Summer 2019

Teaching Chemistry Through An Environmental Science Lens And The Effect Of Student Understanding And Motivation In Learning High School Science

Sara Peterson

TEACHING CHEMISTRY THROUGH AN ENVIRONMENTAL SCIENCE LENS AND THE EFFECT OF STUDENT UNDERSTANDING AND MOTIVATION IN LEARNING HIGH SCHOOL SCIENCE

by

Sara Peterson

A capstone project submitted in partial fulfillment of the requirements for the degree of

Master of Arts in Education: Natural Science and Environmental Education.

Hamline University

Saint Paul, Minnesota

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Capstone Project Facilitator: Laura Halldin
Content Experts: Dustin Haug and Tarah Dahl

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PROJECT SUMMARY

The curriculum unit provided includes content topics of chemical and physical properties of matter through the examples of soil, water, and air. These topics are represented in several of the Minnesota State Science Standards for Earth and Space Science. Each lesson includes an article to show a real-life application of the content, an investigation to introduce the properties, and a slide lecture to explain and link concepts. The unit concludes with an inquiry lab where students will need to apply what they've learned about soil, water, and air. The curriculum unit was designed to answer the following question: *How does teaching Chemistry through an Environmental Science lens affect the level of student understanding and motivation in learning high school science?*

This curriculum was developed to give secondary physical science teachers the option to teach chemistry through student-relevant, socio-science issues-based topics. Topics presented should be relevant to students living in, at a minimum, the United States or similar setting, but use science standards developed for the state of Minnesota. These standards are very similar to the Next Generation Science Standards (NGSS) and should be able to be transferred with ease. The goal of this curriculum is to engage students, enhance motivation to learn science, and to increase understanding of secondary science content.

The curriculum was also designed using Wiggins and McTighe's (2011) Understanding by Design (UbD) method which focuses on creating activities and assessments that truly determine student understanding. Focus was also placed on connecting these assessments and activities with the verbs used within the standards. UbD templates were used to plan individual lessons as well as a unit overview (Wiggins & McTighe, 2011).

This curriculum is meant to be taught in any classroom, but focuses on allowing teachers who do not have access to many, if any, outside resources such as funding, museums, field trips, or the outdoors, to teach content that engages at a level of having access to those resources. This curriculum is considered non-formal, which means it will be using resources outside of and in addition to, the traditional lecture tools such as a presentation or notes-based lecture.

The lessons that make up the following curriculum sample were created using the 6th edition of *Chemistry in the Community (ChemCom)* textbook which was created by the American Chemical Society (2012). This textbook guides students through activities and readings that explore the chemical world by using topics related to sustainability. Most of the topics and the order in which they will be taught are derived from the textbook. Examples and some lab activities were also used as inspiration for the lessons.

The curriculum presented is designed for secondary Physical Science students. The concepts presented will incorporate previously learned material as well as relevant content to support learning of new Chemistry topics. The use of socio-scientific issues, in-class activities, and inquiry based labs creates a non-formal classroom experience.

This curriculum can be taught at any Minnesota high school as it aligns to the Minnesota state science standards. Modifications can be made to the curriculum based on what constitutes as “relevant” to the students within the classroom. The curriculum is meant for students to eventually use what they have learned in order to become responsible citizens who participate in a democratic society in order to shape a sustainable future.

This curriculum was designed and intended for 9th grade Physical Science students at a four-year, public charter high school in a downtown environment. Each class period or “day” presented, represents an 80-minute academic class period on an A/B day schedule. This means that students will participate in the class 2 or 3 times per week.

Unit Cover Page

Unit Title: Properties of Matter Grade Level: 9

Subject/Topic Areas: Properties of Soil, Water, and Gas

Key Words: Matter, Properties, Soil, Water, Gas, Human Impact, Climate Change

Designed By: Sara Peterson Time Frame: 9 class periods (80 minutes/period)

Brief Summary of Unit (including curricular context and unit goals):

This unit covers chemical and physical properties of solids, liquids, and gases using the examples of soil, water and air.

Students will be able to apply this information to an inquiry based lab (summative assessment) and the end of the unit to determine how water and human activities affect soil resources.

Stage 1—Identify Desired Results

Established Goals:

1. Apply knowledge of matter cycles and properties of soil to human impacts on soil derived resources.
2. Apply knowledge of the water cycle and water properties to human impacts on groundwater systems.
3. Apply knowledge of gas properties to human impacts on the atmosphere.

What understandings are desired? ***Students will understand that...***

soils have different properties.
water impacts all aspects of the environment.
gases maintain different properties based upon their environment.
matter and properties interact at various levels.

What essential questions will be considered?

What are the properties of soils?
How does human activity affect soil resources?
What are the properties of water?
How do humans impact groundwater systems?
What are the properties of gases in the atmosphere?
How do humans impact molecular components of the atmosphere?
How do matter cycles interact based on their properties?
How do humans impact the interaction of matter cycles?

What key knowledge and skills will students acquire as a result of this unit?

Students will know...	***Students will be able to...***
the properties of the most common Minnesota soils.	describe the chemical and physical properties of soils.
the properties of water.	describe the properties of water.
the properties of gases.	identify the properties of gases.
how properties of matter, including water, soil, and atmosphere interact.	represent observations and data in order to recognize patterns in the data, the meaning of those patterns, and possible relationships between variables.

Stage 2—Determine Acceptable Evidence

What evidence will show that students understand? *Performance Tasks:*

Investigations of soil, water, and gas.
Inquiry lab on soil texture and soil water permeability.

Student Self-Assessment and Reflection:

Students will participate in writing claim, evidence, reasoning paragraphs throughout the unit.

Stage 3- Plan Learning Experiences and Instruction

Day: 1 Intro: Soil article Activity: Soil investigation Closer: Analysis/ questions	Day: 2 Intro: Quick review Activity: Notes - foldable Closer: CER paragraph	Day: 3 Intro: Water article Activity: Water investigation Closer: Stations clean up	Day: 4 Intro: Water analysis/ questions Activity: Notes - videos Closer: Modeling water properties	Day: 5 Intro: Air quality article Activity: Gas investigation Closer: Analysis/ questions
Day: 6 Intro: Investigation share out Activity: Notes - foldable Closer: Intro to Lab	Day: 7 Intro: Activity: Soil Texture & Soil Water Permeability Lab Closer:	Day: 8 Intro: Activity: Soil Texture & Soil Water Permeability Lab Closer: Reflection		

<table>
<tr><th colspan="3">Stage 1 Desired Results</th></tr>
<tr><td rowspan="6">MN STATE STANDARD BENCHMARK:

9E.1.2.1.2
Plan and conduct an investigation of the properties of soils to model the effects of human activity on soil resources.

ESTABLISHED GOALS:

Apply knowledge of matter cycles and properties of soil to human impacts on soil derived resources.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to…

describe the chemical and physical properties of soils.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…

soils have different properties</td><td>ESSENTIAL QUESTIONS

What are the properties of soils?

How does human activity affect soil resources?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…

the properties of the most common Minnesota soils.</td><td>Students will be skilled at…

measuring properties of soil.</td></tr>
<tr><th colspan="3">Stage 2 - Evidence</th></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td>● Multi-level questions throughout investigation</td><td colspan="2">PERFORMANCE TASK(S):

● Investigation of soil properties
○ pH
○ Temperature
○ Levels of:
■ Nitrogen
■ Phosphorus
■ Potassium</td></tr>
<tr><td>● Rubric</td><td colspan="2">OTHER EVIDENCE:

● Claim, Evidence, Reasoning Paragraph</td></tr>
</table>

Stage 3 – Learning Plan	
Time	*Summary of Key Learning Events and Instruction*
Day 1:	
5 minutes 5 minutes	1. Article read - *The earth is hurting, and it goes beyond carbon emissions;* Jim Conca, Tri-City Herald a. Class questions and discussion
	2. Soil Investigation
40 minutes	a. Stations
10 minutes	b. Clean up
15 minutes	c. Questions/Analysis
Day 2:	
5 minutes	1. Quick Review/Warm up/Bell Ringer
60 Minutes	2. Notes - Chemical & Physical Properties of Soil a. Foldable
15 minutes	3. Claim, Evidence, Reasoning Paragraph

<table>
<tr><th colspan="3">Stage 1 Desired Results</th></tr>
<tr><td rowspan="7">MN STATE STANDARD BENCHMARK:

9E.4.2.1.1
Compare, integrate, and evaluate sources of information in order to determine how specific factors, including human activity, impact the groundwater system of a region.

ESTABLISHED GOALS:
Apply knowledge of the water cycle and water properties to human impacts on groundwater systems.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to…

describe properties of water.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…

water impacts all aspects of the environment.</td><td>ESSENTIAL QUESTIONS

What are the properties of water?

How do humans impact groundwater systems?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…

properties of water.</td><td>Students will be skilled at…

measuring properties of water.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><th colspan="3">Stage 2 - Evidence</th></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td rowspan="2">● Multi-level questions throughout investigation</td><td colspan="2">PERFORMANCE TASK(S):

● Investigation of water properties
○ Solvent
○ Filtration
○ Adsorption
○ Absorption</td></tr>
<tr><td colspan="2">OTHER EVIDENCE:</td></tr>
</table>

● Rubric	● Modeling of water properties
Stage 3 – Learning Plan	
Time	*Summary of Key Learning Events and Instruction*
Day 3:	
5 minutes	1. Article read - *The Uncertain Future of the Boundary Waters* by Stephanie Pearson
5 minutes	a. Class questions and discussion
	2. Water Investigation
60 minutes	a. Stations
10 minutes	b. Clean up
Day 4:	
15-20 minutes	1. Post-investigation questions/analysis
30 minutes	2. Notes a. Properties of water i. Structure ii. Polarity iii. Bonding
10 minutes	3. Video - Tyler DeWitt a. Stations
10 minutes	4. Modeling water properties - Jigsaw
10-15 minutes	a. Practice b. Present

<table>
<tr><th colspan="3">Stage 1 Desired Results</th></tr>
<tr><td rowspan="6">MN STATE STANDARD BENCHMARK:

ESTABLISHED GOALS:

Apply knowledge of gas properties to human impacts on the atmosphere.</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to…

identify properties of gases.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…

gases maintain different properties based on their environment.</td><td>ESSENTIAL QUESTIONS

What are the properties of gases in the atmosphere?

