CBBG Center for Bio-mediated & Bio-inspired Geotechnics

Urease Efficacy in Enzyme Induced Carbonate Precipitation (EICP) in Selected Soil Samples and Experimental Conditions

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College Freshmen Introductory Biology for Majors I and II (BIO 181 & BIO 182)

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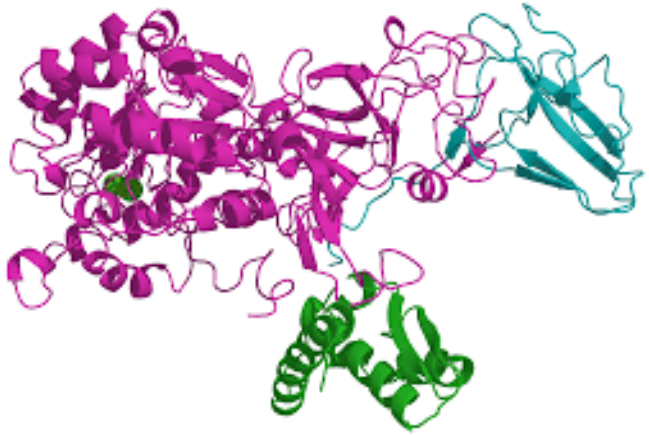
RET Lab Experience Research Summary

Research Background

- Erosion and dust formation are natural or man-made phenomena that have significant economic, environmental, and health-related consequences. Strategies for dust control based on naturally occurring or induced chemical (such as EICP) or biological processes represent a more sustainable alternative to traditional dust control methods, especially to those that rely and use large volumes of water
- This project attempts to determine the efficacy of EICP in selected experimental conditions and soil samples used in current geotechnical engineering research



Enzyme induced carbonate precipitation (EICP):

$$CO(NH_2)_2 + 3H_2O + \text{urease} \rightarrow CO_2 + 2NH_4^+ + \mathbf{2OH^-}$$

General $CaCO_3$ precipitation mechanism:

1) $HCO_3^-{}_{(aq)} + OH^-{}_{(aq)} \leftrightarrow H_2O + CO_3^{2-}{}_{(aq)}$

2) $Ca^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_3(s)$

RET Lab Experience Research Summary

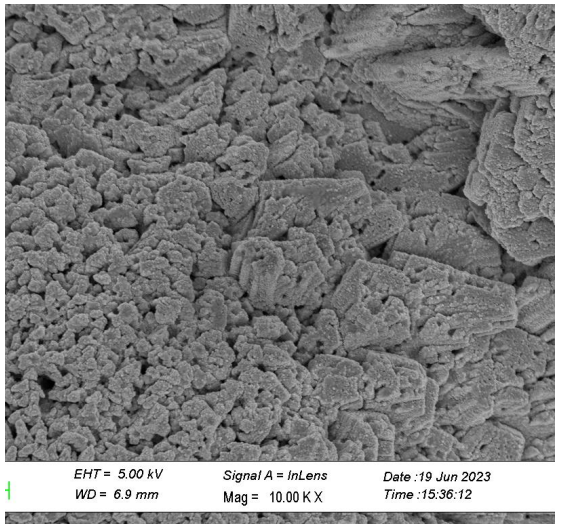
Research Objectives

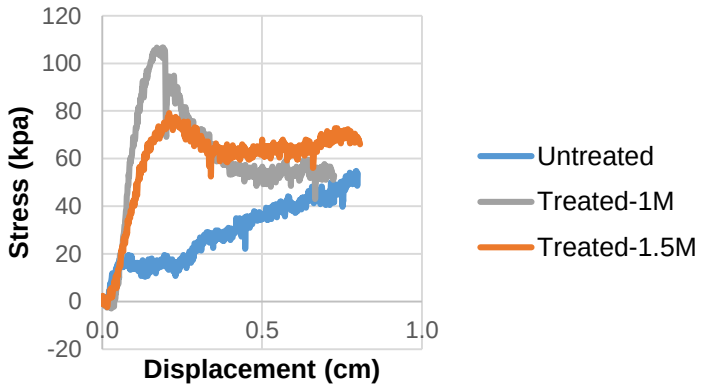
- To test and quantify the efficacy of EICP treatment in Ottawa 20/30 B-2.5 and B-1.5 soil samples by performing Unconfined Compression Strength (UCS) testing and scanning electron microscopy (SEM)
- To test and quantify the efficacy of different EICP solution concentrations in soil samples from Minnesota iron mine tailings by conducting Carbonate, Ammonium, and penetrometer measurements on pan crusts

RET Lab Experience Research Summary

Research Conclusions

- Ottawa 20/30 B-1.5 EICP treated soil sample columns exhibited a much higher stress response (*x*= 462.12 kpa) to unconfined compression than Ottawa 20/30 B-25 EICP treated samples (*x*= 253.67 kpa) (top right)
- Minnesota iron mine tailings soil pan crust untreated samples were three to four times less strong than EICP treated samples. 1M urea, 0.67M $CaCl_2$ EICP solution soil samples exhibited the highest stress response (105 kpa), as determined by penetrometer testing (bottom right)
- Ottawa 20/30 B-1.5 soil is better suited for EICP experimentation. 1M urea, 0.67M $CaCl_2$ EICP solution is the optimal concentration for further EICP treatment experimentation of Minnesota iron mine tailings soil





