WATER RESOURCES LESSON – Drinking Water Treatment Process

TOPIC: The Drinking Water Treatment (DWT) Process

AUTHOR: Beaver Water District (BWD)

PURPOSE: Create an understanding of the process for providing clean, safe drinking water to the general public, businesses, and industries with localized focus on Northwest Arkansas Water Supply, the four Beaver Water District Customer Cities, and surrounding communities.

PROBLEM QUESTION: How does Beaver Water District clean water from Beaver Lake to make it safe for drinking and available for use?

OBJECTIVE(S):

- Research and model the processes that the Beaver Water District (BWD) Drinking Water Plant (DWP) uses to clean water, sourced from Beaver Lake, for drinking.
- Diagram & write brief descriptions for 6 water treatment process steps: 1. Flash Mix, 2. Coagulation, 3. Flocculation, 4. Sedimentation, 5. Filtration, 6. Disinfection. See TEMPLATE page 11.

CLASS TIME NEEDED:

Day 1: - **ELICIT Teacher -** See 7 Es, page 4-6.

1. Determine student background knowledge of public water source(s) and DWT with Anticipation Survey (page 7) and group discussion.
2. Provide overview of the DWT Lesson Components for Days 2-5:
   + Conventional drinking water treatment process. View BWD Drinking Water Treatment Process ANIMATION: https://player.vimeo.com/video/230823039?autoplay=1. See KEYWORDS page 4.
   + Describe DWT process experiment stations for Day 2. Ask student preference for 1 of 4 stations. As best as is practical, assign students to Teams according to station preference for Day 2 Experiment(s) with DWT Processes.
   + ORIENT students for Day 3 BWD DWP Tour OR viewing DWP Tour Video and optional online discussion with BWD professionals. See Teacher Preparation Options 1 & 2, page 3. "SCHEDULE A DWP TOUR" details and student pre-tour orientation information are provided on page 9. **NOTE: Minimum of 2 weeks advance notice is required for scheduling tours.**

Day 2: EXPLORE - **Students** – DWT Processes Experiments.

Day 3: ELABORATE

- **Option 1:** Field trip to Beaver Water District
- **Option 2:** Beaver Water District (BWD) Drinking Water Plant (DWP) Tour Video (https://www.youtube.com/watch?v=PitTveRn7cw&feature=youtu.be) and (optional) online discussion with BWD professionals.

Days 4-5 (as needed): **EXPLORE, EXPLAIN, ELABORATE, EVALUATE.**

- Finish the water treatment portion of the project.

SUBJECT/GRADE LEVEL: K-12 – Physical Science/Life Science/Earth and Space Sciences/Engineering Design

ARKANSAS NEXT GENERATION SCIENCE STANDARDS:

Grades K-2

- Physical Science – 1-PS4-3, 2-PS1-1, 2-PS1-2
- Life Science – K-LS1-1
- Earth and Space Sciences – K-ESS2-1, K-ESS2-2, K-ESS3-1, K-ESS3-3, 2-ESS1-1, 2-ESS2-1, 2-ESS2-2, 2-ESS2-3
- Engineering Design – K-2-ETS1-1, K-2-ETS1-2, K-2-ETS1-3

Grades 3-5

- Physical Science – 5-PS1-1, 5-PS1-2, 5-PS1-3, 5-PS1-4, 5-PS2-1
- Life Science – NA
- Earth and Space Sciences – 3-ESS2-1, 3-ESS2-2, 3-ESS3-1, 4-ESS2-1, 4-ESS2-2, 4-ESS3-2, 5-ESS2-1, 5-ESS2-2, 5-ESS3-1
- Engineering Design – 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3

Grades 6-8/Middle School

- Physical Science – NA
- Life Science – NA
- Earth and Space Sciences – MS-ESS2-4, MS-ESS3-2, MS-ESS3-3, MS-ESS3-4
- Engineering Design – MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

Grades 9-12/High School

- Physical Science – HS-PS1-1, HS-PS1-2, HS-PS1-3, HS-PS2-6
- Life Science – HS-LS2-1, HS-LS2-6, HS-LS2-7, HS-LS2-8, HS-LS4-5, HS-LS4-6
- Earth and Space Sciences - HS-ESS3-1, HS-ESS3-3, HS-ESS3-4, HS-ESS3-6
- Engineering Design - HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, HS-ETS1-4, EVS-LS2-1, EVS-LS2-2, EVS-LS2-6, EVS-LS2-8, EVS3-ETS1-3, EVS-LS2-2

LEARNING PERFORMANCE TARGET(S): Learning expectations for this lesson combine a science practice, crosscutting concept, and core idea embedded in the lesson.

