Teacher's Preparatory Guide
Water purity and filtration – Getting down to the nanoscale

Lesson 3: Water Filtration and Nanoparticles

Purpose: This activity—in which students make a sand filtration device—is designed to be used as an extension to classroom activities related to treating foul water for consumption. Ideally, this activity should be done after students have been introduced to the concept of nanoscale (Lesson 1) and after the lab titled *What Affects the Purity of Water?* (Lesson 2). This class project produces a point-of-use filtration system for needy families who do not have an adequate supply of clean potable water (as in some third-world countries). Pathogens in water are in the micro (bacteria) and nano (virus) scale. Research has shown that removal of water-borne pathogens at the micro- and nanoscale, can greatly improve the health of infants in developing countries.

Level: Middle and High school -- Biology, Chemistry, Physical Science, Environmental Science

Time required: Two 50-minute class periods or one 90-minute block day

Safety Information Safety goggles should be worn while cutting PVC pipe and drilling holes. Keep electrical devices far from water to avoid risk of electrical shock. Wear protective gloves to avoid contact with glue and primer. Use glue and primer in a well-ventilated area to avoid prolonged exposure to fumes. Use care when lifting bags of gravel and sand. Use team lifting practices when lifting heavy objects. Use care when cleaning and working with knife and clipper blades—they present a cutting hazard.

Advance Preparation: Purchase PVC pipes from an hardware/irrigation supply store. Sand and pea gravel should be pre-washed and can be purchased from a landscape company or hardware store. Materials for testing the bacteria level in water can be found at www.hach.com/ or through Lifewater International (888)543-3426. Alcohol prep pads (those used to prepare the skin for an injection) can be purchased from a pharmacy (we used alcohol swabs from B-D Consumer Health Care brand, purchased at www.riteaid.com). Other materials can be bought at a hardware store or at a home and builder's warehouse. Collect enough 1 L plastic bottles for each student group to have one and cut the top off of each bottle. Finally, be sure to conduct this activity when the outside/room temperature is 75ºF/24ºC or higher to allow the bacteria to grow.

Materials per class (makes one filter)

- 12-inch (inside diameter) PVC pipe, cut to 36 inches long
- approximately 4 feet of plastic 3/8 inch outside diameter (1/4 inch inside diameter) hose is needed as an outlet for the filter
- Four plastic electrical ties, each 24 inches long
- a pint (4 fl. oz.) of PVC cement and primer
- a tube (2.8 Fl. Oz.) of 100% silicone clear DAP aquarium sealer
- 3/8 inch drill bit and drill
- a bucket of pea gravel
- a 100-pound sack of #16 pre-washed sand

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- a dolly or hand truck
- a table that is taller than 36 inches (such as a lab table)

Materials per student group

- pathoscreen media, 100 mL 50/pack, Hach part #26106-96
- sterile whirl-pak bag with dechlorinating agent, Hach part# #2075333
- antiseptic alcohol prep pads (also called alcohol swabs/wipes)
- permanent marker (preferably with a thin writing tip)
- a 1 L plastic bottle, with the top cut off
- Understanding scientific inquiry

Background Information

Nanotechnology could lead to advanced water-filtering membranes that may purify even the worst wastewater. Progress is being made in the research of anti-bacterial and anti-viral filters. For example, raw sewage could be poured in one of these advanced filters and come out with clear water on the other end. See article on Nanotechnology and Water Treatment at: https://www.nanowerk.com/spotlight/spotid=4662.php.

Did You Know?

"A child dies every 15 seconds from diarrhea, caused largely by unsafe water and inadequate sanitation."

—*World Health Organization*

Source: http://www.undp.org/water/

http://www.who.int/dg/lee/speeches/2005/ministerialmeeting_healthandenvironment/en/index16.html

"Currently, over 1 billion people lack access to water and over 2.4 billion lack access to basic sanitation."

—*United Nations Development Programme*

Source: http://www.undp.org/water/

Find out more about the global water crisis at the links

Teaching Strategies

Before this activity, review the concepts of size and scale (Lesson1). Build on the inquiry-based interlude by asking the questions below: Students may work in groups of 4–5 students, with each group building a sand filter or it can be built as a class project for demonstration or for use in a third-world community in need. The device built in this lesson has been successful used in Mexico and Africa by the author.

