Engineering Tomorrow

Clean Water

Filtration Systems & Water Conservation

GOAL

To create a filter to reduce the turbidity of water

Breakout Development Team

EDGAR MARTINEZ

College: Columbia University
Major: Civil Engineering, B.S.
Industry Experience: Skanska USA Underpinning and Foundation; John P. Picone Inc.

MUNA DAUD

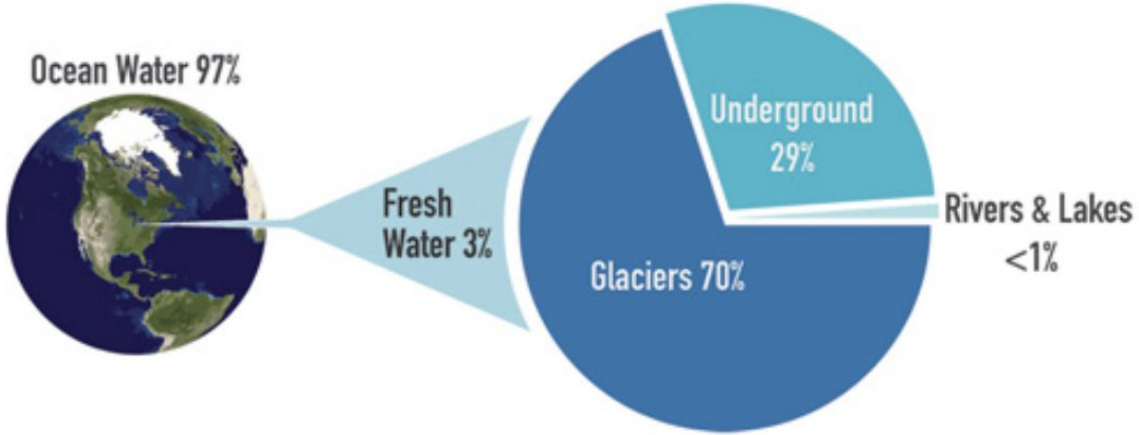
College: The George Washington University
Major: Biomedical Engineering

CAROLINE GILLESPIE

College: Notre Dame ’23
Major: Mechanical Engineering

What is your Water Footprint?

Your water footprint is defined as the total volume of fresh water used to produce the goods and services you consume.



QUESTIONS

1. What do you use water for other than drinking?
2. How many times today have you used water?
3. **What does this tell you about the importance of water?**

Do you know?

Use your math knowledge to try and answer the following questions related to water.

- HOW MANY CUPS ARE IN A LITER OF WATER?

- HOW MANY CUPS ARE IN A GALLON OF WATER?

- HOW MUCH WATER DOES IT TAKE TO MAKE YOUR MORNING LATTE?

Do you know?

Use your math knowledge to try and answer the following questions related to water.

HOW MANY CUPS ARE IN A LITER OF WATER?

A little bit more than 4 cups, 4.22 to be exact

HOW MANY CUPS ARE IN A GALLON OF WATER?

16 cups

HOW MUCH WATER DOES IT TAKE TO MAKE YOUR MORNING LATTE?

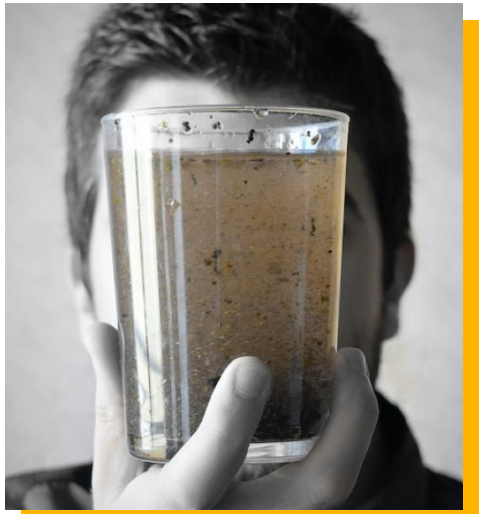
801.8 cups or 190 liters!

Let’s Solve Water

After watching…

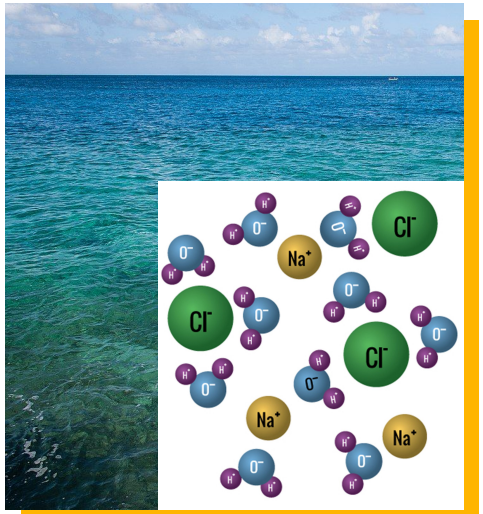
1. What are three things you learned from the video?
2. What are some ways you can lessen your water footprint?

