# TITLE: Oil Pollution Solutions

## *Subtitle: Oil pollution in the marine environment*

**Authors:**
- **Kristin de Nesnera**, PhD Candidate, Ecology and Evolutionary Biology, University of California Santa Cruz
- **Satina Ciandro**, ESNER Academy Teacher, Watsonville High School

**Field tested with:** 11th & 12th grade Marine Biology students, Watsonville High School, Watsonville, CA (Fall 2013)

**Module Type:** Video activity and lab experiment

**Duration:** One 2-hr class session

**Key Materials:**
- Computer Projector, and Computer
- 2-3 sorbent materials: cotton balls, polypropylene pads, straw, hair/fur (can be found a hair salon or pet groomer)
- Vegetable oil, and 100 mL and 1000 mL graduated cylinders
- Shallow aluminum pans, Funnels, Plastic baggies, and Dish soap
- 1 mL plastic pipets (eyedroppers)
- Small containers (~50 mL) for liquid

**Concepts:** Chemical properties of oil, human impacts on the marine environment, evaluating cost vs. benefit of responses to human pollution

**Skills:** Conducting experiments, forming hypotheses, displaying information graphically

**Science Education Standards:**
•**NGSS: HS-ESS3** Earth and Human Activity; **HS-ETS1** Engineering Design
•**National:** Science As Inquiry; Science and Technology; Science in Personal and Social Perspectives
•**California:** Investigation and Experimentation

## Overview:

This project is an opportunity for students to:
- Learn how human activities cause oil pollution
- Learn how oil pollution affects marine resources, the environment, and humans
- Learn about oil spill clean-up technology
- Understand the challenges related to oil spill clean-up
- Learn about sorbent materials and their absorptivity
- Learn how to evaluate the cost-benefit of different clean-up technologies

**Navigate:** Background Materials &Time Starting Point Procedures Standards Supplemental

## Background for Teachers

**Why this matters:** Many people are unaware that oil is one of the most widespread pollutants in the marine environment. The National Resource Council estimates that nearly 206 million gallons of oil pollution enter the world's ocean each year. Why is there so much oil pollution? The main reason is that humans use so much of it. The world consumes approximately 3 billion gallons of oil each day (NRC). This oil is used for fuel, electricity, plastics, asphalt, paint, ink, medicine, and much more.

This module will teach students about sources of oil pollution in the marine environment; the effects of oil pollution on marine life, human health, and economies; examples of major oil spills; and the challenges involved in responding to and cleaning up an oil spill.

**Assumed background:** Students should have a basic understanding of the chemical properties of oil, namely its inability to mix with water. Students should be comfortable measuring and calculating quantities of liquids. Students should also be able to display data graphically either as a scatterplot or bar graph.

**Special context:** Considerable effort has been put into developing new and more efficient oil spill clean-up technologies, however, the fundamental strategies used to clean up oil have changed very little over the last 50 years. The most common techniques used to clean up oil spills in the ocean include the use of skimmers, sorbents, in situ burning, dispersants, and biodegradation. In this module, students will investigate two of these strategies: skimmers and sorbents.

**Scaffolding supplements:**

- PowerPoint lecture: "Oil_Pollution_Solutions_introppt.pptx"

  Introduces students to oil pollution, where it comes from, and the chemical properties of oil that cause environmental damage. Briefly reviews how oil pollution affects marine resources, human health, and economies. Discusses two case studies of major oil spills in California. Concludes by reviewing oil spill clean-up technologies and ways in which students can help reduce oil pollution.

- Video: "insert YouTube link here"

  This video shows students an experimental set up to test the ability of different sorbent materials to absorb oil. Students should follow along and answer questions on Part 1 of the Worksheet.

- Worksheet: "Oil_Pollution_Solutions_activity.docx"

  Includes Part 1, 2, and 3 of the class activity. Part 1 should be completed while students watch the video. Part 2 includes instructions and questions for students to complete during a lab activity testing the effectiveness of two oil spill clean-up methods. Part 3 is optional and may be completed during class if time permits or as a homework assignment.

