

the human element



the human element catalyzed by discovery and knowledge

background

Background:

Scientists around the world are being challenged to balance their knowledge of chemical principles along with the human element to discover innovative solutions to the issue of global drinking water shortages. Before the research groups examine the different options for action taking presented by the Sustainability Corps experts, it is important they understand the basic principles involved in water filtration and how human creativity enters into the solution of the problem. In the following exercise, students will design and test their own filtration system using some basic principles of chemistry.

goal

Goal:

Students will design and test a water filter.

Standards Met: S1, S2, S5, S6, S7, LA7, LA8



Time Required: Two – 45 to 60 minute class periods

objectives

Objectives:

Students will...

- Understand the basic chemical principles involved in water filtration.
- Use human ingenuity and creativity to design a water filtering system.
- Evaluate the effectiveness of their filter system.
- Compare their devices to other research groups in the class.

materials

Materials (for a class of 30 working at six different stations):

- Green Water Monitoring Kit (www.lab.com/g-common2BH.php?ppid=62905&K=science%20lab%20supplies&PHPSESSID=nnnnnb48e3cb439fb540caf429f37c78c225c&PROV=-FW2 Cat #25-5848)

***Note:** For this activity, and the next, we are using the Green Water Monitoring Kit because of its ease of use and relatively inexpensive cost. If the science instructor prefers to use an alternative water testing system, or if they have access to water testing instrumentation, it is perfectly acceptable to substitute it in the place of the suggested kit. If the instructor does substitute their equipment, some modification of the tables and procedures will be necessary.

- 2500g of activated charcoal (Sargent-Welch Cat #WLC95047-06T)
- Six mortar and pestles
- 12 liters of “contaminated water” (see prep below)
- Six – 30 cm long 1” PVC pipes
- Six – 1” PVC caps
- Small drill (electric)
- 24 – 250 mL beakers (paper cups can be substituted)
- Six – 25 mL syringes
- Six – 15 cm square pieces of cheesecloth
- 12 rubber bands
- Six – 15 cm squares of nylon mesh
- 2500g coarse sand (Sargent-Welch Cat#WLC94256-08)
- 2500g fine white sand (Sargent-Welch Cat#WLC94258-09)
- 24 large cotton balls
- Six – 100 mL graduated cylinders
- Six ring stands
- 30 pairs of safety glasses
- One bottle (50 tablets) of iodine tablets (www.rei.com/product/407071)
- Six funnel holders
- One conductivity meter (Sargent-Welch WLS-29745-80A)
- Six funnels
- Six plastic pipettes
- Six ring stand clamps
- Six post-filtering water testing containers with lids (Ziploc or Tupperware work well)
- 12 pieces of filter paper
- One digital scale
- 30 copies of The Human Element Catalyzed by Discovery and Knowledge – Student Background Information sheets
- 30 copies of The Human Element Catalyzed by Discovery and Knowledge – Student Sheet
- The Human Element Catalyzed by Discovery and Knowledge – Teacher Answer Key

Proce



Safety Note: Although this activity may produce potable water, it is never allowable to let students drink (or eat) any substance in a science laboratory. There is always a chance of contamination or an allergic reaction which could be very dangerous to some students. This safety rule should be followed throughout the experiments presented in the module. Make sure that students wear safety glasses at all times as well as any other lab safety clothing necessary during all lab procedures. Also make sure that students wash their hands with anti-bacterial soap thoroughly before leaving the classroom.

duration

Prep

- Collect about 12 liters of “contaminated” water. This can be obtained from a pond, standing water, or made by mixing water with a small amount of nitrogen/phosphate fertilizer, sand, mud, silt and other contaminants the students will need to filter out.
- Measure out 18-250 mL beakers with the following materials: Six with 250 grams of coarse sand, six with 250 grams fine sand, six with 250 grams activated charcoal.
- Put 200 mL of “contaminated” water in each of the six-250 mL beakers.
- Cut six-30 cm sections out of 1 inch inside diameter PVC pipe.
- Drill small holes in the end of the 1” PVC caps.
- Set up six stations in the room with one water test at each station. Set up the remaining water tests at the front of the room at the instructor’s demonstration area.
- Pass out The Human Element Catalyzed by Discovery and Knowledge – Student Background Information sheet the night before the lab and have the students read, highlighting important concepts.



