Pure Water

Take muddy water and make it clean

Lesson Plan

Description: Visitors learn how "raw" water is treated to make clean, safe drinking water. They work in pairs to treat muddy water through flocculation, and watch a filtration demonstration.

Audience: Hands-on activity for families and children ages 8 and up

Length: 20 minutes

Learning Objectives

Visitors learn:

- The major steps in the water treatment process include flocculation, filtration, and the addition of chemical disinfectants.
- A *suspension* is an example of a mixture.
- *Precipitation* is an example of a chemical reaction.

Visitors develop skills related to chemistry and science, including:

- Measuring and pouring volumes of liquids
- Pipetting liquids
- Testing pH of liquids using litmus paper
- Performing controlled experiments
- Observing chemical reactions and physical processes
- Communicating and discussing experiment results

Learning Standards

National Science Education Standards

1. Science as Inquiry
   K-4: Abilities necessary to do scientific inquiry
   K-4: Understanding about scientific inquiry
   5-8: Abilities necessary to do scientific inquiry
   5-8: Understanding about scientific inquiry
   9-12: Abilities necessary to do scientific inquiry
   9-12: Understanding about scientific inquiry

2. Physical Science
   K-4: Properties of objects and materials
   5-8: Properties and changes of properties in matter
   9-12: Structure and properties of matter
   9-12: Chemical reactions

Background Information

Most public drinking water in the United States comes from underground aquifers or from surface streams and reservoirs. Before it comes out of the tap, the “raw” water is processed by a treatment facility. Depending on the quality of the incoming raw water, it could take several hours or up to a day to process, or “finish,” the water and make it ready for the public to drink.

In a typical water treatment process:

- **Alum** is used to coagulate suspended particles, algae, protozoa, viruses, bacteria, and some metal ions (such as iron and manganese) into larger particles. The resulting "sludge" is then removed.
- **Ozone** may be bubbled through the water to kill remaining bacteria, viruses, and protozoa.
- **Activated carbon** filters remove organic compounds and any fine particles that remain in the water.
- **Chlorine** is added to kill bacteria that may have entered the water during the filtration process.
- The **pH level** is adjusted to limit corrosion in the public water system.
- **Fluoride** may be added to help fight tooth decay in the population.

In this program, visitors will treat local, raw water with two processes—flocculation and filtration—to learn how the public water supply is made safe to drink.

FLOCCULATION

Flocculation removes much of the color and contaminants from raw water. Beginning with a sample of visibly muddy water, visitors use **lime** and **alum** is to coagulate suspended particles.

Lime (calcium hydroxide) makes the water basic. When lime dissolves in water, it breaks up into calcium ions and hydroxide ions:

$$Ca(OH)_2 \rightarrow Ca^{+2} + 2OH^{-1}$$

calcium hydroxide → *calcium ion* + *hydroxide ions*

Hydroxide ions make water solution basic. This is verified by using red litmus paper. (Water that is basic will turn the paper blue.)

Alum creates a precipitate because it cannot dissolve in water. Smaller particles in the water stick to the alum precipitate, forming bigger particles. As the precipitate settles out of the water, it takes with it much of the suspended soil, chemicals, and organisms.

The alum, in this case, refers to a compound made up of potassium and aluminum ions (with a positive charge) and sulfate ions (with a negative charge). In solution, the aluminum ion is released and reacts with the hydroxide ion (from the calcium hydroxide) to produce a white, jelly-like aluminum hydroxide that cannot dissolve in water and precipitates.

$$Al^{+3} + 3OH^{-1} \rightarrow Al(OH)_3$$

aluminum ion + *hydroxide ion* → *aluminum hydroxide precipitate*

The precipitate settles to the bottom of the beaker, leaving clarified water.

FILTRATION

The clarified water is then filtered to remove organic compounds and any remaining particles. Gravel, sand, and activated charcoal are often used as a filter.

ADDITIONAL STEPS

Chlorine or another chemical is added to disinfect the water, killing any bacteria or other microorganisms.

Some communities adjust the pH level (acidity or alkalinity) of the water to help maintain the pipes and other infrastructure of the water supply system. Some communities also add small amounts of fluoride to the water to help prevent tooth decay.

