Lesson Outline for ALEX

General Lesson Information

Title: Water Filtration

Overview/Annotation – *Students will build and test a water filter. Specifically, various materials, such as sand, cotton balls, rice, activated carbon, and alum, will be available to build a filter to purify homemade dirty water. Students will cost and build their filter. Then, the students will test their filter using the homemade dirty water and record the amount of time needed to filter 20 mL. This activity will give a hands-on activity for students to learn how engineering and water filtration works by designing, costing, building, and testing a water filter. The goal is to produce a filter that is cheap, works fast, and provides the cleanest water.*

Setting or format (outdoors, in groups, lab, etc.): In groups in a lab or classroom

Intended group size (if groups are used): 2-3

Intended grade level(s):
9-12 (High School) but can easily be adapted for grades 5-8

Approximate Time of Lesson: 30-50 minutes (can be increased by allowing for more trials)

Researcher Biography

Name & Professional Title:
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Brief Description of Research Interests:
Steven – Water and Wastewater Treatment

Associated Standards and Objectives

Content Standards

Environmental Science – Earth and Human Activity

Insight 10 - Design solutions for protection of natural water resources (e.g., bioassessment, methods of water treatment and conservation) considering properties, uses, and pollutants (e.g., eutrophication, industrial effluents, agricultural runoffs, point and nonpoint pollution resources).

Primary Learning Objectives
Students know:
-Sources of freshwater and ocean pollution
-Legislation that addresses the protection of natural water resources
-Methods of water treatment

Students will be able to:
-Obtain, evaluate, and communicate information on the properties, uses, and pollutants of natural water resources
-Analyze and interpret data to evaluate water resources and EPA standard limits
-Design or refine a solution to protect natural water resources, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations
-Identify costs, safety, aesthetics, reliability, cultural and environmental impacts of proposed solution

Students understand that:
-Scientists and engineers can develop technologies that produce less pollution and waste and that preclude ecosystem degradation
-When evaluating solutions, cost, safety, reliability, and aesthetics must be taken into consideration, as well as any social, cultural, and environmental impacts

Additional Learning Objectives
SCI.AAS.ES.HS.10 - Recognize factors that affect natural water sources (e.g., pollution, agricultural runoffs) and identify ways humans can protect them (e.g., methods of water treatment and conservation, and the pros and cons of these methods).

Preparation Information

Total Duration – Approximately 50 minutes

Materials and Resources:
See Appendix 1 for a suggested list of materials needed

Technology Resources Needed:
None but could use a computer with projector to display page 3 of the worksheet (Appendix 2)

Background and Preparation:
Description of information (science content, use of materials, etc.) teacher and/or students will need to know prior to this lesson; list steps for any preparation prior to the lesson

- Safe Drinking Water Act (SDWA, 1974, https://www.epa.gov/sites/production/files/2015-04/documents/epa816f04030.pdf) and subsequent amendments gave the US EPA the authority to (1) determine health-based maximum contaminant level goals (MCLGs) and (2) set maximum contaminant levels (MCLs) or treatment technology (TT) if it is not economically or technically feasible to monitor the contaminant). These standards contribute to the choice of treatment technology for each treatment plant. Primary standards, the National Primary Drinking Water Regulations (NPDWR), are legally enforceable to public water systems and protect public health. Secondary standards are non-enforceable guidelines. States can choose to adopt secondary standards as enforceable standards.

- Important to this lesson plan is the EPA limits on turbidity. Turbidity is a measure of cloudiness of water, so the smaller the number, the clearer the water. The EPA requires most systems to have < 1 Nephelometric Turbidity Unit (NTU) of turbidity, with 95% of the samples taken in a month to have ≤ 0.3 NTUs.
- Teacher – See Appendix 1 for an example of how to build the filter housing. It is advised to have these prepared for the students beforehand.

