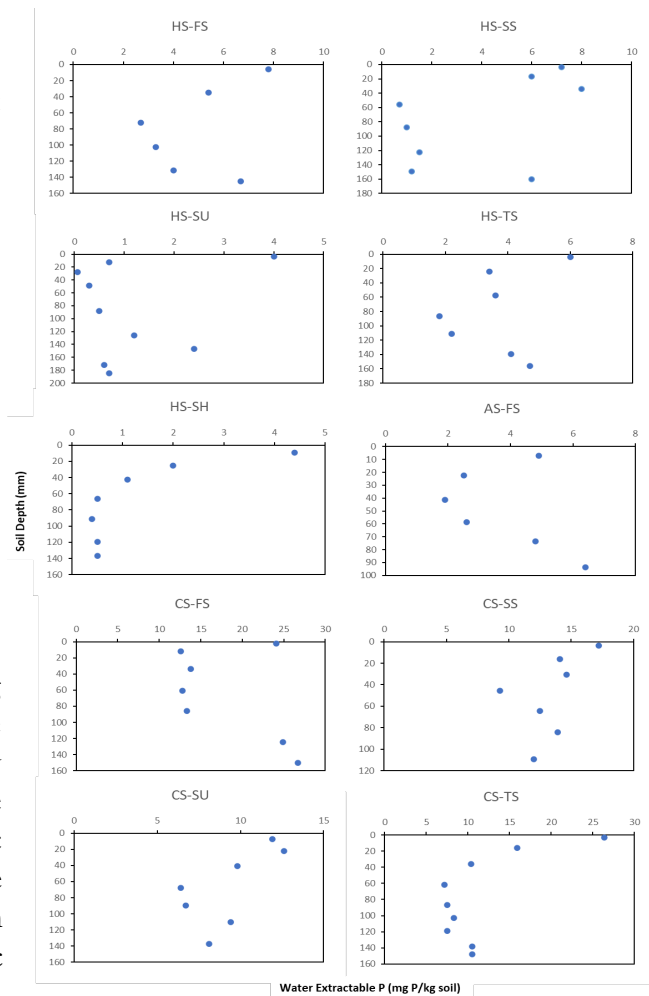
Flow pathways were investigated during each hydrological event via hydrograph recession analysis (Ford et al., 2019; Husic et al., 2019; Nazari et al., 2020). First, the falling limb of each event hydrograph was plotted on a logarithmic scale. Next, linear curves were fit onto each reservoir and the inflection points of the linear trends were determined. A linear increase in slow flow was assumed from the beginning of the rising limb of the hydrograph to the inflection point on the falling limb, this was the point that signified the shift from quick flow to slow flow (Husic et al., 2018). The event contribution for each pathway was then calculated as the area between the two curves for the quick flow pathways and the area under the curve for the slow flow pathway (Nazari et al., 2020).

The fraction of water sources at the watershed outlet was investigated through a mass-balance unmixing approach. This approach has been deemed widely successful for unmixing soil sources (Davis & Fox, 2009; Ford et al., 2020) as well as water sources in similar landscapes and groundwater (Torres-Martinez et al., 2020; Wang et al., 2020). We unmixed event samples collected at the watershed outlet using both isotopic and elemental measurements from source and mixture samples. The stable isotopes of water ($\delta^{18}O$ and δ^2H) and specific conductivity of water were used to estimate the mixing proportions among three identified sources: (1) precipitation, (2) soil and epikarst zone mixture, and (3) phreatic zone. The unmixing system of equations is overdetermined since we identified three sources and are parameterizing these sources with three tracers. Therefore, we chose to conduct a frequentist approach based on error minimization described by Davis and Fox (2009) and successfully utilized in other overdetermined unmixing problems (Ford et al., 2020).

Principal Findings and Significance

Water Extractable P (WEP) from soil samples collected in the watershed displayed interesting trends which were atypical of other agricultural karst landscapes. Vertical profiles of WEP (Figure 1) show high levels of extractable-P at the soil surface and in upper horizons. As depth increases, extractable P levels began to decline, further down the vertical profile we see extractable-P levels increase again; at times exceeding surface levels (AS-FS and CS-FS). Studies in other agroecosystems where manure or inorganic P is routinely applied have shown vertical stratification of soil P levels with elevated P at the surface that decreases into the subsurface layers (Ford et al., 2018; Fenton et al., 2017; Joshi et al., 2018), which differs from our findings in this system. The elevated levels of extractable-P shown in vertical WEP profiles suggest that there may be an underlying source of P derived from parent material contributing to the P load. This evidence suggests that the upper layers of the profile are reflective of legacy P built up from manure and P application while deeper layers reflect weathered phosphatic limestone residuum within the system. We are hypothesizing based on these results that oxygen isotope results will show differences in isotopic composition depending on source connectivity.

Figure 1. Water Extractable P Profiles from Camden Creek upland soils



Initial results obtained from isotopic analysis of spring samples (Table 1) provided some insight into the oxygen isotope of phosphates capability of distinguishing between sources within a karst landscape. We inspected an overall decrease in the average of $\delta^{18}\text{O-PO}_4$ values from the January low flow sampling period to the February high flow sampling period. This suggests that sources present during quick flow may have lower $\delta^{18}\text{O-PO}_4$ values than that of sources present during low flow conditions, suggesting variability in $\delta^{18}\text{O-PO}_4$ to successfully differentiate sources in our system. While results from the first two sampling periods had strong QC outcomes during processing, results from the last two sampling periods illustrated a wide range of values due to complications during analysis. Some samples from these periods demonstrated higher levels of dissolved iron and due to dissolved iron's ability to form an oxide that can scavenge phosphate, this complex is currently being removed. To remove iron we are in the process of treating the remaining samples with a strong acid to dissolve the iron and proceed with cleanup by filtering the sample through a DAX resin and cation exchange resin.

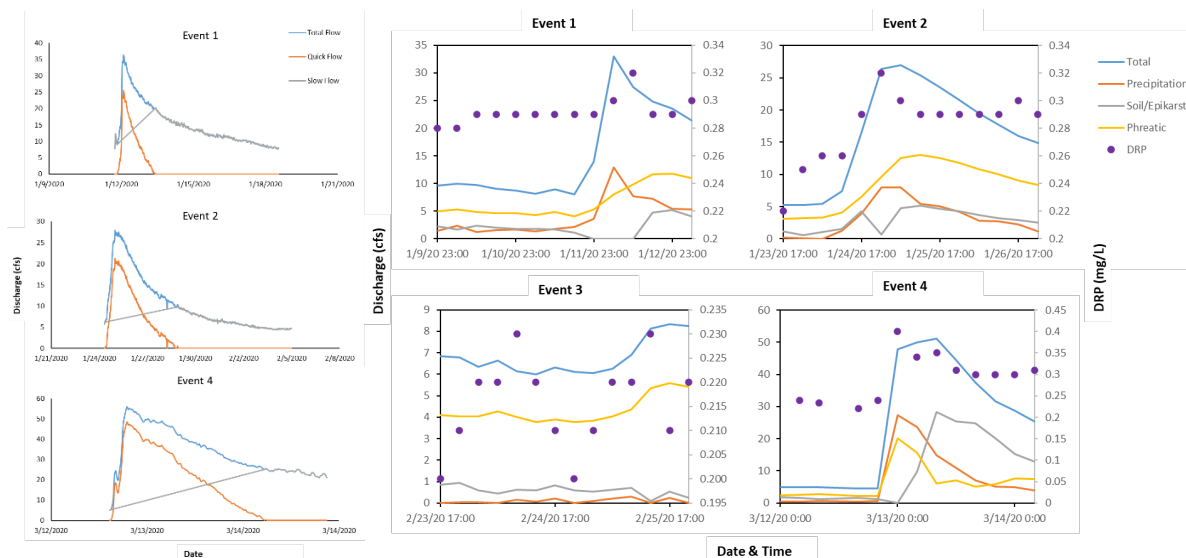
Table 1. The determined oxygen isotope of phosphate values of spatial samples collected at springs

