Pioneer Valley CORAL & Natural Science INSTITUTE

Cleaning Up Oil Spills

Photo by Jesse Bowser

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Objective

Students will compare the sorption capacity of different materials for oil removal. Based on the findings, students will evaluate materials' effectiveness and solutions for implementing the best suitable material for cleaning up oil spills.

Standards Met: NGSS

- *HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.*
- *HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*
- *HS-ETS1-3. Evaluate a solution to a complex real-world problem-based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.*

Background

Despite environmental concerns, oil is an extremely prominent product in our society. Oil is used in the making of our clothes, shoes, furniture, food packaging, toiletries, and most everyday items. It is also used to fuel our cars and heat our homes. Accidents involving transportation tankers, barges, pipelines, refineries, drilling rigs, and storage facilities, occasionally cause oil spills. Oil spills contaminate the water, they are very difficult to clean up and are devastating for the wildlife.

Photo by Sean Gardner, Reuters

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One of the methods for addressing the oil spills is based on the use of oil sorbents – hydrophobic (hydrophobic molecules and surfaces repel water) and oleophilic (having an affinity for oil) materials that effectively bind to oil and, hence, can remove oil from water. In this lab, you will compare the absorptivity of common sorbents, many of which are actually used in oil spill cleanup. Sorbents can be natural organic, natural inorganic, and synthetic. Organic sorbents include moss, hay, feathers, and other carbon-containing compounds. These sorbents can absorb between 3 and 15 times their weight in oil, but also may absorb water. Many organic sorbents are comprised of loose particles and can be difficult to collect in water. Natural inorganic sorbents include clay, sand, glass wool, and more. They can absorb 4 to 20 times their weight in oil, but are not used at the water's surface. Synthetic sorbents are man-made, and similar to plastic and rubber materials. Some synthetic sorbents can absorb up to 70 times their weight in oil! It is important that after use in an oil spill, these sorbents are disposed of properly.

In the News: *Oil Spills & Coral Reefs*

https://www.nytimes.com/2018/06/25/science/coral-reefs-oil-spills.html

How Oil Spills Affect Species Living In and Around the Oceans?

Oil waste affects the food chain on which fish and sea creatures depend on by poisoning the sensitive marine and coastal organic substrate.
Oil destroys the insulating ability of fur-bearing mammals, and the water repellency of a bird's feathers. Without the ability to repel water and insulate from the cold water, birds and mammals die from hypothermia. Many birds and animals also ingest oil when they try to clean themselves, which can poison them.

Fish and shellfish can be exposed to oil when/if is mixed into the water column. Some of the adverse effects to adult fish when exposed to oil are reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproduction impairment. Oil also adversely affects eggs and larval survival.

Experimental Part

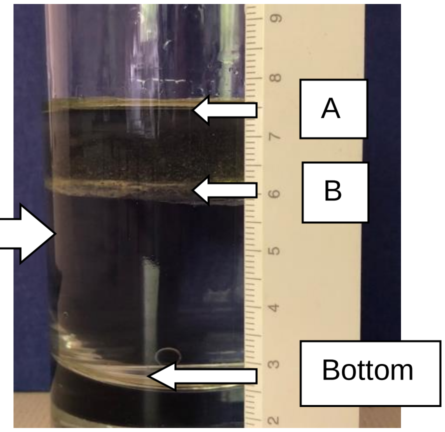
Materials

- Plastic garbage bag for waste disposal
- Container (teachers choice: graduated cylinder (200 mL), narrow liquid measuring cup (200 mL) or any transparent container with straight edges (200 mL) where graduation can be improvised with the ruler or measuring tape as given below)
- Paper or glass bowls
- Tweezers
- Vegetable oil
- Water
- Stainless steel whisk ball (make sure size fit container of your choose)
- 3+ sorbents you want to test (examples: cotton, fur, straw, coconut husk, corn cobs, corn husk, polypropylene pads, shop towels, bird feathers, rubber)

Procedure

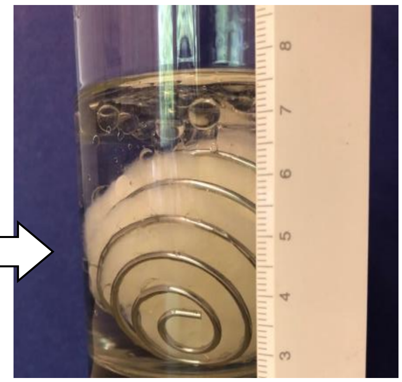
This lesson has been modified to use significantly lower amounts of oil comparing to other available lessons using this experiment.

1. Prepare your sorbents by cutting them into smaller pieces if necessary (make sure they are not too small to escape from whisk ball). When your first sorbent is prepared, divide it into three piles of small amounts each to fit whisk ball to run each trial separately as given in the Table below.



2. Pour 90 mL of water into a container. Slowly add 30 mL of vegetable oil (water-to-oil ratio is 3). What happens? Do they mix? Why is oil on the top? If a layer of bubbles forms, wait a few minutes for the bubbles to disappear.

   Hint for Teacher. *120 mL of oil + water is sufficient volume to fully submerge the whisk ball of 4 cm diameter in 5 cm diameter container. Values in photos do not reflect exact ratio of 3.*
3. Write down the initial levels of oil + water **A** and water level **B** in the Table.



