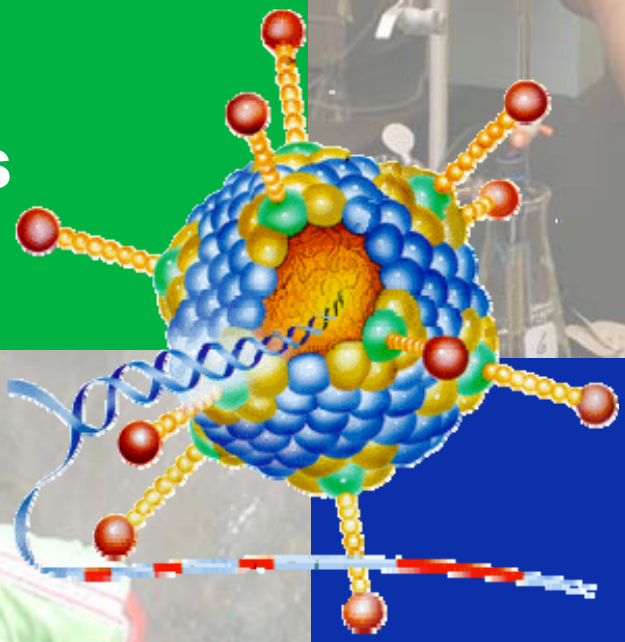
# Super Absorbent Polymers

# Teacher's Guide



The waterCAMPWS
Center for Advanced Materials
for Purification of Water with Systems

*The WaterCAMPWS* Center for Advanced Materials for Purification of Water with Systems
University of Illinois at Urbana-Champaign

**Curriculum Connection**: Biology, Chemistry, or Environmental Sciences

**Bloom's Taxonomy:**

**Grade Level**: 9-12

**Topic**: Polymers

**Lesson Duration**: 30-60 minutes

## Purpose

Polymer chemistry is fairly new and began in the 1940s as a way to recreate substances, such as rubber and polyurethane, that were not available to Allied and Axis forces during World War II. More recently, super absorbent polymers are used in commercial products including baby diapers and specialized potting soils (to help retain water). One common super absorbent polymer, Sodium polyacrylate, belongs to a family of water loving or hydrophilic polymers and has the ability to absorb up to 800 times its weight in distilled water. Differences in the chemical composition of the liquid interact with the chemical composition of the polymer to produce different rates of absorption.

Although it might seem counterintuitive to think that a center concerned with discovering new ways of producing, desalination or decontaminating water would be interested in super absorbent polymers, in fact researchers are very interested in looking at how super absorbent polymers can be used in landscaping and on farms to reduce the amount of water needed. Conservation is still a crucial part of The WaterCAMPWS's mission.

## Learning Goals and Objectives

1. Students will learn key vocabulary associated with polymer chemistry, including hydrophilic, polarity, osmosis, polymer, and cross linking.
2. Students will test a super absorbent polymer, sodium polyacrylate, on water with additives and without.
3. Students will explain hydrophilic properties and its importance to polymer chemistry.
4. Students will understand the relationship between water purification and polymer science.

## Benchmarks and Standards

### Illinois State Learning Standards:

- *11.A.4a* Formulate hypotheses referencing prior research knowledge.
- *11.A.4b* Conduct controlled experiments or simulations to test hypotheses.
- *11.A.4c* Collect, organize and analyze data accurately and precisely.
- *11.A.4e* Formulate alternative hypotheses to explain unexpected results.
- *12.C.4b* Analyze and explain the atomic and nuclear structure of matter.

