Quarterly Report

Enhancing Montana's Energy Resources: Research in Support of the State of Montana Energy Policy Goals

Montana Board of Regents
The Office of the Commissioner of Higher Education
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Reporting Period End Date: October 31, 2015
Report Term/Frequency: Quarterly

Objective 1

Develop methods for creating mineral seals at greater depths (> 5000 feet bgs) and higher ambient temperatures (>35°C) than current ERI biomineralization technology.

Quarter activities and accomplishments

During this reporting period, significant laboratory efforts have been undertaken and hiring staff and students to work on the project was accomplished.

Hirings

- Hired postdoctoral researcher, Dr. Marnie Feder, to work on advanced well sealing technology.
- A Masters level graduate student, Arda Akyel, was also identified to start working on the advanced well sealing technology project.
- An undergraduate Civil Engineering student, Cody West, was hired to study the differences in material properties of the advanced mineral precipitation strategies.

Equipment Purchased

No equipment has been purchased to date.

Milestones

A. September 2015-September 2016: Perform laboratory bench experiments to extend the temperature range for mineral precipitation, and thief zone plugging for enhanced oil recovery (EOR)
    a. The team began developing experimental designs for further assessing the temperature range and upper temperature limits of jack bean urease as well as other prokaryotic and eukaryotic ureases.
    b. Planning started on activities evaluating the kinetics of abiotic urea hydrolysis as well as strategies to enhance thermally induced urea hydrolysis.
    c. Other microbial processes and metabolisms with potential for in situ mineral formation were evaluated. Samples were collected from thermal soils in Yellowstone National Park. Those soils were returned to the laboratory and were used to enrich for thermophilic fungi. Tests to determine the mineral precipitating capabilities of the fungi were started (currently ongoing).
    d. An experiment was started that will evaluate the mechanical properties of microbial versus enzymatically produced mineral precipitation.

B. September 2015-September 2017: Leverage federal funds and partner with a Montana company to initiate and plan a mineral precipitation well sealing field test. Identify interested stake holders, share relevant results and field plan.
    a. Conversations have commenced with Montana Emergent Technologies (Butte, Montana) about possible wells and field deployment strategies.
    b. A newly funded Department of Energy project kicked off October 1, 2015. The $2.0 M project titled “Wellbore Leakage Mitigation using Advanced Mineral Precipitation Strategies” was funded to explore advanced and alternate mineral precipitation strategies in both laboratory and field settings. The project funding

was announced on DOE's website: http://www.energy.gov/fe/articles/doe-selects-nine-projects-receive-funding-carbon-storage-intelligent-monitoring-and-well

Objective 2

Test use of microbially induced calcite precipitation (MICP) to remediate fly ash storage to comply with a new federal regulation (40 CFR Parts 257 and 261 Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals (CCR) From Electric Utilities).

Quarter activities and accomplishments

During this reporting period, several meetings were conducted related to coal combustion residuals. Two of the meetings were conducted with industry (Talen Energy and Southern Company) toward better understanding the needs of industry when designing experiments. Samples were collected from the Colstrip power plant's ash storage ponds. Preliminary experiments were performed and it was observed that biomineralization occurred in fly ash and scrubber waste materials.

Hirings

- Hired postdoctoral researcher, Dr. Marnie Feder, coal combustion residuals (fly ash) stabilization.
- A Master's level student, Abby Thane, was also identified to start working on the project. Ms. Thane began working on the batch experiments necessary for understanding the impact of biomineralization in CCR materials.

Equipment Purchased

No equipment has been purchased to date.

Milestones

A. September 2015- September 2016: Collect samples of bottom ash, fly ash and pond water at the Colstrip plant ponds. Perform laboratory studies to assess the feasibility of MICP CCR pond remediation.
    a. Meetings were conducted and the team received a tour of the facility at the Colstrip coal-fired power plant on October 09, 2015. The hosts were Gorden Criswell and Dayla Topp. The focus was on understanding the process of flue gas treatment and coal combustion residue management. Samples for analysis and assessment of the applicability of biomineralization methods for stabilization of coal combustion residues were taken.
    b. Meetings were held with Southern Company's Ben Gallagher Senior Engineer of Research and Technology Management about potential applications for biomineralization to encapsulate coal combustion waste streams. The focus of the discussion was on MICP application to remediate the flue gas desulfurization waste stream and the fly ash disposal from particulate scrubbers.
    c. Experiments were performed with MICP in fly ash and scrubber wastewater. Successful mineralization was achieved. Additional experiments guided by the advice from Colstrip and Southern Company's engineers are planned.

