HOW TO CLEAN UP AN OIL SPILL

Student Activity Sheet

Name_____ Date _____ Class_____

Oil is the most common ***pollutant*** in the oceans. More than 3 million metric tons[1] of oil contaminate the sea every year. The majority of oil pollution in the oceans comes from land. Runoff and waste from cities, industry, and rivers carries oil into the ocean. Ships cause about a third of the oil pollution in the oceans when they wash out their tanks or dump their bilge water. Oil spills account for less than 15% of the total oil in the oceans but are probably the most obvious form of oil pollution. The damage caused by oil spills is certainly seen right away. We've all seen images of the water's surface and shoreline covered with oil and dying animals and plants. Oil spills will continue to be problem and source of pollution as long as ships and barges move most of our petroleum products around the world.

When oil leaks or spills into water it floats on the surface of both freshwater and saltwater. Oil floats because it is less dense than water. ***Density*** is a property of every liquid, solid, and gas. Density tells how much mass is in a specific volume (mass divided by the volume) of a material. You may have seen this written as an equation:

$$Density = mass / volume$$

It may help to think of density as the relative heaviness of a material or how compact or crowded the molecules are in the material. Denser materials have larger number values than less dense materials. For example, oil has a density of 0.85 g/cm^3 and seawater has a density of 1.02 g/cm^3. When these two liquids are mixed together, the denser seawater forms a layer underneath the less dense oil.

[1] that's equal to about 577,000 elephants

It's much easier to clean-up an oil spill because of oil's lower density. You can imagine how difficult it would be to clean-up a spill if oil was denser than water and formed a layer along the bottom instead of the surface. We humans have come up with some pretty creative ways to clean-up spilled oil and we've described some of the major methods below.

Mechanical

Americans primarily use mechanical methods to clean-up oil spills. Listed here are the three categories of mechanical tools used to contain and recovery spilled oil.

4. *Booms*- It's easier to clean-up oil if it's all in one spot, so equipment called containment booms act like a fence to keep the oil from spreading or floating away. Booms float on the surface and have three parts: a 'freeboard' or part that rises above the water surface and contains the oil and prevents it from splashing over the top, a 'skirt' that rides below the surface and prevents the oil from being pushed under the booms and escaping, and some kind of cable or chain that connects, strengthens, and stabilizes the boom. Connected sections of boom are placed around the oil spill until it is totally surrounded and contained.
5. *Skimmers*- Once you've contained the oil, you need to remove it from the water surface. Skimmers are machines that suck the oil up like a vacuum cleaner, blot the oil from the surface with oil-attracting materials, or physically separate the oil from the water so that it spills over a dam into a tank. Much of the spilled oil can be recovered with skimmers. The recovered oil has to be stored somewhere though, so storage tanks or barges have to be brought to the spill to hold the collected oil. Skimmers get clogged easily and don't work well on large oil spills or when the water is rough.
6. *Sorbents*- These are materials that soak up liquids by either ***absorption*** or ***adsorption***. Oil will coat some materials by forming a liquid layer on their surface (adsorption). This property makes removing the oil from the water much easier. This is why hay is put on beaches near an oil spill or why materials like vermiculite are spread over spilled oil. One problem with using this method is that once the material is coated with oil, it may then be heavier than water. Then you have the problem of the oil-coated material sinking to the bottom where it could harm animals living there. Absorbent materials, very much like paper towels, are used to soak up oil from the water's surface or even from rocks and animal life on shore that becomes coated with oil.

Chemical

Chemicals, such as detergents, break apart floating oil into small particles or drops so that the oil is no longer in a layer on the water's surface. These chemicals break up a layer of oil into small droplets. These small droplets of oil then disperse or mix with the water. The problem with this

method is that ***dispersants*** often harm marine life and the dispersed oil remains in the body of water where it is toxic to marine life.

