MACGILLIVRAY FREEMAN'S

DREAM BIG

ENGINEERING OUR WORLD

CHEMISTRY:

MAKING AN IMPACT ON HABITAT

Grade level: High school chemistry or physical science

Lesson length: 3.25 hours (can be broken down into multiple class periods)

Industrialization has changed our lives for the better in countless ways, but it has done our planet no favors. Manufacturing has taken a toll on our planet's environmental health. The byproducts of production may be especially harmful to plant and animal life if they are released directly into the environment. Engineers are challenged to create ways to allow for the manufacture of useful products while maintaining, or improving, the health of the environment. Students experience one way engineers are preserving environmental health when they are tasked with creating a way to neutralize the acidic byproduct of a new factory.

In the Film

In the film *Dream Big*, teams of engineers compete to create the best underwater robot. Many teams show up with highly refined robots, custom-fabricated metalwork, and laser measurement devices. The team that wins, however, is a high school group using cheap, inexpensive materials like PVC pipe and tampons. Engineers know that sometimes, the best solutions to problems aren't the most expensive or complex. The best solutions are those that limit the need for nonrenewable resources and take advantage of systems we already have in place. For this reason, chemical engineers experiment with using the chemicals left over from everyday human activities to solve problems like energy production and pollution reduction.

NGSS Disciplinary Core Ideas

HS-PS1-6 Matter and Its Interactions

Refine the design of a chemical system by specifying a change in conditions that would increase the effectiveness at creating product equilibrium.

NGSS Engineering Practices

HS-ETS1.A Defining and Delimiting Engineering Problems

Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

HS-ETS1.B Developing Possible Solutions

When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

Key Words/Vocabulary

Acid: A compound that forms H+ ions when dissolved in water.

Base: A compound that form OH- ions when dissolved in water.

Effluent: Wastewater, treated or untreated, that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.

pH: The measurement of hydrogen ion concentration within a solution.

Indicator: A chemical substance used to determine the pH of a liquid; usually, a chemical that will turn colors as the concentration of H+ ions varies.

Solution: A mixture where one substance is dissolved within another.

Materials

Per group:

- ☐ 1 chemistry testing plate or set of small test tubes
- ☐ Set of plastic pipettes or eyedroppers
- ☐ pH test strips
- ☐ Graph paper and pencils
- ☐ Alkaline vegetables: avocados, broccoli, celery, cucumber, kale, spinach (blend each with water to create a solution)
- ☐ Ground bivalve shells (seashells or clam/mussel/oyster shells from restaurant waste)
- ☐ Tea leaves
- ☐ Mortar and pestle
- ☐ Blender
- ☐ 0.1M concentration of hydrochloric acid (HCl), or lemon juice if HCl is unavailable
- ☐ Glassware
- ☐ Safety wear

Per student:

- ☐ Engineering a Neutralizer Sheet

Teacher Prep Notes

This engineering challenge requires students to test solutions on a 0.1M molar concentration of hydrochloric acid (HCl). If you do not have HCl on hand, lemon juice serves as a good alternative.

If you are preparing the solutions used in this activity the night before, blend 1 cup of a vegetable type with ½ cup of water. Prepare tea leaves by blending ¼ cup of tea leaves with ¾ cup of water. Strain out large particles of each solution before extracting your 2 mL solution.

Make sure that students understand the nature of acids and bases. They will need to practice balancing acid-base reaction equations.

Prepare to help students understand the difference between strong and weak bases in terms of the amount of H+ atoms they produce when dissolved in water.

Be prepared to teach students about neutralization processes and techniques.

