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SILVER NANOPARTICLES GREEN SYNTHESIS: WHAT IS GREEN AND SAFE FOR SCIENCE EDUCATION?

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INTRODUCTION

Nanoparticles are 1-100 nm in diameter and exhibit unique properties. These properties make nanoparticles widely used in various industries and consumer products. However, silver nanoparticles have raised cause for concern as they are biologically active, making them potentially toxic. The green synthesis of silver nanoparticles can be made safer with the use of plant extracts (Banerjee et al., 2014; Zhang, Liu, Shen, & Gurunathan, 2016), and designing less hazardous synthesis is included in the 12 principles of green chemistry (Anastas and Warner, 1998).

We developed a workshop to help students better understand green chemistry via nanochemistry, chemical safety and green synthesis with watermelon rind extract in a practical laboratory setting based on authentic scientific work by Ndikau, Noah, Andala, & Masika (2017). To assess the workshop, a questionnaire was designed to measure student interests, attitudes and understanding of the new concepts.

The workshop was piloted in the ChemistryLab Gadolin (part of LUMA Centre Finland) a versatile learning environment for schools that supports teaching and promotes learning and interest in chemistry. Sustainability, including the 12 principles of green chemistry, is the main theme of all activities in the ChemistryLab.

METHOD

Upper secondary students were taught at ChemistryLab Gadolin to synthesise silver nanoparticles and assess their formation with UV-VIS spectroscopy and optimal reaction conditions with the use of graphs from Ndikau et al.'s (2017) results. Then students compared the green synthesis method and conditions to a commercial less green synthesis, and discussed the importance of chemical safety, environmental and health implications of industry and other sustainability aspects in chemistry.

The synthesis begins with the extraction of polyphenols from watermelon rind by boiling 100 g of grated watermelon rind with 400 ml of deionised water. The mixture is filtered, and 50 ml of extract and 40 ml of 0,001 M silver nitrate solution are poured into 200 ml of deionised water. The solution is made strongly basic with NaOH (pH>10) and heated to +80 Celsius for 3 minutes. This method forms spherical silver nanoparticles of roughly 20 nm in diameter. The formation of silver nanoparticles can be observed when the solution exhibits a colour change from clear to yellow to brown (Figures 1 & 2).