How do humans impact molecular components of the atmosphere?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…

properties of gases.</td><td>Students will be skilled at…

measuring properties of gases.</td></tr>
<tr><th colspan="3">Stage 2 - Evidence</th></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td rowspan="2">● Multi-level questions throughout investigation</td><td colspan="2">PERFORMANCE TASK(S):

● Investigation of gas properties
○ Volume
○ Pressure
○ Temperature</td></tr>
<tr><td colspan="2">OTHER EVIDENCE:</td></tr>
<tr><th colspan="3">Stage 3 – Learning Plan</th></tr>
<tr><td>Time

<u>Day 5:</u>

5 minutes

5 minutes</td><td colspan="2">Summary of Key Learning Events and Instruction

1. Article read - Air pollution implicated in up to 4,000 Minnesota deaths per year, Greg Stanley Star Tribune</td></tr>
</table>

	a. Class questions and discussion
50 minutes	2. Investigation of gases
15-20 minutes	a. Stations
	b. Questions/Analysis
Day 6:	
10 minutes	1. Class share-out of investigation observations
60 minutes	2. Notes
	a. Gas relationships - foldable
10 minutes	3. Introduction to Lab

<table>
<tr><th colspan="3">Stage 1 Desired Results</th></tr>
<tr><td rowspan="7">MN STATE STANDARD BENCHMARK:

9E.1.2.1.1
Plan and conduct an investigation of the properties of water and its effects on earth materials and surface processes.

9E.1.2.1.2
Plan and conduct an investigation of the properties of soils to model the effects of human activity on soil resources.

ESTABLISHED GOALS:</td><td colspan="2">Transfer</td></tr>
<tr><td colspan="2">Students will be able to…

represent observations and data in order to recognize patterns in the data, the meaning of those patterns, and possible relationships between variables.</td></tr>
<tr><td colspan="2">Meaning</td></tr>
<tr><td>UNDERSTANDINGS
Students will understand that…

matter and its properties interact at various levels.</td><td>ESSENTIAL QUESTIONS

How do matter cycles interact based on their properties?

How do humans impact the interaction of matter cycles?</td></tr>
<tr><td colspan="2">Acquisition</td></tr>
<tr><td>Students will know…

how properties of matter, including water, soil, and atmosphere, interact.</td><td>Students will be skilled at…

collecting data from various types of matter.

identifying relationships of various types of matter.</td></tr>
<tr></tr>
<tr><th colspan="3">Stage 2 - Evidence</th></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td rowspan="2">● Rubric</td><td colspan="2">PERFORMANCE TASK(S):

● Soil Texture and Soil Water Permeability Inquiry Lab</td></tr>
<tr><td colspan="2">OTHER EVIDENCE:</td></tr>
<tr><th colspan="3">Stage 3 – Learning Plan</th></tr>
<tr><td>Time

<u>Day 7-8:</u>

160 minutes</td><td colspan="2">Summary of Key Learning Events and Instruction

1. Soil Texture and Soil Water Permeability Inquiry Lab</td></tr>
</table>

Claim, Evidence, Reasoning Rubric

	4	3	2	1	0
Claim	Claim directly relates to the content provided and shows understanding of the phenomenon. **OR** Claim answers a previously asked question and shows student understanding of the investigation.	Claim directly relates to the content provided and somewhat shows understanding of the phenomenon. **OR** Claim answers a previously asked question and somewhat shows student understanding of the investigation.	Claim directly relates to the content provided, but does not show understanding of the phenomenon. **OR** Claim answers a previously asked question, but does not show student understanding of the investigation.	Claim somewhat relates to the content provided, but does not show understanding of the phenomenon. **OR** Claim somewhat answers a previously asked question, but does not show student understanding of the investigation.	Claim does not directly relate to the content provided and does not show understanding of the phenomenon. **OR** Claim does not answer a previously asked question and does not show student understanding of the investigation.
Evidence	Evidence provided is sufficient, appropriate, and uses qualitative or quantitative data relating to ALL aspects of the claim.	Evidence provided is sufficient, appropriate, and uses qualitative or quantitative data relating to SOME aspects of the claim.	Evidence provided is somewhat lacking and is not entirely sufficient, appropriate, but uses qualitative or quantitative data relating to SOME aspects of the claim.	Evidence provided is lacking and is not sufficient, appropriate, and uses qualitative or quantitative data relating to SOME aspects of the claim.	Evidence provided is not sufficient, appropriate, and does not use qualitative or quantitative data relating to the claim.
Reasoning	Reasoning uses justification to connect the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.	Reasoning uses justification to connect the evidence to the claim, and somewhat shows why the data counts as evidence by using appropriate and sufficient scientific principles.	Reasoning uses justification to connect the evidence to the claim, but does not show why the data counts as evidence by using appropriate and sufficient scientific principles.	Reasoning lacks justification to connect the evidence to the claim, and does not show why the data counts as evidence by using appropriate and sufficient scientific principles.	Reasoning does not use justification to connect the evidence to the claim. It does not show why the data counts as evidence and does not use sufficient scientific principles.

The earth is hurting, and it goes beyond carbon emissions

BY JIM CONCA

JUNE 28, 2019 04:42 PM, UPDATED JUNE 28, 2019 04:47 PM

Aggressive agriculture without thoughtful planning has changed quite a bit of the Earth's surface — irreversibly. About 40 percent of our planet's land area is agricultural. And most of that is not done sustainably, with any eye toward preserving soil or natural conditions.

We first got an inkling of how important this was almost a hundred years ago during the Dust Bowl. For three decades before WWII, millions of acres of thriving native grassland in the southern Plains were turned into wheat fields. But the one-two punch of the Great Depression and the Great Drought, caused dust storms to move tons of dry soil that had previously been kept in place by the native grasses.

These grasslands, which had evolved over the thousands of years since the last Glaciation, had created a delicate equilibrium with the climate extremes of the Plains, keeping the fertile soil in place. Now they were gone.
From North Dakota to Texas, much of the Great Plains became a desert.

Just 5,500 years ago, giraffes, hippos, lions, and antelopes roamed lands lush in vegetation and vast wetlands in what is now the Sahara Desert. Climate change and overgrazing changed it within only a few decades.

The same happens with forests.

There are three major types of forests, classified according to increasing latitude: Tropical, Temperate and Boreal. More than half of tropical forests have already been destroyed. Only scattered remnants of original temperate forests remain, many of them in Washington State. Ongoing extensive logging in boreal forests will soon cause their complete disappearance.

Sometimes we plant trees on the logged areas, but at best it becomes a mono-culture crop, not a forest. The forest microclimate, soil and animals are all gone.

This is what happened in the Moors of England. They were once covered by dense forests with thick soils, but Iron Age humans clear-cut these forests to smelt iron. They never grew back. There can be no regrowth of most clear-cut boreal or temperate forests since the post-glacial environment that formed them is gone. They can maintain their own microclimate that allows them to continue, but once that's destroyed by clear-cutting, that's it.

Besides the lost forests, their microclimates and indigenous species, a huge amount of soil is lost with clear-cutting, particularly the nutrient-rich top soil. These ecosystems normally hold the soil from eroding. This soil has almost as much carbon in it as the forests, further contributing to global warming.

But forest fires provide the most dire change to global ecosystems. Forests provide more than just economic and recreational services. They contribute to climatic and hydrologic regulation of their landscape. Fires are a natural phenomenon from which most forests normally recover. But climate change and human activities exacerbate the effects of wildfires and causes rapid permanent ecosystem destruction.

A 2016 study reported that the burnt area in the northwestern United States expanded by almost 5,000 percent since 2000.
The fire seasons around the world are expanding, starting months earlier in the spring and going months later into the fall, caused by once-rare droughts. In a vicious cycle, deforestation leads to an increase in fire frequency, which in turn inhibits the regrowth of forest vegetation.

The Washington State Department of Natural Resources (DNR) is worried about this summer's fire dangers in eastern Washington. We're already hotter than usual. "This is becoming the norm," explained DNR spokesperson Janet Pearce. "Last year our fire season started a little earlier and this year on the west side we had about 50 fires in March and that's not typical. On the east side, we're very concerned because it's almost all in drought-like conditions and that could make for a challenging fire year."

But another phenomenon is also occurring — the public might be getting Catastrophe Fatigue with all the Doom and Gloom coming from the scientific community. But while we're telling the public what's going on, and many are finally listening, nothing is really happening to change things.

Most of the conditions under which the global ecosystems evolved are no longer here for them to recover. We won't get them back. But we should preserve what is left.

After a century of clear-cutting, this forest, near the source of the Lewis and Clark River in Clatsop County, Oregon, is a patchwork. In each patch that is not desolate, the trees are all of the same age, a monoculture that has no characteristics of a real forest. WALTER SIEGMUND

Soil Investigation

Introduction

How do the physical and chemical properties of soil affect soil quality? What does soil quality actually mean? The following investigation will explore both physical and chemical properties of soil samples obtained locally.

The physical properties of soil texture will be determined by measuring the heights of the sand, silt, and clay layers at the appropriate time intervals after mixing soil with “softened” water. The rate at which the soil particles settle when mixed depends on their size. Large sand particles settle out quickly, within a minute or so. Silt particles generally settle within 30 minutes, while tiny clay particles may take 24 hours to settle. Dividing the height of the respective soil layer by the combined height of all three layers gives the percentage of each component. The “softening agent” is sodium hexametaphosphate, which causes the colloidal clay particles to clump and settle.

The chemical properties of soil will be evaluated by measuring the pH and testing for the presence of macronutrients. The levels of these soil quality indicators are determined by mixing the soil sample with water and analysing the resulting solutions.

Materials

- Physical and Chemical Properties of Soil - Student Laboratory Kit, *Flinn Scientific*

Procedure

Prelab

Before starting, read the procedure to learn what you will need to do, note safety precautions, and plan necessary data collecting and observations. Your group will work together throughout the procedure and each student will turn in their own work. Reminder: Your work can have similar ideas, but may not be identical.