In Class

Day 1

Pre-filtering Water Tests

- Divide students into their six research groups (their roles) and assign them to one of the stations set up around the room.
- Hand out The Human Element Catalyzed by Discovery and Knowledge – Student Sheet to each student.
- Have the students put on their safety glasses.
- Have each group pick up the following pieces of equipment:
 - One mortar and pestle
 - One plastic pipette
 - 100 mL graduated cylinder
 - 250 mL beaker of coarse sand
 - 250 mL beaker of fine sand
 - 250 mL beaker of activated charcoal
 - 250 mL beaker of “contaminated” water
 - 30 cm section of PVC pipe (1 inch)
 - One ring stand
 - 15 cm square piece of cheesecloth
 - Two rubber bands
 - 15 cm square of nylon mesh
 - Two large cotton balls
 - Two iodine tablets
 - One funnel holder
 - One funnel
 - 1” PVC cap with small holes drilled into it
 - 25 mL syringe
 - One ring stand clamp
 - Two pieces of filter paper
- Explain to the students that the water tests with instructions are located at each of the six stations (from the Green Water Monitoring Kit). There are more than six tests in the kit. Some student volunteers can do the additional tests set up at the front demonstration area. Some tests (coliform bacteria, BOD) need several days before tests can be completed and results can be recorded.
- Using a small portion of the contaminated water from their 250 mL beaker, have each group perform the water test at their station and record the results on The Human Element Catalyzed by Discovery and Knowledge – Student Sheet in Table 1 under “Pre-filtering”.
- When all groups have completed their tests, have them share their results with the entire class.

Making the Filter

- Instruct the students they are to design a water filter using the equipment that they have in front of them. The rules they must follow are:
 - They may use some or all of the material in front of them, but they may not get any additional materials.

- Each group must produce a minimum volume of 100 mL of “purified” water.
- They may filter the water through their device as many times as they want.
- They must design, construct and produce the final purified water sample in the time limit that the instructor has given them.
- Groups are to store their purified water in the container that the instructor gives to them so that it can be used for the post-filtering tests on the following day. Make sure that the containers are labeled with your group’s name.
- Each group must supply a detailed, labeled drawing of their filtering device.
- After the groups have handed their purified water container and the labeled drawing of their filtering device to the instructor, they should clean up their lab stations and wash their hands thoroughly before leaving the classroom.
- Tell the students to put on their safety glasses.
- Pass out each group’s purified water sample from the previous day’s lab.
- On your instruction, have each group rotate through each lab station and perform all of the water tests at that station on their purified sample (some stations may have more than one test to complete).
- Have the students record these results on The Human Element Catalyzed by Discovery and Knowledge – Student Sheet in Table 1 under “Post-filtering.”
- Have one member of each group report the results of their tests to the class.
- Post the drawings of the different filter designs around the classroom.
- Discuss the results with students.
- Have the students clean up their lab station, put away all equipment and wash their hands thoroughly.
- Students should complete the Questions for Thought on their Student Sheet for the next class period.

Day 2

Post-filtering Water Tests

- Set up six stations in the room with one water test at each station. Space out the extra water tests (the ones that were at the instructor’s demonstration table) at several of the stations.
- Have the students return to their lab stations from the previous day.

Assessment

Successful completion of The Human Element Catalyzed by Discovery and Knowledge – Student Sheet.

Student Background Information



Listed below are terminologies and the scientific background you will need to complete this lab. Highlight the concepts you feel are important.

