Investigation of Water Uptake Behavior of Superabsorbent Polymers Composed of N-Vinyl-2-pyrrolidone and Partially Neutralized Acrylic Acid

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Investigation of Water Uptake Behavior of Superabsorbent Polymers Composed of N-Vinyl-2-pyrrolidone and Partially Neutralized Acrylic Acid

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Fast-swelling micrometer sized superabsorbents were synthesized through a rapid solution polymerization of n-vinyl-2-pyrrolidone (NVP) and partially neutralized acrylic acid (PNAAc) under normal atmospheric conditions using N,N'-methylene bisacrylamide (MB) as crosslinker and sodium bicarbonate as porogen. The effect of various parameters such as crosslinker concentration, degree of neutralization of monomer acid, concentration of initiator have been evaluated. Water retention capacity of superabsorbents under varying loads was also examined. The drying behavior of polymers at 37°C was also studied. The gels showed sharp volume transition in solutions of divalent metal ions. The superabsorbents were also characterized by FTIR and TGA.

Keywords superabsorbents, water retention, acrylic acid

Introduction

As a functional polymeric material, superabsorbent polymer (SAP) can absorb and hold large amount of water even under pressure. Due to this excellent water absorbing capacity, they possess a soft, rubbery nature and improved anti-thermogenicity owing to lower free energy of their hydrated interface. Because of these excellent features, they have been employed as potential biomaterials in bioengineering, medicine, and the pharmacy and veterinary fields (1–6). In addition to these applications, superabsorbent polymers are also employed as a soil conditioner for agriculture and horticulture, disposable diapers, water blocking tapes, absorbent pads, drilling field additive, cracks blocking materials, feminine napkins, fire fighting agents, etc. (7–9).

Desired features of superabsorbents are (a) high swelling capacity, (b) high swelling rate and, (c) good water retention capacity under higher loads. However, the majority of the reported superabsorbents comprise only the first feature mentioned above i.e., high absorbency (10). But, in order to use these materials for applications such as baby

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napkins, surgical pads, etc., it is essential that they possess features (b) and (c) mentioned above. Moreover, they should also be biocompatible and they should not cause skin irritation or inconvenience to the users.

In our previous work (11), we reported a detailed investigation of water absorbency, buoyant behavior and mechanical properties of poly(acrylamide-co-acrylic acid) superabsorbents that were intended to be used as gastric retention devices. In the present article, we have described water absorbing capacity and water retention properties of finely ground super absorbent particles prepared from N-vinyl-2-pyrrolidone (NVP) and partially neutralized acrylic acid (PNAAc) through solution polymerization at room temperature under normal atmospheric conditions. A thorough survey of the literature reveals that this copolymeric system has not been reported as superabsorbent material. We used potassium persulfate (KPS) as initiator, tetramethyl ethylenediamine (TEMED) as catalyst and sodium bicarbonate as gas bubbling agent. The gels were crosslinked with N,N'–methylene bisacrylamide (MB), a water soluble material.
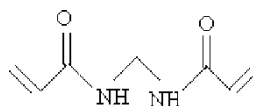
MB: water soluble crosslinker

In a preliminary study, the micrometer sized co-polymeric superabsorbent particles obtained with 55% neutralized acrylic acid demonstrated nearly 155 g/g swelling capacity (Figure 1).

Experimental

Materials

Monomers N-vinyl-2-pyrrolidone and acrylic acid were purchased from Hi Media Lab, Mumbai, India and used as received. The crosslinker N,N'-methylene bisacrylamide
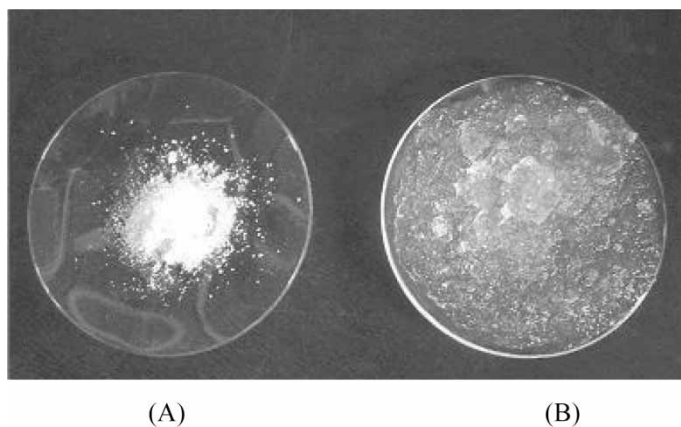

(A)   (B)

Figure 1. Photograph showing 400 μm sized superporous hydrogel sample SAP (55) in (A) dry state and, (B) fully swollen state in distilled water at 30°C.

and initiator potassium persulfate and citric acid were obtained from Research Lab, Pune, India. The catalyst tetramethyl ethylenediamine (TEMED) and other chemicals were purchased from Merck, Mumbai, India. The double distilled water was used throughout the investigation.

