



## Reducing Water Contamination through Nano-Particle Solar Photocatalysis

**Subject:** Using photons to gather energy to purify water (QESST Testbed 3: Sustainability Pathways for TW PV); partner-developed solar lesson

**Grade Levels:** 5th–11th

**Lesson length:** 15 to 40 minutes

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In this lesson, participants explore how solar energy can be used in water treatment processes. According to the World Health Organization (WHO), 1.1 billion people around the world do not have access to safe drinking water. Often local water supplies are contaminated with chemicals or harmful microorganisms. Many effective means of treating water require expensive equipment or processes that are not available. One way to clean contaminated water is through solar disinfection, exposing the water to sunlight for 24 hours. The energy of the solar radiation destroys the contaminants, making the water safer to drink. But this process is slow and not very effective. Engineers have improved on this process for cleaning water with titanium dioxide. The purification process can be improved (made faster and or effective) using a photocatalyst, a substance that speeds up a reaction by absorbing light particles (photons) and passing on energy to other molecules. One cheap and abundant photocatalyst is titanium dioxide (TiO<sub>2</sub>), a semiconductor that can absorb photons and use them to mobilize its own electrons. Titanium dioxide is safe, cheap, relatively abundant, and

found in many everyday substances (e.g., paint, plastic, toothpaste). Photocatalysis work best with nano-structured titanium dioxide (particles about 14–21nm).

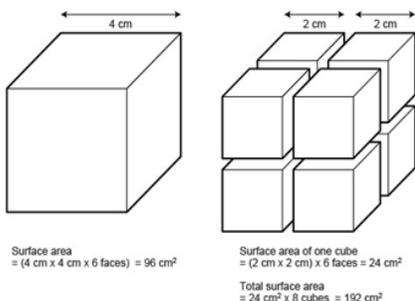
This activity is intended to help participants understand nanotechnology by enacting a model that demonstrates the power of nanotechnology for increased surface area for adsorption and light capture. Nanotechnology focuses on using particles between 1 and 100 nanometers, which are called “nanoparticles.” A small cluster of nanoparticles can have the same volume as a regular particle. However, because there are more nanoparticles than there is one regular particle, the surface area is increased, meaning the cluster will absorb more photons than one particle. These photons are then used to elevate atoms from the valence band to the conduction band. For this activity, the relationship of the particle/nanoparticle sizes and their effectiveness in treating water and the energy needed to treat water will be explored. This activity is designed for 4–8 participants with 1–2 instructors.

## Objectives

- *Learn how the size of nanoparticles affects their efficiency in photon absorption.*
- *Understand the importance of nanotechnology and water treatment.*
- *Participants learn about novel techniques to treat water, and how engineers are applying nanoscience for new applications.*
- *K–12 students apply science knowledge about surface area to a hands-on demonstration that proves conceptual properties.*

## Materials

- Velcro-covered cubes: 1 large, 8 small; large should have same volume as small when small are put together in the same shape. Note: if possible, the small together should weigh more than the 1 large.
- Pom-poms/fuzzy balls to representing photons
- 1 large tray to hold the pom-poms
- Poster explaining the process of nano-enabled photocatalytic water treatment



## Set up

Set up with the pom-poms scattered around in the tray and the small cubes are connected to a size roughly the same as the large cube.

