Teacher's Preparatory Guide

How can Nanoparticles move from Land to Ocean?

Overview: This lab focuses on how nanoscale pollutants on land can reach the ocean environment

Purpose: Pollution, both macroscopic and microscopic, is an important environmental issue for aquatic ecosystems. For this lab, students will model how nanoparticle pollution travels from land to water. This lab is part 1 of a 2-part series of labs designed to help students understand the effect that nanoscale pollutants have on aquatic ecosystems.

Time Required: One 55-minute class period

Level: High school -- Environmental science, life science, chemistry, and physical science

Big Ideas of Nanoscale Science and Engineering: Structure of matter, forces amd interation, and models and simulations

Teacher Background: The marine ecosystem is one of the most abundant and diverse ecosystems on earth and is directly linked to human survival. The ocean covers over 70% of earth's surface and controls the climate and wind patterns and serves as an important resource for humans[1]. Organisms from the ocean can be used for pharmaceuticals, food, fertilizer, food additives (such as in ice cream and toothpaste), and cosmetics[2]. However, marine ecosystems are experiencing great distress due to pollution resulting from an increase in human activities such as ocean dumping, coastal development, and overfishing.

Pollution has a great impact on the ocean environment. It mostly consists of synthetic materials that can migrate into the ocean from land sources (80%) and ships at sea (20%)[3]. Plastics make up 60-95% of the ocean waste and are an increasing hazard because they do not completely degrade[4,5]. While pollution is usually associated with chemical spills or large garbage masses, pollutants can also be nano-size[6]. Nano means one billionth and in this case $1x10^{-9}$ meter. Nanoparticles are too small to see with the unaided eye or even a light microscope as they are below the range of visible light. Nanoparticles, such as nanosilver, have been incorporated into consumer products and can leach into oceans from soil that was contaminated when the item was discarded in a landfill. The nanoparticles can also be created when large objects degrade into nano-size entities. Since they are not visible, they are difficult to remove with conventional pollution removal methods.

Nanoparticles pose a threat to marine organisms because the properties they were engineered to have can harm organisms and lead to an ecological imbalance. For example, silver nanoparticles are incorporated into consumer products because of silver's antimicrobial properties. When released into the environment silver nanoparticles may kill beneficial bacteria, which would disrupt the food chain. Fullerene-C_{60} nanoparticles have been shown to disrupt metabolism and inhibit growth in fish and prokaryotes, respectively[7]. Nanoparticles can travel to the ocean by a process called runoff. Runoff occurs when rainwater soaks into the ground and

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chemicals in the soil are carried downstream into lakes, streams, oceans, and ground water. A small area of contaminated soil or water could contain millions of nanoparticles which can penter and possibly damage marine habitats.

Sources:

1. *"Changing Ocean"(accessed June 28, 2011)* American Museum of Natural History. *http://www.amnh.org/exhibitions/climatechange/?section=ocean&page=climate_control*
2. "Marine Ecosystems," 2009 (accessed August, 2009) http://www.epa.gov/bioindicators/aquatic/marine.html
3. Rios, L., Moore, C., Jones, P., "Persistent Organic Pollutants Carried by Synthetic Polymers in the Oceanic Environment." *Marine Pollution Bulletin* 2007**,** 54, 1230–1237.
4. Moore, C., "Synthetic Polymers in the Marine Environment: A Rapidly Increasing Long-term Threat." *Environmental Research* 2008**,** 108, 131–139.
5. Derraik, J. G. B., "The Pollution of the Marine Environment by Plastic Debris." *Marine Pollution Bulletin* 2002, 44, 842–852.
6. "De-mystifying the "Great Pacific Garbage Patch" or "Trash Vortex"." NOAA Marine Debris Program, 2007–2008 (accessed July, 2009) http://marinedebris.noaa.gov/info/patch.html
7. Seetharam, R. N. and K. R. Sridhar (2007). "Nanotoxicity: Threat posed by nanoparticles." Current Science **93**(6): 769-770.

