Texas A&M AgriLife Extension

EXPLORE

Water Projects

Water Filtration and Electro-coagulation

texas4-h.tamu.edu

EXPLORE

TEXAS 4-H Water Projects

Description

The Texas 4-H Explore series allows 4-H volunteers, educators, members, and youth who may be interested in learning more about 4-H to try some fun and hands-on learning experiences in a particular project or activity area. Each guide features information about important aspects of the 4-H program, and its goal of teaching young people life skills through hands-on experiences. Additionally, each guide contains at least six learning experiences, which can be used as a project guide, or as activities for six different 4-H meetings.

Purpose

Texas 4-H is designed to develop the youth of our state into productive adult citizens. The 4-H Program uses a non-formal educational process of engaging youth in an "learning by doing" process. This includes hands-on opportunities, participation in workshops and clinics conducted by volunteer leaders or professionals, as well as competitive experiences which allow 4-H members to demonstrate the knowledge they have gained. Through this entire process, the youth are learning key life skills such as working with others, teamwork, cooperation, and goal setting. Through all experiences, youth get to interact with adult volunteers and county Extension agents.

What is 4-H?

4-H members across the nation are responding to challenges every day in their communities and their world.

As the youth development program of the Cooperative Extension System of land-grant universities, 4-H is the nation's largest youth development organization, empowering six million young people throughout the United States. Cooperative Extension of 1862 and 1890 land-grant universities provide leadership to engage young people in 4-H in all 3,007 counties of the United States. The impact of the Cooperative Extension partnership is profound, bringing together National Institute of Food and Agriculture of USDA, land grant universities and county government to resource learning opportunities for youth.

Through America's 110 land-grant universities and its Cooperative Extension System, 4-H reaches every corner of our nation—from urban neighborhoods to suburban schoolyards to rural farming communities.

With a network of more than 6 million youth, 600,000 volunteers, 3,500 professionals, and more than 25 million alumni, 4-H helps shape youth to move our country and the world forward in ways that no other youth organization can.

Texas 4-H

Texas 4-H is like a club for kids and teens ages 5-18, and it's BIG! It's the largest youth development program in Texas with more than 550,000 youth involved each year. No matter where you live or what you like to do, Texas 4-H has something that lets you be a better you!

You may think 4-H is only for your friends with animals, but it's so much more! You can do activities like shooting sports, food science, healthy living, robotics, fashion, and photography.

Look for 4-H clubs at your school, an after-school program, a community center, or even on a military base or through the reserves for military families.

Texas 4-H is part of the Texas A&M AgriLife Extension Service and the Texas A&M System. Founded in 1908, 4-H is the largest youth development program in Texas, reaching more than 550,000 youth each year.

The 4-H Motto and Pledge

"To Make the Best Better!"

I pledge: My HEAD to clearer thinking, My HEART to greater loyalty, My HANDS to larger service and My HEALTH to better living, For my Club, my Community, my Country, and my world.

Participating in 4-H

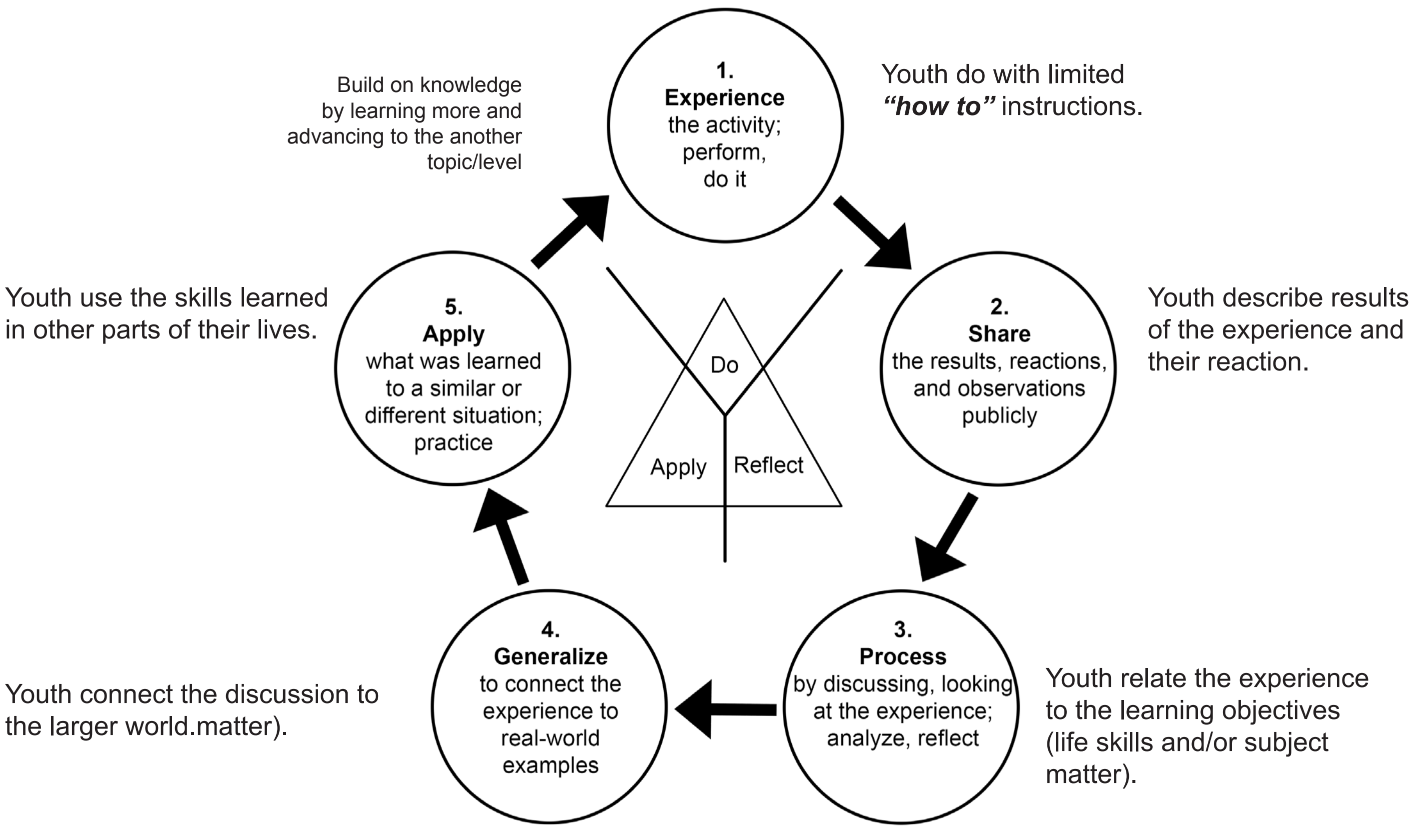
4-H is a great program because it provides options for young people to participate. From a 4-H club located in your community, a SPIN club that focuses on one particular project area, or participating in 4-H through your classroom at school, 4-H allows youth to learn in many different environments. If you are interested in joining 4-H, contact your County Extension Office and ask for a list of the 4-H clubs in your area. If you are a school teacher/educator and would like to use 4-H curriculum or these project guides in your classroom, contact your Extension Office as well for assistance.

4-H “Learning by Doing” Learning Approach

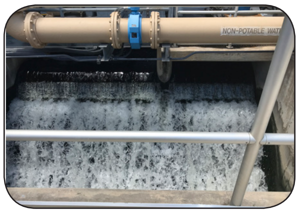
The Do, Reflect, Apply learning approach allows youth to experience the learning process with minimal guidance from adults. This allows for discovery by youth that may not take place with exact instructions.

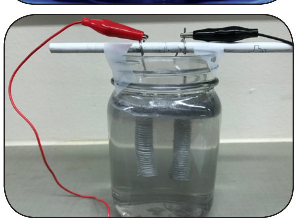
EXPLORE THE CONTENT

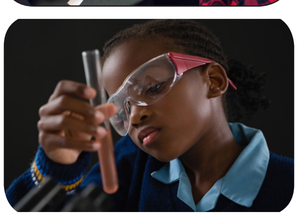
Introduction of the topic, overview and exploration of content, and review of objectives



Lessons







Developed by:
David Smith

EXPLORE
WATER PROJECT

Dirty Water - A Global Reality

TIME:
40 to 50 minutes

MATERIALS NEEDED:
- Pencils/Pens
- Copy of the Pollution Challenge Crossword Puzzle
- Copy of World Water Quality Facts (fill-in-the-blank)
- Small prizes to be given out to winners of the crossword puzzle challenge

OBJECTIVES:
The 4-H member will:
- Learn how water pollution affects people across the globe.
- Learn the most common water-borne diseases.
- Learn the most common water contaminants affecting human health and safety.

KEY TERMS:
Aquifer – an underground layer of rock, gravel, sand, or silt that can store and carry water.
Inorganic substance – any chemical substance that does not contain carbon.
Leaching – the process of water carrying soluble chemicals or substances through soil or rock.
Organic substance – any chemical substance that contains carbon and derived from living organisms.
Pathogens – Disease-causing organisms such as bacteria, fungi, and viruses.
Radioactive elements – Substances that emit radiation, such as uranium, plutonium, and radium.
Toxic chemicals – Inorganic and organic substances that are harmful to the environment or hazardous to your heath if inhaled, ingested or absorbed through the skin.
Water-borne disease – disease spread while bathing, drinking, or by eating food exposed to infected water.

EXPLORE THE CONTENT:
Note: Have participants complete the World Water Quality Facts sheet as you read through Explore the Content.

Access to clean drinking water is essential for human health, national security, and economic prosperity. In wealthy countries such as the United States, clean water is readily available due to investment in water exploration, treatment, and sanitation. Regulation has limited industries and agricultural operations from discharging pollutants into lakes, river, and streams. Even still, water pollution in the US is a problem that threatens drinking water availability and water quality.

It is estimated that 1.2 trillion gallons of untreated sewage, groundwater, and industrial waste are discharged in the US each year resulting in 12 million to 18 million cases of water-borne diseases annually. In fact, 40% of rivers and 46% of lakes are polluted and not suitable for fishing, swimming or aquatic life. More than 73 different pesticides were found in US groundwater. If not for advanced water filtration and treatment technologies, these waters would result in widespread sickness and death.

In many developing countries people spend several hours each day to get water, and it is often polluted. Approximately 2.1 billion people globally lack access to safe drinking water and 4.5 billion people lack proper sanitation which only compounds the problem. In fact, 18% of the world's population defecate in the open where it pollutes nearby water bodies and poses health risks. In developing countries, there are few government regulations or monitoring of water bodies. Consequently, 70% of industrial waste and 80% of sewage are dumped into waters, which then pollute the drinking water supply.

Because they lack adequate filtration and treatment, these populations are more likely to contract water-borne diseases. Contaminated water and poor sanitation are linked to spread of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. Table 1, found at the end of the lesson, lists the most common water-borne diseases and their health effects. On average 842,000 people (including 340,000 children under the age of five) die each year from diarrhea as a result of unsafe drinking water, sanitation, and poor hygiene.

Common Pollutants and Their Sources

Water pollutants include **pathogens, toxic chemicals, and radioactive elements**. Pathogens are disease-causing organisms such as bacteria, fungi, and viruses. Toxic chemicals are inorganic and organic substances that are harmful to the environment or hazardous to your heath if inhaled, ingested or absorbed through the skin. Household products containing toxic chemicals include drain cleaner, ammonia, and pesticides. Radioactive elements are substances that emit radiation, such as uranium, plutonium, and radium. These can cause cancer in people and other living things. Table 2, found at the end of the lesson, lists common drinking water contaminants, their sources, and potential health effects.

Water may become polluted by natural environmental factors and from human activities. Some groundwater contamination, for example, is due to leaching of minerals (salts) and metals (uranium and arsenic) into underground aquifers. These groundwater sources are extremely difficult and expensive to clean up, and therefore are avoided as a source of drinking water. There are a number of human activities that can pollute our surface and groundwater, such as:

- Untreated sewage from homes and industrial plants
- Over-application of fertilizers, pesticides, and other chemicals on crops and lawns
- Spills and leaks of oil, gas, and lubricants
- Improper disposal of radioactive substances (found in watches, digital clocks, television sets, etc.)
- Dumping household trash and waste into rivers and streams

As technology improves, scientists are able to detect more water pollutants at smaller concentrations, such as pharmaceutical drugs and hormones that could have long-term health impacts. In many parts of the world, people need low cost ways to clean up what little water they do have just to survive and help minimize water-borne diseases. In the following lessons, you will explore one such technology.

