FUTURE U.

Bioremediation

Objectives

Students will be able to:

- **Experiment** with sugar and yeast in order to **investigate** the concept of bioremediation.
- **Explain** the benefits of bioremediation after **reading** about current bioremediation efforts.
- **Create** a small compost site and **consider** the effects of composting on a larger scale.
- **Synthesize** what they have learned in order to **develop** a recommendation on how bioremediation could be used in their own community.

Overview

In this lesson, students will be given a scenario in which their local government is calling on junior environmental engineers to learn more about how nature can be leveraged to solve problems. To kick off their investigation, students will be introduced to the term *bioremediation*, and they will work as a class to deconstruct the word's meaning. They will then begin to explore this concept through a sugar spill experiment in which sugar and yeast demonstrate how organisms can be used to clean up contamination. Next, students will work in groups to read about actual cases of bioremediation, and they will share what they have learned with each other. The class will then be introduced to a community-friendly version of bioremediation: composting! As they build their own mini-compost site using two-liter bottles, students will consider how composting is a form of bioremediation and how it could help their community. Finally, students will work in pairs to create a brief report to send back to their local government. The report will summarize bioremediation and articulate specific ways it could benefit their community.

This lesson focuses on

Engineering Design Process

- Designing Solutions
- Creating or Prototyping
- Communicating Results

21st Century Skills

- Communication
- Collaboration
- Critical thinking

Timing

Three 60-minute class periods

Materials

DAY 1

- Devices with Internet access, at least enough for half the class
- Oil Contamination Handout (2 pages), enough for one-quarter of the class
- Oil Contamination Experiment:
    - For groups of four students:
        - 5 test tubes
        - 3 teaspoons of sugar (in a small cup, bag, or bowl)
        - 3 teaspoons of yeast (in a small cup, bag, or bowl)
        - A cup of room temperature water
        - 5 balloons
        - 1/3 teaspoon (measuring spoon)
    - For the class to share:
        - Access to cold water and hot water
        - Lemon juice, one cup
        - Salt, one cup
        - Vinegar, one cup
        - Painter's tape or masking tape
- Bioremediation Research handout, one per student

DAY 2

- How Composting Works article (first two sections only, until the *Making Compost* section), one per student
- Compost Site handout, enough for half the class
- Compost Starter Materials:
    - Enough two-liter bottles for one-third of the class. Prepare these in advance:
        - Cut off about three-fourths of the top of each bottle, leaving a small section still attached. This attached section will act like a hinge, as seen in the image here.
        - Use a nail to punch at least six different small holes in each bottle (all over)
    - For the class to share:
        - Spray bottle filled with water, at least two
        - Dirt, one container (at least 10 cups)
        - Measuring cups or small shovels (to measure the dirt)
        - Newspaper, one
        - Old leaves, one container (at least 10 handfuls)

  - Painter's tape
  - Optional: Used coffee grounds
- Device with the ability to project and play video, one for the instructor
- NowThis video, to project
- Bioremediation Summary Report, one per student

Have you ever wondered…

What is bioremediation?

Bioremediation is a process in which living organisms are used to neutralize contamination and help return the environment back to its original condition. Bioremediation does *not* use chemicals. Instead, it relies on natural organisms such as bacteria, fungi, protists, and other microorganisms to break down the contamination into less toxic or nontoxic substances.[1] According to Cornell University: "Bioremediation of a contaminated site typically works in one of two ways. [In the first instance,] …ways are found to enhance the growth of whatever pollution-eating microbes might already be living at the contaminated site. In the second, less common case, specialized microbes are added to degrade the contaminants." While bioremediation is a safe cleanup strategy for some types of pollution, it's also important to keep in mind that it will not work for everything. In situations where there is a high level of chemicals that are toxic to most microorganisms, bioremediation may not be effective.[2]

What are the benefits of bioremediation?

