COMPLETED PROJECTS SUMMARIES

FY 2018

2017OH540B	Bakshi
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Ohio Water Resources Center

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Dr. Bhavik Bakshi, Professor of Chemical and Biomolecular Engineering at the Ohio State University completed an Ohio Water Resources Center USGS 104(b) and OSU's Office of Energy and Environment jointly funded project titled **"Addressing the Water-Energy Nexus of Fossil Power Generation by Considering Technological, Agro-Ecological, and Economic Options in the Muskingum Watershed"**. The objectives of this work was to investigate various alternative scenarios to understand the trade-offs between energy, water, and CO_2 flows in the Muskingum River Watershed (MRW), and suggest better watershed management solutions that could be "win-win" in terms of multiple objectives for watershed sustainability.

Dr. Bakshi's team employed a holistic TES (Techno-Ecological Synergy) assessment approach to examine watershed sustainability. The results showed that the amount of water supply in the MRW is larger than the amount of water demand, which implies that the reduction in water quantity indicator may not be a huge concern. However, TES metrics for other ecosystem goods and services, such as natural gas, CO_2, and air and water pollutants, show negative values, which indicate unsustainable conditions of activities in the MRW. Since most of the air emissions and natural gas consumption are attributed to thermoelectric power generation, various technological alternatives that include different fossil fuels, cooling technologies, CO_2 conversion technologies, and renewable power generation technologies were examined. It was identified that TES sustainability metrics for carbon sequestration and air quality regulation services can be improved by employing NGCC (Natural Gas-Fired Combined Cycle) power plants with recirculating cooling system and CO_2 conversion to formic acid that uses electricity from wind power generation (Figure 1). The synergistic solution that includes both technological and agroecological alternatives could produce "win-win" outcomes in terms of multiple objectives.

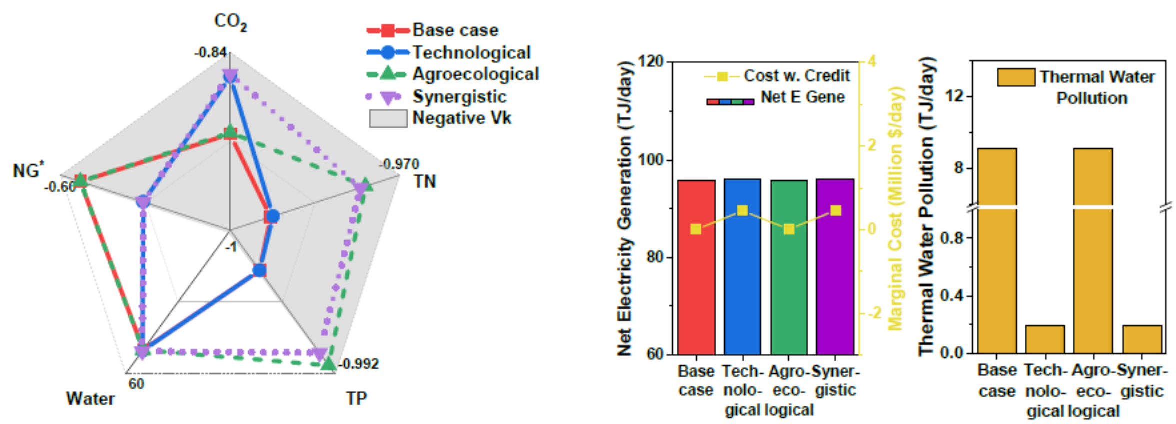


Figure 1 Sustainability indicators for best case scenarios. TES metrics are plotted in radar diagrams. Technological solutions include shale NG-fired combined cycle power plants with recirculating cooling system and 1,000 t/day of CO2 conversion to formic acid with wind power generation. Agroecological solutions include the implementations of no-till practice and the construction of wetlands on available land. The synergistic solution combines both technological and agroecological solutions.

<u>Researcher Profile:</u> Professor Bakshi is an internationally-recognized expert on sustainability engineering. His research focuses on sustainability science and engineering, and process systems engineering. Bakshi is among the first to identify the importance of thermodynamic principles for developing ecological solutions, laying the much-needed fundamental framework for analyzing ecosystems. His contributions to the field of sustainability include bringing useful thermodynamic rigor to various sustainability analyses, pioneering the development of tools for tasks such as process-to-plane framework, introducing the idea of the ecosystem as unit operations, and educating a generation of students in the pioneering field of sustainability.

