

Water Filtration and Purification Through Functional Nanofiltration Membranes

Research Experience for Teachers

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Department: Chemical and Biomolecular Engineering

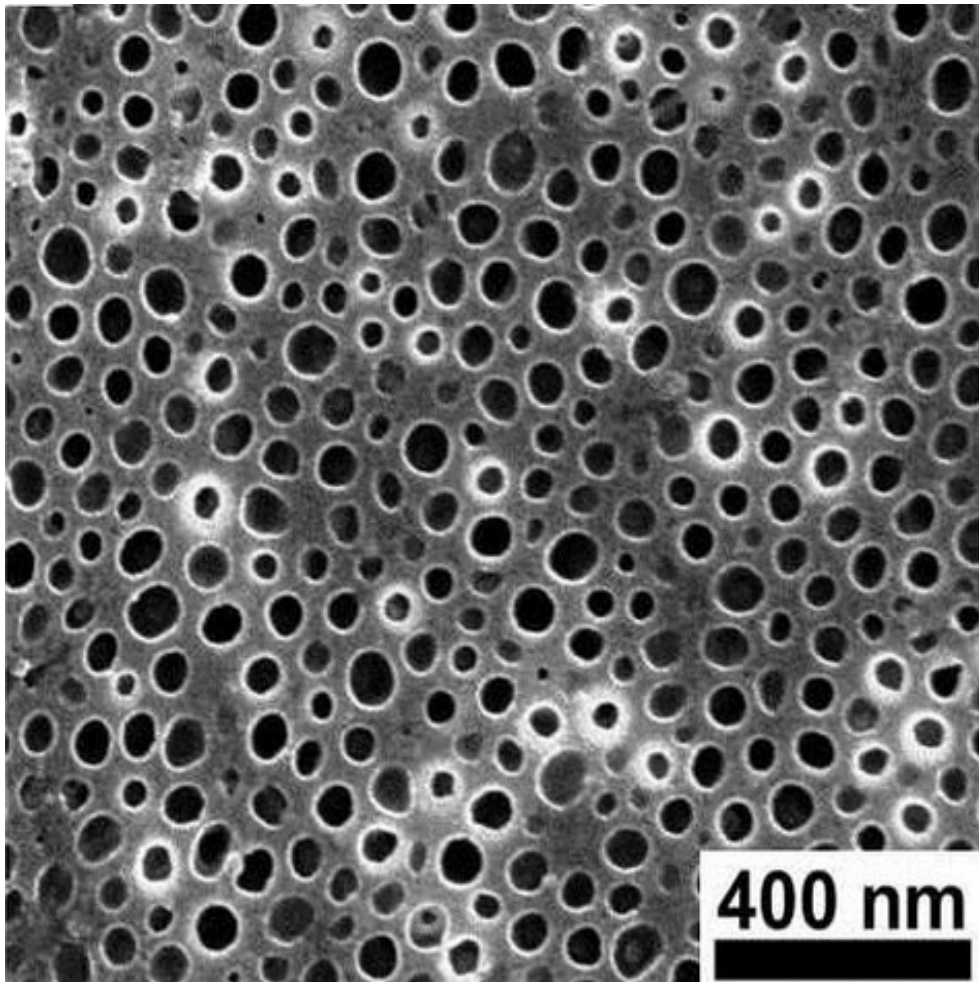
W.A.T.E.R. (Water purification and Advanced Transport Engineering Research) Lab

Introduction

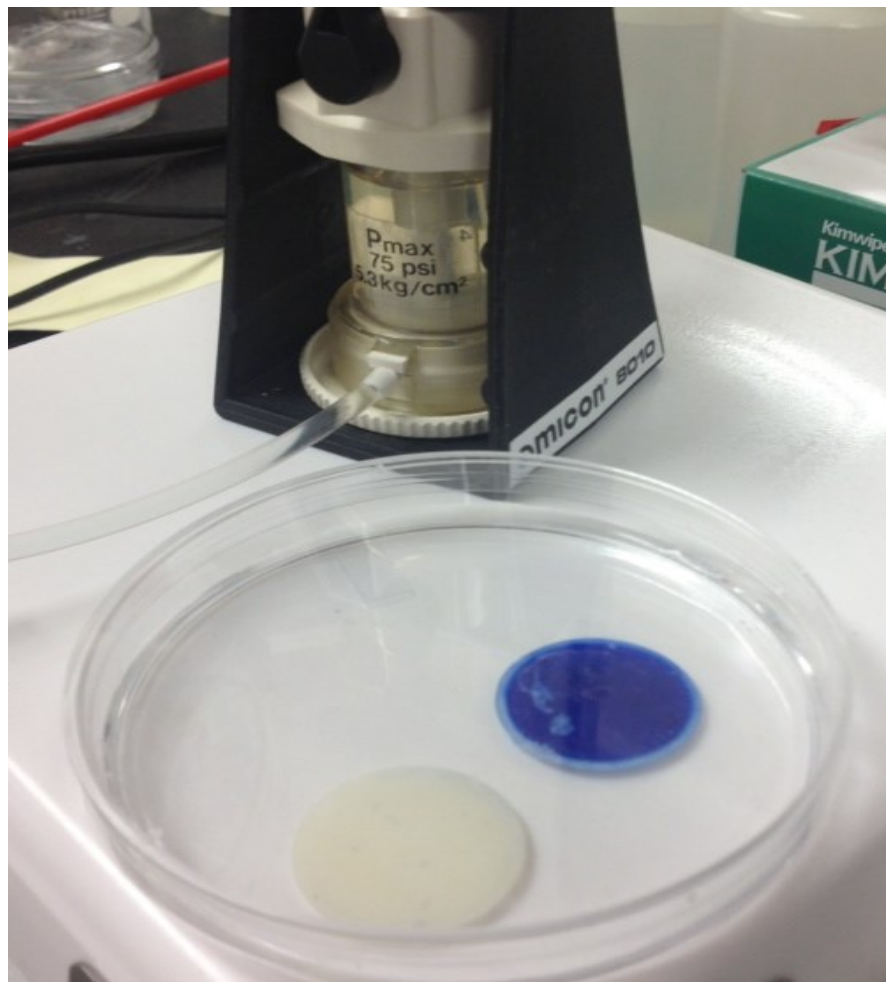
The topic of research for my RET (Research Experiences for Teachers) project is Water Filtration and Purification through Functional Nanofiltration Membranes. I have worked with Siyi Qu, a graduate student who works under Dr. William Phillip. The purpose of this study is to reduce water stress and increase the Earth's available water supply. These membranes help with filtering unwanted particles from water. Water filtration might seem like a pretty easy concept to understand, but this is water purification and desalination at the nano-level. This filtration is done by making copolymer membranes with microscopic pores. These pores typically range from 0.01 to 0.001 microns in size. The membranes need to be robust with high flux (the rate at which water permeates) and good selectivity (filtering necessary particles). My role in this research is to carry out the transport and rejection tests for the copolymer membranes that Siyi Qu has developed. I run solutions, usually dyes, through these membranes during the transport tests, checking for flux and permeability. The transport test is conducted by placing the membrane into a stirred cell. Air is then passed through the cell to push the water through. The water passes through a tube and into a vial which is placed on a scale. I also conduct rejection tests on the solutions to find out the percentage of the particles which the membranes have filtered. The rejection test is conducted by using ultraviolet- visible (UV-vis) spectroscopy. UV-vis spectroscopy compares the absorbance of light from wavelength data from concentration of the sample to the data from a calibration curve formed by carefully prepared set of dye solutions.

Hypothesis

The ideal membrane should be mechanically robust, have high water flux, and good selectivity. We will be able to determine these qualities by conducting transport and rejection tests.



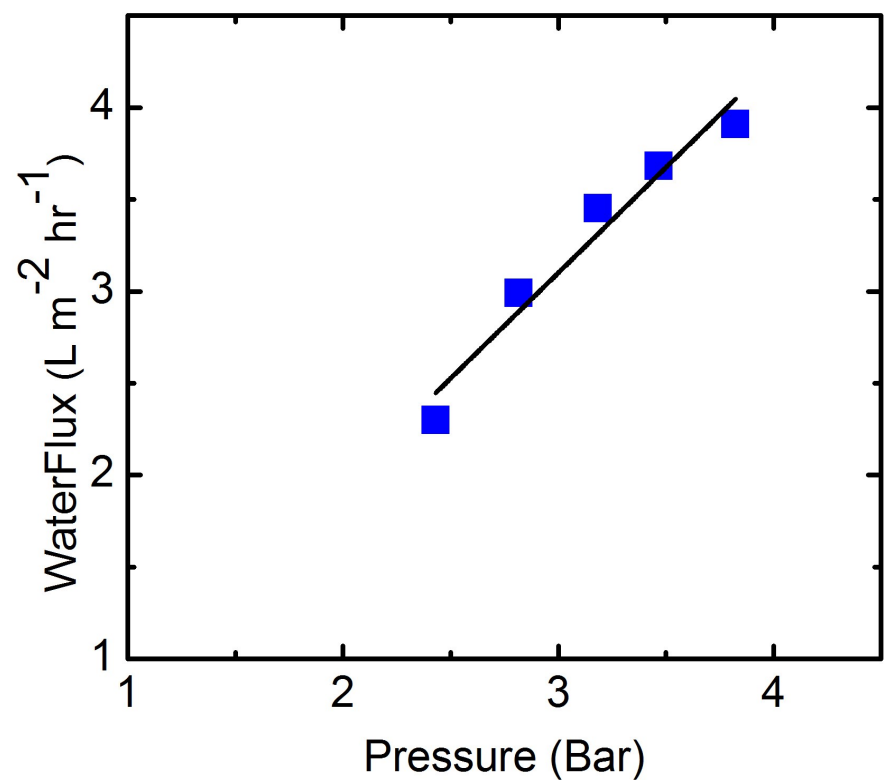
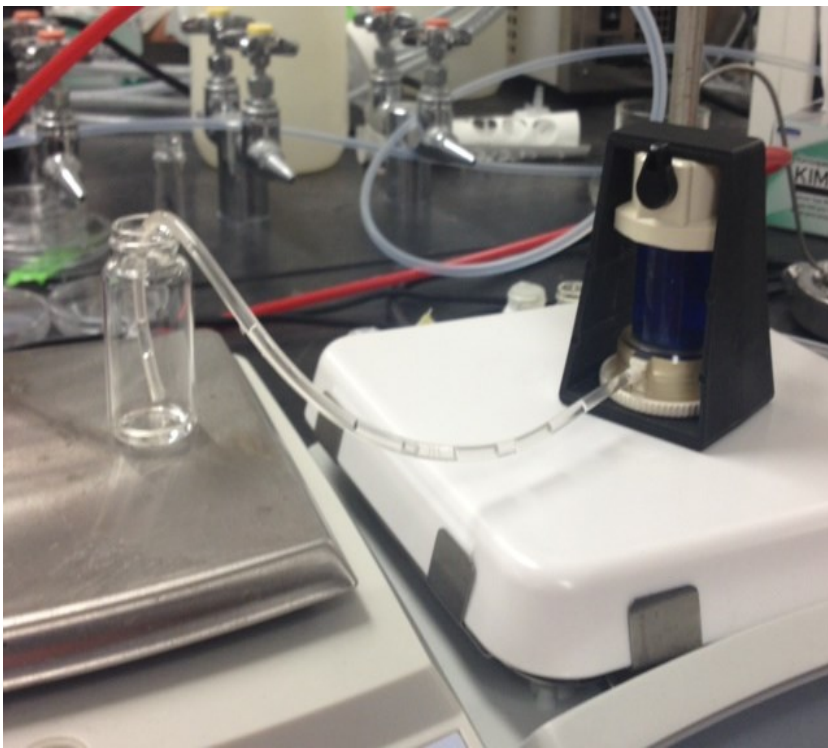
- The image on the left shows a magnified image of the pores from a successful membrane. These pores should be relatively uniform in size and spacing.
- The image on the right shows two membranes in a petri dish. These membranes are tested in a stirred cell which is shown above the petri dish.



Methods/Results

Over the past several weeks, I have tested various copolymer membranes. A copolymer membrane uses more than one monomer to form the polymer. These membranes have modified by the graduate student I am working under, and are formed from ethylene oxide and acrylonitrile monomers. These copolymers must be both hydrophilic, from ethylene oxide, and hydrophobic, from acrylonitrile. The hydrophilic properties allow the water to be channeled through the membrane, while the hydrophobic properties allow the membrane to maintain its structure by creating a structure for the channels.

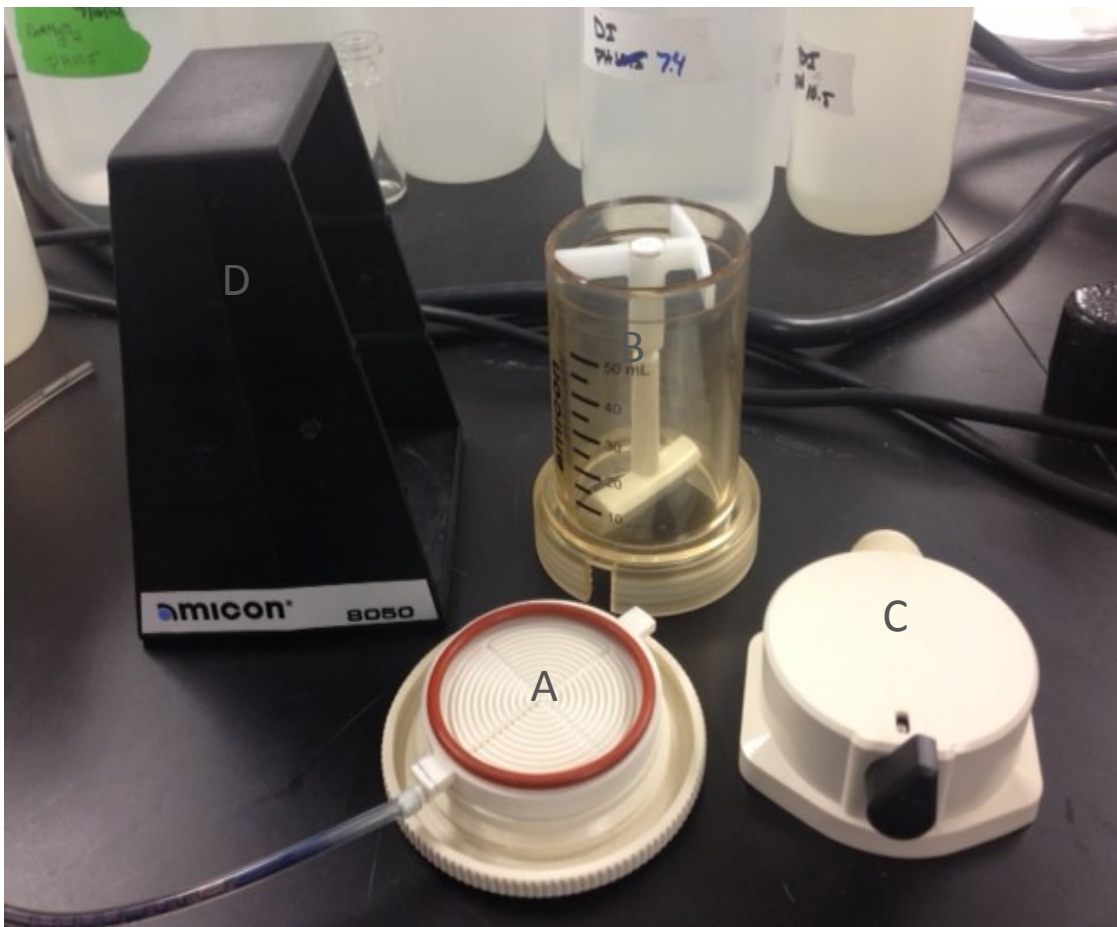
Transport Test



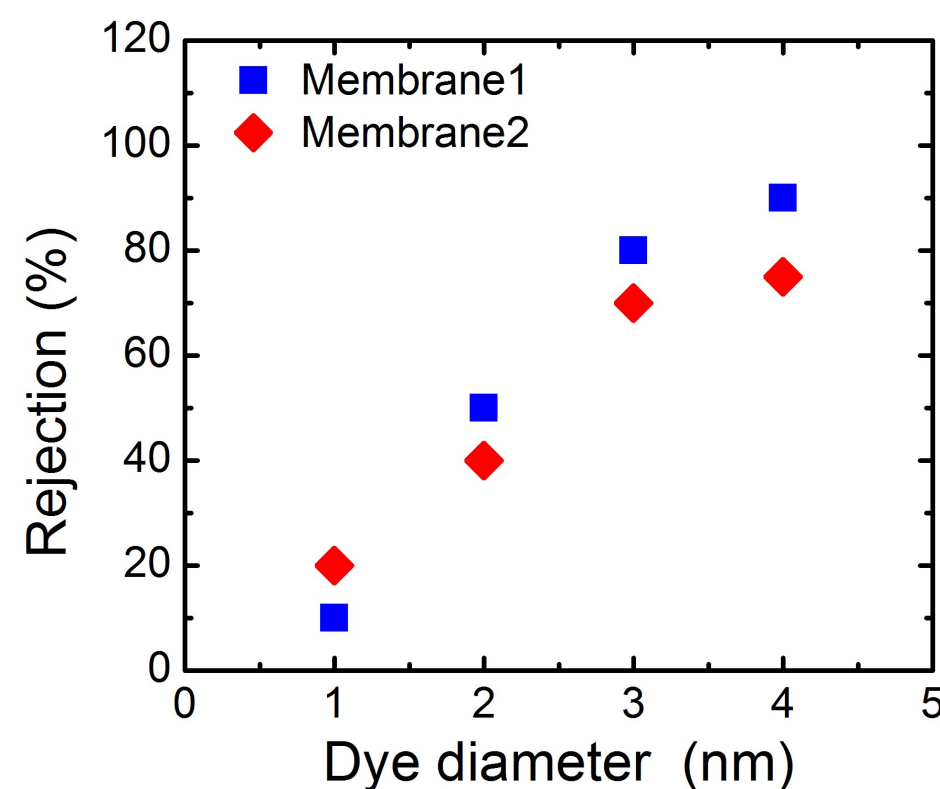
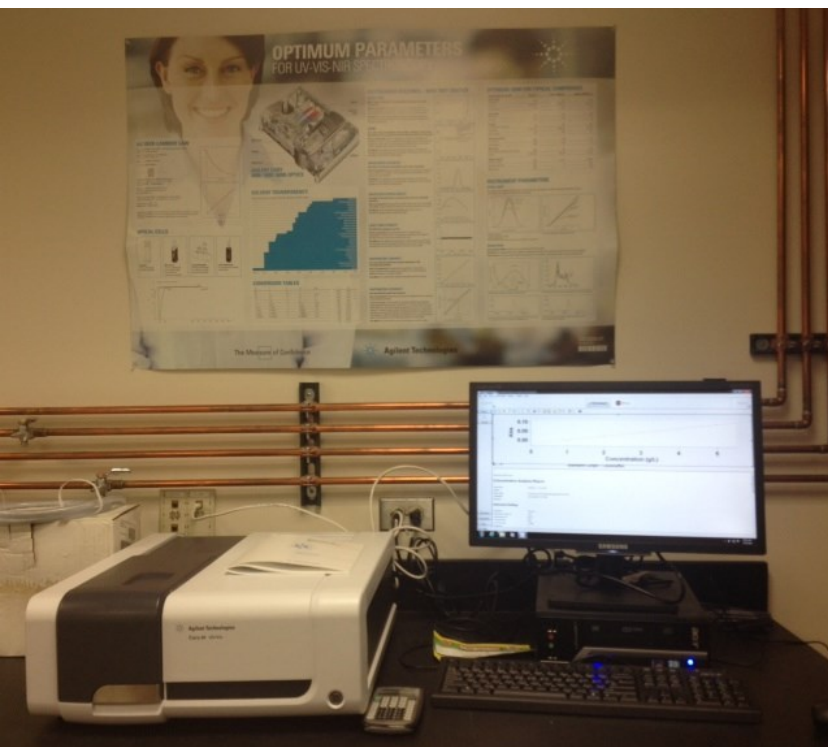
The image on the far left shows a stirred cell. The stirred cell is used to conduct the transport test. We can compare water flux and pressure to determine permeability of the membrane with the stir cell. The membrane is placed at the bottom of the stirred cell, and the cell is then filled with liquid. The stirred cell is placed on a magnetic stir plate, the magnetic stirrer allows the liquid inside the cell to evenly mix the concentration throughout the solution. Nitrogen gas enters the stir cell from a hose, this gas pushes the solution through the membrane. After the liquid permeates the membrane, it enters a tube leading to a vial placed on a balance. The balance will measure the mass of the permeate collected in the vial. Not only can the transport test tell us about permeability, it can help us get an estimate of the pore size in the membrane. For example, if particles from one material pass through the membrane, but the particles from another do not, we can estimate the pore size. These pores are very difficult to see, even with the SEM (Scanning Electron Micrograph), so these estimates are very important. A successful membrane will be selective.

Parts of a Stirred Cell

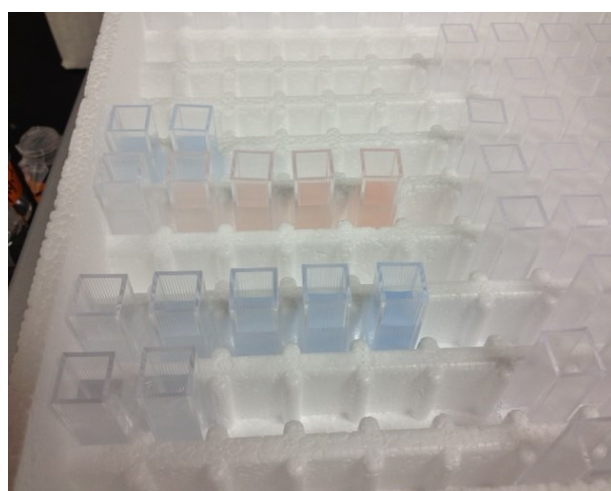
- Letter A shows where the membrane is placed and secured with the O ring.
- Letter B shows the reservoir which holds the liquid.
- Letter C shows the cap, the air hose attaches to the back of the cap.
- Letter D shows the cage that surrounds the stirred cell, so the top does not come off under pressure.



Rejection Test



The rejection test is conducted by using ultraviolet-visible (UV vis) spectroscopy, shown on the far left. UV vis spectroscopy compares the absorbance of light from wavelength data from concentration of the sample to the data from a calibration curve formed by carefully prepared set of dye solutions. For the rejection test, dye samples must first run through a membrane during a transport test. However, flux and permeability calculations are not needed. The dye that has been permeated through the membrane will become the samples for the UV vis spectroscopy. UV vis uses the Beer-Lambert Law, $A = \epsilon bc$, to calculate this information formed in the calibration curve. The chart to the left shows a comparison of rejection between two different membranes using the same dye. The image on the bottom right shows two sets of dyes and two sets of samples for each dye to be tested using UV vis spectroscopy.



WATER STRESS BY COUNTRY

ratio of withdrawals to supply

- Low stress (< 10%)
- Low to medium stress (10-20%)
- Medium to high stress (20-40%)
- High stress (40-80%)
- Extremely high stress (> 80%)

This map shows the average exposure of water users in each country to water stress, the ratio of total withdrawals to total renewable supply in a given area. A higher percentage means more water users are competing for limited supplies. Source: WRI Aqueduct, Gassert et al. 2013

AQUEDUCT

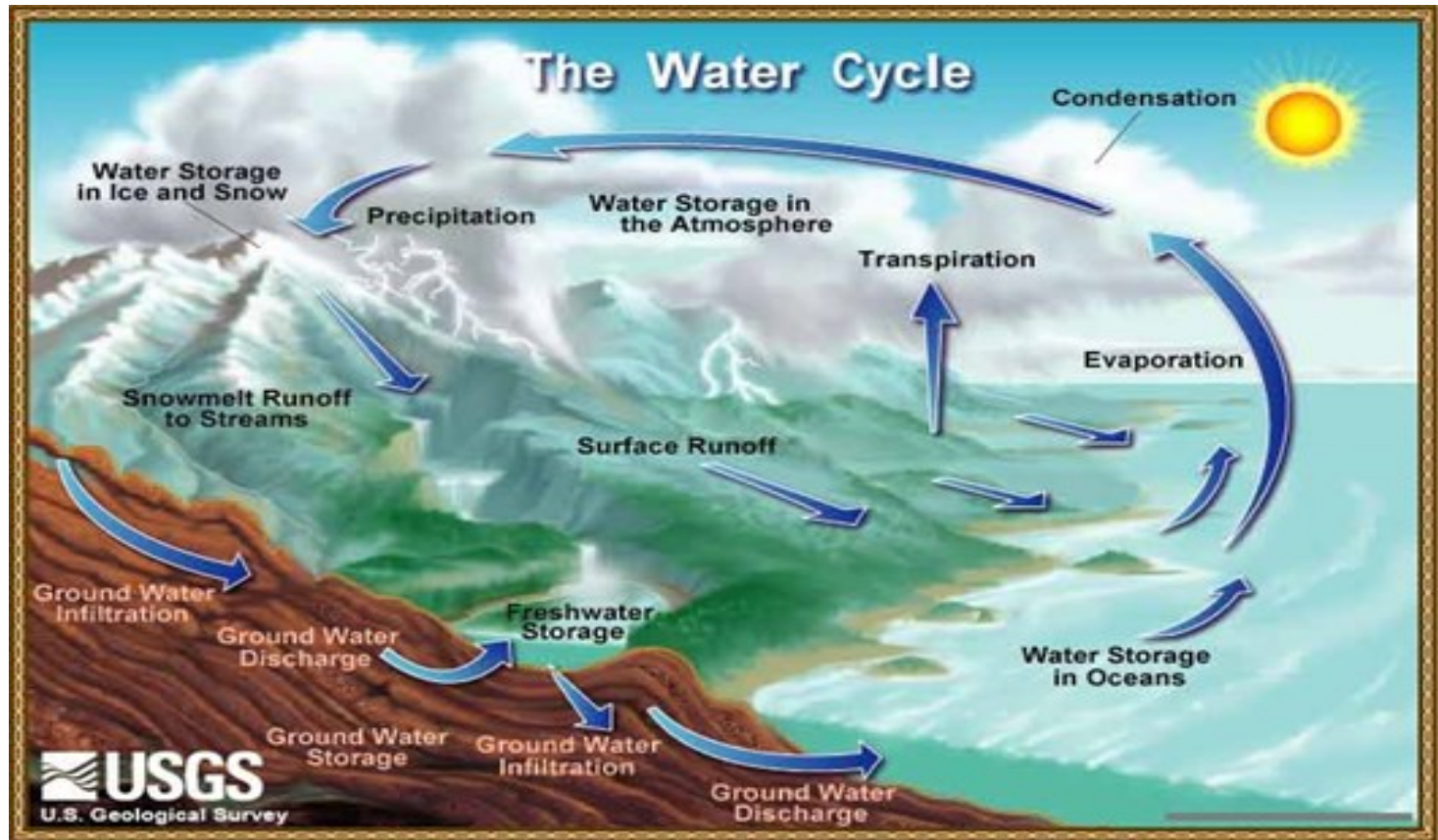
WORLD RESOURCES INSTITUTE

Connection to the Classroom

This work from the WATER Lab will be integrated into the fresh water, surface water, and ground water portion of my Earth Science class.

By the end of the unit my students will be able to:

- Describe each step of the water cycle and explain how pollutants in one step effects the others.
- Discuss why fresh water is a valuable resource.
- Identify several types of water stress and examine ways to decrease it.
- Filter certain particles from water and estimate the pore size of the filter.
- Design and construct a homemade water filter and test its effectiveness.

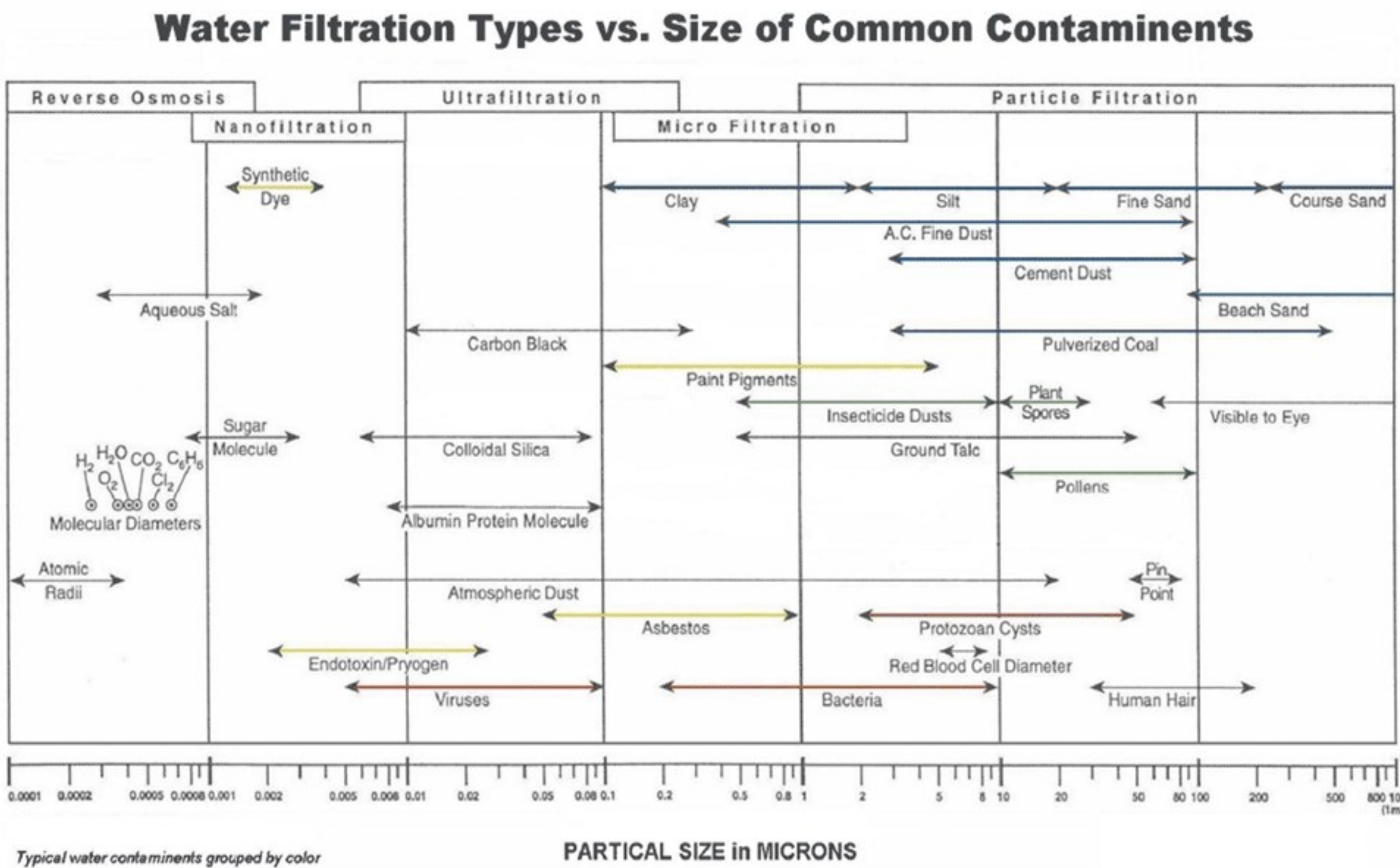


Curriculum Highlights

The WATER Lab focuses on filtering very small particles from water. In the classroom we will study water filtration by working with larger filters and particles.

Indiana Science Standards Covered in Curriculum

- Standard 3: The Earth**
Recognize and describe that earth sciences address planet-wide interacting systems (e.g., the oceans, the air, solid ground, and life on Earth) and interactions with the solar system. (ES.3.1, ES.3.2, ES.3.3)
ES.3.1 Understand that the Earth system contains fixed amounts of each stable chemical element and that each element moves among reservoirs in the solid earth, oceans, atmosphere and living organisms as part of biogeochemical cycles (i.e., nitrogen, water, carbon, oxygen and phosphorus cycles), which are driven by energy from within the earth and from the sun.
ES.3.3 Identify and differentiate between renewable and nonrenewable resources present within Earth's systems. Describe the possible long-term consequences that increased human consumption has placed on natural processes that renew some resources.
- Standard 3: The Earth**
Examine the interrelationships between society and the planet-wide interacting systems and understand the basic physical and chemical laws that control these interactions. (ES.3.4)
ES.3.4 Recognize that fundamental physical and chemical laws control past, present and future dynamic interactions between and within Earth systems.
- Standard 4: The Atmosphere and Hydrosphere**
Understand the structure and circulation of Earth's atmosphere and hydrosphere and explain how natural and human factors may interact with these processes. (ES.4.1, ES.4.2)
ES.4.2 Describe the relationships among evaporation, precipitation, ground water, surface water, and glacial systems in the water cycle. Discuss the effect of human interactions with the water cycle.
- Standard 4: The Atmosphere and Hydrosphere**
Understand that both weather and climate involve the transfer of matter and energy throughout the atmosphere and hydrosphere, driven by solar energy and gravity. (ES.4.3, ES.4.4, ES.4.5, ES.4.6)
ES.4.3 Explain the importance of heat transfer between and within the atmosphere, land masses, and bodies of water.
- Standard 6: Earth Processes**
Understand the cyclical nature of processes that modify the Earth and how humans interact with these cycles. (ES.6.1, ES.6.2, ES.6.3)
ES.6.1 Investigate and discuss how humans affect and are affected by geological systems and processes.



The major activities for this unit will consist of two labs.

In the first lab, students will separate sand from a sand and salt water solution. The students will learn how to separate particles from water and how to determine pore size of the filter by knowing the size of the particles. In the second lab, students will design, construct, and test a homemade water filter.

The equipment needed is as follows:

Sand and Salt Filtration Lab
Filter Paper or Coffee Filters
Funnels
Beakers or Flasks
Table Salt
Fine Grained Sand
Clean Water

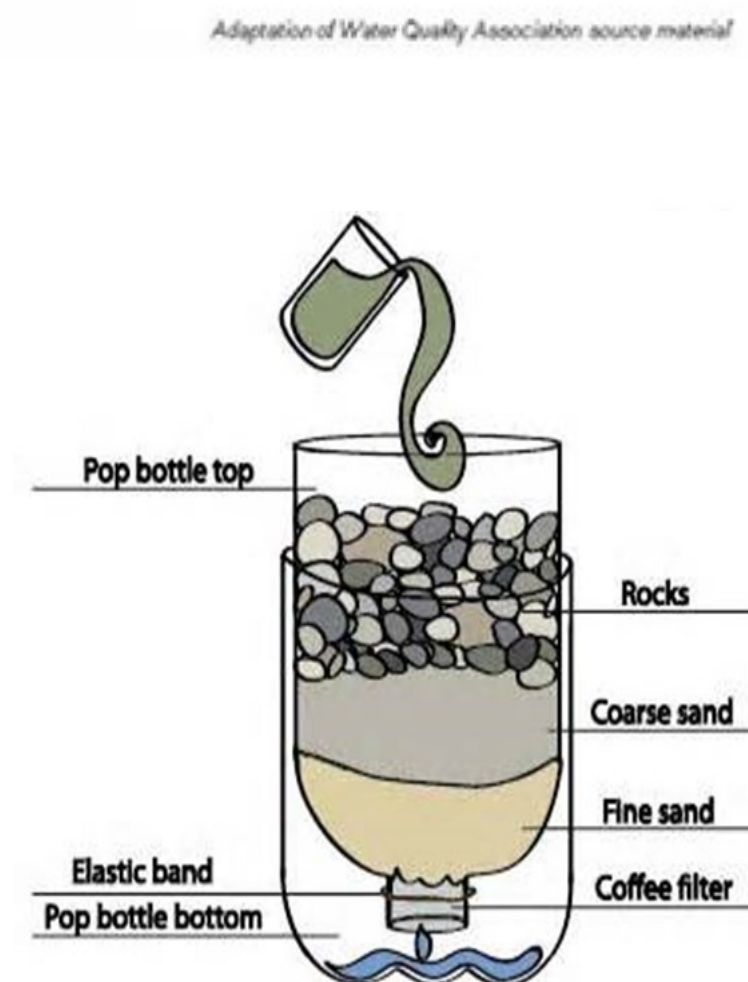
Build Your Own Water Filter Lab
Plastic Bottles
Funnels
Coffee Filters, Filter Paper
Cotton Balls and Rubber Bands
Sand - Fine and Coarse Grained
Gravel and Charcoal
Dirty Water

Filtration

This is the process of using a filter to mechanically separate a fluid (gas or liquid) mixture.

Many methods can be used in filtration but they all intend to separate two or more substances.

http://www.igraete.com/products/element_images/purification.jpg



<https://sp2.yimg.com/br/7d/H+HN.608015988021140058&pid=15.1&P=0>

Conclusion

There are many benefits for water filtration through these functional nanofiltration membranes. These membranes will assist in decreasing water stress across the world. They will aid in water purification through desalination, and removing chemicals that have entered the water from industry, pharmaceuticals, and agriculture. These membranes require less energy to maintain than traditional filtration methods. With continued study and testing of these membranes, they will become an efficient, safe, and economical way of reducing water stress.

Acknowledgements

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