Part A - Physical Properties of Soil

1. Using a plastic spoon, add about 10 cm^3 of air-dried soil to a plastic Snap-Seal vial.
    a. Gently tap the vial on the table to eliminate air space and pack the soil down in the tube.
2. Carefully add 40 mL of distilled water to the vial.
3. Using a graduated plastic pipette, add 1 mL of sodium hexametaphosphate solution to the vial.
4. Cap the vial and snap securely to prevent leakage.
5. Shake vigorously for two minutes to thoroughly mix the contents of the vial.
6. Place the vial in the sectioned off area of the classroom, on the lab table and immediately start timing.
    a. Make sure your vial is not disturbed.

   b. Write your group names on a piece of masking tape and place in on the table in front of your vial
      i. Do not put the tape directly on the vial.
7. After 30 minutes, measure and record the combined height in mm of the sand and silt layers.
8. After 48 hours, measure and record the total height of the clay, sand, and silt layers.
9. Record the color and appearance of the water solution on top of the soil.
   a. Note: The clay will probably look "congealed" and is usually lighter in color than the other layers.

Part B - Chemical Properties of Soil

1. Make sure everyone in your group is wearing goggles and gloves.
2. Obtain TesTab tablets for pH, nitrate, and phosphate testing.
3. Mark the 1-mL level in each test tube
   a. Measure 1 mL of water in a graduated cylinder and add the water to one of the test tubes.
   b. Using a wax pencil, draw a line on the test tube to mark the 1-mL level.
   c. Measure and add 9 mL of water to the test tube and draw a second line to make the 10-mL level.
   d. Hold two test tubes side by side with the marked test tube and draw lines for the 1-mL and 10-mL levels on each.
   e. Discard the water.
4. Using a clean scoopula, add soil to the 1-mL level in each test tube and label the test tubes "pH," "N," and "P."
5. Add distilled water to the 10-mL mark in the "pH" test tube.
6. Add a pH TesTab tablet to the water in the "pH" test tube.
7. Stopper the test tube and shake for 30 seconds.
8. Place the test tube in the test tube rack and allow 2-3 minutes for the soil to settle.
9. Compare the color of the liquid to the pH test tube to the colors on the pH Color Comparison Chart.
   a. Record the approximate pH value in your data table.
   b. Rinse the stopper with water.
10. Using a graduated plastic pipette, add 1 mL of vinegar to both the "N" and "P" test tubes.
11. Add distilled water to the "N" and "P" test tube until the liquid level in each is at the 10-mL mark.
12. Stopper the test tube and shake for 1 minute.
13. Place the test tubes in the test tube rack and allow 3-5 minutes for the soil to settle.
14. Decant 5 mL of liquid from the "N" test tube into a clean test tube and add a nitrate TesTab tablet to the clear liquid.
15. Shake for at least one minute, until the tablet dissolves completely.
16. Place the test tube in the test tube rack and let it sit undisturbed for 5 minutes.
17. Compare the color of the liquid to the colors of the Nitrate Color Comparison Chart

    a. Record the nitrate concentration in your data table.

18. Repeat steps 14-17 with the "P" test tube, using the phosphate TesTab tablet and the Phosphate Color Comparison Chart.
    a. Record the phosphate concentration in your data table.

Analysis Questions

1. Calculate the percentages of sand, silt and clay in the soil sample.

2. Describe the quality of the soil using your results from Part B:
    a. Is the pH of the soil acidic or basic?
    b. Are the nitrate and phosphate levels suitable for plant growth?
    c. If you were a farmer planning to plant crops in this soil, would fertilizer be necessary? Why or why not?

[1] Modified from Flinn Scientific: Physical and Chemical Properties of Soil. (n.d.). Retrieved from https://www.flinnsci.com/

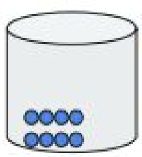
Properties of Matter

I can describe physical and chemical properties of soil.

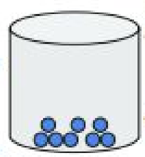
The Kinetic-Molecular Theory of Matter

Particles in nature are in continuous motion.

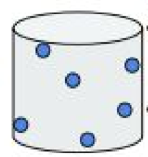
This theory is able to explain the properties of solids, liquids, and gases.



Solid:
- Particles are low energy and generally fixed
- Constant volume, constant shape



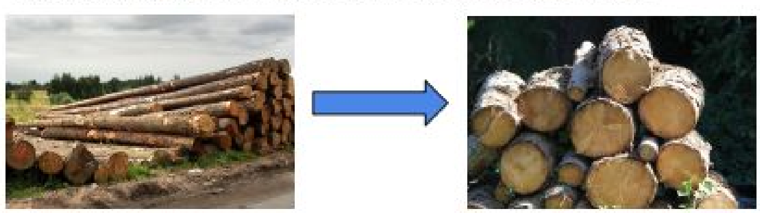
Liquid:
- Particles have some energy, slide past each other
- Constant volume, shape can change



Gas:
- Particles have high energy, "zoom around," hit sides of container
- Volume and shape change based on energy and container

Physical Properties of Matter

Any characteristic or trait of a material that can be observed or measured without changing the composition of the substance in the material

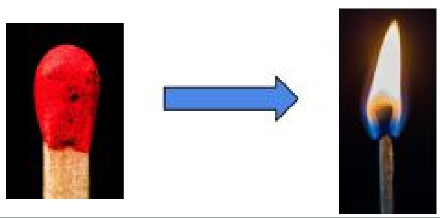


Types of Physical Properties

- Viscosity
- Conductivity
- Malleability
- Hardness
- Melting point
- Boiling point
- Density

Chemical Properties of Matter

Any characteristic or trait that is produced from a change in the composition of matter.



Types of Chemical Properties

- Flammability
- Reactivity

Soil

A stratified mixture of weathered bedrock that includes sufficient organic material, water, and air to support life.

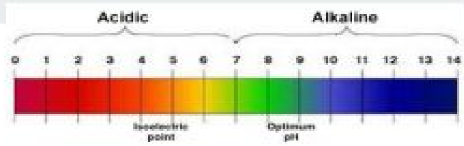
Physical Properties of Soil

- Color
- Texture
- Structure
- Drainage
- Depth
- Susceptibility to Erosion

Chemical Properties of Soil

- pH
- Nitrogen
- Phosphorus
- Potassium

pH



What is it?

The measure of acidity or alkalinity of a soil.

- How acidic or basic is the soil

Why does it matter?

Different types of plants and organisms need different levels of soil pH

Nitrogen (N)

What is it?

Element found in chlorophyll

- Green pigment in leaves

Why does it matter?

Required by plants to produce amino acids and proteins.

Lack of Nitrogen causes stunted growth and yellowing of normally green leaves.

Phosphorus (P)

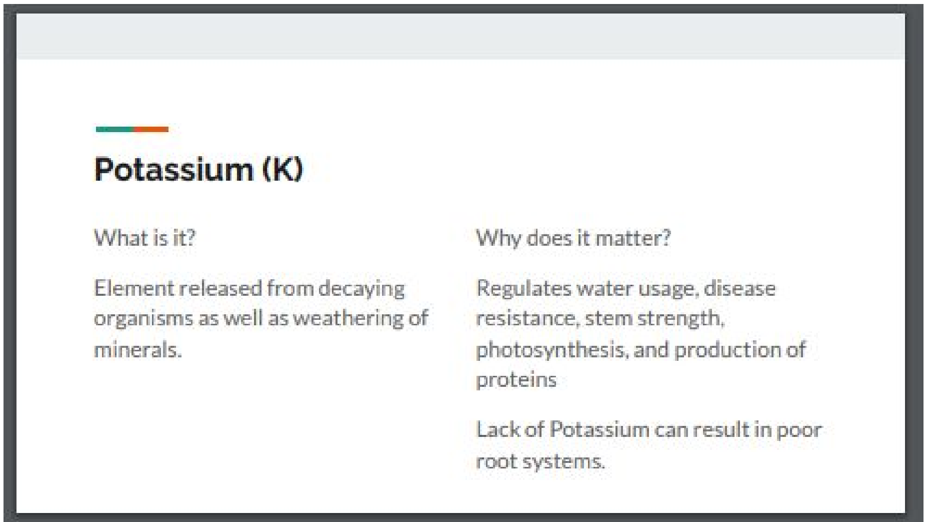
What is it?

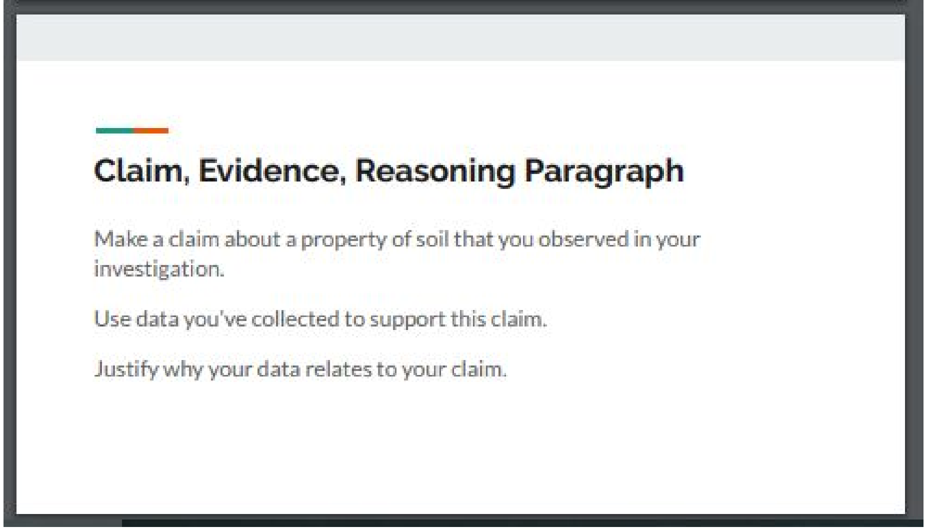
Element released from minerals through the process of erosion and weathering.

Why does it matter?

Provides nutrients for healthy root, seed, and plant growth, photosynthesis and respiration, and many other processes.

Lack of Phosphorus can result in stunted growth and purple leaves.


Potassium (K)
What is it?
Element released from decaying organisms as well as weathering of minerals.
Why does it matter?
Regulates water usage, disease resistance, stem strength, photosynthesis, and production of proteins
Lack of Potassium can result in poor root systems.


Claim, Evidence, Reasoning Paragraph
Make a claim about a property of soil that you observed in your investigation.
Use data you've collected to support this claim.
Justify why your data relates to your claim.

Stephanie Pearson

May 20, 2019

The Uncertain Future of the Boundary Waters

At 1.1 million acres, the Boundary Waters Canoe Area Wilderness is one of the largest and most popular backcountry destinations in the U.S. and a longtime proving ground for adventurers. But now the region is facing the threat of sulfide-ore copper mining. Stephanie Pearson paddles into the wild.