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Water Filtration and Nanoparticles

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Dear Team:

Thank you for your recommendation to get a filter for the stream on our ranch.

To save money, I would like to have you build a filter that will purify the water in the stream so that people on my ranch can drink the water.

Also, please test the filtered water to make sure that it is safe to drink.

Sincerely,

Manuel Ranchero
Ranch Owner
Rancho Felicidad

Guided Dialog

What problems might you have with using sand to remove nano-sized objects from the water? *The space between grains of sand might be large enough to allow nanoparticles to pass through the filter.*

What materials would you need to build a large sand filter? *Answers will vary. Example answers: PVC pipe, saw, PVC cap, PVC cement and primer, drill, plastic tubing, aquarium sealer, electrical ties, sand, and gravel*

What might make a sand filter difficult to build? *Example answer: cutting the pipe, drilling the hole, gluing the cap, sealing the tube*

Some scientists have developed a way to clean water using *bio-sand filters.* They use a method to clean drinking water from creeks, streams, and rivers that may have bacteria in it. Define *bacteria. A bacterium is a single celled organism with some the species involved in infectious diseases. It is very small (*most bacteria range from 1 to 5 microns in size) *but can easily be seen under a microscope.*

What would compose a bio-layer formed at the top of the sand filter that would eat nano-sized particles. *Bacteria* What would you call this process? *Predation*

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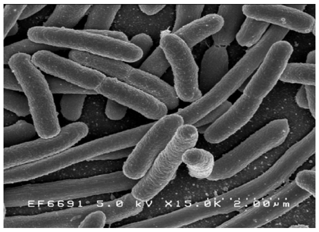
Power Point Slides (separate file)

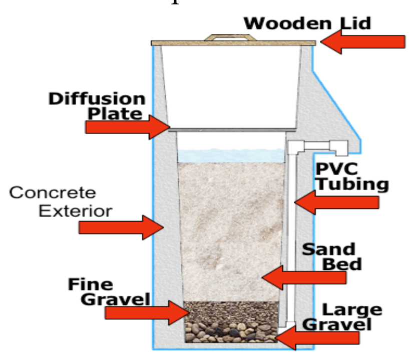
Have students look at the picture of *E. coli*. Explain that these bacteria have sizes that are microscale and are NOT nanoscale. Viruses are in the nanoscale.

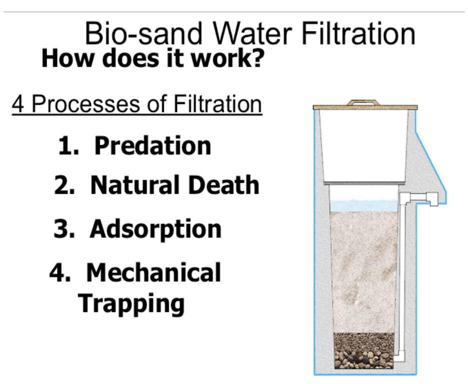


Left: Scanning electron microscope image of *Escherichia coli*, grown in culture and adhered to a cover slip.
Credit: Rocky Mountain Laboratories, NIAID, NIH
Source: NIAID: *These high-resolution (300 dpi) images may be downloaded directly from this site. All the images, except specified ones from the World Health Organization (WHO), are in the public domain. For the public domain images, there is no copyright, no permission required, and no charge for their use.*
http://en.wikipedia.org/wiki/Image:EscherichiaColi_NIAID.jpg

Have students identify the different sources of water pollution from the picture. *Sample answers: bathing and washing in the river, trash and garbage dumped beside the river, people and animals deficating along the river, animal feces can be washed into the well, stored water is not protected from animals or industrial waste*

Ask: What is a bio-sand filter made of? How could we duplicate it?





