ANTIMICROBIAL PROPERTIES OF SILVER NANOPARTICLES

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ABSTRACT

Many people are threatened by the idea of harmful bacteria in their environments. To address this fear, some companies have begun adding silver nanoparticles to everyday items, with the claim that the silver nanoparticles inhibit the growth of bacteria. Silver nanoparticles have now been added to a wide range of consumer products and these types of products are increasing rapidly in availability. In this activity, students explore silver nanoparticles and their effectiveness against bacterial growth in hands-on laboratory activities. First, students

make silver nanoparticles in a safe and simple lab, then use their nanoparticles in an experiment that they have designed themselves. Their experiments test the effectiveness of the nanoparticles as antimicrobial agents. This activity has been designed to stand-alone or to be used in conjunction with other silver nanoparticle-based activities.

MODULE OBJECTIVE

After making silver nanoparticles in a laboratory activity, students design an experiment to determine if silver nanoparticles are effective at inhibiting the growth of bacteria.

MODULE DATA

Keywords: antimicrobial, silver, nanoparticles, experiment, products

Type of activity: Laboratory

Time required: 2 or more class periods

Pre-requisite knowledge: Basic general science

Target grade level: Secondary

MatEd CORE COMPETENCIES COVERED

0. B	Prepare Tests and Analyze Data
1. C	Demonstrate Laboratory Skills
5. A	Apply Safe and Environmentally Appropriate Methods to Chemical Handling
7. M	Illustrate the Nature and Behavior of Emerging Materials Technologies
8. A	Demonstrate the Planning and Execution of Materials Experiments
16. A	Distinguish Effects of Processing Variables on Materials Properties

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EQUIPMENT AND SUPPLIES NEEDED

Students use easily sourced materials and equipment to conduct this straightforward lab. For detailed information about conducting the activity with your students, please go to https://nano-cemms.illinois.edu/materials/antimicrobial_silver_desc.

CURRICULUM OVERVIEW AND NOTES FOR THE INSTRUCTOR

Silver nanoparticles, which some companies promote as inhibiting the growth of bacteria, are becoming a popular addition to numerous products on the market, including sporting apparel, baby items, kitchen supplies, bed sheets, washing machines, and more. Indeed, silver has been known for centuries as having an antibacterial property, which may have something to do with the phrase, “born with a silver spoon in his mouth.” Babies who ate with silver spoons may have been in better health than those who did not, due to the antimicrobial properties of the silver. The small size of silver nanoparticles, combined with their resulting greater surface area compared to mass, allows the silver nanoparticles to be integrated into products at a relatively low cost. The question is: do the silver nanoparticles in the products really keep bacteria from growing on them as some companies claim?

In this activity, middle school or high school students determine if this claim is valid based on the evidence of a safe and straightforward scientific experiment in which they test the effectiveness of silver nanoparticles as an inhibitor of bacterial growth. Students first make the silver nanoparticles by heating silver nitrate and sodium citrate solutions in a test tube in a water bath. After cooling, the resulting yellowish silver nanoparticles are soaked in cut filter paper for later testing. In the next part of the activity, students design an experiment that tests the effectiveness of the silver nanoparticles, determining their own controls. Students begin by inoculating agar plates with a harmless strain of E. coli. Then they determine which controls to include in their experiment by deciding which substances to add to the quadrants of the agar plates. For example, one student might add silver nanoparticle-soaked filter paper to one quadrant of the agar plate, water-soaked filter paper to another, a plain filter to another, and nothing at all to another. One of the quadrants should contain the silver nanoparticle-soaked filters, but the other three can contain options of the students' choosing (other choices include isopropyl alcohol, hand sanitizer, soap, etc.). After adding the various filters, students store the plates in an incubator at 37° C (human body temperature) for 24 hours. Plates can be examined after 24 hours and conclusions drawn about the silver colloid's effectiveness in inhibiting bacterial growth.