Physical

7. *Burning*- Burning of oil can actually remove up to 98% of an oil spill. The spill must be a minimum of three millimeters thick and it must be relatively fresh for this method to work. There has been some success with this technique in Canada. The burning of oil during the Gulf War was found not as large a problem as first thought because the amount of pollution in the atmosphere did not reach the expected high levels. Field-testing is needed to check the feasibility of this technology.

Biological

1. *Bioremediation*- There are bacteria and fungi that naturally break down oil. This process is usually very slow- it would take years for oil to be removed by microorganisms. Adding either fertilizer or microorganisms to the water where the spill is located can speed up the breakdown process. The fertilizer gives the bacteria and fungi the nutrients they need to grow and reproduce quicker. Adding microorganisms increases the population that is available to degrade the oil. A drawback to adding fertilizers is that it also increases the growth of algae. When the large numbers of algae die they use up much of the oxygen so that there isn't enough oxygen in the water for animals like fish.

Over time, a number of things can happen to oil that has been spilled. The oil may evaporate, reach the shore and cover beaches, remain suspended in the water for long periods, or sink into ocean sediments. The problem of cleaning up oil often becomes more difficult the longer the oil is in the water.

Oil spills can happen anywhere and anytime. The paragraph below tells about an oil spill that happened in New England when a tanker ran aground.

Example of an Oil Spill: Narragansett Bay, RI

Narragansett Bay is an important natural resource for the state of Rhode Island. Economically it supports the fishing, boating, and tourism industries. The bay is also extensively used for recreational purposes. Any type of pollution in the waters of Narragansett Bay might alter or limit the use of the bay as a natural resource. Such an incident occurred on June 23, 1989, when the oil tanker *World Prodigy* ran aground on Brenton Reef just south of Brenton Point, RI. The

collision produced several holes in the tanker that caused approximately two hundred thousand gallons of fuel oil to spill into the waters of Narragansett Bay. Figure 1 shows how the oil had moved twenty-four hours after the spill and Figure 2 shows where the oil had moved after five days. Initially the oil moved to the northwest into Mackerel and Hull Coves on Conanicut Island. The wind changed direction and transported the oil south and west into Rhode Island Sound and along the southern coast of Rhode Island. Marine life in these two coves was particularly hard hit. Many small lobsters and crabs died and long-term damage to the ***ecosystem*** resulted. The incoming tide, light wind, and sunny weather all influenced what happened to the oil that was spilled. These three factors, combined with the fact that the oil was low density resulted in most of the oil evaporating**.** The amount of damage done to the environment could have been much worse if the weather and tidal conditions had been different.

In this activity you will demonstrate how wind effects the transport and fate of oil spilled in the sea. You will also use a variety of materials to clean-up your very own oil spill. These materials model many of the cleanup methods you just read about. You will see for yourself how difficult it can be to clean-up oil and which techniques are most efficient. At the same time you will observe the property of density and develop a working definition.

OBJECTIVES:

- Record information.
- Observe the property of density.
- State ways in which an oil spill will harm the environment.
- Describe techniques used to clean-up an oil spill.

MATERIALS:

Container for the oil and water mixture	Graduated Cylinder
Oil (Teacher provided)	Plastic cup
Soda straws	Water (Teacher provided)
Oil Cleanup Tools:	
Styrofoam pieces	Spoon
Eyedropper	Paper towels
Powdered and/or liquid detergent	

You will be using a small container, water, and vegetable oil. The water represents an ocean (or bay, sound, even a lake) and the vegetable oil is the oil that is spilled into the water. As you saw in Figure 2, weather conditions influence what happens to oil once it's spilled in the sea. You will provide the 'wind' that moves spilled oil around your ocean.

PROCEDURES:

1. Fill the graduated cylinder with water until it reaches 150 milliliters. This should fill your 'ocean' container about half full when you pour the water in.
2. Hold one end of a straw just above the surface of the water. Gently blow air through the straw so that air comes out onto the surface of the water. Describe what happens to the water surface.