The new moon is invisible, and the night is black.

My sister, Jen, is paddling in the stern. Her shivering wobbles the bow where I'm sitting. Canoeing in 45-degree weather at midnight dressed in T-shirts and underwear is not our normal behavior while camping in northern Minnesota's Boundary Waters Canoe Area Wilderness in September. But an enormous black bear is on its hind legs, ten feet away, aggressively swiping at the food pack dangling from a low tree branch at our campsite. By the sound of its grunts, it's hungry.

In our panic, we failed to forage for layers. Jen scooped up her sleeping bag and white Labrador, Sunny, I grabbed my knife and headlamp, and we tripped over ourselves to get to the water's edge, where we launched the canoe.

"Can you see it?" Jen asks while Sunny barks in docile intervals. The dog's genes have been so greatly diluted that she doesn't seem to be aware that we're facing a wild animal that can run at speeds up to 30 miles per hour and swim long distances.

"I think it's right under the pack," I say. The bear blends so well into the night that it's impossible to see, until my headlamp catches the glow of its eyes staring us down. It's dipping a clawed toe into the lake, as if testing the water to determine whether it's too cold to swim after us. There's something about its crystalline gaze that makes it look ruthless, like the grizzly that mauled Leonardo DiCaprio's character *in The Revenant.*

"Maybe we should have put the food pack on the island across from our campsite," I say, calculating how long the Clif Bar I stashed in my fanny pack will last two humans and a dog.

Combined, my sister and I have spanned almost a century paddling in the Boundary Waters, a 1.1-million-acre roadless wilderness rich with 1,100 lakes, some so massive that they take days to cross, others so small that you can swim to the other side, most filled with water so fresh that diehard paddlers don't bother to filter it. In total there are 1,200 miles of canoe routes lined by over 2,000 campsites. Jen and I visited the Boundary Waters first as tagalongs with our father, a Lutheran pastor, on his youth-group canoe trips, then on our own family's trips. Later we returned as college-age guides for Wilderness Canoe Base, a camp on Seagull Lake, at the northeastern edge of the Boundary Waters, and finally on annual trips as often as we can escape adulthood, which isn't too hard for me, but my sister is a married physician with three kids.

In college, Jen and I spent entire summers on trail, camping for weeks at a time in this wilderness, mostly guiding urban teens. I've evacuated a kid with a deep cut a day's paddle from help. I've been caught in the middle of the lake with my hair rising straight in salute to an incoming electrical storm. I've carried a canoe eight miles over the Grand Portage, a rugged historical superhighway once used by Ojibwe hunters and French voyageurs to reach Lake Superior. And I've cooked countless soggy meals over an open fire in the rain for hungry, nearly hypothermic campers.

That the bear is now destroying our pack is a result of a lack of vigilance and perfect weather. This morning was one of those rare, glorious late-summer days, with temperatures hovering around 80 and a cloudless blue sky from which the sun shone down on the water to create shimmering diamonds in the ripples. The effect was so mesmerizing that it made us lazy.

Entry points to this wilderness are tightly regulated, and some require a reservation a year in advance. Surprisingly, I found a last-minute permit to put in our canoe at a lake 18 miles northeast of Ely, a former iron-ore mining town turned tourist destination of 3,400 year-round residents that sits near the terminus of Minnesota Highway 169, almost a stone's throw from Canada. We planned to paddle quickly through two small lakes, then portage, with Jen carrying the canoe and me carrying the packs over a rocky, half-mile-long trail into the placid Kawishiwi River and beyond. Our goal was to spend a luxurious five days in the woods, veering off into remote lakes that neither of us have seen.

On our first day, we lined the canoe through riffly, benign rapids and plopped down on a granite rock for an hourlong lunch break, picking all the M&M's out of the trail mix to eat first. From there we paddled and portaged through five more lakes, passing an area deeply scarred by a 2011 forest fire where new spruce were starting their climb toward the sun. By late afternoon, we'd paddled into a small, isolated lake and found a campsite with a sprawling granite slab sloping into the water, lined by pillowy white pines and graced with a flat tent pad. The only missing element was an easily accessible tree branch strong and high enough to hang our food pack. It had been more than 20 years since either of us encountered a bear in the Boundary Waters, so we nonchalantly hung the pack on a branch precariously near our tent. We were impatient to toast the luxurious weather and reminisce away our grief over our father's recent death.

"Do you remember the time Dad hung two fishing lures in a tree and shined a flashlight to make them glow like a bear's eyes?" Jen laughed. "He scared the bejesus out of us."

"My earliest memory of the Boundary Waters is being ridiculed by my older siblings," I said.

"You probably *were* ridiculed, especially when you were six years old and came out of the tent in a frilly flannel nightgown on Lake Gabimichigami," Jen said. "Dad forgot to check what you had packed."

The author's father, grandparents, and other relatives on Lake Vermilion in 1942 (Courtesy Pearson Family)

Jen and I laughed until tears streamed down our faces, remembering misadventures led by our father, a blond-haired, blue-eyed Scandinavian prankster and the man who ebulliently introduced his five kids to the Boundary Waters when Jen was seven and I was three. Since our parents already owned a canoe and a tent, it was by far the least expensive way for them to share the raw joy of the wilderness with us. In November 2017, Dad died of melanoma. As we watched the setting sun sparkle on the water, we had no idea that our existential loss would soon be overshadowed by the very acute loss of our food.

“The good news is that our pack will be a lot less heavy with no food in it,” I say, shivering in the canoe after what seems like hours. Once the bear, tiring of its piñata game, had retreated into the woods long enough for us to feel safe about returning to the tent, we grabbed my sleeping bag and our pads and paddled to a rocky islet a quarter-mile out from our campsite.

“Now, this is living,” Jen laughs as she lies down atop a cliff ten feet above the water. She falls instantly asleep, with Sunny curled at her side.

I stare up at the Milky Way. If I had been in a tent, I wouldn’t have seen this mysterious blaze of billions of stars. I stay awake all night, talking to my dad in my mind, wondering if the bear is his last big cosmic joke on his daughters.

At daybreak, when Jen and I return to the campsite, the food pack is still hanging in the tree, albeit with a ragged hole in one corner. All six chocolate bars, the gorp, the cheese, the cashews, and the dried mango are gone. Baby carrots are scattered everywhere, along with four packets of oatmeal and a bag of coffee, which has a claw hole slashed through its center. The coffee filters are missing, so we find a clean pair of quick-drying underwear in our tent and use the fabric.

“It was our own damn fault,” Jen says as we warm up in the sun, sipping coffee and consulting our maps to retrace yesterday’s route back to the car. “This will teach us to never get too complacent.”

Complacency, change, and loss are three factors that weigh heavily on me these days. As a kid, I assumed that these lakes and woods would remain pristine forever. Now, like the much fought-over Arctic National Wildlife Refuge, this wilderness, too, is in danger. The issue in northeastern Minnesota is a decades-long battle over mining.

Designated in 1964, the Boundary Waters is the most visited wilderness area in the U.S., averaging 155,000 people per year—mainly anglers here to fish for walleye and paddlers who travel among bald eagles, wolves, coyotes, deer, lynx, moose, and, yes, black bears, while moving under their own power past dense pine forests and granite cliffs. When the sun goes down in late summer through winter, the northern lights often dance across the sky.

For centuries paddlers have plied these waters, starting with the Anishinabek and, later, the French voyageurs, pushing westward in search of beaver pelts and a passage to the Pacific Ocean. Because of its harsh climate and rugged landscape, northern Minnesota has also bred explorers like Will Steger and Paul Schurke, the co-leaders of the first unsupported dogsled journey to the

North Pole, in 1986. Both men still live near Ely and use this wilderness as a jumping-off point for exploration.

“I see the Boundary Waters as the first strip of wilderness leading to the Arctic,” Steger told me when I visited him at his homestead outside Ely. In 1985, he traveled 5,000 miles from here to Barrow, Alaska, with a dogsled team. “It’s probably as dangerous north of here as any other place I’ve seen,” he said. “These are big lakes. If you capsize in cold water, you’re not going to live.”

Schurke, who owns Wintergreen Dogsled Lodge near the Boundary Waters and has led many expeditions in the Arctic and the Amazon, said, “The great thing about the Boundary Waters is that it’s wilderness on a human scale. You’re up close and personal every step of the way with the boreal forest, the pristine waters, the exquisite flora and fauna, and the endless shades of blue, green, and brown. It’s wilderness that’s accessible physically and emotionally to people of all ages.”

In September 2015, adventurers Amy and Dave Freeman embarked on a yearlong paddling, dogsledding, and camping expedition in the Boundary Waters as a way to advocate for the wilderness. “One of the best parts about the Boundary Waters is that you can plop a toddler in a canoe and take them out for a sunny July camping trip,” Dave told me. “But this place has moods. In spring and fall, the lakes are freezing and you’re totally isolated. You can challenge yourself in ways that would be like navigating the far reaches of Canada or the heart of the Amazon. There’s constantly challenging conditions, especially in the winter, when it’s 40 below zero and exposed skin starts to freeze in seconds.”

Mining has long been a part of this region, too. South and west of the Boundary Waters, iron ore and its derivative, taconite, have been heavily extracted for more than a century. Between 1888 and 1967, Ely’s five mines produced more than 86 million tons of iron ore. The amount of iron ore mined in northern Minnesota between 1892 and 2018 exceeded 5.1 billion tons, more than three-quarters of the country’s total production.

The irony isn’t lost on me that in 1883, my great-grandfather, Peter Pearson, left Sweden to start a new life in the mining and logging boomtown of Tower, 20 miles west of Ely. Peter logged until 1909, when he could afford to move his wife, Josephine, also a Swedish immigrant, and their growing family onto a homestead ten miles from town.

My grandfather William spent his rare free time fishing and swimming with his eight siblings in Lake Vermilion, a 62-square-mile body of water that sits adjacent to what is now the Boundary Waters. My dad grew up two hours south in Duluth, and in 1963 he honeymooned with my mom on the same Lake Vermilion island where his parents took him on vacation as a boy. Mom and Dad returned from that trip the proud owners of a one-acre piece of shoreline property shaded by towering Norway pines. They built a single-room cabin that eventually grew into their year-round home. Every summer of my childhood I ran around that island, building forts, taking saunas, fishing for walleye, and learning how to flip Swedish pancakes over our outdoor stone fireplace. From our cabin, we could paddle and portage straight into the Boundary Waters. We took the abundance of fresh, clean water for granted. That line of thinking, I have come to realize, is dangerously naive.