Spring Site	JAN-LOW FLOW	FEB-HIGH FLOW	FEB-LOW FLOW	MAR-LOW FLOW
	$\delta^{18}\text{O-PO}_4$ (‰)			
SP1	25.8	27.7	18	-2.27
SP2	38.7	23.2	-18.3	2.46
SP3	26.4	24.2	9.8	10.9
SP4	NM	22.1	19.8	NM
SP6	28	22.7	18.1	35.9
SP7	27	20.8	23	31.2
SP8	29.6	20.4	4.9	19.2
SP11	2.76	22.2	-9.16	26.3
SP15	26	20.1	19.1	NM

*NM = Not Measured

Hydrograph recession analysis yielded evidence of two main pathways in this system: quick and slow flow. This finding agrees with a previous study conducted on historical data from this site (Ford et al., 2019). Each event we sampled was of a different magnitude and demonstrated differences in pathway event contributions (Figure 2). During event 1 the quick flow pathway provided only 15% of the total flow, whereas the slow flow pathway provided 85% of the total flow. Pathways were more evenly distributed during event 4, as the quick flow dominated 48% and slow flow dominated only 52%. Event 2 related similarly with master recessions of this site determined in Ford et al. (2019) and quick flow pathways contributed 33% while slow flow contributed 67% of the total flow. While further development and uncertainty analysis is to be conducted to address error, preliminary model results provide some indication as to how event intensity may play a role into source contribution and ultimately P loading at the watershed outlet. Model results suggest a sharp spike in sources derived from precipitation during the rising limb of the hydrograph, after peak flow precipitation sources decline and contribute less. The beginning of the falling limb of the hydrograph indicates a shift in precipitation dominated sources to soil/epikarst and phreatic source dominated. In fact, the soil/epikarst sources exceed phreatic sources on the falling limb in every event except event 1. This is especially evident in event 4 which had the highest levels of precipitation and antecedent moisture conditions. Event DRP concentrations illustrate both similarities and differences. For every event, post-event DRP levels exceed pre-event levels, however peak concentrations occur at different times on the hydrograph. While events 2 and 4 illustrate peak DRP levels while precipitation sources are dominating, event 1 demonstrates a lag in peak DRP, not occurring until well within the falling limb of the hydrograph. Given the preliminary findings that “High” and “Low” flow spring monitoring periods showed distinct differences in oxygen isotope signatures, we foresee that event-water isotope unmixing will likely provide important insights in storm-event DRP provenance.

Figure 2. Results from Hydrograph recession Analysis for events 1,2 and 4 (left) and calculated proportions of flow from each endmember during an event and the determined DRP concentration throughout the hydrograph (right).



References

- Jarvie, H.P., A.N. Sharpley, P.J. Withers, J. Thad Scott, B.E. Haggard, and C. Neal. 2013. Phosphorus mitigation to control river eutrophication: Murky waters, inconvenient truths, and “Postnormal” science. *J Environ. Qual.* 42: 295–304, doi: 10.2134/jeq2012.0085.
- Jarvie, H., A. Sharpley, V. Brahana, T. Simmons, A. Price, C. Neal, A. Lawlor, D. Sleep, S. Thacker, B. Haggard. 2014. Phosphorus retention and remobilization along hydrological pathways in karst terrain. *Environ. Sci. Technol.* 48(9): 4860-4868.
- Jarvie, H., A. Sharpley, D. Flaten, P. Kleinman, A. Jenkins, T. Simmons. 2015. The pivotal role of phosphorus in a resilient water-energy-food security nexus. *J. Environ. Qual.* Doi:10.2134/jeq2015.01.0030.
- Sharpley, A., L. Bergstrom, H. Aronsson, M. Bechmann, C. Bolster, K. Borling, F. Djodjic, H. Jarvie, O. Schoumans, C. Stamm, K. Tonderski, B. Ulen, R. Uusitalo, P. Withers. 2015. Future agriculture with minimized phosphorus losses to waters: Research needs and directions. *Ambio*, 44(2) S163-S179.
- Smith, D. R., K. W. King, and M. R. Williams (2015), What is causing the harmful algal blooms in Lake Erie?, *J. Soil Water Conserv.*, 70, 27A–29A, doi:10.2489/jswc.70.2.27A.
- Withers, P., K. van Dijk, T. Neset, T. Nesme, O. Oenema, G. Ruback, O. Schoumans, B. Smit, S. Pellerin. 2015. Stewardship to tackle global phosphorus inefficiency: The case for Europe. *Ambio*. 44(2): S193-S206.
- MacDonald, G.K., H. Jarvie, P. Withers, D. Doody, B. Keeler, P. Haygarth, L. Johnson, R. McDowell, M. Miyittah, S. Powers, A. Sharpley, J. Shen, D. Smith, M. Weintraub, T. Zhang. 2016. Guiding phosphorus stewardship for multiple ecosystem services. *Ecosystem Health and Sustainability*. 2(12):e01251.10.1002/ehs2.1251.
- Sharpley, A. 2016. Managing agricultural phosphorus to minimize water quality impacts. *Scientia Agricola*. 73(1): 1-8.
- Alexander, R.B., Smith, R.A., Schwarz, G.E., Boyer, E.W., Nolan, J.V., and Brakebill, J.W.. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. *Environmental Science and Technology*, 42: 822-830.
- Brooks, B. W., J. M. Lazorchak, M. D. A. Howard, M-V. V. Johnson, S. L. Morton, D. A. K. Perkins, E.D. Reavie, G. L.