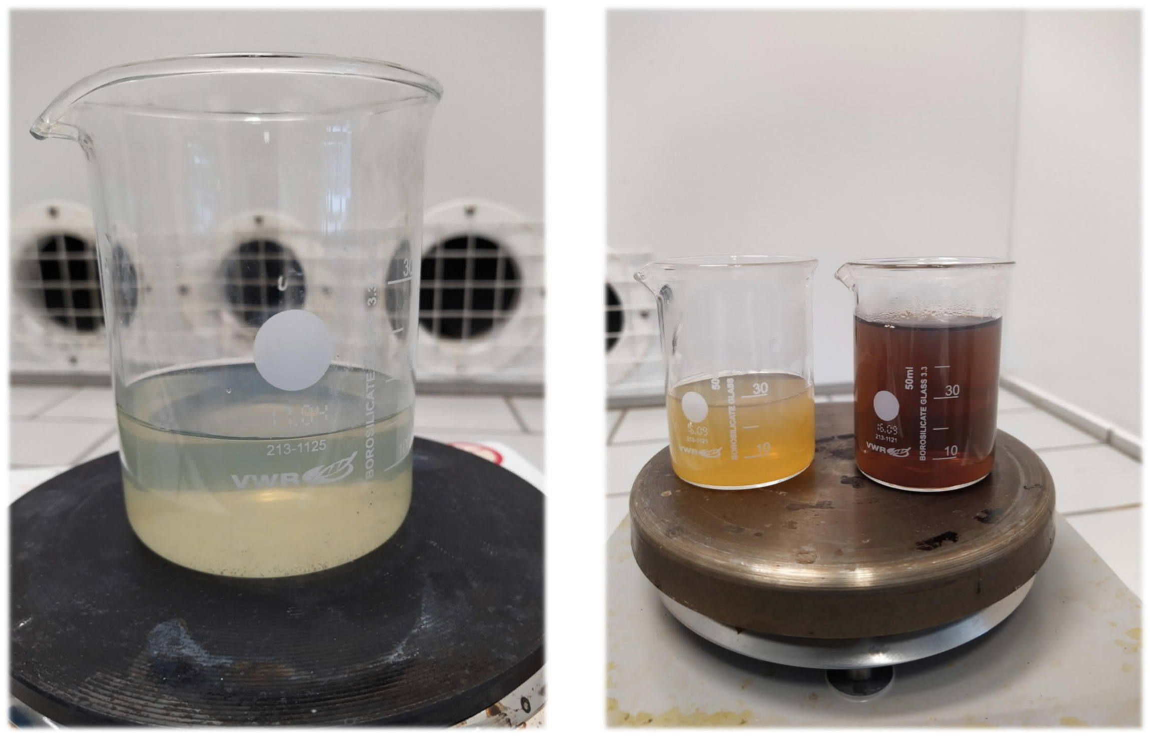

Figure 1 & 2. On the left, the extracted and filtered watermelon rind extract is presented. On the right, two different samples of silver nanoparticles are presented exhibiting the spectroscopic phenomenon: localised surface plasmon resonance (LSPR).

RESULTS

At the end of the workshop, Students' (N=7) attitudes, understanding and interests' regarding nanochemistry, chemical safety, spectroscopy and green chemistry were measured using a 5-point Likert scale questionnaire.

Table 1. Results of the questionnaire.

Question or statement	Mean (N = 7)	SD
How interesting was the experiment?	3.857	±0.639
How meaningful is the green synthesis to society?	3.7142	±1.03
The experiment helped me to understand spectroscopy.	3.857	±0.83
The experiment helped me to understand green chemistry	3.571	±0.50
How interesting do you find nanochemistry to be?	4.1428	±0.83
How important is it to understand the environmental and health impacts of nanoparticles?	4.2857	±0.88
I learned new things about nanochemistry and nanomaterials.	4.000	±0.76
I learned new things about chemical safety and the environment.	3.4285	±1.18
I felt the laboratory experiment was safe regarding nanoparticles and materials. [Y] = Yes, [N] = No	Y =7 N = 0	-

The Likert-scale had the following values: 1 = totally disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, and 5 = totally agree. Standard deviation and mean were calculated based on the 5-point scale.

The first positive result was that the students felt safe working in the laboratory. Other results indicate that students were interested in nanochemistry and viewed silver nanoparticle chemical safety as important for health and the environment. On the other hand, students were divided in their understanding regarding green chemistry, chemical safety and spectroscopic analysis.

DISCUSSION

The large SDs are attributed to the small sample size and make it hard to draw clear conclusions about the data. A revised questionnaire and a larger sample size for the workshop are future goals of this project, as well as thematic interviews about green chemistry and chemical safety. The objective is to understand better (1) What interest do students have in green synthesis of silver nanoparticles? (2) What relationship do students' characteristics have with personal interests regarding green synthesis, green chemistry and chemical safety? (3) How do students perceive green synthesis to better chemistry and chemical safety?

These research questions help us understand how to approach chemical safety and green synthesis in science education. The discussion of silver nanoparticle safety is confronted from a novel, green synthesis perspective challenging notions about nanoparticles and chemical safety in society while also acknowledging the real environmental impact and hazardous characteristics of nanoparticles towards health.

REFERENCES

Anastas, P. T., & Warner, J. C. (1998). *Green chemistry: Theory and practice*. Oxford: Oxford University Press.

Banerjee, P., Satapathy, M., Mukhopahayay, A., & Das, P. (2014). Leaf extract mediated green synthesis of silver nanoparticles from widely available Indian plants: Synthesis, characterization, antimicrobial property and toxicity analysis. *Bioresources and Bioprocessing*, *1*(1), 3. https://doi.org/10.1186/s40643-014-0003-y

Ndikau, M., Noah, N. M., Andala, D. M., & Masika, E. (2017). Green Synthesis and Characterization of Silver Nanoparticles Using Citrullus lanatus Fruit Rind Extract. *International Journal of Analytical Chemistry*, *2017*, 8108504. https://doi.org/10.1155/2017/8108504

Zhang, X.-F., Liu, Z.-G., Shen, W., & Gurunathan, S. (2016). Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. *International Journal of Molecular Sciences*, *17*(9). https://doi.org/10.3390/ijms17091534

Kemianluokka Gadolin