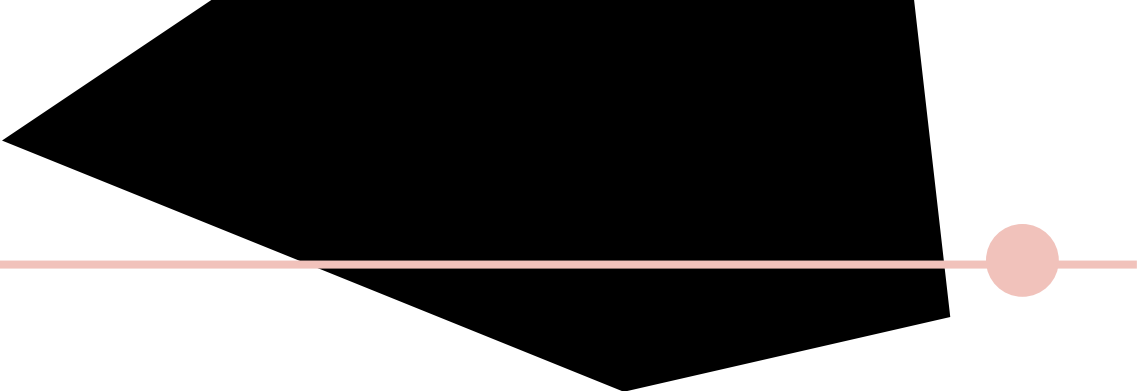
Activated charcoal: Activated charcoal is charcoal that has been treated with oxygen to open up millions of tiny pores between the carbon atoms. By using special manufacturing techniques, a highly porous charcoal that has surface areas of 300-2,000 square meters per gram is produced. These so-called active, or activated, charcoals are widely used to adsorb odorous or colored substances from gases or liquids.

The word adsorb is important here. When a material adsorbs something, it attaches to it by chemical attraction. The huge surface area of activated charcoal gives it countless bonding sites. When certain chemicals pass next to the carbon surface, they attach to the surface and are trapped. Activated charcoal is good at trapping other carbon-based impurities (“organic” chemicals), as well as things like chlorine. Many other chemicals are not attracted to carbon at all – sodium, nitrates, etc. – so they pass right through. This means that an activated charcoal filter will remove certain impurities while ignoring others. It also means that once all of the bonding sites are filled, an activated charcoal filter stops working. At that point you must replace the filter. (www.howstuffworks.com/question209.htm)

Coliform bacteria: Coliform bacteria originate as organisms in soil or vegetation and in the intestinal tract of warm-blooded animals (fecal coli). This group of bacteria has long been an indicator of the contamination of water and possible presence of intestinal parasites and pathogens. The coliform bacteria are relatively simple to identify, are present in much larger numbers than the more dangerous pathogens, and react to the natural environment and treatment processes in a manner and degree similar to pathogens. Thus by observing coliform bacteria, the increase or decrease of many pathogenic bacteria can be estimated.

The many sources of bacterial pollution include runoff from woodlands, pastures and feedlots; septic tanks and sewage plants; and animals and wild fowl. Domestic animals contribute heavily to the bacterial population. Many coliform bacteria enter natural streams by direct deposition of waste in the water and the runoff from areas with high concentrations of animals or humans.

The most likely sources come from where the water is used, the spigot, sink, or unclean containers. Another source includes backflow from a contaminated source, a sink-top carbon filter, bucket of water, or puddle at the end of a hose. Reduced pressure or suction in long waterlines, or drawing in soil water at the joints are sources as well. While most coliforms are



not pathogens, they serve as indicators of the microbial quality of water. Pathogens – the bacteria, protozoa and viruses that make people sick – can be rare and difficult to detect even if they are present in the water. Total coliforms are indicators and are more common and easy to grow. Testing for them provides a margin of safety. Pathogens may not be present if coliforms are, but it would be wise to look for problems just in case. (www.wellowner.org/awaterquality/coliformindex.shtml)

Iodine: Iodine is a naturally occurring element found in seawater and in certain rocks and sediments. There are non-radioactive and radioactive forms of iodine. Iodine is used as a disinfectant for cleaning surfaces and storage containers, in skin soaps and bandages and for purifying water.