DO:

Activity #1:
Briefly review Table 1. Ten Most Common Waterborne Diseases with the group. Have each participant read aloud about at least one disease. Help each student with words that may be difficult to pronounce or whose definition is unfamiliar. Consult a dictionary or do an internet search if needed.

Activity #2:
Briefly review Table 2. Common Drinking Water Contaminants in the United States. Have each participant read aloud about one contaminant. Help each student with words that may be difficult to pronounce or whose definition is

unfamiliar. Consult a dictionary or do an internet search if needed.

Activity #3:
Pollution Challenge Crossword Puzzle. Assign the participants in groups of 2 or 3. Have each group complete the crossword puzzle. Award small prizes to the team that can successfully complete the puzzle the fastest.

REFLECT:

Refer to Table 1. Ten Most Common Waterborne Diseases. Can you share any experiences that you, your family, or your friends have had with any of these waterborne diseases? Where would you expect these diseases to be most common? Why do we in the US have fewer cases of waterborne diseases compared to many other countries in the world?

Refer to Table 2. Common Drinking Water Contaminants in the United States. Name the most common sources of water contaminants in this table. What can we do to reduce contamination at these sources?

Think about where your drinking water comes from. Do you take it for granted that your drinking water is safe? If so, why?

APPLY:

- How has this lesson made you more aware about the health risks associated with contaminated water?
- How has this lesson led you to appreciate the efforts of so many to ensure a clean, safe, and reliable source of drinking water?
- How can you and your community help to protect the drinking water supply from contaminants and diseases?

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Table 1. Ten Most Common Waterborne Diseases

	Disease	Cause	Symptoms
1	Cholera	Caused by ingestion of water infected with the Vibrio Cholerae bacterium. Spread by fecal contamination of food and water.	Symptoms include muscle cramps, vomiting, diarrhea, altered consciousness, seizures, and even coma. Also known as “Blue Death” because the person’s skin turns bluish-gray due to excessive loss of bodily fluids. It can kill the infected person in a matter of hours if left untreated.
2	Diarrhea	Caused by ingestion of water infected with a multitude of bacteria and harmful organisms. Spread through food and drinking water that has been contaminated.	Defined as having three or more loose or liquid stools per day. Can last up to two weeks leaving the victim completely dehydrated.
3	Malaria	Causal protozoan are carried by the female Anopheles mosquito. Spread by the Plasmodium parasite mosquito that breeds in water bodies such as lakes, ponds, and stagnant water.	Symptoms begin 8 to 20 days following infection, include headache, fever, muscle fatigue, back pain, dry cough, nausea, vomiting, spleen enlargement, chills and excessive sweating.
4	Typhoid Fever	Caused by the bacterium Salmonella typhi. Spread through poor hygiene habits and sanitation, and flying insects feeding on feces. Also spreads through contaminated food and water or close contact with an infected person.	Symptoms include high fever, headache, constipation, nausea, vomiting, loss of appetite, abdominal rashes, exhaustion, sleepiness, and diarrhea. Fever generally peaks for three weeks and then gradually subsides over the fourth and fifth weeks.
5	Filariasis	Caused by a parasite carried by black flies and mosquitos that breed in fresh and stagnant water bodies and are the host of the filarial nematode worm. Affects people who live near unsanitary water bodies or sewages.	Symptoms include edema with thickening of the skin and underlying tissues, having a severe effect on the limbs. Leads to elephantitis.
6	Dysentery	Caused by the bacterium Shigella or an amoeba. Spread by fecal contamination of food and water.	Symptoms include inflammation of the intestine and frequent passage of feces with blood and mucus. Can result in severe dehydration if not properly treated.
7	Viral Gastro-enteritis	Caused by a virus; also known as stomach flu. Spread through contact with infected people, or contaminated food and water.	Symptoms include gastrointestinal discomfort, sweating, clammy skin, diarrhea, vomiting, fever and headache.
8	Hepatitis	Caused by a viral infection which causes inflammation of the liver. There are five different types of Hepatitis (A, B, C, D, and E.), each caused by a different virus. Hepatitis A and B are commonly spread through consumption of contaminated water or food.	Symptoms for all types of Hepatitis include chills, fever, jaundice, dark urine, and abdominal discomfort.
9	Amoebiasis	Caused by the amoeba Entamoeba histolytica spread through ingestion of the cyst form of the parasite, a semi-dormant and hardy structure found in feces.	Symptoms include fatigue, diarrhea, flatulence, abdominal discomfort and weight loss. Tends to be inactive for several years, showing no or few signs of infection.
10	Giardiasis	Caused by the parasite Giardia lamblia commonly spread by ingestion of contaminated water or food.	Symptoms include fatigue, nausea, diarrhea, loss of appetite, vomiting, bloating and abdominal cramps, weight loss, excessive gas, headaches, and abdominal pain.

Table 2. Common Drinking Water Contaminants in the United States

Contaminant	Common sources of contaminant in drinking water	Potential health effects from over-exposure
Acrylamide	Nervous system or blood problems	Added to water during sewage/wastewater treatment
Alachlor	Runoff from herbicide used on row crops	Eye, liver, kidney or spleen problems; anemia, cancer risk
Alpha particles	Erosion of natural deposits of certain radioactive minerals	Increased risk of cancer
Antimony	Discharge from petroleum refineries; electronics, ceramics; fire retardants; solder	Increase in blood cholesterol; decrease in blood sugar
Arsenic	Erosion of natural deposits; runoff from orchards	Skin damage or problems with circulatory systems, cancer risk
Asbestos	Decay of asbestos cement in water pipes; erosion of natural deposits	Increased risk of developing intestinal polyps
Atrazine	Runoff from herbicide used on row crops	Cardiovascular system or reproductive problems
Barium	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	Increase in blood pressure
Benzene	Discharge from factories; leaching from gas storage tanks and landfills	Anemia; decrease in blood platelets; increased risk of cancer
Beryllium	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace and defense industries	Intestinal lesions
Bromate	Byproduct of drinking water disinfection	Increased risk of cancer
Cadmium	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	Kidney damage
Chloramines	Water additive used to control microbes	Eye/nose irritation; stomach discomfort, anemia
Chlorine	Water additive used to control microbes	Eye/nose irritation; stomach discomfort
Chromium	Discharge from steel and pulp mills; erosion of natural deposits	Allergic dermatitis
Copper	Corrosion of household plumbing systems; erosion of natural deposits	Short term exposure: gastrointestinal distress. Long term exposure: liver or kidney damage.
Cryptosporidium	Human and animal fecal waste	Gastrointestinal illness (diarrhea, vomiting, cramps)
Cyanide	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	Nerve damage or thyroid problems
2,4-D	Runoff from herbicide used on row crops	Kidney, liver or adrenal gland problems
Fluoride	Water additive that promotes strong teeth; erosion of natural deposits	Bone disease (pain and tenderness of the bones); children may get mottled teeth

Contaminant	Common sources of contaminant in drinking water	Potential health effects from over-exposure
Giardia lamblia	Human and animal fecal waste	Gastrointestinal illness (such as diarrhea, vomiting, cramps)
Glyphosate	Runoff from herbicide use	Kidney problems; reproductive difficulties
Haloacetic acids	Byproduct of drinking water disinfection	Increased risk of cancer
Lead	Corrosion of household plumbing systems; erosion of natural deposits	Infants and children: delays in physical or mental development; children could show slight deficits in attention span and learning abilities. Adults: kidney problems; high blood pressure
Legionella	Found naturally in water; multiplies in heating systems	Legionnaire's disease, a type of pneumonia
Lindane	Runoff/leaching from insecticide used in cattle, lumber, gardens	Liver or kidney problems
Mercury	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	Kidney damage
Nitrate	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	Infants under 6 months old who drink water containing nitrate in excess of the maximum contamination limit could become seriously ill, and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.
Radium 226/228	Erosion of natural deposits	Increased risk of cancer
Selenium	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	Hair or fingernail loss; numbness in fingers or toes; circulatory problems
Styrene	Discharge from rubber and plastic factories; leaching from landfills	Liver, kidney or circulatory system problems
Thalium	Leaching from ore-processing sites; discharge from electronics, glass and drug factories	Hair loss; changes in blood; kidney, intestine, liver problems
Toulene	Discharge from petroleum factories	Nervous system, kidney, or liver problems
Total Coliforms	Coliforms are naturally present in the environment as well as in feces; fecal coliforms and E. coli come only from human and animal fecal waste	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present
Turbidity	Soil runoff	Turbidity is a measure of cloudiness of water. High turbidity levels are often associated with disease-causing organisms and micro-organisms such as viruses, parasites, and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea and associated headaches.
Uranium	Erosion of natural deposits.	Increased risk of cancer, kidney toxicity
Viruses	Human and fecal waste	Gastrointestinal illness (such as diarrhea, vomiting, cramps)

WORLD WATER QUALITY FACTS

1. __________________ gallons of untreated sewage, groundwater, and industrial waste are discharged in the US each year.

2. __________________ to __________________ cases of water-borne diseases are reported annually in the US.

3. __________________ % of rivers and __________________ % of US lakes are polluted and not suitable for fishing, swimming or aquatic life.

4. __________________ different pesticides are found in US groundwater.

5. __________________ billion people globally lack access to safe drinking water.

6. __________________ billion people globally lack proper sanitation.

7. __________________ % of the world's population defecate in the open where it pollutes nearby water bodies and poses health risks.

8. __________________ % of industrial waste and __________________ % of sewage are dumped into waters around the world.

9. __________________ children under the age of five die every year around the world from diarrhea as a result of unsafe drinking water, sanitation, and poor hygiene.

10. __________________ are disease-causing organisms such as bacteria, fungi, and viruses.

11. __________________ chemicals are inorganic and organic substances that are harmful to the environment or hazardous to your heath if inhaled, ingested or absorbed through the skin.

12. __________________ elements are substances that emit radiation, such as uranium, plutonium, and radium.

WORLD WATER QUALITY FACTS - ANSWER KEY

1. **1.2 trillion** ____________ gallons of untreated sewage, groundwater, and industrial waste are discharged in the US each year.

2. **12 million** ____________ to **18 million** _______ cases of water-borne diseases are reported annually in the US.

3. **40** __________________ % of rivers and **46** ____________ % of US lakes are polluted and not suitable for fishing, swimming or aquatic life.

4. **73** ____________________ different pesticides are found in US groundwater.

5. **2.1** _____________________ billion people globally lack access to safe drinking water.

6. **4.5** ____________________ billion people globally lack proper sanitation.

7. **18** _____________________ % of the world's population defecate in the open where it pollutes nearby water bodies and poses health risks.

8. **70** _____________________ % of industrial waste and **80** ______________ % of sewage are dumped into waters around the world.

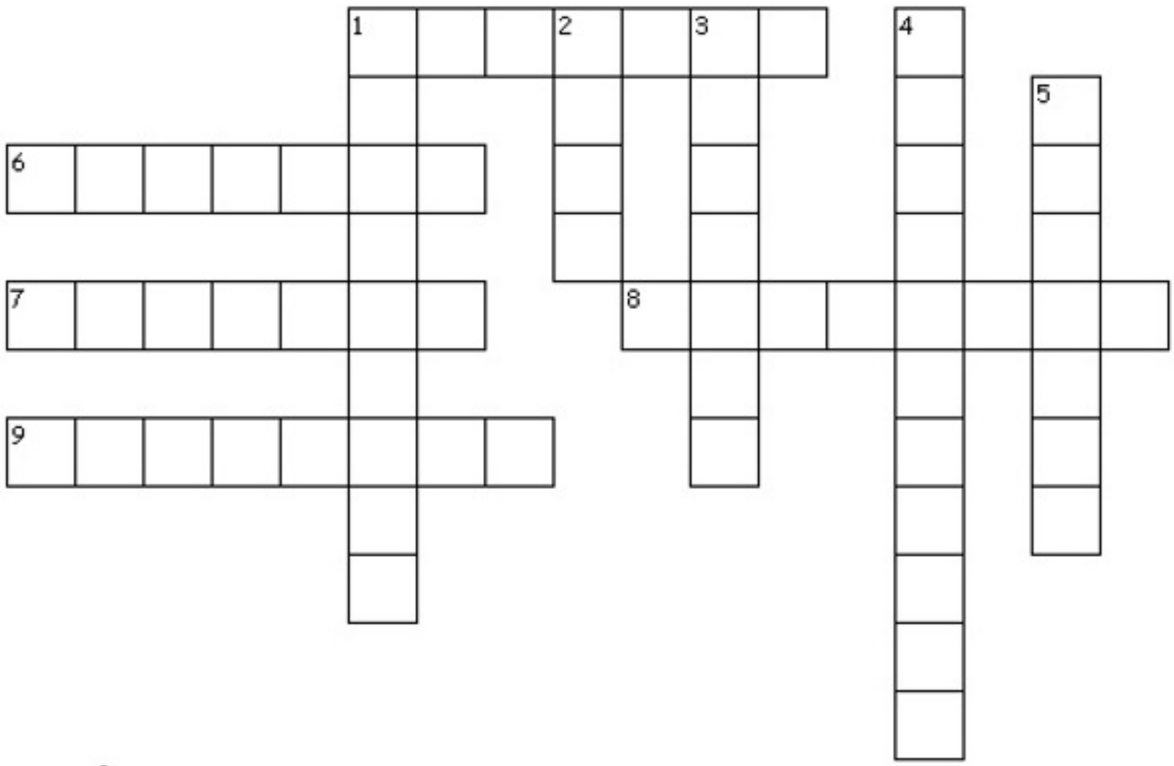
9. **340,000** _______________ children under the age of five die every year around the world from diarrhea as a result of unsafe drinking water, sanitation, and poor hygiene.