Synthesis

The stock solution of monomer partially neutralized acrylic acid was prepared by dropping 40 ml of 40% sodium hydroxide (W/V) into 60 ml of magnetically stirred acrylic acid with ice cooling.

To 5 ml of PNAAc solution, 1 ml of NVP was added in a beaker, followed by the addition of 6.4×10^{-2} mM of crosslinker MB, 3.6×10^{-2} mM of initiator KPS and 47.5×10^{-2} mM of citric acid. Finally, 400 mg of $NaHCO_3$ was added and after shaking for 30 s, 1.72 mM of catalyst TEMED was added. The reaction medium became foamy or fluffy due to the action of the gas blowing agent and simultaneous gel formation. After 30 min, the solid and relatively dried polymer was removed from the beaker and cut into small pieces. The pieces were spread over aluminum foil and heated in an air-recirculating oven at 60°C for 4 h. A hammer type mini-grinder was used for grinding. The grinded powder was passed through a 250 μm sieve and the fraction retained on sieve was collected, the mean particle size as determined by optical microscopy, was found to be 400 μm. The sample shall be designated as SAP (55) where the number in parenthesis denotes the percent neutralization of monomer acrylic acid in the feed mixture. For example, this sample will be designated as SAP (55).

TGA and FTIR Spectroscopy

TGA was performed at the Indian Institute of Chemical Technology (IICT), Hyderabad, India, using a thermogravimeter analyzer (Mettler Toledo TGA/SDTA 851®) controlled by STAR® Software (Mettler Toledo GmbH, Switzerland). About 9.90 mg of a powdered sample of SAP (55) was placed in a ceramic crucible and analyzed over the temperature range 30–1000°C at the rate of 10°C min^{-1} under the dry flow of N_2 at the rate of 10°C min^{-1}. The FTIR spectra of polymer was recorded in a Perkin-Elmer Spectrophotometer ASCII (Perkin-Elmer Cetus Instruments, Norwalk, CT).

Water Absorbency and Retention Tests

Absorption in distilled water and salt solutions was measured by the "tea-bag" method (12), and the swelling ratio (SR) was calculated by the following expression:

$$\text{Swelling ratio (g/g)} = \frac{W_t - W_o}{W_o}$$

where W_o is the dry weight of polymer and W_t is the swollen weight at different times t. Water retention of the swollen gel was determined by a heating oven test at 30°C, as well as by a ZNS-2 Model fluid-loss meter under various pressures for 15 min.

Results and Discussion

TGA of Super Absorbent Polymer

Figure 2 depicts the thermogram obtained for the sample SAP (55). The value of T_{id} (initial decomposition temperature), T_{fd} (final decomposition temperature) and T_{max} (Temperature of maximum rate of weight loss) were found to be 150,750 and 250°C, respectively. It is clear that the polymer sample is quite stable up to 150°C, and so may be considered sufficiently stable.

FTIR of Polymer Sample

The FTIR spectra of copolymer, as shown in Figure 3 contains the characteristic bands. The IR spectra confirms the presence of O-H and N-H stretching vibration at $3439\,cm^{-1}$. The OH stretching vibration are overlapped by N-H stretching which is due to the presence of methylene–bisacrylamide. The 'C=O' absorption of carboxylic acid appears at $1744\,cm^{-1}$, $1632\,cm^{-1}$, and $1408\,cm^{-1}$. The alkane (C-H stretching) appears at $2940\,cm^{-1}$ and (C-H) banding appears at $1448\,cm^{-1}$.

