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(512) 471-5847
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Making Liquid Gold: Water Filtration by People and Mother Nature

Lesson plan for grades: 3-5
Length of lesson: 2 x 45 minute periods
Authored by: Mohammad Javanmardi, Environmental Science Institute, 11/15/12

SOURCES AND RESOURCES:

- Dr. Jay Famiglietti's Hot Science – Cool Talks Lecture: "Last Call at the Oasis: Will there be Enough Water for the 21st Century?" October 26, 2012, UT Austin: http://www.esi.utexas.edu/k-12-a-the-community/hot-science-cool-talks/last-call-at-the-oasis-will-there-be-enough-water-for-the-21st-century

- Groundwater Basics http://www.kalkaskacounty.net/planningeduc0019.asp

POTENTIAL CONCEPTS TEKS ADDRESSED THROUGH THIS LESSON

§112.14-16b. Scientific Investigation and Reasoning, Grade 3,4,5: (2A,2F)
§112.14-16b. Matter and Energy, Grade 3: (5D)
§112.14-16b. Earth and Space, Grade 4: (7C)
§112.14-16b. Scientific Investigation and Reasoning, Grade 5: (3A)

PERFORMANCE OBJECTIVES:

Students will be able to:

- Discuss the importance of and the uses for water
- Design a filtration mechanism by which "dirty" water is made cleaner.
- Notice relationships between their constructed filters and how water is naturally filtered

MATERIALS (per group of four):

- Filter diagram and worksheet
- Filtration Activity
- large plastic bottle or jug with the base cut off
- pieces of cloth (cut up shirts can work)
- pebbles of uniform size
- large or medium grain sand
- whole green leaves
- scissors
- large bin to capture water
- jug of dirty water (see preparation section)

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CONCEPTS:

Physical States: The 3 primary states of matter are called liquid, solid, and gas. These states entail no chemical change but rather physical changes.

Phase Change: Phase changes are the transitions between the 3 primary states of matter. The cause behind these phase changes is often a combination of applied pressure and heat energy.

Aquifer: An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted (source: www.wikipedia.org).

BACKGROUND:

Though water is seen by scientists as a chemical, everyday people see it as a very valuable and useful resource. It is first important to reflect on our everyday routines and realize how many times the average American uses water. Waking up in the morning we drink a glass of water or use the sink to brush our teeth. Even the toilets we use utilize water to properly dispose of human waste. Another common morning routine is taking a shower or bath which often uses gallons upon gallons of water. Around breakfast time some of us like to eat fruit which is first washed in the sink. Amazingly the day has only begun and we have recognized many different occasions where we regularly use water. An inexhaustible list could be written to name all of the uses for water that we have. Some of the items on that list could be as basic as agriculture, washing the car, the swimming pool, and washing our hands. Other items on that list could be things we rarely think about such as hydroelectric energy, plumbing, and industrial uses for water. It is hard to deny the fact that water plays such a dominant role in our lives as well as the lives of other plants and animals that live on the planet.

Water is a common liquid found on earth with a molecular formula of H_20. This formula means that the chemical contains two hydrogen atoms and one oxygen atom. Some of the properties of water include that it is a liquid with a density of 1 g/ml and that it is in the liquid state between the temperatures of 0 and 100 degrees Celsius. Below the temperature 0^o C water becomes a solid commonly referred to as ice and above 100^o C water becomes a gas commonly referred to as steam or water vapor. Water can also absorb a great amount of heat before it becomes a gas which is why our lakes and ponds don't evaporate completely during the hot summers. Another unique characteristic of water is that its solid form (ice) is actually less dense than its liquid form (water). This is not common since most chemicals actually become more compact and dense when they make the transition from liquid to solid. This explains why the ice in our drinks or the icebergs in the oceans float in water (because ice is less dense than water). Thus, the chemical and physical properties of water make in an essential ingredient for life; in fact it is technically considered a nutrient.

Sometimes there are times where we have to go without certain things because of the lack of water. Some summers the lake water level is so low that rocks and underwater plants that are usually hidden by the lake are revealed. There are also moments when plumbing problems occur, which mean that the showers, toilets, and sinks don't work. As brief as those situations might be they are still hard to get through. Keeping that in mind, it is important to realize that not everyone in the world is as fortunate as some of us. In various places such as India and Northern Africa there are sever water shortages that spell disaster for the populations of those areas. Some stories report of children having to walk 10 miles a day simply to get a bucket of water back to their village or town. Other places such as Southern Asia deal with problems regarding water sanitation or cleanliness. Not all the fresh water around is readily good for drinking. Industries and various other sources of human pollution often contaminate water sources making them unusable or even dangerous.