10. **Pathogens** _____________ are disease-causing organisms such as bacteria, fungi, and viruses.

11. **Toxic** ___________________ chemicals are inorganic and organic substances that are harmful to the environment or hazardous to your heath if inhaled, ingested or absorbed through the skin.

12. **Radioactive** ______________ elements are substances that emit radiation, such as uranium, plutonium, and radium.

POLLUTION CHALLENGE



Across

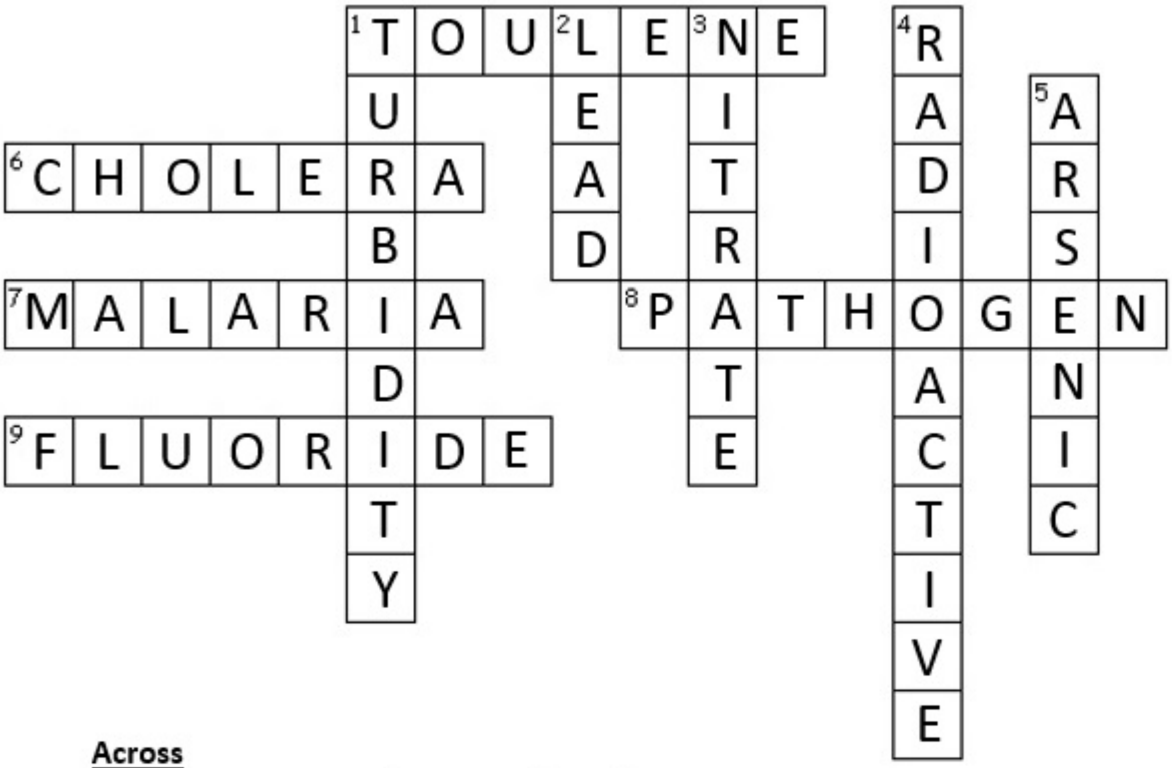
1. Discharge in water from petroleum factories
6. Water-borne disease also known as the "Blue Death"
7. Spread by the Plasmodium parasite mosquito
8. Disease-causing organisms such as bacteria, fungi, and viruses
9. Health effects include bone disease. Children may get mottled teeth.

Down

1. A measure of cloudiness of water
2. Poisoning will lead to learning disabilities in children
3. High levels have been linked to "blue baby syndrome"
4. Examples include uranium, plutonium, and radium
5. A contaminant common in water runoff from orchards

POLLUTION CHALLENGE

Answer Key



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Drinking Water Treatment

TIME:
50 to 60 minutes

MATERIALS NEEDED:
- Paper
- Pencils/pens/highlighters
- Table: Examples of Waterborne Disease Outbreaks in the US

OBJECTIVES:
The 4-H member will:
- Learn the major treatment processes for a community drinking water system
- Learn the most common home water treatment strategies
- Learn water treatment methods used in developing countries
- Explore causes of waterborne disease out-breaks in the US

KEY TERMS:
- Coagulation – the process where a liquid changes to a solid or semi-solid state.
- Disinfection – the process of destroying bacteria and many other types of microorganisms that are likely to cause disease or infection.
- Distillation – the process of purifying a liquid by heating and cooling.
- Flocculation – the process where fine particulates in a liquid clump together forming a floc.
- Sedimentation – the process where solid particles (or flocs) settle to the bottom of a liquid.
- Water-borne disease – disease spread while bathing, drinking, or by eating food exposed to infected water.
- Water filter – A device that removes impurities from water by using a physical barrier, screen, chemical, or biological process.
- Water softener – A device that reduces the hardness of water. It uses sodium or potassium ions to replace calcium and magnesium ions which create "hard" water.

EXPLORE THE CONTENT:
Drinking water in the United States is among the safest in the world. State and national regulations help ensure drinking water for communities is regularly tested for harmful contaminants and micro-organisms that could cause sickness and death. Cutting-edge technologies are available that provide added layers of treatment and protection depending on the raw water source. Surface water is more likely to be polluted since it is in direct contact with human activities. However, groundwater often requires some level of filtration and treatment to protect against mineral buildup in pipes and appliances.

Community Drinking Water Treatment

Public drinking water usually includes many different processes that make water safe to drink and taste good too. Refer to Figure 1.

- Coagulation and flocculation are usually the first step in water treatment. Chemicals are added to the water that cause dissolved particles such as soil, oils, and metals to bind together.
- During sedimentation, these bound particles, called flocs, settle to the bottom due to their weight and density.
- Once the floc has settled to the bottom, the clear water

on the top is passed through filters such as sand, gravel, and charcoal. Dust, parasites, bacteria, viruses and chemicals are trapped in the filter allowing only clean water to pass.
- To protect against parasites, bacteria, and viruses in water when piped to homes, a disinfectant such as chlorine or chloramine is added.
- Finally, many public water supplies add fluoride to the water to help prevent tooth decay.

Home Water Treatment

There are several methods that are used to treat water as it enters the home, or inside the home at the faucet. These methods are most common in homes that are not connected to a community water system, but rather get their water from a groundwater well.

- A **water filter** removes impurities from water by using a physical barrier, screen, chemical, or biological process.
- A **water softener** reduces the hardness of water. It uses sodium or potassium ions to replace calcium and magnesium ions which create "hard" water. Hard water leaves scale and other buildup on pipes and faucets and makes it difficult to create suds in soapy water.
- With **distillation**, impure water is boiled. Steam is collected and allowed to condensate in a separate container. Solid contaminants in the impure water are left behind.
- **Disinfection** kills harmful bacteria, fungi, and pathogens that can cause sickness. Chemical disinfectants include chlorine, chlorine dioxide, and ozone. Physical disinfectants include ultraviolet light, electronic radiation, and heat.

Water Treatment in Developing Countries

While many people in the US and other technologically-advanced countries often take clean water for granted, for much the developing world access to clean drinking water is extremely limited. Approximately 2.2 billion people die each year from waterborne disease, with more than half of those victims under the age of six. The problem stems from source water contamination from human and animal waste, open defecation, unsanitary conditions, and lack of money to build a water treatment system.

Groups such as the United Nations International Children's Fund and the World Health Organization are working to provide solutions for treating and storing safe, clean drinking water at the point of use, or home. Some of these solutions involve providing people a safe way to chlorinate water before drinking to remove most bacteria and viruses. Solar disinfection is another option. With this strategy, people can fill a plastic soda bottle with water, shake it for oxygenation, and place it out in the sun for several hours. The increased temperature and prolonged exposure to ultraviolet light helps to improve water quality. This method is low cost and provides good pathogen reduction. Other strategies involve various methods of filtration by passing water through porous materials such as stones, ceramics, sand, and other natural materials to trap and remove bacteria. A combination of all of these methods is needed to ensure harmful contaminants are removed.

DO:

Despite the best efforts of communities and government agencies to protect against water-borne contamination and diseases, breakdown of equipment, natural disasters, and human error can put hundreds or thousands of people at risk. Read through table 'Examples of Waterborne Disease Outbreaks in the US' found at the end of the lesson.

For each case, circle/underline/highlight the specific waterborne contaminant and cause(s) of the disease outbreak.

REFLECT:

To what extent was <u>mechanical breakdown</u> a contributing factor in disease outbreak in these cases? Give examples, if any?

To what extent was human negligence a contributing factor in disease outbreak in these cases? Give examples, if any?

To what extent was lack of communication a contributing factor in disease outbreak in these cases? Give examples, if any?

In some instances, **cross-contamination** was mentioned as a contributing factor. What is cross-contamination?

APPLY:

- How has this lesson made you more aware of the technologies and processes that provide clean, safe drinking water?
- Assess to community drinking water treatment facilities is restricted to authorized personnel only. Why is this the case?
- Technologies exist to effectively and efficiently remove almost all contaminants from water, making it safe to drink. Given this fact, why are so many people around the world still getting sick and dying from waterborne diseases?