Effect of Initiator Content on Water Uptake

Figure 4 depicts the effect of KPS content on the water absorbency of the resulting SAPs. It is clear that $11.0 \times 10^{-2}\,mM$ seems to be the optimum concentration of KPS for which the resulting polymer shows maximum equilibrium water uptake, nearly 230 g/g in distilled water. However, the water absorbency decreases below and above this optimum concentration value. This may be due to the fact that when the KPS content is increased beyond the optimum value, the reaction becomes so fast that it results in formation of macromolecular chains with low molecular weights, thus causing low degree of swelling of resulting
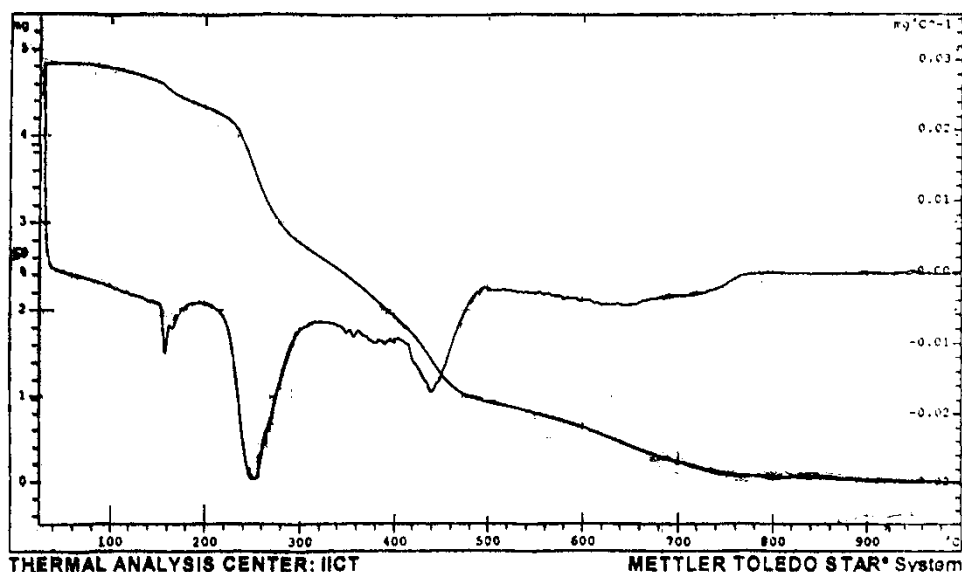
Figure 2. Thermogram of the polymer sample.
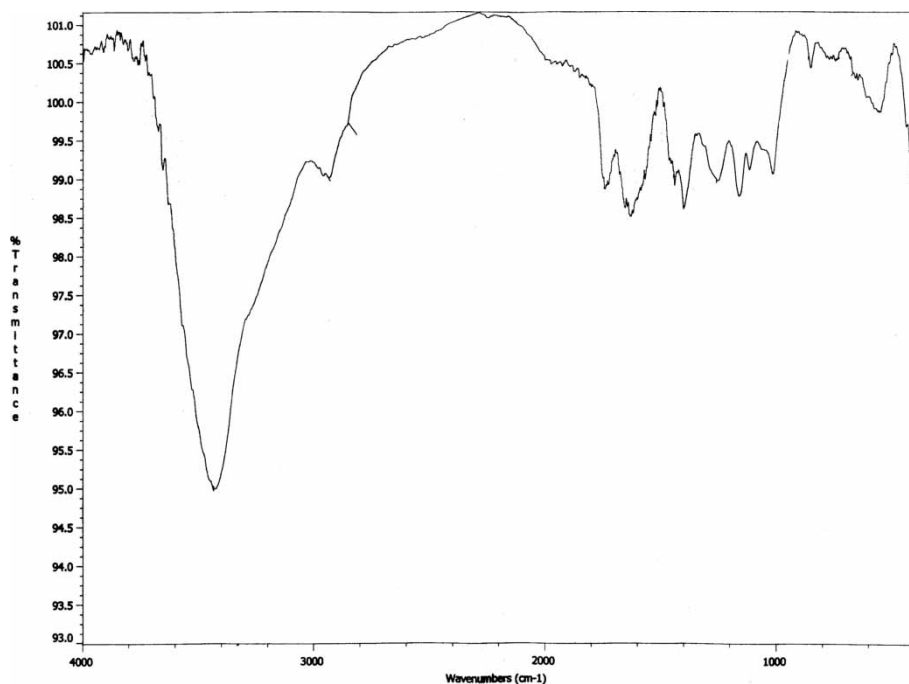
Figure 3. FTIR spectrum of co-polymer superabsorbent.

hydrogels (12, 13). However, when KPS concentration is decreased below the optimum value, it causes a decrease in the number of radicals produced and hence, the rate of polymerization also decreases, thus resulting in termination of high molecular weight segments. This produces relatively a dense or less porous structure, and therefore water

Figure 4. Effect of initiator concentration on the equilibrium swelling ratio of resulting super absorbent samples SAP (55) in distilled water at 30°C.

absorbency decreases. Moreover, with a further decrease in the KPS content, the number of radicals produced becomes so small that an efficient network cannot be produced. This causes a further decrease in water uptake of the resulting gels. Similar observations have also been reported by other workers (14, 15).