- Scott, S. A. Smith, and J. A. Stevens. 2016. Are harmful algal blooms becoming the greatest inland water quality threat to public health and aquatic ecosystems? *Environmental Toxicology and Chemistry* 35: 6-12.
- Shapley, A., H. Jarvie, A. Buda, L. May, B. Spears, P. Kleinman. 2013. Phosphorus legacy: Overcoming the effects of past management practices to mitigate future water quality impairment. *J. Environ. Qual.* 42:1308-1326.
- Mellander, P., Jordan, P., Melland, A.R., Murphy, P.N.C., Wall, D.P., Mehan, S., Meehan, R., Kelly, C., Shine, O., Shortle, G. 2013. Quantification of phosphorus transport from a karstic agricultural watershed to emerging spring water. *Environmental Science and Technology*, 47, 6111-6119.
- Hartmann, A., Goldscheider, N., Wagener, T., Lange, J., & Weiler, M. (2014). Karst water resources in a changing world: Review of hydrological modeling approaches. *Reviews of Geophysics*, 52(3),218-242.
- Husic, A., J. Fox, C. Agouridis, J. Currens, W. Ford, C. Taylor. 2017a. Sediment carbon fate in phreatic karst (Part 1): Conceptual model development. *J. Hydrol. Revised Resubmission*
- Ford, D. C., & Williams, P. W. (2007). *Karst Hydrogeology and Geomorphology*. Chichester, John Wiley & Sons.
- Currens, J. 2002. Kentucky is Karst Country! What you should know about sinkholes and springs. Kentucky Geological Survey Information Circular 4.
- Bolster, C. 2011. A critical evaluation of the Kentucky Phosphorus Index. *J. Ky. Acad. Sci.* 72(1):46–58.
- Bolster, C., T. Horvath, B.D. Lee, S. Melhoupe, S. Higgins, J.A. Delgado. 2014. Development and testing of a new phosphorus index for Kentucky. *J. Soil Water Conserv.*, 69(3): 183-196.
- Ford, W.I., Husic, A., Fogle, A., and Taraba, J. 2019. Long-term assessment of nutrient flow pathway dynamics and in stream fate in a temperate karst agroecosystem watershed. *Hydrological Processes*, In Press, DOI: 10.1002/hyp.13427.
- Husic, A, Fox, J, Adams, E, Ford, W, Agouridis, C, Currens, J, & Backus, J. (2019). Nitrate Pathways, Processes, and Timing in an Agricultural Karst System: Development and Application of a Numerical Model. *Water Resources Research*, 55(3), 2079-2103.
- Nazari, Saeid, Ford, William I, & King, Kevin W. (2020). Impacts of preferential flow and agroecosystem management on subsurface particulate phosphorus loadings in tile-drained landscapes. *Journal of Environmental Quality*, 49(5), 1370-1383.
- Davis, Charles M, & Fox, James F. (2009). Sediment Fingerprinting: Review of the Method and Future Improvements for Allocating Nonpoint Source Pollution. *Journal of Environmental Engineering (New York, N.Y.)*, 135(7), 490-504.
- Ford, W.I, Fox, J.F, Mahoney, D.T, DeGraves, G, Erhardt, A, & Yost, S. (2020). Backwater Confluences of the Ohio River: Organic and Inorganic Fingerprints Explain Sediment Dynamics in Wetlands and Marinas. *Journal of the American Water Resources Association*, 56(4), 692-711.
- Torres-Martínez, Juan Antonio, Mora, Abrahan, Knappett, Peter S.K, Ornelas-Soto, Nancy, & Mahlkecht, Jürgen. (2020). Tracking nitrate and sulfate sources in groundwater of an urbanized valley using a multi-tracer approach combined with a Bayesian isotope mixing model. *Water Research (Oxford)*, 182, 115962.
- Wang, Zhong-Jun, Li, Si-Liang, Yue, Fu-Jun, Qin, Cai-Qing, Buckerfield, Sarah, & Zeng, Jie. (2020). Rainfall driven nitrate transport in agricultural karst surface river system: Insight from high resolution hydrochemistry and nitrate isotopes. *Agriculture, Ecosystems & Environment*, 291, 106787.
- Ford, W.I., Williams, M., Young, M.B., King, K.W., Fischer, E. 2018. Assessing intra-event phosphorus dynamics in drainage water using phosphate stable oxygen isotopes. *Trans. ASABE*, 61:1379-1392.
- Fenton, O, Mellander, P.-E, Daly, K, Wall, D.P, Jahangir, M.M.R, Jordan, P, Richards, K.G. (2017). Integrated assessment of agricultural nutrient pressures and legacies in karst landscapes. *Agriculture, Ecosystems & Environment*, 239, 246-256.
- Joshi, Sunendra, Li, Wei, Bowden, Mark, & Jaisi, Deb. (2018). Sources and Pathways of Formation of Recalcitrant and Residual Phosphorus in an Agricultural Soil. *Soil Systems*, 2(3), 45.

PUBLICATIONS AND PRODUCTS

Radcliff, C. (2021). *Dissolved Reactive Phosphate transport in Karst Drainage of the Inner Bluegrass Region of Central Kentucky: Coupling hydrograph separation and stable oxygen isotopes* (Tentative title). MS Thesis, in preparation, Department of Biosystems and Agricultural Engineering, University of Kentucky.

STUDENT SUPPORT

Cory Radcliff, Graduate Research Assistant, M.S. in Biosystems and Agricultural Engineering, Graduated May 2021.

Daniel Barton, Undergraduate Research Assistant, B.S. in Biosystems and Agricultural Engineering, Graduated May 2020.



Graduate student Cory Radcliff samples springs for water isotope signatures during a low-flow sampling period.

Predicting Harmful Cyanobacteria Blooms in Central Kentucky Lakes

Grant Number: 2019KY290B

PI: Dr. Jason Marion, Associate Professor
Department of Environmental Health Science, Eastern Kentucky University

TECHNICAL REPORT

Problem and Research Objectives

Harmful ‘algal’ blooms from cyanobacteria or cHABs have had significant impacts on the Ohio, Kentucky, and Indiana (OKI) region. Specifically, cHABs have impaired the region’s drinking water supplies, discouraged contact recreation with natural waters, led to stigmatized communities, and have also negatively impacted OKI region vacationers traveling to other parts of the United States, such as the beaches of Florida. Concerns pertaining to these blooms are justified. Cyanobacteria blooms in aquatic ecosystems are known to periodically produce harmful toxins (Carmichael and Boyer; Brooks et al. 2016). Furthermore, cyanobacteria blooms have resulted in harm to fisheries through depleting dissolved oxygen (Scavia et al. 2014). Small human-made freshwater lakes (reservoirs), like those in Kentucky, are also frequently impacted by cyanobacteria formation as such lakes are readily impacted by surface runoff and more rapid temperature changes (Gorham et al. 2017). For this project, which aimed to provide meaningful undergraduate engagement, we also aimed to understand major drivers and predictors of local cyanobacteria blooms across nine central Kentucky lakes. Additionally, we aimed to explore the predictive capability of the recreational water dipstick for characterizing harmful conditions from cyanotoxins.

Methodology

A total of 81 water samples were collected from eight central Kentucky lakes and one central Kentucky pond in the late summer and early fall of 2019. Specifically, samples were collected from Beaver Lake (BL), Cedar Creek Lake (CCL), Guist Creek Lake (GCL), Lake Herrington (HL), Lake Linville (LL), Lake Reba (LR), Taylorsville Lake (TL), and the Stratton pond (SS) on the EKU campus. Samples were assessed for total phosphorus, nitrogen-ammonia + ammonium, nitrate, and total Kjeldahl nitrogen using Hach methods with a Hach DR2800 spectrophotometer. Additionally, data on turbidity was obtained with a Lutron turbidimeter. *In vivo*, real-time, measures of chlorophyll *a* and phycocyanin were obtained with a Beagle Bioproducts – AmiScience handheld dual-channel fluorometer. Water temperature was also obtained. Where resources were available, cyanotoxin concentrations were measured and/or screened using an Abraxis AbraScan with recreational water dipstick test strips for microcystin, cylindrospermopsin, and anatoxin. Additionally, 96-well ELISA plates were analyzed for the three cyanotoxins using appropriate Abraxis kits and a VersaMax microplate reader during late fall 2020. Some preliminary data analysis has occurred using Stata 15.