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - **a.** What are some ways that engineers use unconventional or recycled materials in their designs?
   - **b.** In what ways are engineers working to lessen their impact on the environment?
2. Debrief as a whole class after viewing the film. Allow students to verbally reflect on the guiding questions you gave them.
3. Introduce the design challenge. Students are going to do some chemical engineering. To set context for the challenge, explain that the growth of an industrialized society has changed our lives and our planet. People have access to better medicines, protective homes, faster communication, and many other transformative technologies. The manufacturing of these technologies, however, can take a toll on our planet's environmental health. The byproducts of their production may be toxic and harmful to human, plant, and animal life if released directly into the environment. Licensed professional engineers, P.E.s, are charged with preserving the essentials that protect the health, safety, and welfare of the public. Licensure requirements vary by discipline. Chemical engineers work to create ways to solve the problem of industrial effluents. Tell students that today they are tasked with the same challenge: to create an environmentally friendly way to neutralize the acidic byproduct of a factory's production. For this activity, they are to imagine that the factory owners know that many vegetables are naturally alkaline. Seashells, which can be an unwanted byproduct of seafood processing, are also alkaline. Could the factory use such products to neutralize the acidic byproduct in an environmentally sustainable way?

Research and Gather Information:

60 minutes

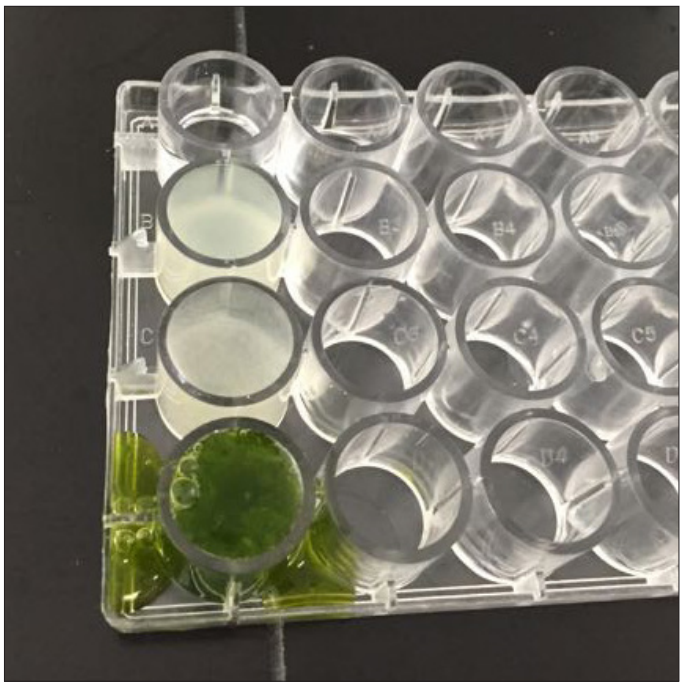
1. Have students research the different causes of toxic discharges into water systems.
2. Look at the Engineering a Neutralizer worksheet with students and point out where to take notes during this research phase of the activity. Teach students about the nature of acids and bases and practice with balancing acid-base reaction equations. Help students understand the difference between strong and weak bases in terms of the amount of H+ ions they produce when dissolved in water.
3. Explain neutralization processes and techniques.
4. Have students investigate the effect of solutions made from food waste on acidic runoff:
   - **a.** Have students fill pH testing wells with 2 mL of 0.1M HCl to represent acidic byproduct. Review how this acid is similar to and different from the acid in mine drainage.
   - **b.** Give students a variety of naturally alkaline foods that are listed in the Materials section. (If you are preparing the solutions the night before, blend 1 cup of each vegetable with ½ cup of water. Tea leaves should be prepared by blending ¼ cup of tea leaves to ¾ cup of water. Be sure to strain out large particles of each solution before extracting your 2 mL solution. If you are having students create their own solutions, have them decide the ratio of liquid to solid they will use and record it on their Engineering a Neutralizer sheet.)
   - **c.** Have students add 2 mL of each alkaline solution to the “acid byproduct” and test the resulting pH. They should complete the table in their worksheet and then discuss results with the class.and what similar things we could use to collect trash from a river.

Plan a Solution:

30 minutes

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge and writing them down in the Plan section of the Engineering a Neutralizer worksheet.