Procedures and Activities

Step-by-step description of lesson that would allow another teacher to successfully complete the lesson (suggest possible reflection or comprehension questions along with examples of correct answers or common misconceptions)

Engagement (sparking interest, introducing phenomenon, engage students' everyday experiences)
Who here likes to drink water? What qualities do you want your drinking water to have (examples: clear, colorless, no smell, no taste)? Does anyone know how the water they drink gets produced/cleaned? Does anyone know how the water they flush down the toilet gets cleaned? Did you know that some countries, including some locations within the USA, are reusing water from sewers as drinking water? Did you know that some people in Alabama do not have access to wastewater treatment? There are numerous treatment options used all over the world, today we are going to use one technique to filter water.
Consider how materials pack together and the size of holes they have in between pieces of that material. For example, which material would you expect to filter out smaller particles, sand or rice, and why?

Main activity (suggest possible reflection or comprehension questions along with examples of correct answers or common misconceptions)
Step by step experimental plan:

1. Prior to the class, the instructor should prepare the homemade dirty water, prepare the filtration housings, prepare the alum, prepare the filter materials, and print the student worksheets.
    a. The homemade dirty water can be made from the recipe in Appendix 1.
    b. The filtration housing can be made from the supplies in Appendix 1. An example image is shown in Appendix 1.
    c. Put 1/8 to 1/4 teaspoon of alum in a small vial (example vial given in Appendix 1). Every group likely will use 1 vial so prepare enough for each group.
    d. It is suggested to put each filter material in a separate container (for example, rectangle food storage containers) for the students to measure quantities from.
    e. The student worksheet is Appendix 2. At a minimum the first 2 pages should be given to the students. It suggested to print double-sided to only use 1 piece of

paper per group. The third page can be displayed on a screen at the front of the class.

2. Each student group will draw and label how they want to build their filter on the worksheet and calculate the cost of their filter using the table on the worksheet. The maximum amount any one group can spend is 75¢ per filter.
3. Each student group will obtain their materials and the polluted water.
4. Each student group will build their filtration system using their materials
5. Using a timer (stopwatch, cell phone timer, etc.), each student group will pour the polluted water into the top of their filter and start their timer once the first drop of water goes through the filter. Each student group will record the time in minutes it takes to collect 20 mL of purified water. Record the time in minutes (decimals are ok!) on the worksheet.
6. Using a calibrated turbidity meter (can get a cheap one from Amazon, an example is given in Appendix 1), the instructor or, if the instructor is comfortable with it, each student group will measure the turbidity of their purified water. Record the turbidity value on the worksheet.
7. Each student group will calculate the total score of their filter using the formula on page 2 of the worksheet. Whichever group has the highest score wins!

Wrap up and Reflection (wrap up activity, reflecting on learning, informal assessments of student learning)
What material do you think filtered out the smallest particles and why?
What factors did you consider as you designed and built your filter?
How do you think changing the size of the dirt particles in the water would change your filter performance?
If you could build another filter, what would you do?