Bioremediation has been used to successfully clean up pollutants such as gasoline, crude oil, pesticides, chlorinated cleaning supplies, sewage, and more. As stated above, bioremediation does not use chemicals, which means that it is more eco-friendly and more sustainable than other types of industrial cleanups. Bioremediation also avoids incineration and landfill dumping—which continues to help protect the environment. In addition, the potential for in-situ bioremediation also enables the contamination to be treated at its source so that large amounts of water, soil, etc., don't have to be moved for treatment. This means that the cleanup process is not only less disruptive but also tends to be less expensive.[1]

Make Connections

How does this connect to students?

Because today's innovations are seemingly limitless, it can be our instinct to automatically think about technological solutions when we seek answers to environmental problems. However, we should not overlook the fact that nature can often provide its own solutions.

For this reason, it's important for students to be aware of the natural processes that can be used to our benefit as we seek to clean up our planet and be environmentally friendly. When we use natural organisms to manage cleanups, we can prevent further pollution and reduce costs. Furthermore, there are certain bioremediation efforts—like composting—that don't require an actual "problem" in order to be implemented! Instead, composting can be used as a proactive way to reduce both our waste and our greenhouse gas emissions.

How does this connect to careers?

Environmental Scientist: Environmental scientists work to protect the environment and human health. Those that work in the field of bioremediation will also apply their background of chemistry, biology, and physics as they work with other scientists and engineers to determine the safest and most effective ways to clean up contamination sites.

Biochemist: Biochemists study the chemical composition of living things, as well as their biological processes like cell development and growth. Those that work in bioremediation will study the effects of pollutants on the environment as well as the organisms that are used in the cleanup process.

Compliance Officer: Compliance officers may be employed at a local, state, or federal level. Those who work in bioremediation ensure that all bioremediation projects are in compliance with environmental laws and that workers adhere to safety regulations.[3]

How does this connect to our world?

The need for bioremediation exists around the world. According to a BBC article that students will read in this lesson, "The U.S. National Oceanic and Atmospheric Administration says there were 137 oil spills in the country in 2018. …Canada's National Energy Board says its pipelines spilled 7,945 tons of oil on average per year between 2011 and 2014, while the European Space Agency estimates that 4.5 million tons of oil spill into the ocean every year." By working with local plants and organisms, the process of bioremediation can be used (and is being used) to break down this oil.

Bioremediation has also proven effective for cleaning up contaminants in soil. Farmers in Ecuador's Amazon Rainforest, for example, are currently using bioremediation to clean up crude oil that has been there for decades. And, closer to home, companies like Boeing are leading remediation efforts around the United States.

In addition, composting—another component of bioremediation—has important global potential. When food and organic waste decomposes in landfills,

it produces methane, which is a greenhouse gas more powerful than carbon dioxide. Communities around the world are therefore starting to invest more in composting systems. Copenhagen, one of the world's greenest cities, stopped sending organic waste to landfills in the 1990s, and several other European countries send less than three percent of their waste to landfills![5] If more countries around the world can follow suit, our planet will reap the benefits.

Sources:

[1] "Bioremediation." The Environmental Literacy Council. enviroliteracy.org/environment-society/waste-management/bioremediation/.

[2] "Bioremediation." Environmental Inquiry, Cornell University and Penn State University. ei.cornell.edu/biodeg/bioremed/.

[3] "Careers in Environmental Remediation." U.S. Bureau of Labor Statistics. bls.gov/green/environmental_remediation/remediation.htm.

[4] "How to Clear the Oil Spills of the Amazon Rainforest." BBC. bbc.com/future/article/20200316-cleaning-up-the-oil-spills-of-the-amazon-rainforest.

[5] "The Global Progress of Composting Food Waste." EcoWatch. ecowatch.com/the-global-progress-of-composting-food-waste-1881788957.html.

Blueprint for Discovery

Instructor Prep: This lesson requires a variety of materials. Before each class session begins, take time to prepare and organize the materials that will be needed.