3. With the graduated cylinder, measure out 20 milliliters of oil. SLOWLY pour the oil into your container so that the surface of the water is covered. The layer formed should be less a $^1/_4$ inch thick.
4. What happens to the oil? Does it sink or float?

5. You are faced with the job of cleaning up the spilled oil using any of the clean-up tools provided. As you are doing this, think about which clean-up method works the quickest and cleaned up the most oil. Using **one** of the clean-up tools, try to remove as much of the oil from the water surface as possible. Try to do this without having the oil mix into the water. Use a cup to store the oil you collect. Write down your observations (on the **Oil Spill Worksheet**) about how each method worked. Remember that you want to recover as much oil possible in the fastest time.
6. After trying one method, choose another of the clean-up tools to see if it works better than the first. Continue trying other clean-up tools until you have used all of them or until your teacher tells you to stop. On the worksheet, rank each method to show which worked the best.
7. If you have time, combine two clean-up methods to see if you can clean-up more oil in a shorter amount of time. Record your results on the worksheet.
8. Answer the Discussion Questions.

DISCUSSION QUESTIONS:

1. Define density.
2. Why does the oil float on top of the water?

3. What effect will oil have on the environment?

4. Which clean-up method has the least impact on the environment?

5. Describe what happened when you blew air onto the surface of with water and then when oil was on the water surface.

6. How would strong winds effect the movement of the oil?

7. Was cleaning up your oil spill more difficult or easier than you thought it would be? Why?

VOCABULARY

Pollutant: Any substance that contaminates or makes the environment impure. Pollutants are commonly man-made wastes.

Density: The mass or quantity of a substance per unit of volume (m/V). The relative heaviness of a material or how compact or crowded the molecules are in the material.

Absorption: The process of taking in another substance, in the same manner that a sponge would.

Adsorption: When a liquid or solid takes up a substance and holds it on its surface, so that the substance coats the molecules of the solid or liquid.

Dispersant: A chemical or material that when added to some other substance causes it to break apart and scatter about.

Bioremediation: Using natural biological processes to correct or counteract an environmental hazard or ecological disaster. An example of bioremediation is adding fertilizer or bacteria to the water to help clean-up an oil spill.

Ecosystem: An ecological unit of all the living organisms plus the nonliving, physical environment and how they function together.

Figure 1. This figure shows the location of the oil in Narragansett Bay, RI, 24 hours after the tanker, *World Prodigy*, ran aground on June 23, 1989. The legend in the lower right corner indicates how thick the oil was on the surface and the ship's location is indicated by the star. (Figure taken from M. Pilson 1990)