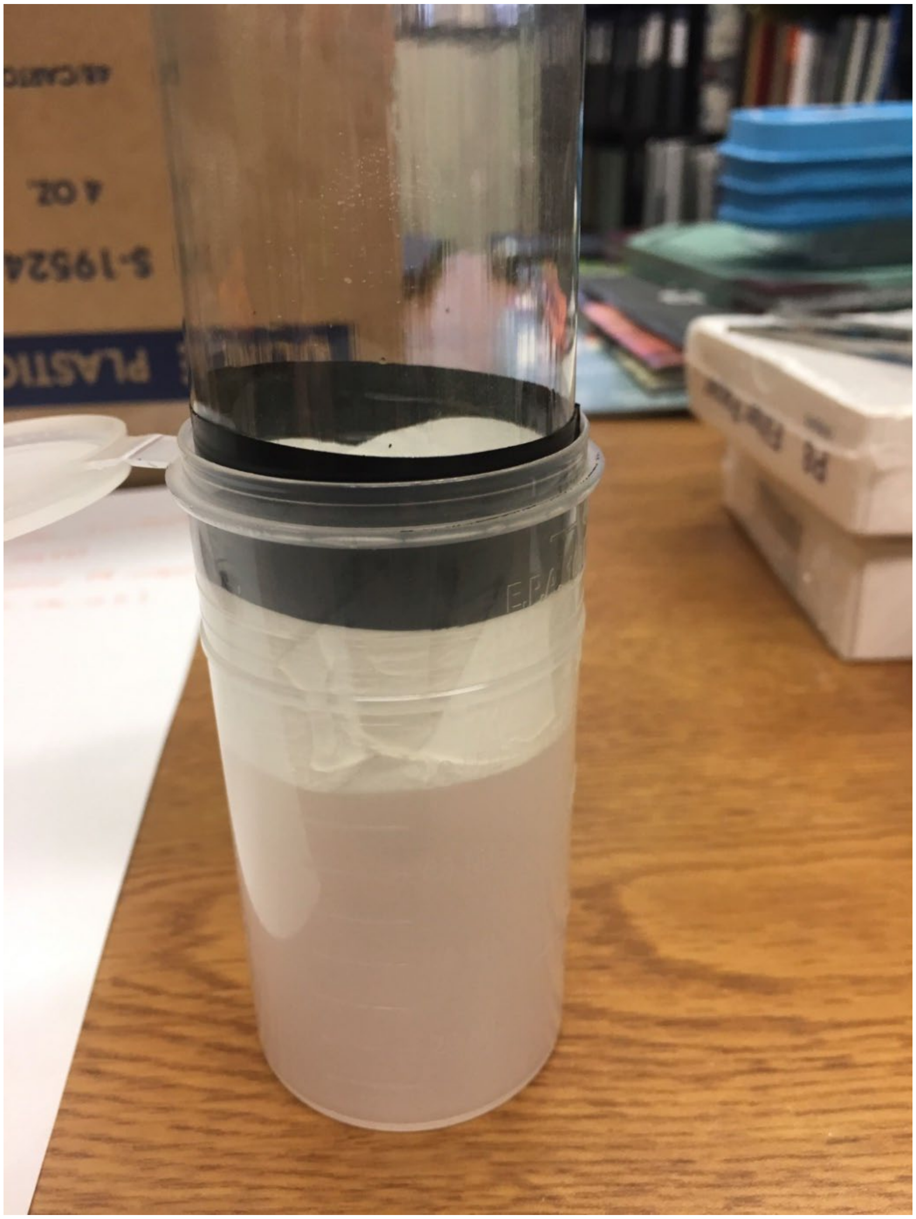
Final product/Summative evaluation (e.g. quiz, presentation, essay, etc., may occur during a later class period)
A sample quiz or test question that directly connects to the experiment described above:
Which material used in this experiment can filter out the smallest particles in water? Why?

More involved project/presentation questions based on this experiment:
How did you decide to design your filter? What factors did you consider as you designed your filter? Did the filter perform as you expected? If you could build another filter, what would you do differently based on your initial trial(s)?

Attachments: *Any materials for the lesson such as video links, worksheets, etc., listed here*
Appendix 1 – List of supplies for the experiment
Appendix 2 – Student worksheet

Supplies For Water Purification Experiment

ITEM
Filter units (ULINE clear plastic tube (S-12642) inside 4 oz plastic vial (S-19524), with filter paper between. Filter paper secured to plastic tube with electrical tape (**see image on next page**), make sure to drill hole in vial at the top, but below the filter paper to prevent pressure build up
Cotton balls
Rice - parboiled
Sand – clean (Fisher Sand Sea Washed, S25-3)
Carbon (Fisher AA4311836, product of Alfa Aesar, Carbon Activated -4+8 mesh, 2x500 g)
Alum (Fisher AC458990010, product of Thermo Sci Acros Organics, Aluminum Potassium Sulfate, 1 kg)
Vials to hold alum (Fisher 0333925B, product of DWK Life Sciences, 4 mL rub/lnd cap 144/pk)
Paper towels (4 rolls)
1/8 teaspoon to put alum in vials (1)
Funnel to help put alum in vials (1)
Tablespoons (3)
Measuring Cups (1 cup, ½ cup, ¼ cup)
Dirty water (80 in 8 oz bottles): add dirt, green food coloring, vinegar, detergent (mix well in 5 gal bucket and add to bottles) – **See recipe on next page**
Foam Trays (Fisher S04188, product of Aquaphoenix Scientific, foam tray 9x12 whitefoam) – Used to contain the mess
Squirt bottle (Fisher S14093, product of Eisco Scientific, PE wash bottle 500 mL)
Little cups [Dixie]
5 gallon waste buckets
Filter paper – Fisherbrand qualitative P8-creped, 11 cm dia. (09-790-12D)
Electrical tape
Dust pan and brush
Turbidity meter (for example, Sper Scientific 860040 Turbidity Meter from Amazon)
TopSoil (Dirt)
Green food coloring
Distilled White Vinegar
Liquid Dish Soap
Rectangle Food Storage Containers (4)
8 oz bottles or plastic cups to put swamp water in
Black Sharpie