Effect of Crosslinker Concentration on Water Absorbency

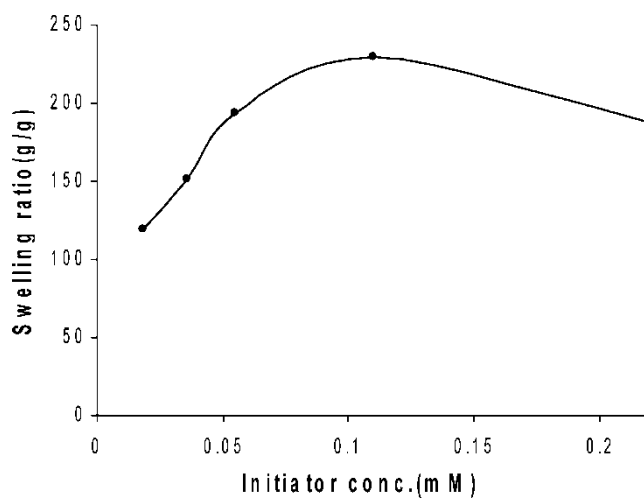In order to investigate the effect of crosslinker concentration on water uptake of resulting hydrogels, hydrogel samples with varying amounts of crosslinker, in the range 6.4×10^{-2} to 22.7×10^{-2} mM were synthesized and their water uptake was measured at different time intervals in distilled water. It is clear from Figure 5 that as the amount of crosslinker in the feed mixture increases, the water absorbency of resulting SAP decreases. This may simply be attributed to the fact that with an increase in concentration of crosslinker, the flexibility of macromolecular chains decreases. Moreover, in the highly dense network there is less free space available for accommodation of solvent molecules, thus resulting in less water absorbency.

Effect of Dilution of Feed Mixture on Water Uptake

The degree of crosslinking of a polymer network is a significant property because it affects the water absorbency by influencing molecular weight between crosslinks. The degree of crosslinking is mainly governed by the fraction of crosslinking agent present in the feed mixture and the extent to which double bonds are consumed during the polymerization. Smaller quantities of crosslinker and diminished final conversion both lead to a less densely crosslinked material. The most important fact is that not all of the double bonds present in the crosslinker are consumed in the formation of crosslinks. In fact, potential crosslinking is also lost due to intramolecular cyclization reactions where both

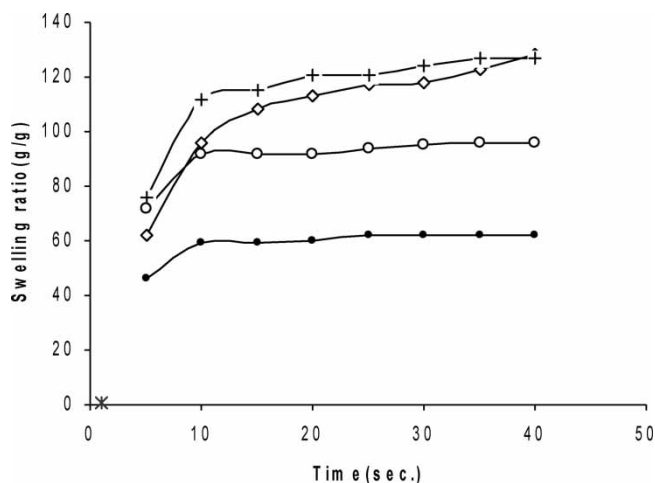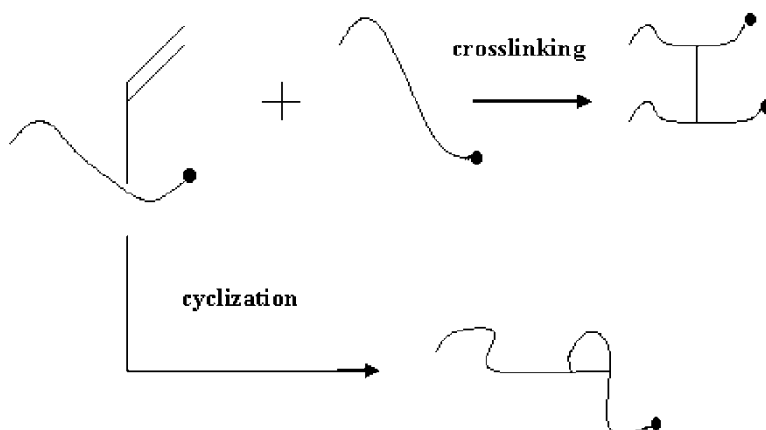**Figure 5.** Dynamic water uptake of SAPs containing 6.4×10^{-2} mM ($\diamond$), 16.2×10^{-2} mM ($+$), 22.7×10^{-2} mM ($\bigcirc$) and 32.4×10^{-2} mM ($\bullet$) of crosslinking agent in distilled water at 30°C.

