Can Nanotechnology Help Clean Up Ocean Oil Spills? Try It Yourself with Ferrofluid

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Experimental Procedure

In this science project, you will test a novel method to clean up oil spills from water using a ferrofluid and a strong magnet. Note that ferrofluids are messy. They stain skin as well as clothes and surfaces. Throughout the procedure, take measures to contain the ferrofluid. Before you start, though, put on an apron and check yourself and your environment: Would it be OK if some ferrofluid spills on your clothes or your work surface?

You will be using a neodymium magnet. These magnets are strong. At all times, keep these magnets away from any magnetized material and computers.

1. Prepare the work area.
    a. Put a white poster board on the ground or the table where you will work. The poster board will protect the surface, provide a clean background for pictures, and enable you to take notes.
    b. Make three columns near the middle of the poster board by drawing four vertical lines, about 4 inches wide and 8 inches long. Title the columns "5 drops ferrofluid," "1 drop ferrofluid," and "No ferrofluid." Figure 4 shows how to organize your work area.

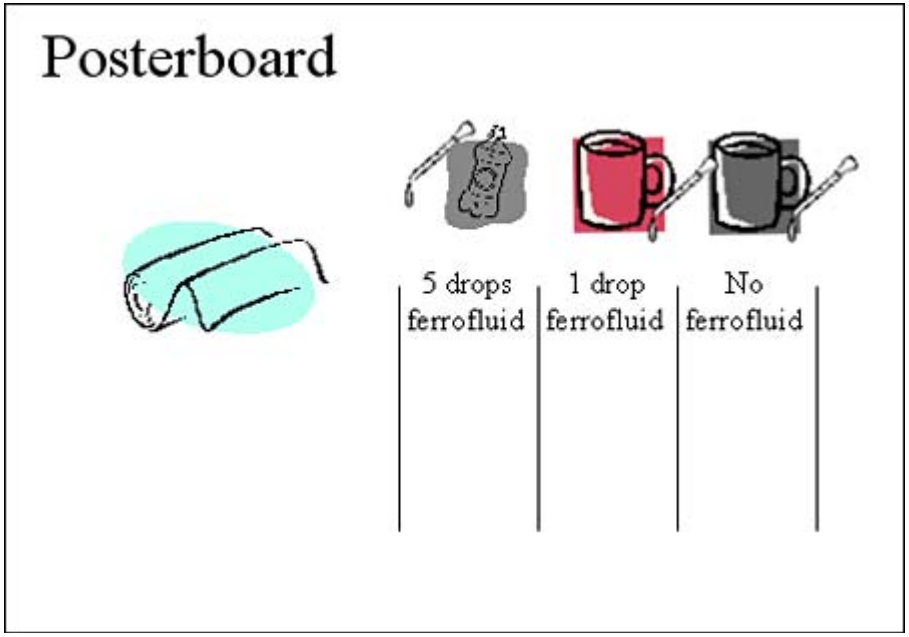

Figure 4. Organize your work area. Use a poster board as the surface to work on for this science project. Three columns indicate the test area. Above them are cups with water and mineral oil and a bottle of ferrofluid. Keep cloth or paper towels within reach to clean up potential ferrofluid spills.

2. Copy the following table in your notebook. You will use it to record your measurements.

	Volume of Mineral Oil Left after Cleaning Procedure (mL)		
	Control: Cleaning procedure without use of ferrofluid	**Cleaning procedure using 1 drop of ferrofluid**	**Cleaning procedure using 5 drops of ferrofluid**
Test 1			
Test 2			
Test 3			
Average			
Efficiency			
Observations			

Table 2. Make a table similar to this in your lab notebook to record the volume of mineral oil left on the water after the cleaning procedure is applied.