What Contaminates Water?



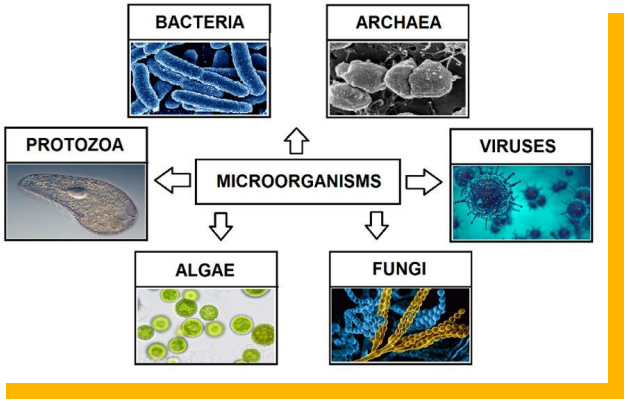
SUSPENDED SOLIDS

Remove by Screening, Settling, Filtration



DISSOLVED MATERIALS

Remove by Softening, Ion Exchange, Reverse Osmosis, Aeration, Deaeration, Adsorption



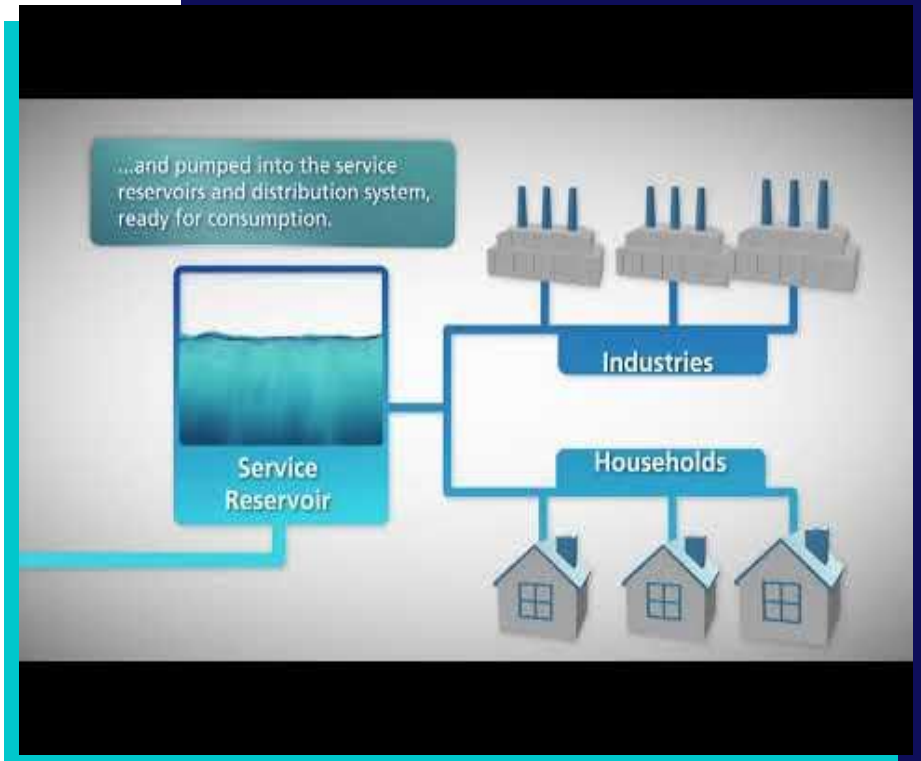
MICROORGANISMS

Remove or make harmless by Chlorination, UV irradiation, Chemical treatment

Water Treatment Is a Multi-Step Process

1. Collect water from various sources including reservoirs, rain, and used water.
2. Add chemicals to coagulate small particles to larger particles called floc which settle and create sludge, which is removed.
3. Filter the clarified water in sand, multimedia filters, or membrane filters.
4. Disinfect using chlorine and ozone.
5. Store and distribute the clean water to homes and businesses.

Each water treatment process is designed based on the contaminants in the original source water.



