Wastewater Treatment Lab

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Overview

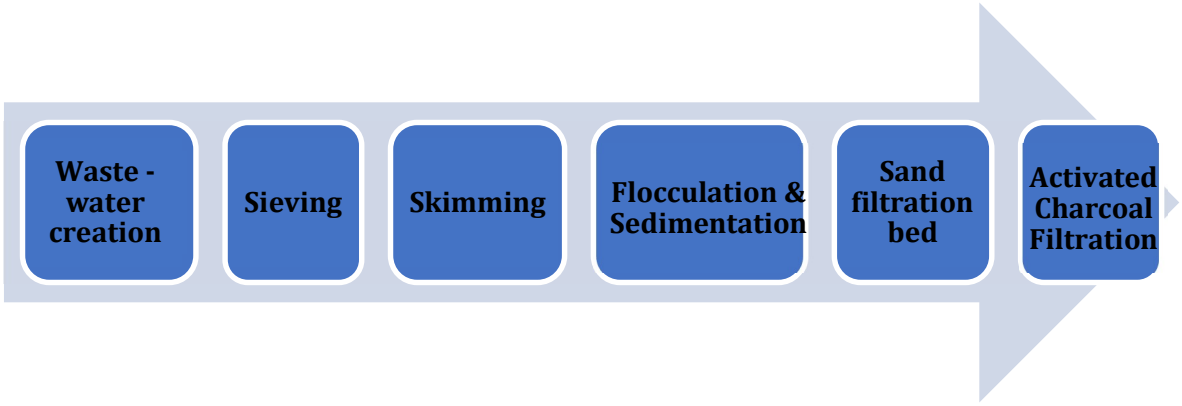
This activity will simulate a real-world wastewater treatment plant using simple steps easily performed at lab scale and familiarize students with the various processes of a wastewater treatment plant. Student will learn about different constituents that make a wastewater streams and how different pollutants are removed from wastewater at each successive stage of water purification. This activity can be used to purify wastewater collected from a local wastewater source or wastewater can be prepared by adding materials such as soils, sands, dry and green leaves, vegetable oils, soaps, food coloring, vinegar etc.

Learning Objective

After this activity, students should be able to:

- Learn about different type of wastewaters: domestic wastewater, industrial wastewater and Why wastewater treatment is required
- Develop and simulate wastewater treatment plant at lab scale
- Understand basic scientific definition and process such as sieving, immiscibility, flocculation & sedimentation, filtration
- Observe different type of wastes as removed at each successive step, screening vs clarification vs filtration
- Compare & contrast the different type of pollutants removed at each successive step
- Compare and measure the quality of water before and after treatment (PH, Temperature, Odor, and Visual

Summary of the lesson activities



How students will demonstrate their learning

- Depending upon initial wastewater samples, students can be asked to evaluate and explain the differences in final treated water

- Students can be asked to investigate the different type of contaminants separated at each stage and explain the reason for it
- Students can classify each of treatment steps into physical, chemical, or biological method of contaminant removal
- Students can be asked to describe different usage of partially treated water
- Students can be asked to investigate local wastewater treatment system/ municipal water treatment facilities to describe similarities and dissimilarities with the process employed in this lab activity

Content Standards:
This lesson is appropriate for earth/environmental science, biology, physical science, and chemistry students, and it addresses the following standards:

North Carolina Essential Standards

Earth/Environmental	EEn.2.2.1; EEn.2.4.1; EEn.2.4.2
Biology	Bio.2.1.1; Bio.2.2.2; Bio.4.2.1
Physical Science	PSc.2.1.1
Chemistry	Chem.2.2.2; Chem.3.2.4; Chem.3.2.6

Next Generation Science Standards
Grades 9-12, Disciplinary Core Ideas/Practices/Cross-cutting concepts:

Science and Engineering Practices	Asking Questions and Defining Problems; Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data
Cross-Cutting Concepts	Cause and Effect: Mechanism and Prediction; Scale, Proportion, and Quantity; Systems and System Models; Structure and Function

Time Requirements

- Activity 1: Background of wastewater & wastewater treatment plants – 10 minutes
- Activity 2: Wastewater sample preparation – 5 minutes
- Activity 3: Primary filtration (Sieving & Skimming) – 15 minutes
- Activity 4: Flocculation & sedimentation – 30 minutes
- Activity 5: Secondary filtration (slow sand filtration) – 10 minutes