ends of the crosslinker molecule react into the same growing polymer chain, forming a loop structure as shown below:

Although, the equivalent amount of crosslinker may be present and incorporated into the network, when cyclization is occurring, the polymer produced is less crosslinked and shows higher water uptake. This phenomenon is more pronounced when the reaction mixture is diluted at the time of polymerization.

In the proposed study, 5 ml of reaction mixture was diluted by adding 1.0 to 5.0 ml of water and the water absorbency of resulting hydrogels was determined in the distilled water. The results as shown in the Figure 6 indicate that water absorbency of resulting superabsorbents increase with dilution of the reaction mixture. The reason is that initially, due to a relatively smaller volume of the reaction medium, the growing macro-radicals are surrounded by unreacted double bonds of other crosslinker molecules. Hence, the chances of their reaction with pendant double bonds to form loops are almost nil. So less cyclization and more crosslinking occurs which causes less water uptake of resulting
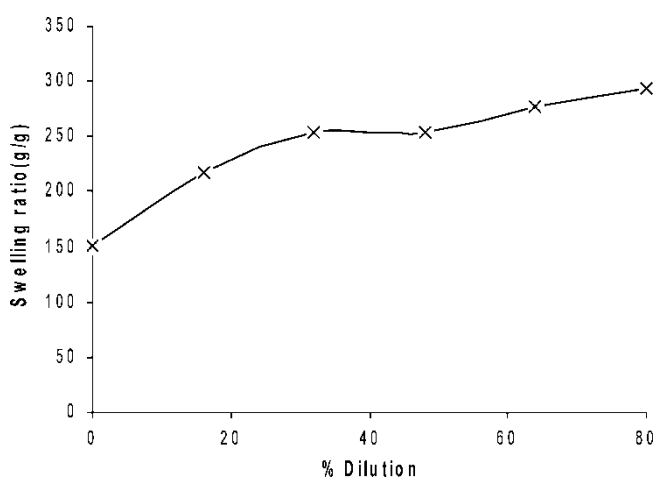

Figure 6. Effect of dilution of reaction mixture on the equilibrium swelling ratio of resulting SAP (55) samples in distilled water at 30°C.

gels. However, on dilution, the volume of the reaction medium increases. Therefore, the concentration of double bonds in the vicinity of growing macroradicals becomes less and the probability of a combination of these radicals with pendent double bonds increases. As a result, more cyclization and less crosslinking occur within the polymer matrix. This finally results in less crosslinked hydrogels which show greater water absorbency. It is also worth mentioning here that dilution of reaction mixture beyond 5.0 ml (i.e., more than 100% dilution) did not result in an effective network formation and so their water uptake behavior could not be investigated. Finally, it can be calculated that 100% dilution of the reaction mixture caused an increase in the swelling capacity of the resulting superabsorbent from 155 g/g to 294 g/g. So, dilution of the reaction mixture is an effective tool to enhance the water absorbency of superabsorbent materials.