Today's Clean Water Lab: Filtration

The Water Problem and Possible Solutions

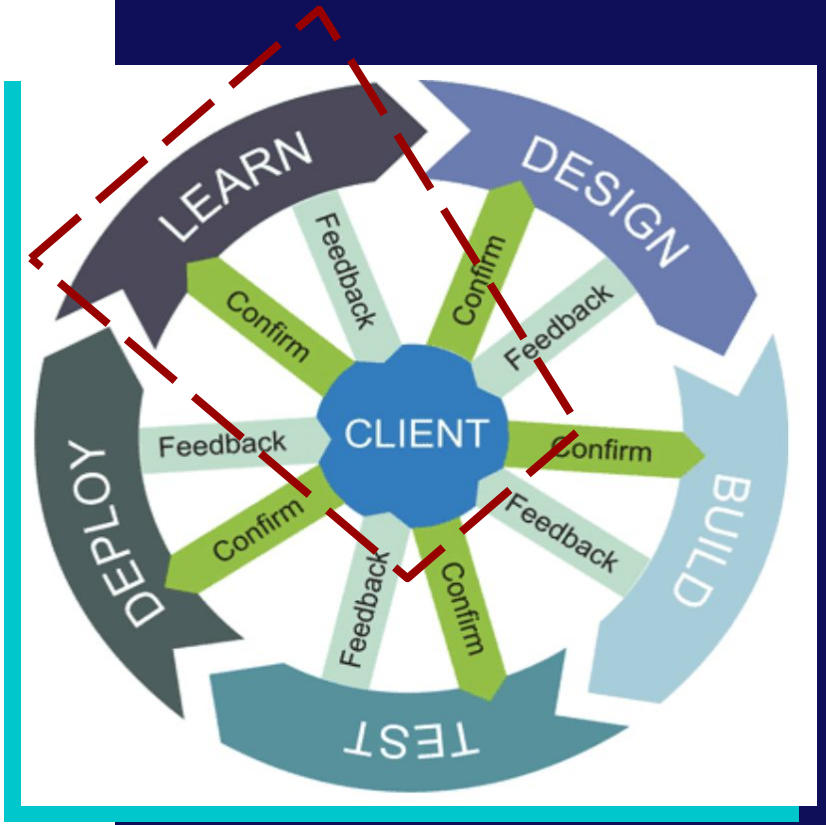
1. Water scarcity needs engineered solutions
2. Water treatment process allows for water reuse
3. Engineers use a process to solve problems

FILTRATION DESIGN CHALLENGE
Design, build, and optimize a water filter

The Engineering Design Process

Iterative Process

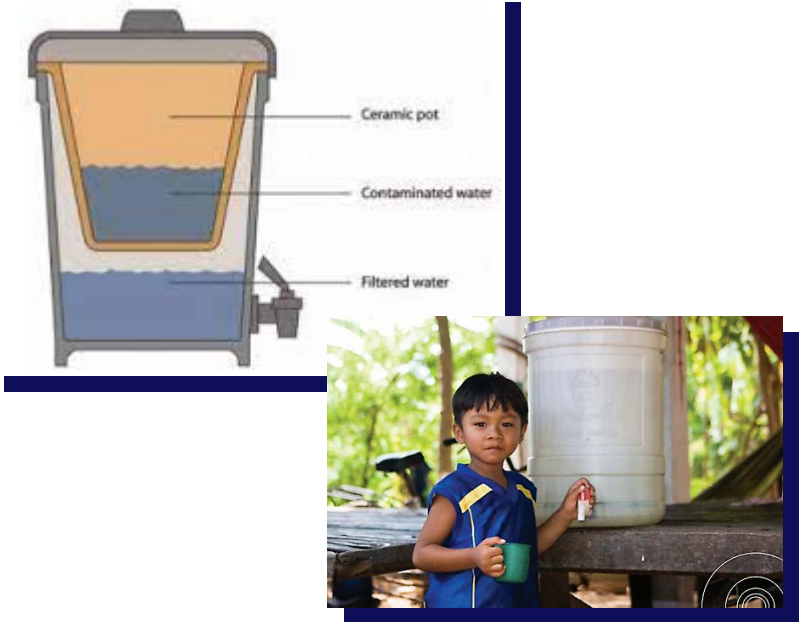
1. Learn / Research / Observe
2. Obtain feedback from customer client
3. Confirm
4. Learn / Research / Observe & collaborate



Let’s Talk About Filtration

LIFESTRAW

Tailored for limited resources
of the client / customer



CERAMIC WATER FILTERS

Inspired by Nature

CLEAN WATER LAB

Filtration

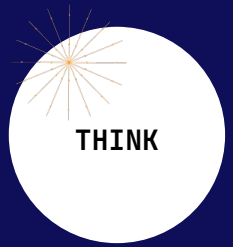
YOUR CHALLENGE

Design, build, and optimize a water filter

What is Water Filtration?