Principal Findings and Significance

The majority of the water quality results demonstrate the lakes assessed were in the eutrophic or hypereutrophic condition on the basis of total phosphorus results (Carlson, 1977). Table 1 shows the

significant variation in mean phosphorus values as well as the intra-lake variation in minimum and maximum total phosphorus concentrations. Overall, Guist Creek Lake (GCL) exhibited extraordinarily high total phosphorus values relative to the other lakes, and some of the maximum values observed exceed maximum values for the 727 lakes studied in this ecoregion of the U.S. by U.S. EPA (2000). Corresponding to these significantly elevated total phosphorus values are relatively higher concentrations of chlorophyll *a*. Recent studies using Guist Creek Lake data illustrate that the nutrient dynamics of nitrogen and phosphorus may be playing a role in modulating cyanobacteria bloom formation in this lake (Hughes and Marion, 2021), and possibly other hypereutrophic lakes in this region of Kentucky – including several in this study.

Table 1: Summary statistics for total phosphorus, the blue-green algae pigment phycocyanin, and chlorophyll *a* across nine central Kentucky waterbodies.

	n	Total Phosphorus (ppm)			Phycocyanin (RFU) ¹			Chlorophyll <i>a</i> (RFU)		
		Mean	Min.	Max	Mean	Min.	Max	Mean	Min.	Max
BL	9	0.300	0.170	0.74	115	89	146	1162	661	1710
CCL	8	0.297	0.079	0.896	51	31	75	386	182	536
GCL	9	0.690	0.297	1.910	82	46	104	1626	710	4000
HL	8	0.245	0.098	1.010	44	24	69	373	228	503
LL	8	0.282	0.103	1.120	58	34	92	353	171	552
LR	8	0.171	0.114	0.201	54	30	71	735	423	1136
SS	8	0.250	0.198	0.288	76	37	170	1449	386	2315
TL	9	0.226	0.125	0.577	61	21	73	623	427	834
WL	8	0.154	0.126	0.187	64	28	77	869	480	1910

¹RFU: relative fluorescence units

An evaluation of the correlations (inclusive of all lakes) demonstrates expected correlations between the blue-green algae pigment, phycocyanin, with chlorophyll *a*, turbidity, total phosphorus, and total Kjeldahl nitrogen (Table 2). Greater analysis that takes into consideration the individual relationships within each lake may demonstrate different (stronger or weaker) correlations as each lake ecosystem has unique communities and nutrient dynamics. Furthermore, correlation analyses in the future may also consider N:P ratios, as they are particularly important in establishing cyanobacteria dominance in some lakes and ponds.

Table 2. Summary statistics for total phosphorus, the blue-green algae pigment phycocyanin (PC), and chlorophyll *a* across nine central Kentucky waterbodies.

	PC	Chl <i>a</i>	Nitrate	Ammonium	Total P	TKN	Temp
Chlorophyll <i>a</i>	<i>0.6425</i>						
Nitrate	-0.043	<i>0.1372</i>					
Ammonium	0.1181	<i>0.2552</i>	-0.032				
Total P	<i>0.3276</i>	<i>0.436</i>	0.133	0.0753			
TKN	<i>0.3031</i>	<i>0.206</i>	-0.065	<i>0.4429</i>	0.0094		
Surface temp	-0.143	-0.1123	<i>-0.323</i>	<i>-0.3743</i>	<i>-0.205</i>	<i>-0.23</i>	
Turbidity	<i>0.4522</i>	<i>0.5872</i>	0.074	<i>0.2787</i>	<i>0.6061</i>	<i>0.231</i>	<i>-0.234</i>

In regard to cyanotoxins, all three cyanotoxins were detected at some point in this study; however, the cyanotoxins anatoxin and microcystin were more readily detected by the methods used in this study (Table 3). Although these toxins were detected frequently in these Kentucky lakes and the Stratton pond, it is noteworthy that the concentrations observed in these natural water samples were far below the risk/advisory limits for finished drinking water for school-age children and adults (U.S. EPA 2015).

Furthermore, as Table 4 demonstrates, the maximum values observed for microcystin and anatoxin rarely exceeded 1 ppb. Among detectable levels from the ELISA plates, these levels on average were below 1 ppb.

Table 3. Presence/absence results from the various cyanotoxin measures performed in this study across the nine studied central Kentucky water bodies.

	Microcystins		Cylindrospermopsin		Anatoxin	
	ELISA plate + (%)	Dipstick + (%)	ELISA plate + (%)	Dipstick + (%)	ELISA plate + (%)	Dipstick + (%)
BL	1/9 (11.1)	1/7 (14.3)	0/9 (0.0)	0/6 (0.0)	0/9 (0.0)	4/7 (57.1)
CCL	0/8 (0.0)	0/5 (0.0)		0/5 (0.0)	3/8 (37.5)	0/5 (0.0)
GCL	0/9 (0.0)	1/7 (14.3)	0/9 (0.0)	1/6 (16.7)	0/9 (0.0)	2/7 (28.6)
HL	0/8 (0.0)	0/5 (0.0)	0/8 (0.0)	0/5 (0.0)	2/9 (22.2)	0/5 (0.0)
LL	5/8 (62.5)	2/5 (40.0)		1/5 (20.0)	1/8 (12.5)	0/5 (0.0)
LR	2/9 (22.2)	0/6 (0.0)		0/5 (0.0)	0/9 (0.0)	0/5 (0.0)
SS	6/9 (66.7)	1/5 (20.0)		0/5 (0.0)	2/9 (22.2)	0/5 (0.0)
TL	1/9 (11.1)	1/7 (14.3)	0/4 (0.0)	3/6 (50.0)	1/9 (11.1)	2/7 (28.6)
WL	0/8 (0.0)	1/5 (20.0)	1/7 (12.5)	0/5 (0.0)	5/9 (55.6)	0/5 (0.0)
Total	15/62 (19.5)	7/45 (13.5)	1/38 (2.6)	5/43 (10.4)	16/79 (20.3)	8/51 (15.7)

Table 4. The mean and maximum results from the ELISA plates for microcystins and anatoxin as assessed in this study across the nine studied central Kentucky water bodies. Locations with no detectable levels by the ELISA plates are reported as <0.150 ppb, which is the detection limit of the test. Locations that did had detectable levels, did not have the non-detect values factored into the mean.

	Microcystins		Anatoxin	
	Mean ELISA (ppb)	Maximum ELISA (ppb)	Mean ELISA (ppb)	Maximum ELISA (ppb)
BL	0.153	0.153	<0.150	<0.150
CCL	<0.150	<0.150	0.264	0.337
GCL	<0.150	<0.150	<0.150	<0.150
HL	<0.150	<0.150	0.478	0.559
LL	0.338	0.574	0.213	0.213
LR	0.965	1.579	<0.150	<0.150
SS	0.298	0.641	0.183	0.185
TL	0.178	0.178	0.530	0.53
WL	<0.150	<0.150	0.809	1.467

The low concentrations of cyanotoxins observed in this study limited the ability to do a thorough assessment of the predictive benefit of the dipstick tests versus the ELISA kit results as many of the results are at or near the lower detection limit of each method. Greater analyses are planned to explore these methods comparisons as well as approaches to use modeling by lake to determine predictive models that may work best using the multiple methods employed in this study. Particularly surprising was the abundance of anatoxin in the water, although the concentrations are relatively low (<1 ppb); anatoxin appears quite frequently at detectable levels in the regional water studied, and this is indicated probable given the scientific literature (Loftin et al. 2007, Christensen and Khan, 2020).