Materials per class:

- 10–12 lbs. of self-hardening clay
- box of gallon-size Ziploc bags
- 6 in. of thick wire (any metal, as long as it is not enameled—for the teacher only)
- 2 popsicle sticks (for the teacher only)
- 5 lb. bag of sand
- bag of teaspoons (biodegradable spoons made from potatoes work just as well as plastic)
- 25 lb. bag of colored fish tank gravel (NOT blue)
- 50 ml bottle of liquid Miracle Gro fertilizer (model of nanoparticle pollutant)
- 1 gal. distilled water per group
- *Cleanup:* a roll of paper towels
- *Cleanup:* a spray bottle of surface cleaner
- *Cleanup:* a bucket large enough to hold all used sand
- *Cleanup:* a bucket large enough to hold all used rocks
- *Cleanup:* a bucket large enough to hold commingled items (sand/rocks and fertilized water)

Materials per lab group of 3–4 students:

- block of clay (about 6 cubic in.) in a gallon Ziploc bag
- bag of small gravel (enough gravel to cover 1/2 of the aluminum roasting tray 1/4 in. deep)
- bag of sand (enough sand to cover 1/2 of the aluminum roasting tray 1/4 in. deep)
- 5 ml (1 tsp.) liquid Miracle Gro fertilizer in a small cup
- beaker with 500 ml distilled water
- 10 ml graduated cylinder
- spray bottle filled with distilled water (size doesn't matter)

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- *Optional:* rolling pin or wooden dowel
- 12 × 24 in. aluminum roasting tray (please *reuse* or *recycle* the aluminum when done)
- teaspoon
- water testing kit
- disposable plastic micropipette

Advance Preparation: Materials may be found here:

Source/Website	Material
any craft store, such as Michael's	Clay
Acquariumphar.com (http://www.aquariumphar.com) or any aquatic or pet store	fish tank gravel (no blue)
PetSmart http://www.petsmart.com/product/index.jsp?productId=2754034	water testing kits (Kits range from about $5–30. The API Freshwater Master Test Kit is recommended; it provides over 800 tests per kit.) *One kit per group is suggested.

1. ***Purchase water testing kits.***
   Purchase one kit per lab group. The vials for testing are glass, so if a vial is broken, a graduated cylinder (10 ml) can be substitute for the vial.
2. ***Make a clay-cutting tool for the teacher only.***
   Wrap one end of the copper wire around the center of one of the popsicle sticks and the other end of the wire around the center of the other popsicle stick. When done, the clay-cutting tool will resemble the capital letter H.
3. ***Cut the clay into 2-pound cubes (~6 cubic inches).***
   Cut clay using the clay-cutting tool and put each cube inside a Ziploc bag. Seal the bag to prevent the clay from drying out.
4. ***Familiarize yourself with the water testing kit instructions before class.***
   The recommended test kit is very easy. The instructions are written on each bottle. If you choose another kit, make sure you know what to do beforehand.
5. ***Label the bins/buckets for easy clean-up.***
   If you are using this just for one class, you may prefer to have students place their trays on a lab cart to expedite the clean-up process. Then, an aide or the teacher can separate the rocks/sand/clay for re-use after class. Or, label one bucket *Sand,* another *Rocks,* and the other, *Commingled items (sand/rocks/fertilizer/water).*

Safety Information: Gloves should be worn at all times. API freshwater testing kit contains chemicals that irritate the eyes and can be harmful if swallowed. Refer to the MSDS for the chemicals used. If eye exposure occurs, flush with water for 15 minutes and immediately seek medical assistance. Use the clay-cutting tool with care, it can cut your hands or fingers.

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Instructional Procedure:

Time	Activity	Goal
5 min	*Optional:* Show video: *The Great Pacific Garbage Patch—Good Morning America* http://news.yahoo.com/blogs/upshot/digging-great-pacific-garbage-patch-143049093.html	To get students thinking about how trash can get from land to the ocean.
5 min	Ask students to list or draw ways contaminants can enter the ocean from land.	Students make a prediction to demonstrate what they already know.
5 min	Explain how *runoff* fits into the water cycle. You may use the *Guided Dialog* section as a launching point for terms.	Students learn the basic terms used when describing a water cycle.
15 min	*Runoff Lab:* Students make their models.	Students will construct the major components of the runoff model.
10 min	As a class, test the water prior to the runoff for baseline measurements.	Initial measurements are needed to determine whether a change occurs.
10 min	Students simulate precipitation and runoff, test a water sample from the model ocean for its pH, ammonia, nitrates, and nitrites content. Record results.	Students model and observe precipitation and runoff. Students test the water to see whether there are pollutants in the model "ocean".
5 min	Clean up. Students put clay in Ziploc bags and seal them for the next group.	Students prepare the space to transition into their next activity.
Homework	Students analyze data on the *Student Worksheet* and draw conclusions on how pollution in our environment can contaminate our oceans. Ask them to suggest some solutions to this issue.	Students determine the effects of runoff and draw conclusions.