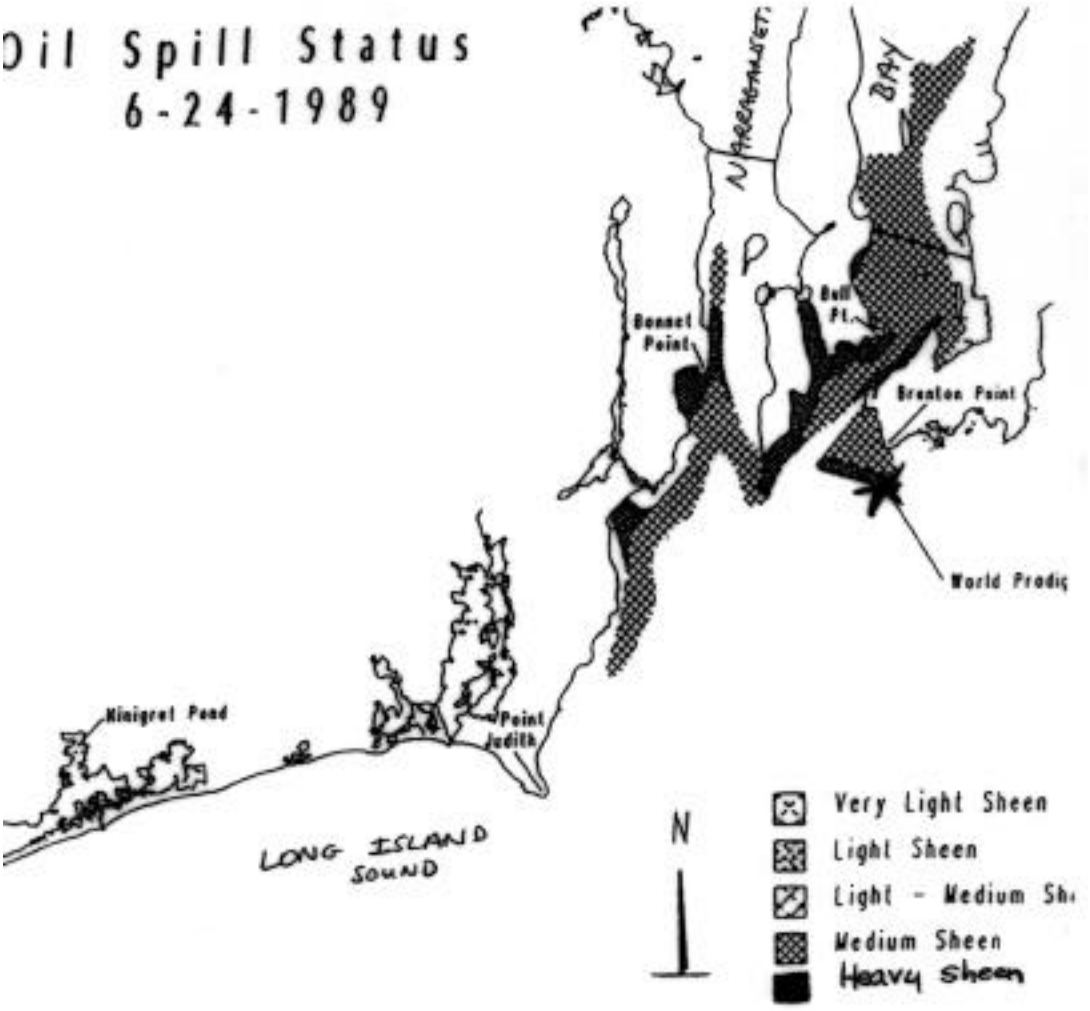
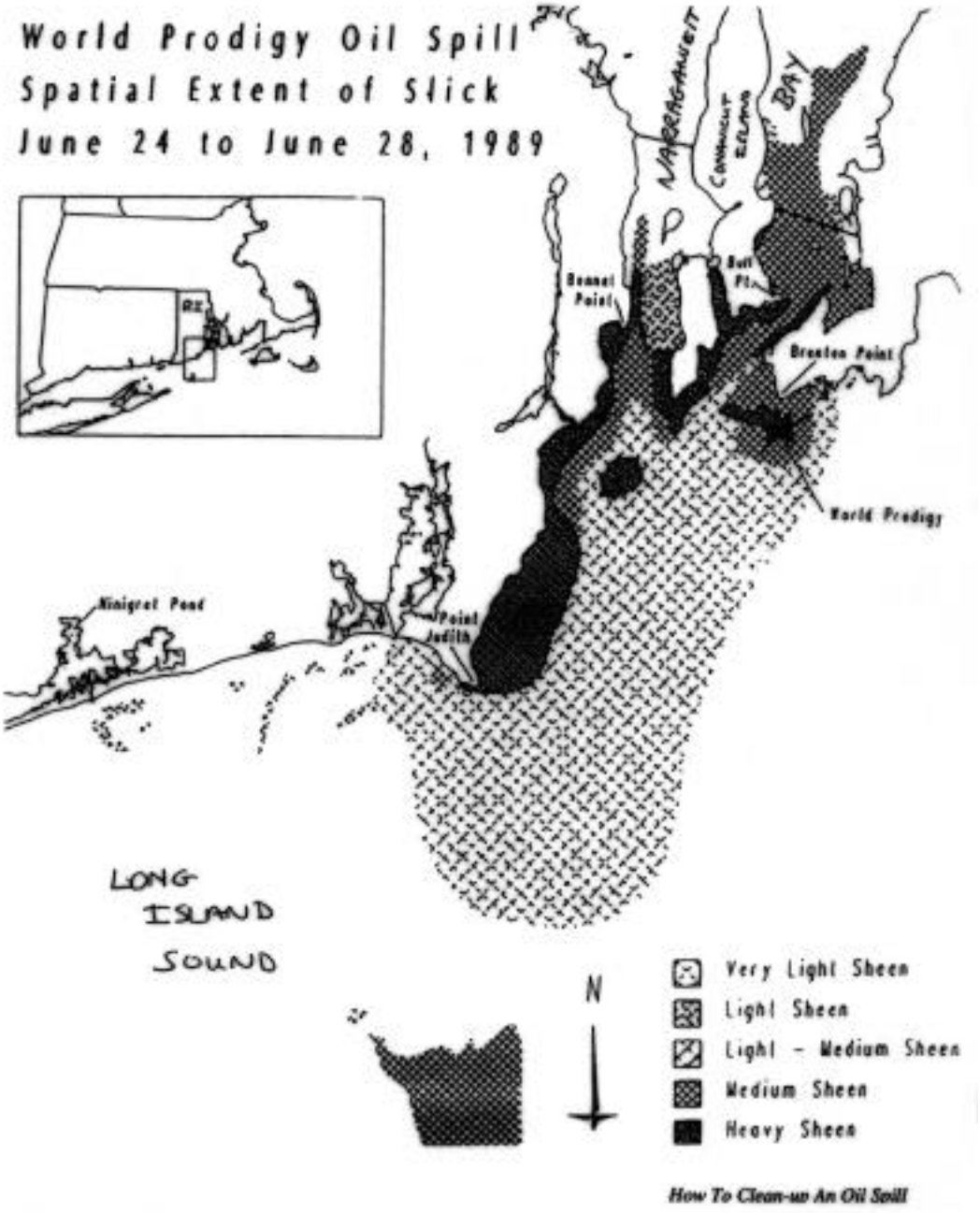