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Water is often seen as an inexhaustible resource like the air. Though there is a great deal of it on the planet there are many causes that have made clean freshwater a sparse resource. A combination of climate change, overpopulation, and human pollution have even further limited the little amount of drinkable freshwater that exists on the planet. To accommodate for this scarcity scientists and engineers have devised several creative ways to purify contaminated water into drinkable water via various filtration processes. (*See minute 13:52 in Jay Famiglietti's Hot Science – Cool Talks lecture, linked in SOURCES AND RESOURCES*). This lesson plan serves to illustrate how aquifers serve as natural filters for freshwater and play an essential role in the water cycle.

PREPARATION:
The materials that are required for the water filtration activity found in the "Explore" portion of the lesson should be collected and organized prior to the day of the activity. These leaves, rocks, and bags of sand can be collected around your school grounds or off-site. The preparation of the "dirty" water is also a key component to the activity. In order to prepare the jug of dirty water it is recommended that crumbling dead leaves, dirt, sand, and small twigs be mixed into a jug of clear tap water. The addition of these materials will create a mixture that is visibly contaminated and unsafe for drinking. Keep in mind the size of your class and gather enough materials and create enough "dirty" water.

ENGAGE:
Teacher says: Today we are going to talk about a liquid that plays a dominant role in our lives as well as the lives of everyone on earth. Can anyone think of what liquid I am talking about?.....It is found almost everywhere on the planet.....It is sometimes called H_20.....That's right, water. Water is something that we notice almost everywhere we go. We notice it in large bodies such as the lakes, rivers and oceans. It can also be felt in the air on foggy days. Has anyone felt their skin become moist after being in the fog for a long time? Well, that's because the fog outside is nothing more than a bunch of water vapor just like the steam from a boiling pot of water or the steam that fills your bathroom after a hot shower.

Water vapor is simply a different form of water. In fact, water comes in 3 forms that we see all of the time. Can anyone name of these 3 forms for me?

Possible student responses: Ice, steam, water vapor, hard, wet, water, liquid, solid, gas

NOTE: Teacher may need to spend some time with students clarifying and refining the official terms of the 3 states.

Teacher continues: Great, so now we have the 3 forms of water listed as solid, liquid, and gas. When we say "water" which of those three *physical states* are we talking about?..... That's right, we are talking about the liquid phase of water. What about Ice and Steam, which phases are those?....Excellent! Ice is the solid form of water while steam is the gaseous form of water. Now that we are talking about gases and solids can anyone tell me about the temperatures at which these commonly occur?..... We typically notice ice at colder temperatures, more specifically below 0^o C, and steam at much hotter temperatures, specifically over 100^o C.

So now that we have recognized that water can also be in the forms of a gas and a solid as well we can now notice that there is even more water around us than we had previously thought. Think about all of the ice at the North and South poles of the earth. All of that is made of water. Think also about all of the gas in the air

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and the clouds in the sky. A great deal of that gas is actually just water vapor. Unfortunately, for there being so much water around us there is actually very little of it that is easily accessed freshwater. Raise your hands if you have heard the terms freshwater vs. salt water..... Okay, let's talk about that briefly. Much of the earth's surface is covered with water (about 75%). Most of that water though is from where?... The Oceans, that is correct. Who here has been to the ocean before?..... Awesome, can anyone describe to me what it was like, particularly the ocean water?

Possible student responses:

- "It was fun to play in until I got a bunch of sea water in my mouth. It was really salty."
- "The ocean water burned the cut I had on my leg."
- "The ocean water tasted like it had salt in it or if the sand had mixed with the water making it taste bad."

Hmmm, very interesting…. So from what everyone has described to me it sounds like sea water is very salty and different from the water we usually drink and use every day. Sea water typically has between 32-36 parts salt for every thousand parts water – which is 70 times more salt in it that a human can safely drink! Wow, that's a lot! This is why so little of the world's seemingly abundant source of water is actually safe for humans to use every day. Of that freshwater even a smaller amount is readily available for us to use since much of it is in the form of ice.

This has become a big issue in many countries around the world. There seems to be lots of water covering the earth's surface but there is so little drinking water that is safe to use. In countries in North Africa, that's where the Sahara desert is, there are many people who struggle to get enough fresh water every day. In other places like India there are problems due to the fact there is little freshwater that is actually clean. Often trash, human waste, and industrial waste pollute sources of freshwater. These toxins that end up in the water make it very unsafe for humans to drink from. (*See minute 15:18 to 15:52 from Jay Famiglietti's Hot Science – Cool Talks lecture, linked in SOURCES AND RESOURCES*)

However, there is still hope. Creative people and scientists work all the time to come up with techniques to purify water so it becomes cleaner and safer to drink or use.

