Engineering a Column to "Decontaminate" water

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Abstract

Concerns about access to clean, potable water are projected to rise with the ever-drying climate and increase in global population[1]. In this 3-day lesson series, students first learn about the projected "Day Zero" of water supplies in Capetown, South Africa, initially considering reasons for the projected water shortage, then thinking about ways that we could increase the amount of fresh and clean drinking water available to people around the world. Students then examine the issue of water contamination, reviewing teacher-provided resources about the chemicals in water and ways to potentially reduce them. Finally, students work in small groups to build their own columns using a variety of media (cups, activated carbon, paper towels, sand) and design methods to collect data about the effectiveness of their columns to remove contaminants. Students create posters to summarize their findings and identify features that successfully remove visible contamination from water.

Focal Standard(s)

ETS1.A: Defining and Delimiting Engineering Problems

Science and Engineering Practices:
Constructing Explanations and Designing Solutions
Analyzing and Interpreting Data

Secondary Standards Covered as part of overall unit but not fully assessed:
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Measurable Objective(s)

Students will be able to:
-Articulate the product they are designing with respect to water purification (ex., "we are designing a product that can filter out _____ from water")=defining the problem
-Develop a procedure using defined materials under a "budget"
-Decide between 3 unique designs or iterations of their product=comparing multiple solutions/approaches
-Use concrete data to determine which design or iteration was most effective at reaching their goal=analyzing and interpreting data

Formative Assessment(s)

Day 1: Read article (linked below in image excerpt) or look at image of reservoir, and answer the question, "Why was Cape Town in the news, and how is this relevant to California?"

[1] A Review of Ion and Metal Pollutants in urban green water infrastructure. Kabir, Daly, and Maggi, 2014

> One of the fundamental problems was that the city's water storage had not kept up with population growth. Since the end of apartheid, Cape Town's population grew from 2.4 million in 1995 to 4.3 million people in 2018. At the same time, the city only built one major dam, the Berg River Dam opened in 2009, increasing storage by 15%, according to local grassroots agency GroundUp. The lack of focus on infrastructure has been blamed on politicking and personality politics.

Day 2: (Do Now) What contaminants are we most likely to find in water, and how can they be removed?

Day 3: How can we evaluate if a design was successful?

Summative Assessment

Poster or digital poster describing group's work on developing filters that successfully remove contaminants that they specify from water.
Criteria: (full rubric to be developed later)
-Includes background research on types of materials that can successfully remove contaminants
-Includes clear and replicable methods
-Includes at least 3 iterations or versions of their design, with data collected for each that informed the process
-Includes at least 2 quantitative measures and 1 qualitative measure of water quality
-Includes a data-based conclusion about which method or iteration of the designmost closely met group's criteria

21st Century Skills and Applications

Environmental Literacy, link here

This lesson series focuses on the society-natural world relationship, as students are considering human resource use, learning about specific examples of nonpoint source water pollution, and designing devices to remove contaminants from water.

Fellowship Description

My fellowship project is focused on designing columns filled with media like sand and biochar or activated carbon that can filter out contaminants from stormwater. As part of the process, I am first reviewing literature on stormwater runoff in the U.S. and abroad to understand the chemical parameters of stormwater, then will use this information to add contaminated soil to water in levels that match those in existing papers. After determining the ideal stormwater creation method, we will develop standard operating procedures for the target contaminants in the water, and begin constructing columns with varied geomedia to determine the ideal amount of biochar, sand, and hydrology of the columns for contaminant removal.

As part of this fellowship, I am gainings skills in reviewing literature as a way to create new methods, in lab techniques of measuring pH, conductivity, salinity, and turbidity of water samples, and ultimately in

chemical analysis of samples using liquid and gas chromatography. In addition, I am strengthening my skills in stoichiometry and chemistry with the stormwater recipe creations.

I am being exposed to careers in the realm of environmental engineering and hydrological monitoring and modeling. My mentor is working to remove organic contaminants from various Department of Defense sites, and his colleagues in the lab are focusing on other biological and metal contaminants of water sources. In addition, I am attending talks by students from related labs who are focusing more on the policy aspect of water, which is helping me understand how academic research informs both education and the political sphere of resource allocation.