## Instructions

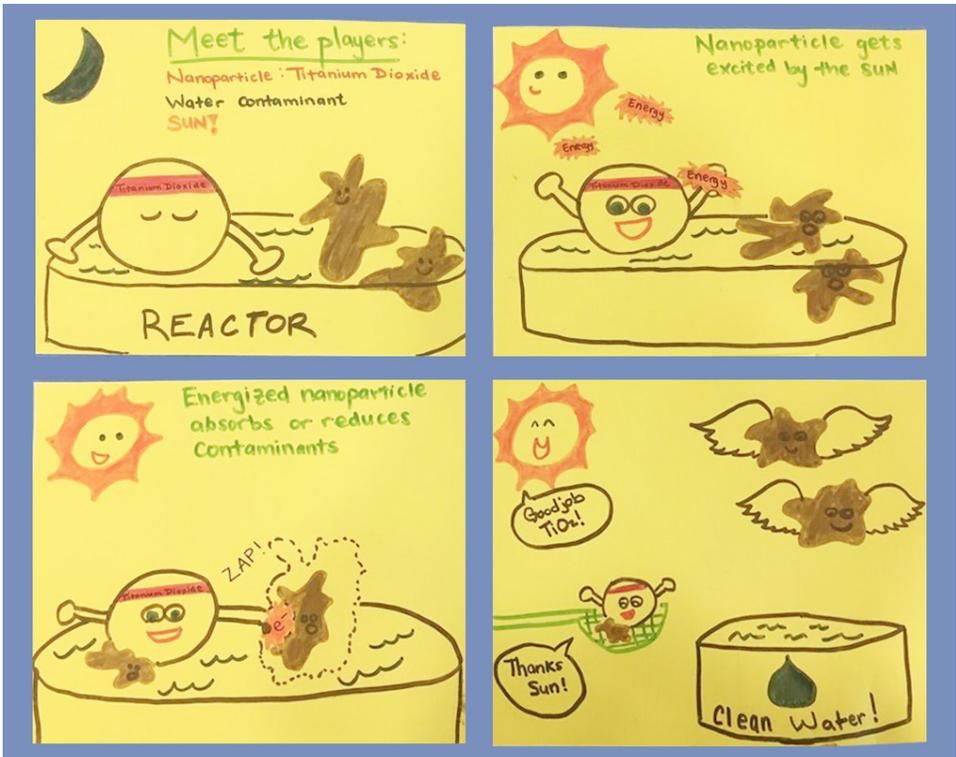
- 1) First, the outreach leader explains the process of photocatalysis by walking participants through the poster:

*One way to clean contaminated water requires two things: titanium dioxide and light particles. Nanoparticles of titanium dioxide are added to contaminated water. At night, the titanium dioxide nanoparticles lose energy and have to “sleep.” They can’t neutralize water contaminants when there is no light from the sun.*

*During the day, when the sun is out, the nanoparticles of titanium dioxide absorb photons, gaining energy from the sun.*

*The absorbed photons energize the nanoparticles, which allows them to neutralize the contaminants.*

*The result of this photocatalytic process is clean, safe drinking water!*



- 2) Give the participant(s) the blocks and explain that these represent particles of “titanium dioxide”. Have the participant(s) attach as many pom-poms (and call them “photons”) as they can to the “titanium dioxide” (TiO<sub>2</sub>) on the surface of the cubes. Set aside the large block with all the pom-poms attached.
- 3) Have the participant(s) split the small “titanium dioxide” (TiO<sub>2</sub>) cubes and call them “titanium dioxide nanoparticles”, then repeat the process. Set aside all the small blocks with all the pom-poms attached.
- 4) Count up the pom-poms that attached to the large block. Then count up the pom-poms that are attached to the set of small blocks. Ask participants which number is higher. Very likely, the number of pom-poms (photons) attached to the 8 small blocks (nano-particles) will be higher than the number attached to the larger block. Ask participants why they think they got this result. Help them understand that objects can have the same volume, but more surface area if one large object is broken up into several small objects. In this task, the “nanoparticles” have a larger surface-area-to-volume ratio and, therefore, work better for treating water – but only when they are exposed to sun where they can absorb photons.

## Assessment

- 1) What is nanotechnology, and how can we use it?
- 2) What are photons? How do they affect the titanium dioxide (TiO<sub>2</sub>)?
- 3) What is a particle? What is a nanoparticle?
- 4) What is the relationship between surface area and volume?