Figure 2. This figure shows how the oil spilled from the tanker, *World Prodigy*, moved into Narragansett Bay from the 24th to the 28th of June 1989. The legend in the lower right corner indicates how thick the oil was on the surface. The star indicates the spot where the ship ran aground. (Figure taken from M. Pilson 1990)



TEACHER STRATEGIES

BACKGROUND INFORMATION:

Oil spills occur in oceans, lakes, and rivers all over the world. Some of these spills are large and very damaging to nature while some are small and occur regularly. Examples of small spills are: used oil from automobiles that is poured down storm drains and the discharge of oil from outboard motors on boats. The extent of damage a spill does to the environment is related to the oil type, size of the spill, weather conditions, location of the spill, and the timing of the spill. Winds, tides, and waves will all have an effect on where the oil goes and how much damage it does.

The oil from a spill can effect the marine environment by:

- coating the substrate and organisms living on nearby shorelines with oil.
- evaporating into the atmosphere to become an aerosol that is transported by the wind.
- breaking into smaller particles in the water that are ingested by zooplankton and small fishes and enters the food chain.
- coating the fur and feathers of mammals and birds, destroying their insulating ability, reducing buoyancy, and harming the animals when the oil is ingested as they clean themselves. Animals die from exposure, drowning, suffocation, or from ingestion of oil.