4. Put 1st whisk ball with your sorbent in the container and lower it slowly until it is completely submerged.
5. Start a timer when the sorbent has been submerged. Let it sit for 30 seconds, then lift it out (use tweezers) and let the filter drain back into the cylinder for an additional 30 seconds.
6. Throw away the used sorbent*, measure the oil + water levels (now marked as **C**) and water (now marked as **D**) in the container and write down in the Table. Scoop out the oil from the container and dispose*.

   ****Disposal!*** *Place used oil and all used sorbents into the garbage bag and throw away with your regular garbage.* ***Do not*** *throw away oil in the sink.*
7. Wash out the whisk ball and container with water and soap. Make sure to rinse out all soap thoroughly before continuing. Repeat these steps for the second and third trial of your first sorbent.
8. Repeat these steps for the three trials of each additional sorbent you are testing.

   Disposal – don't forget! *Place used oil and all used sorbents into the garbage bag and throw away with your regular garbage.* ***Do not*** *throw away oil in the sink.*

# of Trial	Initial			After removing sorbent				
	Oil + Water level[a] (A)	Water level (B)	Oil level (IO=A-B)	Oil + Water level (C)	Water level (D)	Remaining oil (RO=C-D)	Oil removal efficiency (E %)=(IO-RO)*100/RO)	Ratio[b] (D/RO)
Sorbent name								
Trial 1[c]								
Trial 2								
Trial 3								
AVERAGE								
Sorbent name								
Trial 1								
Trial 2								
Trial 3								
AVERAGE								
Sorbent name								
Trial 1								
Trial 2								
Trial 3								
AVERAGE								

[a] *In case of using ruler, levels will be in "cm".*
[b] *Remaining water level divided by remaining oil level*
[c] *For example, Trial 1 is using sorbent of 1st pile in the whisk ball*

Data analysis

1. Calculate the ratio of remaining water-to-remaining-oil for each trial and record it in the data Table. Calculate the efficiency of oil removal based on equation in the Table. Calculate average values for both parameters and write down in the Table.
2. Present your data in a graph. This can be done by hand or on a computer using Excel. You should put the sorbents you tested on the x-axis, and the average ratio on the y-axis. Separate graph should present the sorbents you tested on the x-axis, and the % of only oil removal on the y-axis.
3. Analyze your results.
   Note! *A higher ratio means the sorbent was effective at removing oil relative to water sorption. If any sorbents had a ratio less than initial (the starting water-to-oil ratio), it means it absorbed more water than oil and would not be effective.*
4. A higher % of oil removal indicates better sorbent. Based on you data, how is ratio of remaining water-to-remaining-oil related to only oil removal efficiency?

Conclusion

Best sorbent based on the oil removal efficiency:______________________

Best sorbent based on the ratio:___________________________________

Discussion

1. **Optional:** Do you know what are the currently used technologies for removal of oil from the ocean?
   Hint for Teacher. *Several methods using various technologies have been developed through the years to cleanup oil spills. These methods include: letting the spill break down by natural means, using booms to channel and collect the*

oil, using dispersants to break up the oil, using biological agents to degrade the oil, burn off the oil, and recently using a bell to collect the oil.

2. **Optional:** How would you implement the material to clean the ocean from oil spill? What are the factors you need to consider for removing large amounts oil? Draw a design of what you think would be applicable.

   Hint for Teacher.

   Some suggested designs:

Photo www.oleology.com.au

"Oil Spill Clean-Up Basics

An oil spill can disperse oil over a huge area. The initial problems are to contain the spill and prevent more oil from entering the water. This can be a truly challenging, difficult job. If, as happened recently, a tanker runs aground on the Great Barrier Reef, there are several critical issues:

- *The containment job has to deal with currents on the Reef*
- *The clean-up operation has to find access for vessels through the Reef,*
- *The top priority is to deal with shutting down the leak, wherever it is on the ship*
- *If it's cyclone season, the risk factors for the clean-up operation increase dramatically*

Meanwhile, the clean-up operation must also:

- *Assess the spill in terms of volume*
- *Figure out where the spill is going, at what rate, and in what sort of volume*
- *Get the clean-up rigs, booms and skimmers in to position*
- *Using a large number of onsite staff to manage the issue*

- *Consider other options for clean-up operations, like chemical dispersants and biological agents like nitrogen and phosphorous*

A large spill, in turn, brings with it large problems. If you're dealing with a huge capacity spill, the time factor becomes an issue. Larger amounts of oil come with drastically increased degrees of difficulty. Each of the control measures has to be evaluated for issues like what resources can be delivered onsite. The other factors in play are how quickly and naturally will these resources be adequate to do the job? Will more resources be required?

Add to these problems the fact that an oil spill is quite literally a moving target. The time factor also dictates the damage potential of the spill. Will the spill move out to sea, or will it stay closer to shore and contaminate the Reef? Will the response team deploy the spill equipment in time to increase the capture capacity?"
from https://oleology.com.au/news/oil-spills/mind-blowing-challenge-cleaning-oil-spills/

Take Home Messages
Oil is difficult to separate from water, but by testing basic materials, you can look for simple, cost-effective solutions that can improve water quality.

Lesson Adopted From:
https://www.sciencebuddies.org/science-fair-projects/project-ideas/EnvEng_p025/environmental-engineering/cleaning-up-oil-spills#procedure
https://archive.epa.gov/emergencies/content/learning/web/html/sorbents.html