Materials

FLOCCULATION ACTIVITY

For each pair of visitors

- Clear plastic cup labeled "muddy water"
- Small, labeled container of limewater
- Small, labeled container of alum solution
- 2 jumbo (15 ml) transfer pipettes
- Red litmus paper
- Safety glasses (for each visitor)
- Tray (optional—to catch spills)

Shared materials (for a table of several pairs of visitors)

- 1-liter bottle of muddy water
- Clear plastic cup labeled "control"
- Paper towel (for spills)

For the presenter

- One set of visitors' materials to demonstrate procedure

FILTRATION DEMONSTRATION

For the presenter

- Visitors' cups of clarified water from flocculation activity (at least 2 cups are needed)
- Prepared filtration apparatus (see below for preparation instructions)

Notes to the Presenter

CAUTION: Always supervise visitors during this activity. Be sure visitors wear safety glasses and don't let them taste any chemicals (even the cleaned water).

Set Up

Set up takes approximately 30 minutes. (Set up will take longer the very first time you do the activity.)

- Prepare the muddy water, by mixing about half a cup dirt in about a liter of water
- Prepare the limewater, by dissolving 3 tsp calcium hydroxide in 1 liter of water (shake well to dissolve)
- Prepare the alum solution, by adding 1 tsp potassium aluminum sulfate or ammonium aluminum sulfate to 1 liter of water
- Test the flocculation procedure ahead of time, so you can adjust it as necessary, and advise visitors on the approximate quantities that will work (probably 2-3 squirts
- Prepare the filtration apparatus (see below)

FILTRATION APPARATUS

1. Cut off the bottom of an empty 1-liter soda bottle, and turn it upside down
2. Insert a small piece of filter paper
3. Add a layer of activated charcoal (small chunks for aquariums work well)
4. Add a layer of sand
5. Add a layer of gravel
6. If you like, add another filter at the top to keep contents from spilling (you can remove this when you do the activity)

Program Delivery

Welcome visitors. Explain that they will be working in pairs or groups of three, and divide them among the workstations. Explain to parents that this is a family activity, and they should work with their children.

Did you ever stop to wonder about the water that comes out of your tap? Most of us take our safe, clean water for granted. But where does it come from? How does our community make sure it's safe to use and drink?

Most public drinking water in the United States comes from underground springs, or from surface streams and reservoirs. Before it comes out of the tap, this water is processed by a treatment facility. When the water comes into the water treatment plant, it's called "raw" water. When it leaves the plant hours later, it's called "finished" water.

Today, we're going to learn how raw water is finished! Take a look at this water! *Hold up muddy water bottle.*

This is local water with local dirt! Does this look good to drink? *Response.*

No? Then let's see if we can get it cleaner and safer.

We're going to do two things to treat our water:

1. **We're going to make a precipitate to settle out the big pieces of mud and gunk.**
2. **We're going to run it through a filter to get out smaller things that are still in the water.**

Before we start, let's make sure everyone is wearing safety glasses. *Make sure all visitors are wearing safety glasses.*

PART 1: FLOCCULATION

The first thing we're going to do is a process called *flocculation*. That's a funny word for creating a precipitate, or solid, that will grab the stuff floating in the water, bind it together in globs, and make it fall to the bottom of the water.

Everyone has a cup of muddy water. Give it a good swirl so you can see all the stuff that's in there.

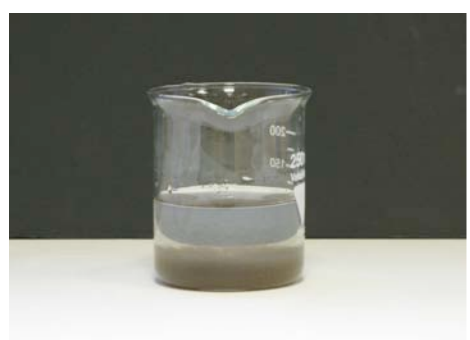
We also have a cup for the table. This cup will be our *control*, or comparison, so we can see what the water would be like if we didn't do anything to it.

To settle out the mud and stuff in your cup, we're going to first change the pH of the water by adding lime to it. Most water is pretty much neutral, meaning it's not a strong acid or base. The lime will make it basic (or alkaline). That will help create the precipitate, or solid, when we add a second chemical called alum.