WATER FILTRATION:

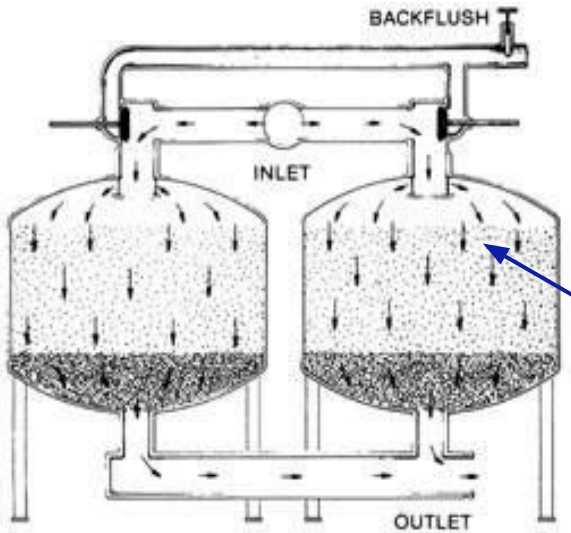
The process of removing or reducing the concentration of particulate matter, including suspended particles, parasites and other undesirable contaminants from dirty water.

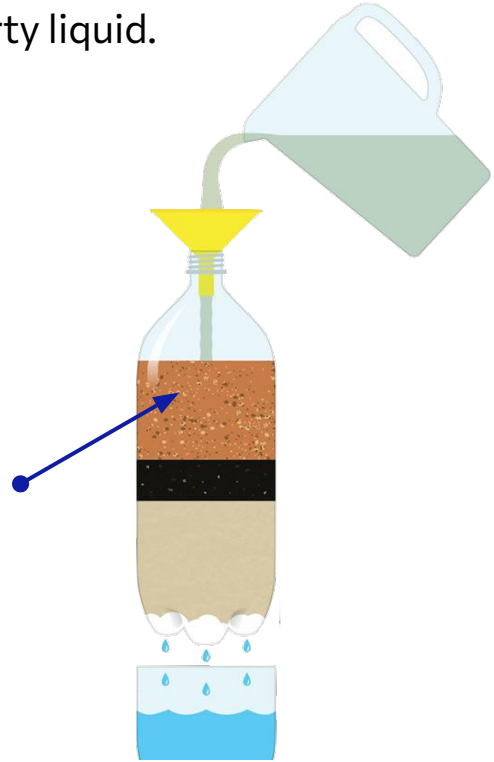


1. What **industries** use the process of water filtration?
2. What **fields of engineering** would be involved in the process of water filtration?

Multimedia Filtration

`MULTIMEDIA FILTRATION:` Water filtration through a container that has layers of different materials (such as sand, gravel, etc) to **trap the solid matter** from the dirty liquid.





Lab Overview

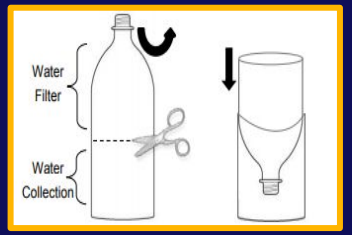
1. **IDENTIFY THE PROBLEM:** What problem or challenge is your group trying to solve?
2. **RESEARCH:** What materials could you use? How could you layer them?
3. **DESIGN YOUR SOLUTION:** List the materials in your filter, their quantity and order.
4. **BUILD YOUR FIRST PROTOTYPE:** Create your first prototype of your water filter.
5. **TEST:** Test your filter by pouring the dirty water you created into your filter.
6. **ANALYZE YOUR RESULTS:** Use your observations and data to answer questions in your student workbook, and determine how to improve your next filter design.

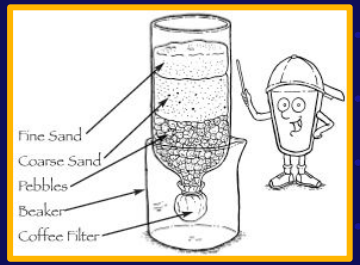
POSSIBLE FILTER SYSTEM MATERIALS

- Gravel
- Sand
- Coffee filter
- Cotton Ball
- Napkin/Paper Towel

Which will YOU use?