Place students in small groups. Using what they have learned, each group of students must create a solution using the natural materials they tested during research that they believe will be capable of neutralizing 25 mL of the acidic byproduct solution. Students must research the chemicals present in each of the materials they chose and write a chemical equation theorizing the acid/base interactions within their solution and the acidic byproduct. Tell students to complete the Plan section of the Engineering a Neutralizer Sheet.



Make It: 30 minutes

When they are ready, students should create their solution. As students are mixing, visit each group, asking questions about what volume of their solution they think will be needed to achieve a neutral pH of 7 in the water system, and the molecular chemistry behind how their solution will work.

Test: 45 minutes

Instruct students to combine the solution they developed with 5 mL of the 0.1M HCl. (Students use the volume of solution they predicted would neutralize the byproduct in the previous step.) Ask them to record the pH range. They should do the same with the following amounts of the acidic solution:

10 mL	15 mL	30 mL
20 mL	25 mL	

At each interval, record the pH on a simple data table. Have students graph the information and create a line of best fit for the data. Using this data and graph, they should predict the volume of neutralizer necessary to bring 1,000 liters of acidic waste to a neutral pH.

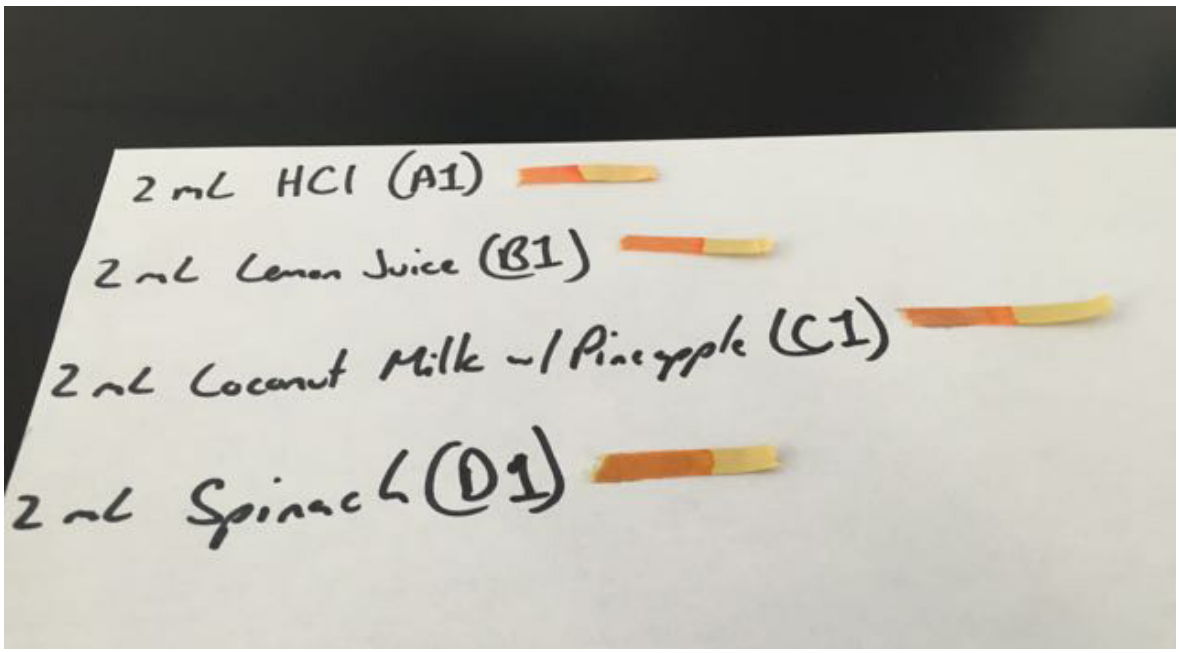
Evaluate: 15 minutes

Have students assess their plan using the rubric found on the Engineering a Neutralizer Sheet.