When an oil spill occurs, the oil floats on top of the water. This is because the oil is less dense than the water. Density is a measure of how much mass an object contains for a specific volume. It can be expressed by the formula: *Density = Mass/Volume*. Seawater has a density of 1.025 g/cm^3, freshwater = 0.998 g/cm^3, and oil's density is typically 0.83-0.95 g/cm^3. A liquid with a lower density will float on top of a liquid with a higher density. Freshwater and oil have lower densities than seawater and both will form a layer on top of the seawater unless some force acts to mix the two.

TEACHER DEMONSTRATION ON DENSITY

Density can sometimes be a difficult concept for students to grasp. In order to facilitate this it is suggested that the teacher do a demonstration on the property of density. Density is a property of all liquids, solids, and gases. The property of density as related to solids is relatively easy for most students to comprehend. If asked which would be denser, a cup of iron or a cup of salt, most students will respond that the iron is more dense (same volume, different mass, therefore

different densities). Density in liquids is sometimes more difficult for students to comprehend. The following demonstration can be done in class to illustrate the property of density in liquids. Saltwater, alcohol, and freshwater all are liquids with different densities. Each liquid is colored a different color to better show the statification of the different liquids. Write the three liquids and their densities on the board. Any liquid that you know the density for can be used in this demonstration. Color with food coloring to make viewing the layers easier.

MATERIALS:

One large test tube	100 ml saltwater density = 1.1g/ cm^3l (red)
100 ml alcohol density = 0.70g/ cm^3 (blue)	100 ml water density = 1.0 g/ cm^3 (yellow)

PROCEDURES AND QUESTIONS:

1. Give a brief introduction on density. Write out the equation on the board. Explain that density is a property of all matter. A good example of this is the comparison of the cup of salt to the cup of iron. Even better is to have items with the same volume but different masses and the same mass but different volumes. Your students will then be able to see how the two parameters of mass and volume affect density. Finding objects that have the same mass but different volumes is sometimes difficult. Try weighing a round marble and then find a Styrofoam ball that is the same mass. The Styrofoam ball should be much larger (different volume) than the marble.
2. After discussing density in solids, ask your students if they think the same property applies to liquids.
3. Have your students suggest how they would demonstrate the property of density using the liquids you've listed on the board.
4. Using student volunteers, have several students come up and slowly pour ten ml of each fluid into a test tube. Make sure they do this very slowly or the liquids will mix. You want to end up with three distinct layers.
5. Have your students describe what has happened to the liquids in the test tube. Ask them: Are layers formed? Which solutions float on top of the other? What does this have to do with their densities?

INSTRUCTIONAL STRATEGIES FOR THE MAIN ACTIVITY:

Materials for the oil spill clean-up are in the kit. **Vegetable oil is not supplied**- you must supply this yourself. You will need water and containers to distribute water and oil to the students. Have students measure out specific volumes of the oil and water. This will allow the student to acquire skills for measuring liquids and working with volumes. Extra straws, cups, spoons, paper towels, and Styrofoam cups (to shred if you run out of the small pieces) are provided. If you need extra containers, plastic fast food containers are available at most grocery stores.

Have the students work in groups of four. Assign a task to each student (equipment manager, note taker, data collector, time-keeper, etc.). Make sure that each student is engaged and allowed to do at least one of the clean-up methods. All are responsible for tidying their area when they are finished.

Write the five clean-up methods on the board with a brief description of each. The Styrofoam in the kit represents the sorbent method of clean-up, the detergent represents the chemical method, and the medicine dropper (simulating a vacuuming device) and paper towels represent mechanical methods. Two methods of clean-up that cannot be demonstrated are the burning of oil and the bioremediation method. These two methods should be included in class discussion.