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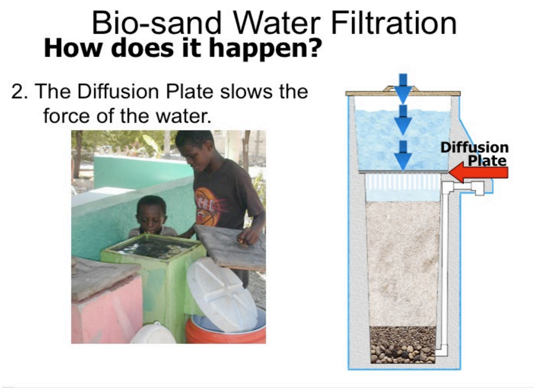

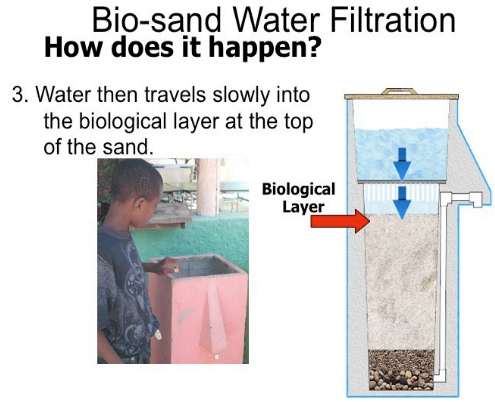

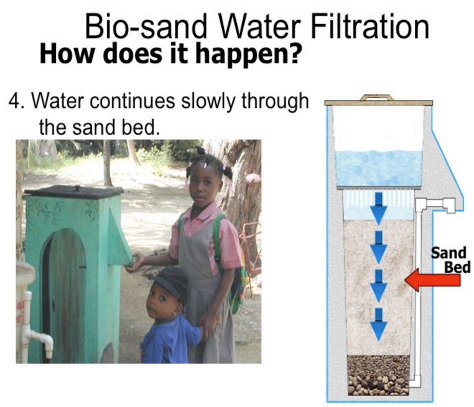

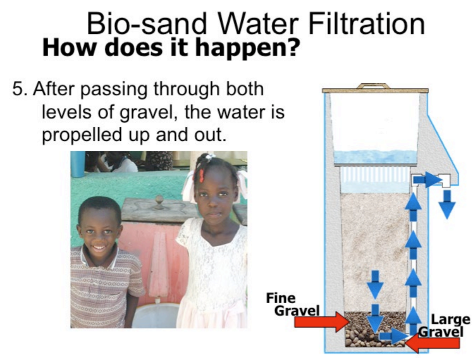

National Science Education Content Standards

Content Standard A

- Abilities necessary to do scientific inquiry
- Understanding scientific inquiry

Content Standard B

- Structure and properties of matter

Content Standard C

- Interdependence of organisms

Content Standard E

- Abilities of technological design
- Understandings about science and technology

Content Standard G

- Science as a human endeavor
- Nature of scientific knowledge

Content Standard F

- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

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Water Filtration and Nanoparticles

Student Worksheet (Answer Key in red)

Date

Dear Team:

Thank you for your recommendation to get a filter for the stream on our ranch.

To save money, I would like to have you build a filter that will purify the water in the stream so that people on my ranch can drink the water.

Also, please test the filtered water to make sure that it is safe to drink.

Sincerely,

Manuel Ranchero
Ranch Owner
Rancho Felicidad

Question Will the filter remove disease-causing bacteria?

Make a Prediction *Answers will vary, but should have a logical argument either for or against the filter. Example answer: No, the spaces between the sand particles will still allow nanoscale particles to pass through.*

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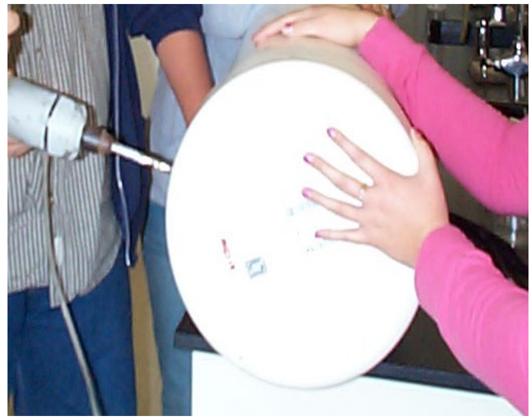
Procedure—Part II: Making the Filter