Effect of Degree of Neutralization of Acrylic Acid on Water Absorbency

The degree of neutralization of acrylic acid in the feed mixture was observed to influence the water absorbency of resulting superabsorbents. We synthesized polymer samples having different percent neutralization of monomer acid in the range 5.48 to 55.00 and determined their water uptake in distilled water. The results, as depicted in Figure 7, indicate that water absorbency increases with percent neutralization, attains maximum value of nearly 205 g/g for gel with 44.8 percent neutralized acrylic acid, and then begins to decrease with a further increase in degree of neutralization of monomer acid. This may be explained on the basis of the fact that with the increase in concentration of neutralized acrylic acid, the fixed charge concentration along the macromolecular chains also increases. This enhances the relaxation of polymer chains, thus finally resulting in higher water uptake of gels. However, when the percentage of neutralization of acrylic acid exceeds 44.8, the resulting SAPs show a decreasing tendency in water absorbency. There may possibly be one reason for observed decrease in the water absorbency beyond optimum percent neutralization. Because of the increased charge density along the growing macroradicals during the polymerization, the chains become highly ionic in nature. The repulsion forces among the negative charges, (i.e., $-COO^-$ groups)
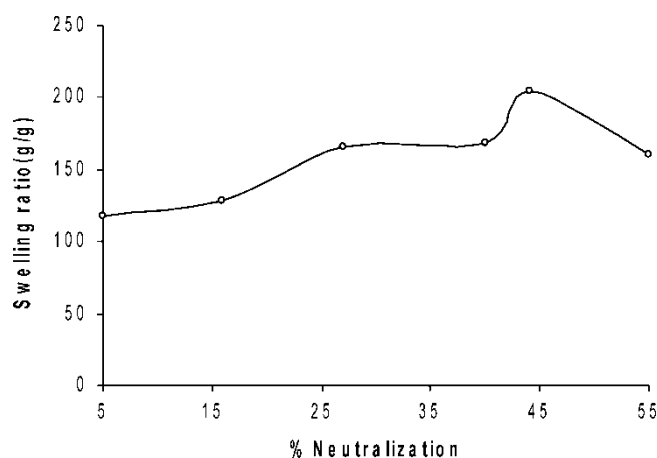

Figure 7. Effect of degree of neutralization of acrylic acid in the feed mixture on the equilibrium swelling ratio of resulting superabsorbents in distilled water at 30°C.

cause the growing polymer chains to be more extended. So, the propagating radical is further away from pendant double bonds of crosslinker molecules. This reduces the chances of cyclization. Hence, more crosslinked polymers are produced which show less water absorbency (16).

Effect of Composition of SAPs on Water Absorbency

The present superabsorbent system has been synthesized from the monomers NVP and PNAAc, which are hydrophilic in nature. However, due to the presence of ionic groups in the latter, it is thought to contribute more towards water absorbency of the resulting polymers. In order to investigate this, we synthesized a number of SAPs, having different molar ratios of NVP: PNAAc, ranging from 1 : 0.66 to 1 : 7.7 and studied their water uptake behavior. Figure 8 depicts the equilibrium water absorbency of resulting polymers. It is clear that as the mole fraction of partially neutralized acrylic acid increases in the feed mixture, the equilibrium water uptake also increases. This may simply be attributed to the fact that with the increase in mole fraction of PNAAc, the number of ionic charges (i.e., $-COO^-Na^+$ groups) along the macromolecular chain increases. This causes an increase in the swelling osmotic pressure, as well as in the chain relaxation process. Both of these features contribute towards enhanced water absorbency of resulting polymers. In this way, water uptake can be controlled by varying the molar ratios of two monomers in the feed mixture.

Salt Effect

The carboxylate groups containing superabsorbent materials have been shown to undergo sharp volume phase transition when placed in a solution of metal ions (17). To investigate this, the samples SAP (55) were allowed to swell completely in distilled water and then placed in the salt solutions of NaCl and $NiCl_2$ of varying molar concentrations in the range 0.01 M to 0.20 M. The results as depicted in Figure 9 clearly show that the fully
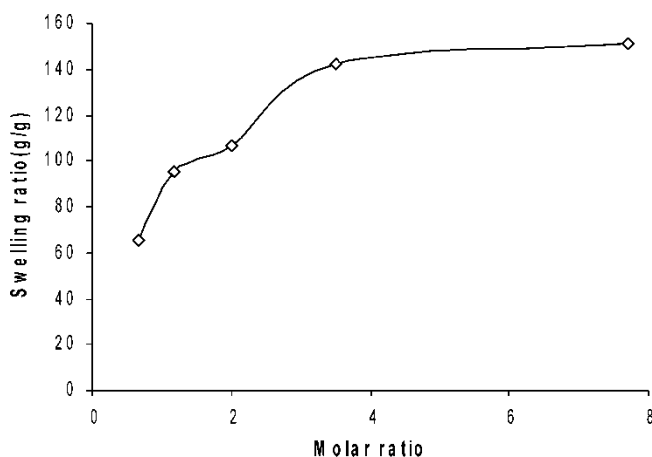