WATER FILTER EXAMPLE

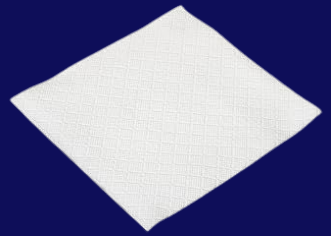




The Components for Water Filters

½ Cup of Pea Gravel

15 x Cotton Balls

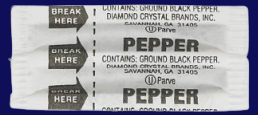


5 x Napkin

½ Cup of Sand

5 x Coffee Filters

1 x Pepper Packet



1 tbsp of ground Cinnamon

Duct Tape Strip (for assembly)

Hints

- **Your group will build multiple filters to test with contaminated water.** Your filters will be judged based on how much water they can filter each time, and how clear your filtered water is. You will measure water clarity using the rubric figure and container you have created.

- Before building anything, **think about how the water will flow through the materials in your filter, how it could clog**, what limits flow rate and filtration effectiveness, and how that impacts your planning. Consider the design in the layering of different filter materials, or even which materials you would use.

- **You should pre-saturate / test your system** with your clean water before using it with dirty water to test the expected flow rate you will achieve, and to make sure any filter material contaminants are washed out.

- Use the **iterative process** to improve your filters based on what you observed from the previous ones.

- Be sure to take before and after photos of your water and your filter system to share with the class!

Water Filtration Walk Through

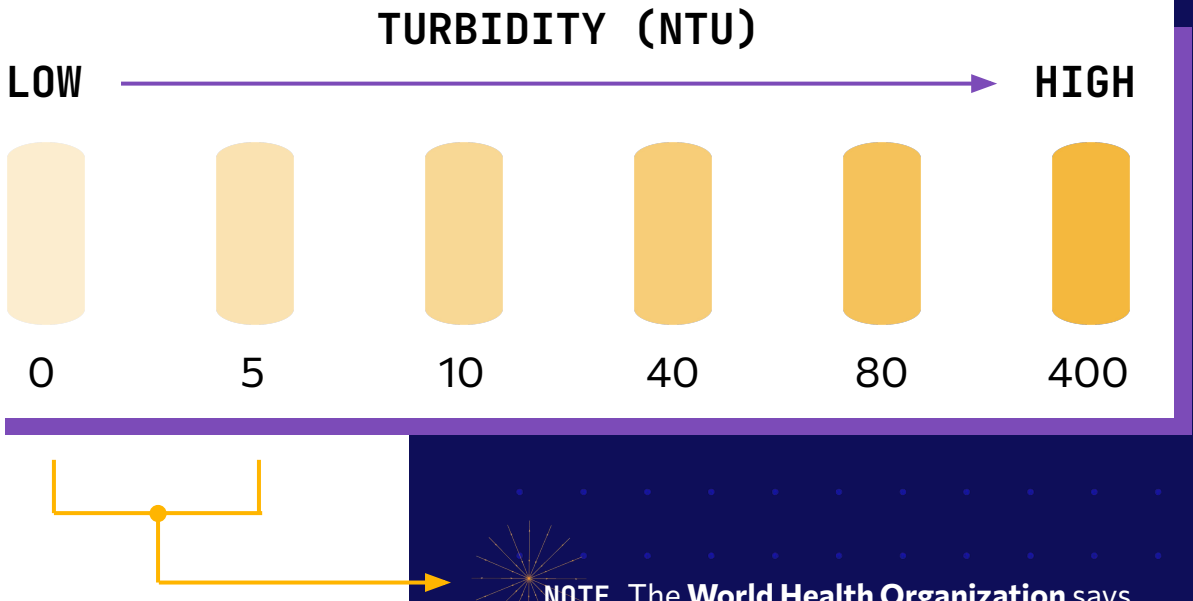
RESULT ANALYSIS PART 1:

Turbidity of your Water Sample

What is Turbidity?