RET Instructional Lesson Implementation

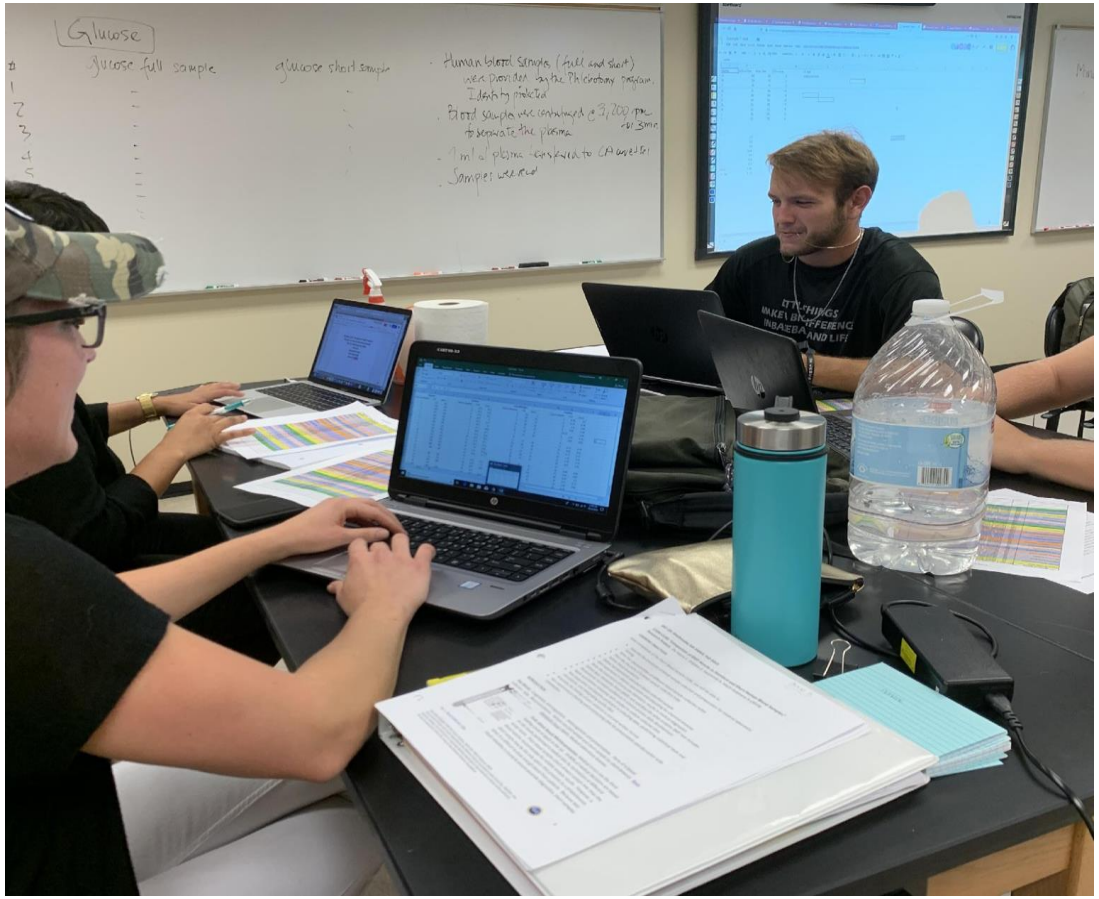
Lesson Description

Problem Based Learning: Students are introduced to the problems associated with dust control and to alternative and more sustainable control methods that rely on biomediation (more specifically biocementation). Students are then introduced to the EICP method and to urease, the enzyme that catalyzes EICP. Students are asked to list environmental factors that can impact the efficacy of EICP, and what experimental design needs to be in place to test it.

Course-based Undergraduate Research Experiences (CUREs): The project is designed and implemented as a CURE, expanding for 6-8 weeks out of a 16- week semester.

Collaborative Learning: The project is conducted collaboratively by groups of 4 students. Each student has a role in the project.

Assessment: Pre and post surveys and formative and summative assessments



RET Instructional Lesson Implementation

Lesson Objectives

- Describe connections between geotechnical engineering, soil science, and biochemical processes
- Describe fugitive dust and soil erosion and current methodologies used for their control
- Describe the economical, environmental and health related problems associated with fugitive dust and erosion
- Describe the most common types of biomediated methodologies to control fugitive dust and erosion
- Describe the process of Enzyme Induced Carbonate Precipitation (EICP)
- Identify and describe the role of enzymes and supplemental proteins in biogeochemical reactions through EICP
- Demonstrate how experimental conditions affect the efficacy of urease and of EICP
- Design experimental protocols, analyze results, and draw conclusions. Acquire proficiency with geotechnical laboratory techniques

Thank you!
Questions?

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