Notes: This engagement portion can be adjusted to best fit the classes understanding of the properties of water, the phases of water, and other topics addressed by this engagement section.

EXPLORE:

Teacher says: Today we are going to do a fun problem solving activity. In front of you there are jugs of "dirty water." Your group's job today is to use the materials in the basket to construct a filtration device that will make your jug of water cleaner than it is now. Before we start this activity I want to go over some safety issues that we all need to recognize. The water in front of you is very dirty and will get you very sick if you drink it. This is still true even after you filter it. I don't want to see anyone drinking any of this water. A second thing that I want everyone to be aware of is that some of the materials we will be using will have sharp edges so please respect yourself and your fellow students next to you by being careful with these materials and tools.

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Instructions:

1. In front of you is a jug of dirty water. Notice how it does not have the clearness of normal water but instead has this dirt color. This sample is an example of the water that some people have to filter in order to have a supply of fresh water. Rain water that has just made contact with surface soils has this color, as it contains particles of dirt and mud.
2. In front of you is also a basket full of various materials such as scissors, various pieces of cloth, pebbles, sand, green leaves (freshly cut) that you will use to construct a water filter. Your group should also have a large basin to capture the filtered water as well as a filter casing that in this case is a simple water jug with the large base removed.
3. Your group should create a filter using the materials in your basket that you believe will best filter the dirty water. This is accomplished by layering materials in your filter casing so that the undesired substances can be removed from your jug of dirty water. See diagram on Filter worksheet (listed in MATERIALS). Once an idea is created, the plan and design for your group's filter should first be sketched onto the worksheet in the appropriate space.
4. Using an agreed upon system that has also been sketched onto the *Filter worksheet* (see MATERIALS section), construct a filtration device that you think will capture as much filth and dirt as possible from your jug of dirty water.
5. Once your filtration system is constructed check in with your teacher so you can be approved to proceed with your test.
6. Once your filtration system has been approved proceed by slowly pouring the water from the dirty jug through the large open end of your filter so that the water comes out of the small end and into your large bin of water. One or two of your teammates can hold the filtration device over the bin while another teammate pours the dirty water carefully through the filter.
7. Once most or all of the dirty water has been poured through your filter you should have a bin full of moderately clean water (**note this water is still not drinkable!!!**). At this point ask your teacher to come to your group and look at how your water looks. Your teacher will pour some of the water from your bin into a clear glass and place a white sheet of paper behind it. The whiter the liquid the cleaner your filtered water is.
8. Hold on to your groups filter and place it on a paper towel so that it dries as the rest of the groups finish.

Teacher says: Wow, there were some creative and interesting filters out there. Let's have the groups come up one at a time with their filter, their glass of filtered water, and their design drawing they did.

- Teacher will call groups up to the front of the class one at a time to explain their filter designs and how successful their design was in terms of capturing the dirt from jug of dirty water.

EXPLAIN :

Teacher says: The amazing part of this activity was that many people around the world use similar ideas when they filter the water that they drink every day. I want to address some of the ideas that your groups had in terms of filtering the dirty water. Your materials included various pieces of cloth, fresh leaves, sand, pebbles, and other objects. Most of the designs used the cloth to hold the sand and other materials from coming out the bottle's end and falling into your bind of clean water. Some of you instinctively did this while others had to find out the hard way. Let's figure out why layering the materials in a certain order is so effective at filtering the dirty water.

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- Teacher will use a chalk or dry-erase board in order to draw visuals to explain how the filters functioned. (See materials for "filter diagram explained")

So first off we had a plastic jug/bottle with the base cut out. Notice that there are two ends to this bottle. A large open end allows us to easily pour the dirty water through. A smaller funneled end permits the filtered water to come out. Let's now look at materials individually. What can someone tell me about the cloth and how it was useful in filtering the dirty water?

Possible student responses:

- "The cloth held all of the other materials together."
- "The cloth had very tiny holes so it could stop everything besides the water from going through."
- "Maybe the cloth soaks up all of the bad water and lets all of the good water through."

Those are some interesting responses. The cloth actually does have many tiny holes for the water to go through. These holes however might be too small for other things to go through like sand, dirt, and rocks. This means that we catch the stuff we don't want in our water while allowing the cleaner water to drip through it into our basin. Let's now look at the other materials. We should figure out how these materials helped filter our dirty water. In order to do this we must look at the shape and properties of these materials.