DAY 1

1. Begin class by asking students to demonstrate, by a show of hands, if they believe that all citizens, no matter their age, have the power to make a difference when it comes to protecting our environment.
2. Go on to explain that students are about to pretend that their local government is calling on junior environmental engineers and scientists to help their community tackle important environmental issues. The students' first challenge is to learn more about how nature can be leveraged, or used, to solve problems.
3. Write the word *bioremediation* on the board, and ask students to break the word apart and think-pair-share* the term's meaning.

   *In a think-pair-share, students think about the question independently, discuss their answers with a partner, and then share their thoughts with the larger class.

4. Once several students share what they believe bioremediation means based on its word parts, be sure the class understands that:

    - The prefix bio means life or living things.
    - *Mediation* refers to stopping or solving a problem.
    - The prefix *re* means again or *backwards.*

    Therefore, bioremediation refers to a process in which living organisms are used to return a contaminated environment back to its original condition.

5. Explain that students are about to participate in an experiment that will help them understand how this works. Prepare the class by completing the following:

    - Divide students into groups of about four, and distribute an Oil Contamination handout to each group.
    - Explain that students are about to explore how to clean up an oil spill. In this experiment, sugar will represent the oil. Yeast, which is a microorganism in the fungi kingdom, will represent the living organism.
    - Read through the handout's directions together.

      Tip: Depending on the needs of the class, it may be helpful to demonstrate Step 4, so students fully understand what this will look like.
    - Then ask students: Why are we placing balloons over the test tubes? Ensure students understand that when the sugar (or oil) is consumed by the yeast (or living organism), carbon dioxide is released. Therefore, the more carbon dioxide that is released and the bigger the balloon becomes, the better the cleanup is working.
    - Explain that the goal of this experiment is to see what connections students can make between their results and real-life bioremediation efforts.
    - Finally, pass out the group materials and also show the class where they can find the hot water, cold water, vinegar, lemon juice, and salt.

6. When the experiment is complete, bring the class back together to discuss the results. Ask:

    - What variables seemed to best help the yeast break down the sugar?
    - What variables didn't seem to help the yeast break down the sugar?
    - How is this related to bioremediation?
    - What could this teach us about cleaning up spills and fixing problems in our own community?

7. Now that students have a general understanding of bioremediation, explain that they are going to read more about how it is being used around the world. To prepare students for the next portion of the class session:

    - Distribute one Bioremediation Research handout to each student.
    - Divide the class into pairs.
    - Assign each pair a letter: A, B, or C. Try to ensure that roughly one-third of pairs are assigned each letter.
    - Review Part One of the handout's instructions. Explain that students will have about twenty minutes to read their article(s) and jot answers to the questions provided. The class will then regroup and share what they have learned.
    - Encourage students to get to work!

8. Once about 20 minutes have passed and/or most groups are wrapping up, bring the class back together and lead them through the following discussion questions:
    - Who can share a quick summary of the bioremediation efforts you read about? (Begin with Group A, then move to Group B, and then Group C.)
    - Based on what you have read, what are the benefits of bioremediation? How could it help ecosystems and communities?
9. Wrap up by telling the class that next period, they will further explore how bioremediation could help their own community and local ecosystems.

DAY 2

1. Welcome students back to Day 2, and thank them for helping their community learn more about how to use nature to tackle environmental challenges.
2. Tell the students that today is going to begin with another vocabulary challenge. On the board, write *in-situ bioremediation* and *ex-situ bioremediation*. Explain that these are the two main classes or categories of bioremediation, and instruct pairs to discuss what they could mean.
3. Once students have shared their thoughts, explain that:
    - In-situ bioremediation occurs when the contaminated area (soil or water, for instance) is left in place and treated where it is. This helps makes sure that the contamination isn't spread during transport.
    - Ex-situ bioremediation occurs when the contaminated waste is removed and brought to a treatment area. This may allow the bioremediation process to be better controlled.
4. Explain that there is one type of ex-situ bioremediation that *everyone* can participate in: Composting! By a show of hands, ask students to demonstrate if they have heard of the term *composting* before or if they already compost at home.
5. Distribute the first two sections of the *How Composting Works* article to each student. Give student pairs a few minutes to read the article together and underline the details that explain how composting is related to bioremediation.
6. Then regroup and ask students to share what they have learned. Be sure students understand that composting is an example of ex-situ bioremediation because organic waste is removed from the site (from your plates, your trash, etc.) and added to soil. When exposed to oxygen and water, microorganisms in the soil will eat the waste and break it down. Explain that when this is done correctly, composting can result in a rich, healthy, and natural fertilizer that will help plants grow!
7. Tell students that today they will get a taste of what composting consists of by building their own mini-composting sites. Divide the class into groups of about four or five students (or enough groups so that each group can have a bottle). Then perform the following steps as you prepare students to get started:
    - Distribute a couple of *Compost Site* handouts to each group, and read through the directions together.
    - Then give each group one bottle and explain that the top of each bottle has been cut so students can add/remove compost and water. The small holes are there to allow air to circulate throughout.