Students will gain functioning knowledge of and expertise in:

- Local/regional public water supply source(s)
- Watershed(s) and Source Water Protection (SWP)
- Drinking water treatment processes: raw water intake, flash mix, coagulation, flocculation, sedimentation, filtering, disinfection, distribution
- Natural and Man-Made Hazards, Disasters, and Risks Affecting Water Supply: Flood, Drought, Pollution
- Water Resources Policies and Regulations

SCIENCE AND ENGINEERING PRACTICES:

Lab and field work. asking questions; defining problems; developing and using models; planning, and carrying out investigations; acquiring data, analyzing, graphing, and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; obtaining, evaluating, and communicating information.

CROSSCUTTING CONCEPTS:

Patterns; Cause and Effect; Scale, Proportion, and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change

CCSS CONNECTIONS: (include mathematical concepts and reading, writing, speaking, and listening opportunities in the lesson)

All exist throughout the lesson. ELA/Literacy. Mathematics

TEACHER PREPARATION:

Option 1: A minimum of 2 weeks advance notice is required for scheduling BWD Tours & Speakers. Tours & Speakers scheduling is dependent on staff availability on requested date(s). See "Schedule A Drinking Water Plant (DWP) Tour" details on page 9.

Option 2: If a field trip is not possible, email education@bwdh2o.org to schedule an online meeting with guest speakers and view the BWD VIRTUAL Drinking Water Plant Tour:

https://www.youtube.com/watch?v=PitTveRn7cw&feature=youtu.be

- Gather materials needed.

MATERIALS:

4 L water	30 mL alum	rubber band
600 mL soil or mud	30 mL of bleach	tap water
overhead transparency	500 mL fine sand	tablespoon
2 plastic pitchers	500 mL coarse sand	splash goggles
3 2-Liter plastic bottles or 2 bottles & beaker	250 mL fine gravel	stopwatch
funnel	250 mL coarse gravel	2 cotton balls for plug
scissors	250 mL activated charcoal	coffee filter

Additional Resources	UA Center for Math & Science Education (CMASE): https://cmase.uark.edu/	NW Arkansas Education Co-Op: https://www.starfishnw.org/

- Prepare "RAW WATER"; add approximately 2 1/2 cups (600 mL) of soil or mud to 1 gallon (4 L) of water.
- Prepare instruction sheets for the respective processes (7 Es / EXPLORE) and other handouts as needed.
- Decide the procedure for selecting student teams. Each team of 2-5 students will be responsible to divide the work evenly by possibly having smaller subgroups as they collaborate to build a water treatment model.

BACKGROUND INFORMATION/CONTENT:

- The process of water treatment cleans water and makes it safe for people to drink.
- Our drinking water comes from both surface and groundwater. Water in lakes, rivers, and swamps contains impurities that may make it look and smell bad.
- Water is such a good solvent that it is known as the universal solvent. It picks up all kinds of contaminants causing water in nature to often not be clean and safe enough for people to drink.
- Water may contain harmful chemicals, bacteria and other organisms that can cause disease even though it looks clean. In the United States today, waterborne diseases are no longer a health threat because of our water treatment systems. In many other countries, this is not the case. See "WATER QUALITY: It's Not So Clear" Demonstration on page 13 and "Can You See Water Pollution?" at this Izaak Walton League of America link: https://www.iwla.org/publications/outdoor-america/articles/outdoor-america-2015-issue-1/youth-activity-can-you-see-water-pollution .
- At the water treatment laboratories, technicians test water to ensure that our drinking water supply is free of disease-causing bacteria. These test results are reported to state and local governments.
- Our drinking water is kept safe and adequately available on demand through cooperative policy making and the collective efforts of federal, state, and civic governments and local water supply systems, like Beaver Water District. See the Ozarks Water Watch "POLICIES PROTECTING OUR WATER" video: https://youtu.be/DHxNjsB9f1s
- The Safe Drinking Water Act and its amendments set the standards for public drinking water. The Environmental Protection Agency administers these standards.
- Use the Beaver Water District "Making Water Safe to Drink" PDF in BWD Lessons & Activities Water Quality Column 1: https://padlet.com/aebbrecht/5erwrnh42a0mpdp6
- Beaver Water District's three water treatment plants clean and maintain the quality of drinking water by taking it through the following processes: 1. raw water intake, 2. flash mix, 3. coagulation, 4. flocculation, 5. sedimentation, 6. filtration, 7. disinfection, 8. storage, 9. distribution.

Keywords

Raw Water Intake: Pumping water from lake, river, reservoir, or well to the treatment plant.

Flash Mix (also Rapid Mix): High pressure injection of a chemical coagulant solution into a large volume of water.

Coagulation: Sticking together or clumping of dirt and other particles.

Flocculation: Process using gentle stirring to bring floating or suspended particles together to form larger "floc" particles that settle out when they become too heavy to float.

Sedimentation: The layered settling of particles of different densities the bottom of a basin or water body.

Filtration: The substance (water) is poured through a filtering system (made of layers of materials) designed to trap the contaminants that did not settle out during sedimentation.

Disinfection: Chlorine is added to the water to kill germs that may cause disease.

Distribution: Moving or sending out materials from a central place to a larger area or more users.

Potable: Liquids safe for drinking.

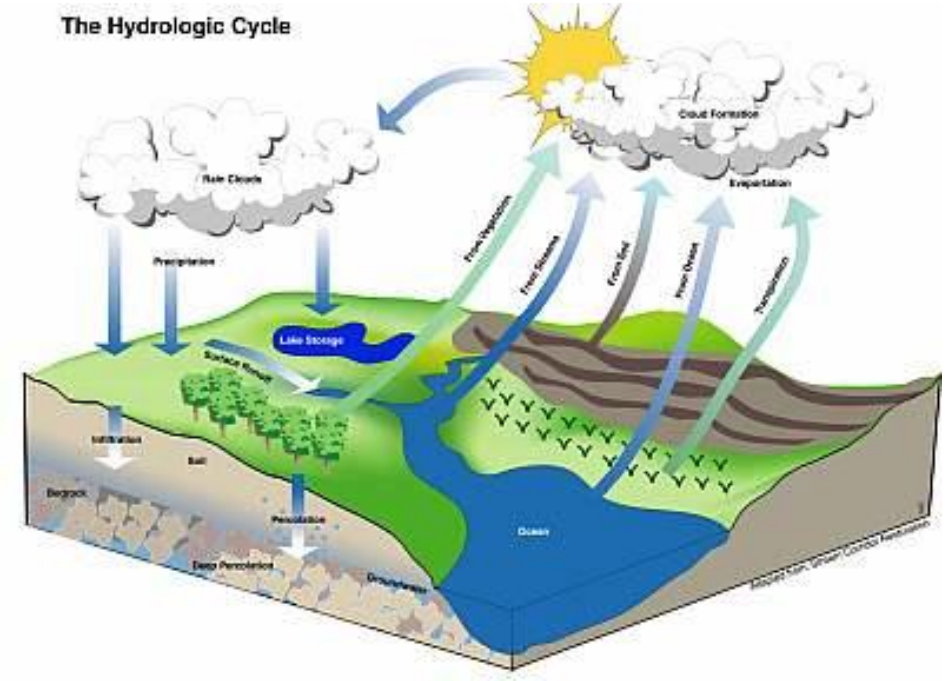
7E'S "POTABLE" DRINKING WATER TREATMENT

ELICIT

Have students complete the Anticipation Survey, then use the Survey to guide a class discussion (see Example Questions). Teacher or students record answers on a dry erase board, smartboard, poster, etc.