1. In a well-ventilated area, paint primer around the inside rim of the PVC cap. Be sure to cover the entire inside surface of the cap. (Use the brush that comes with the primer.)
2. Measure the height of the cap. Paint primer on the outside of the PVC pipe to the same depth as the height of the cap.
3. Allow the primer to dry by following the instructions on the can.
4. Apply the PVC cement around the inside rim of the cap.
5. Place the PVC cap on one end of the PVC tube and firmly tap it down with a rubber mallet or your hands to secure it in place.
6. Allow the cement to dry by following the instructions on the cement.
7. Drill a 3/8-inch hole in the cap for a 3/8-inch plastic hose. Be sure to wear goggles as you drill to protect your eyes from projectiles.
8. Insert 3/8-inch hose into the hole.
9. Apply silicone aquarium sealer around the outside of the plastic hose so that water will not leak out. Then, ask someone with really long arms to apply the sealant to the inside of the hole.

Safety Alert!

Wear protective gloves while using primer and cement.

Work in a well-ventilated area.

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10. Use plastic electrical ties to hold up the 3/8 inch hose along the outside of the bio-sand filter.

11. Pour water through the PVC pipe to test whether the system leaks. Water should only exit via the tube.
12. If the system has any leaks, mark the leakage with a permanent marker and allow it to fully dry. Then apply aquarium sealer to the marked areas.
13. Repeat steps 11–12, until the system has no leaks.

14. Add 1/4-inch of pea gravel to the bottom of the bio-sand filter to a depth of 2 inches making sure it covers the plastic hose at the bottom of the filter.

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15. Place the bag of ***clean*** #16 grit sand atop a table. Place the PVC pipe below it, with the capped end touching the floor. Gently scoop the sand into the filter. Continue adding sand until it is 2 inches below to top (for a water reservoir).
16. Take the filter outside. Add a bucket of water to flush the system to ensure that it is working.

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Procedure—Part II: Testing the Filter

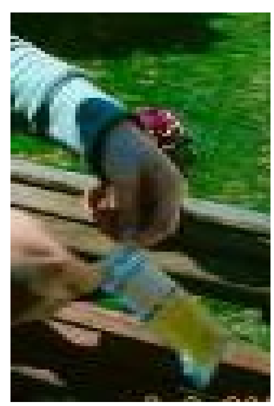
Materials
- knife or nail clipper
- pathoscreen media
- sterile bag with dechlorinating agent
- 2 antiseptic alcohol preparation pads or alcohol swabs/wipes
- permanent marker
- 1 L plastic bottle, with the top removed

Safety Tip

Use care when cleaning and using blades—they are sharp and can cut.

1. Wearing protective gloves, remove an alcohol swab from the foil pouch and use it to carefully clean the knife or nail clipper blade.
2. Place the swab atop a flat surface.
3. Use the knife or clipper to open the pathoscreen media and carefully place the media on top of the opened alcohol wipe. Make sure that the contents do not spill out!
4. Use another alcohol wipe to wipe the tube (outside and just on the edge of the inside, if possible) where the water will exit. Lay the tube on top of the wipe to keep the tube clean and free of contamination.
5. Label the sterile bag with your name, date, and time.
6. Open the sterile bag by tearing off the top of the bag along the perforation. Be sure NOT to contaminate the inside of the bag. Leave the small tablet of sodium thiosulfate in the bag—it will remove chlorine from the water.
7. Hold the bag by the wireless white strips at the top and pull. The bag will open.
8. Let the water run for about 30 seconds.
9. Fill the bag to the 100 mL line with the water. If the bag fills above this line, pour out the excess water.
10. Add the pathoscreen media powder to the bag containing your water sample—this nutrient will help any bacteria present to quickly multiply and allow you to detect their presence. Be sure to add **all** of the powder to the bag.

11. Pull the white wire strips taut to close the bag.
12. Firmly hold the wire strips, and carefully but quickly flip the bag 3 times so that the bag folds tightly over the wire to create a tight seal. Fold the wire strips over to seal the bag, as shown in the image at right.
13. Observe the contents of the bag. If the sodium thiosulfate has not fully dissolved, gently shake the bag. Prevent water from leaking out by not squeezing the bag.
14. Place the bag in the 1 L bottle with the top removed for safe transport. Store on a level surface where it will not tip.



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Data Collection:

15. Record the color of the bag, the date, and time in the table below.
16. After 24 hours, observe the sample bag and record your observations in the table below. What color is the sample? If it is yellow, does it have black spots?
17. After 48 hours, repeat step 16.

