GT-2 Permeability of Bio-cemented Sand Mixtures

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Lesson Details

Subject Area(s): AP. Environmental Science and Environmental Science.

Focus Grade Level: 9-12

Grade Level Range: 9-12

Research Background

Describe the background and problem being addressed in the research (one paragraph in present tense).

Urban sprawl with increasing population and civil infrastructure demands worldwide, the availability of suitable soil sites for construction continues to decrease and ground improvement is now an integral part of sustainable modern development projects. Microbially-induced calcite precipitation (MICP) uses naturally occurring bacteria to bind soil particles together through calcium carbonate ($CaCO_3$) precipitation thereby increasing the soil strength and stiffness.

Lesson Summary

Summarize the lesson (one paragraph in present tense).

Students will engage in 3 weeks long lab investigation to propose sustainable solutions to problems related to recycling waste material and improving the shear strength and stiffness of soil for civil engineering with “Microbially Induced Calcite Precipitate” (MICP) method. Students will use urease hydrolysis by microbes to cement sand/soil mixtures. Students will use the lab protocol developed by the MICP research team at GT. Students will make modifications to the protocols as required in order to suit the class group size and hybrid /traditional/block class schedules.

Materials and Equipment

List any materials or equipment that may be needed for this lesson. Especially items that may need special ordering. Consider including URLs for ordering specifics

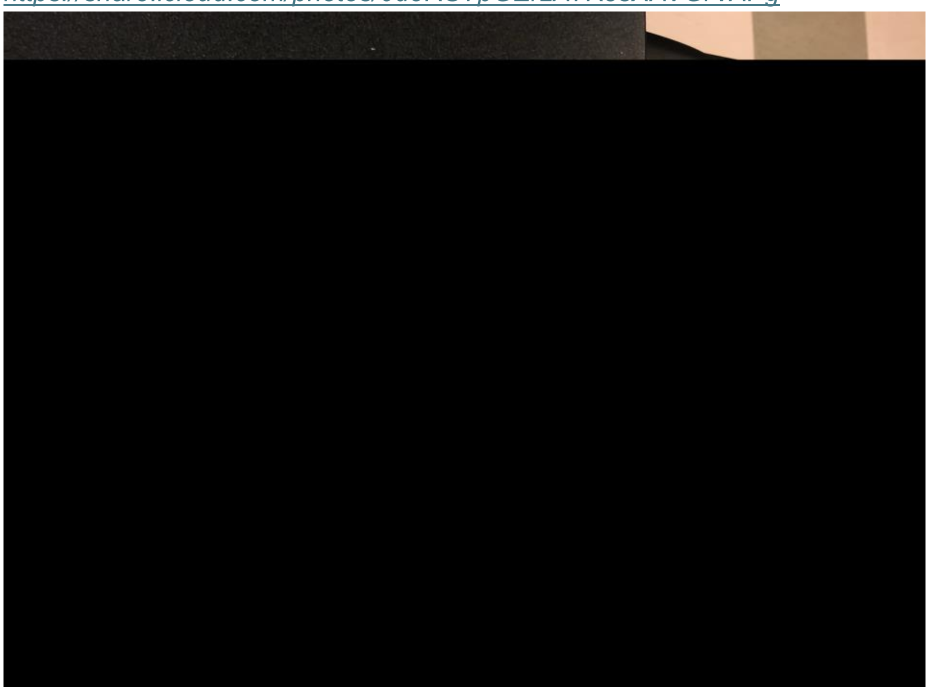
1. *Sand sample*
2. *Yeast extract*
3. *Urea*
4. *NH_4Cl*
5. *Sodium acetate trihydrate*
6. *NaOH*
7. *$CaCl_2$*
8. *Hydrochloric acid*
9. *Scotch-brite pad*
10. *Syringe.*
11. *Beakers*
12. *Measuring cylinder*