References

- Brooks, B.W., Lazorchak, J.M., Howard, M.D., Johnson, M.V.V., Morton, S.L., Perkins, D.A., Reavie, E.D., Scott, G.I., Smith, S.A., and Steevens, J.A. 2016. Are harmful algal blooms becoming the greatest inland water quality threat to public health and aquatic ecosystems? *Environ. Toxicol. Chem.* 35, 6-13.
- Carmichael, W.W., and Boyer, G.L. 2016. Health impacts from cyanobacteria harmful algae blooms: Implications for the North American Great Lakes. *Harmful Algae* 54, 194-212.
- Christensen, V.G. and Khan, E., 2020. Freshwater neurotoxins and concerns for human, animal, and ecosystem health: A review of anatoxin-a and saxitoxin. *Science of the Total Environment*, 736, p.139515.
- Gorham, T., Jia, Y., Shum, C.K. and Lee, J. 2017. Ten-year survey of cyanobacterial blooms in Ohio's waterbodies using satellite remote sensing. *Harmful Algae* 66, 13-19.
- Loftin, K.A., Graham, J.L., Hilborn, E.D., Lehmann, S.C., Meyer, M.T., Dietze, J.E. and Griffith, C.B., 2016. Cyanotoxins in inland lakes of the United States: Occurrence and potential recreational health risks in the EPA National Lakes Assessment 2007. *Harmful Algae*, 56, 77-90.

Hughes, S.E., and Marion, J.W. 2021. Cyanobacteria growth in a nitrogen- and phosphorus-spiked water from a hypereutrophic reservoir in Kentucky, USA. *Journal of Environmental Protection* 12(2):75-89. <https://doi.org/10.4236/jep.2021.122006>

Scavia, D., Allan, J.D., Arend, K.K., Bartell, S., Beletsky, D., Bosch, N.S., Brandt, S.B., Briland, R.D., Daloğlu, I., DePinto, J.V., and Dolan, D.M. 2014. Assessing and addressing the re-eutrophication of Lake Erie: Central basin hypoxia. *J. Great Lakes Res.* 40, 226-246.

U.S. Environmental Protection Agency. 2000. Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria—Lakes and Reservoirs in Nutrient Ecoregion IX. EPA 822-B-00-011. <https://www.epa.gov/nutrient-policy-data/ecoregional-nutrient-criteria-lakes-and-reservoirs-documents>

U.S. Environmental Protection Agency. 2015. EPA Drinking Water Health Advisories for Cyanotoxins. <https://www.epa.gov/cyanohabs/epa-drinking-water-health-advisories-cyanotoxins>

PUBLICATIONS AND PRODUCTS

Barned, S., Mills, A., and Marion, J.W. (2020). *Assessment of Predictive Measures of Cyanobacteria in Three Recreational Lakes in the South-Central Kentucky*. Oral and Poster Presentation at the 84th National Environmental Health Association Annual Education Conference, July 13-16, New York, NY. [Canceled due to COVID-19]

Barned, S., Mills, A., and Marion, J.W. (2020). *Assessment of Predictive Measures of Cyanobacteria in Three Recreational Lakes in the South-Central Kentucky*. Poster Presentation at the 2020 KWRRRI Annual Symposium. [Canceled due to COVID-19]

Hughes, S.E., and Marion, J.W. (2021). Cyanobacteria growth in a nitrogen- and phosphorus-spiked water from a hypereutrophic reservoir in Kentucky, USA. *Journal of Environmental Protection* 12(2):75-89. <https://doi.org/10.4236/jep.2021.122006>

Turner, A., Sexton, L., and Marion, J.W. (2020). *An Assessment of the Predictive Capability of Water Quality Measures for Estimating Cyanotoxin Concentrations in Six Central Kentucky Lakes*. Oral and Poster Presentation at the 84th National Environmental Health Association Annual Education Conference, July 13-16, New York, NY. [Canceled due to COVID-19]

Turner, A., Sexton, L., and Marion, J.W. (2020). *An Assessment of the Predictive Capability of Water Quality Measures for Estimating Cyanotoxin Concentrations in Six Central Kentucky Lakes*. Poster Presentation at the 2020 KWRRRI Annual Symposium, March 23. [Canceled due to COVID-19]

STUDENT SUPPORT

Swade Barned, B.S. Environmental Health Science (May 2020), Eastern Kentucky University.

Amber Turner, B.S. Environmental Health Science (December 2020), Eastern Kentucky University.

Lana Sexton, B.S. Environmental Health Science (December 2020), Eastern Kentucky University.

Austin Mills, Undergraduate Student in Environmental Health Science, Eastern Kentucky University.

Nickson Rotich, B.S. Medical Laboratory Science (December 2020), Eastern Kentucky University.



Left: ECU senior environmental health science student, Amber Turner, assessing the concentration of total phosphorus in one of nine central Kentucky lakes.

Center: ECU senior environmental health science student, Lana Sexton, pipetting standard solutions and lake water samples to a 96-well plate that is part of a kit that detects one of the cyanotoxins measured in this study.

Right: ECU senior environmental health science student, Amber Turner, adding antibody solution to a 96-well plate that is part of a kit that detects and quantifies cylindrospermopsin (one of three cyanotoxins evaluated in this study).

Development of Buoyant Photocatalysts for Cleaning Contaminated Streams and Water Bodies

Grant Number: 2019KY291B

PI: Dr. Matthew J. Nee, Professor
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Co-PI: Lovence Ainembabazi, MS Student
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TECHNICAL REPORT

Problem and Research Objectives

Organic compounds have been identified as major concerns for wastewater management. While wastewater management practices are often centered on removal of nanomolar concentrations of organic compounds, a unique set of challenges is presented by the catastrophic-level discharge of a compound directly into water resources like rivers, lakes, and oceans. US Census data¹ from 2010, suggest that, among land-locked states, Kentucky has the highest percentage (2.3%) of its total area covered by water, and is therefore subject to threats from contaminant sources, both internally and due to transportation on and industry along the Ohio River. Organic chemicals (anything containing carbon in its structure) can be particularly problematic, as such spills often float as a slick on top of the water surface. Sources of these organic compounds include pharmaceuticals,² agricultural industries,³ and textile industries,⁴ though nearly every human industry produces some waste output to water resources. Photocatalytic degradation of aqueous organic waste using TiO₂ or other photocatalysts has been advanced as remedy,⁵⁻⁸ however, the use of TiO₂ in any powder form contends with a challenge of stable suspensions from water, which makes it difficult to separate the photocatalyst from the water in the final stages of the degradation process.⁹ This is particularly problematic for large-scale environmental catastrophes, as occurred during the 2014 Elk River incident, during which thousands of gallons of 4-methylcyclohexane methanol was discharged over a matter of days into a tributary of the Ohio River in West Virginia.^{10,11} In that incident, the only attempts to perform cleanup were the addition of activated carbon as a sorbent because there was not a known alternative. Generally, most such spills are either allowed to dissipate, or are contained and removed mechanically, a time- and labor-intensive process. A comprehensive CDC study ranging over many years tracked “acute hazardous substances events” in thirteen different states (Kentucky was not one of them).¹² This study found that in 2009 (the last year for which data are available), reported almost 5,000 such events (averaging 385 per state) releasing over 4,000 different compounds. Of these events, 2% occurred during water-based transport. In 20% of events, the compound released was classified as a volatile organic compound, much like in the Elk River spill. Photocatalytic degradation would clearly have an advantage over sorption on both fronts (effective removal and targeting a slick), provided that a material which is able to be dispersed and contained could be developed. In such cases, a buoyant photocatalyst is needed that can be distributed over the spill, then easily be removed after treatment.⁹ We have recently developed a new approach to buoyant photocatalyst supports that surmounts all of the technical challenges to such use, and, during the funding period, we incorporated

photocatalysts which are superior to TiO_2 , extending the range of usefulness for this material.¹³ There are many metal-oxide photocatalysts (including ZrO_2 , SnO_2 , Al_2O_3 , ZnS , and Fe_2O_3) that are available for purchase in fine powder form. As we justify in the *Related Research* section, this project was focused on ZnO and WO_3 , two commercially available photocatalysts.