Nitrates:

- Nitrate is a colorless, odorless and tasteless compound that is present in some groundwaters.
- Nitrate can be expressed as either NO_3 (nitrate) or $\text{NO}_3\text{-N}$ (nitrate-nitrogen). Nitrate levels above the EPA Maximum Contaminant Level of 10mg/l $\text{NO}_3\text{-N}$ or 45mg/l NO_3 may cause methemoglobinemia in infants.
- Proper management of fertilizers, manures and other nitrogen sources can minimize contamination of drinking water supplies.

- Nitrate (NO_3) is a naturally occurring form of nitrogen found in soil. Nitrogen is essential to all life. Most crop plants require large quantities to sustain high yields.

The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amounts, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Due to its high mobility, nitrate also can leach into groundwater. If people or animals drink water high in nitrate, it may cause methemoglobinemia, an illness found especially in infants.

Nitrates form when microorganisms break down fertilizers, decaying plants, manures or other organic residues. Usually plants take up these nitrates, but sometimes rain or irrigation water can leach them into groundwater.

Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to result from human activities.

Common sources of nitrate include:

- fertilizers and manure
- animal feedlots
- municipal wastewater and sludge
- septic systems
- N-fixation from atmosphere by legumes, bacteria and lightning

(www.ext.colostate.edu/pubs/crops/00517.html)

*Chemical Reaction during Nitrate Test:
Nitrate #1 TesTabs contain sulfamic acid, which destroys any nitrite that will give a positive interference. Nitrate #2 TesTabs contain zinc, which reduces nitrate to nitrite, and chromotropic acid, which reacts with nitrite to form a pink color.

Phosphates: Phosphates are chemical compounds containing phosphorus. Phosphorus is a non-metallic element that is necessary for life and is found in rock as inorganic phosphates. As water runs over and through rocks it carries off small amounts of minerals such as calcium, magnesium and phosphates. Inorganic phosphates are a plant nutrient and are taken in by plants with water and incorporated into organic phosphate compounds. Animals obtain their essential phosphorus from phosphates in water and plant material. Natural waters have a phosphorus concentration of approximately 0.02 parts per million (ppm) which is a limiting factor for plant growth. On the other hand, large concentrations of this nutrient can accelerate plant growth.

Phosphates enter waterways through manmade sources also. Per capita, we contribute approximately 3.5 pounds of phosphate yearly to our environment. The addition of large quantities of phosphates to waterways accelerates algae and plant growth in natural

waters; enhancing eutrophication and depleting the water body of oxygen. This can lead to fish kills and the degradation of habitat with loss of species. Large mats of algae can form and, in severe cases, can completely cover small lakes. As a result, water can become putrid from decaying organic matter. When the concentration of phosphates rises above 100mg/liter, the coagulation processes in drinking water treatment plants may be adversely affected. Manmade sources of phosphate include human sewage, agricultural run-off from crops, sewage from animal feedlots, pulp and paper industry, vegetable and fruit processing, chemical and fertilizer manufacturing and detergents. (<http://extoxnet.orst.edu/faqs/safedrink/phos.htm>)

*Chemical Reaction during Phosphate Test:
Phosphorus TesTabs contain ammonium molybdate which reacts with phosphorus to form a phosphomolybdate complex. This is reduced to a blue complex by ascorbic acid.

Dissolved oxygen: Dissolved oxygen analysis measures the amount of gaseous oxygen (O₂) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis.

Total dissolved gas concentrations in water should not exceed 110 percent. Concentrations above this level can be harmful to aquatic life.



Fish in waters containing excessive dissolved gases may suffer from “gas bubble disease”; however, this is a very rare occurrence. The bubbles or emboli block the flow of blood through blood vessels causing death. External bubbles (emphysema) can also occur and be seen on fins, on skin and on other tissue. Aquatic invertebrates are also affected by gas bubble disease but at levels higher than those lethal to fish.

Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. (www.state.ky.us/nrepclwater/wcpdo.htm)

*Chemical Reaction during Dissolved Oxygen Test: Dissolved Oxygen TestTabs contain sodium citrate and 2,4 Diaminophenol dihydrochloride. Dissolved Oxygen, in a solution buffered by sodium citrate, oxidizes a proportionate amount of 2,4 Diaminophenol dihydrochloride to produce a colored solution.

BOD: Biochemical (or Biological) Oxygen Demand is a chemical procedure for

determining how fast biological organisms use up oxygen in a body of water. It is used in water quality management and assessment, ecology and environmental science. BOD is not an accurate quantitative test, although it could be considered as an indication of the quality of a water source.

Most pristine rivers will have a five day BOD of less than 1mg/l. Moderately polluted rivers may have BODs in the range 2mg/l to 8mg/l. Efficiently treated municipal sewage treated by a three stage process would have a BOD value of about 20mg/l. Untreated sewage is variable but might average out at around 600mg/l in Europe and as low as 200mg/l in the USA or where there is severe groundwater or surface water infiltration. (The generally lower values in the USA derive from the much greater water use per capita than in other parts of the world.) Slurry from dairy farms is around 8000mg/l and silage liquor around 60000mg/l. (http://en.wikipedia.org/wiki/Biochemical_oxygen_demand)

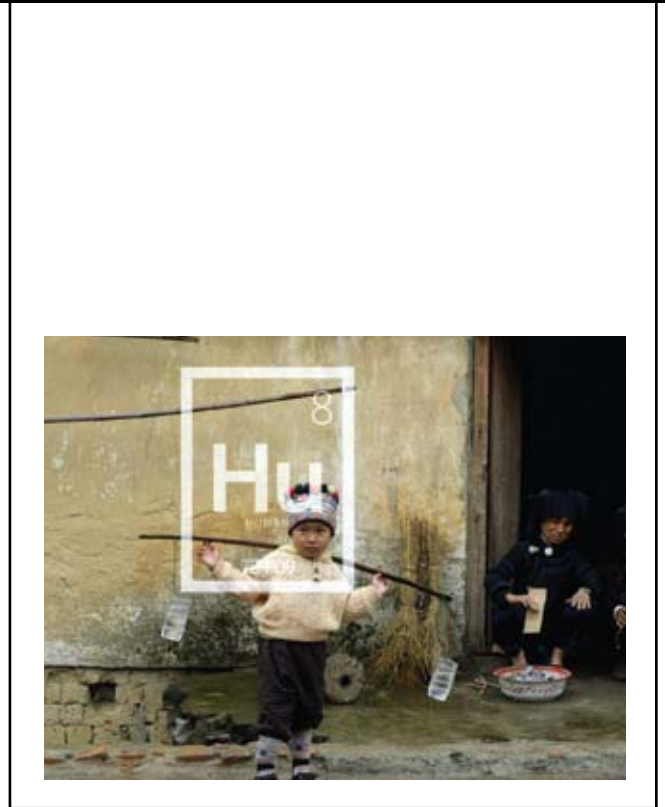
pH (Potential of Hydrogen): A measure of the degree of the acidity or the alkalinity of a solution as measured on a scale (pH scale) of 0 to 14. The midpoint of 7.0 on the pH scale represents neutrality, i.e., a “neutral” solution is neither acid nor alkaline. Numbers below 7.0 indicate acidity; numbers greater than 7.0 indicate alkalinity.

*Chemical Reaction during pH Test: pH Wide Range TesTabs contain mixed pH indicators, which are sensitive to pH and undergo specific color changes with variation in pH.