Figure 1. Dr. Jake Beaulieu and Megan Berberich collecting sediment cores with K-B corer

Dr. Ishi Buffam, Assistant Professor of Biology and Geography at the University of Cincinnati completed an Ohio Water Resources Center 104(b) funded project. The project, **"Characterizing the Link Between Algal Bloom Biomass and Methane Production in Ohio Reservoirs"**, aimed to characterize the relationship between algal blooms and sediment CH_4 production rates in Ohio reservoirs, as mediated by sediment organic matter quantity and quality and the sediment microbial community.

Algal blooms and their known negative environmental impacts associated with nutrient enrichment have been the leading cause of impairments of Ohio's surface waters. However, there has been little research evaluating the increased potential for in-lake production and emission of methane (CH_4) associated with eutrophication. Some lab studies show the potential for increased methane production in surface water sediments when labile algal organic matter is added, but it is unknown whether this relationship translates to the field scenario.

Dr. Buffam's team took samples from Harsha Lake in Ohio and determined CH_4 production rates, composition of organic matter in sediment and genetic composition of methanogens (Figure 1). The results indicated that quantity of organic matter but also source (terrestrial versus algae derived) were both important for methane production rates in the reservoir. For Harsha Lake, areal CH_4 production rates were highest in the riverine portion of the reservoir, even when rates were normalized to organic matter quantity (OM) (Figure 2). This suggests that not only was OM more abundant in the riverine zone, it was also more readily utilized by methanogens. Additionally, this zone was the shallowest, and the researchers determined methanogen archaea community shift towards acetate utilizers in locations with higher terrestrial OM contribution. Based on our results that show high degree of spatial variation in CH_4 production rates, studies of reservoirs as well as natural lakes with substantial riverine inputs should take into consideration a spatially-aware sampling approach to determine CH_4 production and emissions, rather than sampling only at a single deep location.

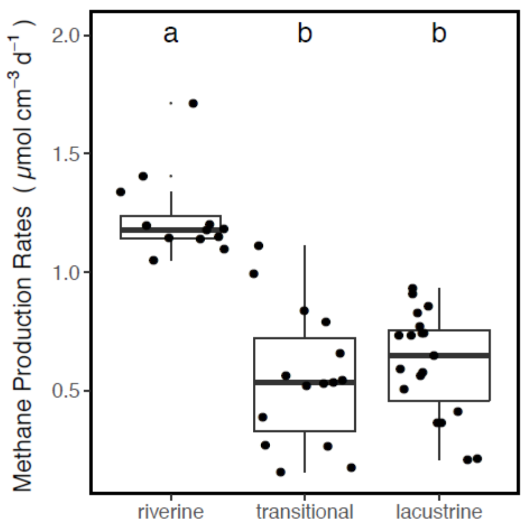


Figure 2. Potential methane production rates from sediment slurries in each of the reservoir zones, normalized to sediment volume

Published in: Berberich, M., J.J. Beaulieu, T.L. Hamilton, S. Waldo and I. Buffam. 2019. Spatial variability of sediment methane production and methanogen communities within a eutrophic reservoir: importance of organic matter source and quantity. **Limnology and Oceanography**. doi: 10.1002/lno.11392.

Researcher Profile: Dr. Ishi Buffam received his Ph.D. from the Swedish University of Agricultural Sciences. His research training stems from aquatic chemistry and biogeochemistry, and more specifically focuses on carbon and nitrogen transformations and hydrological transport with boreal and temperate watersheds. He also has experience in putting freshwater carbon cycling processes into the context of landscape and regional scale carbon cycling.

Dr. Chin-Min Cheng, a Senior Research Associate in the Department of Civil, Environmental, and Geodetic Engineering at Ohio State University completed an Ohio WRC funded project via OWDA titled **"Separation of Phosphorous- and Nitrogen Nutrients from agriculturally Degraded Waters Using Previous Filter Material Developed from Industrial By-products"**. The goal of the project was to demonstrate the feasibility of applying low-cost and environmentally-sustainable approach to agriculture drainage water (ADW) handling and treatment.