Normally, bacteria growing on an agar plate will produce colonies, areas of growth of a large number of bacteria originating from a single cell. If these colonies start close enough and grow together, they produce a lawn, which covers the surface of the plate. Where the silver nanoparticle-soaked filters have been placed, there should be a "halo" of inhibition surrounding the filter, since the silver nanoparticles diffused out of the filter paper and inhibited the growth of the bacteria in this zone of inhibition. Colonies or a lawn should be apparent on most of the agar, but not seen 1-2 millimeters around the edge of the silver nanoparticle-soaked filters. Students will discover that other substances may also produce a zone of inhibition, but not all will. This activity is described more fully in an April/May 2008 article in *The Science Teacher*.[1] Please visit this website to access a teacher guide, presentation, procedure, worksheets, and more for this activity: https://nano-cemms.illinois.edu/materials/antimicrobial_silver_desc.

Additional activities can be used in connection with this lab to increase knowledge of silver nanoparticles and related issues. Before actually conducting the lab, students can become familiar with the numerous products containing silver nanoparticles and present their research to the class. A list of the known products containing silver nanoparticles can be found at www.nanotechproject.org. Then this lab can be conducted as a means of determining if the claims the companies are making are justified. After doing the lab, students can then focus on the societal implications of the use of silver nanoparticles in a Jigsaw activity that focuses on the benefits and unintended consequences of using silver nanoparticles in a washing machine that releases silver nanoparticles onto clothes. Students suppose that a hospital is considering using these washing machines and take on a variety of character roles to research, examine, and discuss this issue. These three connected activities have been well-developed by Nano-CEMMS and have been published in *The Science Teacher* and *Exemplary Science for Resolving Societal Changes*[1][2] All of these activities are discussed in great detail, with accompanying handouts, worksheets, teacher guides, etc. at https://nano-cemms.illinois.edu/materials/silver_social_issues_desc.

These activities come out of the field of nanotechnology. Nanotechnology is an interdisciplinary area of science and engineering that involves the manipulation of matter at the atomic or molecular level. One nanometer is one billionth of a meter and a human hair is about 100,000 nanometers in diameter. This field has the potential to revolutionize many areas, including energy, medicine, defense, and more. The "Antimicrobial Properties of Silver Nanoparticles" activity may also be integrated with other nanotechnology based activities that can be accessed at https://nano-cemms.illinois.edu/materials.

MODULE PROCEDURE

Procedures are discussed in the previous section. To learn more about the other silver nanoparticles activities, please see the articles in *The Science Teacher* and *Exemplary Science for Resolving Societal Changes*[1][2]. The information can also be accessed here: https://nano-cemms.illinois.edu/materials/silver_social_issues_desc.

ACKNOWLEDGEMENTS

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DISCLAIMER

At the date this paper was written, the URL link referenced herein was deemed to be useful supplementary material to this paper. The authors do not warrant or assume liability for the content or availability of the URL referenced in this paper.

REFERENCES

1. Muskin, J., Wattnem, J., Ragusa, M. and Hug, B., "Real Science or Marketing Hype: Student-Designed Experiments Test the Antimicrobial Effects of Silver Nanoparticles," *The Science Teacher*, 75(4), 57-61 (2008).

2. Muskin, J., Wattnem, J., and Hug, B., "Linking Science, Technology and Society by Examining the Impact of Nanotechnology on a Local Community," *Exemplary Science for Resolving Societal Changes*. Edited by Robert Yager, p83-92 (2010).

3. Nano-CEMMS/Antimicrobial Silver: https://nano-cemms.illinois.edu/materials/antimicrobial_silver_desc

4. Nano-CEMMS/Materials: https://nano-cemms.illinois.edu/materials

5. Nano-CEMMS/Silver Social Issues: https://nano-cemms.illinois.edu/materials/silver_social_issues_desc

EVALUATION PACKET

Student evaluation questions (discussion or quiz):

1. Draw the quadrants of the petri plate and describe any bacterial growth that you observe in each quadrant.

2. If you observe any differences in growth of bacteria between the sections, provide an explanation for these differences.

3. If you could conduct the experiment again, what would you change? What would you do the same?

4. Some companies that are using silver nanoparticles in their products claim that the products have antimicrobial properties. Are their claims justified?

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the lab work as presented? Did it add to student learning? Please note any problems or suggestions.
4. Was the background material sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the exercise generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the module clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. What was the most interesting thing that you learned?