3. Prepare your water. Use colored water to increase visibility.
    a. Fill a cup with at least 100 milliliters (mL) of tap water.
    b. Add one or two drops of food coloring to the water.
    c. Mix so the food coloring dissolves in the water.
    d. Put the cup above the columns as shown in Figure 4.
    e. Place a pipette next to it. This pipette will only be used for the colored water.
4. Prepare the mineral oil.
    a. Pour about 25 mL of mineral oil in a small cup. Having the oil in a cup will make it easier to use your pipette.
    b. Put the cup above the columns, next to the cup with colored water.
    c. Place a graduated pipette next to it. This pipette will only be used for the mineral oil.
5. Prepare the ferrofluid.
    a. Put the bottle with ferrofluid next to the other two cups, above the columns on your posterboard.
    b. Place a pipette next to it on a cloth or paper towel. This pipette will only be used for the ferrofluid.
    c. Have a cloth or paper towel ready to clean up any spilled ferrofluid.
    d. Put on gloves.
6. Prepare to wash out your graduated cylinder.
    a. Fill the sink or a large bowl with warm water.
    b. Add dishwashing liquid to the water.

7. Have an empty cup ready to hold discarded fluid.
8. Prepare your test.
    a. Put one petri dish in each column, three in total.
    b. Use a pipette to fill each petri dish with about 14 mL of the colored water. If you are using a different size of petri dish, fill the petri dishes until the water level is a couple of millimeters high.
    c. Use the graduated pipette to add exactly 2.5 mL of mineral oil to each of the Petri dishes. This represents your oil spill.
        i. It is important that each petri dish receive exactly the same volume of oil so the results can be compared against each other.
        ii. Aim to release the oil near the middle of the petri dish.
9. Make the oil magnetic by adding ferrofluid.
    a. Shake the bottle of ferrofluid before opening.
    b. Test how it feels to let one drop out of the pipette back into the bottle.
    c. For the petri dish in the "1 drop ferrofluid" column, place one drop of ferrofluid in the middle of the oil spill.
    d. For the petri dish in the "5 drops ferrofluid" column, place five drops of ferrofluid in the oil spill, preferably distributed over the oil surface.
        i. If a drop falls on the water surface instead of the oil spill, observe what happens. (Does the ferrofluid float on the water? Does it sink?) Make a special note in your notebook. This information will be valuable when analyzing your data.
    e. Close the ferrofluid bottle and place the pipette on the cloth or paper towel next to it.
    f. Note that you will not add ferrofluid to the petri dish in the column titled "no ferrofluid." You will use this petri dish as a control and reference.
    g. Wait and observe for about one minute. Does the ferrofluid distribute itself over the oil spill? Does it go into the water? Do you see ferrofluid sinking to the bottom of the petri dish?
    h. Optional: Take pictures.
10. Clean up the oil spill with a magnet.
    a. Repeat the following cleanup procedure for all three petri dishes, starting with the one above the column titled "No ferrofluid added."
        i. Open a clean plastic sandwich bag.
        ii. Put the neodymium magnet in one of the corners of the plastic bag, as shown in Figure 5.

Figure 5. Place the neodymium magnet in the corner of the sandwich bag. It is now ready to pick up the magnetized oil spill in an oil cleanup procedure.

iii. Move the magnet enclosed in the sandwich bag through the oil in one movement. It works best to slightly submerge the magnet in the liquid and try to pass through the complete oil spill in one movement as best you can. *Note:* It is important to choose one method of moving the magnet through (or over) the oil spill and then stay with it throughout this project. You want to compare the efficiency using different amounts of ferrofluid. Different methods of moving the magnet through the fluid might influence the results.
iv. Wipe the bag off on a paper towel or cloth.
v. Put the magnet in the other corner of the plastic bag. This corner should still be clean and dry; if not, use a new bag.
vi. Pass the magnet in the bag through the oil a second time.
vii. Wipe the bag off on a paper towel or cloth and put it in the trash bag.
viii. Write any special observations in your notebook. Does the leftover oil look clean or dirty? Is there any ferrofluid left in the liquid left in the petri dish? If so — is it floating, sinking, or suspended?
ix. Optional: Take pictures. *Note:* It might be difficult to see the leftover oil in the picture, particularly in the petri dish with no ferrofluid.