Excessive releases of phosphorous (P) and nitrogen (N) from soil to drainages is a leading cause of eutrophication in of water bodies. To prevent accumulation of nutrients in surface waters, reduction of nutrient concentrations in ADW is required. While many best management practices focus on source reduction and minimizing transport, these methods have not proven to prevent dissolved phosphorous loses, which is the most readily available to aquatic organisms. Instead, end-of-tail filtration has been suggested as a better approach, although ideal filter materials have yet to be identified.

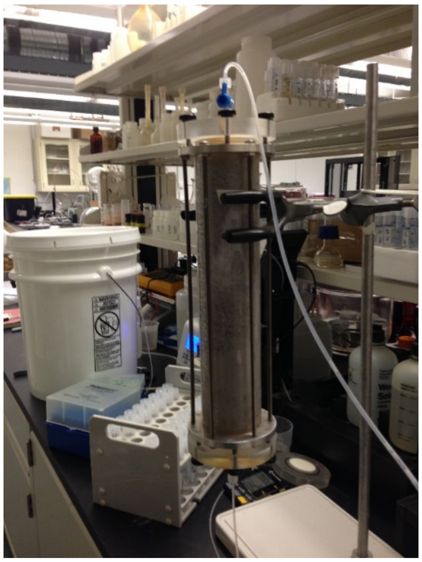


Figure 1 Laboratory set up of column test sorption experiments

In this study, Dr. Cheng with his students modified compositions of coal fly ash, stabilized flue gas desulfurization (FGD) materials (P-type), and bauxite leaching residual (red mud)(N-type) in order to improve selective nutrient-adsorbing capabilities of potential end-of-tail filter for ADW. A series of batch and column tests (Figure 1) were carried out and the results suggest that the filter material containing red mud did not have the expected adsorption effect on nitrate. However, the pervious filter material made from the coal combustion by-products, i.e., fly ash and stabilized FGD material, was found to be able to effectively remove phosphate and potentially nitrate from ADWs (Figure 2). The results showed over 77% of nitrate removal was achieved after one pore volume passing through the column, and increased to 98% after 168 hours. For phosphate, over 99% of removal was achieved after 28 pore volumes, an increase from the 82.5% observed after one pore volume. The reduction of nitrate is unlikely through an adsorption mechanism and other processes might have contributed to the observed nitrate reduction. This study suggests an end-of-tail filtration approach using agricultural and industrial wastes can be developed as an alternative to current BMPs to reduce nutrient discharges from crop lands and produce value-added products containing concentrated phosphate.

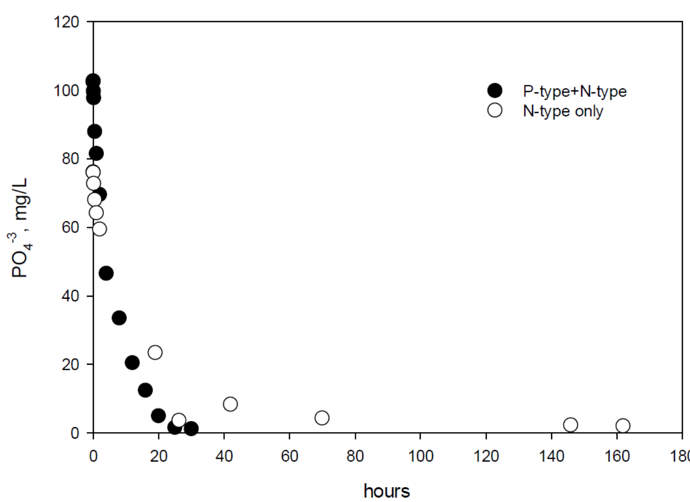


Figure 2 Temporal trend on phosphate removal in the clos- loop column system using two types of the studied materials

<u>Researcher Profile:</u> Dr. Chin-Min ("Jason") Cheng earned both his PhD and MSc in Civil Engineering, with a specialization in Environmental Engineering and Water Resources, from The Ohio State University. He is a registered professional engineer in the state of Ohio. His research interest include Applying principals of geochemistry in exploring beneficial use of industrial wastes and assessing the associated environmental responses and Membrane-based wastewater treatment technology.

