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Preparation and Properties of Superabsorbent Nanocomposite of Acrylamide/Acrylic Acid/Bentonite for Uses in Agriculture with Different Soil Salinities

Zahra Jazebi[1], Mahmoud Reza Hojjati[1]* and Ali Kasraian[2]

1. Department of Chemical Engineering, Shiraz Branch, Islamic Azad University, Shiraz, Iran

2. Department of Soil Science, Shiraz Branch, Islamic Azad University, Shiraz, Iran

hojati_m@iaushiraz.ac.ir

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Abstract

Scarcity of water as well as shortage of water reservoirs is a major global issue excruciating by an increase in population. Saving water in irrigation is a vital solution in protecting water reservoirs and takes high priority among other possible solutions. Superabsorbents are cross-linked hydrophilic polymers with the ability to reversibly swell in water as well as absorbing high volume of water, thus superabsorbents have attractive application in agriculture. In this research, the effect of synthesis factors such as acrylamide and acrylic acid monomers, the amount of bentonite and the ratio of cross-linker to initiator on swelling behavior and water absorbency of hydrogel were investigated and their absorbtion and desorbtion in sour solution and soil was determined. Superabsorbents were synthesized by solution polymerization and their chemical structures were characterized by FTIR, SEM, XRD, TGA, and DSC. The results showed that an increase in cross-linker would decrease the equilibrium swelling, and by using the optimum of the initiator, an increase in acrylamide and acrylic acid, the equilibrium swelling would increase. An increase in bentonite would increase equilibrium swelling, but additional bentonite will decrease it. By optimizingmentioned additives, a superabsorbent was prepared with the water absorbency of 1125 g/g. The results of absorbtion and desorbtion of optimized superabsorbent in highly sour solutions and soil have showed that the synthesized superabsorbent is highly practical in sour solutions, thus suitable in highly sour soils.

Keywords: Superabsorbent, Nanocomposite, Bentonite, Acrylic Acid, Acrylamide.

Introduction

Nowadays, scarcity of water resources is a global problem. A very serious water crisis has been created because of world population growth, increasing demand for water, food and energy, and misuse of water resources. On the other hand, salinization of water resources is also a growing problem, resulting in salinization of agricultural soils and reduction in agricultural productivity. Hence, researchers are trying to find novel, efficient, and economical ways to improve traditional agriculture. Superabsorbents are hydrophilic cross-linked polymers, which are popular in agriculture since they are capable of reversibly absorbing large amounts of water. [1-3]. Hydrogels are made of natural or synthetic hydrophilic polymers with three-dimensional structure. If hydrogels expose to water, absorb it and swell, but do not dissolve in water. Superabsorbent (SAP) is a hydrogel with an absorption capacity of up to 20 times its weight. Hydrogels have attracted considerable attention over the past 50 years due to their exceptional role in a wide range of uses, such as medicine, pharmaceuticals, agriculture, and health products [4]. Poly (Acrylic Acid- Co-Acrylamide) hydrogel is one of the most important popular hydrogels due to their relatively inexpensive monomers, easy polymerization and high molecular weight masses [5]. There are different methods to improve the efficiency of hydrogels and to overcome their limiting factors (such as relatively high prices, improved water absorption properties, and water resistance [5]). Two common methods include making alloys by blending synthetic and natural polymers together, and the addition of mineral packings such as mica [6] graphene oxide [7], Attapulgite [8], laponite [9], and AlZnFe2O4 [10]. Clay powder is one of the most important mineral packings commonly used.

Materials & methods

Acrylamide (AM), Acrylic acid (AA), and ammonium sulfate (APS) were purchased from Daejung, N,N’-Methylenebisacrylamide (MBA) from Titrachem and bentonite from Sigma Aldrich. Superabsorants ware made by solution polymerization method. First, different concentrations of bentonite dispersed in 20 ml distilled water for 12 hours. It was then added slowly to a flask containing acrylamide, acrylic acid, crosslinking agent, and 30 milliliters of distilled water, which was previously exposed to nitrogen gas flow for one hour. After 45 minutes, the temperature was increased to 40°C. To neutralize acrylic acid, a 3M sodium hydroxide solution was used. Finally, the initiator was added to the solution and temperature was gradually increased to form the gel. After gel formation, it was divided into smaller pieces and washed with distilled water. It was then dried under vacuum for 3 days at 60°C. To evaluate the superabsorbent performance, a control sample was prepared by excluding bentonite and having similar conditions of composite synthesis. The rate of water absorption in a free swelling condition without applying external pressure is calculated using equation (1) [11].

$$Q_{H_2O} = (m_2 - m_1)/m_1 \quad (1)$$

In eq. (1), m1 is dry sample weight, m2 is swelled sample weight, and QH_2O is grams of water per gram of sample. In order to study the performance of superabsorbents in saline soils, superabsorbents were first treated in solutions with different salt concentrations. For this purpose, 2 grams of dry superabsorbent were shaken for 10 hours in these solutions. After that, the superabsorbent was removed using a sieve and then weighed. The amount of water absorption in salt solutions was obtained using equation (1). In order to investigate the effect of salinity on superabsorbent efficiency in agriculture, the amount of water absorption and desorption in soil was investigated for samples pretreated with salt. For this purpose, a sandy loam soil was used. The soil was completely dried before use and passed through a 2 mm sieve. The same amount of superabsorbent and soil was used for all samples. After pouring the soil and superabsorbent in each pot, they were watered with a certain amount of water. After drainage, each pot was individually weighed and the operation was repeated at a specific time each day. In this way, the amounts of absorbed and desorbed water by each pot were measured over time and the results were compared.