List of chemicals and their URLs from Carolina Science

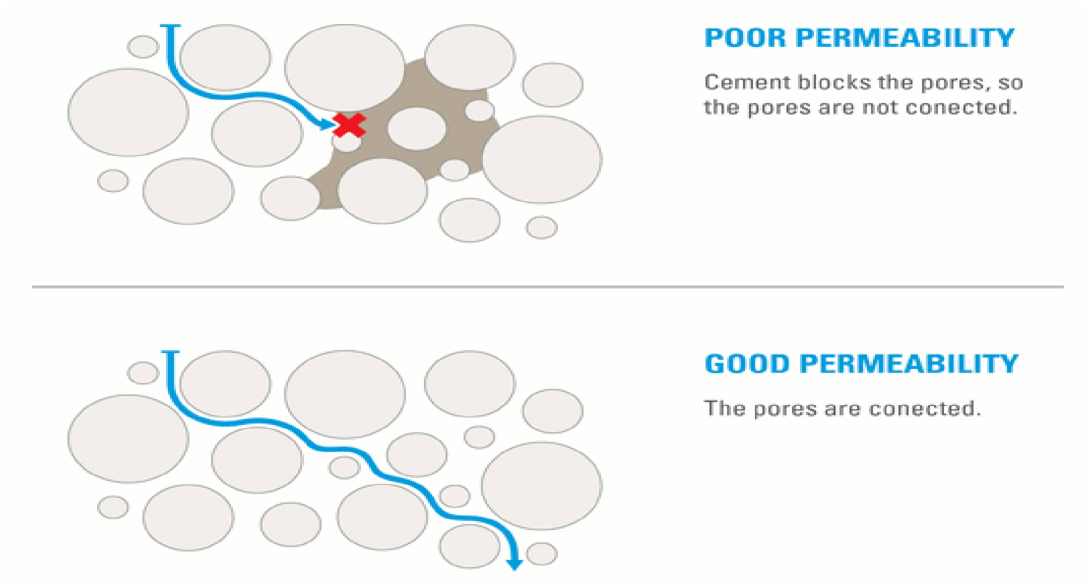
1. Urea: https://www.carolina.com/specialty-chemicals-t-z/urea-crystal-laboratory-grade-500-g/897650.pr?question=urea
2. Ammonium Chloride: https://www.carolina.com/specialty-chemicals-a/ammonium-chloride-1-m-laboratory-grade-500-ml/843805.pr?question=ammonium+chloride
3. Yeast Extract: https://www.carolina.com/biotechnology-culture-media/tryptone-500g/216741.pr?question=yeast+extract
4. Sodium Acetate Trihydrate: https://www.carolina.com/specialty-chemicals-s/sodium-acetate-trihydrate-crystal-reagent-grade-500-g/888050.pr
5. Sodium Hydroxide: https://www.carolina.com/specialty-chemicals-s/sodium-hydroxide-pellets-laboratory-grade-30-g/889425.pr?question=sodium+hyroxide
6. Calcium Chloride: https://www.carolina.com/specialty-chemicals-b-c/calcium-chloride-anhydrous-pellets-4-8-mesh-laboratory-grade-500-g/851840.pr?question=calcium+chloride
7. Hydrochloric acid 1N https://www.carolina.com/specialty-chemicals-d-l/hydrochloric-acid-in-glass-bottle-121-m-acs-grade-500-ml/867790.pr?question=hydrochloric+acid

Attachments

https://share.icloud.com/photos/0deRSTpGErzA7K3sXAVGrVAPg



Link to student pictures of MICP lab Oct. 23 - https://share.icloud.com/photos/0f1YLYRTnlhMadSjX2xloumlg



Educational Standards

Add appropriate STEM standard(s)/course competencies that students would learn from completing this lesson. For each standard, include the source, standard number(s)/letter(s), grade band and text.

K-12 Teachers

Add at least one standard from the Next Generation Science Standards (NGSS). Optional – add State Standards and/or International Technology and Engineering Educators Association (ITEEA) Standards.

NGSS standards

Georgia Standards of Excellence GSE

SEV1.

HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. *[Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.*

HS-ESS3-4. HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. *[Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]*

Obtain, evaluate, and communicate information to investigate the flow of energy and cycling of matter within an ecosystem.

c. Analyze and interpret data to construct an argument of the necessity of biogeochemical cycles (hydrologic, nitrogen, phosphorus, oxygen, and carbon) to support a sustainable ecosystem.

SEV4. Obtain, evaluate, and communicate information to analyze human impact on natural resources.

a. Construct and revise a claim based on evidence on the effects of human activities on natural resources - Land Use.

b. Design, evaluate, and refine solutions to reduce human impact on the environment including, but not limited to, smog, ozone depletion, urbanization, and ocean acidification.

SEV5. Obtain, evaluate, and communicate information about the effects of human population growth on global ecosystems.

a. Construct explanations about the relationship between the quality of life and human impact on the environment in terms of population growth, education, and gross national product.

c. Construct an argument from evidence regarding the ecological effects of human innovations

(Agricultural, Industrial, Medical, and Technological Revolutions) on global ecosystems.

d. Design and defend a sustainability plan to reduce your individual contribution to environmental impacts, taking into account how market forces and societal demands (including political, legal, social, and economic) influence personal choices.

ITEEA

5. Students will develop an understanding of the effects of technology on the environment.

20.Students will develop an understanding of and be able to select and use construction technologies.

Community College Faculty

At least one Community College Course Competency (AZ MCC Course Competencies). Optional – add NGSS, STATE and/or ITEEA (for upper high school).

Learning Objectives

Students will explain the beneficial role of microbes in soil improvement for sustainable development and to solve problems.

Students will describe the urea hydrolysis reaction by soil microbes.

Students will do lab investigation to collect data , analyse & write a Claim Evidence Reasoning

Vocabulary

vocab word/phrase (lower case)	*Definition punctuated like a complete sentence even if it's only a phrase.*
MICP	Microbes Induced Calcite Precipitation
Bio-stimulation	Addition of materials to enhance the growth and activity of indigenous microorganisms in a soil or contaminated site.
Bacteria	Unicellular microorganism that lacks organelles. 3D model
Calcite	A white or colourless mineral consisting of calcium carbonate. Formula: $CaCO_3$
Cementation	The binding together of particles or other things by cement.
Permeability	The state or quality of a material or membrane that causes it to allow liquids or gases to pass through it.

Lesson Procedure

Provide an in-depth explanation of how the lesson will progress in the classroom, including step-by-step instructions so another teacher could implement the lesson as intended.

Pre Lab reading - What is Soil Overview. Students will read & take notes week before the lab.

Students will do the MICP lab investigation for 3 weeks as follows. Below lesson setup is modeled based on the CBBG GT RET model. RET MICP Research Project 2023

Experiment

1. A porous filter - in this case, a small circular scotch-brite pad is fitted at the bottom of the syringe. The column is filled with water up to 50 ml . Then it is filled with sand/soil by wet deposition up to 50 ml mark.

2. A low concentration CaCl 2 solution is passed through the column. This is known as fixation solution. It allows for the fixation and retention of bacteria (Harkes et al., 2010).

3. Then, the bacterial solution is flushed down the column. This method of injecting a particular bacterium is called 'bioaugmentation'; alternatively, in field conditions, the native bacteria are fed the required nutrients to grow by means of a 'stimulation *solution' and that process is called 'bio-stimulation'. The bacterial solution injected also contains urea. A period of 24-48 hours is allowed for the bacteria to hydrolyze the urea and increase the pH of the medium.*

4. In the last stage, cementation solution containing $CaCl_2$ is passed every day for a period of 10 days typically. $CaCO_3$ would have precipitated and the column is disassembled to measure calcite content.

Week 1

Day 1 - Introduction of MICP, Overview of the project & gather materials - 50 minutes class

Day 2 -Teacher will Demo as students Set up the lab - Prepare columns, and flush stimulation 1 solution to grow microbes.

