Nanotreatment of Water

Center for Nanotechnology Education

Version 110218

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Nanotreatment of Water

Abstract

This is a module about technologies that use forces and interactions at the nanoscale to treat water. Learners will select a water treatment problem, determine which contaminants are present in their water, and use the described nanotechnologies and their knowledge of intramolecular forces to identify the most effective water treatment system.

Outcomes. After completing this module, students will be able to

- Compare the effectiveness of different nanotechnologies to treat contaminated water
- Prepare and present technical information about a water treatment system

Prerequisites

- Basic understanding of the structure of matter as consisting of atoms that interact to form molecules.

Alignments to Education Standards

Appendix A: Alignments to Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS)

Science Concepts

- All interactions of matter are influenced by different types of forces, such as gravity, inertia, and electrostatic forces.
- At different size scales, different forces predominate.

Nanoscience Concepts

- At the nanoscale, forces of electromagnetic attraction and repulsion are much more significant than gravity or inertia
- Nanoparticles have certain properties that make them useful for collecting and/or neutralizing water contaminants.

Background Information

The Centrality of Water Use

Every person on this planet uses water multiple times every day. One of the leading causes of death (especially in children) is waterborne disease (*Water facts: Water,* 2013). These deaths could be prevented by providing a way to clean the water for use. The world is facing a well-documented water crisis (see water.org for more information). The population is increasing exponentially (United States Census Bureau, 2013). With more and more people in need of fresh water, and the vast majority of water on earth (>96%) too salty to drink, the concern is growing. While some fresh water is available for human use (United States Geological Survey, 2013), many locations on the globe are already water poor – lacking the ability to sanitize and distribute clean water for cooking and drinking (World Meteorological Organization, 1996).

> "Seeing water coming from the tap ranging from ecru to chocolate colored is not something we often have to deal with in our homes with indoor plumbing and running water that comes from our treatment plants with their large flocculation and sedimentation tanks and chlorine treatment."
>
> –Jeff Katz
> Huffington Post

Water Treatment in Developed Countries

Typical water treatment in the United States involves a number of steps to remove undesirable objects (like sticks), tastes (like algae), waterborne pathogens (like hepatitis A), and chemicals (like lead). The Environmental Protection Agency (EPA) lists these as typical steps for treatment:

1. Coagulation – addition of chemicals to attract dirt in preparation for sedimentation
2. Sedimentation – allowing the combined chemical-dirt particles to settle out of the water under gravity
3. Filtration –removing small particles by forcing the water to flow through screens and filters
4. Disinfection –chemically killing bacteria and microorganisms, typically by adding chlorine (United States Environmental Protection Agency, 2012)

Water Treatment in Developing Countries

Depending on your students' background they may have a hard time conceiving of water in the developing world (e.g., water shortages, lack of safe water). The water treatment ranges from non-existent, through container settlement, cloth straining, gravity-powered sand filters, personal ceramic filters (e.g., LifeStraw), boiling, and intermittent treatment with chemical disinfectants. For more information, and a helpful table to share with students, Go to: Water

Treatment Implementation for Developing Countries (http://www.cawst.org/en/resources/pubs/position-papers/category/8-position-papers?download=23%3Awater-treatment-implementation-for-developing-countries).

Used Water Needs Treatment

As a species, we use water in many ways we that may not come to mind immediately, such as growing crops, raising animals, and extracting minerals. After such uses, the water may contain pesticides, waterborne diseases, and/or heavy metals. This water (sometimes called wastewater) needs to be treated before it is ready for reuse. The Nanotreatment Plan cards each contain one approach to water treatment for students to address. How much treatment the water needs depends on the next application of that water. One of the natural questions your students may come to during the course of this module is: How clean does the water need to be?