- Show students where they can find the rest of the Compost Starter materials.
- If you brought in the optional coffee grounds, tell the class now and explain that they should add these after Step 3.
- Show students a sunny location where they can place their compost starters when they are complete.

8. Then instruct students to carefully follow each of the handout's steps and begin!
9. Bring the class back together once their compost starters are complete. Ensure students have read through the handout's "Next Steps" section so they know how to continue to care for their compost site.
10. Then acknowledge that these compost bins are miniature examples of composting's full potential. Ask students to consider and share: How could a larger scale of composting benefit your community?
11. Once several students have shared, play this NowThis video to give them an idea of how one city—New York City—composts on a large scale. As they watch, encourage students to continue to think about how composting could benefit their own community.
12. Conclude the class session by passing out one Bioremediation Summary Report to each student. Explain that students will now apply what they have learned to provide an individual report back to their local government that details how their community could leverage nature to tackle environmental issues.

    Review the handout's directions, answer questions as needed, and then encourage students to begin their reports.
13. When there are about five minutes left in class, bring the class back together and ask students to share some of their recommendations.
14. Finally, thank the class for their experimentation, research, and analysis. Encourage them to consider the many environmental careers—from environmental scientists and engineers to biochemists, biophysicists, conservationists, hydrologists, and more—as they begin to think about their own futures. Then wrap up by reminding them of the importance of doing their part to protect the environment today and every day.

Extend

Over the next month, students can continue to tend to their mini-composting sites. Once they have an understanding of the correct combination of air, water, soil, brown matter, and green matter that composting requires, they can try to expand their composting efforts into a larger bin or outdoor area at home or at school!

National Standards

Next Generation Science Standards

Engineering Design

- MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Earth and Human Activity:

- MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- Disciplinary Core Idea ESS3.C: Human Impacts on Earth Systems: Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3) (MS-ESS3-4)

Common Core English Language Arts Standards

Reading:

- CCRA.R.1: Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

Writing:

- CCRA.W.2: Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

Speaking and Listening:

- CCRA.SL.1: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.

Oil Contamination Handout, page 1 of 2

Scenario: Stormwater runoff has resulted in used motor oil in a lake in your community, and the lake's ecosystems are beginning to suffer. Follow the steps below to investigate how bioremediation may be able to help clean up this mess!

1. Use the painter's tape to label your test tubes: Control, #1, #2, #3, and #4.
2. Sugar will represent the motor oil in this experiment. Place 1/3 teaspoon of sugar in each test tube.
3. Now create your control, which is the test tube that you will compare the other test tubes to. In this investigation, the control test tube will contain only sugar and water—so you can see how much CO2 this solution emits. To create your control:
    - Fill your control test tube about halfway full with room temperature water.
    - Place your thumb over the top of the test tube, and shake it to mix the sugar and water together.
    - Place a balloon over the top of the test tube.
    - Place it aside.
4. Now you will test to see which variables (if any) help break down the sugar. Begin by filling Test Tube #1 halfway with room temperature water. Place your thumb over the top, and shake it to help dissolve the sugar. Then drop 1/3 teaspoon of yeast into the test tube, and quickly cover the test tube with a balloon. Now place your thumb over the balloon and again gently shake the test tube to mix the solution. Place it aside.
5. Repeat Step 4 with Test Tube #2, this time replacing the room temperature water with cold water.
6. Repeat Step 4 with Test Tube #3, this time replacing the room temperature water with warm water.
7. Repeat Step 4 with Test Tube #4, this time adding a substance of your choice (lemon juice, salt, or vinegar) to the sugar and water solution before adding the yeast.
8. Now sit back and observe your results. It may take a few minutes before you notice any changes. As you do, record your observations in the *Bioremediation Observations Chart*.
9. Remember that carbon dioxide is produced as the living organism (yeast) consumes the oil (sugar). Therefore, the bigger the balloon, the more successful the cleanup. Based on this knowledge, discuss and jot:
    - Did the yeast (living organism) break down the sugar (oil)?