TURBIDITY

Cloudiness of a fluid caused by mixed-in particles – similar to smoke in the air. Turbidity measures water quality in units of NTU on a scale from 0 to 400

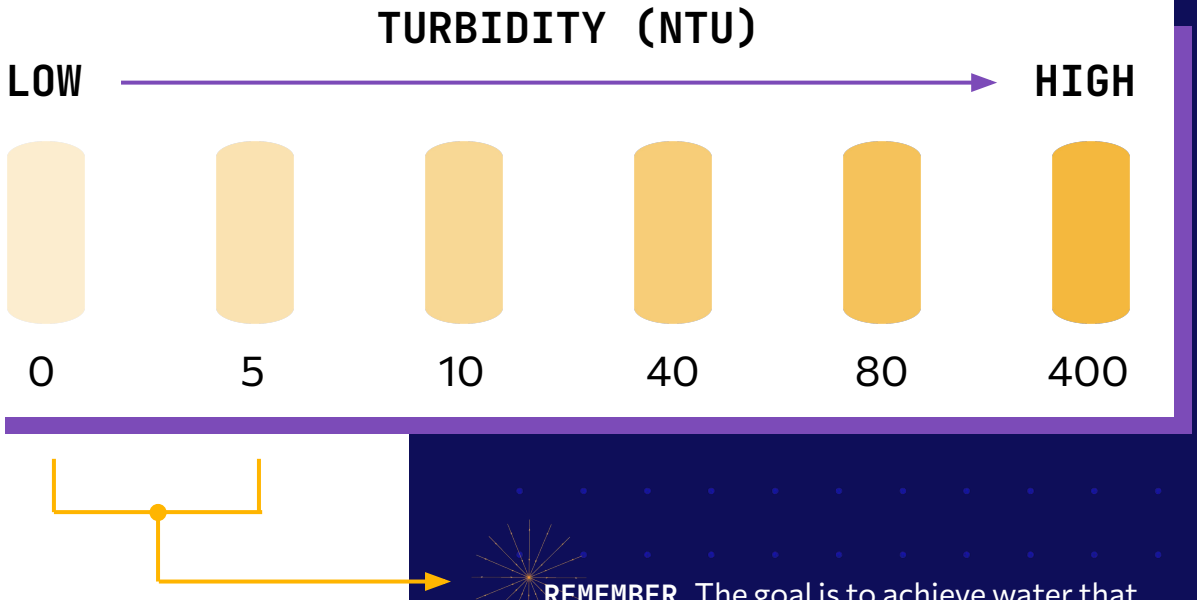


NOTE The **World Health Organization** says that the **turbidity of drinking water** should always be **below 5 NTU**.

Turbidity of your Water Sample

DIRECTIONS

Determine the turbidity of your water sample by comparing it to the turbidity chart below. On the next slide determine the cost related to this turbidity value.



REMEMBER The goal is to achieve water that has turbidity **less than 5 NTU** to get the lowest cost.

RESULT ANALYSIS PART 2:

Determine the Economics of your Design

Cost Associated with Turbidity of your Water Sample

How much water did you 'produce' in your filter in 60s? The flow rate of your filter is also important

How effective was your filter?
Find the cost of additional filtering based on the turbidity you recorded.

Turbidity	Not Filtered. Not cleaner.	Filtered Water 400 - 80 NTU	Filtered Water 80 - 10 NTU	Filtered Water 5 - 0 NTU
ADDED COST	$100	$70	$40	$10

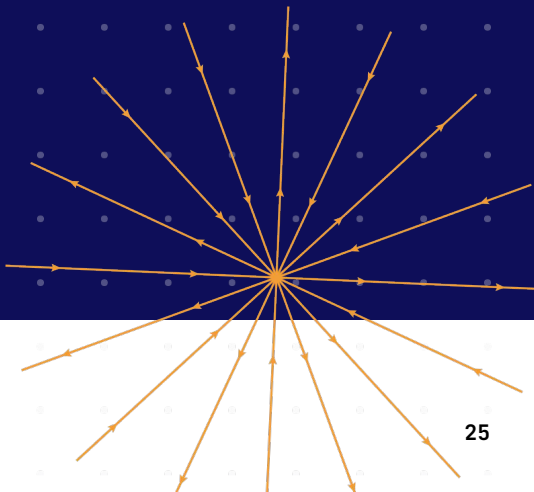
REMEMBER Lower turbidity means "cleaner" water. Cleaner water requires less additional treatment which lowers additional processing cost.

Continue to Explore

- **IF YOU LIKED TODAY'S BREAKOUT, YOU MAY BE INTERESTED IN THESE TOPICS:**
  - Osmosis and Reverse Osmosis
  - Stokes Law
  - Clarifier Design
  - The Social Impact of Clean Water
  - Fluid Dynamics
- **TYPES OF ENGINEERING RELEVANT TO TODAY'S CLEAN WATER BREAKOUT:**
  - Environmental Engineering
  - Chemical Engineering
  - Civil Engineering
  - Materials Science

Further Resources and Extension Activities

This section will provide an overview of the extension and optional. These activities are opportunities for students to dive deeper and ideate. The materials associated with the extension labs may not provide as many detailed instructions as the main lab activity.



