Sheen-Oil-Mousse: 3 Fractions of Spilled Oil

Grade Level: 6-12
Length: 60-90 Minutes
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NGSS Standards

MS-PS1-1 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

Crosscutting Concepts

Cause & Effect Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, & Quantity In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

Stability & Change For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Overview

Oil undergoes changes in marine ecosystems.

Objectives

- Students will examine the basic characteristics of oil.
- Students will identify the three fractions of spilled oil.
- Students practice converting units, calculating area, and consider scale and proportion as they visualize how oil spreads.

>>Note: this activity is best paired with other activities that help students to analyze and interpret data about chemical reactions in more familiar substances. Petroleum and hydrocarbons are really complex substances to investigate!

Materials

- ☐ 1 Cubic Centimeter 10W-40 Motor Oil or Crude Oil
- ☐ 1 Quart Sea Water
- ☐ Electric Hand Whisk or Egg Beater, or a Glass-Jar with Lid
- ☐ 1 Large Bowl
- ☐ Eye Dropper
- ☐ Graduated Cylinder
- ☐ 2 Bowls, 6” in Diameter
- ☐ 1 Large Flat Pan or Tray
- ☐ 4 Feathers (craft of real)
- ☐ 4 Small Rocks
- ☐ 1 Oil Absorbent Pad
- ☐ Rulers
- ☐ Pens or Pencils

Related Resources

Pair With Critter Clean-Up Lesson; Oily Experiments Lesson; Oil Spill in a Pan

Websites
https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/weathering-processes-affecting-spills

Notes

Materials (continued)

- ☐ Paper
- ☐ Calculators
- ☐ State or U.S. Map with Scale
- ☐ Example or Photo of Tar Ball
- ☐ Science Notebooks

Background

When oil is spilled, it begins to change both physically and chemically. Some amount of the lighter, volatile compounds turn to gas and disperse in the air. The remainder of the toxic oil usually spreads out from the main slick as fingers of very thin, iridescent sheen on the surface of the water. This layer of sheen can be deadly to seabirds and other marine life that spend time on the surface.

As oil on the surface is agitated by wind and begins to weather, it changes. Within about two weeks it begins to form mousse: a thick, gel-like mixture of oil, air, and water. Media images of birds and other animals covered with mousse and heavy crude oil may leave the impression that this thick oil is the problem following an oil spill. This simple experiment demonstrates that even a small amount of oil in a sheen can be deadly.

The different forms an oil spill can take will determine which clean up method(s) will be most effective.

<u>Mechanical skimming</u> of oil is considered the response method least harmful to the environment, but it requires large quantities of equipment and personnel, as well as fair weather. It is a multistage process –first you need to contain the oil, then you need to recover the oil, next you need to temporarily store and transport the oil, remove the water from the oil, and finally dispose of the oil. In each stage the oil is handled, so special safety equipment and training is needed. The process is time: consuming and can bottleneck at any stage, breaking down the system. Equipment used can include skimmers, booms, suctioning devices, and buckets.

<u>Chemical dispersants</u> are used to break oil into small droplets in the upper part of the water column. They cause a chemical change to occur in the oil that allows it to disperse into the water column. This removes oil from the surface, potentially reducing impact on surface-feeding and -breathing animals. However, as the oil disperses through

the water column and sea floor, it may increase the impacts on other species. Some studies show that dispersants speed up natural dispersion, degradation, and evaporation. Other studies show that the dispersants themselves are highly toxic and also may be ineffective in cold waters. To be effective, dispersants must be applied soon after a spill, since weathered oils are hard to disperse. Mixing energy from wind and waves is also needed. Pre-approval is required from the government before dispersants can be applied on a spill.

Shoreline clean-up involves the physical removal of oil from beaches. This is the most labor and equipment intensive response method. Techniques must be chosen carefully. Removal of oiled sediments and biotic materials can sometimes create environmental problems such as beach erosion. Pressurized hot water used to wash oil off of rocks can kill intertidal invertebrates. Running heavy equipment on shorelines can sometimes do more damage than the oil. A variety of shoreline clean-up methods are available. The one(s) used depends on the beach type, location, type of oil, and the equipment and manpower available. Citizen clean-up programs after the Exxon Valdez Oil Spill involved many different shoreline clean-up techniques, such as oiled seaweed pick-up on beaches. Seaweed is a natural oil collector so the more picked up meant less oil spread back out to bays and estuaries. Pom-poms made of oil-absorbent material were also used to pick up oil, and oil-absorbent pads were used to wipe off individual rocks. A rock washing program was developed by tying rocks in special bags where they would be washed by the tidal action of the ocean. Once back in the ocean, the oil can be picked up by mechanical skimming. Bioremediation, the use of fertilizer to increase populations of oil eating bacteria, was also tried. There is some evidence that bioremediation using oil eating bacteria is more effective in warmer climates.