Turbidity: Turbidity is the measure of water clarity. The more suspended solids in the water, the murkier it becomes. The increased turbidity of water can reduce the diversity of life in three ways:

- Suspended particles absorb heat from sunlight and warm the water. Warmer water holds less oxygen and organisms begin to suffer. Also, some organisms cannot live in the warmer water.
 - Particles also block sunlight. Plants and algae grow less and release less oxygen from photosynthesis.
 - Particles also settle on the bottom and can cover and suffocate fish eggs and insect larvae
- Turbidity is often tested by dropping a Secchi disk into the water and measuring at what depth it disappears. (www.lalc.k12.ca.us/target/units/river/tour/turbidity.html)

*Turbidity Test in Kit: turbidity “target” is placed below the bottom of a clear tube. The sample turbidity causes a “fuzziness” of the target. The degree of “fuzziness” is matched to target standards calibrated in Jackson Turbidity Units (JTU).



Student Sheet

Name _____ Date _____

Table 1 – Water Test Results

Test	Pre-filtering	Post-filtering
Temperature (°Celsius)		
Turbidity		
pH		
Dissolved O ₂		
BOD		
Nitrates		
Phosphates		
Coliform Bacteria		
Conductivity		

Remember these rules that you must follow while designing your own filter:

- You may use some or all of the material in front of you, but you will not get any additional materials.
- Your group must produce a minimum volume of 100 mL of “purified” water.
- You may filter the water through your device as many times as you want.
- You must design, construct and produce the final purified water sample in the time limit that the instructor has given you.
- You are to store the purified water in the container that the instructor gives to you so that it can be used for the post-filtering tests on the following day. Make sure that the container is labeled with your group’s name.
- You must supply a detailed, labeled drawing of your filtering device.

Draw Your
Filter Below:



Questions for Thought:

1. Was your original filtration system successful? How did you measure success?
2. Describe any adjustments you made to your original model.
3. Were you able to remove all impurities? Which impurities do you believe are still in your purified water?
4. What were some of the limitations of your system? How could you correct them?
5. Do you think your filtration system would be cost effective? Why or why not?

6. In the Table below, list each component of your system along with the function you think it has in filtering the water.

Component	Function

Answer Key

Table 1 – Water Test Results

Test	Pre-filtering	Post-filtering
Temperature (°Celsius)		
Turbidity		
pH		
Dissolved O ₂		
BOD		
Nitrates		
Phosphates		
Coliform Bacteria		
Conductivity		

Answers will vary



Questions for Thought:

1. Was your original filtration system successful? How did you measure success?

Success of the student's filtration system can be measured by the amount of contaminants that it has removed. The results from their pre and post filtration test should be a good indicator of their success.

2. Describe any adjustments you made to your original model.

Answers will vary.

3. Were you able to remove all impurities? Which impurities do you believe are still in your purified water?

It is highly unlikely that the students were able to remove all of the contaminants. What impurities remain will depend on the system that they have designed.

4. What were some of the limitations of your system? How could you correct them?

Volume produced might be one of the limitations that the students list. Effectiveness in removing all of the contaminants may be another limitation. Another variable might be how efficient the materials in each layer are packed to avoid "channeling." To eliminate this problem, each layer must be tapped down firmly and uniformly.

5. Do you think your filtration system would be cost effective? Why or why not?

Most of the materials that the students used in the design of their filter system are relatively inexpensive - however, some of the materials may be difficult to purchase (PVC) in developing countries and substitutes (bamboo tube) may have to be used.

6. In the table below, list each component of your system, along with the function you think it has in filtering the water.

Component	Function
<i>Iodine</i>	<i>Kills pathogens</i>
<i>Activated charcoal</i>	<i>Removes (absorbs) certain contaminants</i>
<i>Filter Paper</i>	<i>Removes larger size particles</i>
<i>Cotton Balls</i>	<i>Acts as a spacer or filter</i>
<i>Coarse Sand</i>	<i>Filters medium sized particles</i>
<i>Fine Sand</i>	<i>Filters small particles</i>
<i>Cheesecloth</i>	<i>Used as a filter</i>
<i>Nylon Mesh</i>	<i>Used as a filter</i>
<i>Other Equipment</i>	<i>Supports and contains filtering materials</i>