- Did anything seem to help the yeast (living organism) break down the sugar (oil) more effectively?

- Was anything in your experiment ineffective in helping the yeast (living organism) break down the sugar (oil)?

- How can you connect your results to bioremediation and cleanup efforts in the real world?

Bioremediation Observations Chart

Test Tube	Water Temperature	Sugar	Yeast	Additional Ingredient	Results: Qualitative Observations
Control	Room temperature	1/3 teaspoon	none	----------	
1	Room temperature	1/3 teaspoon	1/3 teaspoon	----------	
2	Cold	1/3 teaspoon	1/3 teaspoon	----------	
3	Warm	1/3 teaspoon	1/3 teaspoon	----------	
4	Room temperature	1/3 teaspoon	1/3 teaspoon		

Bioremediation Research

Group A:
Amazon Cleanup: tinyurl.com/tqosvvl

Group B:
Iraq Pollution Cleanup: tinyurl.com/yxxuxtbn
Soil Contamination in Germany: tinyurl.com/u7culo2

Group C:
Boeing in Action:

- tinyurl.com/vmppefq
- tinyurl.com/sf6y2zo

Instructions: Read your assigned article(s) with your partner and jot answers to the following questions.

1. How is bioremediation being used by Boeing?

2. How is bioremediation helping this location or community?

3. Are there any considerations that should be kept in mind or any circumstances where bioremediation may not be successful? (If your article does not address this, you may leave this blank.)

Compost Starter

Instructions: Follow these directions to build your compost starter in your empty bottle.

1. Add a cup of dirt to the bottom of your bottle.
2. Shred newspaper (tearing it is fine!) until you have about a handful. Add this to the top of the dirt.
3. Also add a handful of dry leaves.
4. Use a spray bottle to spray the inside of the bottle until these contents are moist but not soggy.
5. Position the top back on the bottle. If needed, add a piece of tape to keep it in place.
6. Place your compost bottle in the sun.
7. Read through the "Next Steps" below so you know how add compost and take care of your compost site in the future.

Next steps:

1. **Today or tomorrow:** After lunch, add any vegetable or fruit scraps that you have left over. If your group doesn't have any scraps, try to bring in some leftover vegetable scraps, egg shells, or used coffee grounds from home. Once you have added this organic waste, be sure to replace the bottle's top, and let it sit in the sun!
2. **Every day:**
    - Check on your compost's moisture levels. If it looks very wet or slimy, remove the bottle's top and let the compost dry a bit. Or, if the contents look very dry, add a couple sprays from the spray bottle.
    - Roll the bottle around or use a spoon to mix the contents and help them breathe.
3. As your organic waste begins to break down, you can slowly add more scraps and dirt. However, you must do this slowly. Give everything time to break down first!
4. In about a month, you should be able to remove your compost, add it to a pot or soil, and use it as fertilizer to help a plant grow.

Bioremediation Summary Report

Create a brief report for your local government that:

- Summarizes the concept of bioremediation.
- Explains specific ways that bioremediation could benefit your local community and its ecosystems. You may consider problems that already exist, as well as problems that could occur in the future.
- Provides a recommendation on whether your local government should leverage (or use) nature to solve environmental problems and why.