Sample	Description at 24 hr	Description at 48 hr	Is bacteria present?	Conclusion
1	*black*	*black*	*yes*	*lots of bacteria in initial sample or these bacteria quickly grow*
2	*yellowish/cloudy*	*yellow with black percipitate or black dots*	*yes*	*not many bacteria in initial sample or these bacteria slowly grow*
3	*yellow*	*black*	*yes*	*not many bacteria in initial sample or these bacteria slowly grow*
4	*yellow*	*yellow with black percipitate or black dots*	*yes*	*not many bacteria in initial sample or these bacteria slowly grow*
5	*yellow*	*yellow*	*no*	*bacteria not detectable; water may be safe to drink*

Materials for disposal

- bucket
- bleach
- water
- straight pin
- spray bottle containing bleach and water in a 1:10 ratio
- paper towels

Disposal of materials:

18. Wear a pair of protective waterproof disposable gloves.
19. Remove the sample from the transport bottle and have a lab partner hold the bag upright as you fill the 1 L transport bottle halfway with tap water.
20. Add bleach to the transport bottle until it is ¾ full. Gently shake the bottle to mix the bleach with the water.
21. Place the sample bag in the water bottle and push it down to submerge the bag.
22. Use the straight pin to puncture the bottom corner of the bag. Allow the contents of the bag to empty into the bottle.
23. Flush with tap water the fluid contents of the bottle. Do **NOT** flush the bag.
24. Repeat steps 21–23 to disinfect the inside of the bottle and the bag. You may open the bag and rinse the inside of the bag.
25. Dispose of the bag, pin, bottle, and gloves in a way that they cannot be recovered, such as placing them in a biohazard bin. Pins should be disposed of in a closed cardboard box before placing them in a biohazard bin. Be sure that pins do not go directly in a plastic bag—they can puncture the bag.
26. Use the spray bottle containing bleach water to disinfect any surfaces that might have come in contact with the sample.

Safety Alert!
The contents of the bag may contain disease-causing bacteria that could cause diarrhea or other illness. Wear gloves and use caution at all times during disposal.

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Analysis of results:

27. If the water sample in your bag is black or has black dots in it, then bacteria has been detected. If it is yellow with no trace of black, bacteria has not been detected. Is bacteria present in your samples? For each sample, record your answer in the table on the previous page.

28. Why did you clean the cutting tools and water tube before testing the water for bacteria?

    Dirty tools or water tube could contaminate the water sample.

29. Why must the sample be at room temperature for 24 hours before you can expect a color change? *It takes time for bacteria to multiply and grow to detectable levels.*

30. How might doing this experiment on a very cold day affect the results? *Bacteria would not grow as quickly or would not grow at all to be at detectable levels. So, the bag might appear yellow even when bacteria is present.*

31. How might doing this experiment on a very hot day (over 90°F) affect the results? *The heat might kill bacteria present and result in a negative test, which would be inaccurate.*

Conclusion

32. In your data table, notice the trend of color throughout the period of time that you tested. What conclusions can you draw about how quickly or slowly the bacteria grew? What can you conclude about how much bacteria were initially present in the sample? Record these conclusions in the data table.

33. Is the filtered water safe for human consumption? *Yes, my water was safe for human consumption.*

34. What recommendations would you make to improve the filter? *Answers will vary.*

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35. Were the materials filtered out of the water on the macro, micro or nanoscale?

All three should have been filtered out but is dependent upon the actual water sample.

36. Suppose your filter system did not work well. What could you recommend to the people who work on that ranch that they do while you test another filter? Explain your answer. **(Hint:** review your answer in step 31.) *I would recommend that people boil the water, because the high temperature is likely to kill disease-causing bacteria before drinking.*

37. Across the Disciplines: Bonus Project: Researchers who develop filtration devices often test for what particles are filtered out. Write a 2-page paper describing one of the following:

- techniques (light, chemicals, etc.) used to identify microscale and nanoscale objects filtered from water
- tools used to see nanoscale objects that are often found in water
- various nanofiltration devices and how they differ from microfilter
- how biolayers assist with filtration

38. Inquiry Extension: Using the information from your project in step 36, brainstorm a procedure on how you could test the size of particles that are filtered from the water.

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