Dr. G. Matt Davies, an Assistant Professor in Soil and Plant Community Restoration in the School of Environment and Natural Resources at Ohio State and Dr. Gil Bohrer, completed an Ohio WRC 104(b) funded project titled **“Bog HELPR: Bog History, Ecosystem status and Land-use for Peatland Restoration in Ohio”**. The goal of the project was to collate data on the spatial distribution of peat bogs in Ohio and combine this data with a ground survey to assess the bogs’ ecological condition, information that might be used for potential restoration. The research is based on the increasing recognition that restoration of wetland ecosystems can play an important role in mitigating the effects of diffuse agricultural pollution in watersheds and increasing catchment resilience in the face of climate change. There can, however, be significant trade-offs inherent in restoration, not least the potential impacts on greenhouse gas emissions.

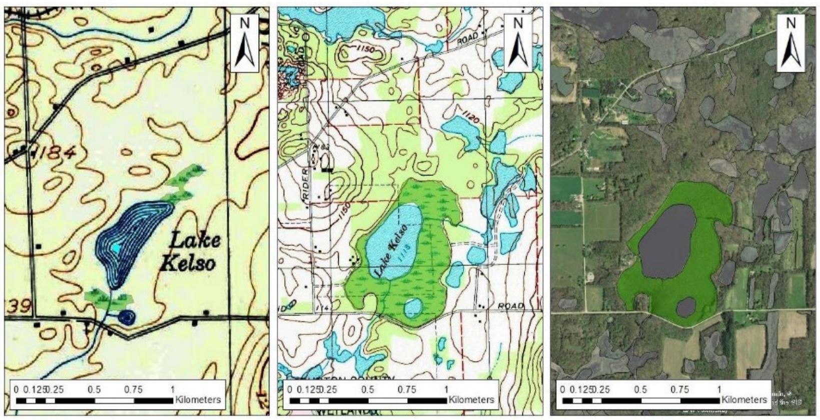


Figure 1: From left to right the pictures show a 1900's era USGS Topo Map, a 1994 Topo Map and an aerial image from 2009. Areas mapped as peat bog are shown in green.

The research evaluated four methods to determine their usefulness in peatland restoration in Ohio: using historical maps for classification, peatbog hydro-chemistry, vegetation community composition, and soil microbial community composition. The research team evaluated a total of 70 potential bog sites (Figure 1), and developed bog classification maps. These maps will provide an invaluable resource that catalogues areas where peatland cover has been lost and that should be a priority for ground survey to assess restoration potential. From hydrochemical analyses, it was determined that Ohio’s peat bogs can most likely be identified as poor fen systems. This conclusion was supported by the high electrical conductivity with a wide range (33-597 µs/cm; median = 70 µs/cm). Additionally, carbon stock estimates confirm that, regardless of their small size and total area, Ohio’s peat bogs are a critical store of ancient carbon (See Figure 2). In assessing the vegetative and microbial communities within the peat bogs, the research showed there bryophytes (non-vascular plants) are useful as indicators of peatland hydrochemical status. This discovery will be important for rapidly monitoring sites where knowledge on varying water table and water quality conditions is not available.

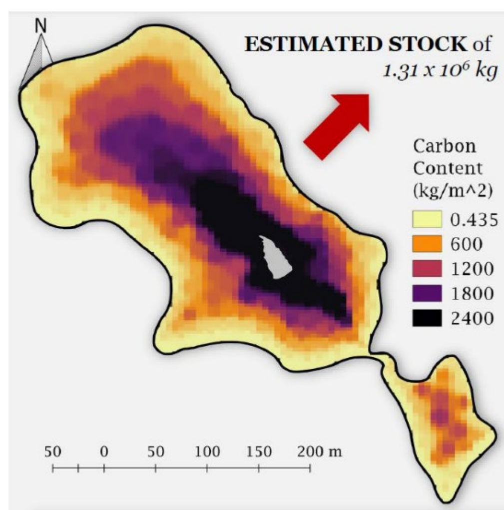


Figure 2: Distribution of peat carbon stocks across Flatiron Bog, Portage County, OH. Organic soil depths at the center of the bog were >10 meters.