- Clean-up cost chart: "Oil_Pollution_Solutions_costchart.docx"

  Gives dollar costs for oil spill clean-up methods, including use of equipment, personnel, and waste disposal. To be used in Part 2 of the lab when students are planning and evaluating the cost of their clean-up methods.

## Module Description

### Materials:

- Projector
- Computer
- 100 mL graduated cylinders (1 per group)
- 1000 mL beakers (1 per group)
- 1000 mL graduated cylinders (1 per group)
- Plastic funnels
- Water
- Vegetable oil (100 mL per group)
- Shallow pans (Disposable aluminum casserole pans work great) (2 per group) (Fig. 4)
- Sorbent materials: cotton balls, polypropylene pads, hair (can be obtained at a hair salon or animal groomer) (Fig. 1)
- Plastic snack size baggies (2-3 per group)
- 1 mL disposable plastic pipets (to be used as "skimmers") (Fig. 2)
- Container (~50 mL) of any type to be used as "waste water containers" for the skimmer method (2-3 per group) (Fig. 3)
- Dish soap

**Fig. 1**: Sorbent materials: polypropylene, cotton balls & hair (from left to right)

**Fig. 2**: "Skimmers": 1 mL plastic pipets

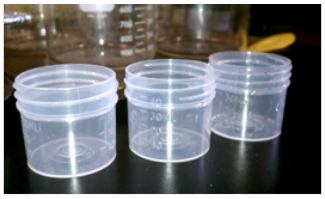

**Fig. 3**: Plastic waste containers for skimmers

**Fig. 4**: Aluminum pan "ocean" with pre-measured vegetable oil for spilling

**Preparation:**

For the lab activity (Part 2 of the worksheet):

- Divide students into groups of 4-6
- Prepare polypropylene by cutting pads into smaller pieces (~ 2" x 1")
- Have students design their clean-up plan prior to receiving supplies. Students should decide which materials and equipment they want to use, how much, and how many people will be a part of the clean-up. Encourage students to consult the cost chart while they are planning.
- Depending on time, resources, and student ability teachers may wish to prepare the "oceans" (aluminum pans with ~3 cups of water) and measure out the oil to be "spilled" (50 mL for each ocean) beforehand.

### Timeline:

One 2 hour class period

1. Introductory lecture on oil pollution (30 min)
2. Part 1- Video experiment: Testing the effectiveness of different sorbents (~20 mins)
3. Part 2- Evaluate oil spill clean-up methods (~ 1 hour)
4. Review and clean-up (10 mins)
5. Part 3- (optional) Design your own clean-up method - recommended homework assignment

## Starting Point For Inquiry:

A PowerPoint is provided to introduce students to oil pollution in the marine environment. It begins by explaining what oil pollution is and how much enters the marine environment each year. Students are then asked why so much oil pollution enters the ocean. Have students think about whether they are currently near something that uses or was created by oil products. Then explain to students that nearly everything in modern life comes from or uses oil products (ink, synthetic fibers, plastics, etc.). Emphasize that the main reason oil pollution exists is because of our large consumption of these materials. The PowerPoint continues by reviewing the chemical properties of oil, the sources of oil pollution in the marine environment, some of the negative effects of oil pollution, and two case studies of major oil spills. Students show gain an understanding of how problems and expense associated with oil pollution. The PowerPoint concludes by reviewing the major oil spill clean-up technologies used today. Students then learn about two of these technologies and explore their cost efficiency during the class activity.

## Detailed Procedure:

**Part 1: Video** (20 mins):

Intro (5 mins)

Before playing the video it is helpful to briefly introduce the three parts of the lab. This will help students understand how the information they learn in the video will be useful for the following lab experiment. The slides at the end of the introductory PowerPoint can be used for this purpose. It is also helpful to review the two key vocabulary words (sorbent and absorptivity) at the end of the introductory PowerPoint.

