Erosion Control of EICP-treated Soil

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Lesson Details

Subject Area(s): Chemistry

Focus Grade Level: 10th Grade

Grade Level Range: 9-12th Grade

Research Background

Rainfall-induced soil erosion presents a significant yet often overlooked challenge. Intense and sporadic rain events can lead to severe soil erosion, stripping away valuable topsoil, degrading the land, and causing sedimentation in downstream waterways. This can disrupt local ecosystems and reduce the land's agricultural potential.

This research project explores Enzyme-Induced Carbonate Precipitation (EICP), an innovative biogeotechnical method that strengthens soil. EICP is both cost-effective and environmentally friendly, making it a promising solution for reducing erosion and improving soil stability. Traditional methods to mitigate soil erosion, such as synthetic chemical stabilizers or physical barriers, can be expensive and environmentally harmful. EICP utilizes urease enzyme extracted from jack beans to catalyze the reaction between calcium chloride and urea. The resulting reaction leads to the precipitation of calcium carbonate within the soil.

This process increases soil cohesion and stability, making it more resistant to erosion by water. By enhancing soil stability, EICP can help maintain the integrity of our landscapes, support agriculture, and protect ecosystems from the damaging effects of rainfall-induced soil erosion. This research aims to evaluate the effectiveness of EICP in improving soil resistance to rainfall-induced soil erosion.

Lesson Overview

Students will explore the chemistry behind EICP, learn about its practical applications, and evaluate its potential to transform erosion management globally. Additionally, they will compare the effectiveness of the EICP method with traditional synthetic methods used to precipitate calcium carbonate for controlling soil erosion.

Students use the engineering design process to consider the problems associated with soil erosion while proposing solutions to this problem. Students will learn about the chemical reactions involved in biocementation and synthetic cementation processes.

Students will learn how geotechnical engineers study the soil and implement novel techniques for treating soil including mixing-compacting and spraying methods. Students will research and design ways to determine the soils' resistance to erosion after treatment. Students will analyze each method's effectiveness at improving sand samples compared to untreated soils.

Materials and Equipment

- Gloves
- Lab Coats
- Goggles
- Local soil or sand samples
- Graduated cylinders
- Weigh boat
- 600 mL beaker
- post-it easel paper
- Filter paper
- Sodium carbonate
- Calcium chloride
- Deionized water
- small aluminum pans
- metal containers
- balance
- watering can

Attachments

5E Lesson Plan Structure

Visual/Manual Classification of Soils Literature Paper

Visual/Manual Classification of Soils Handout

Lab Activity: Soil Classification

Video: Soil Classification Demonstration

Notice and Wonder Image & Video Library

Chemical Reactions Worksheet

Lab Report: Synthetic Precipitation of Calcium Carbonate

Educational Standards

K-12 Teachers

HS+C.P1U1.5: Plan and conduct investigations to test predictions of the outcomes of various reactions, based on physical and chemical properties patterns.

HS+C.P1U1.7: Use mathematics and computational thinking to determine stoichiometric relationships between reactants and products in chemical reactions.

STEL-1N: Explain how the world around them guides technological development and engineering design.

HS.P1U1.3: Ask questions, plan, and carry out investigations to explore the cause and effect relationship between reaction rate factors.

HS.E1U3.14 Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other

Learning Objectives

- Students will delve into the chemistry behind Enzyme-Induced Carbonate Precipitation (EICP) and understand the chemical reactions involved in the process.
- Students will learn about the practical applications of EICP in mitigating rainfall-induced erosion and its potential to transform erosion management practices globally.
- Students will use the engineering design process to identify and propose solutions to the problems associated with soil erosion.

- Students will explore the synthetic process of preparing calcium carbonate and the chemical reactions involved.
- Students will learn how geotechnical engineers study soil and implement novel techniques for treating soil, including mixing, compacting, and spraying methods.
- Students will research and design experiments to determine the soil's resistance to erosion after treatment with different methods.
- Students will analyze the effectiveness of various soil treatment methods, including EICP, in improving the erosion resistance of sand samples compared to untreated soils.
- Students will present their findings (digitally or with a poster) on the comparative analysis of EICP and traditional methods, demonstrating their understanding of the science and engineering principles involved.