Example Questions:

- How did you use water today?
- What is the source of the water you use?
- Is your water clean and safe?
- How do you know?
- How is water cleaned so it is safe for you to drink and use?
- How is potable water provided for use?



SOURCE: https://www.uaex.edu/environment-nature/water/quality/images/quality-Hydrologic-Cycle400.jpg

- What is the cost of drinking water from your faucet compared to bottled water?
  - "How Much Does a Bottle of Water Cost in the U.S.? ThoughtCo.com - https://www.thoughtco.com/cost-of-a-bottle-of-water-4773937#citation-5

ENGAGE

Students view, take notes, and diagram the "BWD Drinking Water Treatment Process ANIMATION" at this link: https://player.vimeo.com/video/230823039?autoplay=1

This may be done as a whole class, as student teams at one computer, or as individuals in the computer lab.

EXPLORE

NOTE: This project is a Water Treatment Simulation: Therefore, the end-product is not safe to drink.

The activity procedure may be done in any of the following groupings:

1. Whole class project (4 teams of 4-7 students each with one team per process then team presentations on process/results)
2. Demonstration set up at each end of classroom (Split class into 2 groups with 4 teams of 2-4 students each)
3. Each group of 2-7 students does all 4 process experiments (if time and materials allow)

Safety - All participants should wear splash goggles during their part of the demonstration.

1. Coagulation Team demonstrates to class:

- Pour the "**RAW WATER**" into a 2-liter bottle with the top cut off or a large beaker.
- Add 30 mL of alum to the water.
- "**FLASH MIX**" alum into the water by stirring the mixture slowly for 5 minutes.
- During this time, students predict outcome and record observations.

2. Flocculation/Sedimentation Team demonstrates to class:

- Let the "**FLASH MIX**" solution (water mixed with alum) stand undisturbed for about 20 minutes. This allows floc to "settle" out and collect on the bottom of the bottle. The clarified water above the floc layer is called "**SETTLED WATER**."
- Set the stopwatch to sound at 5-minute intervals.
- All students observe and record changes at each 5-minute interval.

3. Filtration Team demonstrates to class:

- Construct a filter from the bottle with its bottom cut off as follows
- Place the 2 cotton balls in the original bottle opening.
- Attach the coffee filter to the outside neck of the bottle using a rubber band.
- Turn the bottle upside down placing it in a beaker or cut-off bottom of a two-liter bottle.
- Pour a layer of pebbles into the bottle. The filter will prevent the pebbles from falling out of the neck.
- Pour the coarse sand on top of the pebbles.
- Pour the fine sand on top of the coarse sand.
- Hold or suspend the filter above a sink or a separate container. **CAREFULLY** pour and allow 3 L (or more) of clean tap water to drain **SLOWLY** through the filter to clean it. Try not to disturb the top layer of sand as you pour the water.
- Next, place the filter bottle above a beaker or 2-liter bottle bottom and pour the **top two-thirds of the "SETTLED WATER"** through the filter, allowing the "**FILTERED WATER**" to collect in the beaker or bottle bottom.
- Set the remaining (one-third bottle) of "SETTLED WATER" aside.

4. Teacher Disinfection (Chlorination) Teacher demonstrates to class:

- Add 30 mL of chlorine (bleach) to the "**FILTERED WATER**."
- All students compare the treated and untreated "**RAW WATER**". Observe (appearance and smell) and record.

EXPLAIN

In groups of 3-4 students, list the steps in the water treatment process using and explaining the terms **coagulation, flocculation, sedimentation, filtration,** and **disinfection**. Place one term on each of 6 index cards. Write the vocabulary term on one side with the explanation of the term on the back. Take turns placing the cards in order, first using just the fronts of the cards. Then shuffle the cards and place them in order using just the backs of the cards while naming the step as you read the description

ELABORATE

You, your family, and a few others are shipwrecked on a deserted tropical island. There is a stream of fresh water on the island, but it does not appear to be clean. There are supplies on the boat which has grounded on the island as well. The supplies include food, clothing, and cleaning supplies, as well as many other items. Write a story explaining how you will provide safe, clean water for your family.