<u>Researcher Profile:</u> Dr. G. Matt Davies completed his post-doctoral research at the University of Washington in Seattle and a lectureship at the University of Glasgow in Scotland. His research focuses on the management and restoration of peatland ecosystems and has included studies on the effects of grazing and wildfires on the release of carbon from temperate peatlands.

Dr. Pelagia-Iren Gouma, a Materials Science Engineering Professor in the College of Engineering at Ohio State, completed an Ohio WRC funded project via Office of Energy and Environment titled **"Composite Membranes for Produced Water Clean-up"**. The goal of the project was to study innovative water treatment technologies that can make removal of metals and radionuclides from fracking wastewater cost effective and scalable.

Within Ohio, hydraulic fracturing, or fracking continues to be a common method for energy production in which oil or gas is extracted from rock and shale formations by drilling and injecting high-pressure water and chemicals into wells. This process uses millions of gallons of water and leaves the wastewater produced filled with salts, proprietary industrial chemicals, radionuclides, and toxic metals. Properly cleaned produced water could be highly valuable, and it will reduce concerns about the use of large amounts of water in the fracking process.

Figure 1 Milind Pawar, graduate student, demonstrating production of amyloid fibrils for membrane synthesis

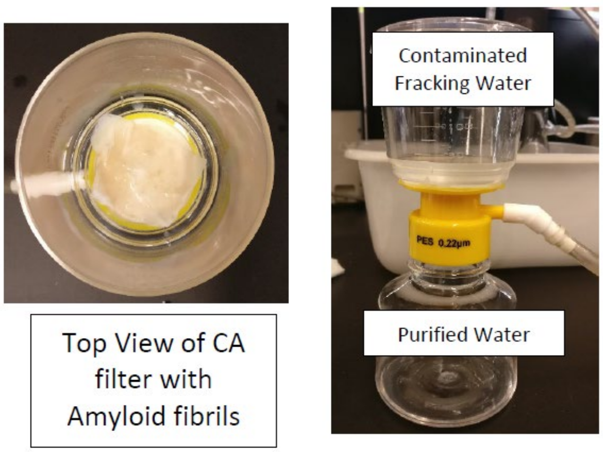


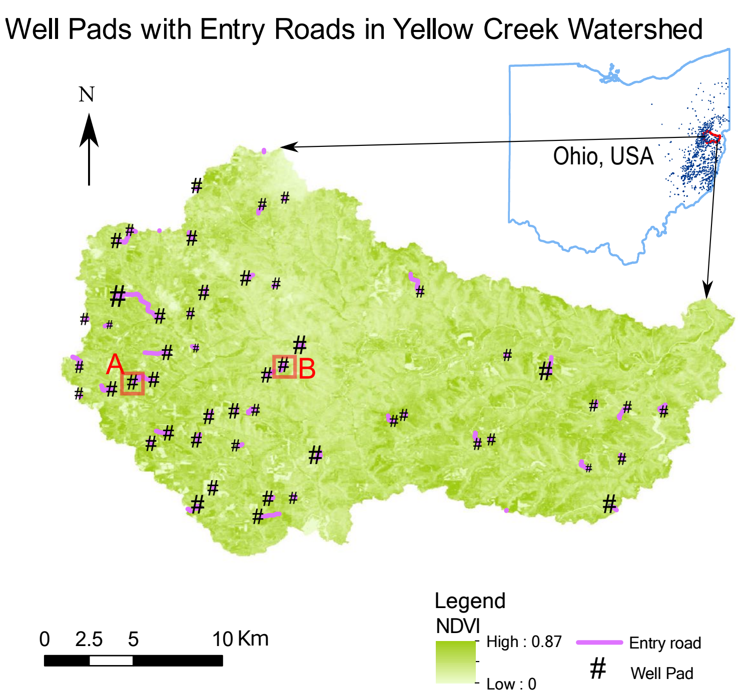
Figure 2 Cellulose Acetate membrane with amyloid fibrils assembled to filter produced water in lab experiment