Play video (10 mins)

- The video walks students through an experiment testing the absorptivity of three different sorbent materials. Teachers should advise students to take notes on the materials used and on the experimental procedure so that they would be able to repeat the study in the future. Space is provided for this on Part 1 of the activity worksheet.
- Pause the video to allow students to make a hypothesis about which material will absorb the most oil. During this time teachers can pass around samples of the materials so students can see and touch them. If time allows, have the students create a bar graph of their predictions.
- Pause the video again to allow students to note the amount of oil and water remaining after each sorbent material is tested on the activity worksheet. Students may need to be walked through how to calculate the amount of oil and water absorbed by each sorbent. How to calculate the amount of oil and water absorbed by each sorbent:
    - Start by having students note the volume of water remaining in the measuring cup.
    - Then show students how the volume of oil remaining can be calculated by subtracting the volume of water remaining from the total volume of liquid in the measuring cup.
    - Finally, have students subtract the amount of oil (or water) remaining from the amount of oil (or water) they started with. This will give them the amount of oil and water that was absorbed by each sorbent

Follow-up questions (5 mins)

If time allows, students can answer some of the follow-up questions on Part 1 of the activity worksheet or move directly into Part 2 and complete questions later.

**Part 2: Lab experiment** (~1 hr) Evaluating two oil spill clean-up methods

Introduce activity (5 mins):

In this portion of the lab, students will evaluate the efficiency of two different oil spill clean-up methods in a hands-on activity. These two methods are called the skimmer method and the sorbent method in the lab. These both mimic actual methods that are used to clean up oil spills. Students should be divided into groups of 4-6 students. Each group should divide into two teams: one to test the skimmer method and one to test the sorbent method. Teachers should explain to the students that the goal of this activity is to clean-up as much oil as possible for the last amount of money. Explain how materials used, waste disposal, and personnel all come with a cost. Teachers can have the skimmer and sorbent teams compete to see who can conduct the most cost-efficient clean-up.

Designing a clean-up plan (10 mins):

Once the general activity has been explained, students should design their clean-up plan within groups. Teachers should hand out copies of the cost chart so students can consult this while they are designing a plan. The sorbent time should choose which sorbent material that would like to test and the skimmer team should decide how many skimmers they want to use. Both teams should estimate how long they want to conduct their clean-up and how many people they want to use.

Gathering supplies (5 mins):

Once students have designed their clean-up plan they should gather supplies for the activity. Each team should get a shallow pan with ~3 cups (750 mL) of water "the ocean", 50 mL of vegetable oil, and the appropriate clean-up and disposable equipment (sorbent and baggies for the sorbent team; "skimmers" and waste water containers for the skimmer team). To save time, teachers can prepare pans with 3 cups of water and/or measure out 50 mL quantities of vegetable oil ahead of time. This will eliminate a major bottleneck in the procedure.

Testing the clean-up method (15 mins):

Once students have their supplies, they should pour the vegetable on their "ocean" and start their clean-up effort. Teachers should make sure students time their effort and keep track of what they use, how many people are used in the clean-up effort, and how much waste they produce (i.e. amount of waste water, number of cotton balls) so they can be charged for the cost of the clean-up. A data chart for this information is provided on the activity worksheet. Students should also be encouraged to keep notes on the specifics of the technique they use (for example how many minutes they allowed sorbents to sit). Students should stop their clean-up effort after no more than 5 minutes (but may use less time as a way to maximize clean-up efficiency!).

Calculating amount of oil cleaned and cost (15 mins):

After the cleanup, the students will need to calculate the how much oil they removed during their clean-up. There are two methods for doing this. Which one the students use will depend on the clean-up method they used (skimmer or sorbent). A data chart is provided for this on the activity worksheet.