EVALUATE

- Each student constructs a booklet of the steps in the water treatment process. See TEMPLATE on page 11.
- Students should illustrate and explain the process, including each of the following terms: **coagulation, flocculation, sedimentation, filtration, and disinfection**.
- True or False and Explain

  a. Our community has a safe water supply. **True:** Clean, safe, good tasting water is what the Beaver Water District supplies.
  b. There is enough clean water in nearby areas to support all the people living here now and in the future. **True**: As long as we protect our watershed.
  c. What gets dumped into or taken out of local streams, rivers, and lakes is more important than what happens to the land surrounding the rivers. **False:** Both are important. What happens on surrounding land (in the watershed) ends up in the local streams, rivers, and lakes.

EXTENSIONS

- Play Beaver Water District's Watershed and Water Safety Jeopardy Games. Download from the Beaver Water District (BWD) website Secchi Day Science Fair. Scroll down "Column 2 Technology & Policy" to Jeopardy games: https://padlet.com/BWDEducation/hner5s2v7zn0m3bz
- Students research methods for converting salt water to fresh water suitable for drinking.

DRINKING WATER TREATMENT ANTICIPATION GUIDE

	QUESTIONS	DAY 1 INTRODUCTION		LAST DAY WRAP-UP	
1.	The total volume of water on Earth is unchanging. (True or False)				
2.	Of all the water on Earth ____% is SALTWATER and ____% is FRESH	____% Saltwater ____% Fresh		____% Saltwater ____% Fresh	
3.	From your perspective, what are the most important uses of water?				
4.	What was the world population when you were born/Then vs. Now?	Then:		Then:	
		Now:		Now:	
5.	In what watershed do you live?				
6.	What is your drinking water source?				
7.	Is the NW Arkansas Public Water Supply natural or manmade?				
8.	How much water do you use each day?				
9.	What value do you place on having access to a reliable supply of clean, safe water?				
10.	What does “Source Water Protection” mean to you?				
11.	What is the #1 pollutant in lakes, rivers, and streams?				
12.	List 3 things you can do to help protect and/or improve water quality.				

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SCHEDULE A DRINKING WATER PLANT TOUR

The Beaver Water District Water Education Center located at 301 N Primrose Road in Lowell, AR, can accommodate groups of up to 120 individuals at a time. A MINIMUM OF 2 WEEKS ADVANCE NOTICE IS REQUIRED to schedule tours for large groups of more than 40 students. We request a ratio of 1 adult per 12 students.

Access the online "Tours & Speakers" Request Form to schedule a group Drinking Water Plant Tour: https://www.bwdh2o.org/education-outreach/tours-speakers/.

Group tours can be set for mornings between 9 AM and Noon and afternoons between 1 PM and 4 PM. Teachers/School Group Tour Leaders are asked to provide 2 or 3 dates and a timeframe (see options, below) for scheduling a 2 to 3 hour visit between 9 AM and 4 PM. After receiving school tour date/time preference(s) the BWD Tour Host will send confirmation for one of the tour dates and times. If the BWD Water Education Center Calendar allows, the second tour date/time preference will also be confirmed as a backup "Rain Date."

Option 1 – 9 AM-Noon

Option 2 – 10 AM-1:00 PM

Option 3 – 1:00 PM-4:00 PM

Option 4 - Other time frame specified

Divide large student groups of 50 or more to smaller groups for rotations between the DWP "windshield-walking" tours and BWD Careers Q&A Sessions. Q& A Sessions are contingent on BWD Staff/Employee availability.

Wear clothing appropriate for weather, stair-climbing (capri slacks or long pants recommended), and COMFORTABLE WALKING SHOES. Arrive prepared to observe and note key aspects of the treatment process and the BWD Careers Q&A Session.