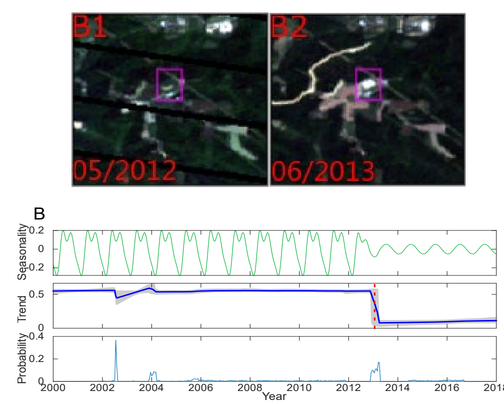
Celulose acetate filters have been shown previously as superior oil absorbants. Dr. Gouma and her team have reached two major breakthroughs in membrane development for produced water treatment: (i) they managed to extract amyloid fibrils from wheat by-products and (ii) they have successfully managed to encapsulate amyloid fibrils into non-woven mats of cellulose acetate via a single step process of electrospinning. They are working on evaluating the assembled membrane capability to treat produced wastewater from hydraulics fracturing. Due to the affordable nature of the membrane constituents and the potential for it to efficiently remove toxic metals and radionuclides via filtration, this technology could be of significant use in addressing water pollution issues, such as fracking wastewater.

<u>Researcher Profile:</u> Dr. Perena-Iren Gouma is the Edward Orton, Jr., Chair in Ceramic Engineering. Gouma has a joint position as professor of materials science and engineering and professor of mechanical and aerospace engineering and will join The Ohio State University. She is director of the Advanced Ceramics Research Laboratory at Ohio State.

Dr. Elizabeth Myers Toman, Visiting Assistant Professor in the School of Environment and Natural Resources at The Ohio State University, and Dr. Kaiguang Zhao completed joint Ohio Water Resources Center and Office of Energy and Environmental at OSU funded project titled **“Landscape fragmentation and water yield with unconventional shale oil and gas development in Ohio”**. The project aimed to document environmental consequences and impacts of the development of shale oil and gas in Ohio and be useful to inform local policy and best management practices.

Development of unconventional shale oil and gas through hydraulic fracturing has transformed the energy landscape of the United States. However, its environmental impacts remain poorly understood, especially regarding landscape fragmentation and changes to local or regional hydrology. Dr. Toman’s team focused their research on Yellow Creek watershed in Eastern Ohio. They collected remote sensing data and developed a time series algorithm, BEAST, for detecting landscape disturbances. The results showed that 44 out of 50 well pads showed abrupt changes in land cover vegetation that occurred within two months before or after the well pads had been developed. The total area disturbed by oil and gas development was 98 ha (less than 0.3% of the total watershed area) of which 66 ha were originally in pasture or cropland and 21 ha were forest. There were no significant changes in storm runoff duration, maximum instantaneous discharge, time to maximum instantaneous discharge, or runoff volume between the storm events before and during oil and gas development at the outlet of the watershed. This may be due to the other varied and ongoing anthropogenic land uses within the watershed. Furthermore, the addition of oil and gas development in the studied watershed was likely not large enough to overwhelm the influences of the other land uses occurring in the watershed including surface coal and industrial mineral mining.





Figures. Well pads with entry roads in Yellow Creek Watershed shown on a NDVI (vegetation index) map for 2017. The size of the symbols is proportional to the size of each well pad. The BEAST algorithm used LANDSAT imagery at well pad “B” (top right) to detect a change in land cover consistent with timing of the well pad development.

Researcher Profile: Dr. Elizabeth Toman completed her PhD. (dual degree) in Forest Engineering and Civil Engineering and MSc. in Forest Hydrology at Oregon State University. Dr. Toman’s research interests lie in the broad areas of forestry, hydrology, and transportation. More specifically she is interested in what occurs when and where these spheres meet. She studies the influence of land management activities such as road construction and use, forest harvesting or vegetation removal, and oil and gas exploration, on stream water quality.

Dr. Susan Welch, a Research Scientist in the School of Earth Sciences at The Ohio State University, along with Drs. David Cole and Julie Sheets, completed an Ohio WRC project funded via OWDA and OEE sub-awards titled **"Remediation of Hydraulic Fracturing Flowback Fluids by Trace Element Extraction"**. The goal of this project was to understand the evolution of the major and trace element composition of flowback/produced fluids (FP fluids) and investigate strategies to actively remove potentially toxic or economically important elements. The results of these experiments could eventually be scaled up and applied to hydraulic FP fluids storage facilities to potentially recover economically valuable metals from this waste product.