Methodology

The methodology described in the proposal was followed with only minimal adjustments needed to the composition of the polymer as we changed catalysts from TiO_2 to ZnO and WO_3 . In short, a porous polymer substrate was made using an emulsion method developed by our group.¹³ Addition of photocatalyst into the emulsion resulted in incorporation of the photocatalyst into the material upon heat curing, resulting in 1-2 mm beads comprised of thousands of microspheres with exposed photocatalyst. Morphology and incorporation were confirmed using scanning electron microscopy (SEM). Porosity was assessed based on surface-area-to-volume ratio (SAV), measured by Brunauer-Emmett-Teller (BET) nitrogen desorption isotherms. To ensure that photocatalyst crystal structures are maintained, Raman spectra were collected routinely, with x-ray analysis (XRD) measured once materials were optimized.

Loaded beads float atop our model pollutant solution, allowing top-irradiation of the material and solution to initiate the photocatalytic degradation process. The visible absorption spectrum of the solution is measured as a function of irradiation time for each photocatalyst-polymer bead batch, and the rates of degradation of methylene blue dye are used as a measure of the best material.

Principal Findings and Significance

Both ZnO and WO_3 were relatively straightforward to incorporate into the polymer bead morphology. Optimized beads showed high SAV areas, with no disruption to the intended crystal structure due to the synthetic process, which occurs at only 85°C . These two photocatalysts were chosen because we anticipated that each would have an advantage over the previously-used TiO_2 . The photocatalytic degradation data shown in Figure 1 show steeper slopes for ZnO and TiO_2 than for WO_3 , which indicates that ZnO and TiO_2 have faster removal rates. When other factors are considered (such as adsorption, rather than degradation of pollutant, which will not substantially increase the rate at which pollutant would be removed in a spill circumstance), WO_3 performed similarly to TiO_2 . However, ZnO significantly and consistently outperformed the other two. The work shown in Figure 1 appears to be typical and reproducible, as confirmed during the final year of extended funding.

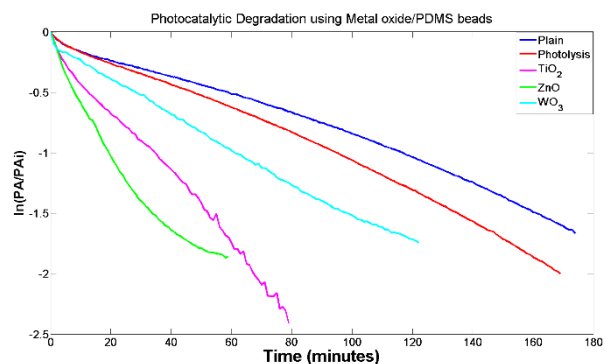


Figure 1. Natural log of methylene blue concentration as a function of time for PDMS beads with and without the indicated photocatalysts. The steeper the slope, the faster pollutant is removed from the solution.

The significance of these findings is that we have demonstrated that we can expand our porous polymer morphology from TiO_2 to other metal oxides without difficulty. At this stage, we are

confident that the next stage in our research will be to begin using more sophisticated photocatalysts, and to explore more cost-effective polymers. Currently, we use polydimethylsiloxane (PDMS), but methacrylates and polystyrene are both being considered for future extensions of this work. This will be necessary as we begin to work towards a product that can eventually be produced for use by municipalities and other emergency agents in a chemical spill. Already, one follow-on proposal has been submitted to NSF, but was not selected for funding. Resubmission is planned this summer.

References

1. US Census Bureau, 2010 Census of Population and Housing, Population and Housing Unit Counts, CPH-2 1. US Government Printing Office: Washington, DC, 2012; p 41.
2. Kanakaraju, D.; Glass, B.; Oelgemöller, M., *Titanium dioxide photocatalysis for pharmaceutical wastewater treatment*, Environmental Chemistry Letters, 12, 27-47 (2014).
3. Sud, D.; Kaur, P., *Heterogeneous Photocatalytic Degradation of Selected Organophosphate Pesticides: A Review*, Critical Reviews in Environmental Science and Technology, 42, 2365-2407 (2012).
4. Akpan, U. G.; Hameed, B. H., *Parameters affecting the photocatalytic degradation of dyes using TiO₂-based photocatalysts: A review*, Journal of Hazardous Materials, 170, 520-529 (2009).
5. Kabra, K.; Chaudhary, R.; Sawhney, R. L., *Treatment of Hazardous Organic and Inorganic Compounds through Aqueous-Phase Photocatalysis: A Review*, Industrial & Engineering Chemistry Research, 43, 7683-7696 (2004).
6. Tokumaru, K., *The research on photocatalysis in early days*, Kokagaku, 36, 153-162 (2005).
7. Tanaka, K., *Purification of waste water by titanium dioxide photocatalysis*, Ryusan to Kogyo, 53, 69-74 (2000).
8. Vohra, M. S.; Tanaka, K., *Photocatalytic degradation of aqueous pollutants using silica-modified TiO₂*, Water Research, 37, 3992-3996 (2003).
9. Singh, S.; Mahalingam, H.; Singh, P. K., *Polymer-supported titanium dioxide photocatalysts for environmental remediation: A review*, Applied Catalysis A, 462, 178-195 (2013).
10. Cooper, W. J., *Responding to Crisis: The West Virginia Chemical Spill*, Environmental Science & Technology, 48, 3095-3095 (2014).
11. Whelton, A. J.; McMillan, L.; Connell, M.; Kelley, K. M.; Gill, J. P.; White, K. D.; Gupta, R.; Dey, R.; Novy, C., *Residential Tap Water Contamination Following the Freedom Industries Chemical Spill: Perceptions, Water Quality, and Health Impacts*, Environmental Science & Technology, 49, 813-823 (2015).
12. US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. *Hazardous Substances Emergency Events Surveillance Annual Report 2009*; Division of Health Studies: Atlanta GA, 2010; pp 1-41.
13. Bertram, J. R.; Nee, M. J., *A Buoyant, Microstructured Polymer Substrate for Photocatalytic Degradation Applications*, Catalysts, 8, 482-495 (2018).

PUBLICATIONS AND PRODUCTS

Ainembabazi, L., and Nee, M.J. (2019, November). Incorporation of Metal Oxides into a Polymer Substrate for Buoyant Photocatalysts. 105th Annual Meeting of the Kentucky Academy of Science, Berea, KY.