Teaching Strategies:

1. ***Have small lab groups of 3–4 students.***
   This activity works best in small lab groups of 3–4 students. To save time, split each group into teams of 2 students. One team will make the mountain/stream, the other team will make the beach/ocean. Together the two teams put their model together as a group.
2. ***Misconception Alert***
   We suggest using rocks that are NOT blue. In testing this lab in the classroom, some students assumed the blue rocks were the "ocean".
3. ***Water Testing Information (You may want to review with students before starting the lab.)***
   - **pH:** determines acidity or alkalinity of a substance. The lower the number, the more acidic the substance is. Pure water should have a pH of ~7.
   - **Ammonia: (**NH_3) is produced from fish through their gills and urination. It is known to be toxic to fish at about 1ppm in a freshwater environment.
   - **Nitrate: (**NO_3^-) helps prevent high levels of ammonia. Nitrate levels should not be above 40 ppm. If a higher level persists, it can cause fish disease.

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- **Nitrite: (**NO_2^-) hinders fish from normal respiration and can quickly kill them. Natural bacteria convert ammonia into nitrite. Even trace amounts are known to cause stress and disease in marine organisms**.**

Guided Dialog: *Before* beginning the lab, review the meaning of these terms:

Water cycle *The movement of water between the ocean, land, and the atmosphere.*
Precipitation *Water released from clouds in the form of rain, snow, or hail.*
Percolation *The filtration of water through rocks, gravel, and dirt.*
Condensation *The changing of water vapor into a liquid form.*
Runoff *Water or melted snow returning to a larger body of water (e.g., river, lake, ocean)*

Ask students: What are the components of the water cycle? How are these components similar? Different? *The major components of the water cycle include transpiration, evaporation, precipitation, percolation, condensation, and runoff. All components work together to circulate the water here on Earth. Transpiration and evaporation consist of pulling water from plants or bodies of water into the environment, while precipitation and condensation consist of returning the water to original sources through runoff and erosion.*

A diagram of the water cycle can be found by a Google search for "water cycle" images

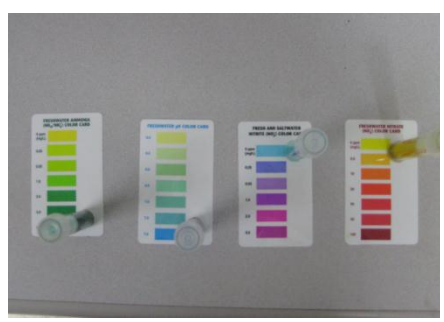
Directions for the Activity:

Procedure: a Mini-Guide

Step 1: Create a clay mountain with a river or stream.

Step 2: Add sand and rocks to each side.

Step 3: Add dried mountain on top of the rocks.



Step 4: Test the distilled water sample using a test kit for the initial, unpolluted conditions.

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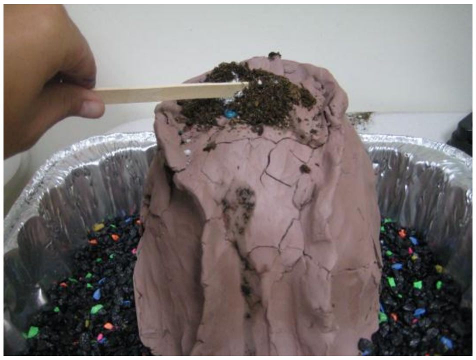
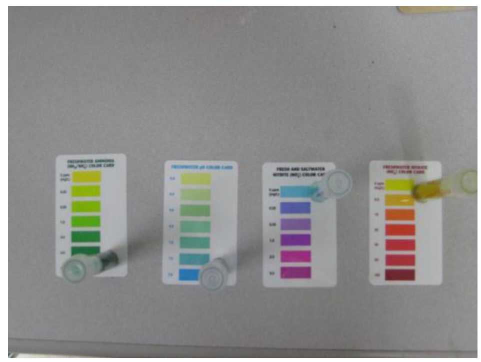


Step 5: Evenly distribute fertilizer (the “nanoparticles”).

Step 6: Spray distilled water over the mountain area 100 times.

Step 7: Pipette the polluted water sample from the “ocean” after runoff occurs.



Step 8: Test the polluted water using a test kit.