11. Measure how much oil is left on the water.
    a. Repeat the following procedure for all three petri dishes.
        i. Carefully transfer all of the leftover liquid (water, oil, and ferrofluid) from the petri dish to the graduated cylinder. Some oil will stick to the petri dish. Try to get as much as possible in the cylinder. Do not use a funnel, as more oil would stick to the funnel and lower the readings even more.
        ii. Wait till all of the oil settles on top of the water in the cylinder.
        iii. Read the amount of oil left on top of the water. Make sure you have the oil layer level with your eye. The oil layer can have a curved shape. A close-up picture like the one shown in Figure 6 can help you make readings more accurate.

Figure 6. This close-up picture of a graduated cylinder can help determine the volume of oil left on the water. Make sure your camera is level with the oil fluid and markings on the cylinder are visible before taking a picture.

iv. Record your reading in a table similar to Table 2 in the appropriate column.
v. Add observation notes where needed. Make observations that might be important when transferring the technique to cleaning up oil on the sea.
vi. Discard the fluid from the cylinder in a cup.
vii. Wash your cylinder carefully with the warm, soapy water.
viii. Dry the inside of your cylinder with a paper towel wrapped around a drinking straw.

12. Empty your cup with the discarded fluid in a sink or toilet, and place the used petri dishes in a pile to wash later.
13. Repeat steps 8 through 12 two more times for a total of three tests for each cleaning procedure.
14. Tidy up the workspace, wash the petri dishes and cylinder, and discard all dirty paper towels and cloths as well as the pipette used to transfer the ferrofluid.
15. Analyze your data.
    a. Calculate the average volume of leftover mineral oil from the three tests and record the results in your data table.
    b. Calculate the efficiency of the cleanup procedures and record the values in your data table. If you need a refresher, look back in the Introduction tab for the definition and equations of efficiency. For your convenience, Equation 3 is repeated, with the volume of the original oil spill replaced by the amount used in this test, i.e. 2.5 mL. Use the average amount (in milliliters) of oil left over after cleanup to calculate the efficiency.

    Equation 3:

$$efficiency = 1 - \frac{\text{volume of leftover oil (mL)}}{2.5\ \text{mL}}$$

    c. Make a bar graph of the data.
        i. Make a bar graph of the volume left over for the two cleanup procedures and the control (the one with no ferrofluid).
        ii. Make a bar graph of the efficiency of each cleanup procedure and the control.
        iii. You can make your graphs by hand or use a website like Create A Graph (http://nces.ed.gov/nceskids/CreateAGraph/default.aspx) to make the graphs on a

computer and print them. You can also use a spreadsheet program like Microsoft® Excel®.

d. Does your data confirm that a ferrofluid can be used in conjunction with a strong magnet to remove an oil spill from water on the small scale tested?

16. Thoughts and conclusions.
    a. How does the control compare to the cleanup using one drop of ferrofluid and the cleanup using five drops of ferrofluid?
    b. Do you see some shortcomings to your tests? Things to think about:
        i. Does the oil left on the petri dish when transferring the fluid to the graduated cylinder influence your measurements? Would they bias your results in a systematic way? If so, do they make your efficiency look better or worse?
        ii. What does the efficiency of the control tell you?
        iii. Is it still possible to compare the control with the different cleanup methods and draw conclusions?
    c. Would you classify the method efficient on this scale? Would applying this method on a bigger scale automatically yield similar efficiencies?
    d. Which advantages, shortcomings, and points to work on did you identify for using a ferrofluid to clean up oil spills on water?
    e. In what ways could you improve the method?
    f. Seeing your results, do you think it is worth investigating the method at a much larger scale with the objective of using it to clean up oil spills at sea? Would you say specific points need to be improved and/or investigated before proceeding?