Ainembabazi, L. (2019). *Incorporation of Metal Oxide into a Polymer Substrate for Buoyant Photocatalysts for Water Remediation*, Master's Thesis, Department of Chemistry, Western Kentucky University.

Ainembabazi, L., and Nee, M.J. (2019, April). Incorporation of metal oxides into a polymer substrate for buoyant photocatalysts. Spring 2019 American Chemical Society National Meeting and Exposition, Orlando, FL.

Ainembabazi, L. and Nee, M.J. (2019, March). Incorporation of metal oxides for buoyant photocatalysts. 49th Annual WKU Student Research Conference, Bowling Green, KY.

Schulte, C. and Nee, M. J. (2020, November). Polydimethylsiloxane as a substrate to facilitate the use of photocatalysts in the breakdown of organic water pollutants. Presentation at the 106th Annual Meeting of the Kentucky Academy of Science, Virtual Meeting.

Schulte, C., Ainembabazi, L., and Nee, M.J. (2020, May). Effectiveness of Polydimethylsiloxane Beads with Incorporated Photocatalysts at Addressing Organic Water Pollution. 50th Annual WKU Student Research Conference, Bowling Green, KY.

STUDENT SUPPORT

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Comparison of Water Loss Audit Methodologies in High Loss Kentucky Utilities

Grant Number: 2019KY295B

PI: Dr. Scott Yost, Associate Professor
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TECHNICAL REPORT

Problem and Research Objectives

While all drinking water utilities have water losses, excessive water loss can negatively impact the financial health of the utility by producing water not delivered to billed customers. High water loss volumes can affect a utility's scoring in project prioritization and can result in enforcement actions from regulatory agencies. In Kentucky, the regulation of water utilities is divided between the Kentucky Division of Water (KDOW) and the Kentucky Public Service Commission (PSC). The Kentucky PSC regulates investor-owned utilities, water districts, water associations, and the rates of municipal utilities that sell to those under full PSC jurisdiction (over half of the Kentucky water utilities). While the KDOW does not have specific regulated threshold covering water loss, the Kentucky PSC regulates water loss using a 15% unaccounted-for water threshold.

The AWWA's Water Loss Control Committee has expressed strong concerns about expressing water loss as a percentage of any form. Percentage loss indicators have been demonstrated to be misleading because the lowered customer consumption would increase the percentage of water loss, even when the lost volume does not change. The latest guidance from AWWA and codified in the newest version of the AWWA free water audit software omits water loss as a percentage. Instead, non-review water, reported as both volume based and cost based, is the recommended terminology and standard for assessing a utility's performance.

Methodology

The initial objectives of this study is to perform top down water loss audits in at least three small, rural utilities in Kentucky with water loss above 35% in order to 1) compare water loss auditing methods, 2) explore the most current recommended practices, 3) compare prioritization of systems using the new indicators, and 4) educate utilities and regulatory bodies on best practices and recommended focus areas. As we developed the training material and began working with the utilities, it became clear that much more time was needed in objective 4, educating both the utilities and the regulating agencies, and hence the vast majority of the project was in pursuing this objective.

We conducted the three AWWA Water Audit workshop for small utilities. Each of these were 6-hour long onsite workshops. The first two workshops were using version 5 of the software. The newest version was scheduled to be released before we started this project, but it was not released until December 4, 2020. The third workshop, held in December of 2020, did utilize the latest version. Where the first two workshops had 4 and 8 participants, respectively, the final 6-hour workshop had 4 participants. In all workshops there was a wide cross section of utility personnel, including office

managers, plant managers, commissioners, and accounts managers, account clerks, and field personnel. All workshops were approved by Kentucky DCA for continuing education credits for plant operators, and the newest workshop was approved by Kentucky PSC for commissioner/board members.

Principal Findings and Significance

During the onsite interaction we presented the AWWA water audit terminology (i.e, revenue, non-revenue water and examples of each), methodology and data needed to conduct the audit, and the extensive process of grading the uncertainty of the data used in conduction the audit. While most of the terminology and methodology was learned quickly, many participants struggled with the data confidence grading. While the participants learned how to conduct the water audit, we were able to learn about each utility's current operational and management practices, and in turn give them insight into industry wide practice and standards. In addition, all three utilizes gained immense knowledge as to the role of various key personnel and support staff in performing the Water Audit.

Previous workshop participants struggled with the data validity grading as it was a more wholistic approach. Participants of the workshop read a series of narratives which outlined various aspects of a utility's management, operations and maintenance, field protocols, accounting, technologies, and personnel responsibilities, and based on the descriptors, attempted to come up with a validity score. Not only did most not understand the terminology, but they were also lost in the complex narratives and descriptions. Generating the breakdown of revenue and non-revenue water, the focus of regulatory reporting, was relatively easy. But the data grading, which leads to a much more complete understanding of operational and management practices, was a large hurdle for participants to overcome. The workshop was modified on the fly to spend more time in data validity scoring, allowing groups discussion and consensus answers.

With the release of AWWA Water Audit version 6 of the software came remarkable improvements in the data grading. The new Water Audit software has a series of questions for each of the 19 areas (input information needed to conduct the audit) with drop down menu choices where the user picks the most appropriate answer. The answers combine to give a score (1-10) in each of the 19 areas, as well as a composite score (from 0-100). While these 100 or so questions can be a bit overwhelming at the onset, the December workshop participants had a much better perspective of the individual components, and hence could come up with an applicable/appropriate answer. The workshop modifications carried over to this updated workshop and we continued to spend more time in data validity scoring and encouraging/leading groups discussion.

Other important aspects of the workshops included identifying the key personnel within the utility who would be the primary and secondary source of information for the 19 input areas to determine revenue and non-revenue water. Ideally, every person who was identified as a primary source of information would be attending the workshop. In all workshops, the participants covered most of the key areas. In the second workshop, which had 8 people, we asked each participant why they were in attendance. Two of them replied that they had no idea. These two participants were part of the office staff (billings and records). At the end of the workshop, it became clear to all attendees of these two people's vital role in conducting the audit and the information only they could provide. In all

workshops, all participants left with a better understanding of their role in the organization and how their colleagues depend on each of them for the needed water audit information.

Another adjustment that was made was the result of seeing the impact of the updated methodology compared to the original methodology used in developing the workshop and training. The greatly improved data grading, leading to a more complete and thorough understanding, was needed to be shared with the participants in the original workshop. Hence, we developed a workshop update- a 3 hour training session to teach the original participants the new data grading protocol, based on the question and multiple choice answers. All participants in the workshops will receive training on the AWWA Water Audit version 6.

Besides devoting more time for the data validity grading, we also focused more on the results and how this can lead to action plans and possible changes in internal processes, written policy details and important references/requirements in official contracts with water suppliers and consumers. The economic component of the water audit, showing the impact of non-revenue water, was highlighted. This information adds much more depth to the analysis than just the water loss quantity. There is still work left to do on the performance indicators. We have not fully mapped the current PSC regulated water loss to the water audit key performance indicators. With only 3 data points (the three utility workshops), the connections were inconclusive.