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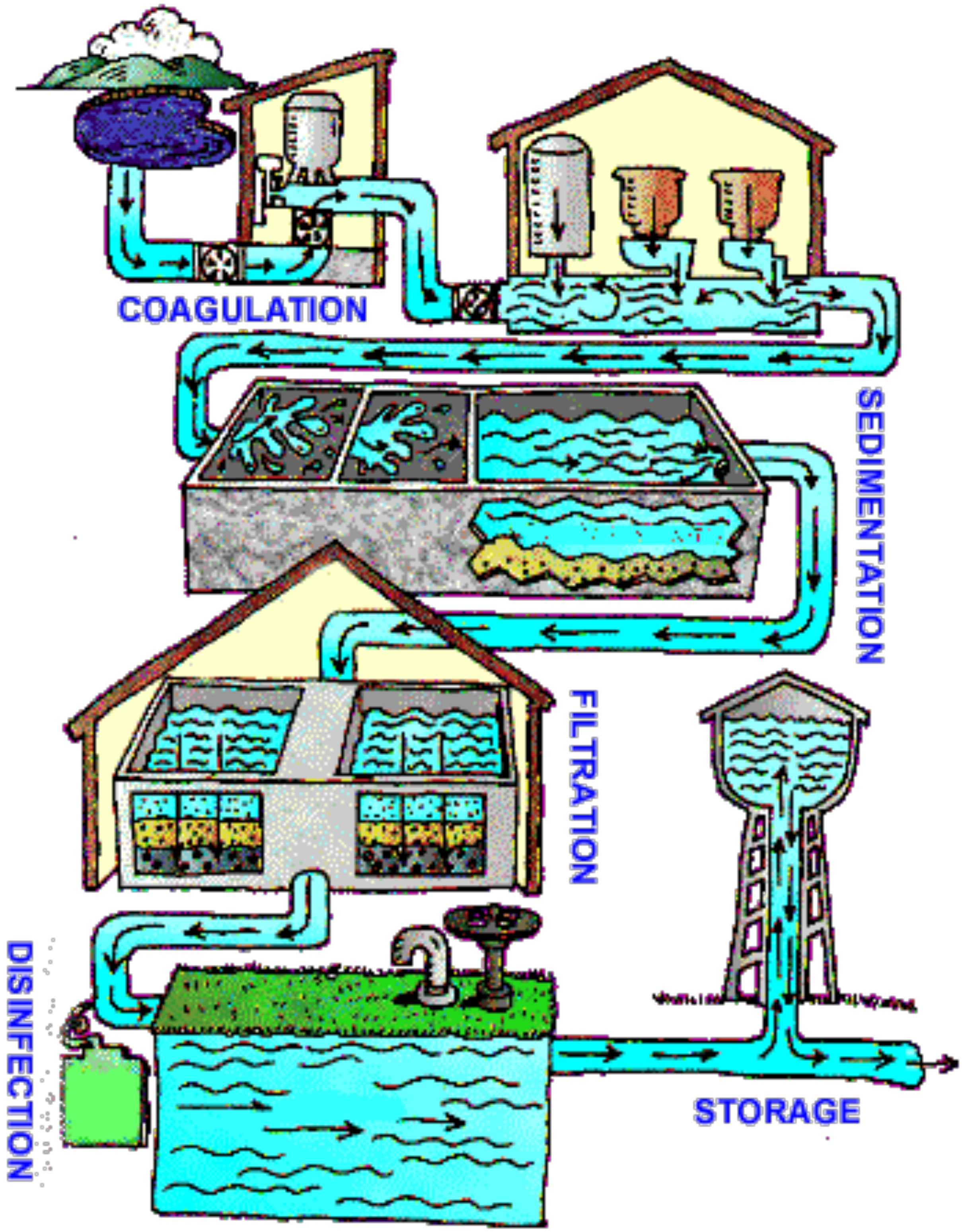
Figure 1. Community Drinking Water Treatment Processes



Source: United States Environmental Protection Agency.

EXAMPLES OF WATERBORNE DISEASE OUTBREAKS IN THE US

DATE	STATE	DESCRIPTION OF OUTBREAK
August 2012	Utah	Twenty-eight individuals who lived on the same street in the same neighborhood reported gastrointestinal illness within a seven-week period. Stool samples from five individuals were positive for Giardia intestinalis. In the month prior to the first case of illness, the neighborhood's drinking water pipe system changed from one public water system to another. This likely caused low pressure in the neighborhood pipe system. The change in water pressure temporarily allowed contaminated water to flow into the drinking water system. The source of the contaminated water was a previously unknown cross-connection between the drinking water system and an irrigation system. Since the cross-connection was fixed, no further illnesses were reported.
August 2012	Wisconson	Nineteen people who attended a wedding held at a banquet facility became ill with gastrointestinal problems. An investigation showed that 70% of people affected were exposed to tap and 21% of people affected were not exposed to tap water. The attendee's stool samples tested positive for norovirus, as did samples of faucet tap water and septic system wastewater. The water source for the facility was an older well that did not meet recent standards for well depth. The owner of the property was not aware of this and had not properly maintained the facility's septic system. This resulted in leaching from the septic system into the well area prior to the outbreak. The facility owner was required to dig a deeper well and install a new septic system.
February 2013	Maryland	Fourteen office workers developed multiple symptoms of illness including vomiting, headache, dizziness, fatigue, rash, confusion, palpitations, or loss of consciousness. Water samples as well as cream of wheat and oatmeal prepared with the water and consumed by some of the people showed high level of nitrite and nitrate. High levels of nitrite and nitrate were also found in the potable hot water system, in mixed hot/cold pipes, and in the leftover food. An investigation revealed that a corrosion inhibitor containing sodium nitrite was mistakenly added to the hot water system instead of the heating and cooling (HVAC) system.

September 2013	Ohio	Six individuals became ill after drinking potable water which originated from Lake Erie. A drinking water operator detected microcystins (liver toxins) in treated drinking water. The toxin in the water came from a cyanobacterial (blue-green algae) bloom in western Lake Erie, the raw water source for the drinking water system. The health department was notified that samples exceeded the Ohio EPA allowable maximum levels for cyanobacteria and a 'Do Not Drink' advisory was issued. The next day a health advisory was issued to medical providers, hospital workers, and veterinarians to ward about potential exposures.
October 2014	Ohio	One hundred people became sick with gastrointestinal symptoms following a wedding held in a barn at an apple orchard. After being notified by a guest six days later, the health department followed up to determine the source of the illness. After interviewing attendees and staff, it was found that non-potable tap water was used to make the beverages. The owner of the orchard had not intended for the untreated water to be used for human consumption. He verbally told members of the family, but there were no signs posted. The water originated from a spring on the side of hill and was pumped to the barn. Water from the spring and kitchen sink used to prepare the beverages tested positive for total coliform and Cryptosporidium parvum. Interviews of guests revealed that only the guests that got sick drank water or beverages containing the tap water.

Source: Adapted from Centers for Disease Control and Prevention surveillance reports.

Electro-coagulation - A Shocking Way to Clean Water

TIME:
40 to 50 minutes

MATERIALS NEEDED:
- Pencils/pens
- Large easel pad with markers
- Blank copies of the Electro-coagulation Diagram
- Copies of the Wonders of Electro-coagulation word find
- Small prizes to be given out to winners of the word find challenge

OBJECTIVES:
The 4-H member will:
- Learn how the physics of electricity is used to change chemical properties of water.
- Learn how electro-coagulation separates contaminants from dirty water.

KEY TERMS:
- Alternating current (AC) – An electrical current that reverses direction many times a second. Alternating current is typically used in homes.
- Anode – In electro-coagulation, it is the "sacrificial" electrode which releases positive charged metal ions (Me+).
- Cathode – In electro-coagulation, it is the electrode which produces hydrogen gas (H2) and negatively charged hydroxyl groups (OH-).
- Direct current (DC) – An electrical current flowing in only one direction.
- Electrical circuit – A continuous path for electrons to flow.
- Electro-coagulation – A method to filter contaminants out of water using small amounts of electrical current.
- Electrode – A metal plate through which electrons flow.
- Flocculent – Suspended solids, metals, emulsified oils, and other contaminants that clump together and settle out during the electro-coagulation process.

EXPLORE THE CONTENT:
Note: As you explore the content, list the (15) key words (in bold) on the easel pad for added emphasis.

In lesson 1 you learned that for people in developing countries, access to healthy, safe, and reliable drinking water is often limited. Water pollution from industrial waste, agricultural chemicals, animal waste, and poor sanitation results in sickness, disease, and death. Since developing countries also tend to be poor, its' people need low-cost, easy-to-use methods to filter out contaminants.

Elequa, a non-profit organization based in San Antonio, designs low-cost water filtration methods for people in developing countries. The filtration system directs a small amount of electricity through water which separates suspended solids such as soil, oils, grease, and metals from the water. This process is called "electro-coagulation".

How does electro-coagulation work?

You have heard it said that "electricity and water don't mix." In most cases this is true. However, electricity can be used to remove harmful contaminants from water. 'Electro-coagulation' uses the power of electricity to change the electrical charges of different particles in water. This causes these particles to clump together (or **coagulate**) so that they can be filtered out.

Figure 1 shows a small-scale electro-coagulation water filtration system. The system requires a **direct current** (DC) power supply, two short pieces of wire, and two metal **electrodes**. These electrodes are usually iron (FE) or aluminum (Al). Electrodes are submerged in a container of 'dirty' water. Electricity flows through the negative terminal (-) of the power source, through a wire, and to one of the electrodes called the **cathode**. Electricity then moves through the water to the other electrode (called the **anode**), through the wire, and back to the negative terminal (+) of the power source. This completes the electrical **circuit**.

As electricity passes through the cathode, metal ions are released into the water. On the surface of the cathode, water is split into **hydrogen gas** (H2) and **hydroxyl groups** (OH-). When electricity flows through the water towards the anode, surface charges on suspended solids are destabilized. This reaction causes suspended solids, metals, emulsified oils, and other contaminants to clump together, forming what is called **flocculent**. As electricity flows into the anode, **metal ions** (Me+) are released from the electrode and attach to the flocculent. Because the anode is slowly losing metal ions, it is also called the **sacrificial** electrode. The flocculent may either float to the surface or sink to the bottom depending on the density and structure of the contaminants.

Electro-coagulation can change other chemical properties of water (such as pH, alkalinity, and hardness) and make it taste better. Contaminants such as bacteria and viruses <u>may</u> also be immobilized or killed, which then can be filtered out of the water with the coagulated solids. However, electro-coagulation is considered a <u>pre-treatment process</u> only. To ensure the water is free from bacteria and viruses, additional treatment is required.

While the concept of using electricity to treat water is not new, recent technology in electronics is making electro-coagulation less expensive, more accessible, and more efficient in filtering water. This makes it possible for a greater number of people to have cleaner drinking water. Elequa, for example, is using off-the-shelf **Arduino** micro-processors to convert alternating current (AC) which is most common, to direct current (DC) and to regulate output power supply. The processor is used to switch the direction of electrical current thereby extending the life of the electrodes.

DO:

Activity #1:

Review the Electro-coagulation Diagram, pointing out the direction of electron flow and the reactions taking place. Emphasize how the change in electrical charge of contaminants cause them to clump together.

Activity #2:

Pass out copies of the Electro-coagulation Diagram to each participant. Have each participant fill in the blanks with the correct term. Optional: Award small prizes to the person who successfully completes the diagram fastest.

Activity #3:

Assign the participants into groups of 2 or 3. Pass out a copy of the Wonders of Electro-coagulation word find to each group. Optional: Award small prizes to the team who successfully completes the word find fastest.

REFLECT:

Think about all of the different components of an electro-coagulation system. If you were to build one from scratch, what parts would you need?

This type of water filtration system is commonly used in the US, but it is only one of many treatment processes used to make sure the water is safe to drink. Can you think of any ways we filter out pollutants from water? [Correct answers may include chlorination, ultraviolet light, reverse osmosis, etc. primarily used to remove bacteria and viruses.]

APPLY:

- How can electro-coagulation technology help citizens in developing countries reduce sickness and death?
- What are some problems that may limit adoption of this technology in developing countries?
- Electro-coagulation should be considered pre-treatment only. Why is this the case?

