Teacher's Preparatory Guide

Can Small Pollutants Harm Aquatic Organisms?

Overview: This activity focuses on how nanoscale pollutants can affect a marine ecosystem.

Purpose: Students will test the effects of silver nanoparticles on aquatic organisms and discuss the effects on a global scale. This lab is part 2 of a 2 part series of labs (see Part I: Can Small Pollutants Harm Aquatic Organisms? Lab) designed to help students understand the effects that nanoscale pollutants may have on marine ecosystems.

Time Required: **Day 1**: 45–55 minute period (introduction and lab); **Day 2**: 40 minute period (observations and nanoproducts activity); **Day 3**: 45–55 minute period (wrap-up and discussion).

Level: High school – environmental science, chemistry, life science

Big Ideas: Size dependent properties, models and simulations, science and technology

Teacher Background: Throughout history silver has been used for its antimicrobial properties. In 1200 B.C., the Phoenicians used silver containers to keep food, water, and wine from spoiling. Silver dollars were added to milk in the early 1900s to keep it fresher[1]. Before the discovery of antibiotics, silver was used to treat bacterial infections[1]. More recently, manufacturers have been using silver (ions and nanoparticles) in items such as washing machines, toilet seats, and socks to retard bacteria growth. In current medicine, a diluted solution of silver nitrate is used to protect a baby's eyes at childbirth if the mother has chlamydia or gonorrhea[1]. In 2008, out of the 600 products utilizing nanoparticles, 20% of them contained silver[2]. While silver is effective in treating ailments and retarding bacterial growth, too much silver can cause a condition known as *argyria,* which causes the skin to turn a bluish/silver hue.

Silver is usually manufactured in the form of nanosilver for consumer products. Nanosilver, shown in Figure 1, is composed of silver particles that range in size from 1- 20 nm[3]. Nano means one billionth (10^{-9}) and the particles cannot be visualized with the unaided eye. The particles can be made either by cutting a large piece of silver into nanoparticles or the combination of silver atoms into nanoparticles. The particles can exist as individual nanoparticles (Figure1B) or as a colloidal suspension (Figure 1A). The particles can be incorporated into consumer goods such as socks or used as coatings in paints or washing machines.

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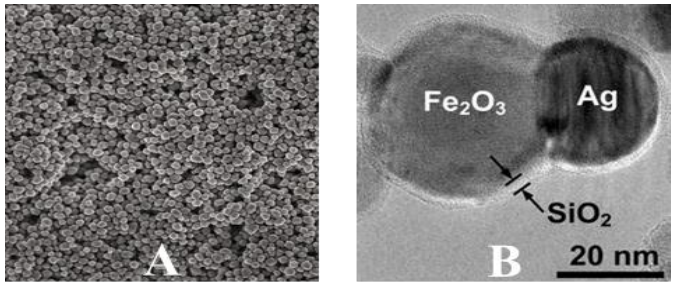

Figure 1: Pictures of a cluster of silver nanoparticles (A) and a silver nanoparticle that is coated with silicon dioxide (B)[4,5].

While silver nanoparticles have many beneficial uses, there are still concerns about its safety within the environment. For example, what happens if you wash antibacterial socks containing silver nanoparticles? A study by Arizona State University found that these nanoparticles were making their way through the wastewater treatment center, where they can enter natural waterways such as streams, rivers, ponds, lakes, and even the ocean[6]. Once in our natural waterways, can the nanoparticles effect marine ecosystems or us? If so, how could that, in turn, affect that organism and that organism's food chain? What would happen if nanoparticles are absorbed into a major portion of the ocean's plants that are at the base of the energy pyramid? These answers are unknown and are currently being researched; however, it is important to contemplate the ramifications of how we are currently using our planet's resources and the long-term effects of our choices.

Sources

1. "The Antibacterial Effects of Silver and Its Compounds" (2009) (accessed August, 2009) http://www.saltlakemetals.com/Silver_Antibacterial.htm
2. Bland, Eric. "Nanotech Raises "Toxic Sock" Alert" (2008) (accessed August, 2009) http://www.abc.net.au/science/articles/2008/04/10/2213433.htm
3. http://www.nano-silver.com/ (accessed August 2011)
4. http://theholisticdentist.files.wordpress.com/2010/07/nanosilver.jpg
5. http://www.ethlife.ethz.ch/archive_articles/110512_Plasmonischer_biosensor_su/index_EN
6. "Nanoparticle Silver is Mainstream, but are Those Socks Really Toxic?" (2008) (accessed August, 2009) http://www.rdmag.com/News/2008/04/Nanoparticle-silver--is-mainstream,-but-are-those-socks-really-toxic-/

Additional References

1. Inspiration for this lab was drawn from an experiment done by a 13-year-old, Eric, which can be found at the link below (accessed August, 2009) http://www.amnh.org/learn-teach/young-naturalist-awards/past-winners/2008/investigating-the-effect-of-silver-nanoparticles-on-aquatic-organisms

- **Materials per group of 3–4 students**
- gloves
- 6 glass specimen vials
- 6 nickel-sized round labels
- distilled water
- graduated cylinder

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- disposable pipette
- a tsp. of colloidal silver (550 ppm) in a cup
- a permanent® marker
- a cup of California Blackworms (about 20 worms/group)
- 2 popsicle sticks
- 2 toothpicks
- a cup containing 3 pieces of *Elodea* plant, each piece about 3 cm long
- 10 ml graduated cylinder
- paper towels
- a 250 ml beaker with ~100 ml distilled water

Advance Preparation Materials may be purchased or ordered from:

Items	Source
California Blackworms *(To avoid worm deaths, worms need to be refrigerated and rinsed daily in water to keep for 7–10 days—no food required.)*	local aquatic store (~ $4–5/oz.)(1 oz. contains several thousand worms) or **Aquatic Foods** (http://www.aquaticfoods.com/worms.html)
Elodea plants *(Need sunlight and water to survive.)*	local pet or aquarium store (~ $4–5 per bunch) (1 bunch is enough for 1 class of 35–40 students.)
Colloidal Silver *(Store in a cool dark place, such as inside a classroom cabinet. Do not store in the refrigerator or freezer.)*	local health food store or Internet This lab was tested using Natural Path Silver Wings brand at 500 ppm concentration. (One bottle should suffice for several classes.)

Safety Information: Students should wear gloves at all times to prevent contamination.

Instructional Procedure

Time	Activity	Goal
Day 1		
5 min	*Warm-up:* Have students draw an energy pyramid and label each trophic level.	Students review trophic levels: producers, primary consumers, secondary consumers, tertiary consumers
5 min	*Class discussion:* Discuss silver nanoparticles and colloidal silver. Ask students to predict the affects of the silver dilutions on the aquatic organisms.	Students will make an educated guess based upon their knowledge of the ecosystems and how a contaminant like silver may affect the aquatic organisms.
5 min	Show this video on the *Blue Man*: http://abclocal.go.com/kfsn/story?section=news/local&id=5843725	Students can see the effects of colloidal silver on a human who used a lot for a long time.
25 min	*Lab: Aquatic Organisms and Silver*	Students will cultivate their lab skills.
5 min	Students put their vials in a box and store the *Elodea* near a window and the worms inside, not in direct sunlight.	Students prepare the space to transition into their next activity.

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Day 2		
5 min	*Warm-up:* Create a food chain using: Elodea, Shark, Seal, and Small Fish.	Students review how *Elodea* fit into the big picture.
10 min	*Observe/Record:* aquatic organisms.	Students will record observations of the aquatic organisms.
30 min	*Nanoproducts Activity:* www.nnin.org/nnin_k12nanotechproducts.html Use products with silver nanoparticles.	Students create a commercial of the current products on the market that contain silver nanoparticles.
Day 3		
5 min	*Warm-up:* Explain the difference between an *autotroph* and a *heterotroph.*	Students review vocabulary terms.
10 min	*Observe/Record:* aquatic organisms.	Students will record observations of the aquatic organisms.
30min	*Lab:* Analysis and Conclusions.	Students analyze their data and draw conclusions.
5 min	Clean up.	

Teaching Strategies

1. ***Have small lab groups of 3–4 students.***
   This lab works best in groups of 3–4 students (depending on class size).
2. ***Review basic background knowledge.***
   Students should understand how energy/food cycles through a food web and the water cycle.
3. ***Misconceptions Alert***
   - During the lab, remind students that **C** is for **Control,** NOT colloidal silver.
   - Some students may have the misconception that the worms die due to lack of food. Blackworms eat phytoplankton and tiny marine organisms and can go 7–10 days without food. Point out that the California Blackworms used in this lab are not in the same food chain as the *Elodea* plant.
   - Some worms may appear dead and are still living. Remind students to lightly shake the vial and look at the worms for at least 20 seconds before recording their observation.

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

Community *All of the populations of different types of producers and consumers living in the same place.*
Trophic levels *Each step in the transfer of energy and matter in a community.*
Producers *Plants that make the food for the entire community.*
Consumers *Organisms that obtain food by eating other organisms.*
Food chain *The sequence of organisms through which food passes in a community.*
Example: grass ⇒ grasshopper ⇒ lizard ⇒ bird…
Food web *All of the interconnected food chains in an ecosystem (arrows go from energy source to the consumer).*
Elodea *Also known as the aquatic weed; serves as a habitat to young fish and invertebrates.*
Blackworms *Found in North America and Europe; used as food for freshwater fish.*
Nano *A billionth of; 1 nanometer = 1 billionth of a meter.*

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Colloidal silver *Silver nanoparticles suspended in water that is used orally and topically to cure many ailments.*
Autotroph *An organism that uses sunlight to make its own food (for example, Elodea).*
Heterotroph *An organism that must eat another organism to obtain energy (i.e, worms).*

Ask students to describe the transfer of energy within an energy pyramid. *Plants are always the first organism within a food chain and obtain their energy from the sun. When the plant or organism is consumed, energy passes to the next organism. 90% of the energy is lost as it passes on to the next level; therefore, 10% is passed on to the organism consuming the prey.*

Procedure Checkpoint

Vials containing *Elodea* plant pieces

Vials containing worms

Cleanup:

First Day: Students put their vials in a box and store near a window but not in direct sunlight.

Last day: Since colloidal silver is an over the counter product, you may dilute the solution to less than 0.47 ppm and pour the contents down the drain. Please contact your local hazardous waste department or consult with your district for proper disposal. Vials can be re-used after they are cleaned with water.

Going Further: In the testing phase of this lab, we also experimented with 20 ml industry-grade aqueous solution of silver nanoparticles (10 nm in size), which gave similar results to the colloidal silver. This makes sense—true colloidal silver (pure silver particles suspended in water) ranges from 0.001–0.01 microns, which equals 1–10 nanometers (nm) in size. Industry-grade nanoparticles can cost nearly $300 for 20 ml, whereas colloidal silver costs about $10-20 for a 4 oz. bottle. We also tested this lab using silver nitrate, a larger form of silver.

An extended activity could be to make silver nanoparticles using silver nitrate and run the experiment again to compare, or test with silver nitrate and see its effects. The lab at the following link (used with high school students) is an inexpensive way to make silver nanoparticles: http://www.juniata.edu/services/ScienceInMotion/chem/nano.html

Assessment
Completion of:

- lab portion = 25 points (must participate equally within the lab group)

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- student worksheet = 35 points (each question is worth 5 points)

Resources

- Video on how colloidal silver turned a man's skin blue http://abclocal.go.com/kfsn/story?section=news/local&id=5843725
- Jean-Michel Cousteau's Ocean Futures Society http://www.oceanfutures.org/
- NOAA Marine Debris Program: "De-mystifying the "Great Pacific Garbage Patch" or "Trash Vortex"" http://marinedebris.noaa.gov/info/patch.html
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- The Great Pacific Garbage Patch: http://www.schooltube.com/video/c412e0e5292291dbd194/The-Great-Pacific-Garbage-Patch-Good-Morning-America
- Heal the Bay http://www.healthebay.org
- U.S. Geological Survey: The Water cycle http://ga.water.usgs.gov/edu/watercyclesummary.html
- Jean-Michel Cousteau: Ocean Adventures: "Call of the Killer Whale" video (2 hrs. on PBS or available for purchase on PBS website: http://www.pbs.org/kqed/oceanadventures/)
- 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/

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 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 changes in climate, human activity, introduction of nonnative species, or changes in 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.

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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.
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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