If you look at the sand you can realize that it is actually just a bunch of very tiny little rocks. When the sand is packed together it is hard to imagine anything going through it. In other words, there are no clear visible holes in the packed sand. This can also be seen with the pebbles and rocks when they are piled on top of one another.

- Teachers should draw circles on a board to represent a side view of a bunch of sand and rocks. Then the teacher should draw arrows weaving through the circles and pointing down to represent and show how water travels between the little cracks and holes that the packed sand and pebbles form. It is vital to point out that the sand, because it is a finer and smaller than the pebbles, has smaller cracks and holes thus acts as a better filter for smaller contaminants such as dirt.

Let's now look at the green leaves. Can anyone think of a reason why we used green leaves instead of old dry leaves?

Possible student responses:

- "The green leaves make the water taste fresher."
- "The green leaves don't crumble like the old dry leaves do which is why they would be better in a filter
- "The surface of the green leaves can better catch the dirt form the dirty water."

Those are some great ideas. The green leaves make a better filter materials because they don't crumble like dry leaves do. If you have a material that crumbles and mixes in with the water then you are simply adding more material that needs to be filtered out of the water which is not what we want to do. These leaves act as

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great way to catch and stop the dirty stuff in the water such as the bits of large dirt or twigs.

Now that we have talked about all the materials and how they work to filter the dirt out of water let's figure out why layers of these materials in a particular order filters better than other orders. Filters work best if they catch everything that is in the water. When looking at the dirty water the most noticeable things are the little pieces of leaves and twigs that are floating around. Those are the large objects that we can easily remove. We can do this by using the green leaves and placing them so that they are at the top of the filter. The next thing we notice in the jug of dirty water is the small grains of dirt that are making the water look dark. These can be removed by the pebbles and sand which would be placed beneath the leaves. The last thing we have to worry about is all of the very tiny particles in the dirty water as well as holding the sand in the filter so that it does not pour out of the small end. This can be fixed by using the cloth at the very bottom so it can not only catch all of the very tiny particles but also hold the filter together and from pouring out the end into the filtered water.

All of your presentations were very creative and inspiring. Some of your filters managed to get more of the undesired substances out of your water than others. Some of your filters not only captured undesired substances but also absorbed some of the precious water which meant that your yield was very little. Although that would not be a problem in this classroom for the purpose of the activity, it would be very problematic in a region that not only has contaminated water but also has very little of it to sacrifice. An example of this is the Jordan River. Considering that it moves and crosses various territories the water source is greatly competed for in often a hostile manner. Another problem to add to this drastic situation is that there is a continuous flow of human sewage that is either dumped in or finds its way into the Jordan River by adjacent populations. This contamination makes the situation go from bad to worse. (*See minute 45:06 from Jay Famiglietti's Hot Science – Cool Talks lecture, linked in SOURCES AND RESOURCES*)

The examples simply don't stop there. There are currently hundreds of nations that struggle with the task of supplying sanitary freshwater to their entire population. Unfortunately this formidable task is simply made harder by adding other variables into the equation such as the fact that the climates everywhere are changing dramatically and that there seems to be a severe reallocation of water to various parts of the globe.

ELABORATE:

Teacher says: All of you have constructed filters that utilized layering techniques of various natural materials in order to filter some contaminated water. For the most part, these materials did a great job of getting rid of large undesirable particles from your filtered bin water. Even though this simple project would not be enough to turn the contaminated water into pure drinking water it is a step in the right direction. However, it is essential to see that **these filters actually resemble and parallel many of the characteristics of how the environment naturally filters groundwater.**

Let's first refer back to the activity that was completed with the filters that you all built. We went into more detail and discussed how each of the materials specialized in capturing various undesired substances and particles from the dirty water so that it would not end up in the finished product. We mentioned how the leaves are at the top layer so they capture the very large objects and particles while the small stones and sand captured much smaller particles such as the soil and dirt. The final component of your filters was the cloth which had the smallest pores and was best suited at the end in order to hold all of the other materials from

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falling out of the base of your filter. Notice how the leaves, sand, and rocks can all be found out in the environment.

Think about the rain water that falls from the sky and ends up in puddles on the ground. What are some of the predictions on what happens to these puddles of water? Where does the water go?

Possible student responses:

- "The water goes straight down and some of it will evaporate later."
- "Puddles will stay there for a really long time because water can't go through the concrete."
- "Lots of the water goes underground and into the soil for the plants to use."

