Oil Spill Recovery – “Fetched Up Hard Aground”

Recommended for Grades:
7th – 12th grades

Alaskan Academic Standards
SA1.1, SA1.2, SB1.1, SB3.1

Nutshell
Students will watch a video presentation outlining the history of oil spills in Alaska; investigate the methods used to determine different chemical properties of petroleum-based spills; and experiment with a variety of cleanup materials and scenarios.

Concepts
- Alaskan inland and coastal waters are susceptible to petroleum-based spills from commercial ships and tankers, fuel storage tanks, fuel trucks, and the pipes used to transport oil.
- Petroleum-based products can have different properties, such as viscosity and volatility, which affect how oil spill cleanup is conducted.
- Water temperature, presence or absence of ice, and proximity to land are important factors in oil spill containment and cleanup.

Objectives
Students will be able to:
- Explain what viscosity is and give examples of fluids with high and low viscosity.
- Explain what volatility and flashpoint are and why it is important to know the flashpoint of any spilled petroleum product.
- Name several methods of oil spill cleanup and what environmental factors affect oil spill cleanup.

Lesson Outline

35 minutes	Activity #1	30-minute video and class discussion
20 minutes	Activity #2	Oil Viscosity Lab
15 minutes	Activity #3	Oil Volatility Lab
20 minutes	Activity #4	Oil Spill Cleanup Methods Lab
5 minutes		Wrap-up and conclusion

Activity #1: Students will watch a 30-minute presentation (on CD) about the Exxon Valdez oil spill
Materials needed:

- "Then and Now – The Alaska Oil Spill at 20" produced and provided by the Prince William Sound Regional Citizens' Advisory Council (www.pwsrcac.org)

Follow this video with a discussion. Many of the students may have heard about the spill from parents who worked on the spill cleanup, or lost jobs due to fishing closures. Ask students to share their parents' stories of the spill and discuss how they can help with a cleanup if a spill occurs again in Alaska's waters.

Activity #2: Students will learn about viscosity by conducting a laboratory experiment using the scientific method to determine the viscosity of four common liquids. Students will record their results using a laboratory data sheet.

Background information:
Read or paraphrase the following information for your students:

When an oil spill occurs the first step, before any cleanup efforts are put into play, is to determine certain physical and chemical properties of the oil. The thickness or ***viscosity*** of the oil will determine how quickly the oil will spread after a spill. ***Viscosity is a measure of a fluid's resistance to flow.*** Thicker liquids are more ***viscous*** and flow more slowly than thinner, less viscous liquids. Honey is an example of a substance with high viscosity.

Petroleum-based oils are divided into three classes based on their viscosity: light, medium or heavy. Category 1 oils have the viscosity of water, Category 2 oils are about as thick as honey, and Category 3 oils are very thick, like hot tar.

Ask students to name as many petroleum products as they can think of. On a blackboard classify them under the Category 1, Category 2 and Category 3 headings. The following chart is a suggested outcome for this exercise.

Viscosity Ranges for petroleum products		
Category 1 (light)	Category 2 (medium)	Category 3 (heavy)
Free flowing (like water)	Slow pouring (like honey)	Barely flowing (like tar)
• diesel • gasoline • heating oil • kerosene	• Bunker A • Fuel Oil No. 4 • lubricating oils • medium crude	• Bunker B and C • Fuel Oil No. 6 • weathered crude • bitumen

Laboratory Experiment #1: *Viscosity*

Setup: provide beakers or paper cups of the following four substances (or substitute others, but have a range of thicknesses) for each group of students. Number the beakers 1 – 4.

Materials per group of students:

- 50 ml apple juice
- 50 ml corn syrup
- 50 ml chocolate syrup
- 50 ml condensed milk
- A small kitchen funnel with a pour opening of about ¼"
- 1 large beaker or cup to collect the flowing liquid
- A stop watch
- Data sheet

Ask students to work in groups of no more than four and complete Section I of the Student Worksheet.

