Composting – Out of Sight Not Out of Mind

Objectives

- To compare the degradability of various utensils
- To determine optimum conditions for biodegradation

Skill Level: Middle school and High school	**Prep time:** 10 minutes **Class time:** Several club meetings/ class periods separated by a month or more.

Materials (Per Group)

- Trowel
- Trash items
    - Several fork handle pieces (1/2 inch long) from the Fork it over – Design a Biodegradable Utensil activity
    - Standard plastic utensil handles (cut into ½ inch pieces)
    - Commercial biodegradable utensil handles (cut into ½ inch pieces)
    - 1 paper plate cut into ½ in squares
    - 2 Lettuce leaves cut into ½ in squares
- 3 2-liter bottle
- 10 cups of soil (Garden soil works best; avoid using potting soil because it does not have all of the organisms and bacteria that help with decomposition.)
- 3 cup water
- 2 pairs of rubber/latex gloves
- 2 spoons/popsicle sticks
- Measuring cups (1 cup, 1/2 cup, 1⁄4 cup)

Next Generation Science Standards

Disciplinary Core Idea:

PS1.A: Matter and Its Interactions
ESS2.A: Earth Materials and Systems

Performance Expectations:

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Practices	Crosscutting Concepts
☐ Asking questions / defining problems	☐ Patterns
☐ Developing / using models	☐ Cause and effect: Mechanism / explanation
☒ Planning / carrying out investigations	☐ Scale, proportion, and quantity
☒ Analyzing / interpreting data	☐ Systems and system models
☐ Math / computational thinking	☒ Energy / matter: Flows, cycles, conservation
☐ Constructing explanations / design solutions	☐ Structure and function
☐ Engaging in argument from evidence	☒ Stability and change
☐ Obtaining / evaluate / communicate	

Background Information

Plastics play an important role in our daily lives. On average, Americans collectively use 2,500,000 plastic bottles every hour, but few of these bottles are recycled or reused. Many of the plastic bottles that we use today are not biodegradable. Biodegradable means that a certain material is capable of being decomposed, or broken down. Plastics are also used in schools, hospitals, homes, grocery stores, restaurants, businesses, research labs, and many other places. Just look around for a minute and you'll see how many things are made of plastic!

Plastics were used all the way back to Roman times with the use of natural resins such as amber and shellac. Native Americans even used plastics to make ladles and utensils out of natural materials. Commercialization of bioplastics started to happen in the 1800s when John Wesley Hyatt Jr. developed an alternative for ivory billiard balls. His products were later found to be flammable and not a successful alternative. In the 1920s Henry Ford used soybeans to manufacture automobiles. Soybeans were used in a number of parts like steering wheels, trim, and dashboard panels. Today, in the United States alone there are over 20,000 facilities that employ over 1.5 million workers and ship over $300 billion in plastic products each year. Unfortunately, most of this plastic is not biodegradable.

Standard plastics cause many problems in the environment. Some types of standard plastics degrade faster than others, but depending on the type of plastic, it may never break down. Much of it goes to landfills, but it can also end up on the side of the road, in waterways, and different places in our environment. This is becoming a huge problem for our wildlife, as it is very detrimental and can destroy habitats for us and other organisms.

Scientists are exploring ways to make plastics better for the environment by making them able to disintegrate naturally. One way of doing this is creating a plastic that biodegrades rapidly. Microbes are able to digest materials if they can break the bonds between the elements. Unfortunately, petroleum-based plastics are bonded using a carbon-carbon bond, something the microbes have not evolved to break. Natural compounds contain peptide bonds (between nitrogen and carbon) and carbon – oxygen bonds that microbes are very capable of breaking. When making biodegradable plastics that are microbe friendly, the trade-off is that the plastic may not be as strong. This may not be a big problem depending on the product. If a car were made with biodegradable parts, it might not last very long. When it comes to disposable utensils, like forks and knives, it is possible to make products that are strong enough to be useful, but still be biodegradable.

Figure 1. Biodegradation of a plastic bottle. Ref.

Bioplastic can be categorized into three different types: Degradable, biodegradable, and compostable. The difference between the three is how long it takes for them to break down. Degradable plastic is just something that breaks down into smaller plastic pieces through a process called oxo-degradation. A chemical is added to standard plastic that breaks down in the presence of oxygen. After the plastic is thrown away, oxygen begins to break down the additive. However, the plastic gets to a point where it is just really small but cannot break down anymore; even microorganisms cannot break it down. This is the difference between degradable and biodegradable plastics. Microorganisms can break down biodegradable plastics into compounds that can be used for plant and animal nutrition through a process of either hydro-degradation or photo-degradation. Hydro-degradation requires water to break down the plastic for microbes and photo-degradation required sunlight. First, microbes break down the carbon-nitrogen or carbon-oxygen bonds in the chains of the polymer so the materials can actually participate in the creation of other organic molecules. Therefore, the bioplastic is broken down and participates in the carbon cycle. Compostable products are a little more vague. By definition compostable products degrade in a reasonable time in a compost pile. For example, 60% of the material has to degrade in 180 days.

Despite the type of degradation that occurs, it is valuable to have products that can become part of the natural carbon cycle.

The challenge is to find ways to eliminate plastic forks from the waste stream that do not degrade. In this activity students will play the role of a chemical engineer to design a bioplastic material that could be used for biodegradable utensils. The challenge is to use this knowledge create a biodegradable plastic that is still capable of having tensile strength. The handle of a fork experiences high force when used to cut food. This activity focuses on developing a material that would be best for this use. Students need to remember that the plastics they develop in the lab may not have the strength that a commercial material would have. On the other hand, they should keep good notes because a college student developed a formula for a bioplastic that was purchased by an industrial company for $100,000. They might stumble upon a formula that works better than anything on the market.

Engage

Students should be interested in seeing how exactly their forks degrade in comparison to other materials. In previous activities students have learned about the various types of degradation out there based upon the various plastic materials utensils can be made out of. This can be compared to other materials that we know degrade rapidly. With this activity students can manipulate real world variables, like rainwater. Without the ability to degrade, most items would sit in our landfills forever.

Explore

Experiment Questions:

- What material do you predict to degrade the fastest and why?
- How soon do you expect to see results for each material?
- How do microorganisms play a role in each material?
- How can you tell if an item is degrading?

Procedure:

1) Cut off the bottom of the 2-liter bottle and use it as a stand.
2) Label the bottles: Control, low-oxygen, high-oxygen
3) Label each trash type so they can be identified later
4) For control landfill, fill the bottle with 3 cups of soil and place the trash on top of the soil.
5) For two remaining landfills fill the bottle with 2 cups of soil and place samples of each trash

type on the soil. Add 1 cup of soil to cover the trash.

6) Place the landfills in a location where they can be exposed to the sun and any smell will not be a problem.
7) Have students predict which material will degrade first and why
8) Sprinkle ½ cup of water on top the soil weekly to simulate rain
9) Observe the landfills weekly to determine how quickly the materials degrade. For the high oxygen landfill, scrape back the top layer of soil to observe the degradation in process. Do not disturb the control or low oxygen landfills.
10) At the end of the experiment (after materials have started to degrade in the high oxygen landfill) dig up the trash in the low oxygen landfill. Record results.

Explain

- Which materials degraded first? Which did not degrade? Explain why you think this is the case.
- Did materials degrade in the control landfill? What do you think the affect of soil is on degradation?
- Can you see differences in degradation between the high and low oxygen landfill? How do you think this would impact the design of a landfill?
- Do you think water improved the degradation process? How would this impact the design of a landfill?

Elaborate

- Find data for degradation of materials in a commercial landfill. How does this compare to your landfill? Why do you think they are different?
- Design a procedure to optimize a landfill. How will the design control various substances such as water, soil, sunlight, and oxygen?
- Visit a local landfill in your area. Is this landfill, optimized for best degradation? Why or why not.

Resources

Additional Resources:

- Landfill Science
- Landfill Design
- Do biodegradable items really break down?

Resources Used:

- Teach Engineering