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- What is electrocoagulation? Watertechtonics, Inc. Retrieved March 6, 2018 from: http://www.watertectonics.com/electrocoagulation/
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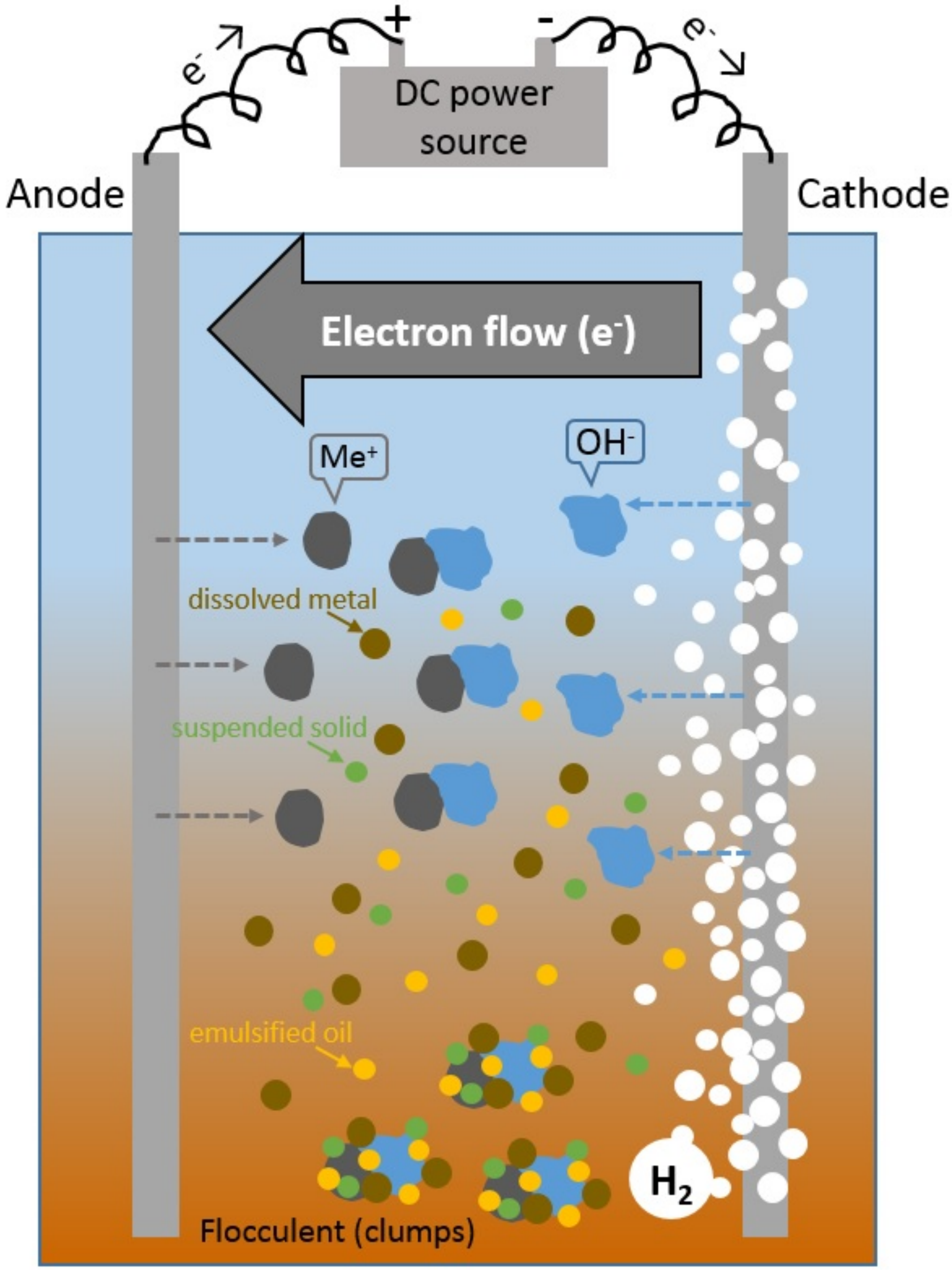
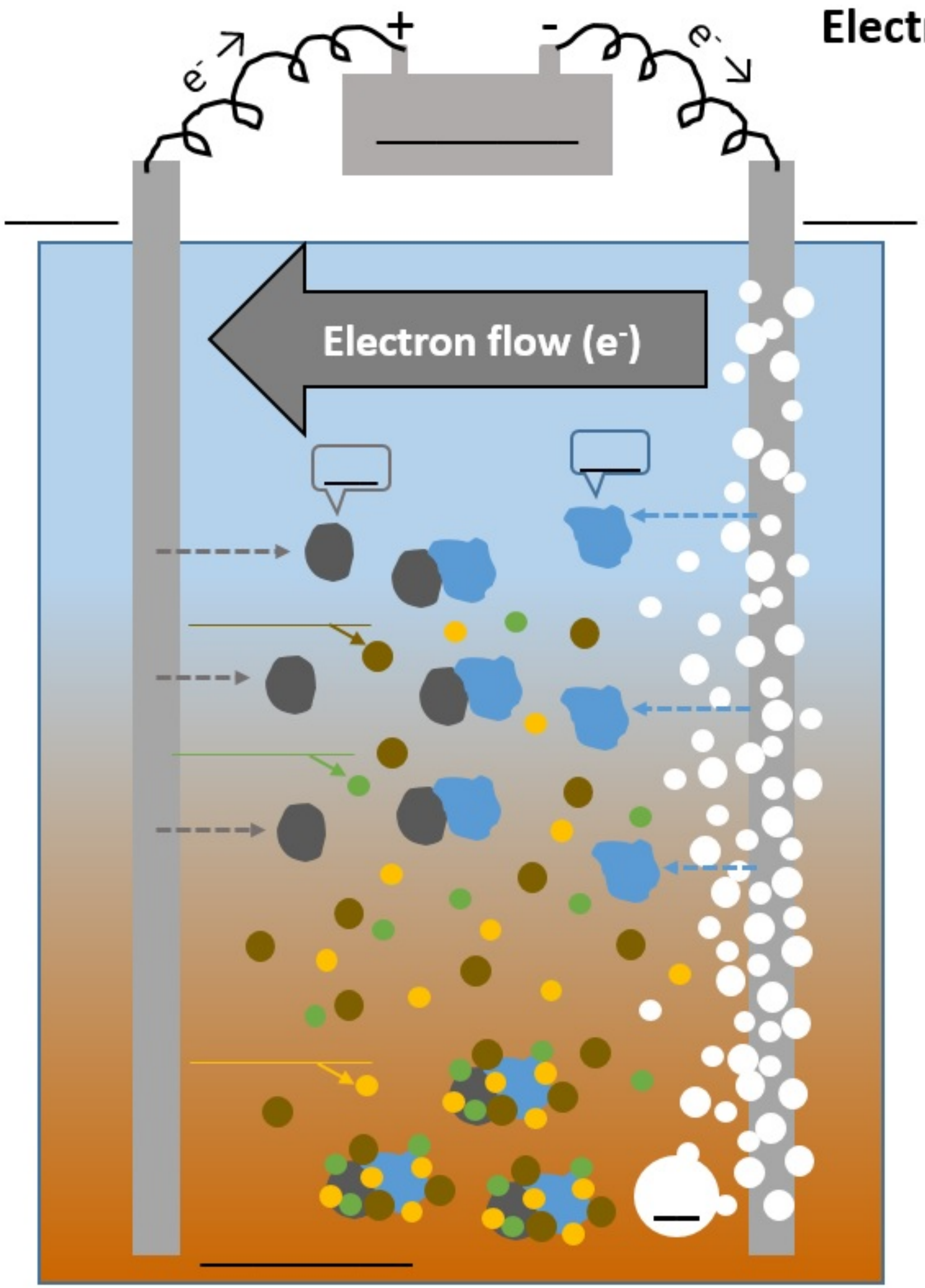
Figure 1. Electro-coagulation





Electro-coagulation Diagram

Labels:

- DC power source
- Flocculent (clumps)
- H_2
- Me^+
- Dissolved metal
- Suspended solid
- Emulsified oil
- OH^-
- Anode
- Cathode

Wonders of Electro-coagulation

V	D	W	H	F	D	E	P	A	E	Q	Y	U	T	D	R	P	T	V	I
I	F	U	H	E	P	T	D	Z	K	H	P	V	N	O	P	G	I	R	F
G	V	Q	I	E	G	U	X	O	P	W	N	O	E	C	Y	D	U	E	H
J	K	Z	Z	E	N	I	K	V	H	Y	D	B	L	X	U	P	C	Q	K
V	E	D	L	O	T	F	Y	Z	C	T	M	Z	U	L	V	C	R	M	R
I	E	E	L	E	C	T	R	O	D	E	A	V	C	F	U	Z	I	L	O
G	R	E	A	S	E	W	N	E	T	U	I	C	C	Y	I	T	C	N	T
D	P	J	B	Q	Y	H	T	A	W	V	X	A	O	C	I	L	I	Z	H
G	I	A	L	B	D	A	L	H	N	V	N	G	L	P	D	U	T	O	F
P	P	L	T	V	L	L	F	P	F	I	V	P	F	Z	D	M	Y	E	N
C	J	Y	X	U	H	T	E	M	A	M	M	N	X	R	O	H	L	C	R
C	K	B	G	C	X	X	Z	H	B	W	N	A	A	W	Y	T	D	Y	G
A	M	A	V	Y	Z	U	Q	Y	M	N	R	Q	T	D	Z	B	J	E	A
I	O	U	K	Y	T	C	B	D	M	T	E	M	R	N	L	Q	Q	Y	Q
C	T	N	E	R	R	U	C	R	J	W	K	O	H	V	O	L	Z	N	A
H	X	M	A	D	I	H	F	O	U	X	X	H	K	X	X	C	N	H	N
V	P	G	V	I	C	J	E	G	L	Y	I	X	Z	X	Q	Z	V	J	O
J	S	E	F	S	P	D	L	E	L	T	G	Y	A	E	Y	K	E	M	D
Z	P	D	H	T	Y	E	D	N	O	N	R	E	H	N	R	L	M	Y	E
Q	E	U	U	E	Q	K	D	M	P	A	X	R	B	V	G	N	A	V	Z

ANODE
CIRCUIT
CURRENT
FLOCCULENT
HYDROXYL
ARDUINO
COAGULATE
ELECTRODE
GREASE
METAL
CATHODE
CONTAMINANT
FILTER
HYDROGEN
POLLUTION

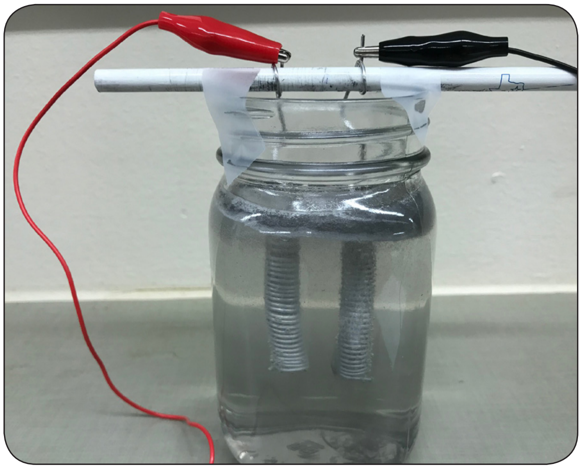
Wonders of Electro-coagulation

KEY

V	D	W	H	F	D	E	P	A	E	Q	Y	U	T	D	R	P	T	V	I
I	F	U	H	E	P	T	D	Z	K	H	P	V	N	O	P	G	I	R	F
G	V	Q	I	E	G	U	X	O	P	W	N	O	E	C	Y	D	U	E	H
J	K	Z	Z	E	N	I	K	V	H	Y	D	B	L	X	U	P	C	Q	K
V	E	D	L	O	T	F	Y	Z	C	T	M	Z	U	L	V	C	R	M	R
I	E	E	L	E	C	T	R	O	D	E	A	V	C	F	U	Z	I	L	O
G	R	E	A	S	E	W	N	E	T	U	I	C	C	Y	I	T	C	N	T
D	P	J	B	Q	Y	H	T	A	W	V	X	A	O	C	I	L	I	Z	H
G	I	A	L	B	D	A	L	H	N	V	N	G	L	P	D	U	T	O	F
P	P	L	T	V	L	L	F	P	F	I	V	P	F	Z	D	M	Y	E	N
C	J	Y	X	U	H	T	E	M	A	M	M	N	X	R	O	H	L	C	R
C	K	B	G	C	X	X	Z	H	B	W	N	A	A	W	Y	T	D	Y	G
A	M	A	V	Y	Z	U	Q	Y	M	N	R	Q	T	D	Z	B	J	E	A
I	O	U	K	Y	T	C	B	D	M	T	E	M	R	N	L	Q	Q	Y	Q
C	T	N	E	R	R	U	C	R	J	W	K	O	H	V	O	L	Z	N	A
H	X	M	A	D	I	H	F	O	U	X	X	H	K	X	X	C	N	H	N
V	P	G	V	I	C	J	E	G	L	Y	I	X	Z	X	Q	Z	V	J	O
J	S	E	F	S	P	D	L	E	L	T	G	Y	A	E	Y	K	E	M	D
Z	P	D	H	T	Y	E	D	N	O	N	R	E	H	N	R	L	M	Y	E
Q	E	U	U	E	Q	K	D	M	P	A	X	R	B	V	G	N	A	V	Z

ANODE	ARDUINO	CATHODE
CIRCUIT	COAGULATE	CONTAMINANT
CURRENT	ELECTRODE	FILTER
FLOCCULENT	GREASE	HYDROGEN
HYDROXYL	METAL	POLLUTION

BUILD YOUR OWN ELECTRO-COAGULATOR



TIME:
50 to 60 minutes

MATERIALS NEEDED
Items needed to construct a single electro-coagulation unit:
- Charged 9-Volt battery
- (2) small wire leads (~12-18 inches long) with alligator clips on each end
- 6 feet of 18 gauge aluminum wire
- 16 ounce glass Mason jar
- Tap water (~14 ounces per jar)

Additional items:
- Small bottle of black acrylic paint
- Scotch tape
- Wire cutters
- Blank sheets of paper
- Pencils/pens

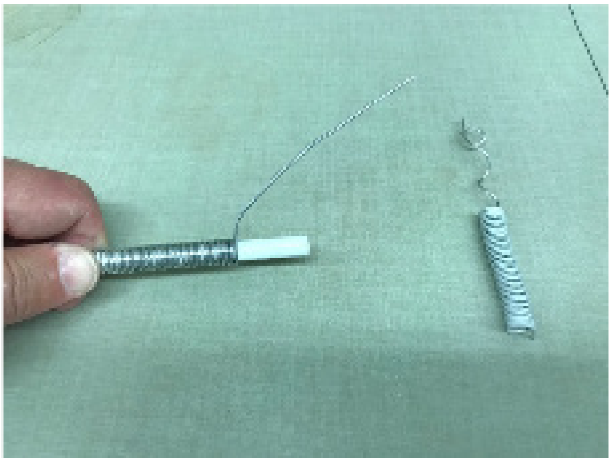
OBJECTIVES:
The 4-H member will:
- Learn how to build a small scale electro-coagulation system.
- Learn to identify different variables in the system that affect how quickly water is cleaned.