**NSES Standards:** In grades 9-12, students will learn:

- *Content A* Abilities necessary to do scientific inquiry & understandings about scientific inquiry.
- *Content B* Structure and properties of matter, motions and forces, and interactions of energy and matter
- *Content E* Abilities of technical design and understandings about science and technology
- *Content F* Personal and Community health, population growth, natural resources, environmental quality, natural and human induced hazards, and science and technology in local, national and global challenges
- *Content G* Science as a human endeavor, nature of scientific knowledge
- *Teaching A* Plan an inquiry-based science program for their students
- *Teaching B* Guide and facilitate learning
- *Teaching D* Design and manage learning environments that provide students with the time, space and resources need for learning science.
- *Teaching E* Develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

## Materials and Equipment

Materials required for this lesson are (for each group of students):

- 3 400 mL beakers
- 200 mL water
- 200 mL lemon juice
- 200 mL vegetable oil
- sodium polyacrylate
- 4 plastic spoons
- 2 teaspoons NaCL, table salt

## Introduction

Polymers are both natural occurring and manmade and consist of a large number of molecules. Molecular weights of polymers typically range from 100,000 to one million atomic mass units or AMU's and contains a minimum of 10,000 atoms. Polymer chemistry is fairly new and began in the 1940s as a way to recreate substances, such as rubber and polyurethane, that were not available to Allied and Axis forces during World War II. Other polymers, like superabsorbent polymers, were not developed until the 1970s. At the U.S. Department of Agriculture, Edward B. Bagley and his colleagues developed a superabsorbent starch-based material, which was known as "Super Slurper". This superabsorbent starch was the first of its kind to be commercialized and was the precursor to modern superabsorbent polymers. The superabsorbent polymers that are currently being produced commercially are made of partially neutralized acrylic acid, one of the most widely used being sodium polyacrylate.

Sodium polyacrylate belongs to a family of water loving or hydrophilic polymers. It has the ability to absorb up to 800 times its weight in distilled water. Sodium polyacrylate is a powder which can usually be found in disposable diapers and takes the form of a coiled chain. There are two important groups that are found on the polymer chains, carbonyl (COOH) and sodium (Na). These two groups are important to the overall absorption potential of the polymer. When the polymer is in the presence of a liquid, the sodium dissociates from the carbonyl group creating two ions, carboxyl (COO-) and sodium (Na+). The carboxyl groups then begin to repel each other because they have the same negative charge. As a result of the repulsion between the like charges, the sodium polyacrylate chain uncoils or swells and forms a gel substance. The action of swelling allows more liquid to associate with the polymer chain. There are four major contributors to sodium polyacrylate's ability to absorb liquids or swell. These contributors are hydrophilic chains, charge repulsion, osmosis, and cross-links between chains. Ions in the polymer chain such as carboxyl groups (COO-) and sodium (Na+) attract water molecules, thus making the polymer hydrophilic. Charge repulsion between carboxyl groups allow the polymer to uncoil and interact with more water molecules (See figure 1).

Polymer:
a large molecule made by linking together smaller molecules.

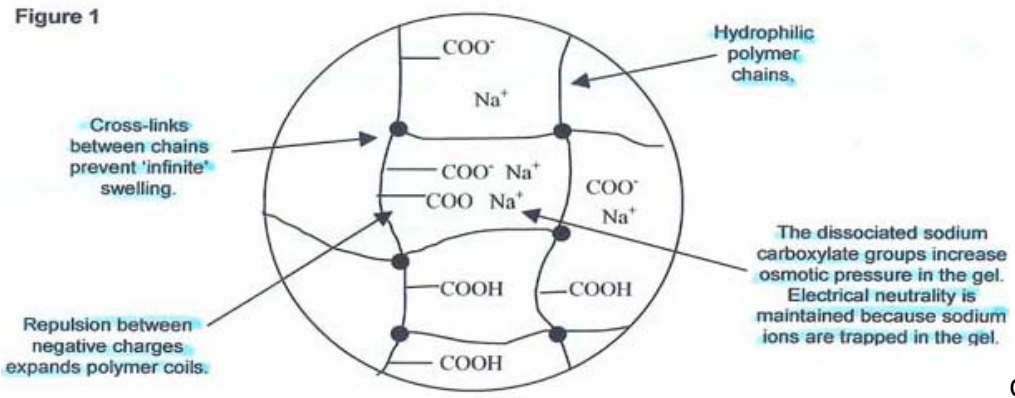
Hydrophilic:
a polar molecule or group that can form strong hydrogen bonds with water.