Further Extension Activities

Settling: Clarifier

Hands-On Water Quality Test

Interactive Online Simulation

CLEAN WATER OPTIONAL LAB EXTENSION #1

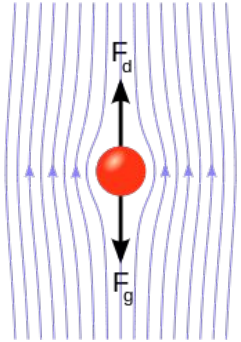
Settling: Clarifier

Optional extension activities are opportunities for students to dive deeper and ideate. The materials associated with the extension labs may not provide as many detailed instructions as the main lab activity.

YOUR CHALLENGE

Design, Build, and Optimize a Settling Step and Add it to Your Filtration Step

Water Treatment Fundamentals



STOKES LAW:

$$V = \frac{d^2 g(\rho_p - \rho_s)}{18\eta}$$

BROWN WATER

FLOCCULATION, COAGULATION & SETTLING IN A CLARIFIER
Removes larger suspended solids

MICROFILTRATION
ULTRAFILTRATION
Removes smaller solids and bacteria

Reverse Osmosis (RO)
Removes dissolved solids

Disinfection (Chemical or UV)
Kills any remaining organisms

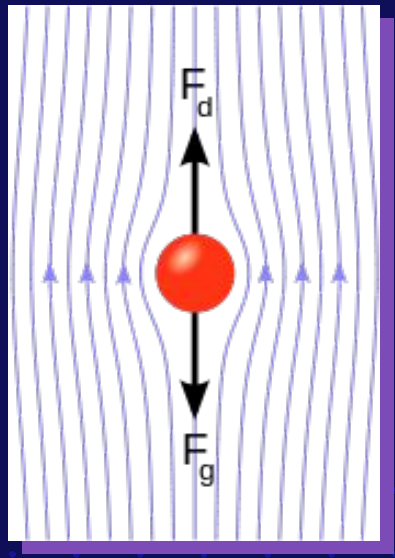
CLEAN WATER

Particle Settling Rate

The settling velocity of a solid particle in water is given by **Stokes Law**:

$$V = \frac{d^2 g(\rho_p - \rho_s)}{18\eta}$$

- **WHERE:**
  - V – settling velocity in m/s
  - d – particle diameter in m
  - g – gravitational constant (9.78 m/s2)
  - ρp – density of the particle (kg/m3)
  - ρs – density of water (1000 kg/m3)
  - η – dynamic viscosity of water (0.001 kg/(m s))



QUESTION 1 If you have suspended particles of clay (density of 1600 kg/m3) that are 0.00001 m (10 microns) in diameter in water, how far will it settle in 5 min?

QUESTION 2 What if they were 0.00005 m (50 microns) in diameter?

A Simple Clarifier

A clarifier is a step in the water treatment process where the water is slowed down to give time for particles and floc to settle to the bottom, while the cleaner water at the top goes to the next step.

Combine this Clarifier with your Filter to make a two-step Treatment Process

1. Cut a plastic water bottle in half

2. Make a few small holes on one side of the end of the bottom half to act as a weir where the clarified water will flow through

3. Insert the bottom half backwards into the top half

4. Orient your clarifier at an angle with the holes to the top and slowly pour in the dirty water. You should see that the retained water has more particles than the clarified water

Engineering Ideas To Consider

- Can you build a structure to hold your clarifier so that the clarified water output goes directly into your multimedia filter?
- How does the speed at which you pour in your water impact how much settles in the clarifier and doesn't pass to the filter?
- How would you decide how many, how large, and what pattern of holes you would use in your clarifier?
- Are there any additives you could mix with your dirty water before pouring it into the clarifier that would make the clarifier more effective?
- Can you think of other designs of a flowing system with a "slow step" which can act as a clarifier? Design and sketch a system on paper and explain why you designed it that way.

FACT Natural pools or eddies in a stream or river is nature's way of clarifying water as that is where debris has time to settle out making the downstream water clearer.

Further Extension Activities

Settling: Clarifier

Hands-On Water Quality Test

Interactive Online Simulation

CLEAN WATER LAB OPTIONAL EXTENSION #2

Hands-On Water Quality Test

Conduct a series of guided qualitative water tests at home or school to determine the purity and safety of your drinking supply.