Figure 1. A stock image of fly ash particles bound together with biominerals.

B. September 2016-September 2017: Assess and plan field demonstration of MICP in CCR ponds (as appropriate). Work with MT company (Montana Emergent Technologies, MET) to implement the MICP technology in the field.
    a. Conversations with MET have begun on ideas for how field deployment could be achieved.

Objective 3

Assess the potential to use bacterially driven mineral formation for removal of heavy metals, such as cadmium, arsenic and selenate from water produced by coal mining operations, coalbed methane, and enhanced oil recovery.

Quarter activities and accomplishments

A site visit was made to the Colstrip coal fired power plant operated by Talen Energy. At the site visit, samples from the pond wastewater and coal combustion residue were obtained for analysis of biomineralization based treatment and stabilization of the wastes.

Laboratory scale batch tests using synthetic groundwater containing selenium were performed to evaluate the potential for co-precipitation or reduction of selenate during microbially driven calcium carbonate precipitation. The experimental methods were developed for the studies and research assistants were trained on the appropriate analyses. The first set of batch studies were performed and results are currently being analyzed.

Hirings

- Neerja Zambare, Graduate Student Research Assistant – Neerja's role is to conduct laboratory studies on bioremediation of produced water samples.

- Lydia Aman, Undergraduate Research Assistant – Lydia will assist Neerja in completion of the laboratory studies listed in the milestones for this objective.

Equipment Purchased
No equipment has been purchased to date.

Milestones

A. May 2016: Laboratory studies in synthetic mining wastewater with key heavy metal contaminants using model bacterial strains. Contact site(s) of interest to obtain water samples. Discuss potential and strategies for implementation of the technology with local Montana companies (e.g. Montana Emergent Technologies and Enviromin).
    a. Meetings were conducted with Talen Energy engineers Gordon Criswell and Dayla Topp and received a tour of the facility at the Colstrip coal fired power plant on October 09, 2015. The focus was on understanding the process of flue gas treatment and coal combustion residue management. Samples for analysis and assessment of the applicability of biomineralization methods for stabilization of wastewater contaminants were taken. The contacts at Talen identified selenium as a contaminant of concern in water from flue gas desulfurization. Pond water samples were taken from the site and transported to MSU for analysis and testing.
    b. Dr. Lauchnor and Dr. Gerlach held a conference call with individuals from environmental consulting firms and regulatory agencies in the area. The call was organized by Roger Hoogerheide, EPA Superfund project manager in the Helena office. The focus of the call was to inform the participants of the current microbially driven precipitation research and potential applications and to generate interest in collaboration.

B. January 2017: Biomineralization studies in batch and flow reactors using real or synthetic waste water.
    a. Experimental designs have been developed for assessing the utility of the ureolysis-induced calcium carbonate precipitation technology for the co-precipitation of various heavy metals relevant to coal combustion residues.
    b. Methods were developed for analysis of selenium and calcium in precipitate and liquid samples, mineral analysis of precipitates via X-ray diffraction, and microscopy of precipitates via Scanning Electron Microscopy (SEM). Graduate student Neerja Zambare was trained on the SEM and sample preparation methods.
    c. Batch studies employing these experimental designs were conducted using our model bacterium, *Sporosarcina pasteurii* to evaluate the potential for selenate removal. Studies were conducted in an artificial groundwater recipe with selenium, urea, and microorganisms supplemented at the initial time. Studies were run over a one-week duration and precipitates formed during that time were analyzed at the end point. Preliminary results indicate some selenium was detected in precipitates formed via the ureolytic microbially driven precipitation.

C. June 2017: Completion of laboratory investigations on technology scale-up and final assessment of potential for bioremediation of coal- and enhanced oil recovery-generated industrial wastewater.
    a. Meetings with Talen Energy engineers at the Colstrip Power Plant provided insight and direction on contaminants of concern, such as selenium, and data on the water quality at the power plant. This information will be used for final assessment of scale-up potential.