- Activity 6: Tertiary filtration (activated charcoal filtration) – 20 minutes
  Total time – 90 minutes

Materials

Included in the kit:

- 1500g Fine Sand
- 1500g Coarse Sand
- 1500g Fine Gravel
- 300g Activated Charcoal
- 25g Potassium Aluminum Sulfate (Alum)
- 25g Calcium Oxide (Lime)
- 5g Kaolin (clay) Powder
- 5mL Green Food Coloring
- 25mL White Vinegar
- 75 Plastic cups
- 15 Stirring Sticks

Needed but not provided in the kit:

- Buchner funnel and filtration flask
- 3 250/300 ml glass flasks
- Cheese clothes
- Pipettes
- 1 2000 ml glass flask
- Potting soils, sands
- Dry leaves, green leaves, twigs

Safety

Ensure that students understand and adhere to safe laboratory practices when performing any activity in the classroom or lab. Demonstrate the protocol for correctly using the instruments and materials necessary to complete the activities and emphasize the importance of proper usage. Use personal protective equipment such as safety glasses or goggles, gloves, and aprons when appropriate. Model proper laboratory safety practices for your students and require them to adhere to all laboratory safety rules.

Background Information

What is wastewater? Wastewater could be the water used by household and industry or it may contain rainwater including snow & ice melt. This wastewater contains myriad of contaminants and pollutants which are very harmful for human health & environment. This water must be treated before its released back to the system.

Nature has an amazing ability to handle certain amount of waste & pollutants, but billions of gallons of wastewater generated by households & industry can overwhelm our natural ecosystem. Wastewater treatment plants are designed to remove harmful contaminants to sufficient level that treated water can be released back to environment or it can be reused again. Exact level of treatments and required process depends upon the final end

use of treated water. Apart from a matter of caring for our environment and our own health, government's regulations also make it mandatory to treat wastewater.
In United States, the Federal Water Pollution Control Act of 1948 was the first major U.S. law to address water pollution which was later amended in 1972 to become the Clean Water Act (CWA). Currently, CWA establishes the basic norms for regulating pollutant discharge into the water.

Wastewater treatment plants are designed to handle different kind of contaminants such as organic matters, big and small solid particles, sands, oils, chemicals, bacteria, virus etc. Toxic chemicals & overabundance of organic matter can make water uninhabitable for many water living species and plants. Organic matters consume oxygen present in the water to be decomposed. Overabundance of organic waste and nutrients also promotes accelerated growth of algae & aquatic plants which is referred as algae boom or eutrophication. Algae boom or eutrophication covers the water bodies reducing penetration of sunlight which prevents photosynthesis which further depletes the amount of dissolved oxygen in water. Fish are sensitive to oxygen level in water and may die due to lack of it. Apart from fish, clean water is used by many animals who can die if water is contaminated with harmful pollutants. Wastewater also contain harmful bacteria and virus which are cause of many dieses and equally harms human as well as animals.
A wastewater treatment plant engages several processes such as filtration, sedimentation, clarification, aerobic & anaerobic digestion, and disinfectants to remove as much pollutants as possible. After this, it might be helpful to name and describe each step of the treatment process that is simulated in this lab or add a list of terminology and definitions.

Preparation

- Either collect wastewater samples to be treated from a local source or prepare the wastewater sample by adding soils, sands, small stones, green leaves, dry leaves, twigs, vegetable oils, soapy water (these items have not been provided in the sample kit)
- Also add Kaolin clay, food coloring, vinegar (included in the kit) to give a color and odor the wastewater sample
- Prepare the wastewater sample at least 2-3 hours before the activity. Ideally prepare one day before the activity, thoroughly stir it and let it settle
- Filtration beds can also be prepared in advance to save the time during activity.