Dr. Welch's conducted experiments with FP fluids to determine the extent to which different species would be partitioned into secondary mineral phases, either by allowing the solutions to age and oxidize, or by adding different amendments to induce mineralization, such as sodium carbonate and phosphate and sulfate rich solutions. The geochemical behavior of trace elements in these experiments was complex. Naturally aged FP fluids precipitate akaganeite (β- FeO(OH,Cl)) (Figure 1), but most trace metals measured (Rb, Cs, Ni, Cu, Zn, Pb) were not co-precipitated with this phase, however Si, U and Th were scavenged from solution.

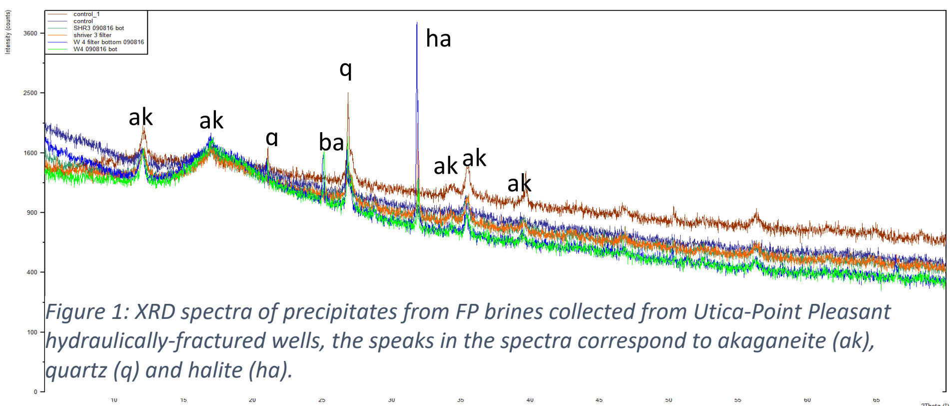


Figure 1: XRD spectra of precipitates from FP brines collected from Utica-Point Pleasant hydraulically-fractured wells, the speaks in the spectra correspond to akaganeite (ak), quartz (q) and halite (ha).

The results showed that carbonate addition removed Ca as calcium carbonate, as well as other trace metals, but only small amounts (~ 10s %) of Sr and Ba were removed. Addition of sulfuric acid or simulated acid mine waste resulted in the formation of barite-celestite and gypsum phases, and removal of Ca, Ba, Sr, Ra and some trace metals (La, Cu, Zn) from solution; however, mineralogy depended on the concentration of sulfate added. For example low levels of sulfate resulted in the formation of small barite roses without significant Sr removal from solution. On the other hand, intermediate levels of sulfate resulted in the precipitation of euhedral Sr-bearing barite crystals, as well as celestite with elongate crystal habit and removal of Ba and Ra from solution.

<u>Researcher Profile:</u> Dr. Susan Welch graduated from the University of New Hampshire with B.S. in Geology and B.A. in Chemistry and attended graduate school at the University of Delaware, where she received her Ph.D. in Oceanography. She is a Research Scientist at the School of Earth Science, OSU. She works as an analytical geochemist with expertise in analyzing water and sediment samples. Her research interests are in the field of Low Temperature Geochemistry and Biogeochemistry. Her current work focuses on CO2 sequestration, and the reactivity of trace mineral phases on the geochemistry of natural waters.

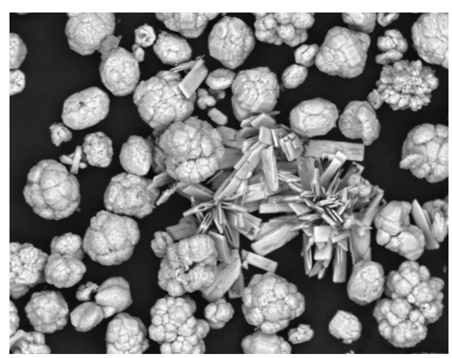


Figure 2 SEM images of barite (Ba(Sr)SO4) precipitates from the low sulfate treatment