Objective 4

Assess geologic carbon sequestration potential via EOR in oil and gas fields and storage in saline formations near Colstrip, MT, utilizing fine-resolution geospatial methodologies to estimate storage potential, source to sink infrastructure, and enhanced oil production from fields that meet screening criteria.

Quarter activities and accomplishments

Activities this quarter include participation in the MREDI kick-off meeting, compilation of existing energy and surface infrastructure data, and implementation of a geospatial database. A review of relevant publications and available GIS data was conducted, resulting in the assimilation of well data; oil and gas field characterization and production information; surficial data including topography, energy, and transportation infrastructure; land usage; and produced water quality. The GIS analyst began the process of converting this information into formats compatible with the geospatial database. Information collected to date was used to inform preliminary assessments of oil and gas fields proximal to Colstrip and develop a preliminary framework describing the geologic stratigraphy and formation properties (including porosity, permeability, and water quality) of the area.

Hirings

There were no new hires this quarter.

Equipment Purchased

No equipment has been purchased to date.

Milestones

A. July 2015 – July 2016: Assessment of carbon storage and EOR potential
    a. The team identified available datasets and began the process of converting characterization data into digital formats.
    b. Screening and assessment of enhanced recovery potential of proximal fields and saline storage viability will be derived from subsurface models built using ESRI ArcGIS, utilizing this data created and maintained in an enterprise, geospatially-enabled database.
    c. Accurate metadata is being documented within the database in preparation for a final data package.

B. December 2016: Completion of the interactive mapping application
    a. An enterprise geodatabase was built to house the complete dataset and tuned for use with the interactive mapping application software.

C. June 30, 2017: Final Report and data package
    a. As stated above in Milestone A, preparations have began for the final data package.

Objective 5

Develop methods to integrate phototrophic microbe based air capture of CO2 and evaluate potential byproducts.

Quarter activities and accomplishments

MSU

The MSU team has been characterizing the growth of an algal isolate in CBM production water for CO_2 capture and production of biomass and lipids. In addition, the behavior of the algae is being monitored with respect to microbial populations indigenous to CBM production water. Specifically, experiments began to determine community dynamics during cultivation and biomass accumulation.

With respect to outdoor cultivation, new lab space with adjacent outdoor space was identified, and lab conditions are being established. Equipment such as water tanks, air diffusers, temperature probes, and light probes were purchased and are being tested.

MT Tech

Activities and accomplishments during this quarter include attendance of the MREDI kick-off meeting, the September meeting of the Montana Board of Regents, at which the MREDI grant was announced, and meeting with Drs. Spangler and Zhou to discuss the project. At this meeting, Dr. Spangler gave us samples of the microalga *Nannochloropsis gaditana* that originated from experimental ponds and laboratory trials. I then examined and took light micrographs of *N. gaditana* at magnifications of 400X and 1000X (Figure 1) and am maintaining the sample cultures of *N. gaditana.* In addition, Dr. Zhou and I met to discuss the possibility of using freshwater macroalgae as an additional source of plant fertilizer. To begin exploring subsequent sources of funding, I attended a videoconference presented by the DOE-EPSCoR program. One of the main activities is recruitment of a graduate student. Several candidates were interviewd and Kunle Ogansukin accepted the position, an Environmental Engineering Master's Degree Student at Montana Tech.

Hirings

MSU

Logan Hodgskiss (MS) was hired to research needs, purchase equipment, and conduct experiments.

MT Tech

Kunle Ogansukin, Environmental Engineering Master's Degree Graduate Student, will test microalgae and other algae as potential fertilizers for plants.

Equipment Purchased

MSU
Equipment purchased this quarter are the light probes and temperature probes to measure outdoor growth conditions and the sequencing kits for molecular ecology of algal communities in CBM production water.

MT Tech
Hemacytometer for counting microalgal cells in suspension culture.

Milestones

A. December 2016: Growth characteristics under outdoor conditions (temperature and sunlight) in meso-scale ponds will be determined
    a. MT Tech: This work will be conducted in the spring and summer of 2016.
    MSU: Equipment has been purchased and is being tested.