Activity #3: Students will learn about volatility by observing as the instructor conducts a laboratory experiment. The experiment will be followed by a classroom discussion of the volatility (flash point) of petroleum-based oils and why this knowledge is important to oil spill response.

Background information:
Read or paraphrase the following for your students: Petroleum-based oils are made up of a complex mixture of hydrocarbons. Unexplained or mystery spills can be traced back to their ships of origin through their chemical "fingerprint" much in the same way human fingerprints are used to solve crimes.

Once oil is exposed to air it tends to separate into lighter and heavier compounds. The lightest compounds quickly turn to gas and evaporate into the atmosphere. This evaporation is due their high ***volatility***. ***Volatility is defined as a measure of how quickly a substance forms a vapor at normal temperatures and atmospheric pressure.***
Volatile oils, like gasoline or light crude, evaporate easily at normal temperatures. Medium crude oil can dissipate up to 40 percent of its liquid volume to evaporation, while heavy crude loses only about 10 percent of its liquid volume to evaporation. Oil spill response teams measure the oil for its density, viscosity, water content, response to dispersants (more on this in the next activity), and ***flash point***.

The flash point of a combustible liquid is the temperature at which a vapor is given off that will ignite in air when a flame is passed over it. Highly volatile oils often have a low flash point. For example, some cooking oils have a lower flash point than others. When any cooking oil is heated on a stove it is nearing its flash point when it begins to smoke.

Why would the flash point of an oil spill be important to know? A light crude oil spill may be left to dissipate into the atmosphere on its own, while massive cleanup efforts are needed for a heavy crude spill in order to prevent it from coating coastlines and endangering wildlife far from the initial site of the spill. Additionally, light crude oil can combust easily, creating an extreme safety hazard, while heavy crude is less flammable and poses fewer ignition risks. Finally, fumes from highly volatile oils can be toxic to humans and wildlife. So knowing the type of oil in the spill is key to oil spill cleanup.

Flash point can be measured by using a test called the Cleveland Open Cup. This calls for the use of an open metal container filled with a sample of the oil. The oil is then heated and a small flame is passed over its surface. When the oil ignites or flares the flash point temperature is recorded. Using this method it was determined that motor oil has a flash point of 420 – 485°F, diesel fuel has a flash point of 100 – 130°F, while gasoline has a flash point of -45°F. So gasoline will ignite even in Alaska's cold winter weather, which is why it's so useful for cars and snow machines!

Laboratory Experiment #2: *Volatility*

Setup: teachers can conduct this experiment in front of the class (preferably under a fume hood) rather than have students working with flammable cooking oils. If students conduct the laboratory experiment they should all wear eye protection and work in teams of no more than four.

Materials per group of students:

- Two 15 ml dropper bottles filled with two different cooking oil samples. The samples should differ as much as possible in their flash point. Below is a list of several oils and their flash points. Label each dropper bottle with the type of oil they contain.

Oil:	Flash point:
• Avocado oil, refined safflower oil	• 510 – 520°F
• refined corn oil, almond oil, roasted peanut oil, soybean oil	• 420 – 450°F
• canola oil, grape seed oil, extra virgin olive oil, sesame oil	• 400 – 410°F
• lard, unrefined corn oil, vegetable shortening, butter	• 320 - 370°F
• unrefined sunflower, unrefined flax or unrefined safflower oil, unrefined olive oil	• 225°F

- 6 crucibles (3 numbered #1, and 3 numbered #2)
- Popcorn kernels – 2 per crucible
- Tongs to handle crucibles
- Hotplate
- Safety goggles
- Hot pad or mitt
- Permanent marker
- Baking soda (in case one of the samples catches fire)

Experiment:

1. Explain that you are going to conduct an experiment with common kinds of cooking oil in order to determine which one is the most volatile.

2. Place all six crucibles on an **unheated** hotplate and drop 2 kernels of popcorn into each crucible.

3. In all crucibles labeled #1 put 15 drops of the high-flash point oil (roasted peanut oil for example).

4. In all crucibles labeled #2 put 15 drops of the low-flash point oil (unrefined olive oil for example). Don't tell the students which oil is in which crucible!