Day 3-5 Flush stimulation 2,3 & 4

Week 2

Day 6 -10 Continue to flush stimulations 3 & 4 (in morning & evening), Flush cementation solution & continue cementations 2,3,4,5

Week 3

Day 7- 8 continue cementations 6&7, 8&9

Day 9 - Continue cementation

Day 10 - Disassemble columns and measure calcite content by acid dissolution

Day 11 - Post Lab discussion, Results & Summary to write CER

The 2023 RET summer research schedule.

Below schedule will be followed with modified dates per DCSD school year of 2023-24.

Day/Date	Details
1.June 14th	Prepare columns, and flush stimulation 1 solution to grow microbes.
2.June 15th	Flush stimulation 2
3.June 16th	Continue to flush stimulations 3 & 4 (in morning & evening)
4.June 17th	Flush cementation solution 1 to start cementation process
5.June 18th	Continue cementations 2 & 3 (in morning & evening)
6.June 19th	Continue cementations 4 & 5 (in morning & evening)

7.June 20th	Continue cementations 6 & 7 (in morning & evening)
8.June 21st	Continue cementations 8 & 9 (in morning & evening)
9.June 22nd	Continue cementation 10
10.June 23rd	Disassemble columns and measure calcite content by acid dissolution

Introduction/Motivation

How do you grab students' interest? Written toward the students. Include an engineering context.

Students will watch two short videos (link below) & answer the questions (see below the links.)

Fundamentals of Biocementation and research for sustainable soil improvement solutions using bacteria *Dr. Brina from NC Biocementation*

As you watch the video, keep the following questions in mind to answer in your journal

1. What are these scientists curious about -- what do they want to know?

2. What data will be collected?

3. How will this data help scientists answer their questions?

Learning Activities/Strategies

Describe any learning activities and strategies you intend to use. Not all teachers know the same strategies by the same names, so describe how the activities and strategies work, or connect to a document that you will attach that has more description.

Small flexible grouping strategy will be used for this MICP hands on lab investigation.

All materials will be posted on Canvas for students to access the information throughout the 3 weeks of lab duration and later.

Closure

Help students bring it all together. Written toward the students.

Students will make connections with the Lesson & the Lab by writing a Claim, Evidence & Reasoning.

Real world application Video PBS - These cement-making bacteria could build the cities of the future. Watch the video to write the applications of MICP.

Assessment

Provide a description of any assessments used to evaluate student outcomes aligned with the learning objectives.

Formative Assessment

Describe how you will check for understanding during the process of learning. Include detailed sample items and/or list the name of the actual assessment that you will be attaching.

Pre Lab reading - What is Soil Overview. Read and write notes in your journal.

Matching activity with **Laminated card sorting** to correctly match the following.

Week 1 - Soil Components Matching activity

Week 2 - Soil Types Matching activity

Week 3 - What's in Soil & Why is it important

Summative Assessment

Describe the final check for understanding after learning is complete. Include detailed sample items and/or list the name of the actual assessment that you will be attaching.

Writing Claim Evidence & Reasoning by the students. CER

Oct.23 Tucker High school - MICP Student presentation
https://www.icloud.com/photos/#0f1YLYRTnlhMadSjX2xloumlg

Contributors

Individuals

List the names of any person who participated in the development of this instructional unit (teachers, mentor, lab director, education staff, etc.).

Dr. Susan Burns

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References

List citation information for any graphics or copyright material used in the development of this lesson.

1. Rahman, M.M., Hora, R.N., Ahenkorah, I., Beecham, S., Karim, M.R. and Iqbal, A., 2020. State-of-the-art review of microbial-induced calcite precipitation and its sustainability in engineering applications. Sustainability, 12(15), p.6281.
2. Almajed, A., Lateef, M.A., Moghal, A.A.B. and Lemboye, K., 2021. State-of-the-art review of the applicability and challenges of microbial-induced calcite precipitation (MICP) and enzyme-induced calcite precipitation (EICP) techniques for geotechnical and geoenvironmental applications. Crystals, 11(4), p.370.

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