Vocabulary

soil	the upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles.
soil type	a member of a soil series distinguished primarily by texture.
gravel	a loose aggregation of small water-worn or pounded stones.
silt	fine sand, clay, or other material carried by running water and deposited as a sediment
sand	a loose granular substance, typically pale yellowish brown, resulting from the erosion of siliceous and other rocks
clay	a stiff, sticky fine-grained earth, typically yellow, red, or bluish-gray in color and often forming an impermeable layer in the soil
heterogeneous	diverse in character or content.
composition	the nature of something's ingredients or constituents; the way in which a whole or mixture is made up.
soil index properties	the properties of the soil that help to classify and identify the properties of soil for purposes of engineering
mineralogy	a subject of geology specializing in the scientific study of the chemistry, crystal structure, and physical (including optical) properties of minerals and mineralized artifacts
void	empty spaces in the soil structure
erosion	the gradual destruction or diminution of something.

Lesson Procedure

Introduction/Motivation

1. Show the pictures from the Notice and Wonder Image and Video library by numbering the images and posting them around the room. Ask students to record their responses to the following guiding questions in their notebooks for each image:
    a. What is happening in the photo?
    b. Why do you think this happens?
    c. Do you think any societal or environmental impacts are posed by what is happening in the video or photo?
2. Choose a video from the Notice and Wonder Image and Video library and discuss the above mentioned guiding questions with them.

3. Inform students about the backstory for each photo and video, and continue to introduce the focus of the lesson by prompting students to share previous knowledge they may have about liquefaction, earthquakes, or flooding.
4. Introduce the idea of mineralogy by showing samples of soils from the neighborhood and asking what they notice and wonder about the soils. Comment on the "looseness" of the particles and composition.

Learning Activities/Strategies

- Notebooks: instruct students to answer guiding questions in their notebooks.
  - Students will begin with a personas discussion: have students identify roles in the project based on their strengths and skills.
  - Students will also evaluate their soil cementation outcome by writing a reflection after the erosion test.
- Lab Activity: Soil Classification
  - Students begin engaging with the topic by reviewing virtual simulations. These simulations help to introduce students to the tests they will perform, and this helps students better understand the soil triangle for classification of soils.
    - Soil Texture Simulation
    - Soil Health Simulation
- Soil Introduction Demonstration: This explain portion allows students to read about the soil testing they will perform prior to the soil cementation/stabilization
- Visual/Manual Classification of Soils
- Lab Activity: Precipitation of Calcium Carbonate
- Engineering Design: What is the best method for introducing calcium carbonate to the soil samples?
  - Each group in your class can use a different approach: adding calcium carbonate directly to the soil, adding solutions of both precursors to the soil, mixing and compacting the soil, and untreated soil with water only.
  - Create a competition for the best approach and let the test be the water erosion trial!
- Testing and Analysis: How does the application method compare? Be sure that you explain that currently, percolation is used to treat soils prior to building structures.

Closure

To close out this lesson, have your class engage in the following activities to reflect on the outcomes of each stage and discuss the implications of the findings.

1. Begin by having students summarize their findings on the most effective method of calcium carbonate preparation and soil treatment. Encourage them to highlight the differences between the soil cementation methods used to improve the soil before building.
2. Have each group present their results, including data, observations, and conclusions of their soil treatment processes. This will allow students to compare their findings and understand different perspectives.
3. Facilitate a brief class discussion and debate using the following guiding questions:
    - How does EICP compare to traditional methods based on effectiveness and environmental impact?
    - What are the potential benefits and drawbacks of using EICP on a larger scale?
    - How might this biogeotechnical method be implemented in real-world scenarios?
4. Ask students to reflect on what they have learned during the lesson by writing a journal entry in their notebook answering the following questions:
    - What surprised you about this lesson?
    - How can the knowledge you've gained be applied to other engineering or environmental challenges?
    - How has your understanding of the importance of soil erosion and its solutions evolved?
5. Discuss potential future research or projects that could stem from their findings. Encourage students to think about other innovative methods that could be explored or how EICP could be improved.
6. Conclude with final thoughts and summarize the importance of innovative solutions like EICP in addressing environmental challenges. Highlight the value of scientific inquiry and biogeotechnical methods in making sustainable advancements.

Assessment

Formative Assessment

Participation in discussions and activities

Lab notebook entries and observations

Chemical Reactions Worksheet

Visual/Manual Classification of Soils Worksheet

Demonstrations and performance during Lab Activities
Group evaluations

[Exam on soil types, erosion, and weathering]

Summative Assessment

Research summaries and interactive notebook entries

Group project proposals and experimental designs

Engineering Design presentation (rubric linked in attachments)

Closure Reflection Assignment

Contributors

Individuals

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References

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