Filtration

Station 2

You may choose to use a filter as part of your water treatment system. Focus your work at this station on these three questions:

- **What do you know about filters and what do you need to find out?**
- **What substances will a filter remove from water?**
- **How could you determine if a filter is effective in removing substances from water?**

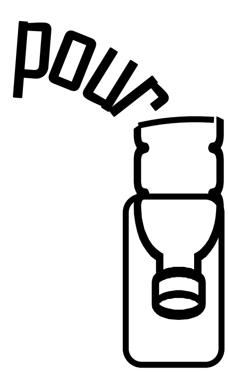
You are not limited to the information provided at the station as you investigate methods of filtration. Experimentation at this station will guide your decisions about designing a filter for the overall water treatment system.

Record information in your journal, including ideas and questions you have, as you learn about this topic.

Comparing Media

Step 1:

Some common materials (often called media) used in filtration systems are shown at this station. Your filtration system may use some or all of these media. You may also choose other materials to use. How does the filtration process vary, or differ, as these different media are used as filters? Add a sample of water to each media to investigate the effectiveness of each one as a filter.

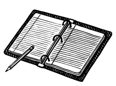


Removing Contaminants

Step 2

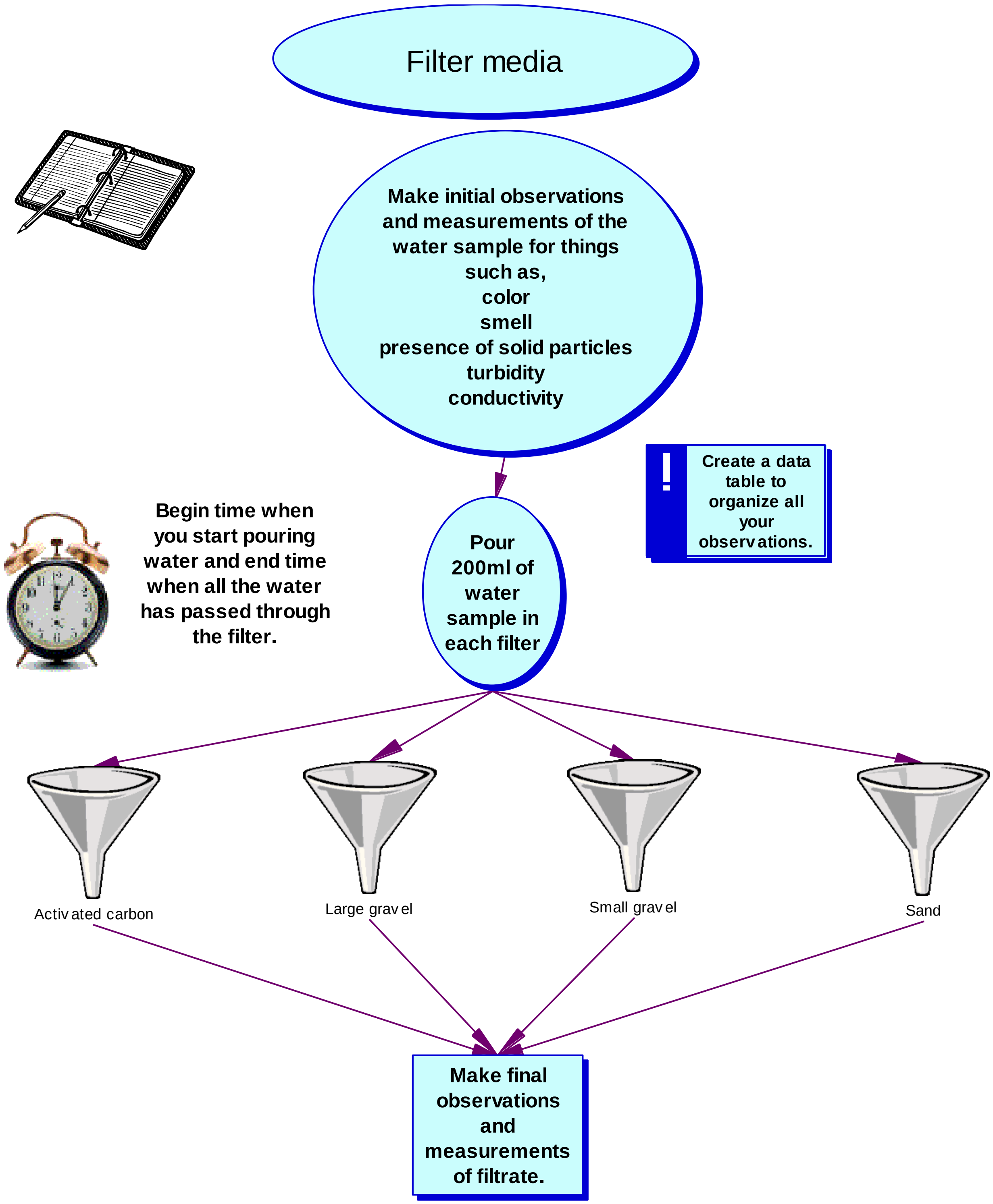
A. One of the focus questions is, “What substances will a filter remove from water?” (Color and odor are not substances but may be caused by substances in the water). Sort the paper strips provided for this step into two categories. The categories are substances that a filter will remove from water and substances a filter will not remove from water. Additional information or evidence may be needed to complete your sorting, but complete the sorting at this time. You will have an opportunity to collect evidence that will help you to revise your groupings.

B. Choose at least 3 of the substances that you predict a filter would remove. You will test these substances in the next step. Look ahead to Step 3 and the diagram of the procedure. This diagram should help you answer the following questions.

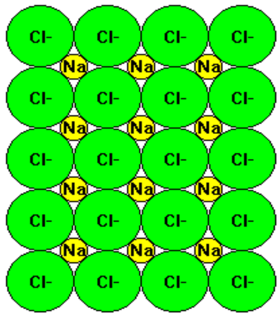


Think about this:

1. *What data will you collect?*
2. *Will you need to collect initial and final readings?*
3. *Design a table to organize your data.*


Filter media
Make initial observations and measurements of the water sample for things such as,
color
smell
presence of solid particles
turbidity
conductivity
Create a data table to organize all your observations.
Begin time when you start pouring water and end time when all the water has passed through the filter.
Pour 200ml of water sample in each filter
Activated carbon
Large gravel
Small gravel
Sand
Make final observations and measurements of filtrate.

Step 3:



The conductivity of a water sample indicates if a solution has dissolved **ions** (charged particles). Ground water picks up ions as it flows through soil and over rocks and minerals. You cannot see or visually measure the concentration of these ions. When ionic substances such as salts (Figure 1), dissolve in water, the individual ions **dissociate** or break apart from solid particles. As a result, testing the conductivity of the water sample is a good way to indicate the presence of ions.

Figure 1: Common table salt. Salts are made of positive and negative ions that are arranged in a crystal. Common table salt (NaCl) is only one type of salt. (http://www.uwgb.edu/dutchs/EarthSC202Notes/minerals.htm)

Porosity is used to describe the ability of a material to allow movement of fluids through it. The fluids move through pores (Figure 2), or small holes or passageways in the material. The particle size of the media controls the pore size. Media with large sized particles has large pores which filter out large suspended solids. This filter will allow small and medium sized particles to pass through. Likewise, media with small particles has small pores, which filter out all but very small particles. Therefore, the particle size of the media is an important design feature in your water filter.

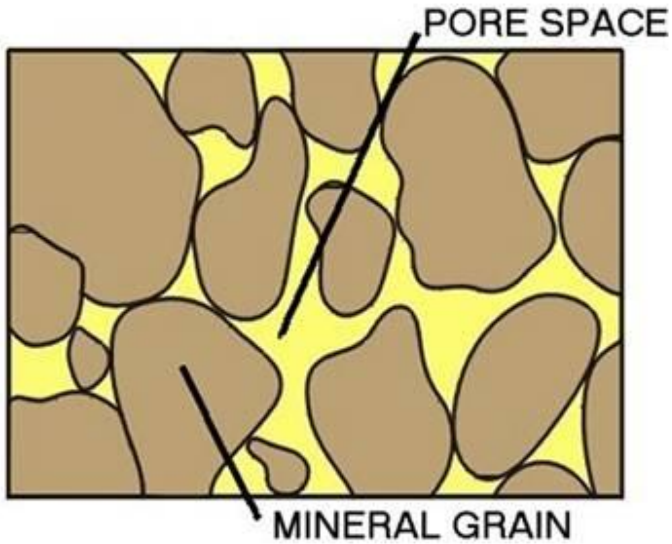


Figure 2: Pores are the spaces between grains of sand, minerals, or other material. Water and gases pass through pores. (http://amiadini.com/newsletters/images/envEnl-143_clip_image002.jpg)

Filter **permeability** is the rate that your water sample passes through the filter media. Use the measurements of time from your tests at this station to determine the flow rate for the media at this station.

Step 4:

Calculate this:

Use the time data you collected at this station to calculate flow rate (Q) and loading rate (v_a) by following these steps.

a. Flow rate (Q) is the volume (V) of water passing through the filter (measured in mL) in the time (t) measured in seconds.

$$Q = \frac{V}{t}$$

b. Find the average radius of your filter in centimeters. Use this measurement to calculate the surface area (SA) of the filter in cm^2.

Hint: Measure the diameter of your bottle and take an average. Remember to divide the diameter by 2 to get the radius!

$$SA = \pi r^2$$

c. Finally, calculate the loading rate (v_a) of your filter. Use your values from **a** and **b** in your calculation.

$$v_a = \frac{Q}{SA}$$

Step 5:

Think about this:

What types of "green" (recyclable or recycled) material might you use in a filtration system for drinking water? With your team, list at least 4 different materials.

5. *What would be the pros and cons for using each of these materials? Organize your answer in a table*
6. *Order the materials in your list with the material you think is the best listed first.*

Review the Presentation Rubric with your team to find out what is expected as you complete this phase of your design process. Remember that a water filter is only one part of a water treatment system.

1. As a team, identify the materials you will use in your plan for the filtration system. Consider the following as you make decisions about your design.

2. Once the questions above have been answered, draw a scaled diagram of the filtering system. Label each layer present in the diagram and provide essential measurements of the parts in the filter.

3. Prepare to justify your design by answering the following question. *How does your filter system help to meet the requirements for your water treatment system?*

4. Make a prediction about how you think your designed filter will perform. Relate your predicted performance to the requirements for your drinking water.

Designing the filter:

- What are the requirements for your drinking water?
- What media will make the filter more "green"?
- How many different materials will we use?
- What proportion of each material will we use?
- What order will we place each media in the filtration bottle to maximize load rate and still be effective?

*****Use a 2 liter soda bottle for your filter.***
*****Use at least 2 kinds of recycled or "green" materials***

NOTE: This filter will be one part of your water treatment system. You will learn about other parts of the system at other stations

Teacher Pages

Water Filters for Drinking Water

Background:

Filtration removes suspended particles from water and other solutions and in the process reduces the turbidity. Filtration works by separating suspended and colloidal materials as water passes through a porous medium. As water passes through the pores, the suspended solids and colloidal material may be retained by the media and the pores. The water leaving the filter has a lower turbidity due to the retention of solids in the filter.

The type of media in the filter classifies the filter. A sand filter consists of only sand. A dual media filter contains sand and gravel. Other materials have been used in filters, including coal, or recycled materials like shredded tires or plastic chips. The use of recycled materials is a sustainable (green) engineering concept.

The structure, or nature, of the media controls the pore sizes. Therefore, some media have large pores, which excludes only large suspended solids. Likewise, small media has small pores, which excludes all particles except those that are very small. Therefore, decisions about what material to use are important in design an effective filtering system.

Filter systems also can be classified by loading rate. Loading rate is a measure of the flow rate, or velocity, of water passing through a unit area of the filter. A slow sand filter has a typical loading rate of 2.9 to 7.6 $m^3/d\text{-}m^2$) whereas rapid sand filters have a loading rate of 100 to 475 $m^3/d\text{-}m^2$. (Note: m stands for meters and d stands for days.) The difference between slow sand filters and rapid sand filters is the grading of sand in a rapid sand filter. By grading the sand, the particle sizes change, thus changing the pore size between the media. Dual media filters have a loading rate up to 300 $m^3/d\text{-}m^2$. The figure below is a drawing of a filter.