In-situ burning is the technique of burning the spilled oil. It creates a temporary air pollution problem that may pose a risk to people and animals exposed to the smoke. Unwanted fires can also happen, and controversy exists about this method's effectiveness and hazards. Burning works best on fresher oil. Specialized equipment and trained personnel are necessary.

Preparation

Set up this activity outside if possible, or somewhere inside where there is good ventilation. The tools and kitchen supplies used in this activity should not be used for food ever again.

Introducing the Lesson

Begin by (re)introducing these definitions of physical changes and chemical changes:

- A physical change occurs when a substance changes state or substances combine, but the result does not change the original substance(s) into a new substance(s). Some physical changes are easier to reverse than others. In a change of state, particles have less motion (freezing) or more motion (heating).

- Chemical changes occur through chemical reactions and involve the rearranging of atoms. A substance or substances change to make a new substance(s). Matter and mass are conserved, but chemical reactions are not normally easily reversible because the atoms of a substance are rearranged. There are four main signs of a chemical reaction: precipitate, gas, color change, and/ortemperature change.

Explain to students that they will be investigating how oil behaves in water and trying to determine whether a physical change has occurred and whether a chemical change has occurred. Remind students that oil is toxic; they should try not to inhale large amounts of the volatile compounds and should avoid touching the oil.

Activity

Sheen

1. Pour a layer of saltwater about one inch deep into each of the bowls. Have a student use the eyedropper to drop a single drop of motor oil onto the surface of the water in one of the bowls. Examine the sheen that forms. Look closely for evidence of a chemical change and discuss as a class whether a chemical change has taken place.

>> Educator Tip: If you are using crude oil or motor oil, some lighter, volatile components of the oil may off-gas when you do this. Students may notice the oily fumes. Gas can be a sign of a chemical reaction, but in this case the gas is noticed because crude oil contains a soup of different 'weights' of hydrocarbons. When the container is opened, the lighter gases vaporize. It is a great opportunity to discuss as a group how the signs of a chemical reaction don't necessarily mean a chemical reaction has occurred.

2. Have a different student dip two feathers into the bowl of plain saltwater as the control. Remove the feathers and place them on top of each other in a well-ventilated or sunny spot to dry. Then have someone else dip two new feathers into the bowl containing the oil sheen. Remove the feathers. Can anyone see the oil? Place the feathers on top of each other next to the control feathers to dry. Save the oiled saltwater and move on to the next steps as the feathers dry.
3. Demonstrate the way oil leaking from a tanker, pipeline, or drilling rig spreads out to form a slick on the surface of the water by pouring a layer of sea water into the large, flat tray and dropping a cubic centimeter of oil on to the water's surface.
4. Have students compute the area in centimeters of the slick that forms. Then compute the area of a slick that could be formed by a liter of oil; just multiply by 1000. The *Exxon Valdez* Oil Spill was measured in gallons. There are 3.785 liters in one gallon, so students can calculate the size of a slick formed by one gallon of oil simply by multiplying the slick formed by a liter times 3.785. Approximately 11 million gallons of oil were spilled in the *Exxon Valdez* Oil Spill, so have students multiply by11,000,000. Finally, students can convert the slick size to square centimeters; divide their answer by 929 (1 square foot = 929 square centimeters) and then divide by 27,900,000 (1 square mile = 27,900,900 square feet). Record this final number as a projection of the slick size for an 11,000,000-gallon oil spill.
5. Provide students with copies of a local or U.S. map. Have students identify the scale of the map. Calculate the scaled size of the projected slick (divide the projected slick size in square miles by the scale mile: inch or mile: centimeter). Have students color a scaled oil spill on the map. What areas would be oiled?
6. Revisit the feathers. What happened? Did both sets of feathers dry at the same rate? Are any of the feathers matted together? Discuss how even a tiny amount of oil may cause bird feathers to mat together. In this condition, feathers cannot be fluffed for warmth and birds may die of hypothermia.

Mousse

1. Take half of the oiled water from previous experiments and pour into a large bowl. Mix with an eggbeater for at least twenty minutes.

