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Applications of Super Absorbent Polymer: A Review

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ABSTRACT

One of the amazing inventions of science is super absorbent polymers capable of absorbing liquids. Super absorbent polymers (SAP's) are materials that have the ability to absorb and retain large volumes of water and aqueous solutions by swelling. Various applications of super absorbent polymers are being explored by various experiments across the world. The mechanism of absorption by these polymers and their few applications are being discussed.

Introduction

Super absorbent polymers (SAP's) ideal for use in water absorbing applications such as baby nappies and adults incontinence pads to absorbent medical dressings and controlled release medium.

Early super absorbents were made from chemically modified starch and cellulose and other polymers like poly vinyl alcohol PVA, poly ethylene oxide PEO all of which are hydrophilic and have a high affinity for water. When lightly cross-linked, chemically or physically, these polymers became water-swellable but not water-soluble [1]

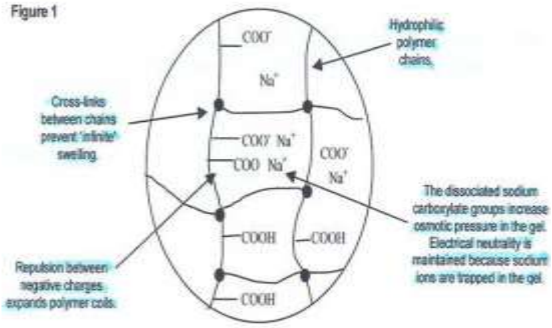
Today's superabsorbent polymers are made from partially neutralized, lightly cross-linked poly acrylic acid. In water they swell to a rubbery gel that in some cases can be up to 99wt% water.

There are super absorbent fibers commercially available today. While significantly more expensive than the granular polymers, super absorbent polymers offer technical advantages in certain niche markets including cable wrap, medical devices and food packaging[2].

Mechanism

There are several mechanisms to the process of swelling, all of which contribute to the final swelling capacity (or centrifuge retention capacity CRC – which is the amount of 0.9 wt% saline solutions that a SAP can retain under free swelling conditions when surface water has been removed in a centrifuge.

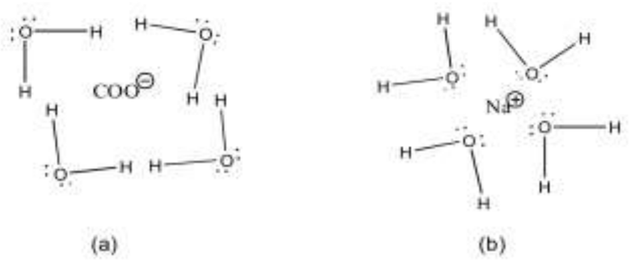
Figure 1



The polymer backbone in SAP is hydrophilic i.e. 'waterloving' because it contains water loving carboxylic acidgroups (–COOH).

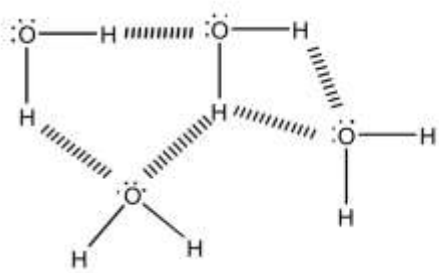
Hydration

This is the interaction of ions of a solute with molecules of a solvent i.e. COO^- and Na^+ ions attract the polar water molecules.



Hydrogen Bonding

Hydrogen bonds are electrostatic interactions between molecules, occurring in molecules that have hydrogen atoms attached to small electronegative atoms such as N, F and O. The hydrogen atoms are attracted to the non-bonding electron pairs (lone pairs) on other neighbouring electronegative atoms



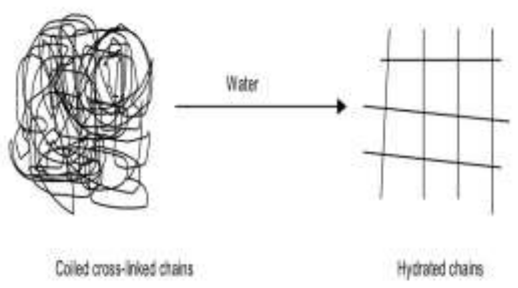
In water the electronegative atom is oxygen which pulls the hydrogen's electrons towards itself setting up a dipole in the molecule. The positive hydrogen atoms are attracted to the oxygen lone pairs on other water molecules.