B. July 2016: Obtain and test algal byproducts for macronutrient and micronutrient composition. Recruit a graduate student to work on this project.
    a. MT Tech: Initial algal samples have been obtained and a student is applying to graduate school in order to work on this objective.
    MSU: This milestone will begin once the larger scale algal cultures are achieved under outdoor conditions.

C. July 2017: Tests will be targeted towards those plants that showed responses to the algal fertilizer.
    a. MT Tech: Planning began on this objective. Field and laboratory work will commence during the summer of 2016.
    MSU: This milestone will be started at a later date.

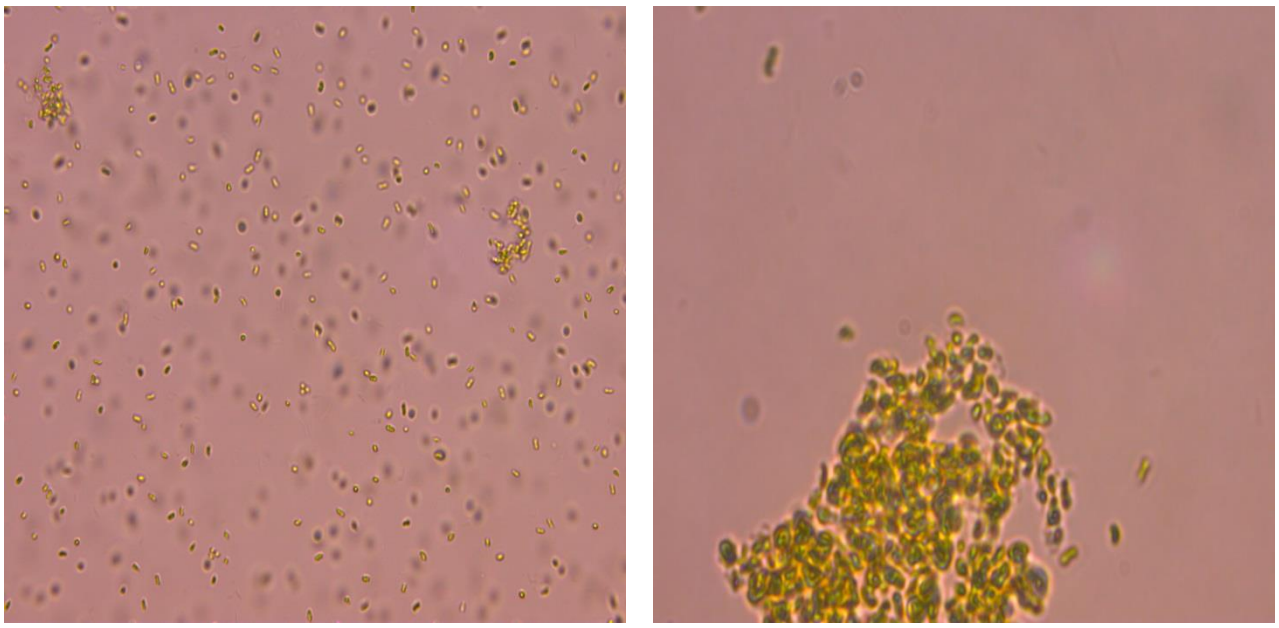

Figure 2. *Nannochloropsis gaditana*, 400x (left) and 1000x (right) cells in suspension culture,

Objective 6

Develop methods to stimulate repeated methane production in coal bed methane (CBM) projects.

Quarter activities and accomplishments

During this reporting period, preparations began for this objective in the areas of personnel recruitment, instrument purchase, information collection on the research site, geographic information system (GIS) data collection, and remote sensing data order and assessment. A graduate student has been recruited for this project. Quotes were requested and have started coming for a spectroradiometer to be purchased. Summit Gas has been identified as having the positions of all coalbed methane impoundments within the Montana Powder River Basin (PRB). Basic GIS data for the research site, including the boundary, geological map, coal distribution, etc. about the PRB basin was collected. Regarding remote sensing data collection for assessment of CBM retention ponds, the Digital Elevation Model (DEM) data and Landsat 8 data over the Montana PRB was ordered. The possible coverage by the hyperspectral imaging system, Hyperion, over the Montana PRB was assessed.