Teachers continues: Those are some really great answers. Most of you had some accurate ideas of what happens to the water after in lands on the ground. However, I bet most of you did not think that the water the hits the ground is later filtered naturally by the earth below our feet. As an example, we will make references and comparisons to the way water finds its way into many Texas aquifers. Imagine the leaves and rocks you used in your filters to be the topmost layer of the ground (this is the ground we see). Runoff water and rainwater can sit on this surface and slowly seep through it to the next layer beneath it. Beneath this layer are often sand, finer rocks, or even clay. These compare to the small rocks and sand that you used in your filter. Remember that these materials were better at capturing smaller particles and substances in the water due to their level of compaction. One of the last layers underground is very thick bedrock that has micro-cracks and crevices in it. These small paths can allow water to travel through them but at a very slow rate. In some cases, it can take water weeks to only travel several meters!

One of the large problems that many countries are recently facing is that population growth is putting a real strain on the amount of ground water available for consumption. In many places around the world including California, the water table has dropped many meters due to the fact that the groundwater in that area is rapidly vanishing. Imagine a tire being deflated; the ground water is literarily occupying a huge amount of space that is now gone thus lowering the level of the ground. We should also recognize that rain is a vital component to groundwater filtration via natural means. Recent climate changes have caused the water cycle to intensify in some regions. Texas has a history of droughts, and is predicted to have even a dryer climate than before while places such as the Congo are expected to have even more floods than they already do. (See minute 40:02 *from Jay Famiglietti's Hot Science – Cool Talks lecture, linked in SOURCES AND RESOURCES*)

It is important to realize that these natural means of creating clean freshwater are being jeopardized by overconsumption of water as well as dramatic climate changes around the world.

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EVALUATE:

Teacher says: As we have learned today, water is a vital resource to life on Earth. Unfortunately water is not as abundant as we would like it to be. Many countries around the world struggle with contaminated/dirty water and not having enough freshwater. The fact that the human population is growing rapidly means that there is even less clean freshwater to go around. Today we went over basic filtration techniques that could be used to filter certain types of dirty water. We also went over some basics regarding how your filters relate to how water is naturally filtered beneath our feet. Answer the last 4 questions on your worksheets. If you have any questions simply raise your hand and I will be right there.

- Teacher walks around answering student questions and guiding students to complete their worksheet.

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Making Liquid Gold: Water Filtration Worksheet

Filter Casing

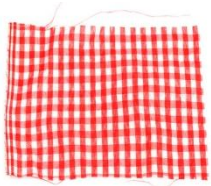
Large rocks

Sand

Leaves

Pebbles

Cloth/Fabric



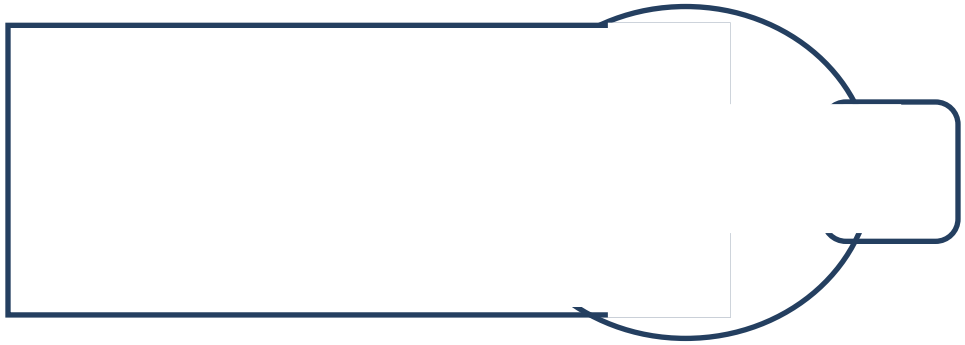
Step 1: Use the double ended bottle as your filter casing. Start by having the large end facing up and the small end being the bottom (like a funnel). Insert the cloth from the top to the bottom so that no material can fall out of the bottom end.

Step 2: Use the other materials in layers so that you can capture undesired substances from the dirty water.

Step 3: Pour "dirty" water through top end, have it travel through your filter and out the bottom end into the bin.

Design Sketch

Top



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Making Liquid Gold: Water Filtration Worksheet

Instructions: Read the questions carefully. Answer in the lines provided.

Question 1: Where did you get your ideas from when your group designed your filter? Have you seen it done before?

_____
_____
_____
_____

Question 2: Describe how the layering of the materials worked to capture the undesired substances from the dirty water?

_____
_____
_____
_____

Question 3: What kinds of things did you filter from the water? What kinds of things do you think your filter would be unable to remove?

_____
_____
_____
_____

Question 4: Explain how your filter device is similar to how water is filtered naturally underground.

_____
_____
_____
_____