Oxygen has two lone pairs of electrons and each is capable of hydrogen bonding to two other water molecules [4].

These effects decrease the energy and increase the entropy of the system. Due to the hydrophilic nature of SAP the polymer chains have a tendency to disperse in a given amount of water (i.e. they are trying to dissolve in the water), which leads to a higher number of configurations for the system and also increases entropy [5].

Dissolving Of Sap

Cross-links between polymer chains form a three-dimensional network and prevent the polymer swelling to infinity i.e. dissolving. This is due to the elastic retraction forces of the network, and is accompanied by a decrease in entropy of the chains, as they become stiffer from their originally coiled state.



There is a balance now between the forces of retraction and the tendency for the chains to swell to infinite dilution. The degree of cross-linking has a direct effect on the level of swelling of the polymer and the strength of the network i.e. Increased cross-link density = decreased swelling capacity = increased gel strength.

Cross-linking in superabsorbent polymers

There are two main types of cross-linking in most superabsorbent polymers.

- Bulk or core cross-linking
- Surface cross-linking

Bulk Or Core Cross-Linking

This normally takes place during the polymerization stage of superabsorbent production.

Cross-linking is the joining of molecules – generally joining two or more macromolecules with a smaller molecule. The most important type in the case of super absorbents, and the most common, is the covalent cross-link. In SAP manufacture the most common types of cross-linker are organic molecules that contain two or more polymerisable double bonds. These molecules are incorporated into the backbone of the polymer chains as they grow during the polymerization reaction [6]].Several factors determine the incorporation of the cross-linkers in to the polymer and their distribution along the polymer backbone.

Surface Cross-Linking:

This is a newer process that improves the absorption against pressure profile of the polymer.

Historically it is known that SAPs with no surface treatment and low internal cross-linking tend to show high swelling capacities but poor absorption against pressure. Improving the swelling capacity of SAP by decreasing the core cross-linking, i.e. decreasing the cross-linking density, is limited by the accompanying increase in extractable polymer content of the gel. Likewise the increase in capacity would lead to a decrease in the uptake of liquid when the SAP was under load, for example a baby sitting on its diaper [7].

This means that when a pressure is applied on the SAP, liquid is not absorbed effectively in these areas. Moreover the pressure on the semi-swollen gel can cause a blockage in the area preventing further liquid entering the gel bed and being absorbed by dry SAP underneath. This phenomenon is called gel blocking and causes diapers to leak [8]. Hence increasing the swelling capacity using conventional means (lowering core cross-linker) leads to an overall decrease in capacity under load.

SAPs are organic materials with well-known general structure. For instance, the agricultural SAP with the name of “cross-linked acryl amide/potassium acrylate copolymer” has been recorded in the most valid data centre of chemicals, i.e. the Chemical Abstracts In the material safety data sheet (MSDS) of the superabsorbent manufacturers, they are called as “Safe and Non-toxic Material” [9].

Conclusion

Super absorbent polymers are being commonly made from petrochemical starting materials i.e acrylic acid. SAPs have been applicable increasingly in many uses ranged from personal care products to agriculture. Its various useful products include super absorbent soil polymer, Absorbent Pads, Super Absorbing Baby Diapers, Super Absorbing Adult Diapers, Feminine Sanitary Napkins, Gel Wound Dressing. SAPs, however, possess typically higher cost and less performance than their fully synthetic counterparts. Besides various applications, the most volume of SAP world production (106 tons/year) is yet consumed in hygienic uses, i.e., disposable diapers (as baby or adult diapers, feminine napkins, etc.) [10].

SAPs have created a very attractive area in the viewpoint of super-swelling behaviour, chemistry, and designing the variety of final applications. Thus, we increasingly walk in a green area becoming greener via replacing the synthetics with the bio-based materials, e.g., polysaccharides and polypeptides. This, however, is a long-term perspective. More or less, the acrylic kingdom will extend its domination in the future markets.

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