EXPLORE THE CONTENT:
Lesson 3 introduced electro-coagulation and explained how to use electricity to filter out contaminants such as suspended solids, metals, and oils from water. If needed, refer to Lesson 3 for a quick review of how the system works. In this lesson, students will build their very own electro-coagulation system using a 9-volt battery as the direct current (DC) power source. A small drop of black acrylic paint will be mixed with water to simulate pollution. They will also create your own electrodes using aluminum wire and observe the system in action. Suggestion: Group students into teams of 2 or 3 to minimize supply costs.

DO:
Step 1: Fill a container with ½ gallon of warm tap water. Add one drop of black acrylic paint and mix thoroughly. Caution: Avoid adding too much paint. This will turn the mixture too dark and you will not be able to see the electrodes.

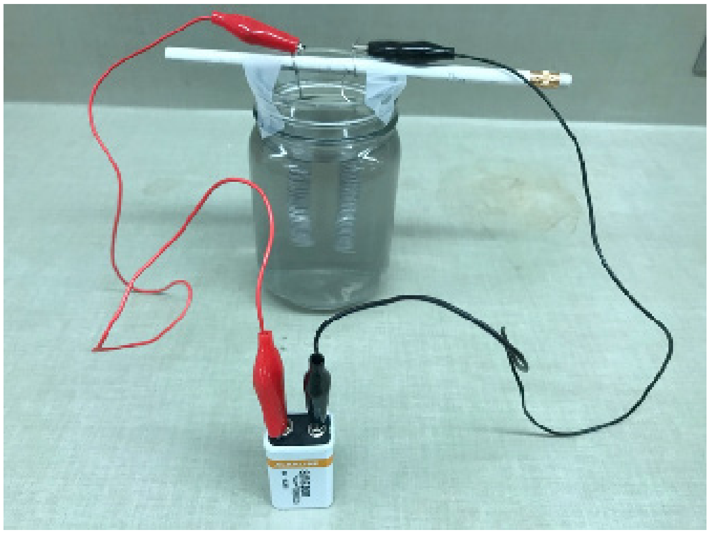
Step 2: Fill a clean Mason jar with the mixture as shown.

Step 3: Create two electrodes. Cut (2) 3-foot pieces of aluminum wire. Wind one piece of aluminum wire around a pencil as shown. The wind should be approximately 2 inches long leaving another 2 inches of straight wire at the end. Repeat for the second piece of aluminum wire.



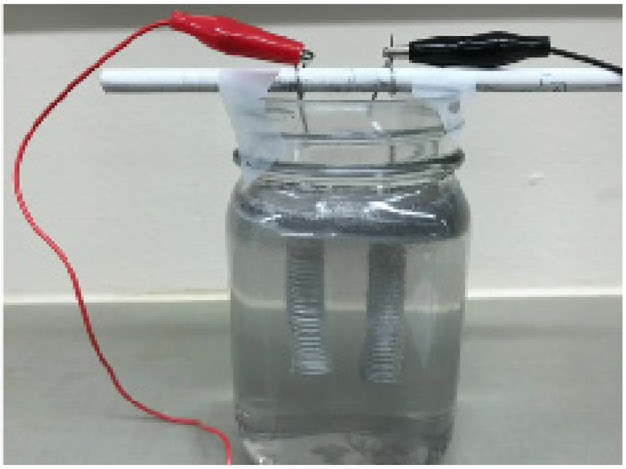
Step 4: Loop ½-inch to 1-inch of the end of each wire around the pencil. Leave enough wire at the end to attach an alligator clip. Space the electrodes ½-inch to 1-inch apart.

Step 5: Submerge the electrodes in the water, resting the pencil on top of the Mason jar. Use scotch tape to secure the pencil to the jar. Make sure the electrodes inside the jar are not touching.



Step 6: Connect the wire leads to the electrodes using the alligator clips as shown. Connect the other end of the wire leads to the positive and negative terminals on the 9-volt battery. It does not matter which wire lead is connected to each battery terminal.

Step 7: Observe the electro-coagulation system in action! Let the system run for a minimum of 20 minutes.



Step 8: Sketch out the system and label the following: power source, cathode, anode, and direction electrons are flowing. [Refer to Lesson 3: Figure 1 for a depiction of the process.]

REFLECT:

Present your sketch. What is happening at the cathode? What is happening at the anode? Which electrode is considered the "sacrificial electrode"?
Continue to observe the system. Describe any change in water clarity over time.
Name some of the variables in the electro-coagulation system. What factors, if adjusted or changed, would affect how quickly water is cleaned?

APPLY:

- The electro-coagulation process causes contaminants to clump together. How might these contaminants be taken out leaving only clean water behind?
- The power source in this lesson was a single 9-volt battery. What other direct current power sources may be used in developing countries and at a larger scale?
- Based on your observations, how could this system become more effective and efficient at removing contaminants from water?

REFERENCES:

- What is electrocoagulation? Watertechtonics, Inc. Retrieved March 6, 2018 from: http://www.watertectonics.com/electrocoagulation/
- Martin, Laura (2014). Electrocoagulation: A Shocking Approach to Wastewater Treatment. Water Online. January 24, 2014. Retrieved March 6, 2018 from https://www.wateronline.com/doc/a-shocking-approach-to-wastewater-treatment-0001
- Electrocoagulation versus chemical coagulation. Powell Water. Retrieved March 6, 2018 from http://powellwater.com/electrocoagulation-vs-chemical-coagulation/

Advanced-Level Electro-coagulation

EXPLORE THE CONTENT:

In lesson 4, students built a small scale electro-coagulation system powered by a 9-volt battery. In this lesson students will filter water using an advanced-level electro-coagulation system which offers several advantages. Instead of a 9-volt power source, this system will use a 12-volt DC adapter that is plugged into any 120 volt power outlet. The power will be continuous and there is no need to replace batteries. The extra 3 volts of electricity also allows more electrical current to flow, thus speeding up the filtration reaction inside the jar. In addition, the circuit board micro-processor is programmed to switch the direction of electrical current periodically. As a result, the life expectancy of electrodes is extended.

TIME:

50 to 60 minutes

MATERIALS NEEDED:

Electro-coagulation kit (1 kit per 3 to 4 students):

Option 1. Purchase a pre-assembled Elequa Electro-coagulator kit. Elequa is non-profit organization based in San Antonio, Texas. Cost is $50.00 per kit plus shipping. To purchase, email Elequa at info@makewater.org and mention Texas 4-H. The kit includes:

- (1) 12-volt AC power adapter
- (1) Pre-programmed Arduino micro-processor
- (2) Wire leads with pin and alligator clip connectors
- (2) Iron and (2) aluminum electrodes
- (1) 3-D Printed Mason jar lid with slots for electrodes
- (1) USB cable

Option 2. Build your own kit. A parts list of essential components is found at https://hackaday.io/project/20812-make-water-coagulator-kits#menu-description. Assembly and programming instructions are included. Requires computer and internet access to download code to the circuit board.

(2) 16 ounce glass Mason jars with lids for each group
Unfiltered water from pond, stream, or well
Small piece of sandpaper
pH, hardness, and alkalinity test strips (often found in stores that sell swimming pool and aquarium supplies)
Electrical conductivity (EC)/total dissolved solids (TDS) meter (optional)
pH meter (optional)
Large coffee filters
Latex gloves for each student handling water
Goggles for each student handling water
Paper towels
Pencils/pens
Data collection sheet found at end of lesson

OBJECTIVES:

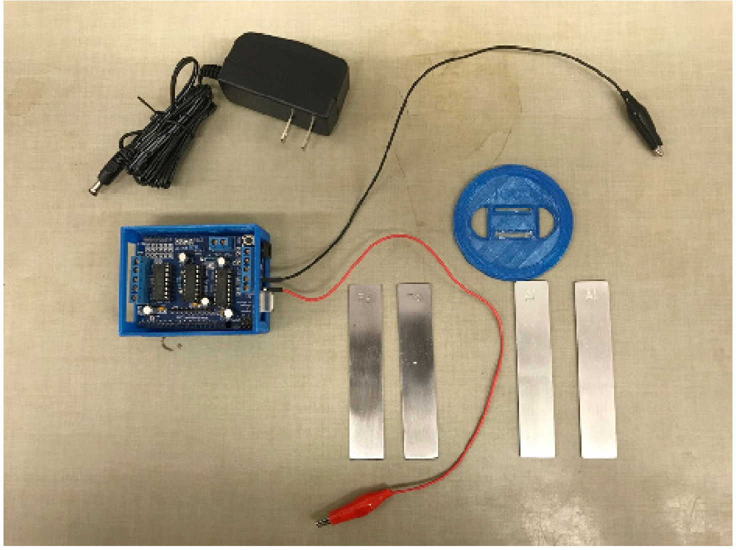
The 4-H member will:

- Learn how to set up and use an advanced-level electro-coagulation system.
- Learn how to conduct basic water chemistry tests to measure changes before and after electro-coagulation.
- Explore how to identify and change variables in the experiment to improve the effectiveness of electro-coagulation.

This lesson offers two options for an advanced-level electro-coagulation. Students may either assemble their own using parts purchased separately, or use a pre-assembled, pre-programmed kit purchased through the non-profit company, Elequa, based in San Antonio. Elequa has as its mission to develop low-cost technologies that provide clean drinking water for developing countries. Visit https://www.makewater.org/ to learn more.

Figure 1 shows the Elequa Electro-coagulation system components.

Figure 1. Elequa Electro-coagulation System



Testing Water Chemistry

In this lesson, you will observe and measure changes in water quality before and after electro-coagulation. One observation is water clarity. You will also test for **pH, alkalinity, and hardness** since they can be easily measured using inexpensive color-coded test strips. Other water tests may be conducted, including electrical conductivity (EC) and total dissolved solids (TDS), with inexpensive digital meters.

What is pH? pH is a measure of acidity or basicity of a liquid. pH ranges from 0 - 14, with 7 being neutral. pH less than 7 indicates an acid, whereas pH greater than 7 indicates a base. Technically, pH is a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic.

What is alkalinity? Alkalinity refers to the capability of water to neutralize acid (also known as buffering capacity). A buffer is a solution to which an acid can be added without changing the concentration of available H+ ions (without changing the pH) appreciably. The alkalinity of natural water is determined by the soil and bedrock through which it passes. The main sources for natural alkalinity are rocks that contain carbonate, bicarbonate, and hydroxide compounds. Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. Alkalinity is commonly expressed in parts per million (ppm) or milligrams per liter (mg/L).

What is hardness? Water hardness is the amount of dissolved calcium and magnesium in water. Hard water is high in dissolved minerals, both calcium and magnesium. When using hard water, more soap or detergent is needed to get things clean, be it your hands, hair, or your laundry. When hard water is heated, such as in a home water heater, solid deposits of calcium carbonate can form. This scale can reduce the life of equipment, raise the costs of heating the water, lower the efficiency of electric water heaters, and clog pipes. Hardness is commonly expressed in parts per million (ppm) or milligrams per liter (mg/L).