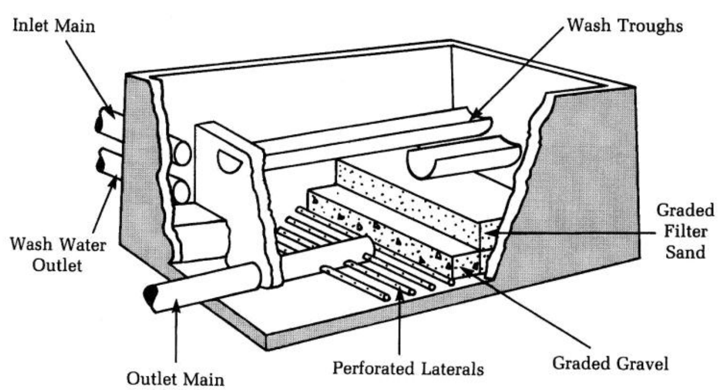


FIGURE 3-40
Typical cross section of a rapid sand filter. (*Source:* American Water Works Association, *Water Treatment Plant Design*, 1969.)

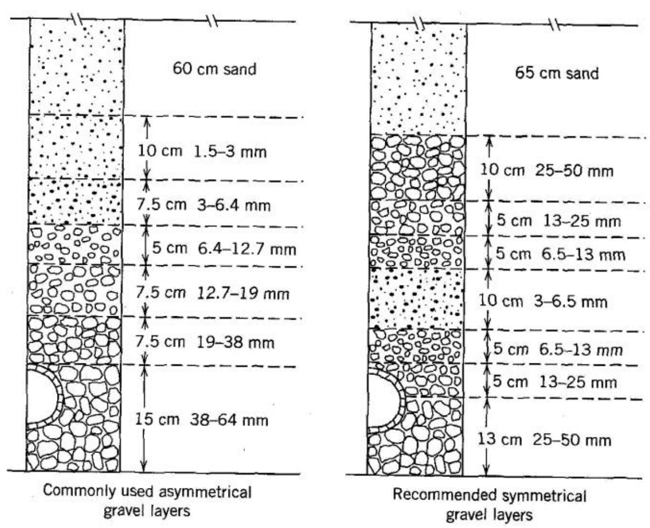
Source: Davis, M.L. and Cornwell, D.A. 2008. Introduction to Environmental Engineering, Fourth Edition, McGraw Hill, New York, NY.

The effectiveness of a water treatment filter is measured using turbidity percent removal. Measures of turbidity removal provide evidence of the effectiveness of a filtering system and whether it effectively removes suspended solids and results in water that meets the quality standards enforced by the agency regulating water quality.

The table below presents some of the design characteristics for rapid sand and multimedia filters. Filters have maximum dimensions of 10 m wide and 10 m long. The depth of the filter depends on the number of media layers and the thickness of the layers. Figure 2 compares the design characteristics of two different filters.

Table 1. Design characteristics of Rapid Sand and Dual Media Filters

	Rapid Sand	Dual Media
Total Depth	0.6-0.7 m (2-2.3 ft)	0.6-0.8 m (2-3 ft)
Graded Gravel Layer	0.5 m (1.6 ft)	0.5 m (1.6 ft)
Rate of filtration	100-475 $m^3/d\text{-}m^2$	>300 $m^3/d\text{-}m^2$



Supporting gravel layers for sand filters. From G. M. Fair, J. C. Geyer, and D. A. Okun (1968), *Water Purification and Wastewater Treatment and Disposal,* vol. 2, copyright © 1968 by John Wiley & Sons, Inc. Reprinted by permission of John Wiley & Sons, Inc.

Figure 2. Filter Media Layers

After hours of operating rapid sand or a dual media filter, the pores in the filter become clogged with suspended solids. To treat more water, pores are cleaned to remove the suspended material. Backwashing is the process to clean a filter. In normal filter operation, water enters the top of filter, passes through the pores and is collected at the bottom of the filter. In backwashing, pressurized water is reversed to flow up through the filter and is collected at the top of the filter. The backwash water contains a high concentration of suspended solids because the suspended solids that were in the filter are now removed. The backwash water must be treated to remove the suspended solids. To treat the backwash water, the water is returned to the head of the water treatment plant.

After water is treated by a filter, the water flows in channels or pipes to the disinfection process.

Purpose:

- Demonstrate the physical removal of water contaminants.
- Compare behavior of dissolved to suspended (visible) contaminants.
- Calculate flow rate and loading rate.

Outcomes and Indicators of Success

By the end of this station, students should be able to

1. explain how porosity affects the function and effectiveness of a filter.

   To achieve this outcome, students must make observations as they
   - filter water through media of different grain size,
   - record the time it takes for a sample of water to pass through different media, and
   - compare the flow rate and loading rate of several filter media.

2. observe and analyze the characteristics, or properties, of water.

   To achieve this outcome, students will
   - observe and describe characteristics, or properties, of their water sample before and after filtering and
   - compare and contrast water characteristics before and after filtering.

3. design a filter as part of a water treatment system.

   To attain this outcome, students will
   - synthesize the information they gained as they observed the filtration process and result and
   - present their filter design in a scaled and labeled diagram.

4. model green engineering practices.

To attain this outcome, student will

- consider at least 2 different recycled materials as a media in a water filter,
- establish and document the pros and cons of each type of recycled material available for use in a water filter, and
- use these pros and cons as criteria to select at least two materials for use in their water filter.

Materials at the station:

4 pre assembled filters with only one type of media in each
Media to use:
activated carbon—found in most aquarium shops
gravel (two sizes)
sand—do not choose sand that is too fine or the water will take too long to filter.
cotton to plug the bottom of the funnel
a yucky and turbid water solution
(You will need 800 mL of this water each time the station is used. Prepare the water sample by adding coffee, coffee grounds, and garlic salt to water.)
stopwatch
calculator
4 rulers
envelope
cutout words from *Master 1: Water Contaminants*
conductivity tester
turbidity test kit
nitrate test kit
computer with Internet access

Station set-up

1. Prepare the 4 funnel systems by using a cut 2-L soda bottle. Plug the mouth of the bottle with cotton so the media will not fall through the funnel.

2. Prepare enough of the water sample so that 800 ml are available for each group that uses the station. The water should contain: brewed coffee to discolor the water, coffee grounds, and garlic salt to add odor and ions for conductivity.

3. Place calculators, rulers, and a stop watch at the table.

4. Place the conductivity, turbidity, and nitrate testers along with their protocols at the station.

5. Cut out the words from Master 1 and place in an envelope for Step 2.

6. Set up a computer with Step 4 information on the screen. Ensure that the computer has Internet access.

7. In Step 5, students identify green materials to use in their filter. They will use these materials as they build their filter system in the next phase of the engineering design process. Make note of these materials and either have students bring them from home or make arrangements to have these materials available.

In Step 1, students will explore to determine the flow rates and effectiveness of the different media provided. They will make observations to help in the future design of the filter system.

In Step 2, students will sort cards to decide what items can be filtered out of water. They will then choose items to test to verify they are correct.

Answers to Think About This #1-3:

1. Answers will vary. Students will observe patterns of filtration to make these decisions.
2. Students will want to time the flow through the filters as well as compare the before and after clarity of the samples.
3. The table should clearly communicate the filter component, size and results from testing.

In step 3, students will look at pores sizes in filtering materials. They will also determine the flow rate of their filter as time is a critical factor in designing an efficient system.

Answers to Think About This #4-6:

4. Student answers will vary. They will want to provide materials that are readily available from home.
5. Student answers will vary, but they should clearly communicate pros and cons.
6. The justification will help in the process of ordering the materials for a final selection.

Master 1: Water Contaminants

soils	**acidity**
dissolved salts	**nitrates**
color	**smell**
bacteria	**plant pieces**
sand	**insects**