Guiding the lesson using the 5E Learning Cycle

Engage (10-min)

1. Provide an overview of wastewater system and the waste water treatment plants. Give example of wastewater treatment plants in Raleigh & North Carolina (link below)
   https://raleighnc.gov/services/content/PubUtilAdmin/Articles/TreatmentPlants.html
2. Explain the need of wastewater treatment. Emphasize on the scarcity of clean water and problems of contaminated water being faced by many countries
3. Explain the good prospects of a career in wastewater management.
   https://blog.epa.gov/2015/12/03/career-beat-drinking-water-and-wastewater-treatment-plant-operators/
   https://www.indeed.com/q-Wastewater-Treatment-jobs.html

Explore

1. Prepare different type of wastewater samples by adding varying contaminating materials as well as quantity.
2. Let students observe the type of contaminants removed at each cleaning steps
3. Ask students to note down their observations of treated water after each cleaning steps in terms of clarity, color and odor

Explain

1. Explain about importance of each cleaning steps in a wastewater treatment plant. How initial sieving action to remove the bigger particles help in preventing damage of pipes in actual water treatment plants
2. Explain why immiscible liquids (oils, soaps) float on water
3. Explain flocculation & sedimentation process and why are they required in wastewater treatment process

Elaborate

1. Why two different filtration beds, sand filtration & charcoal filtration, are required for wastewater treatment. What is the purpose of each filtration beds
2. Explain why activated charcoal is able to remove color and odor from the wastewater sample

3. Different usage of partially treated wastewater samples

Evaluate

1. Ask students to complete the observations table provided in the student guide
2. Evaluate the response of students to the questions provided in the students guide
3. Students can be asked to investigate local wastewater treatment system/ municipal water treatment facilities to describe similarities and dissimilarities with the process employed in this lab activity

Differentiated Learning and Extension Activity ideas

- *This activity is easily replicable and can be extended for as many users.*
- *To extend the activity, teachers can provide all materials to the students, but not the procedure, so that students must design and test their own process to treat their water sample.*

Answers to Questions in the Student Guide

1. List the materials that were removed at each successive steps of the treatment process
    - After initial sieving – *Bigger size particles (sand, stones, leaves, twigs etc.)*
    - After skimming – *Immiscible liquids such as oils, soaps*
    - After flocculation & Sedimentation – *No material removal but solid particles will settle down at the bottom leaving clear water at the top*
    - After sand filtration – *sediment solid materials*
    - After First pass charcoal filtration – *partial removal of color and odor*
    - After multiple pass (3 or 4) charcoal filtration – *Nearly complete removal of color & odor*

2. Identify the different layers of liquids that formed after the sieving (initial screening of bigger particles) process and why?

The top layer was composed of oils & soaps while the bottom layer was of wastewater. (Slightly bigger particles will settle down at the bottom). The oil layer is on top of the water because of the difference in density of the two liquids. The oil is less dense than the water and so is on top

3. If a body of water is odorless and clear, is it therefore safe to drink? Explain your answer.

Not necessarily—many chemical pollutants, bacteria, viruses, protozoa are odorless, colorless, and invisible yet are toxic or pathogenic.

4. What are some uses for the partially treated water represented by this activity?

The water might be used for irrigation. It could also be released into wetlands, lakes, streams, rivers, or oceans for additional bioremediation. Further tertiary treatment could result in the removal of chemical and biological contamination and render the water safe for drinking.

5. Which agency is responsible for regulating standards for drinking water and wastewater in the USA

EPA (United States Environmental Protection Agency) enforces federal clean water and safe drinking water laws, provides support for municipal wastewater treatment plants, and takes part in pollution prevention efforts aimed at protecting watersheds and sources of drinking water.
https://www.epa.gov/regulatory-information-topic/regulatory-information-topic-water#:~:text=EPA%20regulates%20the%20discharge%20and,wastewater%20dischargers%20and%20treatment%20facilities.

Supplemental Resources

- https://www.epa.gov/environmental-topics/water-topics
- https://blog.epa.gov/2015/12/03/career-beat-drinking-water-and-wastewater-treatment-plant-operators/
- https://raleighnc.gov/services/content/PubUtilAdmin/Articles/TreatmentPlants.html
- https://enva.com/case-studies/flocculants-in-wastewater-treatment
- https://www.britannica.com/technology/water-supply-system/Coagulation-and-flocculation
- https://www.thoughtco.com/how-does-activated-charcoal-work-604294
- https://www.me.psu.edu/cimbala/me433/Lectures/Activated_Carbon_or_Charcoal_Filters.pdf

Name _____ **Student Guide**
Date _____

Overview "During this activity, you will develop a knowledge of the processes performed at a water treatment plant and understand the reasons for each process. Examine the changes in the water after each treatment step is performed, in particular physical characteristics of water, such as clarity, color, odor, and how they are affected from the beginning of the treatment process until the end