Traditional iron-ore mines are almost depleted in northern Minnesota. But the Duluth Complex, an eyelid-shaped mineral deposit that begins southwest of Duluth and arcs 150 miles northeast through Superior National Forest and portions of the Boundary Waters, reportedly holds four billion tons of copper, nickel, platinum, palladium, silver, and gold that could be worth more than $1 trillion.

In 1978, the Boundary Waters Canoe Area Wilderness Act banned mining within the wilderness and established a 222,000-acre protected zone along entry corridors that would further shield fish and wildlife and ensure the highest water-quality standards throughout the entire Rainy River Drainage Basin, which also encompasses nearby Voyageurs National Park. But in 1966, preceding the ban, the Bureau of Land Management had issued two 20-year federal mineral leases on 4,800 acres of Forest Service land, one directly adjacent to the Boundary Waters and the other within five miles. Twin Metals Minnesota, a subsidiary of the Chilean conglomerate Antofagasta, eventually acquired them. The leases are within the 1854 Treaty Area, lands that the Chippewa ceded to the federal government in exchange for payments and provisions, in addition to reserving the right to hunt, fish, and gather in perpetuity.

The leases have been renewed twice, in ten-year increments. Since 2005, Twin Metals has drilled more than 1.4 million feet of core samples from 700 holes in preparation for an estimated $1.6 billion underground copper, nickel, and precious-metals mine located approximately nine miles southeast of Ely. Twin Metals' efforts stalled out during the Obama administration, after the BLM denied a third lease-renewal request in 2016, citing environmental risks. But in May 2018, the Interior Department under the Trump administration reinstated the two leases. And in December 2018, the BLM proposed to renew the leases for ten more years, pending the completion of the agency's process, which includes reviewing 39,000 public comments in response to its environmental-assessment report. On May 15 of this year, the BLM renewed the leases.

What has many concerned about mining in this area is that the Duluth Complex metals are contained in sulfide ore, which would require a vastly different extraction process than the one used by the region's traditional iron-ore mines. When sulfide ore and its waste tailings are exposed to air and moisture, sulfuric acid is created. Water is the vehicle through which sulfuric-acid compounds can leach from mine sites and create acidic drainage, which can contaminate lakes, rivers, groundwater, and everything living in them.

"The primary difference is that the iron ore mined in Minnesota and the rest of the world is basically a sulfide mineral that has already been oxidized," says David Chambers, a geophysicist and president of the Montana-based Center for Science in Public Participation. "When you mine nonoxidized ore for copper, nickel, lead, and zinc, the waste contains sulfide minerals, which are the primary threat for acid drainage. And that's typically toxic to aquatic species at relatively low levels."

Twin Metals has not yet released the plan of operation for its proposed mine. But spokesman David Ulrich says the company is creating underground mining techniques and other design considerations that will meet or exceed local, state, and federal regulations to minimize and avoid environmental impacts. Ulrich also cites that "21st-century technology allows us to do our work with remarkable precision and safety."

While sulfide-ore mining techniques vary and continue to evolve, in the past some safety records have caused concern. A 2012 study by the nonprofit Earthworks reviewed 14 U.S. sulfide-ore copper mines—predominately open-pit—which produced 89 percent of the country's copper in 2010, the most recent data available from the U.S. Geological Survey. All the mines experienced pipeline spills or other accidental releases. Tailings spills occurred at nine operations, and at 13 of the 14 mines, the study says, "water collection and treatment systems have failed to control contaminated mine seepage, resulting in significant water-quality impacts."

That risk is more worrisome in Minnesota, where 6 percent of the surface area is water—more than any other state in the country. The three-million-acre Superior National Forest, which contains the Boundary Waters, holds 20 percent of the freshwater in the U.S. national-forest system. It also borders Lake Superior, the largest and least polluted of the Great Lakes, which holds 10 percent of the world's fresh surface water. The Kawishiwi River, which my sister and I paddled, is under such threat from the potential mine that the nonprofit advocacy group American Rivers designated it the third most endangered river of 2018.

Now that the federal mineral leases have been renewed, Twin Metals will submit its formal plan of operation to the BLM. According to Ulrich, it expects to do that "in the near future." Once the plan is submitted, it will undergo a complex environmental review, involving multiple state and federal agencies and including time for public commentary, in order for the BLM to create a final environmental-impact statement. If the plan is approved, Twin Metals must obtain permits from various regulatory agencies. The entire process can take years. (But approval can happen. In March, after more than a decade-long environmental review process, the company PolyMet was granted its final permit by the Army Corps of Engineers for a separate sulfide-ore copper-nickel mining project 52 miles southwest of Ely. PolyMet hasn't announced a timeline for the mining to begin.)

Last June, after the federal mineral leases were reinstated, nine northeastern Minnesota businesses and one environmental group joined forces to sue the Interior Department, seeking to overturn the decision. That lawsuit is pending. Meanwhile, Congress has requested the government documents and scientific and economic reports that administration officials used to justify the lease reinstatements.

“The Boundary Waters is being challenged by forces unlike anything we’ve seen in decades, if not a century,” Ely native Becky Rom, a former corporate lawyer and the national chairwoman of the six-year-old Campaign to Save the Boundary Waters, recently told a group of supporters.

For people who enter the Boundary Waters from the west, the gateway is Ely, a town of hipster tourist cafés, dark taverns, trinket shops, and canoes stacked five high on outfitter lawns. Adventurers, miners, artists, and environmentalists live side by side yet are sharply divided about how to use and protect the surrounding woods and waters.

A study published in 2018 by Harvard University economist James H. Stock showed that over a 20-year period, an economy based on copper, nickel, and precious-metal mining would provide temporary growth in employment and income, but because of the boom-bust cycle of mining, it would ultimately underperform and potentially harm Ely’s current economy, which is based on the outdoor-recreation industry and people moving to the area for its beauty and livability.

For its part, Twin Metals says that the mine project would create hundreds of jobs in the region. Joe Baltich, the owner of the Northwind Lodge and Red Rock Wilderness Store, is in favor of that. Baltich served as the mayor of Ely in 1985 and is the founder of the nonprofit Fight for Mining Minnesota. “The best path forward, I maintain, is solid employment through mineral resource use,” he tells me over the phone. “We’re sitting on a natural resource that is worth $500 billion. There’s enough in that hole to make our taxes go away and still make money.” And, he adds, “The anti-miners are anti-everything. When it comes down to it, they don’t even want you to touch the Boundary Waters.”

“It’s a Chicken Little thing. ‘The sky is falling, the sky is falling,’ ” says mining consultant Jay Mackie, who grew up in the middle of what is now the Boundary Waters Canoe Area Wilderness. (In 1965, the federal government moved his family off their land to create the BWCAW.) “Minnesota has the most stringent environmental rules in the nation,” he says. “If the permits are issued according to those rules, then I have no problem with the mine going forward. I think it’s for the strategic benefit of the United States, and it will benefit the area big-time. Tourism here does not pay a living wage to any multitude of people for 12 months.”

If not yet outwardly hostile, the vibe in Ely is certainly tense. “Mining is of course the elephant in the town,” says Steve Piragis, a lake ecologist and the owner of Ely canoe outfitter Piragis Northwoods Company, one of the businesses suing the Interior Department. “The undercurrent is silent but deafening.”

Mackie, who has lived in or near Ely his entire life, told me, “I’m 76 years old, and I have never seen the polarization like it is today. There’s no reasoning, there’s no communication, there’s no nothing, and that’s the sad part.”

It’s hard to live with that tension, Piragis tells me. But, he says, “Our business depends on the purity of the wilderness experience, and Ely’s prosperity depends on it as well. With so few untrammeled wildlands still holding on, the Boundary Waters Canoe Area Wilderness is worth all we can do to help save it. This geographic wonder of 1,100 lakes in a million acres exists nowhere else on the globe."

I've sent letters to politicians and participated in protests, but my only true antidote is to paddle these lakes as much as I can. Last August, a month before my sister and I set out, I rallied my boyfriend, Brian Hayden, to canoe a circuitous route bordering Canada that I frequently traveled with teen campers 30 years ago.

More of a cyclist than a paddler, Brian hasn't camped in the Boundary Waters for years. "It's exactly as I remember it," he says on the first night, as we watch a loon dive underwater while we swat mosquitoes at sundown. "The water is so crystal clear."

By day two of our four-day trip, we've paddled and portaged across six lakes into the fickle big water of 4,919-acre Knife Lake. We start early, paddling the length of it into South Arm Knife Lake, passing eight loons, a few soaring eagles, and a burn area that disorients me. In 2013, a forest fire charred nearly 200 acres, and instead of the towering pines and mountainous relief of my memories, the shoreline feels sparse and barren, like the Arctic tundra in summertime. But the water is still luxuriously cool and fresh, and the way it drizzles off my paddle with every stroke puts me in a trance I've known since I was three years old.

The beauty of a canoe trip is that when you're paddling, you have nothing else to do but take in the scenery, monitor the weather, talk, and think. I think about all the people nationwide who have stepped up in support of this wilderness. Since Becky Rom and other Ely business leaders organized the Campaign to Save the Boundary Waters in 2013, more than 340,000 Americans have publicly commented to the federal government in support of protecting it.

Last summer, 17-year-old Joseph Goldstein, a leukemia survivor from Springfield, Illinois, formed Kids for the Boundary Waters, an arm of the Northeastern Minnesotans for Wilderness organization "run by kids for kids who know and love the Boundary Waters."

"The Boundary Waters is like a gateway drug," Goldstein says in his promotional video. "It opens the doors for adventure."

Filmmaker and ski mountaineer Jimmy Chin grew up in southern Minnesota and still supports his home-state wilderness through the Campaign to Save the Boundary Waters. "It's true untouched wilderness, and its intrinsic value as such cannot be overstated," he wrote me in an email. "But it's so much more. It's priceless habitat, its forests are critical for carbon capture, and it's one of the places left to offset the other wilderness areas we are destroying and giving up to mining interests."

By midafternoon, Brian and I paddle out of the burn and find a site with a rocky point that faces east toward tomorrow's sunrise. The lake is legendary for its walleye and trout, but Brian and I neglected to pack fishing rods. Instead, he jury-rigs a tarp over our cooking area while I gather water and scout a tree for the bear pack. When our chores are finished, we strip and splash into the calm, cool water, swimming laps around a small island sprouting six miniature white pines.