Hirings

Zhaoming Zhou, a graduate student has been recruited for this project. He will start his study at Montana Tech in the Spring 2016 semester. Under Dr Xiaobing Zhou's advising, Zhaoming Zhow will process satellite images to estimate the pond area within Montana PRB and monitor algae growth using spectral method.

Equipment Purchased

No equipment has been purchased to date.

Milestones

A. July 2015 – July 2016: Estimate areal coverage of CBM ponds using Hyperion or Landsat data
    a. Relevant parties were contacted (Montana Bureau of Mines and Geology in Billings Office, Montana Board of Oil and Gas Conservation, BLM Miles City Field Office, Summit Gas Resources, Inc.) for the locations and number of CBM water retention ponds within Montana PRB. Summit Gas Resources, Inc. has this information.
    b. Basic GIS data including boundary, geological data, coal distribution data, etc. about the PRB basin was collected and will be integrated with remote sensing data for systematic analysis.
    c. Some preliminary remote sensing data was gathered for assessment of CBM retention ponds. The Digital Elevation Model (DEM) data and Landsat 8 data over the Montana PRB was ordered and received.
    d. The possible coverage by the hyperspectral imaging system, Hyperion, over the Montana PRB was assessed.
    e. A preliminary literature review was conducted on the algorithm development for the areal coverage of CBM ponds.

B. July 2015 – December 2016: Evaluate time-course for methane production during consecutive stimulations

a. Experiments were initiated with native coal and indigenous microbial communities under two different nutrient levels.

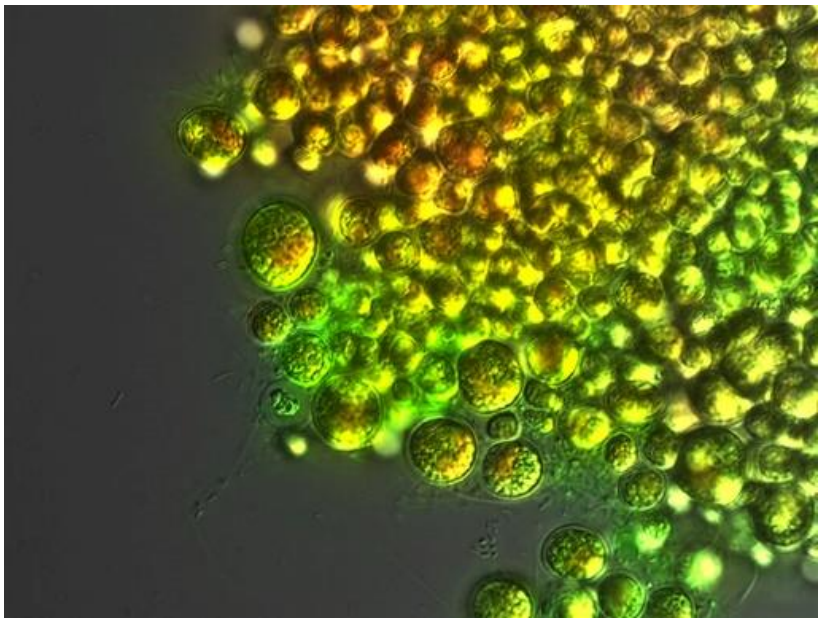

Figure 3. Image of the algal isolate from CBM production water

C. July 2016 – July 2017: Monitor mesoscale growth of algae using spectral methods
   a. This milestone will be focused on in the second year of this project. However, some literature review was done for the algae monitoring from remote sensing point of view.
   b. Two of three required quotes were obtained to purchase a spectral radiometer for monitoring algae growth.
   c. Discussions were initiated with Montana Tech biology professor Martha Apple on growing algae at Montana Tech so that timely consecutive minoring will be easier to carry out.
   d. Some water storage tanks for growing algae were purchased. The algae will be grown at Montana Tech in collaboration with Martha Apple's group.

Expenditures to Date

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	All Budgets	Spent to Date
Salaries & Benefits	717,237	5,601
Subcontract Payments		
Montana Tech	222,667	
Montana Emergent Technologies	75,000	

Operations	160,096	2,102
Equipment	25,000	
Total Costs	**1,200,000**	**7,703**