BWD YOUTH PLANT TOUR GUIDE

BUS STOP 1

"Clear" SETTLED-WATER outfall exits sedimentation basin and flows through underground pipe to FILTER DECK.

pH SCALE														
ACID/Acidic							Neutral	BASE/Alkaline						
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

BUS STOP 2

pH ADJUSTMENT – Add Base/alkaline compound to raise pH: LIME ($CaCO_3$) or SODIUM HYDROXIDE (NaOH)

COAGULANTS – Alum ($KAl(SO_4)_2 \cdot 12H_2O$) & Ferrous Sulfate ($FeSO_4$)

DISINFECTION – Chlorine is added to kill bacteria or micro-organisms

WALK STOP 3

FLASH MIX & FLOC – coagulants alum & ferrous sulfate are added to lake water which attract dirt to form larger and heavier particles.

COAGULATION - The clumping of small particles together forming larger, heavier particles.

WALK STOP 4

FLOCCULATION CHAMBERS - Mixers bring coagulant and dirt particles together. Increasingly larger floc particles form as water moves toward sedimentation basin.

WALK STOP 5

SEDIMENTATION – Gravity pulls floc particles downward to "settle" on bottom of basin.

WALK STOP 6

FILTRATION - passing of water through activated charcoal, sand, and garnet to remove smallest sediment particles

BUS STOP 7

CLEAR WELL – Concrete basin holds 12 million gallons of clean, safe "finished-water."

DISTRIBUTION PUMPS – Powerful high-speed pumps send water to Customer Cities Water Utilities.

WATCH THE BWD DRINKING WATER PLANT TOUR VIDEO AND LABEL EACH PROCESS PICTURED

https://www.youtube.com/watch?v=PitTveRn7cw&feature=youtu.be

		
		
		
		

DRINKING WATER TREATMENT (DWT) PROCESSES

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"WATER QUALITY- IT'S NOT SO CLEAR"

Air bubbles and pressure in water lines can make your drinking water look cloudy .... for a few seconds. SOURCE: https://www.usgs.gov/special-topic/water-science-school/science/water-color?qt-science_center_objects=0#qt-science_center_objects

BACKGROUND

The "quality" of a water body partly depends on what the water is to be used for. There are many uses for water in Arkansas - human consumption, cooking, cleaning, recreation, wildlife, irrigation, livestock, navigation, industrial cooling, etc.

All water bodies have a designated use assigned by the Arkansas Department of Environmental Quality in Arkansas' Regulation 2. The cleaner streams in Arkansas are designated as "fishable and swimmable".

When many people think of water quality, they are actually thinking of water clarity. People tend to think that the clearer the water, the better. But, there are many things that can affect the quality of water and may not allow it to meet its designated uses. Some "pollutants" can be seen simply by looking while others may not. Sediment, for example is easy to see in the water, but may not make the water unsafe for swimming at all. On the other hand, some chemicals contaminants that may be as clear as water, can affect the usefulness of water they are in a stream or lake.

OBJECT

Students will evaluate the quality of different water samples through visual observation:

Fill six clear jars with different "samples"

a) Clear tap water and a drop of food coloring

b) Clear tap water and a little bit of fertilizer (e.g. Miracle Gro, Jobe's Organic, Osmocote)

c) Clear tap water and some table salt

d) Water from a dirty mud puddle

e) Water from a clear stream or lake

f) A clear liquid which is not water at all (rubbing alcohol works well)

At first, don't reveal what's in each jar and let the students look at them to decide which one has the **best quality of water.** (They may choose the rubbing alcohol as being the best because it looks so clear).

After they have made their choice, go back and talk about the liquid in each jar. Discuss 1) the difference between water clarity and water quality, 2) whether each sample might be safe to drink, safe to swim in, suitable for fish habitat, suitable for irrigation, safe for cooking, useful for transportation, etc., 3) that your criteria of water quality might change depending on how the water might be used, and 4) how some of the worst looking samples may be the easiest to treat for various uses.

A set of water samples showing increasing turbidity (left to right), as well as changes in color.
Photo Credit: Village of Chase, British Columbia. SOURCE: https://blogs.worldbank.org/water/how-test-water-quality-here-are-some-low-cost-low-tech-options