Home Water Quality Testing

- Color, Taste, & Odor Test
  - Use these 3 key components to compare bottled, distilled water with your household tap water
  - Take note of any funky tastes, smells, or colors in household water

- Water Hardness Test
  - **Water Hardness**: total concentration of dissolved calcium and magnesium solids in water sample
  - Dispense tap water into ladle/large spoon
  - Leave spoonful of water sitting for 24-48 hrs
  - Once all water has evaporated look for white spots or sticky residue on spoon

In-Depth Testing Guide: https://www.raynewater.com/blog/how-to-test-your-water-quality-at-home-without-a-kit/

Home Water Quality Testing

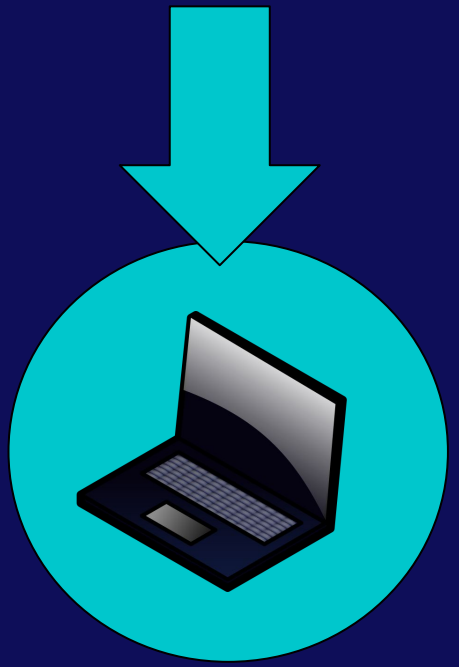
- Visual Test
  - Fill a clear glass bowl or glass with tap water
  - Place container in bright light and use a magnifying glass to observe any floating particles
  - Not all contaminant particles are visible to the naked eye
  - Not all contaminants are harmful but still a good indicator of water quality

- Dissolved Solids Test
  - Fill a small pot with 1 Cup of tap water
  - Heat water to a boil on stovetop
  - Turn off heat when most of the water has evaporated
  - Once the pot has cooled completely run your fingers along the bottom of the pot to feel for gritty or chalky residues that may indicate dissolved solids in your water

Further Extension Activities

Settling: Clarifier

Hands-On Water Quality Test



Interactive Online Simulation

CLEAN WATER LAB OPTIONAL EXTENSION #3

Interactive Online Lab Simulation

Follow the water sampling and testing procedures carried out in a true lab using a step by step online simulator.

Part A: Sampling Lab

Part B: Testing Lab

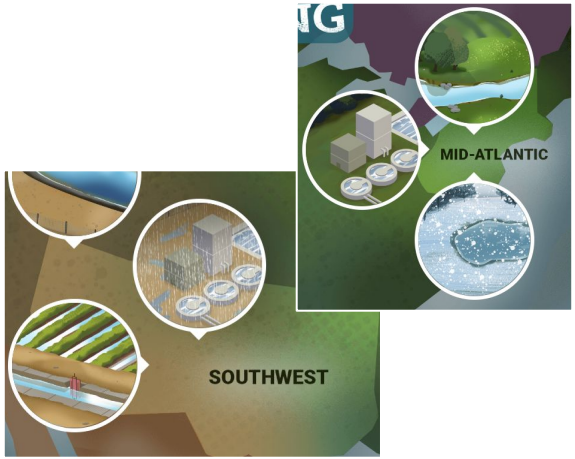
Part A: Sampling Lab

- Use this link to access the lab
  https://conserve.nmsu.edu/conserve-sampling-app/index.html
- Choose a water source:
  - **Locations:**
    Southwest: Pond, Canal, Wastewater Treatment Plant

    Mid-Atlantic: Stream, Pond, Wastewater Treatment Plant
  - **Types of Data:**
    pH: how acidic/basic the water is

    Temperature: how hot or cold the water is

    Turbidity: color of the water
- Complete the What Have You Learned on next slide



Part B: Testing Lab

- Use this link to access the lab
  https://conserve.nmsu.edu/conserve-testing-app/index.html
- Can start on either day:
  - **Day 1:**

    Learn how to prepare samples to later analyze the grown colonies
    - Dilution: Make a liquid thinner/weaker by adding water or solvent
  - **Day 2:**

    Count the colonies and use data to perform calculations
    - Total Coliforms (TC): Bacteria found water influenced by surface water or waste
- Complete the What You Have Learned on next slide

Thank you!