Mix the following in a 5 gallon bucket to make each batch of homemade dirty water:
1 gallon of dirt
1 to 2 cups on vinegar
¼ to ½ cups of dish soap
3 to 4 good squirts of green food coloring

Team members ____

Water Filtration

The **purpose** of the experiment is to design a filter to purify water.

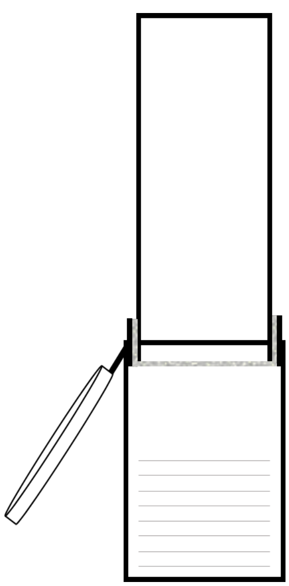
You will **evaluate** your design based on (1) the cost of the filter, (2) the time it takes to filter 20 milliliters (mL) of dirty water, and (3) the purity of the filtered water.

Here are the **materials** available to build your filter and their costs.
In the table, write how much of each you will use and calculate the cost for each material and the total cost to build your filter. Maximum 75¢

Material	Price	How much we will use	Cost
1 cotton ball	2¢	×	= ¢
1 tablespoon of rice	3¢	×	= ¢
1 tablespoon of sand	5¢	×	= ¢
1 tablespoon of carbon	10¢	× **(2 max)**	= ¢
1 vial of alum	25¢	× **(1 max)**	= ¢
TOTAL COST TO BUILD OUR FILTER (maximum is 75¢) →			= ¢

Our Filter Design

Draw and label



Our Data

Cost to build our filter

_________ ¢

Time to filter 20 mL of the dirty water

_________ minutes

Turbidity of filtered water

_________ NTU

TURN OVER THE SHEET TO DETERMINE YOUR FILTRATION SCORE!

Score Your Design

Enter values from your data page into the table and calculate scores for each row.

Variable	Value	Multiplication factor	Score
Cost to build our filter (¢)		× 10	= (A)
Time to filter 20 mL of dirty water (minutes)		× 20	= (B)
Turbidity of filtered water (NTU)		× 1	= (C)

TOTAL SCORE = 1000 – (A) – (B) – (C)

Our Score ______

Challenge

You are working for Alabama Clean Water Engineering Company and have been asked to design a new water filtration system for a community with a polluted water supply.

The community gives you a list of three requirements:

(1) The system should be CHEAP

(2) The system should work FAST

(3) The water should be POTABLE

You have 5 materials to put in your filtration system: cotton balls, rice, sand, carbon, alum. <u>You can use them in any order and different amounts, but you can spend a maximum of 75¢ for your filter system</u>.

Designing your filtration system

(1) **Write** down how much of each material you will use in the table.

(2) **Use your math skills to calculate** the cost to build your filter with these materials, and **write** down the cost in the data box.

(3) **Draw** your filter design and label the materials in your drawing.

(4) **WHEN ASKED, send** one partner to obtain your materials and polluted water.

(5) **Build** your filtration system using the materials in your design.

(6) **WHEN INSTRUCTED, filter** the water, and **record** the time in minutes needed to collect 20 milliliters (mL) of purified water.

(7) **Record** the turbidity of your filtered water in the data box.

(8) **Calculate** your score and **record** it on the back of the sheet.