Background
Nature has an amazing ability to handle certain amount of waste & pollutants, but billions of gallons of wastewater generated by households & industry can overwhelm our natural ecosystem. Wastewater treatment plants are designed to remove harmful contaminants to sufficient level so that treated water can be released back to environment or it can be reused again. Exact level of treatments and required process depends upon the final end use of treated water. Wastewater treatment plants are designed to handle different kind of contaminants such as organic matters, big and small solid particles, sands, oils, chemicals, bacteria, virus etc. Toxic chemicals & overabundance of organic matter can make water uninhabitable for many water living species and plants. A wastewater treatment plant engages several processes such as filtration, sedimentation, clarification, aerobic & anaerobic digestion and disinfectants to remove as much pollutants as possible.

Materials

1. Plastic cups
2. Plastic stirrers
3. Fine sands, coarser sands, fine gravels
4. Activated charcoal
5. Alum (Potassium Aluminum Sulfate)
6. Calcium oxide
7. Buchner flask & Buchner funnel
8. Cheese clothes
9. 3 250/300 ml glass flasks

Procedure

1. Transfer the wastewater sample your instructor has prepared earlier into a 500 ml flask. Make an initial assessment of its clarity, color and odor
2. Take a Buchner flask and keep a Buchner funnel with perforated plates on top of the flask to form a filtration system. Cut a piece of cheese cloth and cover the perforated plates of the funnel
3. Quickly stir the wastewater sample and pour it over the Buchner funnel and cheese clothes. This step will filter out the bigger size particles from the sample and the wastewater sample for further treatment will be collected into the Buchner flask

4. Observe the filtered wastewater sample and assess its clarity, color and odor. Let it settle for five minutes
5. After five minutes, immiscible liquids such as vegetable oils & soaps should form a separate layer on top of the wastewater sample. Take a 50 ml pipette and carefully skim off the immiscible liquids using pipette.
6. Again, make an assessment of the remaining wastewater sample regarding its clarity, color, odor and not down your observations
7. Weight approximately 1 gram of Alum (Aluminum sulfate) provided in the sample kit and add it to the wastewater sample. Stir the sample for 2-3 minutes and let it settle for further 2-3 minutes.
8. Observe your wastewater sample, addition of Alum should start the flocculation process in which smaller particles will clump together to form a bigger floc and gradually settle down at the bottom.
9. Add a small amount of calcium oxide (CaO) to the sample and stir it for 2-3 minutes. Addition of calcium oxide will raise the pH of wastewater sample and accelerate the flocculation process.
10. Let the wastewater sample settle down and complete the flocculation process. Meanwhile, prepare the sand filtration bed and charcoal filtration to be used in the upstream processes
11. Take two plastic cups from the sample kit and make 8-10 small holes at the bottom of both plastic cups. Make a bed of finer sand materials up to 2 cm. in height into one of the cups with holes. Add coarser sands at the top of finer sand to make a bed of 2 cm in height. Finally, add gravels on top of coarser sand up to 2 cm. in height and complete the sand filtration bed
12. Place charcoal from the sample kit into another plastic cup with holes at the bottom and form a charcoal bed of 2 cm. height. Be careful while making the small holes in the cup. Too small holes will delay the filtration process while too open holes will leak sand and charcoals from the bottom.
13. While preparing filtration bed, quickly but gently stir the wastewater sample few times
14. Thoroughly wash the just prepared sand and charcoal filtration beds by gently pouring water from the top until you observe clean water coming out at the bottom
15. After both filtration beds are ready, assess the wastewater sample and note down your observations
16. Take two 250/300 ml flasks and carefully arrange the filtration beds on top of both flask
17. Gently pour your wastewater sample over sand filtration bed. Filtered water should collect in the flask kept at the bottom of the sand filtration bed
18. Observe the filtered sample and note down your observations.
19. Pour your filtered water sample over the charcoal filtration bed just you did with the sand filtration bed. Again, note down your observation after charcoal filtration is complete
20. Repeat 3 to 4 rounds of filtration over the charcoal filtration bed and observe your sample each time. After multiple pass, your filtered water should look transparent free of any color, odor of fine particles.
21. Make your final observation and note down its clarity, color, and odor. Please note, the final filtered water is still not ready for drinking.