5. Turn the hotplate on high and stand well back from it as the oil will splatter when the corn pops.

6. Watch closely as the oil heats and note which crucibles pop the corn the first – it should be all the crucibles labeled #2 and containing the low-flash point oil.

7. Ask students to answer the questions on their worksheet under Section II.

Note: if teachers elect to have students conduct this experiment divide the class into groups of four and provide each group with just two crucibles and 4 kernels of corn. All groups should put 15 drops of high-flash point oil into the crucible they label #1 and 15 drops of low-flashpoint oil into the crucible they label #2. Have them compare their results. All groups should find that the low-flash point oil popped the corn first. Some hotplates don't heat evenly, which can produce false results.

Activity # 4: Students will explore oil spill cleanup methods using a variety of materials. Adjustments during the experiment process will reflect natural occurrences over time during and after an oil spill cleanup operation, including the effects of wind and ocean turbulence.

Materials per group of students:

- 4" deep plastic dish pans
- About one gallon of cold water
- 8 tablespoons of salt
- 5 or 6 rocks – fist size and smaller
- Rubber gloves for each student
- 12 Q-tips
- 6 cotton balls
- Eye droppers
- 1 spray bottle filled with water
- Dish soap in a small dropper bottle
- six 8" pieces of yarn
- Two spoons
- 1 beakers or paper cup to collect waste oil
- News paper
- A book of matches
- Miracle grow plant food in small dropper bottle
- 6 ice cubes or small pan of ice

Teacher's materials:

- ¼ cup dark-colored cooking oil in a beaker per group of students
- Egg beaters

Set up

Before students arrive set up the following for each group of 4 – 6 students:

- Place the plastic dish pan on newspaper and pour in one gallon of cold water (or to about one inch in depth).
- Mix in 8 tablespoons salt to replicate the salinity of sea water (the egg beaters will help)
- Pile rocks in one corner of the dish pan to a height of an inch or more above the level of the water, and place the ice cubes on or near the rocks.
- Lay out rubber gloves, Q-tips, cotton balls, spray bottles filled with water, dish soap, yarn, eye droppers, spoons, paper cups, plant food, and matches.

Background

Introduce the activity by explaining that students will be working together to clean up a simulated oil spill using some of the following methods.

Read or paraphrase the following information for students:

Because oil is less dense than water, it floats on the water's surface. After a spill the first response is often to try to contain the oil in one location with the use of a barrier, called a ***boom***. A boom can be made of long rope-like floats made up of special absorbent material, or it can be as simple as a chain of logs tied together and set afloat just beyond the spill area. Equipment to scoop up the spilled oil is then brought in. This equipment is generally a vacuum system that sucks up the oil and empties it into a waiting barge, but can be a simple as using buckets by hand. Chemical detergents may be applied to help break up slicks of oil, much as dish soap helps remove grease from your dishes.

Cleanup methods depend on several environmental factors, including how close the spill is to the shore, the direction of tides, wave height, and weather conditions. The properties of the fuel spilled, such as viscosity and volatility, are also important.

Warmer air and water will cause the oil to evaporate more quickly, while cold temperatures slow evaporation. Strong winds that result in breaking waves can cause lighter oil to churn into a foam, called "mousse" and makes cleanup efforts much more difficult. Heavy oils can form a large tarry matt or smaller tar balls. Tides and currents can greatly impact how oil moves over the water. Oil floats on seawater much like a raft set adrift, floating in and out with the tides, and moving laterally by the currents along the coastline. As spills of crude oil come in contact with the shoreline they coat it with a thick, toxic blanket that can smother animals and plants that come in contact with it. All forms of petroleum oil, including the fumes, can be deadly to marine life.

Cleanup methods include the following:

Mechanical skimming: Mechanical skimming is done with the aid of booms. Oil captured within the boom is skimmed off through suction or with buckets and stored in 50-gallon barrels or in the hold of an empty tanker.