Let's go ahead and get started, and while we're observing the process I'll explain more about what's happening.

Flocculation procedure:

1. Add a transfer pipette full of the lime solution to the muddy water.
2. Dip a piece of pH indicator paper into the beaker and observe the color. If the litmus paper turns blue, the solution is basic. If it stays red, add more lime solution.
3. Add a pipette full of alum solution to the muddy water mixture. Observe for a moment. If nothing happens, add another pipette full of alum.
4. A thick precipitate will form and begin to settle out.



What's happening? Do you see the cloudy white precipitate that's forming?

Let's take a look at how this happens in clear water so we can see it better. *Demonstrate the formation of the precipitate in a clean container:*

1. Pour about an inch of limewater into a clear cup or jar.
2. Test the limewater with a litmus strip. Note that it's basic.
3. Pour an equal amount of alum into the container.
4. Observe the precipitate forming.

So, when lime and alum are combined, they react and form a precipitate. Now look at your muddy water again. When we make this chemical reaction happen in the muddy water, the precipitate helps bind up the mud and other gunk in the water, and makes it settle out.

Let's take a look at our control, now. In comparison, how much of the mud has settled out? Not much. So we have a good idea that it was this chemical reaction that helped to remove a lot of the mud from our water.

PART 1: FILTRATION

This water on the top is pretty clear. Would you drink it? *Responses.*

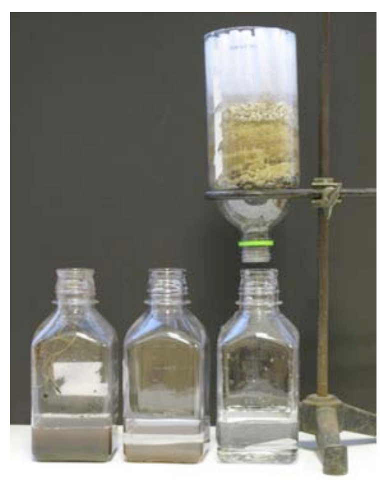
No? Then we still have more treating to do! Next, we're going to filter the water.

We can filter our water by pouring it into this bottle that's filled with different layers of material. The water will pass through gravel, sand, and activated charcoal.

To see how well our filter works, we'll pour some water through the filter and leave some out as a control, or comparison. *Demonstrate the following procedure.*

<u>**Filtration procedure**</u>

1. Set aside one cup of flocculated muddy water to serve as a control.
2. Take the remaining cups and carefully pour off the clear top layer of each into a clean container. This is your "clarified" water.
3. Carefully pour the clarified water through the filter. Be sure you have a container underneath to catch the water!
4. Compare the water that went through the filter to the clarified water that didn't (the control).



Can you see a difference between the water that went through the filter and the water that didn't? Which one looks cleaner? *The water that went through the filter looks cleaner.*

Why does the filtered water look cleaner? *The gravel, sand, and charcoal captured little pieces of mud and other particles in the water.*

Each layer in the bottle traps finer and finer particles. Relatively big chunks are caught in the gravel. The sand captures particles that are a little smaller. The charcoal gets the smallest particles.

Filtration removes additional pieces of dirt and other things from our drinking water. But it's still not safe to drink, because the filter can let through tiny microorganisms that can make us sick.

The final stage in water processing is to add something to disinfect the water and kill those microorganisms. Does anyone know of a chemical that is used in some water treatment facilities?
Answers will vary; chlorine and ozone are likely responses.

Chemicals like chlorine are often added in very small amounts to purify the water and make it safe to drink. We're not going to do that stage of processing. When they're concentrated, those chemicals can be dangerous. And we're working with such a small amount of water that it would be difficult for us to dilute them to the safe and appropriate concentration.

That means that although our water looks pure, it's not safe to drink like the water that comes out of our tap. So we're not going to taste it!

But now we know how our drinking water gets to be safe and clean!

Clean Up

- Paper towels that have been used to clean up spills can be disposed of in the trash Unused limewater and alum solution can be saved for future use.
- Liquid mixtures can be flushed down the sink. Solids can be disposed of in the trash.
- Supplies should be washed and dried before storage.

Credits
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