Engineers must often decide between solutions that may not be perfect. For example, using seashells to neutralize effluent may be very practical for a seaside community with a nearby source. On the other hand, bringing seashells to an inland location may be expensive and require the use of trucks or trains that could contribute to air pollution. How should any leftover solids be disposed of? Discuss the practicalities of the “best” solution in light of your local community.

Licensed professional engineers, P.E.s, are charged with preserving the essentials that protect the health, safety, and welfare of the public. By meeting standards in education, exams, and experience, professional engineers demonstrate that they have the skills and knowledge needed to perform their jobs. As licensed professionals, they must continue to practice in a manner that is both technically competent and ethically sound. Their first responsibility is to protect the public.

How does this plan address a licensed professional engineer’s responsibility to protect the public?



Taking It Further

Learn about this engineering in the real world: Engineers are passionate about creating a better tomorrow. They are the creative forces that drive the development of ever more innovative ways to solve environmental issues that arise from our industrialized lifestyle.

In the United States, engineers are inventing ways to keep the Appalachian Mountains' river systems healthy and safe for years to come. Read and learn more about the reengineering of their pollution cleaning processes here: westech-inc.com/en-usa/industry-solutions/mineral-overview/acid-mine-drainage

The byproduct of Greek yogurt is acidic whey. Learn the challenges of dealing with a growing amount of acidic byproduct: modernfarmer.com/2013/05/whey-too-much-greek-yogurts-dark-side/

Document your students' work through our social media outlet: #dreambigfilm

Dream Big: Engineering Our World is a film and educational project produced by MacGillivray Freeman Films in partnership with the American Society of Civil Engineers and presented by Bechtel Corporation. The centerpiece of the project is a film for IMAX and other giant screen theaters that takes viewers on a journey of discovery from the world's tallest building to a bridge higher than the clouds and a solar car race across Australia. For a complete suite of *Dream Big* hands-on activities, educational videos, and other materials to support engineering education, visit discovere.org/dreambig. The *Dream Big* Educator Guide was developed by Discovery Place for the American Society of Civil Engineers.

ENGINEERING A NEUTRALIZER SHEET

Name: _____

Problem to Be Solved

Create a way to neutralize 25 mL of acidic byproduct from a factory.

Research and Gather Information

1. Fill in the blanks with acid, base, or neutral.

   a. The neutralization of a strong acid with a strong base produces a _____ solution.

   b. The neutralization of a weak acid with a strong base produces a _____ solution.

   c. The neutralization of a strong acid with a weak base produces a _____ solution.

2. Testing natural alkaline solutions: What is the pH of a mixture of 2 mL of acidic byproduct and 2 mL of each of the following solutions?

Material	**pH when added to 2 mL factory discharge**
Solution with ground sea shells	
Tea	
Solution with alkaline vegetable (insert name):	
Solution with alkaline vegetable (insert name):	

Plan

☐ The criteria of the engineering and design challenge are:

☐ The constraints of the engineering and design challenge are:

☐ Write the step-by-step directions of the solution you plan to make. Include the volume of each material and total volume of solution.

☐ Explain the chemical processes that will lead to the neutralization of your acidic solution.

Make It!

Evaluate

Use the following rubric to assess your design.

Criteria for this design challenge (Fill in each row with a description of criteria that needed to be met)	Did your design meet the criteria for the challenge?	Why or why not?
Constraints for this design challenge	**Did your design follow the constraints?**	**Why or why not?**
Marketability of this design	**Is your design marketable?**	**Why or why not?**
What is the environmental impact of your procedure? Can it be scaled up for factory use?		

DREAM BIG VIDEO SERIES

WATCH *VIRTUAL MODELING: ENGINEERING THE FUTURE*

Engineers not only create the tools that produce virtual environments, they also use the virtual world to study and build the real world. Learn how engineers are changing the worlds we imagine and live in. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.

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