Chemical Dispersants: Light (category 1) oils are sometimes treated with dispersants, similar to washing grease off dishes with detergent. Oils with a thickness of less than 0.1 mm thick can be treated by spraying dispersants from airplanes and boats within 2 – 5 days of the spill. Dispersants work best on seas with some wave action to mix the chemicals with the oil, like spraying into a sink full of water to generate suds from the dish soap. Flat, calm waters allow the oil to retain surface tension rather than breaking into droplets to mix into the water column where naturally occurring microbes break it down. Dispersants also enable a greater percent of the oil to evaporate off. Dispersants are less effective in cold water, and some are environmentally toxic.

Burning: Burning is used to treat smaller spills when the oil on the water surface is at least 2 mm thick. Waves should be less than 6 feet in height, without breaking waves, and wind direction should carry the smoke away from any populated areas.

High pressure washes: Once oil reaches the shore, cold sea water is sometimes used to hose oil from the beach back into the water where it can be skimmed off and disposed of. Hot water was used during the Exxon Valdez spill, but because the hot water killed the plants and small organisms at the tide line, beach recovery was slower than on beaches that were not subjected to hot water. High pressure washing has the disadvantage of driving oils down into the sand or below the rocks. Areas that were high-pressure washed during the Exxon Valdez oil spill contain pools of oil a foot or less below the surface even today.

Bioremediation: To promote recovery, oiled beaches may be treated with fertilizers (nitrogen and phosphorus) that promote the growth of naturally existing oil-eating bacteria. The bacteria speeds the decomposition of toxic oils, shortening the time of recovery from 5 – 10 years to 3 – 5 years in trials conducted in Prince William Sound after the Exxon Valdez oil spill.

Cleaning by hand: Oiled beaches can be cleaned by hand with shovels and absorbent pads to mop up puddles and wipe off rocks. A trench can be dug and oil washed into the trench where it can be sucked up with a vacuum system. Similarly a backhoe or front-end loader may be used to remove areas of oiled beach that have hardened into tar balls or asphalt patches.

Presence of Ice: Oil spills aren't just limited to open oceans, and can occur adjacent to or in streams, and on the ice. Open stream cleanup methods are similar to those used on the ocean, with the use of booms placed downstream of the spill intended to capture the spill at a place where it can be contained and skimmed off. Oil spills on ice accumulate in cracks in the ice, or in pockets of water under the ice. Oil can be collected by cutting or drilling holes into the ice and skimming or pumping the oil out of the hole as it bubbles up. If the ice is thick enough (several feet) the oil can be burned out of the ice.

No Response: Sometimes the best response is no response. Cleanup crews can cause unintended damage to a fragile ecosystem, and when an area is only lightly oiled it may be best to allow the area to recover on its own.

Experiment:

Ask students to examine the stations laid out before them. They can name their landform (the rocks at one end) and the body of water if they like. Explain that in this simulation they will help to clean up an oil spill that has occurred by using the materials placed in front of them. Give them a moment to determine how they will prepare for the spill that is coming their way. At the point farthest from the rocks place about a quarter cup of oil, and let the students proceed with cleanup efforts.

After a few minutes use the egg beaters to churn up the water as if the seas were subject to heavy chop, and move the oil towards land. Again, allow students to proceed with cleanup efforts. You may also want to add wind & waves (get creative) to make the situation more challenging.

Wrap up and Conclusion

Ask students to discuss what difficulties they had with clean up and what would have helped them to clean up the spill more effectively.

Ask how a large oil spill would impact their community. Prompt them to factor in jobs, tourism, fishing resources, drinking water, air quality, wildlife, and outdoor activities like kayaking, fishing, camping and hunting.

Ask students to consider how small spills can occur and what they do to the environment on a lesser scale. Share with them that while major spills do occur, smaller spills occur with much more regularity and ultimately introduce a much greater percent of toxic oil into the natural environment and do the most damage.