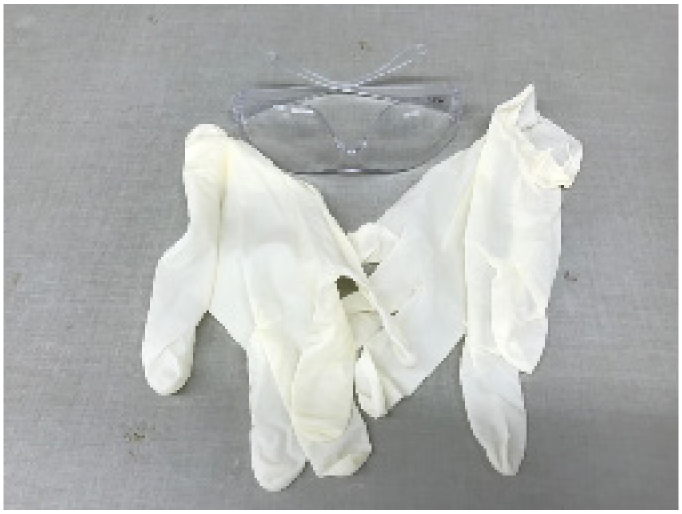
What is electrical conductivity? Electrical conductivity (EC) is a measure of dissolved material in water. This determines the ability of the water to conduct electrical current. EC is measured in units called Seimens per unit area (e.g. µS/cm, or micro-Seimens per centimeter). The higher the dissolved material in water, the higher the EC.

What is total dissolved solids? Total dissolved solids (TDS) are inorganic salts (mainly calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amount of organic matter that are dissolved in water. TDS in drinking-water can come from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process. TDS is commonly expressed in parts per million (ppm).

DO:

In this lesson, participants will construct their own advanced-level electro-coagulator or use the Elequa Electro-coagulation system to filter water from a well, pond, lake, or stream. Water quality is tested before and after treatment to document any changes in water chemistry. Finally, participants identify variables in the system, which if changed, would improve the effectiveness and efficiency of the system.

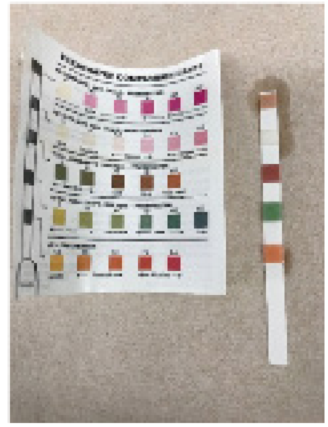
Step 1: Make sure participants who are handing the unfiltered water wear latex gloves and goggles.

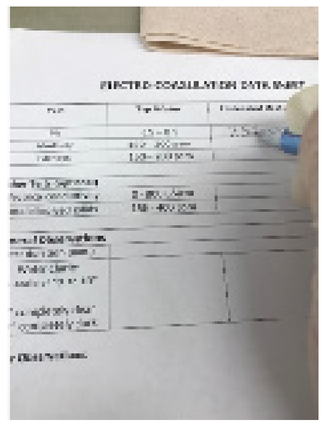


Step 2: Discuss the source of water collected. Where did it come from? What are some potential contaminants in the water?

Step 3: Pour unfiltered water into a clean mason jar as shown. Insert the water quality test strips and follow the instructions that come with the strips. Record data for pH, alkalinity, and hardness on the data collection sheet. If you have electrical conductivity (EC), total dissolved solids (TDS), and/or pH meters, take and record readings on the data sheet.







Step 4: Insert the slotted jar lid into the band and screw onto the jar.

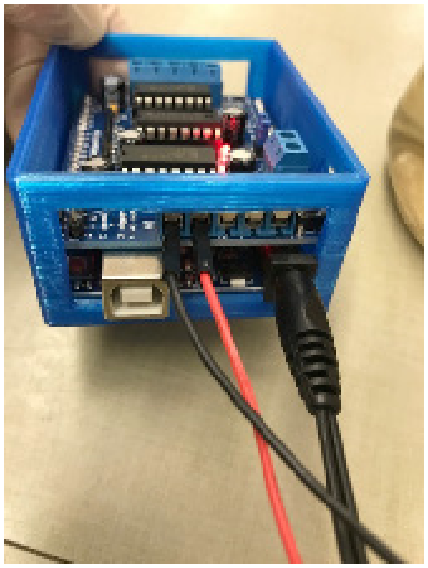

Step 5: Insert the electrodes into the middle slots and into the jar. Make sure they are straight and are not touching. [Sandpaper can be used to remove any shiny finish or corrosion on the electrodes improving their ability to conduct electricity.]

Step 6: Attach the pin-end of the wire leads into the ports on the micro-processor as shown. It does not matter which lead is connected to each port.

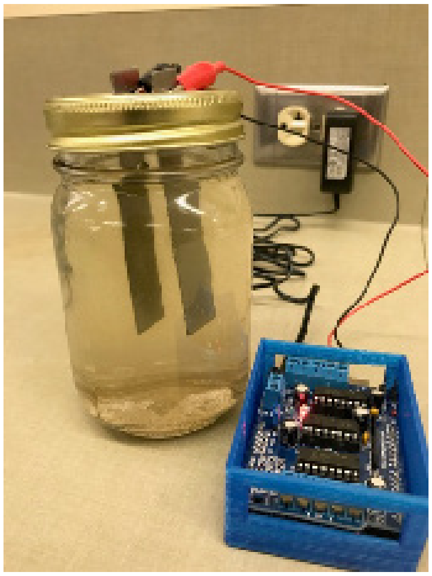
Step 7: Connect the alligator clip ends of the wire leads to each electrode. It does not matter which lead is connected to each electrode.

Step 8: Plug the power adapter into an AC wall outlet.

Step 9: Plug the other end of the power adapter into the micro-processor as shown. Current will immediately begin to flow to the electrodes. Start timer.



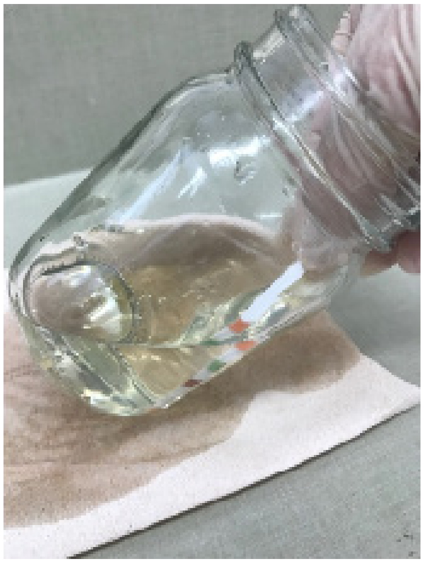
Step 10: As the electro-coagulation system is operating, observe and record any visual changes in the water.

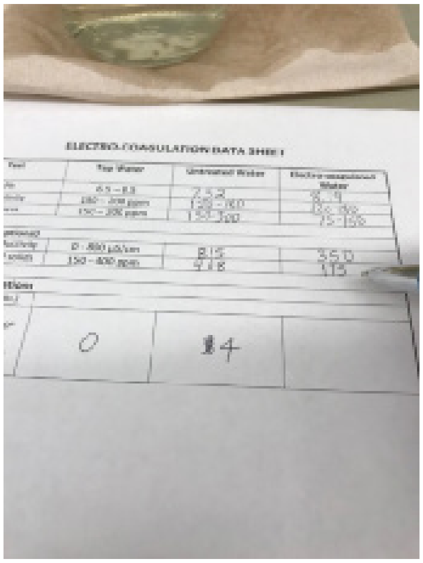


Step 11: After 30 minutes of operation, unplug power to the micro-processor and remove the lid and electrodes.

Step 12: Place and secure a coffee filter in the opening of a second clean Mason jar and secure with the lid. Slowly pour the coagulated water over the coffee filter, filling it about a quarter full. It is not necessary to filter the whole jar of water. Filter just enough water to submerge the water test strip.

Step 13: Insert the water quality test strips and follow the instructions that come with the strips. Record data for pH, alkalinity, and hardness on the data collection sheet. If you have electrical conductivity (EC), total dissolved solids (TDS), and/or pH meters take and record readings on the data sheet.





Step 14: Flush coagulated solids and water down a toilet. Throw away gloves in trash. Clean jars with soap and water.

REFLECT:

What is the source of the unfiltered water? Were you able to see any pollutants with the naked eye? If so, what did you see?

What changes did you witness throughout the electro-coagulation process? Did you see anything unexpected or surprising?

What advantages does the advanced-level electro-coagulation system have over the 9-Volt powered system that you built in Lesson 4?

Did the water quality tests show any change in water chemistry?

APPLY:

- What are some variables (things that can be changed or adjusted) in the test that would affect the effectiveness of electro-coagulation in treating water?
- Based on your understanding of electro-coagulation, how might the setup you used today be modified or improved to make the system work faster?
- What alternative sources of power could be used to operate an electro-coagulation system?
- Other than filtering drinking water, what are some other applications of this technology?

REFERENCES:

- What is electrocoagulation? Watertechtonics, Inc. Retrieved March 6, 2018 from: http://www.watertectonics.com/electrocoagulation/
- Martin, Laura (2014). Electrocoagulation: A Shocking Approach to Wastewater Treatment. Water Online. January 24, 2014. Retrieved March 6, 2018 from https://www.wateronline.com/doc/a-shocking-approach-to-wastewater-treatment-0001
- Electrocoagulation versus chemical coagulation. Powell Water. Retrieved March 6, 2018 from http://powellwater.com/electrocoagulation-vs-chemical-coagulation/

ELECTRO-COAGULATION DATA SHEET

Test	Tap Water	Untreated Water	Electro-coagulated Water
pH	6.5 – 8.5		
Alkalinity	150 – 200 ppm		
Hardness	150 – 200 ppm		
Other Tests (optional)			
Electrical conductivity	0 - 800 µS/cm		
Total dissolved solids	150 - 400 ppm		
General Observations			
Test duration (min.)			
Water Clarity On scale of "0 to 10" "0" completely clear "10" completely dark			

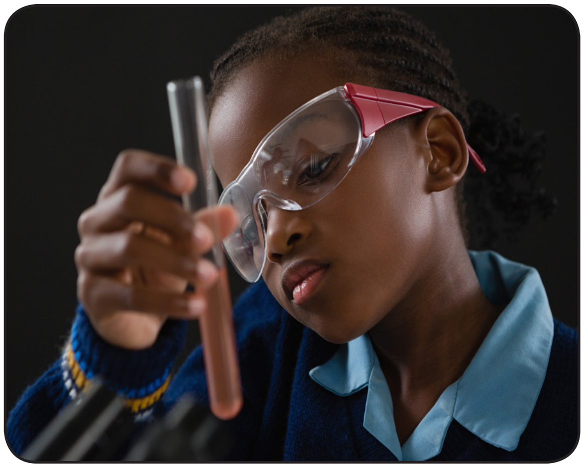
Untreated Water Description

Describe the Variables Involved

Other Observations:

Photograph and send this page to Info@MakeWater.org with the subject line "**Data**" to have your results logged and shared with the community. Use hashtag **#makewater** when posting on social media.

Design and Conduct an Electro-coagulation Research Project



TIME:
Varies with research objectives and expirementation

MATERIALS NEEDED:
- Participants may build their own electro-coagulation system (refer to lessons 4 and 5) OR use the Elequa Electro-coagulation System (lesson 5).
- Glass Mason jars with lids
- Unfiltered water from pond, stream, or well
- Small piece of sandpaper
- pH, hardness, and alkalinity test strips (often found in stores that sell swimming pool and aquarium supplies)
- Electrical conductivity (EC)/total dissolved solids (TDS) meter (optional)
- pH meter (optional)
- Large coffee filters
- Large rubber bands
- Latex gloves
- Goggles
- Pencils/pens
- Data collection sheets (should be customized according to research project objectives)

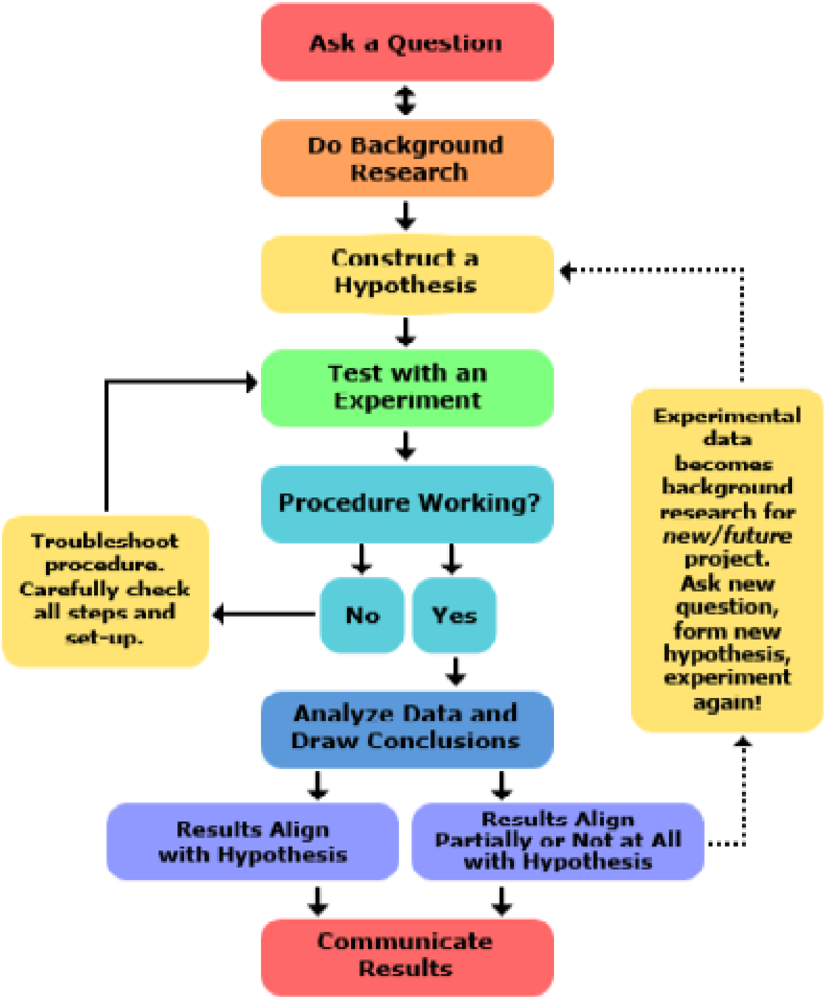
OBJECTIVES:
The 4-H member will:
- Review the basic steps of the scientific method and how it is applied in scientific research.
- Learn how to design and conduct an electro-coagulation research project.
- Learn how to create a scientific poster for the electro-coagulation research project.