Figure 8. Effect of molar ratio of partially neutralized acrylic acid to N-vinyl-2-pyrrolidone in the feed mixture on the equilibrium swelling ratio of resulting superabsobent samples SAP (55) in distilled water at 30°C.
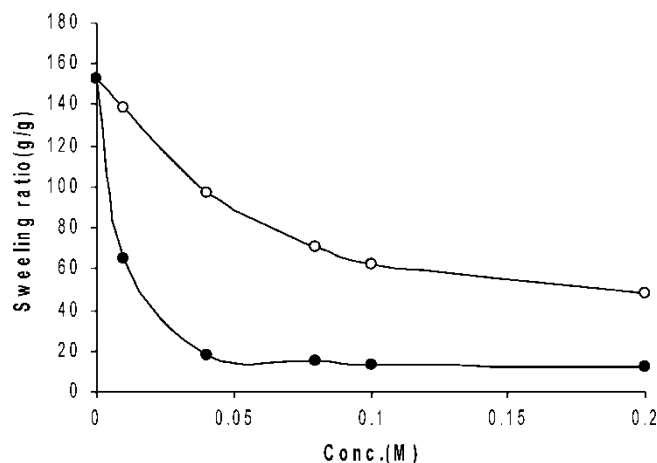
Figure 9. Effect of concentrations of NaCl (○) and NiCl$_2$ (●) in the swelling media on the equilibrium swelling ratio of the sample SAP (55) at 30°C.

swollen SAP undergoes sharp volume phase transition in the NiCl$_2$ solutions while the sample deswells gradually in the NaCl solutions of same molar concentration. The observed findings may be explained as follows:

When a fully swollen sample is placed in NaCl solutions, the presence of Na$^+$ ions outside the gel phase causes a decrease in the ion-osmotic swelling pressure (IOSP), thus finally resulting in a decrease in the water uptake. With the increase in the concentration of Na$^+$ ions in the outer solution, the IOSP continues to decrease, thus causing the SAP to deswell further. However, this process is gradual because there is no other factor operating in the gel-solution system to decrease the water uptake. However, when the fully swollen samples SAP (55) are placed in NiCl$_2$ solutions, a sharp volume phase transition is observed. The drastic decrease in water absorbency may be attributed to the ion-exchange process between Ni^{2+} ions of external solution and Na$^+$/H$^+$ ions present within the swollen polymer gel. This ion-exchange process decreases the water absorbency in two ways. First as the entry of single Ni^{2+} ion into the gel phase is accompanied by removal of two monovalent ions from gel phase to solution phase, the ion osmotic swelling pressure decreases more rapidly. Moreover, in the gel phase, the Ni^{2+} ions also bind to the $-COO^-$ groups of two different polymeric chains thus serving as additional crosslinks within the polymer network. The formation of additional crosslinks is due to the strong complexing tendency of transition metal ions with COO$^-$ groups present along the macromolecular chains in the polymer (18).

Pad Performance Test (PPT)

As mentioned earlier, the present SAP system is intended to be used as hygienic products like disposable diapers, sanitary napkins, etc. Therefore, it is important that it should be tested for its capacity to retain water under different loads. For this, we synthesized samples SAP (55) having different concentrations of crosslinker, namely 22.7×10^{-2} mM and 6.40×10^{-2} mM and allowed them to swell completely in distilled water. Now, their water retention capacity was investigated under varying loads, up to the maximum value of 2000 Nm^{-2}. Figure 10 depicts the water retention
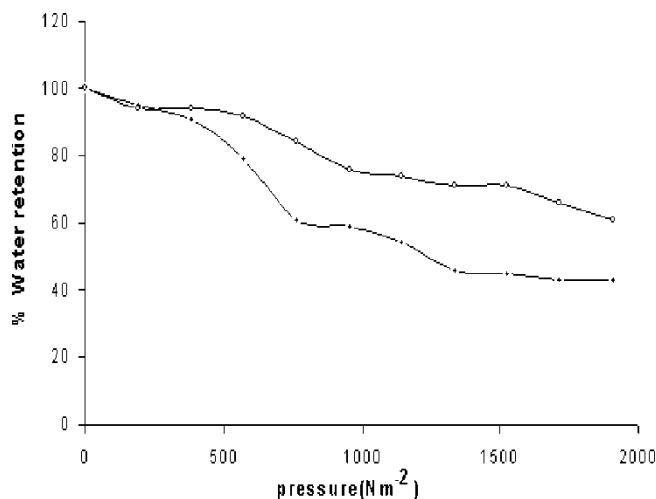
Figure 10. Effect of external pressure on the percent water retention of sample SAP(55) prepared with 22.7×10^{-2} mM (○) and 6.40×10^{-2} mM (+) of crosslinking agent at 30°C.