Optional Activities:

1. Students will learn about the movement of oil in water as it is subjected to the directions of wind and waves.

Oil spills on water move in relation to winds and currents. Because water is denser than air, water currents have a much greater effect on oil movement than wind speed. Oil moves at the same speed as an ocean current but only at about 3% of the speed of a surface wind. If wind and current are moving in the same direction, the oil movement in that direction is determined by adding current speed and 3% of the winds speed. If the current and wind are moving in different directions then the movement of oil on the water surface can be determined by combining the two speeds.

See if students can determine the following:
If a spill occurs in an ocean with a current moving due north at 2km/h and a wind speed is moving due east at 20km/h, what direction will the spill move and how far will it move in that direction in one hour? In five hours?

2. Students will gain an understanding of how large an oil tanker is and much oil is carried in an oil tanker.

Materials needed:

- Flagging tape
- Chalk

The Exxon Valdez measured 967 feet long by 166 feet wide and held 53,100,000 gallons of oil. As tankers go the Exxon Valdez was mid-sized. (The largest tanker in operation is the Jahre Viking which measures 1504 feet long and 226 feet wide. Because of its size crew members often use bicycles to travel around the ship.) In order to gain a better sense of the size of the Exxon Valdez students will make an outline of the ship:

- Measure one student's average stride for 10 strides. Determine how many strides they would need to take in order to walk the 967 foot length of the Exxon Valdez. Mark where they begin with flagging tape and have them walk the number of strides calculated and flag the end point to indicate the length of the Exxon Valdez. Do the same for the width. If possible, use chalk to draw the full size of the ship. Now do the same for the Jahre Viking.

- Students may also use graph paper to draw the size of both the Exxon Valdez and the Jahre Viking. Using ¼" grid paper, assume each square is 25 feet long.

- Ask students to imagine how far the oil on board these ships would spread if it were only a few millimeters thick.

Alaska SeaLife Center
windows to the sea

STUDENT WORKSHEET

Student names:

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

Section I: *Viscosity*

1. What is viscosity? Write a definition and give examples:

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2. Look at the four liquids in the containers in front of you. Each liquid has a different viscosity.
   Write down the number of the beaker which appears to contain the least viscous fluid: ____________

   Write down the number of the beaker which appears to contain the most viscous fluid: ____________

3. Conduct an experiment with the fluids to measure their viscosity.
   a. Select one person in your team to be the time keeper. They should familiarize themselves with the use of a stopwatch, or use a wristwatch with a second hand to keep track of the time.

   b. Use the large empty beaker or cup to capture the fluid you are timing.

   c. The time keeper will say "flow" and start the stopwatch as anther person pours all the fluid from beaker #1 into the funnel. The time keeper will stop the watch and note the time when the last of the liquid flows into the cup from the funnel.

   d. Record the time on the data form below.

   e. Repeat this process for each of the fluids and record the time for each on the datasheet.

Rank each beaker according to how viscous it is, with a "1" being the most viscous.

	Beaker #1	Beaker #2	Beaker #3	Beaker #4
Flow Time:				
Ranking				

4. Discuss with your group how the viscosity of crude oil would affect what happens to that oil when it is spilled into a body of water. Write a short paragraph below based on your group discussion:

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Section II: *Volatility*

1. What is *volatility*? Write a definition:

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2. How does volatility relate to *flash point*?

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3. In the experiment conducted, which oil popped the popcorn first?

The oil in the crucibles labeled #1 ___________
The oil in the crucibles labeled #2 ___________

4. Popcorn pops when naturally occurring water inside the kernel reaches a boiling point of 100° C (212° F) and turns to steam – causing pressure inside the kernel which then explodes, turning the kernel inside out. Oil with a low flash point reaches 100°C sooner than oils with a high flash point. Based on this information, which oil had the lowest flashpoint?

The oil in the crucibles labeled #1 ___________
The oil in the crucibles labeled #2 ___________