Carbonyl:
a group consisting of a carbon atom with a double bond to oxygen.

**Osmosis**:
the passage of solvent molecules from a dilute solution through a semipermiable membrane to a more concentrated solution.

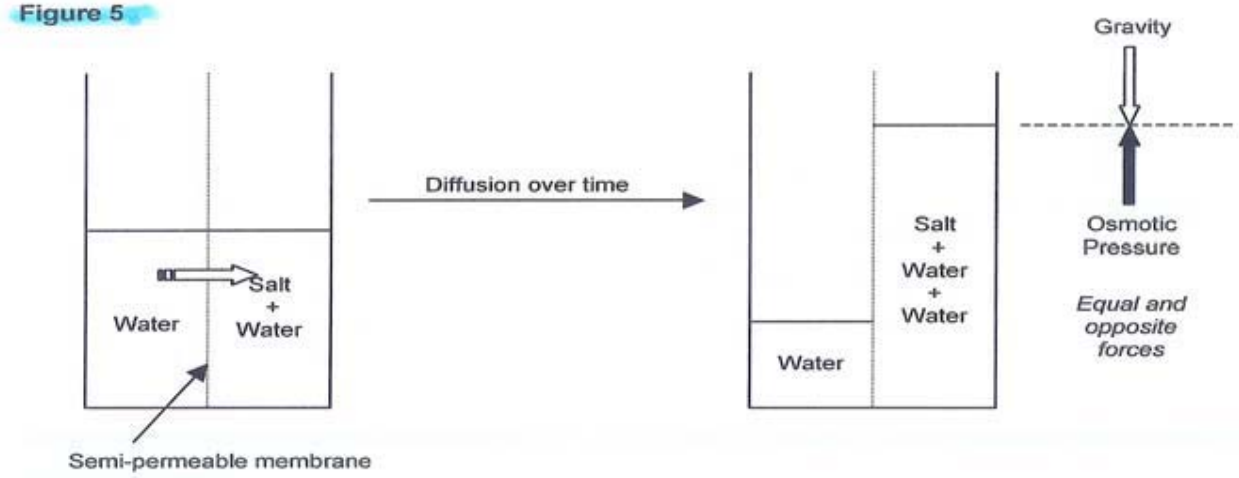
**Cross linking**:
the joining of two or more macromolecules with a smaller molecule.

Figure 1




Osmosis occurs when two aqueous solutions of different concentrations are separated by a semipermiable membrane. Water then moves across the membrane from lower to higher concentrated solutions until the concentrations are equal on both sides of the membrane. In the case of sodium polyacrylate, once sodium ions dissociate from the polymer chain, they are able to move around freely. The polymer swells due to the difference between the concentration of liquid inside and outside of the gel because of the presence of free sodium ions in the gel. The liquid is absorbed inside to polymer to equalize the difference in concentration.

Figure 5




Cross links between polymer chains prevent the polymer from dissolving in water and other liquids. When the chains become hydrated, the cross links prevent them from moving around randomly. This decrease in random movement or entropy produces a stiff gel. The number of cross links in the polymer affects the amount of absorption for the polymer as well as the strength of the gel. For example, the more cross links in the chain, the less able the polymer is to absorb liquids and the stronger the produced gel.

## Activities

1. Present the introduction to this lab or some other related appropriate introduction to polymers or osmosis.
2. Divide students into groups. Distribute to each group the materials needed for the lab.
3. Allow the students to follow the procedures listed in their lab books.
4. Have students complete the comprehension and analysis questions in their lab books.
5. Conclude the lab with a discussion of their results.

## Conclusion

Have the students clean up the lab. If there is time, discuss the results of the experiment as a class.

## Assessment

The lab book should provide an assessment tool for this lesson.

## Extension