Results and Discussion

The use of superabsorbent polymers in agriculture is a new efficient approach. It saves water and chemical fertilizers that are highly soluble in water, improves the density, reduces water evaporation, increases water penetration into soil, and reduces the risk of flooding and soil erosion. The results indicate that Equilibrium water absorbency for superabsorbent composite are significantly affected by amount of crosslinker, initiator dosage, molar ratio of AA/AM and content of bentonite, among these factors, the mass ratio of crosslinking agent to initiator is of the greatest impact. Maximum swelling was achieved using 6 mg crosslinking agent and 60 mg initiator. The fractional factorial results showed that the optimal amount of acrylamide, acrylic acid, and bentonite are 5 g, 7 g, and 1%, respectively. The superabsorbent was able to increase the soil water content to agricultural level for plant growth. Contact of superabsorbent with common soil salts (sodium chloride and calcium chloride) reduces the optimum absorption and desorption capacity of superabsorbent from 1125 in distilled water to 15 g/g. However, in case of superabsorbent treatment with very high salt concentrations, the soil containing superabsorbent can hold water more than the soil without superabsorbent. After seven days, the soil sample containing superabsorbent treated with salt showed 1/3 times more water than the soil without superabsorbent. FTIR indicates that the grafting reaction occurs between –COO groups and –OH groups on the surface of bentonite through ester formation. SEM studies illustrate more finely dispersion of the clay particle in the polymer matrix. XRD analysis shows that the polymerization reaction is performed on the surface of bentonite and the XRD pattern of composites is not changed. TGA and DSC implies that introduction of bentonite into the polymer network leads to an increase in thermal stability of the composites.

Conclusions

Scarcity of water as well as shortage of water reservoirs is a major global issue excruciating by the increase in population. Saving water in irrigation is a vital solution in protecting water reservoirs and takes high priority among other possible solutions. Superabsorbents are cross-linked hydrophilic polymers with the ability to reversibly swell in water as well as absorbing high volume of water, thus superabsorbents have attractive application in agriculture. In this research, the effect of synthesis factors such as acrylamide and acrylic acid monomers, the amount of bentonite and the ratio of cross-linker to initiator on swelling behavior and water absorbency of hydrogel were investigated and their absorbtion and desorbtion in sour solution and soil was determined. Finally, the results showed that increase of cross-linker would decrease the equilibrium swelling, and by using the optimum of the initiator, the increase of acrylamide and acrylic acid, the equilibrium swelling would increase. The increase in bentonite would increase equilibrium swelling, but additional bentonite will decrease it and the highest water absorbency is obtained when 1 wt.% bentonite is incorporated. Water absorbency of these composite materials is also significantly dependent on properties of external saline solutions. the results of absorbtion and desorbtion of optimized superabsorbent in highly sour solutions and soil showed that the synthesized superabsorbent is highly practical in sour solutions, thus suitable in highly sour soils.

References

[1]. Tolk J. A., Evett S. R., Xu W. and Schwartz R. C., *"Constraints on water use efficiency of drought tolerant maize grown in a semi-arid environment,"* Field Crops Research., Vol. 186, pp. 66-77, 2016.

[2]. Porkka M., Gerten D., Schaphoff S., Siebert S. and Kummu M., *"Causes and trends of water scarcity in food production,"* Environmental Research Letters, Vol. 11, No. 1, 2016.

[3]. Musyimi D. M., *"Ecology and physiology of plant growth in relation to soil salinity,"* Scientia, Vol. 11, No. 1, pp. 26-31, 2015.

[4]. Ahmed E. M., *"Hydrogel preparation, characterization and application,"* Journal of Advanced Research Vol. 6 No. 2, pp. 105-121, 2015.

[5]. Xie J., Liu X. and Liang J., *"Absorbency and adsorption of poly (acrylic acid-co-acrylamide) hydrogel,"* Journal of Applied Polymer Science, Vol. 106, No. 3, pp. 1606-1613, 2007.

[6]. Lin J., Wu J., Yang Z. and Pu M., *"Synthesis and properties of poly (acrylic acid)/ mica superabsorbent nanocomposite,"* Macromolecular Rapid Communications, Vol. 22 No. 6, pp. 422- 424, 2001.

[7]. Huang Y., Zeng M., Ren, J., Wang J., Fan L. and Xu Q., *"Preparation and swelling properties of graphene oxide/poly (acrylic acid-co-acrylamide) super-absorbent hydrogel nanocomposites,"* Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 401, pp. 97-106, 2012.

[8]. Qi X., Liu M. and Chen Z., *"Study on swelling behavior of poly (sodium acrylate-CO-$_2$-acryloylamino-2-methyl-1-propanesulfonic acid)/attapulgite macroporous superabsorbent composite,"* Polymer Engineering & Science, Vol. 55, No. 3, pp. 681-687, 2015.

[۹]. باقری مرندی غ. و بهارلویی م.، *"سنتز نانوکامپوزیت های هیدروژل آکریل آمید و ایتاکونیک‌اسید با استفاده از خاک رس لاپونیت و مطالعه جذب رنگ دانه بلور بنفش،"* علوم و تکنولوژی پلیمر (فارسی) دوره ۲۴، شماره ۶، ۵۰۶-۵۱۴، ۱۳۹۰.

[10]. Shahid S. A., Qidwai A. A., Anwar F., Ullah I. and Rashid U., *"Improvement in the water retention characteristics of sandy loam soil using a newly synthesized poly (acrylamide-co-acrylic acid)/$AlZnFe_2O_4$ superabsorbent hydrogel nanocomposite material,"* Molecules, Vol. 17, No. 8, pp. 9397-9412, 2012.

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[11]. Natkański P., Białas A. and Kuśtrowski P., *“The synthesis of poly(acrylic acid)-bentonite and polyacrylamide-bentonite composites for adsorption applications,”* Chemik, Vol. 66, No. 7, pp. 742-749, 2012.