Fellowship Connection to School/Classroom

The Luthy lab is focused on environmental engineering to deal with water-based contamination, and the research of my mentor focuses on ways to use geomedia in columns to filter out contaminants that normally run off in stormwater. This lesson plan builds on the idea of "biochar" and activated carbon as useful tools to decrease contamination in water, and challenges students to engineer filtration columns to create clean water under a budget reflective of the constraints of research labs and R&D teams. The engineering challenge is presented in the context of the larger lab project to remove organic contaminants from air force base sites, which explicitly ties together the fellowship and the lesson series.

Instructional Plan

Day 1: Intro to lesson, building student empathy for the situation and doing research (65 minutes)
Objective:
-Students build empathy for the "Day Zero" problem in Cape Town, and can articulate how climate change, infrastructure, and human population are interwoven factors involved with water scarcity
-Students identify 3 Secondary Drinking Water standards that they have a way to measure and view as important measures of water quality

Day 2: Introduction to engineering challenge, students articulate their group's specific task, groups research available materials and sketch design prototypes (65 minutes)
Objective:
-Students research the available filtration materials, and create 3 drawn prototypes for column designs based on their research within the allocated project budget
-Students develop a means to quantify and qualify the success of their setups using available tools

Day 3: Testing of 3 water-filtration devices (130 minutes, block period; or 2 normal periods)
Objective:
-Students test their 3 designs, and collect data about the Secondary Water quality from each design

Day 4: Making conclusions about their designs (65 minutes)
Objective:
-Students create a summary poster or digital project which describes their experimental design and methods, displays their data, and makes a conclusion about which design most effectively improved the quality of the water

Day 5: (Optional but recommended) Sharing of results in presentation or poster session (65 minutes)
Objective:
-Students either share their results in short 2 minute presentations (per group), or do a poster session and give other groups feedback on their work

Supply List

Day 1:
Dixie Cups
"Contaminated" water (with coffee grounds, or with food coloring that makes it appear brown, depending on student allergies)

Day 2-4:
Gravel
Sand
Activated Charcoal, available from Amazon Prime for $30 for 2 lb at this link
Soil/Dirt
Coffee Filters
Cotton Balls
Plastic Cups
Water contaminants: food coloring (for color), coffee grounds (for color), garlic (for odor), ground crackers (for turbidity)

Optional Materials to Improve Measurement Accuracy:
Total Dissolved Solids:
Total Dissolved Solids meter for $18
TDS, Electroconductivity meter for $15

Turbidity:
Arduino Turbidity Sensor for $14 (would need Arduino and interface)
Alternative: create a turbidity column using the directions from this link, which includes a 2-3' long tube, a small piece of plastic, paint, and a meter stick

Bibliography

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O'Donnell, Norah, and King, Gayle. "Cape Town is on the Verge of Running Out of Water." https://www.youtube.com/watch?v=jRSJBz0EoBQ *CBS This Morning*, January 28 2018. Web. Accessed 6/20/18.

Keywords

Water Contamination
Water Purification
Infrastructure
Filtration
Organic/Inorganic contaminants

Water Quality Parameters: pH, Turbidity, Conductivity

Links to Files in this ETP

Days 1-5 full lesson write-out (Detailed lesson plan)
Potential extensions for days 1-5

Day 1 Google Slideshow (guiding lesson for the day)
Day 1 student handout (guiding student research)
Day 1 key/teacher guide (with answers and suggested responses)

Day 2 Google Slideshow (guiding lesson for the day)
Day 2 student handout (guiding research and prototyping)
Day 2 key/teacher guide (with answers and suggested responses)

Day 3 Google Slideshow (guiding lesson for the day)
Day 3 student handout (guiding student investigation)
Day 3 key/teacher guide (with answers and suggested responses)

Day 4 Google Slideshow (guiding lesson for the day)
Day 4 Summative Assessment Rubric
Day 4 Student handout with rubric and directions

Day 5 Google Slideshow, to be finished
Day 5: Teacher link to Google Forms Quiz (this will make a copy for teacher to edit and use)
Day 5: Link to Teacher Answer Key for Google Forms Quiz
Day 5: Student handout for Gallery Walk