The Need for New Approaches

Many western approaches to water treatment (e.g., solvent extraction, activated carbon adsorption, and common chemical oxidation) are costly and time-consuming (Berger, 2008). Recent advances in nanotechnology allow us to design solutions that are more nimble and targeted. For example, nanomaterials that can strip water of toxic metals or tea bag-like structures that contain biocides to treat waterborne illness (Sanderson, 2012). The approaches that hold the most promise are the "…ones we can integrate into existing systems," says Mamadou Diallo, an environmental engineer at both the California Institute of Technology and Korea Advanced Institute of Science and Technology. That means, for example, membranes enhanced with nanoparticles that can slot seamlessly into water treatment plants. (Sanderson, 2012)

Applying Advances in Nanotechnology to Water Treatment

Nanotechnology continues to advance and many techniques have been applied to water treatment. Unfortunately the effects of different nanotechnologies on Earth's ecosystems have not been fully determined; this needs to happen before we employ various nanotechnologies in large-scale applications (Berger, 2008). One example is water purification through the use of nanoparticles. Such particles have the ability to chemically break down pollutants, but may harm beneficial microorganisms downstream of (or even within) the water treatment plant. Current technologies are described on the nanotechnology cards, but the module could readily be adapted for students to conduct their own research as the field is rapidly moving forward.

Focus on Forces

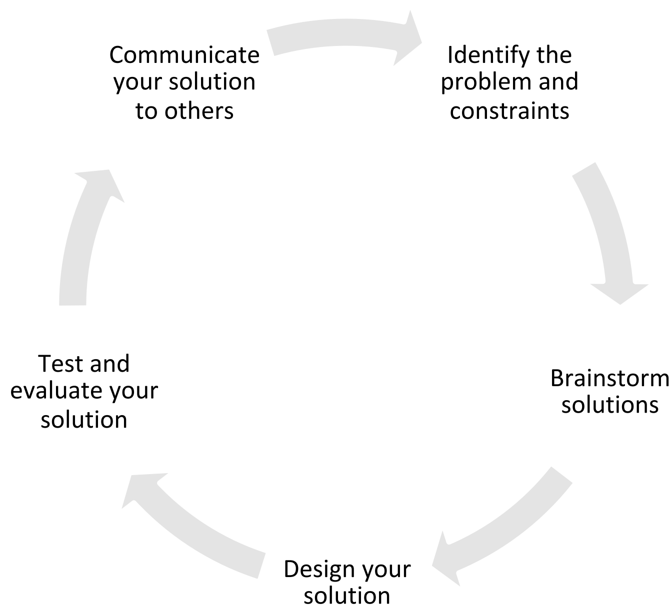
One of the key features of nanoscale materials (like nanoparticles or nanowires) is that the dominant forces they are subject to are different than the ones in students' everyday lives. Students assume, from their life experiences, that gravity will dominate phenomena at the nanoscale as it does at the macroscale. This module focuses students' attention on the kinds of interactions that nanomaterials have with contaminants. One of the key pieces of information students are given on the Contaminant and Technology Cards is the kind of forces that a material experiences. Students should use this information as part of their design process.

> *Note:* If your students need help understanding how the shift in forces causes particles to behave differently, try some of these fun games:

- Nanobots
- Electric Field Hockey

The Design Cycle

This module invites students to problem-solve a water treatment problem in their own way. Involving student creativity is motivating and results in novel approaches that others may not have considered. As students engage with the material, it will be helpful for them to consider the Engineering Design Cycle. The design cycle is represented in many different ways, but all of them include the following key features:



This module focuses students' attention on the value of communicating their solution to others. In order to communicate effectively, students will need to synthesize the information on the cards and present technical information about their ideas. Their presentation should also include solid graphics to help explain their ideas.

> *Note*: If you are able to provide additional time for this module, students might research the nanotechnologies available instead of providing the cards. This would further support practice 8 and several ELA CCSS standards.

Notes for Instructors

Materials

1. Water Quality Problem (Appendix B: 1 set per class)
2. Water Contaminant Cards (Appendix B: 1 set per group of 3–4 students)
3. Nanotechnology Cards (Appendix B: 1 set per group of 3–4 students)
4. Chart paper and markers, or digital tool access for students to present their system design.

Set-up

- Print cards for your class or group, as described in Materials.

Procedure

1. Arrange the students into teams of 3–4.
2. Give students this, or a similar, relevant water quality problem to introduce the activity. "People start getting sick after drinking water at a local business. You are called in to help solve this problem. In your teams, begin a list of the steps you think would need to be taken to solve this problem."
3. Have teams share steps with the large group, while creating a compiled list that fits into the engineering design process diagram (in Background Information). What else needs to be added?
4. Explain that each team will be using parts of the design process to solve a real world water quality problem. Teams will need to present and defend their choice of the most effective nanotechnology water treatment system to solve the problem.
5. Randomly give a Water Quality Problem card to a team, or allow each to choose a different problem.
6. Give each team a set of Water Contaminant cards. After dividing them among their group, have them discuss each card and decide which are relevant to their problem.
7. Prepare for teams to share their water quality problems with the large group by creating a class or individual summary table to record this information: Problem, contaminants, nanotechnology treatment).
8. In discussing which (if any) nanotechnology would be useful, consider the size of the water contaminant, and which forces may at work in each situation. Forces include
    a. Gravity: most important for larger water contaminants that have some mass, like larger particles of sand and dirt. It has very little effect on things smaller than a one micrometer in size.
    b. Inertia: also important for more massive contaminants. Inertia allows particles to be removed with filters as the particles impact the filter medium. Like gravity, inertia is most important for larger water contaminants. Inertial impaction is effective for particles greater than about one half micrometer (500 nanometers) in size. It is not effective for contaminants in atomic or molecular form.
    c. Electrostatic force: the attraction and repulsion of materials by electric charges. This force becomes more important for smaller contaminants, that is, particles

smaller than 500 nm. It is one of the only ways to capture contaminants in atomic or molecular form.

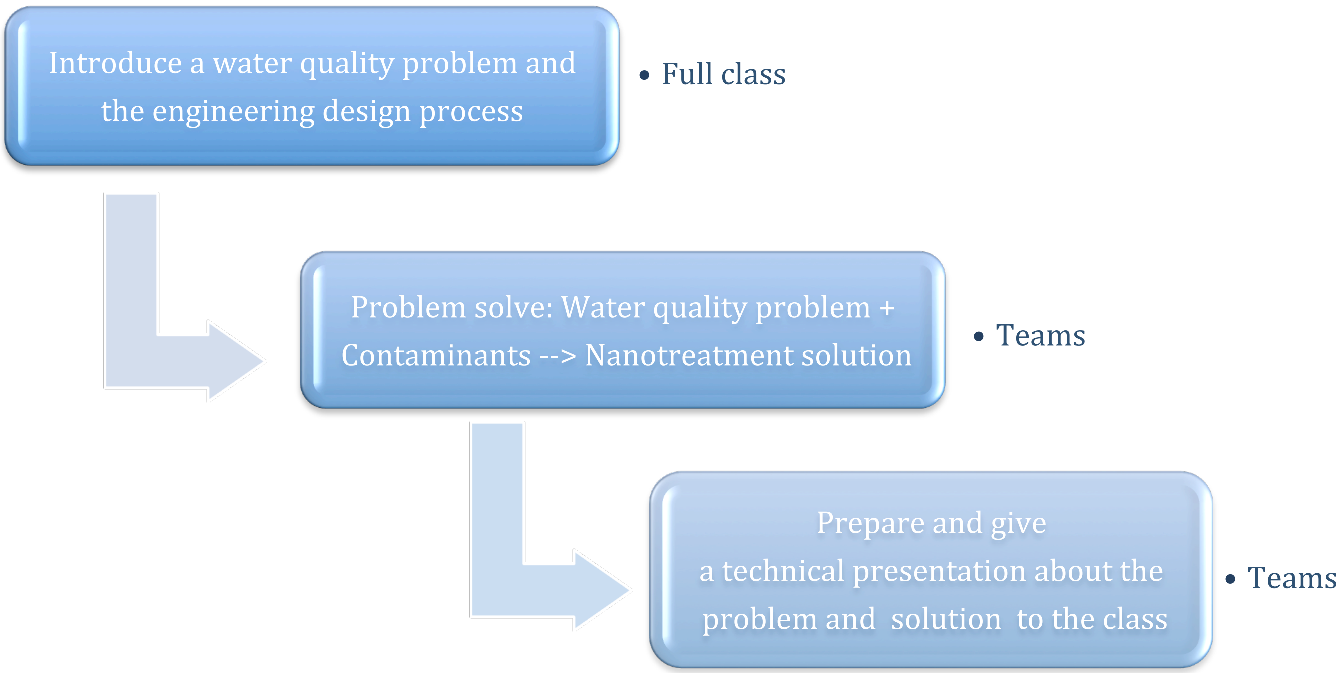
9. Have teams share problems and contaminants, while recording the information on the summary table. Discuss any similarities and differences noticed in the problems and contaminants.
10. Give each team a set of Nanotechnology cards. After dividing the cards among their group, have them discuss each card and determine which solution(s) would be the most effective treatment system for their water problem. Extension option to build relevance: Students could find photos, articles or videos about an actual water quality problem described on their cards, and prepare a multi-media presentation.
11. Have teams present their water treatment solution with the class, while the listeners record their choice in the summary table. Teams should defend their choice by explaining:
    - Why do you think this nanotechnology is the most effective treatment of your water quality problem?
    - What are the risks to this treatment?
12. After each presentation, encourage the listeners to
    - ask questions for presenters to clarify and defend their plan
    - compliment the strengths of the solution and presentation.

Presentation Rubric

Faltering	Trying	Practicing	Mastering
Delivery			
Presenters do not seem prepared or appear very uncomfortable. Presenters read heavily from their notes and do not engage with the audience, perhaps staring at floor or frequently turning away from the audience.	Presenters are prepared, but may appear uncomfortable. Delivery moves along but includes distractions (many “ums”). Presenters make some effort to make eye contact only a few times but may speak to the visual aid rather than the audience.	Presenters are prepared and speak clearly and directly to the audience. Delivery is clean with infrequent distractions. Presenters make frequent eye contact with the audience, and may try to include members with the content.	Presenters are well prepared and appear comfortable with their topic. Delivery is interesting and flows logically. Presenters speak clearly and directly to the audience, striving to engage all members by encouraging questions and feedback from the audience.
Content			
Presentation consists of facts or ideas that are not connected. Ideas or concepts may not be clearly explained. The organization does not help the audience understand the filtration system.	Information presented is familiar – the audience may not be learning much that is new. The organization may make it hard for the audience to understand the filtration system.	All information provided is relevant. The organization helps make effective connections. The presenter builds upon what the audience already knows to create understanding of the proposed filtration system.	Information is well ordered and engaging. The organization helps the listener make connections to what they already know to understand the filtration system.
Visual Aids			
Visual aids are not referred to by the presenters. They are not strong quality and are labeled either poorly or not at all.	Visual aids provide some detail, but do not help tell the story. Labeling may be partial.	Visual aids are well done and help tell the story. They are referred to during the presentation. They are labeled.	Visual aids are creative, well executed, labeled informatively, and consistently referred to in order to enhance the audience's understanding of the story.
Credibility			
Presenters do not mention where they obtained the information they are presenting.	Presenters make some effort to provide references to their sources to support their ideas.	The presenters refer to sources to support their ideas.	Presenters weave source information into storyline and refer to all sources at least once.

Learning Activity: Nanotreatment of Water

Activity Flow Chart



Nanotreatment of Water

Materials

1. Water Quality Problem cards
2. Water Contaminant cards
3. Nanotechnology cards
4. Chart paper and markers

Procedure

1. Break into teams of 3 to 4 people each
2. Your instructor will give your team a Water Quality Problem card and a set of Water Contaminant cards. Discuss each card and decide which are relevant to your problem.
3. Your instructor will give your team a set of Nanotechnology cards. After dividing the cards among your group, discuss each card and determine which solution(s) would be the most effective treatment system for your team's water problem.
4. In discussing which (if any) nanotechnology would be useful, consider the size of the water contaminant, and which forces may at work in each situation. Forces include
    a. Gravity: most important for larger water contaminants that have some mass, like larger particles of sand and dirt. It has very little effect on things smaller than a one micrometer in size.
    b. Inertia: also important for more massive contaminants. Inertia allows particles to be removed with filters as the particles impact the filter medium. Like gravity, inertia is most important for larger water contaminants. Inertial impaction is effective for particles greater than about one half micrometer (500 nanometers) in size. It is not effective for contaminants in atomic or molecular form.
    c. Electrostatic force: the attraction and repulsion of materials by electric charges. This force becomes more important for smaller contaminants, that is, particles smaller than 500 nm. It is one of the only ways to capture contaminants in atomic or molecular form.
5. Share your team's water treatment solution with the rest of the class. Be prepared to defend your choice by explaining:
    - Why do you think this nanotechnology is the most effective treatment of your water quality problem?
    - What are the risks to this treatment?

Discussion Questions

1. How is nanotechnology changing the effectiveness of cleaning water?
2. What are the most and least common water contaminants?
3. What are some real-world examples of technology and nanotechnology being used to clean water?
4. What new questions and “I wonder…” thoughts do you have based on your new knowledge?

Contributors

- Sandra Weeks – McREL International
- Editing and revisions by Laura Arndt of McREL International and James Marti of the University of Minnesota
- Alignments to Education Standards completed by McREL International

Resources

Videos

- "How to make filthy water drinkable," From TedTalks: www.ted.com/talks/michael_pritchard_invents_a_water_filter?language=en
- "NEWT Center will use nanotechnology to transform water treatment," From Rice University: www.youtube.com/watch?v=WvIiXqukFuA
- "NANO-TECH has created a water purifier," From SciTech: www.youtube.com/watch?v=3t876hn4_UM
- "Nano Technology Clean Water," From The Green Economy TV Show: www.youtube.com/watch?v=Ukf74pJes7Q
- "Purifying water using solar-activated water treatment technology from Puralytics," From EarthSayers TV www.youtube.com/watch?v=gv1mXSp90Fo

Simulations

- "Nanotechnology Water Treatment," www.youtube.com/watch?v=y322eNtug_w
- "Single file in a carbon nanotube," www.youtube.com/watch?v=9L-SfLwBbto

Articles

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Appendix A: Alignments to Education Standards

Alignment to the Next Generation Science Standards

Table 1 clarifies the nature of the alignments by Scientific and Engineering Practice (Practice), Disciplinary Core Idea (DCI), and Crosscutting Concept as related to a Performance Expectation.

TABLE 1. ALIGNED PRACTICES, DISCIPLINARY CORE IDEAS, AND CROSSCUTTING CONCEPTS

PRACTICE	***DCI***	***CROSSCUTTING CONCEPT***
HS. *Constructing explanations and designing solutions:* Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. *Strong in student materials*	HS.ETS1.A: *Defining and Delimiting Engineering Problems:* Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. *Strong in teacher and student materials*	HS. *Influence of Engineering, Technology, and Science on Society and the Natural World:* New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. *Partial in teacher and student materials*
	HS.PS2.B: Types of interactions: Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *Partial in teacher and student materials*	

Alignment to the Common Core State Standards for English Language Arts/Literacy and Mathematics

Alignments in Table 2 were made to the Anchor Standards, unless a more specific version of the standard was a closer fit to the skills in the module.

TABLE 2. ALIGNED COMMON CORE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY
CCR.L.6: Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when encountering an unknown term important to comprehension or expression. *Partial in teacher and student materials*
CCR.SL.1 Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively. *Partial in student materials*
CCR.SL.2 Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience. *Strong in student materials*

No alignments to mathematics were found.

Appendix B

NanoTreatment Cards

Note: Print these cards on cardstock and laminate them for repeated use.

Water Quality Problem 1

Cleaning water for drinking, cooking, and bathing in a developed country

What contaminants affect this water?

Bacteria

Pesticides

What other factors do you need to consider?

- Literate population
- Expects clear water = clean water

Water Quality Problem 2

Cleaning water for cooking and drinking in a developing country

What contaminants affect this water?

Bacteria

Viruses

Cyanide

What other factors do you need to consider?

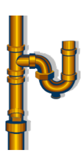
- Illiterate population
- Little to no infrastructure to support large-scale water treatment

Water Quality Problem 3

Cleaning water for irrigation in a semi-developed country

What contaminants affect this water?

Cadmium



Lead

Pesticides

What other factors do you need to consider?

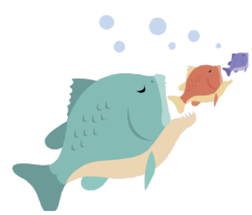
- Semi-literate population
- Intermittent power supply

Water Quality Problem 4

Cleaning water for industrial use in soft drinks

What contaminants affect this water?

Cadmium



Mercury

What other factors do you need to consider?

- Lots of existing systems
- Removal of taste and odor is key

Water Quality Problem 5

Cleaning water for vaccines

What contaminants affect this water?

Viruses

Bacteria

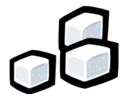
What other factors do you need to consider?

- Lots of existing systems
- No shortage of energy
- Removal of all contaminants is key

Water Quality Problem 6

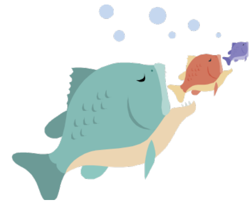
Desalinating ocean water to use as drinking water

What contaminants affect this water?



Salt

Bacteria



Mercury

What other factors do you need to consider?

- Requires a lot of energy
- We typically extract salt out of the water – is there a way to extract only the water?

Water Quality Problem 7

Treating water for livestock to drink

What contaminants affect this water?

Pesticides

Bacteria

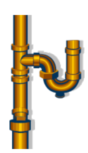
What other factors do you need to consider?

- Electrostatic interactions are sensitive to pH and salt concentrations

Water Quality Problem 8

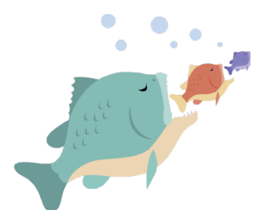
Reclaiming water contaminated by industrial use

What contaminants affect this water?



Lead

Cadmium



Mercury

What other factors do you need to consider?

- Lots of existing systems

Water Contaminant B

Coliform bacteria

Source: Soils, plants, animals, human sewage, agricultural and storm runoff.

Hazards: Most coliform bacteria do not cause disease, but are an easy way to monitor for more dangerous organisms that cause diarrhea.

Size: 500–2000 nm

Dominant force(s): Gravity, Inertia, Electrostatic (influenced weakly by charge)

Water Contaminant V

Viruses

Source: Fecal matter, animal urine

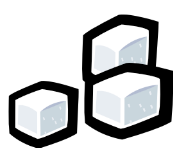
Hazards: Hepatitis, meningitis, colds, gastroenteritis.

Size: 27–100 nm

Dominant force(s): Electrostatic (influenced by charge) electrostatic interactions, which are sensitive to pH and salt concentrations

Water Contaminant S

Salts



Source: Contact with the ground and oceans in the water cycle

Hazards: Drinking salt water causes dehydration, nausea, weakness, and possible death.

Size: 0.1–0.2 nm

Dominant force(s): Electrostatic, (influenced strongly by charge)

Water Contaminant P

Pesticides

Source: Runoff from farm fields; water treatment plants (chlorine), pesticide disposal.

Hazards: Effects depend on type, amount, and duration of exposure, but include cancer, nerve damage, hormone disruption.

Size: 0.24–0.75 nm

Dominant force(s): Electrostatic (influenced by charge),

Water Contaminant L

Lead
(Pb++ or Pb+)

Source: Lead pipes and solder that is used to connect pipes. Leaded gasoline.

Hazards: Mental and physical development delays in children; high blood pressure and kidney problems in adults.

Size: 0.079–0.143 nm

Dominant force(s): Electrostatic (influenced heavily by charge)

Water Contaminant C

Cadmium
(Cd++)

Source: Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints.

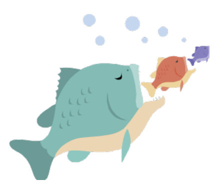
Hazards: Kidney damage

Size: 0.092–0.124 nm

Dominant force(s): Electrostatic (influenced heavily by charge)

Water Contaminant M

Methylmercury



Source: Industrial processing of coal and metals contributes mercury to aquatic systems where it complexes to form methylmercury. It is biomagnified in these food chains.

Hazards: Impaired neurological development in children (for example, thinking, memory, attention, language, and fine motor and visual spatial skills)

Size: 0.110–0.133 nm

Dominant force(s): Electrostatic (influenced by charge)

Water Contaminant Y

Cyanide (CN^-)

Source: Industrial contamination from production of paper, textiles, plastics

Hazards: Lowers B12 levels, prevents cells from using oxygen, disrupts thyroid and nervous system function.

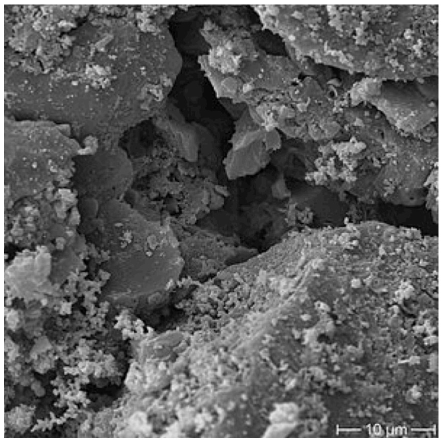
Size: 0.090 nm

Dominant force(s): Electrostatic (influenced heavily by charge)

Nanotechnology: Activated Carbon / Activated Charcoal

Potential

- Effective adsorbent of a variety of non-polar substances—typically taste and odor.



Risks with activated charcoal

- Non-toxic
- Does not affect metals, cyanide, or alcohols; destroyed by high or low pH

Subject to forces: 1) Electrostatic (influenced weakly by charge); 3) Inertial (larger particle contaminants may impact charcoal and be separated from water)

Size: 2–50 nm

Image: Activated charcoal through a scanning electron microscope

Credit: http://upload.wikimedia.org/wikipedia/commons/thumb/6/65/Activated_Charcoal.jpg/300px-Activated_Charcoal.jpg

Nanotechnology: Solar Water Disinfection

Potential

- Sunlight through clear water for 6+ hours will treat most water for bacterial pathogens.
- This process is sped up by adding a catalyst such as silver and titanium dioxide nanoparticles.

Risks with silver nanoparticles

- Creation of free radicals and silver chloride in the body
- Cellular death
- Accumulation in the liver
- Smaller particles are more reactive than larger ones

Subject to forces: 1) Electrostatic 2) Gravity (larger particles will settle out and can be separated.

Size: 1–100 nm

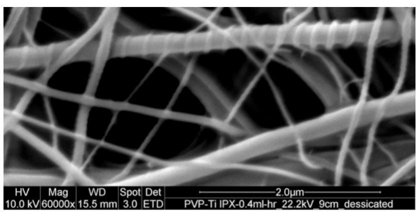
Image: A solar water disinfection table

Credit: http://upload.wikimedia.org/wikipedia/commons/thumb/6/67/Indonesia-sodis-gross.jpg/320px-Indonesia-sodis-gross.jpg

Nanotechnology: Nanobiocides

Potential

- Nanobiocides such as metal nanoparticles and engineered nanomaterials may be incorporated into nanofibers and show high antimicrobial activity and stability in water.
- Titanium dioxide nanoparticles break down common organic contaminants such as hormones, pharmaceuticals, or manure—when exposed to light
- Nano-sized silver is used to kill bacteria.



Risks

- Creation of free radicals and silver chloride in the body
- Cellular death
- Accumulation in the liver
- Smaller particles are more reactive than larger ones

Subject to forces: Electrostatic (influenced heavily by charge)

Size: 1 to 100 nm

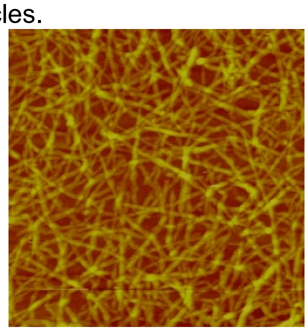
Image: Titanium dioxide nanofiber spiral

Credit: http://upload.wikimedia.org/wikipedia/commons/thumb/2/25/Titanium_dioxide_nanofiber_spiral.jpg/220px-Titanium_dioxide_nanofiber_spiral.jpg

Nanotechnology: Nano-cellulose filter

Potential:

- From plants or bacteria
- Transparent, electrically conductive, stronger than steel
- Nanocellulose can filter out nitrates in city water, paint dye residues in printing and textiles, and metal ions from industrial waste. It has also been shown to remove virus particles.



https://en.wikipedia.org/wiki/Nanocellulose#/media/File:AFM_Innventia_nanocellulose.JPG

Risks:

- Biodegradable
- Inert
- Non-toxic
- Stable in wide range of pH

Subject to forces: Electrostatic (may attract charged particles); inertia (particles flowing through filter may impact on fibers)

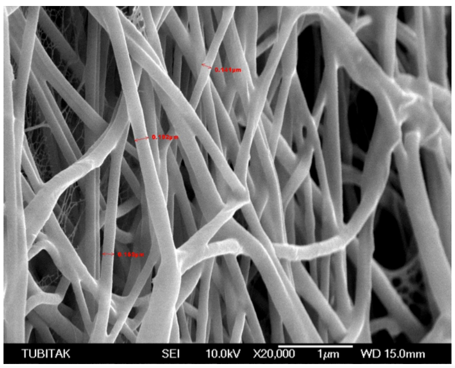
Size: 5-20 nm x 10 nm to several micrometers

Image: Carboxymethyl nanocellulose

Nanotechnology: Electrospun Nanofibers

Potential

- Useful in filtration—these fibers can be built into membranes with a high surface area. Also, the material being spun can be manipulated to give control over pore size and modification of the surface chemistry.



Risks
May carry similar risks to manufacturers as asbestos fibers: cancer

Subject to forces: Electrostatic (may attract charged particles); inertia (particles flowing through filter may impact on fibers)

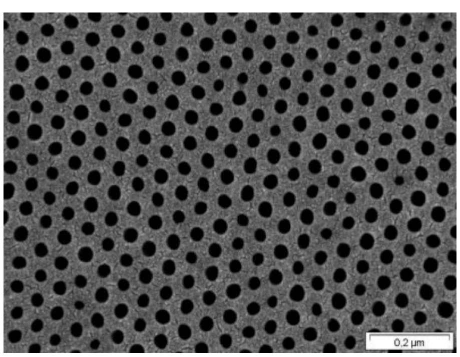
Size: 10–1,000 nm

Image: Electrospun nanofibers

Credit: http://upload.wikimedia.org/wikipedia/commons/thumb/d/db/N2_2.kesit.JPG/220px-N2_2.kesit.JPG

Nanotechnology: Nanoporous membrane

Potential:
These self-assembled membranes are used to desalinate saltwater, and remove molecules such as micro-pollutants and pharmaceutical residues from water.



Risks:

- May be too expensive to use widely

Subject to forces: Electrostatic (may attract charged particles); inertia (particles flowing through membrane may impact on surface)

Size: 10–1,000 nm

Size: 3 - 15 nm

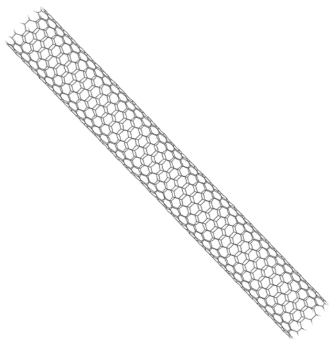
Image: Nanopore membrane

www.nanowerk.com/news2/newsid=29282.php

Nanotechnology: Carbon Nanotubes

Potential

- Water can travel through the tube, while other materials cannot.



Risks

- Can cross the cell membrane.
- May interfere with or damage DNA
- May carry similar risks as asbestos fibers: cancer

Subject to forces: Electrostatic (variably influenced by charge)

Size: 1.0 nm diameter

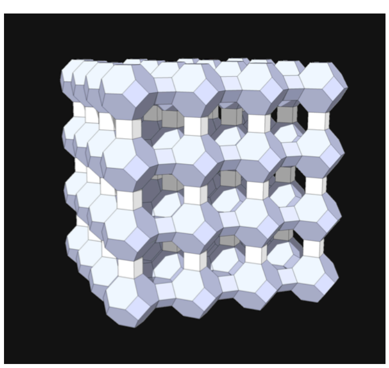
Image: Simulated Carbon NanoTube

Credit: Source=Wikipedia commons |Date=03 03 2007 |Author=User:Gmdm |

Nanotechnology: Zeolyte

Potential

- Utilizes the existence of nanoscopic pores in zeolite to act as a molecular sieve
- Exchanges Na^{+} for other ions, such as K^{+}, Ca^{+}, Mg^{2+}, Cu^{2+}



Risks

- Naturally occurring substance.
- None known when used in processing water. Not recommended to take internally.

Subject to forces: Electrostatic (influenced heavily by charge)

Size: 0.003–0.010 nm

Image: Zeolite

Credit: http://commons.wikimedia.org/wiki/Category:Zeolite#mediaviewer/File:Struttura_molecolare_di_una_zeolite.png