- Sorbent method: Students using the sorbent method will need to measure the oil remaining on their "ocean" in order to calculate how much oil they removed. It helps to first pour the contents of their pan ("ocean") into a 1000 mL beaker. Then using the beaker students can slowly pour the liquid into a 1000 mL graduate cylinder. Students

should wait a few minutes to allow the oil and water to separate, and then measure the amount of oil that was remaining in their pan after their clean-up. This amount should be subtracted from the amount of oil that was "spilled" (50 mL) to calculate how much oil was removed by the sorbent.

- Skimmer method: Students using the skimmer method can directly measure the amount of oil they removed because all the oil they removed will be in their waste water containers. Students should slowly pouring the contents of their waste water containers into a 100 mL graduated cylinder using a funnel (a larger graduated cylinder may be necessary if more than two waste water containers were used). Allow the oil to separate from any water and then have the students record the amount of oil they removed.

If they haven't already done so, students should also count the materials and calculate the cost of their cleanup using the cost chart provided. A data chart to calculate the cost of each clean-up item is provided in the oil spill activity worksheet. Students can then evaluate the efficiency of each cleanup method by calculating the cost per mL of oil removed.

Clean-up (10 mins):

**Part 3 (optional)**: This section challenges students to think about the how they would go about cleaning up an oil spill that has reached a rocky shoreline. This could be completed in class or as a homework assignment. Encourage students to be creative in designing a clean-up method.

## Assessment:

Following the completion of this activity, students should be able to calculate the cost efficiency ($/unit of oil cleaned) of an oil spill clean-up method. Students should be able to graph the results of their clean-up method study and compare their clean-up strategy to others. They should also be able to think critically about the use of oil spill clean-up technologies in a variety of situations.

## Possible pitfalls:

- This module requires students to do several simple calculations. Students who have difficulty with proportions and/or measuring quantities of liquids may find these calculations challenging. Those students may need additional guidance and scaffolding and it may be helpful to walk through example calculations with these students.

- Many students experience financial stress in their own lives. For those students, it is important to emphasize in Part 2 of the lab activity that they are not actually going to be charged for their oil spill clean-up. Remind students that while it is good to keep their clean-up costs low, they also want to maximize the amount of oil they clean-up. If this is of particular concern, providing a budget or fake money for the activity may be helpful.

- Part 2 of the lab activity requires an extensive amount of clean-up. It is helpful to strategize ahead of time to make this easier. Hot water and copious amounts of dish soap are necessary to remove the vegetable oil from the pans and measuring devices. Advise the students not to stack the aluminum pans after the experiment- this coats the outside of the pans with vegetable oil making more clean-up work.

## Glossary:

Sorbent: Material used to absorb liquids
Absorptivity: The amount of liquid that can be absorbed by a sorbent

## Science Education Standards Addressed

**Next Generation Science Standards (NGSS):**

Disciplinary Core Ideas

**HS-ESS3** Earth and Human Activity

- **ESS3.A**: Natural Resources
  - All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (**HS-ESS3-2**)
- **ESS3.C**: Human Impacts on Earth Systems
  - The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (**HS-ESS3-3**)
  - Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (**HS-ESS3-4**)

**HS-ETS1** Engineering Design

- **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. (**HS-ETS1-3**)

Crosscutting Concepts

- Systems and System models
- Influence of Science, Engineering, and Technology on Society and the Natural World
- Stability and Change

Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Planning and carrying out investigations
3. Analyzing and interpreting data
4. Using mathematics and computational thinking
5. Constructing explanations (for science) and designing solutions (for engineering)

**National Science Standards (NSES)**

A. Science as Inquiry (p.175-176)
E. Science and Technology (p.192-193)
F. Science in Personal and Social Perspectives (p.198-199),

**California Public Schools Standards (SCSCPS)**

Investigation and Experimentation,

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

**a.** Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
**b.** Identify and communicate sources of unavoidable experimental error.
d. Formulate explanations by using logic and evidence.
l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

NSES (http://www.nap.edu/catalog/4962.html)
SCSCPS (http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf);