NanoSilver Socks Demonstration

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Arizona Science Center

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Summary: Increasingly corporations are putting nanoparticles into every day objects to enhance their functioning. Rarely, however, can these particles be easily observed. “Nanosilver Socks” is a quick hands-on demonstration that shows the presence of nanosilver particles in consumer goods as well as wastewater.

Big Idea: Nanoparticles are being put into everyday objects and then get washed into wastewater and our environment.

Learning Goals:

Nanoparticles are not visible, but their presence can be measured.

Convey an understanding of how scientists collect and analyze data.

[If the demonstration is paired with a discussion it is possible to additionally convey the following learning goals:]

Nanoparticles may be put into consumer products, but they are often released into the environment as well.

There are some potential environmental and health consequences of using products that contain nanoparticles.

Program length: 5 minutes per set of readings.

Background Information:

Manufacturers are using nanosilver in a number of products (including clothing, cosmetics, toothpaste, coatings, would dressings, paints, kitchenware, and others) because at the nanoscale a small amount of silver can kill a large amount of bacteria. The nanosilver can kill bacteria that cause disease as well as bacteria that generate unwanted odors.

For instance, a few hundred micrograms of nanosilver particles can be woven into the fibers of socks and can both curb athlete's foot and eliminate foot odor. It can be difficult, however, to keep the nanosilver attached to the sock. When the socks are washed, some of the nanosilver particles are washed out and end up in the wastestream. This silver can then be measured (which is the technical part of this demonstration). They continue to have their antimicrobial properties (killing useful microbes as well as harmful microbes) as they are distributed throughout the environment. One place where bacteria are very helpful is in wastewater treatment systems where we use bacteria to clean wastewater.

Materials:

Sock with nanosilver – A number of products on the market are made with fabrics enhanced with nanosilver. The trick to making this demonstration work is to use a piece of fabric that releases its silver into water quickly. Some products do this much more than others. We found that a fuzzy "lounging sock" sold by Sharper Image released enough silver to produce a measurable signal on reasonably simple instruments. Unfortunately Sharper Image no longer sells that product. But other products may work just as well. We suggest trying a few different products to see which give the best readings before the demonstration.

Other nanosilver enhanced products – There's no reason to use socks specifically except that they are a nice size for an average beaker and they're common enough that people readily identify with them. In addition to socks it would also be possible to use shirts, shampoos, soaps, cosmetics, and toothpastes that also contain nanosilver. A good place to start is the Project on Emerging Nanotechnologies product inventory [http://www.nanotechproject.org/inventories/consumer/]

Sock (or other product) without silver – This is optional but does help to emphasize the difference between products by using a product that does not contain silver.

Ion selective electrode probe (ISE probe) – This is the most important part of the set up. Unfortunately it is also pretty expensive. ISE probes are made out of both plastic and glass. If you hope to allow children to be more hands on with the probe we highly recommend you use a plastic probe as it will be much less likely to break. [You can purchase an ISE probe (EW-27504-28) from Cole-Parmer scientific equipment catalog for $205]

pH meter – This links up with the ISE probe and has a digital readout so that you can quickly see the quantity of silver in the water. [You can purchase a YSI pH meter (EW-59351-00 for $240 from Cole-Parmer]

Two beakers – Ideally you should use clear plastic beakers. Again, this is to reduce the possibility of breakage. It is good to have clear ones, however, so that the audience can easily see the socks. It's probably best not to use too big a beaker. One liter beakers work pretty well for socks.

Shaker table – This is optional. It's just as easy to shake the beaker by hand. But the table does add a nice visual (and sound) effect and makes the experiment look more scientific. Do make sure there is some adhesive on the top of the table to help make sure the beakers adhere to it.

Distilled water – the purity of the water is necessary so that there are no interferences with the probe.

Lab book – One way to bring this experiment to life more for children is to have them actually record the readings in a lab book. Again, this is optional.

Presenting a program:

Set up time: 10 minutes

Program time: 5 minutes (This would be the time for one set of readings. Total time depends on how many readings and how many deputized "scientists" you'd like to have)

Clean up time: 5 minutes

Safety: The primary safety concern occurs when you stir the probe in the beaker. If both are made of glass there is a danger that one or both could break. Using materials made out of plastic should reduce these risks. If the shaker table does not have a sticky surface, the beakers could fly off it. The dangers generated from exposure to nanosilver particles are unknown.

Procedure:

Pour distilled water into two beakers (enough water to submerge the product).

Put the nanosilver sock into one of the beakers and a regular sock in the other beaker (if you are using two).

Set them on the (optional) shaker table. Set shaker table at a low rpm level – fast enough to agitate the water, but not so fast that things go flying.

Plug ISE probe into pH meter and set meter to millivolt mode.

Put probe into beaker with sock without nanosilver and record millivolt reading. (If you are not using a sock without nanosilver, take a baseline reading of distilled water.)

Put probe into beaker with nanosilver sock and record reading. The demonstration is working when you can see a higher millivolt reading with the nanosilver sock.

Troubleshooting: The number one issue with this program is finding a material that easily releases silver into distilled water. If you use tap water or any water that has chloride ions in it, the silver will bond with the chloride ions and not be measurable. There's also a chance that other substances released by the product could also bond with the silver or interfere with the probe. It may take a bit of trial and error to find a product that clearly produces results. The specific probe you use should come with a manual describing different chemicals that may interfere with it functioning properly. If you don't get a reading, make sure your pH meter has batteries in it!

Discussion: This demonstration frequently leads to a number of questions. Below are some example answers to common questions.

What is the benefit of having silver in any product?

> Manufacturers claim that silver prevents the growth of odor causing bacteria as well as dust mites, mold, and fungus.

If the silver comes off, will the socks no longer be antimicrobial?

Over time and after several washings the silver can be washed out of the sock and it will lose its antimicrobial properties. Some companies say their socks are good for 20 washings, some say 100 washings.

Is silver in water bad?

Silver has been shown to have adverse effects on many aquatic organisms (i.e. fish and insects). The effects are dependent, however, on the concentration of silver in the water. Just a little silver will likely not have much effect. The effects also depend on whether or not the silver bonds with other elements. If it is free floating it is much more likely to be harmful to aquatic animals, but, for instance, if it bonds with chloride it settles and would have little effect.

Where does the silver go?

Generally waste water from your house enters a municipal wastewater treatment system. From there the silver does one of two things. One, it can pass through the treatment and be reintroduced into lakes and streams with the rest of the water. Or two, it settles into the sludge produced by the wastewater treatment. This sludge is often used as fertilizer, therefore the silver ends up in soil used for farming.

Is there an environmental risk of using silver?

There are three places where there are potential safety or health issues. The first risk occurs when people have direct contact with the nanosilver. We know that silver is very good at killing bacteria. We don't know what effect it has on our health. The second risk occurs when silver passes through a wastewater treatment system into lakes and streams. When fish and other animals are exposed to it it can negatively impact their health. The third risk occurs when silver ends up in the soil after being discarded by the wastewater treatment plant. Scientists are studying all of these questions so that we can know more about the effects and risks of nanosilver and other nanoparticles.

Is the risk worth the benefit?

This depends on your specific point of view. For some people smelly feet don't cause a huge problem. For others, however, keeping feet free of bacteria is very important. For example soldiers in the field for extended periods of time and without easy access to doctors could benefit greatly from having clean socks. Diabetics have difficulties healing. If they get a foot infection there is a much higher chance than for other people that they may have to have toes or even feet amputated. In these cases it might be worth increasing the environmental and health risks. The fact is that right now we don't know the full extent of the dangers of nanosilver. Some people think that clean smelling feet aren't worth the risks that nanosilver socks generate.

Is there any regulation of (nano)silver?

The Environmental Protection Agency (EPA) does regulate pesticides and in at least a couple cases has looked into companies selling products with nanosilver designed to kill bacteria. There are hundreds of products, however, that have not been addressed by the EPA. The EPA does try to limit the amount of silver in our natural waterways and set standards for how much silver can be released into lakes and streams.

[See attached posters for additional information.]

Going further:

If you borrow a silver probe from someone who has used it before they may have created a calibration curve. Using this curve, you would be able to determine the actual concentration of silver in the water based on the millivolt readings from the pH meter. You can then use this concentration multiplied by the volume of water to give you the total mass of silver released by the sock.

Additional articles:

Troy M. Benn and Paul Westerhoff, "Nanoparticle Silver Released into Water from Commercially Available Sock Fabrics," *Environmental Science & Technology*, **2008**, *42* (11), pp 4133–4139. [http://pubs.acs.org/doi/abs/10.1021/es7032718]

"As Nanotechnology Goes Mainstream, 'Toxic Socks' Raise Concerns; Unknown Risks from Nanosilver Cited," Science Daily, April 7, 2008. [http://www.sciencedaily.com/releases/2008/04/080406175050.htm]

Woo Kyung Jung, et al., "Antibacterial Activity and mechanism of Action of the Silver Ion in Staphylococcus aureus and Escherichia coli," *Applied and Environmental Microbiology*, April 2008, pp. 2171-2178.