ANSWERS TO DISCUSSION QUESTIONS:

1. Density is defined as the mass of a substance per unit of volume. It can be expressed by the formula Density= Mass/Volume. Density refers to the compactness of a substance's molecules.
2. Oil floats on top of the water because it is less dense and therefore lighter than the water. The water supports the oil just as it would support a piece of Styrofoam. The difference in density means that the two fluids will not readily mix.
3. A spill in the local environment would result in the short terms effects such as: marine life and the shoreline being contaminated by oil, possible closing of fishing areas, damage to marine mammals and birds, and the closing of recreational areas. Long term effects may be decline in populations of affected species or even health effects to humans from eating contaminated foods or swimming in contaminated water.
4. No one method is completely harmless to the environment. The Styrofoam pieces are coated in oil and then they are scooped out using the spoon. This method is not very effective and is time consuming. You are also left with the problem of what to do with the oil and Styrofoam mixture. Styrofoam is also a pollutant. The medicine dropper is effective but you also collect a lot of water. In a real spill storage of collected oil and water is a problem. The paper towels

are effective but again you are left with the problem of where to store and dispose of the collected materials. The detergent acts to break down the oil and the result is a mixture of oil, water and detergent. This method however does not remove oil from the water but mixes it with the water.

5. The wind (breathe) caused the water and oil on its surface to move. Blowing harder caused some of the oil to mix in with the water.
6. Strong winds will move the mass of oil from its original location and also mix the oil in with the water. This would make cleanup much more difficult and cause more damage to marine life.
7. Answers may vary. Make sure the students give a reasonable for why.

Approximate Time Required: One class period. Additional class time may be required for the teacher demonstration.

Target Audience: Science.

Extensions:

<u>Grades 4- 6</u>

1. Do this activity as a teacher demonstration with assistance from your students. Follow the demonstration with a class discussion of the results. Students should record what they have observed.
2. After doing this activity, students could write newspaper articles describing a pretend oil spill that has just occurred in Narragansett Bay. They should report the type of oil that has spilled and the quantity. They should also report on the weather conditions in the bay and what is being done to clean-up the oil. The effects on wildlife should be included in the report. Was the fishing industry effected? Research on past oil spills may provide information for their article. Magazine or newspaper photos of past spills can be included or alternatively students may draw their own pictures.

<u>Grades 9- 12</u>

Oil tankers carry a variety of oils. The majority of spills, however, involve crude oil that has an average density of 0.80 g/cm^3.

1. Obtain samples of various oils such as home heating oil (#8), auto engine oil (10W 40), waste auto oil, and marine engine oil (different value).

a. Have students determine the density of each of the oils selected by weighing exactly 20 ml of the oil on a triple beam balance using a small beaker. Beaker weights will have to be pre-determined by the students.

b. Proceed with the experiment as described in the activity. Have students notice any differences in the time needed or the difficulty in cleaning up the oil.

Questions:

a. What is the density of each of the oils? Which oil is closest in density to seawater?

b. Which oil is the easiest to clean up of those used? Explain. The most difficult? Explain.

c. What is the density of crude oil most commonly carried by tankers in transit to oil refineries? Which oil used in the lab has the density closest to that of crude oil? What happens to the majority of the crude oil spilled in the ocean based on your lab experience?

d. Crude oil has a disastrous effect on wildlife. Wildlife must have spilled oil removed from them. Of the methods presented, which conservation or other groups to treat use affected wildlife?

2. Determine the density of various oils as described in #1. Have your students use all clean-up methods for each oil type (i.e., three oil types x four methods = 12 small experiments) as described in the original activity. Calculate the percentage of oil recovery for each of the oil types and methods used. This can be done by measuring the initial oil used and the oil recovered. Since it is impossible to squeeze all of the oil out of the paper towels, some determinations of oil recovered will have to be made by measuring the amount of oil on the towels, or Styrofoam by weight.

   Example: Paper towel weight final weight = 12.6 g
   Paper towel's initial weight = 10.4 g
   2.2 g oil recovered

   Using the weights of the oils (for 20 ml) students can calculate the percent of oil recovered.

   Example: Oil recovered = 0.061 x 100 = 6.1% oil recovered.

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