What strikes us both as we stretch out on the flat rock to dry off is the absence of noise—no call of a loon, gentle lap of waves, or wind whistling through the pines. Instead, we feel the eerie pre-storm silence of the woods, before the sky turns pink, the clouds roll in, and all hell breaks loose in the heavens.

Until then, we lie in awed wonder.

"You don't hear silence like this anymore," Brian says, intermittently dozing off in the sun. Eventually, the rain comes in steady, gentle drops, and we suit up in raingear to explore the hill behind our campsite, where we find hundreds of plump, juicy blueberries.

"Let's leave some for the bears," Brian says, laughing at my blue teeth.

Done with our berries and a dinner of freeze-dried Thai noodles, we zip into the tent and fall asleep until the storm converges on us, the cracks of thunder and lightning flaring frighteningly close together.

The next morning breaks clear and smells clean. We dry out our gear, eat breakfast burritos, and load up to start the return paddle toward Ely via a string of six lakes that border Canada. The sun is bright, the wind is at our back, and we pass a half-dozen turtles sunning themselves on scattered rocks and a family of otters splashing along the shoreline. We don't say much, mostly because I'm struggling to feel the peace that, until now, this place has emanated. These lakes are where my great-grandfather, my grandfather, my father, my mother, my siblings and I, and countless others before and after us first felt the joy and freedom of the wilderness. If this million-acre universe of wild things and fresh, clean water is ever contaminated, I think, what else is there?

Foul Water Investigation

Introduction

Your objective in this lab is to clean up a sample of “foul water,” producing as much “clean water” as possible, to a point where it could be used for hand-washing. (***Caution***: Do not test any water samples by drinking or tasting them.) To accomplish this goal, you will use several different water-purification procedures:

- Oil–water separation
- Sand filtration
- Charcoal adsorption with filtration

Procedure

Prelab

Before starting, read the procedure to learn what you will need to do, note safety precautions, and plan necessary data collecting and observations. Data tables must be created and approved by your teacher. Your group will work together throughout the procedure and each student will turn in their own work. Reminder: Your work can have similar ideas, but may not be identical.

Part A - Before Treatment

1. Using a clean, 100 mL graduated cylinder, obtain approximately 75 mL of foul water.
    a. Record the *exact* volume of the foul water sample in your data table.
2. Describe, in detail, the color, odor, clarity, presence of oil, and presence of solids of your original sample.
    a. Record your observations in the “Before Treatment” section of your data table.
    b. Draw and color a diagram of your graduated cylinder and its contents.

Part B - Oil-water Separation

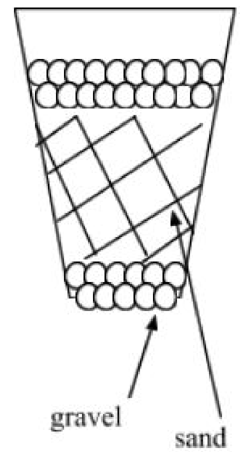
If oil and water are mixed together and left undisturbed, the oil and water do not noticeably dissolve in each other. Instead, two layers form. The oil floats on top because it is less dense than water.

3. Allow your sample to sit, undisturbed in the graduated cylinder for two minutes.
4. Use a plastic pipet to remove as much of the upper liquid (oil) layer as possible and place it in the 25 mL graduated cylinder.
    a. Record the exact volume of liquid that you removed on your data table.
    b. Record the volume of liquid sample remaining in the graduated cylinder in the “After Oil-water Separation” section of your data chart.
    c. Record a detailed description of the color, odor, clarity, presence of oil, and presence of solids of your sample.
    d. Draw and color a diagram of your graduated cylinder and its contents.

5. Dispose of the liquid (oil) in the “WASTE” beaker inside the fume hood and place your small, 25 mL graduated cylinder in the “USED” bin next to the “WASTE” beaker.

Part C - Sand Filtration

In filtration, solid particles are separated from a liquid by passing the mixture through a material that retains the solid particles and allows the liquid to pass through. The liquid collected after it has been filtered is called the **filtrate**. A sand filter traps and removes solid impurities— at least those particles too large to fit between sand grains—from a liquid.



6. Using a nail, make 5 – 10 small holes in the bottom of a disposable cup.
    a. Leave the nail at the table with the disposable cups so other groups don’t have to search for it.
7. Add gravel and sand layers to the cup as shown in the diagram to the right.
    a. The bottom gravel layer prevents the sand from washing through the holes. The top layer of gravel keeps the sand from churning up when the water sample is poured into the cup.
8. Set up a filter stand like the example on the front table. Make sure the bottom of the cup is no higher than the top of the beaker.
9. Place a clean, dry 250-mL beaker under the sand filter.
    a. Gently pour the sample to be filtered into the cup.
    b. Catch the filtrate in the beaker as it drains through.
    c. Tapping the cup several times will allow you to get out a few more drops of water.
10. Dispose of the used sand and gravel in the trash can near the teacher’s sink.
    a. Give your graduated cylinder to the teacher to clean and dry for you before moving on to the next step.
11. Pour the filtrate into a clean, dry 100-mL graduated cylinder.
12. Observe the properties of the filtered water sample and measure its volume.
    a. Record your detailed description in the “After Sand Filtration” section of your data chart.
    b. Draw and color a diagram of your graduated cylinder.

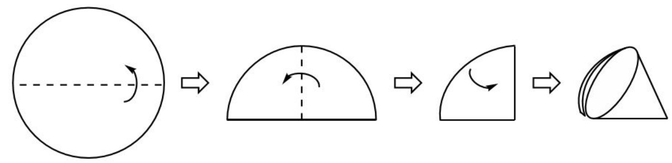
Part - D Charcoal Adsorption and Filtration

Charcoal adsorbs (attracts and holds on its surface) many substances that could give water a bad taste, a cloudy appearance, or an odor.

13. Reconfigure your filter set up with a plastic funnel, ring clamp, and clean, dry 250-mL beaker.

   a. Be sure to lower the ring so that the funnel stem extends inside the lip of your clean, dry 250-mL beaker. See example on front table.

14. Fold a piece of filter paper, as shown in the illustration to the right.



15. Place the folded filter paper in a funnel.
    a. Hold the filter paper in position and moisten it slightly so that it rests firmly against the base and sides of the funnel cone.
    b. Discard any liquid from this step and dry out your beaker.
16. Pour the water sample into a clean, dry, 250-mL Erlenmeyer flask.
    a. Ask your teacher to add a small scoop of activated charcoal to the flask.
17. Swirl the liquid in the flask for about 20 seconds.
    a. Gently pour the liquid through the funnel.
    b. Liquid should not flow between the filter paper and the funnel because that might permit unwanted charcoal and other solid matter to seep into the filtrate.
18. If the filtrate is darkened by small charcoal particles, once again filter the liquid through a clean piece of moistened filter paper.
    a. Discard the used filter papers in the trash can by the teacher's sink.
19. When you are satisfied with the appearance and odor of your charcoal-filtered water sample, pour the filtered water sample into a clean, dry 100-mL graduated cylinder.
    a. Record the final volume of the liquid sample remaining in the graduated cylinder in the "After Charcoal Absorption" section of your data chart.
    b. Record a detailed description of the color, odor, clarity, presence of oil, and presence of solids of your sample.
    c. Draw and color a diagram of your graduated cylinder and its contents.
20. Pour the final results of your filtered water sample into a round bottom flask.
    a. Cover the opening of the flask with a bit of plastic wrap.
    b. Use the BLUE TAPE and label your flask with the date, hour, and last name of one of your lab crew members.
    c. Place your flask in the bin under the fume hood.

Clean Up

21. Thoroughly wash all dirty equipment with soap and warm water.
    a. Put any wet equipment on the drying rack to dry.
    b. Return any other equipment to the location where you found it.
22. Get a copy of the analysis questions from the front table.
    a. Discuss as a group, but write your own answers.

Analysis Questions

1. What percentage of your original foul water sample did you recover as purified water? This value is called the **percent recovery**. Show your work for full credit.

   % recovery = final volume ÷ initial volume x 100%

2. What volume of liquid (in mL) did you lose during the entire purification process? Show work and include units for full credit.

   Volume lost = Initial volume – final volume

3. How did your results compare with the rest of the class? Did you get the highest or lowest percent recovery? What reasons can you give for your group's ranking?

4. Were there any mistakes or possible sources of error in your results? If yes, what were they? If no, what allowed you to work so accurately?

5. Do you think your water is pure enough to wash your hands in? Why or why not?

6. What was the most AND least interesting portions of the investigation for your group? Why?

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[2] Modified from American Chemical Society, (2012), *Chemistry in the community*. (6th ed.), New York, NY: Freeman

Properties of Matter

I can describe physical and chemical properties of water.

Properties of Water

Density

Melting Point

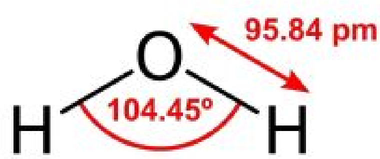
Boiling Point

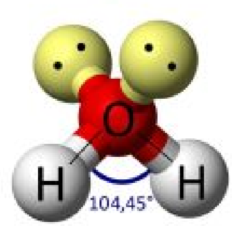
Structure

Water has a bent structure.

Recall, like charges repel.

The 2 lone pairs of electrons that are not bonded, force the hydrogens downward, giving the molecule a bent shape.



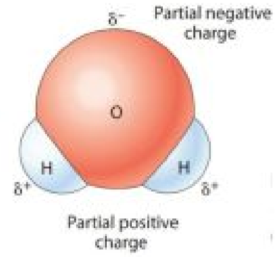


Polarity

Water is polar.

Recall, electrons are negative.

The unbonded electrons that have forced the hydrogens downward, have a partial negative charge. This gives water a negative charge on the oxygen side, and a partial positive charge on the hydrogen side.

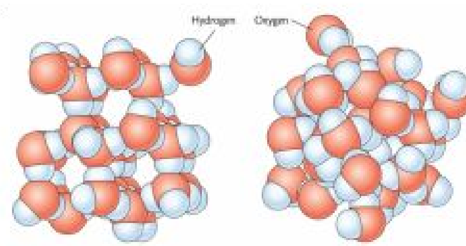


Bonding

Water molecules bond to each other using hydrogen bonds, which utilize cohesive forces.