>> *Educator Tip: You can also put some oily water into a mason jar, about halfway full. Add a few additional drops of motor oil. Close the lid and have students take turns shaking the jar for the next 15-25 minutes.*

2. After twenty minutes, skim off the froth of oily mousse that forms. It should look kind of like brown frothed egg whites, or oily whipped cream. Have students measure it. Is it more or less than the amount of oil that was poured into the bowl (approximately ½ cubic centimeter of oil plus ½ drop of oil went into the bowl)? What happens to an oil slick at sea that is agitated by high winds and strong seas for two weeks or more? That is what happened to the Exxon Valdez oil in the Gulf of Alaska, and it formed mousse.
3. Discuss with students whether mousse represents a chemical reaction or simply a physical change. Look for evidence of a chemical reaction.

>> *Educator Tip: Mousse is mostly a physical change. Air and water are caught up in a web of oil, and this is called an emulsion. The actual atoms within each substance are not rearranged to create new substances; instead, tiny droplets of water and pockets of air are dispersed throughout the oil. This is what increases the volume of the oily mousse mixture. However, sometimes oxidation (see below) or other chemical changes may also occur as an emulsion forms.*

4. During the *Exxon Valdez* oil spill, thick foamy mousse blew ashore and remained in the intertidal areas. If you were able to create the oily mousse, blow and pour some of the mousse onto a few dry rocks to illustrate how it clings to the shore rather than washing back out to sea.

>> *Education Extension: Try putting some of the mousse and remaining oiled water in a clear container. Let this sit for a few days, ideally in a sunny location. Meanwhile, put pure oil into a different clear container. Let it sit for a few days, in a dark location. Check back in a few days to see if there is any evidence of oxygenation. Use sight and sense of smell to compare the two samples.*

5. Show students photos or examples of tar balls. Explain that when oil weathers over time in the present of water, sunlight, and oxygen a process calls oxygenation. This is a chemical reaction that happens when oils react with oxygen (from the air or the water). One sign of this chemical reaction is that the color of the substance may change. Sometimes oxidation breaks the oil into soluble products that dissolve into the water; other times it forms heavy tars, like the tar balls. Weathering is a complex phenomenon that includes both physical and chemical changes. Scientists who study the way oil weathers after a spill still don't understand it fully yet.

>> *Educator Tip: For more information on weathering, see https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/weathering-processes-affecting-spills*

6. Option 1: Begin a discussion or have students write about the potential effects of mousse and tar on intertidal life:

- What happens to animals such as chitons, snails, and limpets which normally crawl across the surface of the rocks looking for food? Do you think they can remain attached and move with gooey mousse covering the rocks?
- Barnacles attach themselves to rocks and reach their fragile legs out to capture food from the water. What happens to the barnacles if they are covered with mousse or tar?
- Clams and mussels filter food out of the water by pulling water into their siphons. What would happen if they were covered with mousse?
- Many shorebirds and ducks feed on barnacles, clams, and mussels. What happens to these birds if their foods are covered in mousse, or if they accidentally feed on tar balls instead of food?
- There are many kinds of crabs which live on the shore. Crabs breathe by means of gills, which are located just under the top shell. What will happen if mousse gets in their gills?
- Many people harvest chitons, snails, limpets, clams, mussels, crabs, or birds. How would people be affected by mousse or tar?

Option 2: An alternative discussion would be to introduce students to methods for cleaning up spilled oil: skimmers, adsorbent materials, burning, or dispersants. See below for information about these methods. Have students respond to the following prompts in their science notebooks or through discussion:

- Which method do you think would work best on a sheen of oil? Which methods would be most difficult to use on a sheen of oil?
- Which methods do you think would work best on oily mousse? Which methods would be most difficult to use on oily mousse?
- Are there any methods listed that could be used to clean up highly weathered oil? Can you think of any other methods that might work?
- Are there any methods listed that could be used to clean up mats of oil or tar balls that have sunk to the ocean bottom? Can you think of any other methods that might work?

Wrap-up

Ask students if they have ever seen oil in the water. Discuss sources of small amounts of oil pollution, such as fuel oil spills or oily bilge water on recreation and commercial boats, as well as oil leaks on land from cars, trucks, ATVs, etc. How can these sorts of small spills be prevented? Follow-up with a trip to the harbor or a large parking lot to look for evidence of tiny oil spills and learn more about prevention. This activity pairs very well with “Critter Clean Up.”

Assessment

Working in small groups, ask students to describe a physical change that components of crude oil could go through. (Evaporation, freezing, and emulsion are some examples). Ask them to explain in writing or verbally why this represents a physical change. Then have students describe a chemical change that components of crude oil could go through. (Burning and oxidation are two fairly simple examples). Ask them to explain in writing or verbally why this represents a chemical change.

Pair With

- Critter Clean-Up Lesson Plan
- Oily Experiments Lesson Plan
- Oil Spill in a Pan Lesson Plan