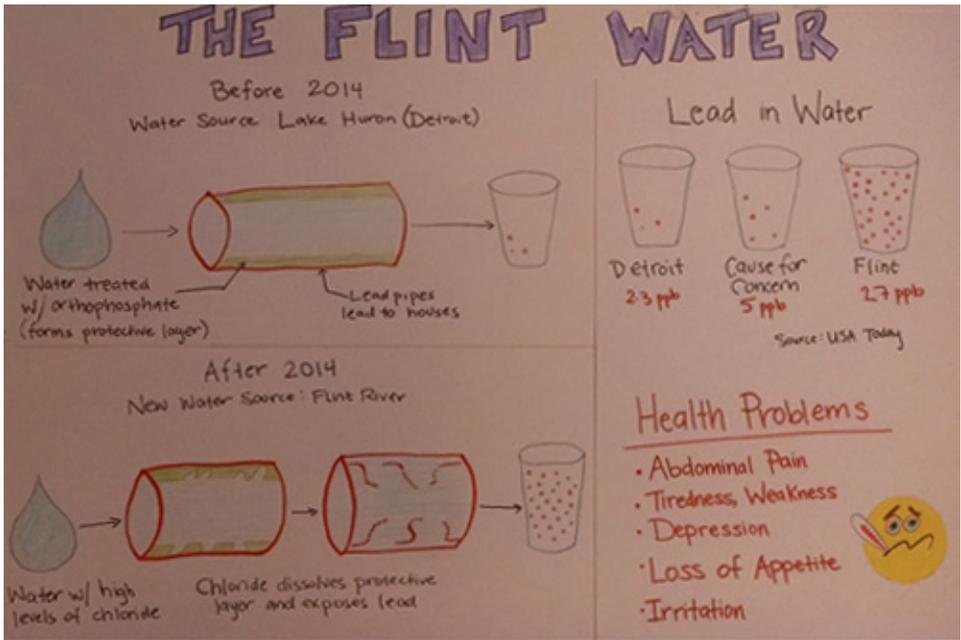
## Deepen your Knowledge

One critical and recent example of why we should pay attention to centralized water treatment plants and distribution systems is the Flint Water Crisis.

Flint’s original water source, Lake Huron water, was treated with orthophosphate, which formed a protective scale on the lead distribution pipes that led from the water treatment plants to homes. In 2014, the city switched to the Flint River, which had high chloride levels (almost 8 times higher than the Huron water). The corrosive water broke down the protective scalant on the pipes and began to corrode the pipes, leading to excessive lead leaching into the water (5 parts per billion lead is cause for concern, Flint water was 27-100 parts per billion lead).

In Flint, Michigan, a changed water source and cost saving water treatment measures led to leaching of toxic lead from pipes into drinking water. To visually demonstrate the phenomena that occurred, Styrofoam (scalant) was painted with nailpolish (lead pipe). The Styrofoam was first sprayed with water, and no effect was seen. The water source was changed to acetone, visually identical to tap water, but the acetone dissolved the Styrofoam (scalant) and eventually dissolved the nail polish (pipe). We spoke about the importance of water regulations and treatment plant compliance, as well as how water travels through the distribution system to homes. An accompanying poster (below) was used as a visual aid.

While many attendees may have heard about the Flint Water Crisis, many are likely unaware of the scientific cause of the problem. Through a simple visual demonstration,



attendees learn about chemistry concepts such as solubility, the importance of water treatment for public health, as well as the infrastructure problems the US faces.

Below are some pages where you can read more about NEWT research, nanoparticles, and more about this engineering research:

[www.NEWTcenter.org](http://www.NEWTcenter.org)

[www.nsf.gov/nano](http://www.nsf.gov/nano)

<http://rsc.li/2o1471X>

<http://bit.ly/2nVdTkB>

<https://www.youtube.com/watch?v=e2QpT1vCD08>

<https://www.youtube.com/watch?v=ch9P9yFIdXE>