Recal, opposite charges attract.

Hydrogen bonds are not really a bond, but more so an attraction (cohesive force) between the polar sides of the water molecule.



Water Jigsaw with Tyler DeWitt

You will be split into groups to watch Tyler DeWitt on YouTube.

Each group will watch a different video

After watching the video, your group will use the whiteboard to present the information you learned to the class.

Group 1: Dissolving Compounds in Water

Group 2: Hydrogen Bonding

Group 3: Distillation

Group 4: Phase Changes

Air pollution implicated in up to 4,000 Minnesota deaths a year

State researchers say risk is rural as well as urban.

By Greg Stanley Star Tribune JUNE 11, 2019 — 8:43PM

Air pollution contributes to as many as 10% of all deaths in Minnesota every year, while sending an additional 1,300 people to the hospital with heart and lung problems.

And the threat isn't confined to major cities. Airborne contaminants harm residents in every part of the state, especially the elderly, the poor, children with asthma, the uninsured and people with pre-existing medical conditions, according to a joint analysis released Tuesday by the Minnesota Department of Health and the Minnesota Pollution Control Agency (MPCA).

"This really reflects that it's not just a big city issue anymore, but you see it in these certain vulnerable populations," said Kathy Raleigh, a principal epidemiologist with the Health Department.

While it's no surprise that pollution is harmful to human health, over the past several years state health and air pollution officials have tried to calculate its toll on the public. In 2015, the state released a first-of-its kind study that focused on the Twin Cities and found that two of the most common pollutants — fine particles and ozone — contributed to as many as 2,000 deaths a year in the metro area alone.

Expanding that study to the entire state this year, researchers found that the death rate attributable to air pollution was actually higher in rural areas than in cities and was particularly bad in southern Minnesota and along the state's border with South Dakota. That's in part because those areas have higher proportions of older adults and people who are uninsured than the metro.

It also shows that air pollution, once considered primarily an urban problem, now afflicts the entire state, Raleigh said.

"We see some higher fine particulate matter in the metro, and then ozone has been a little higher in southern Minnesota, but air pollution across the state doesn't change a lot," she said.

What does change, she said, is the underlying conditions of the population. The report found that pollution aggravates existing health problems such as heart and lung disease. It tracked hospital visits and deaths caused by heart and respiratory events and compared them with the annual air quality of each county. It is estimated that pollution contributed to between 2,000 and 4,000 deaths throughout a single year.

Long-term progress

Air quality has generally been improving since Congress passed the Clean Air Act in the 1970s. Some of the biggest gains have come recently from power plants, as more and more shifted from coal to natural gas. A majority of the most harmful air pollutants are now coming from smaller and more widespread sources such as cars, trucks and backyard fires, which are not regulated in the same way as factories and power plants, according to the MPCA.

Minnesota has reduced fine particle pollution by about 10% over the past decade, according to the agency's data. The report estimates that if the state reduces those levels by another 10% it could prevent up to 500 deaths and more than 100 hospitalizations and emergency room visits annually.

However, some of the worst pollutants are now generated outside the state and carried in by the wind from events such as the wildfires in Canada and the Pacific Northwest.

It's not enough to just cut pollutants within the state, Raleigh said. More needs to be done to help make vulnerable residents more resilient.

"We can see those populations with a higher percent in poverty and higher percent uninsured are more vulnerable," she said. "If we can do more to decrease those structural inequities, those barriers, that will lay the foundation."

Air Investigation

Introduction

Gases such as carbon dioxide and water vapor are naturally present in the atmosphere. Because atmospheric gases are generally colorless, odorless, and tasteless, you might doubt that they are forms of matter; they seem to be "nothing." However, gases do have definite physical and chemical properties, just as the materials in the other two states of matter - solids and liquids - do. In this investigation, you will complete activities that illustrate some properties of air.

Procedure

Six stations have been set up around the lab. At each station, you will complete the activities indicated for that station. These activities can be done in any order; that is, work at station 4 can be completed before station 2's activities, and so on. Follow these general instructions.

- Reread the procedure
- Review your prediction
- Complete the activity
- Record your observations
- Reset the station to its original condition

Prelab

Note safety precautions and plan necessary data collecting and observations. Your group will work together throughout the procedure and each student will turn in their own work. Reminder: Your work can have similar ideas, but may not be identical.

Station 1:

1. Draw some air into the syringe provided.
2. Seal the tip by placing a cap on the open end.
3. Holding the cap in place, gently push the plunger down with your thumb.
4. Release the plunger.
5. Record your observations.

Station 2:

1. Inflate and tie off two (2) balloons so that they are approximately the same size; about the size of a grapefruit.
2. Use tongs to submerge one inflated balloon in an ice-salt water bath.
3. Use tongs to submerge the other inflated balloon into a container of hot tap water.
4. Record your observations.

Station 3:

1. Place the plastic cup, upright on the electronic balance and press "Tare."
2. Place the inflated balloon on the cup so that it doesn't roll away.
3. Record the mass of the balloon.
4. Remove the balloon and cup from the balance and press "Tare."
5. Place the deflated balloon on the balance.
6. Record the mass of the deflated balloon.

Station 4:

1. Insert the rounded end of a new, uninflated balloon part way into an empty pop bottle, stretching the balloon's neck of the mouth of the bottle.
2. Try to blow up the balloon so that it fills the bottle.
3. Remove and discard the used balloon.
4. Record your observations.

Station 5:

1. Fill a test tube to the rim with water.
2. Cover the test tube opening with a piece of paper.
3. While holding the paper to the top of the test tube, invert the test tube over the sink.
4. Without causing any sudden movements, gently remove your hand from the paper while still holding the test tube inverted over the sink.
5. Repeat the process with the test tube half-full of water.
6. Record your observations.

Station 6:

1. Everyone in the group, put on the safety goggles provided.
2. Place about 5-10 mL of water into a clean, empty pop can.
3. Place the can on a hot place and bring the water to a boil.
   a. You should be able to hear the water boiling as well as see steam coming from the top opening of the can.
4. Using tongs to handle the can, quickly remove the can from the heat and immediately invert it into a container of ice water.
5. Record your observations.

Analysis Questions

1. Which of the stations suggests that air is composed of matter? Explain using observational evidence to support your answer.

2. For each station, briefly describe how well your predictions corresponded with the actual results you observed, and propose explanations for any differences between your predictions and the observed results of the station.

3. For any of the stations:
   a. Describe your observations in detail
   b. Explain the role of air in the station
   c. Draw particle models that show the interactions between the gas particles and the other particles of matter.

4. Describe an experience outside of this investigation that suggests:
   a. Air is matter
   b. Air exerts pressure

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[3] Modified from American Chemical Society, (2012), *Chemistry in the community*. (6th ed.), New York, NY: Freeman

Properties of Matter

I can identify physical and chemical properties of gases.

Gases

KMT Gases: "Ideal Gases" have the following properties:

1. Gas particles are in constant random motion

2. Gas particles contain all of their mass at one point; the particles themselves occupy no volume; the volume they occupy is due to particle motion and collisions

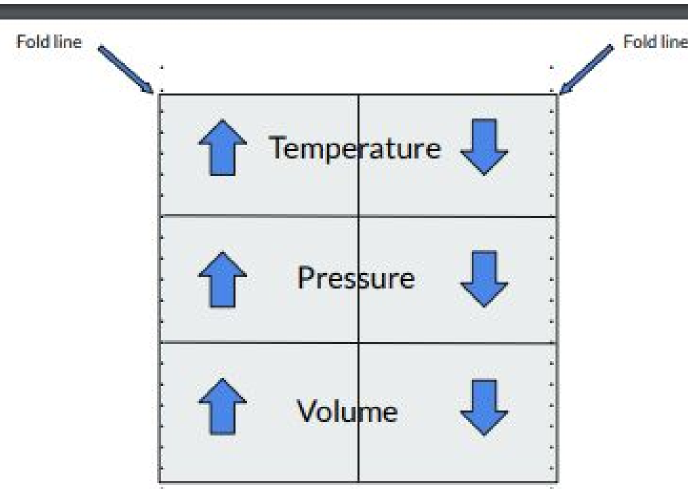
3. Collisions between gas particles are perfectly elastic (no energy is lost during the collision)

4. Gas particles have no attraction for each other

Foldable

You'll need the following:

- 1 piece of paper
- 1 scissors
- 1 glue stick



Temperature - Lussac's Law

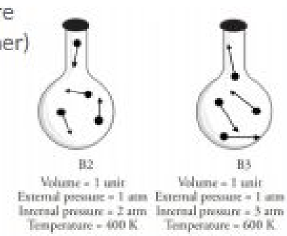
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

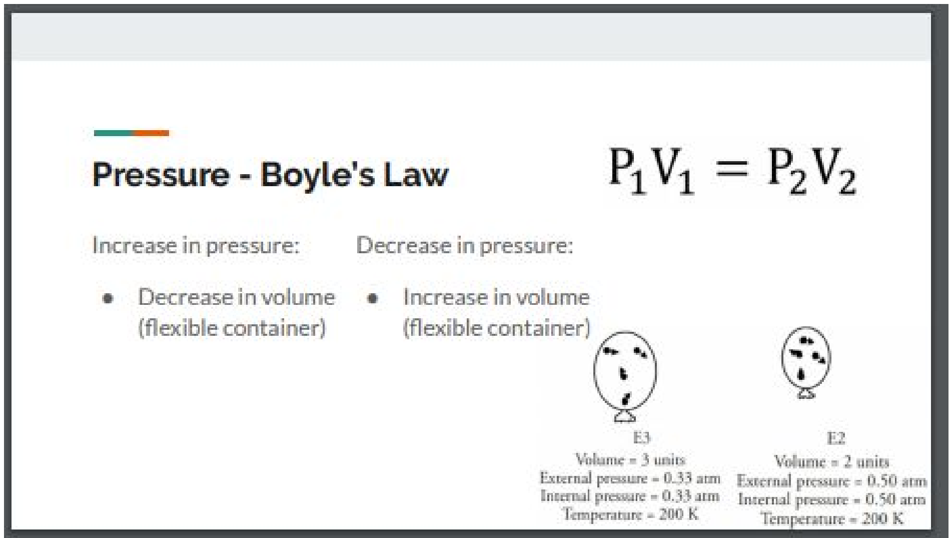
Increase in temperature:

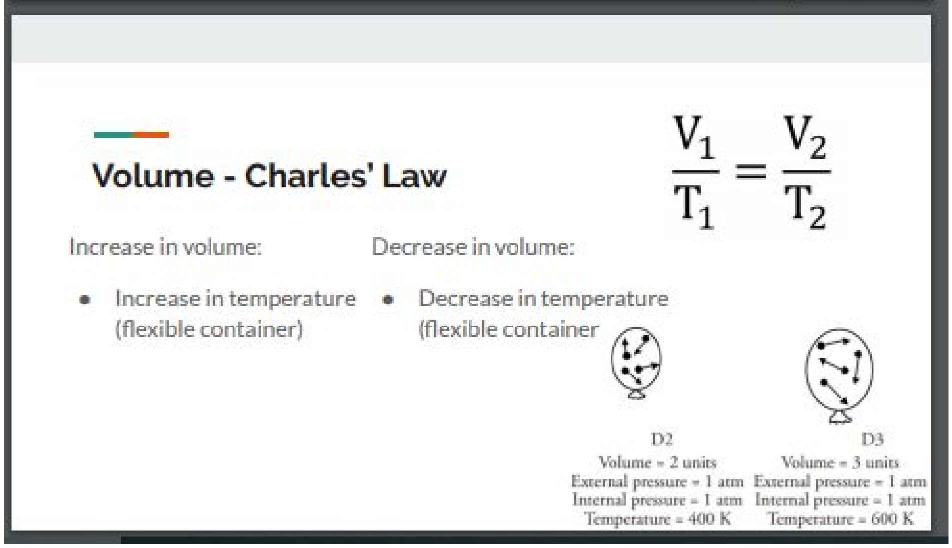
- Increase in pressure (nonflexible container)

Decrease in temperature:

- Decrease in pressure (nonflexible container)



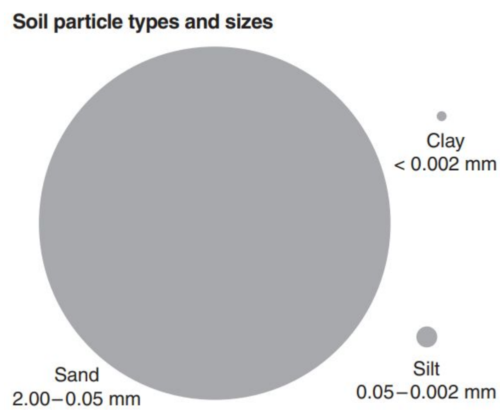

Pressure - Boyle's Law
$P_1V_1 = P_2V_2$
Increase in pressure:
• Decrease in volume (flexible container)
Decrease in pressure:
• Increase in volume (flexible container)
E3
Volume = 3 units
External pressure = 0.33 atm
Internal pressure = 0.33 atm
Temperature = 200 K
E2
Volume = 2 units
External pressure = 0.50 atm
Internal pressure = 0.50 atm
Temperature = 200 K


Volume - Charles' Law
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Increase in volume:
• Increase in temperature (flexible container)
Decrease in volume:
• Decrease in temperature (flexible container
D2
Volume = 2 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 400 K
D3
Volume = 3 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 600 K

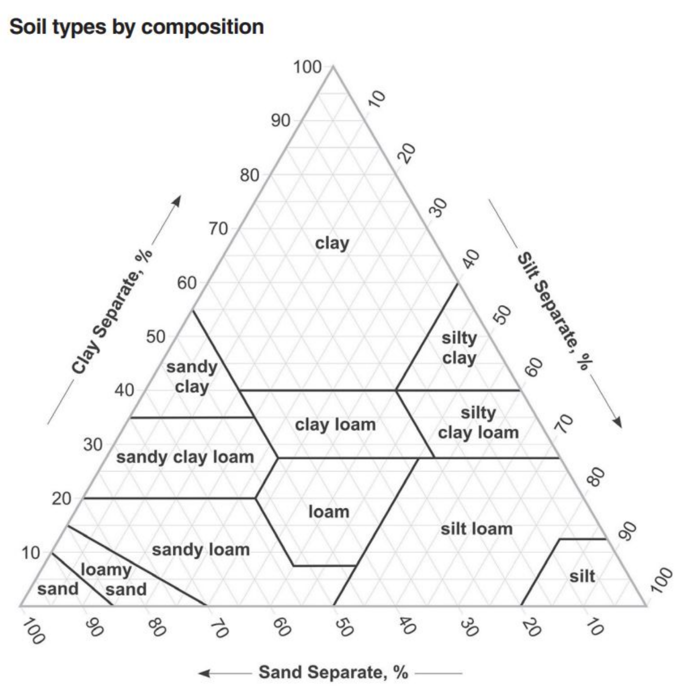
Soil Texture and Soil Water Permeability Lab

Introduction

When it rains, water lands on the ground and flows into streams, rivers, gutters, and sewers. It can also soak into the ground. The ground is made up of rock and soil. Soil is composed of many small particles. In between these particles are pores. Water can flow into and through these pores. *Soil water permeability* is defined as the rate at which water can flow through the pores of a soil. Rainwater tends to seep into soils that have high soil water permeability and tends to pool on top of or flow over soils with low soil water permeability. There are several different physical properties of soil that can affect the rate at which water flows through it.



One of the physical properties of soil that affects soil water permeability is soil texture. Soil is composed of small particles that vary in size, shape, and chemical composition. There are three main types of soil particles (see the figure to the right): (1) sand particles are between 0.05 mm and 2.0 mm in diameter, (2) silt particles are between 0.002 mm and 0.05 mm in diameter, and (3) clay particles are smaller than 0.002 mm. Soil texture describes the relative proportion of sand, silt, and clay particles by weight in soil sample. Earth scientists use a soil texture triangle (such as the one shown below) to classify soils according to 12 textural categories, based on the proportions of each particle type in the soil sample. For example, a soil that is composed of 30% clay, 10% silt, and 60% sand is classified as a sandy clay loam; whereas a soil that consists of 20% clay, 40% silt and 40% sand is classified as a loam.



Geotechnical engineers are often concerned about the water permeability of soil because they are responsible for building structures on or in the ground, and the rate at which water flows through soil can have an adverse effect on these structures. Geotechnical engineers must therefore understand how the physical properties of soil affect the rate at which water flows through it. In this lab, you will have an opportunity to examine how texture, which is an important physical property of soil, affects soil water permeability.

Question

How does soil texture affect soil water permeability?

Use what you know about soil composition; scale, proportion, and quantity; and the importance of tracking how matter moves into, through, and out of a system to plan and carry out an investigation to determine the relationship between soil texture and soil water permeability.

Materials

You may use any of the following materials during your investigation:

- Soil sample A
- Soil sample B
- Soil sample C
- Soil sample D
- 12 Coffee filters
- Paper towels
- Gloves (required)
- Scoopula
- 1 Graduated cylinder (100 ml)
- 1 Graduated cylinder (50 ml)
- 1–4 Funnels
- 1–4 Beakers (each 250 ml)
- 1–4 Support stands with ring and clamp
- 1 Stopwatch
- 1 Wax marking pencil
- Electronic balance
- Flowchart for soil texture by feel

Safety

Follow all normal lab safety rules. In addition, take the following safety precautions:

- Wear gloves throughout the entire investigation (which includes setup and cleanup).
- Handle all glassware with care.
- Report any spills immediately, and avoid walking in areas where water has been spilled.
- Wash hands with soap and water when done collecting the data and after completing the lab.

Procedure

Before you begin to design your experiment using this equipment, think about what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine what type of data you need to collect, think about the following questions:

- How can you track water flowing through soil?
- What information about a soil sample do you need to determine its texture?
- What information will you need to calculate a rate?
- What type of measurements or observations will you need to record during each experiment?
- When will you need to make these measurements or observations?

To determine how you will collect the data, think about the following questions:

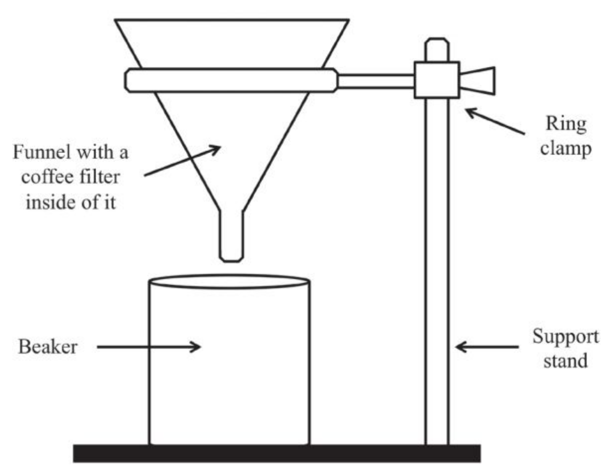
- What will serve as your independent variable and dependent variable?
- How will you vary the independent variable during each experiment?
- What will you do to hold the other variables constant during each experiment?
- What types of comparisons will you need to make?
- What measurement scale or scales should you use to collect data?
- What will you do to reduce error in your measurements?
- How will you keep track of and organize the data you collect?

To determine how you will analyze the data, think about the following questions:

- What calculations will you need to make?
- How could you use mathematics to describe a relationship between variables?
- How could you use mathematics to document a difference between groups or conditions?
- What types of patterns might you look for as you analyze your data?
- What type of table or graph could you create to help make sense of your data?

1. Determine the rate at which water flows through a soil sample using the equipment illustrated to the right.
2. Place a sample of soil inside the coffee filter
3. Add water to the soil.
    a. The water will flow through the soil and the coffee filter and then land in the beaker. Your teacher will let you know where you can get samples of different types of soil.

Equipment needed to measure the rate at which water flows through a sample of soil



Summary

Write a one-page summary of your investigation. Your summary should include the following:

- Description of lab set-up (this can include a drawing/diagram)
- Detailed procedure
- Investigation results (including your data table)

Claim, Evidence, Reasoning

Once your group has finished collecting and analyzing your data, you will need to develop an initial claim. Your claim needs to include evidence to support your claim, and a justification of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims.

You may work and discuss as a group, but your summary and CER must be your own work.

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[4] Modified from Sampson, V., Murphy, A., Lipscomb, K., & Hutner, T. (2018). *Argument-driven inquiry in earth and space science: Lab investigations for grades 6-10*.

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