Cleanup: Students should put the clay in the plastic bag and seal it so that it does not dry out. This will allow the clay to be reused in the next class. Collect the sand in a common bucket or bin for reuse. Collect the small rocks in a separate bucket/bin for reuse. Save as much as you can in each bin that is not commingled. Collect the commingled items (sand mixed with rocks, the water mixed with fertilizer) in a separate container. These items can safely be poured over several plants that may appreciate the food. Heavily dilute water testing kit results with tap water before pouring down a sink.

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Enhancing Understanding: Cover this section *after* the activity.

pH before 6.2 and pH after 7.2 = 1 rise in pH, went from acidic to alkaline.

Nitrate before 0 ppm and after 1.5 ppm = 1.5 ppm rise in nitrate levels.

Nitrite before 0 ppm and after .1 ppm = 0.1 ppm rise in nitrites.

Ammonia before 0 ppm and after 5 ppm = 5 ppm rise in ammonia level.

The rise in all levels could affect the lives of the aquatic organisms being exposed to these toxic levels of pollutants caused by the "nanoparticles" in the water. Mass deaths of fish, aquatic plants, plankton and other sea creatures could be the result. Additionally, polluted water affects humans. If the model was a real beach, most likely it would have been closed due to the toxic readings taken.

Going Further: Students who have a good grasp of the content of the lab can be further challenged with the following:

1. Ask groups to share their data and write all data on the board. Ask: What errors could have occurred when you or other groups collected the data? How could that have varied the results of your readings? *Other groups could have mismeasured the amount of water needed for testing or added too little or too much of the drops needed to test the various levels. Also, the color of the tube of water tested is somewhat subjective, and the colors for numbers on the card could be mis-read. If one person thought the color was the same for 2 ppm and it was really closer to 3 ppm that could have affected their results.*

2. *Class debate:* One side of the class will be opposed to making any changes to our current pollution situation and the other side with be a proponent of current laws (i.e. making recycling mandatory, heavy fines for pollution, etc.).

3. *Nanoparticles*: Ask the students to discuss how this lesson is a model of nanoparticle pollution and how these particles can move from land to water. Do they see a concern with having nanoparticles in the environment? What type of nanoparticles do they think are in our environment? *Nanoparticles could be silver, carbon nanotubes, degraded plastics, toxic metals from manufacturing.*

Assessment

1. Students created a proper model to demonstrate runoff. (20 pts.)
2. Students tested the water sample collected after the precipitation using the water testing kit and recorded the results. (10 pts.)
3. Students completed the student worksheet. (20 pts.)
4. Students participated in the class debate. (10 pts.)

Resources

- Video showing information on the water cycle
  http://www.youtube.com/watch?v=QqNUTlY5foQ
- Video showing more information on runoff
  http://www.youtube.com/watch?v=DOj6OhwVHKY

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- Video: The Great Pacific Garbage Patch: http://www.schooltube.com/video/c412e0e5292291dbd194/The-Great-Pacific-Garbage-Patch-Good-Morning-America
- NOAA Marine Debris Program: "De-mystifying the "Great Pacific Garbage Patch" http://marinedebris.noaa.gov/info/patch.html
- U.S. Geological Survey: The Water Cycle http://ga.water.usgs.gov/edu/watercyclesummary.html
- Silver nanoparticles and the environment
    - http://www.ncbi.nlm.nih.gov/pubmed/21159383
    - http://www.zsf.jcu.cz/jab/6_3/havel.pdf
    - http://www.eetimes.com/electronics-news/4076753/Nanoparticles-leaching-into-environment
    - http://www.environmentalhealthnews.org/ehs/newscience/silver-migrates-from-nanoparticle-treated-fabrics/

Carbon nanotubes and environment
http://phys.org/news160726972.html
http://www.ncbi.nlm.nih.gov/pubmed/21071063

EPA reports on nanotechnology
http://www.epa.gov/ncer/nano/publications/index.html

National Science Education Standards (Grades 9–12)

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard D: Earth and Space Science
- Geochemical cycles

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards

California Science Education Standards (Grades 9–12)

Biology/Life Science, Content Standard 6: Ecology

b. Students know how to analyze changes in an ecosystem resulting from alterations in climate, human activity, introduction of non-native species, or population size.

d. Students know how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.

f. Students know at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid.

Earth Science, Content Standard 9: California Geology

a. Students know the resources of major economic importance in California and their relation to California's geology.

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c. Students know the importance of water to society, the origins of California's fresh water, and the relationship between supply and need.

Investigation and Experimentation, Content Standard 1

a. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
d. Formulate explanations by using logic and evidence.

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