We realized we needed to expand the outreach to acquire more data sets. To do this, we reached out to the Kentucky PSC to gain access to a broader group of utilities, not just the ones under a regulatory microscope (those utilities with 35% water loss or greater). We recently met with the director of the PSC and proposed a plan to gain access to other regulated utilities. We have an early agreement to present the plan before the entire board. The main challenge is that the PSC still requires water loss to be reported, and the new AWWA Water Audit purposely omits the water loss reference and calculation. As a bridge, we modified the Water Audit software to still calculate water loss so that the PSC could have their regulated utilities use the new version and still follow reporting requirements. We anticipate that once approved by the board, the utilities will use the AWWA Water Audit version 6 modified software for their reporting. And then from the reports we would have all the information needed to complete the analysis between water loss and AWWA key performance indicators. While we will offer help to any utility who want to use the Water Audit software, will still are focused on outreach to the troubled utilities as we move forward under new funding.

When it comes to analyzing how the percent water loss compares to Key Performance Indicators, Table 1 shows a summary of the results for the three utilities. While each of the three utilities are on the PSC watch list (greater than 35% water loss), two of the utilities happen to be serve a more rural customer base, as given by the number of connections per mile of water main; the number of connections per mile of main would be smaller. The smallest utility (based on the number of service connections) does have the greatest (preliminary) water loss. When normalizing for the number of connections and miles of water main, the real losses far outweigh that of the two other utilities, an order of magnitude greater than the other two. Considering the economic impact, as shown by the last column in Table 1, each of these utilities have a very significant financial burden. Even though utility #1 has a greater percentage loss than utility #2, it has the lowest normalized financial impact. This preliminary and very limited data shows that the Kentucky PSC may have justification to review the regulation to be more encompassing, rather than based strictly on percent water loss.

Table 1. Comparison of Water Loss to certain Key Performance Indicators

Utility	Connections	Connect/mile	Supply MG/Yr	Water Loss (%)	Non Revenue		Unit Real Losses		Real Loss Cost (\$/conn/yr)
					MG/yr	\$M/yr	gal/conn/day	gal/mile/day	
1	5600	13	392.48	42.3	166	0.554	67.9	895	63.17
2	4337	16	253.01	38.9	98	0.325	61.3	955	72.84
3*	853	19	243.27	59.4	145	0.216	421.4	8024	226.11

* preliminary results, not validated for version 6 of the AWWA Water Audit software

The following were the significant outcomes of this work:

- 1) Trained the key personnel from three challenged Eastern Kentucky utilities in the conducting AWWA Water Audit (version 6).
- 2) Created a 6-hour workshop on the Water Audit methodology, one 6-hour workshop on the new Water Audit methodology and one 3-hour update workshop.
- 3) The workshops have been approved for continuing education credits by DCA and PSC for operators and commissioners, respectively.
- 4) Started working with Kentucky Public Service Commission on expanding the use of AWWA Water Audit methodology in regulated utilities.
- 5) Modified the AWWA Water Audit software so that PSC regulated utilities could use it to meet current regulatory guidelines.
- 6) There is indication that the regulating agencies have a need to review current regulations, which are based solely on percent water loss.

PUBLICATIONS AND PRODUCTS

Yost, S.A. and N. Fields. (2020, July). AWWA Free Water Audit Instruction, Workshop conducted at Estill County Water District, Irvine, KY.

Yost, S.A. and N. Fields. (2020, October). AWWA Free Water Audit Instruction, Workshop conducted at West Liberty Water District, West Liberty, KY.

Yost, S.A. and K. Emmett. (2020, December). AWWA Free Water Audit Instruction (v6), Workshop conducted at Big Sandy Water District, Catlettsburg, KY.

Yost, S.A. and K Emmett. (2021, February). AWWA Free Water Audit Update Instruction (v6), Workshop conducted at Estill County Water District, Irvine, KY.

Yost, S.A. and K Emmett. (2021, March). AWWA Free Water Audit Update Instruction (v6), Workshop conducted at West Liberty Water District, West Liberty, KY.

STUDENT SUPPORT

Natalie Fields, Undergraduate Student, Department of Civil Engineering, University of Kentucky.

Katie Emmett, Undergraduate Student, Department of Biosystems & Agricultural Engineering, University of Kentucky.



Student researcher Natalie Fields (standing) helps participants (seated) conduct the AWWA Water Audit at the first onsite workshop.

Information Transfer Program

Grant Number: 2019KY292B

Dr. Lindell Ormsbee, Director
Kentucky Water Resources Research Institute

Steve Evans, Assistant Director
Kentucky Water Resources Research Institute

Emily Koyagi, Research Analyst
Kentucky Water Resources Research Institute

Information transfer activities are an important part of the overall program of the Kentucky Water Resources Research Institute. There are 4 main ongoing components: (1) an annual symposium, (2) the institute's website, (3) other electronic distribution of information, and (4) technical presentations and workshops.

Planning and preparation for the 2020 Kentucky Water Resources Annual Symposium began in the fall of 2019. The contract for the meeting venue was finalized, the call for presentation abstracts was distributed, the agenda was set, guest speakers were invited, attendees were registered, and the full proceedings document was drafted. On March 11, 2020, just twelve days before the symposium was to be held, the decision was made to cancel the 2020 Kentucky Water Resources Annual Symposium due to the COVID-19 pandemic. The 2020 symposium was initially postponed until fall 2020 and then ultimately cancelled due to the ongoing pandemic. The 2021 Kentucky Water Resources Annual Symposium will be held on September 13, 2021.

The official Web site of the Kentucky Water Resource Research Institute, www.research.uky.edu/KWRRI, is hosted by the University of Kentucky. Maintenance of the web site and social media accounts are ongoing throughout the year. KWRRI continued to increase its social media presence via Twitter (<https://twitter.com/UKWater>) throughout the grant period which is demonstrated by the acquisition of 67 new followers, 431 profile visits, and over 25,000 tweet impressions.

In 2018, the KWRRI began issuing a semiannual electronic newsletter that spotlights KWRRI's research, highlights 104b supported water research conducted across the commonwealth, announces upcoming events and requests for proposals, and shares news and other relevant information. The goal of the newsletter is to facilitate information sharing and increase communication among those in Kentucky's water community. The newsletter is distributed to 782 subscribers- 36% academia (faculty and staff); 30% local, state or federal government; 15% students; 12% private sector; and 7% NGOs/non-profits. During the reporting period, KWRRI produced three editions of its semi-annual newsletter (Spring 2019, Winter 2019, Summer 2020).

KWRRI continues to update its repository in UKnowledge's digital collection, <https://uknowledge.uky.edu/kwrri/>. UKnowledge captures, stores, organizes, and provides open and stable worldwide access to UK's intellectual capital, and facilitates reuse of deposited materials to the

extent warranted by copyright law or by the licensing terms of the concerned materials. The repository includes historical KWRRRI reports, annual symposium proceedings, technical reports, and the Water Distribution System Research Database.

The institute cooperates closely with other groups and agencies in planning information transfer activities in the Commonwealth including support for seminars/lectures, technical workshops and presentations, support of additional websites and databases, and participation in open houses and engagement events. For example, during the FY 2019 grant period, KWRRRI hosted an interactive exhibit at the UK College of Engineering's annual Engineering Day, held on February 22, 2020, that was attended by over 3,000 people. KWRRRI also participated in the KGS virtual open house on October 16, 2020.

Institute staff members also serve a variety of support roles on technical committees and advisory panels for agencies and volunteer organizations to help disseminate relevant information about ongoing activities and research results to a wider audience.