EXPLORE THE CONTENT:

What is the Scientific Method?

The scientific method is a step-by-step process to explore and answer questions through experimentation. Although there are different versions of the scientific method, the goal is always to discover cause and effect relationships by asking questions, designing and performing experiments, and examining the data. Figure 1 is one depiction of the scientific method that will be discussed in this lesson. Though it is shown as a series of steps, it may be necessary to back up and repeat steps as needed to better define the research project.

Figure 1. Steps of the Scientific Method



1. Ask a Question: The scientific method begins with asking a question about something you observe.

Example. You observe that in your lawn turns much greener after big rain storm compared to when you use the sprinkler system.

2. Do Background Research: It is always beneficial to learn basic knowledge about your subject or topic. Use the library or internet search to help you find background information, scientific facts, and examples of similar research. This will also spur more ideas for experimentation and the type of data to collect.

Example. Search the internet for information on the type of grass in your lawn, what are its nutrient needs, and the differences between rain water and your local water supply.

3. Construct a Hypothesis: A hypothesis is an educated guess about cause and effect, or how things work. It is a statement whose validity can be tested through experimentation. It allows you to make a prediction: "If ________ [I do this] ________, then ________ [this] ________ will happen." Predictions should include an independent variable and dependent variable and be measureable.

An independent variable is a factor that you change in an experiment.
A dependent variable is the factor you observe or measure in an experiment.

Example hypothesis. "If I use only rain water to water my lawn, then my lawn will be greener than if I use my sprinkler system."

4. Test Your Hypothesis by Doing an Experiment: Your experiment determines whether your hypothesis can be supported or not, and whether your prediction is accurate. To be valid, you should only change one factor (independent variable) at a time while keeping all other conditions the same. The experiment should also be repeated several times to ensure that results did not just happen by accident or chance.

The experimental procedure defines all materials needed, what factors will be controlled, what factors will be measured, how often, how many times the test will be repeated, etc.

Example (abbreviated). Rain water will be diverted from the roof and collected in a 50-gallon barrel. A second 50-gallon barrel will be filled with water from my sprinkler system. The experiment will be conducted in June and during a week when no rainfall is predicted. The test area will be located in a 5-foot by 5-foot area in my front lawn in full sun conditions. The 25 square foot area will be divided in half. A watering can will be used to treat half of the test area with rain water, and the other half with water from the sprinkler system, to a depth of 0.5 inches. At 1, 2, 3, and 4 days following treatment, the color of the grass will be matched to a green color chart having a numerated rating scale ("1" being very pale greenish-yellow, and "10" being very dark green). Color ratings will be recorded on a data sheet. The test will be repeated 2 more times on different areas of the lawn. [In this experiment, the independent variable is the water source, and the dependent variable is lawn color.]

DATA COLLECTION SHEET

		Color Rating*				
Test #	**Treatment**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Observations**
1	rain water					
	sprinkler water					
2	rain water					
	sprinkler water					
3	rain water					
	sprinkler water					

*Color rating scale: "1" = pale greenish-yellow; "10" = very dark green

5. Analyze Your Data and Draw a Conclusion: After the experiment is complete and measurements made, analyze them to see if they support your hypothesis or not. Keep in mind that there is absolutely nothing wrong with a failed hypothesis. If fact, scientists often find that their predictions were not supported by the evidence. In such cases, scientists learn a great deal more about their subject as there are unforeseen variables and exceptions that often come to light.

Example (abbreviated): After three replicated (identical) tests, color ratings indicated that lawn irrigated by rain water was consistently greener than lawn irrigated by sprinkler water. The hypothesis "If I use only rain water to water my lawn, then my lawn will be greener than if I use my sprinkler system" is supported by the data.

DATA COLLECTION SHEET

		Color Rating*				
Test #	**Treatment**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Observations**
1	rain water	3	6	7	8	Initial conditions dry
	sprinkler water	3	4	5	5	
2	rain water	4	7	8	9	Cloudy on days 3 and 4
	sprinkler water	4	4	5	5	
3	rain water	5	8	9	10	Sunny conditions all week
	sprinkler water	5	6	6	7	

*Color rating scale: "1" = pale greenish-yellow; "10" = very dark green

6. Communicate Your Results: To complete your research project you will prepare a written report or poster display. A report or poster should contain the follow headings and information.

- *Abstract*. A short summary of the experiment which includes the purpose of the experiment, and no more than three sentences explaining the procedure, results, and conclusion.
- *Introduction*. Describes the problem or goal of the experiment. It provides background information, and discusses the independent variable, dependent variable(s) and hypothesis.
- *Materials and Methods*. Describes the experiment's design. What materials were used? How was data collected? How often data was collected? How was the data analyzed?
- *Results*. Describes and presents data using tables, graphs, and photographs. All figures should contain a caption. Measured data should always include units of measure.
- *Conclusions*. The first sentence states the hypothesis or research question. Subsequent text should answer the research question, explain the results, and discuss procedures that influenced the results.
- *References*. List all sources of information used in the report (websites, publications, books, etc.). There are many different reference citation styles, including APA (American Psychological Association) and Chicago/Turabian style. These style guides can be found on the internet.
- *Acknowledgments*. A formal printed statement that recognizes individuals and institutions that contributed to the work being reported.

The Electro-coagulation Research Project

Previous lessons explored how electro-coagulation is used to filter out suspended solids, oils, and other contaminants from untreated water. After experimenting with different methods and materials, you have likely made some general predictions about the electro-coagulation process such as how the process could be made faster or more effective. There are numerous possibilities for research and experimentation. Here is a short list of questions about electro-coagulation that you could investigate further using the scientific method.

- Is there one type of metal electrode that works faster than another to clean up dirty water?
- Should electrodes be placed close together or far apart?
- Does electro-coagulation work better for one source of water compared to another?
- How does the pH of treated water vary if I use different types of electrodes?
- Does adding table salt to untreated water speed up the electro-coagulation process?

DO:

Participants will design and complete a research project focusing on electro-coagulation. Refer back to the explanation of the scientific method to complete the following steps.

Step 1: Ask a question.
Step 2: Do background research.
Step 3: Construct a hypothesis.
Step 4. Test your hypothesis by doing an experiment.

REFLECT:

Analyze your data. Does the data support your hypothesis and predictions? If not, what new information did you learn by doing the experiment that will help you make future predictions?

How can your data best be summarized to easily communicate the results (graph, table, bullet points, etc.)?

What conclusions can you draw from your research on electro-coagulation?

APPLY:

- Create a scientific poster explaining your research project and results.
- Present your poster to peer groups, teachers, or others.
- Refine and present your poster at science fairs and contests such as the Discover Science Method Research Poster Contest held each year at Texas 4-H Roundup.
- Photograph the poster and send it to Info@MakeWater.org with the subject line "Poster" to share it with the community.

REFERENCES:

- What is electrocoagulation? Watertechtonics, Inc. Retrieved March 6, 2018 from: http://www.watertectonics.com/electrocoagulation/

- Martin, Laura (2014). Electrocoagulation: A Shocking Approach to Wastewater Treatment. Water Online. January 24, 2014. Retrieved March 6, 2018 from https://www.wateronline.com/doc/a-shocking-approach-to-wastewater-treatment-0001

- Electrocoagulation versus chemical coagulation. Powell Water. Retrieved March 6, 2018 from http://powellwater.com/electrocoagulation-vs-chemical-coagulation/

- APA Citation: http://writing.wisc.edu/Handbook/American_Psychological_Association_%28APA%29_Documentation_M.pdf

- APA Video CitationPoster Creation Using Microsoft Power Point: https://www.youtube.com/watch?v=1c9Kd_mUFDM

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ELECTRO-COAGULATION DATA SHEET

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Untreated Water Description			
Describe the Variables Involved			
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TEXAS A&M AGRILIFE EXTENSION

MARKING INSTRUCTIONS

CORRECT: ● INCORRECT: ☑ ⊠ ◒ ◓

4-H Explore
Project Book Evaluation - Water

1. Please read the statement in the left column of the table below. Bubble in the circles that describe your level of understanding **BEFORE** attending this program. In the section on the far right, bubble in the circles that describe your level of understanding **AFTER** attending this program. You will have two bubbles per row.

LEVEL OF UNDERSTANDING: 1 = Poor, 2 = Average, 3 = Good, 4 = Excellent	BEFORE				AFTER			
As a result of participating in the Water project lessons and activities…	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
I understand the challenges we face in having a safe and reliable source of drinking water.	○	○	○	○	○	○	○	○
I understand the basic methods to treat water so it is safe to drink.	○	○	○	○	○	○	○	○
I understand how electricity is used to filter out water contaminants.	○	○	○	○	○	○	○	○
I understand how to build my own electro-coagulator.	○	○	○	○	○	○	○	○
I understand how to improve the effectiveness of an electro-coagulation system.	○	○	○	○	○	○	○	○
I understand how to design and conduct an electro-coagulation research project.	○	○	○	○	○	○	○	○

2. For each statement below, fill in the bubble that best describes you.

INTENTIONS TO ADOPT: **As a result of participating in the Water Project lessons and activities…**	**Yes**	**No**	**Unsure**
I can discuss with others the importance of water in our daily lives.	○	○	○
I can identify the major sources of water pollution and help to prevent contamination.	○	○	○
I will use what I have learned to be a better steward of water.	○	○	○
I plan to become more informed about water in my community.	○	○	○
I plan to apply what I have learned about water in educating my peers.	○	○	○
I plan to learn more about the importance of water to my local economy.	○	○	○

3. For each statement below, fill in the bubble that best describes your level of agreement with the following statements.

BEHAVIOR CHANGES: **As a result of participating in the Water Project lessons and activities…**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
I am more comfortable working in a team.	○	○	○	○
I am more willing to listen to others.	○	○	○	○
I am more comfortable speaking with others.	○	○	○	○
I am more confident in my abilities as a leader.	○	○	○	○

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Please continue on the back.

MARKING INSTRUCTIONS

CORRECT: ● INCORRECT: ☑ ☒ ◒ ◓

3. What is the most significant thing you learned in the Water project?

Please tell us about yourself.

Gender: ○ Female ○ Male

I consider myself to be: ○ African American ○ Asian American ○ Native American ○ White ○ Other

I consider myself to be: ○ Hispanic ○ Non-Hispanic

Grade: ○ 3rd ○ 5th ○ 7th ○ 9th ○ 11th ○ 4th ○ 6th ○ 8th ○ 10th ○ 12th

Most of the time, you live . . .

- ○ Farm or ranch
- ○ Town less than 10,000
- ○ City between 10,000 - 50,000
- ○ Suburb of city between 50,000
- ○ Central city/urban center with more than 50,000

Please provide any additional comments below.

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Thank you!