capacity of the two samples. It is clear that sample prepared with a higher concentration of crosslinker demonstrates better water retention capacity as compared to the other sample under similar loads. This may be attributed to the fact that the sample with the higher degree of crosslinking possesses comparatively rigid or less flexible chains. Therefore, on putting loads of increasing order, it is not compressed to a greater extent thus permitting less water to come out of the swollen polymer network. On the other hand, the lightly crosslinked sample has more flexible chains and hence, it is compressed to a greater extent for the same range of applied loads, thus resulting in greater loss of embedded solvent. This indicates that the superabsorbent with a highly crosslinked network demonstrates greater water retention capacity and is more suitable for being used as surgical pads, baby napkins, etc. However, the polymer with a higher degree of crosslinking shall also have low water absorbing capacity, while a higher water uptake is required for such applications. It means the degree of crosslinking plays a dual role in deciding the utility of water absorbing pads and an appropriate concentration of crosslinker should be used so that the SAP should have fair water retaining capacity without compromising water absorbency.

Water Retention Capacity

The superabsobent polymers to be used in baby diapers and as soil conditioners must have the tendency to retain water for a longer period under normal conditions. In other words, the swollen particles should possess a minimum drying rate. In order to investigate this aspect, we synthesized the SAP samples with the same degree of crosslinking, but with different acrylic acid contents, 24.97 mM and 69.38 mM, respectively and studied their water retention capacity at 30°C. The results, as shown in Figure 11, clearly indicate that the two samples demonstrate a different water retention capacity. The sample with the higher acid content shows greater retention power as compared to the other sample. This can be explained on the basis of the fact that in the sample with 69.38 mM of monomer acid, there are more charged $-COO^-$ groups and hence, there are more electrostatic interactions between the charged carboxylate groups and polar water molecules
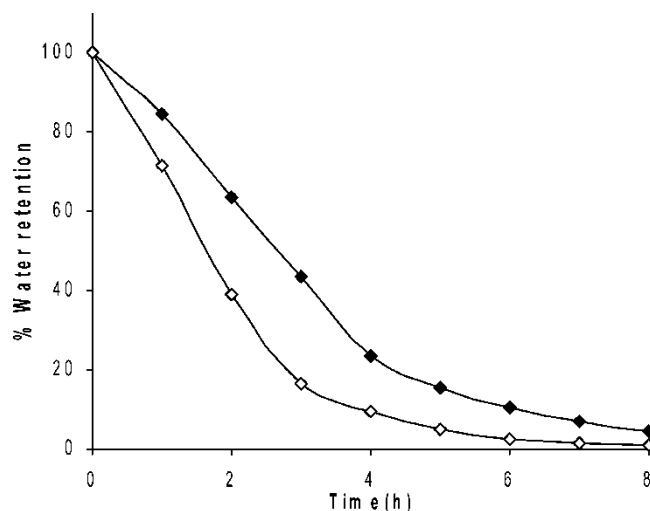
Figure 11. Percent water retention as a function of time for the sample SAP(55) prepared with 24.97 mM ($\diamond$) and 69.38 mM ($\blacklozenge$) of partially neutralized acid at 30°C.

within the swollen network. Consequently, this results in less water loss when allowed to dry at 30°C. On the other hand, the electrostatic interactions between the $-COO^-$ groups and immobilized water molecules in the sample with 24.97 mM of acrylic acid are relatively less. This results in greater water loss on drying at the same temperature. Thus, it may be concluded that the sample with a higher acid content shows greater water retention power and hence, is more suitable for the purpose of use in hygienic products and in soil conditioning. Almost similar results have also been reported by other workers (19).

Effect of Mode of De-watering of Gelled Foamy Mass on Water Uptake

Although the entire studies, described above, has been carried out with 400 μm sized superabsorbent particles obtained by grinding the foamy gelled mass into fine particles (see Experimental), it may be interesting to see that the de-watering of foamy gelled mass by different methods can result in the variation in the water uptake capacities of resulting ungrinded gelled mass. In order to investigate this aspect, we synthesized the sample SAP(55) and the foamy gelled mass was immediately cut into two pieces. The first piece was allowed to dry in an electric oven at 40°C for a period of 72 h, while the other piece was immediately put in the cold methanol for de-watering. After 2 h, it was also taken out and further dried at room temperature. These two samples were denoted as SAP(55)$_{air,40°C}$ and SAP(55)$_{MeOH,10°C}$, respectively where the subscript air, 40°C and MeOH, 10°C stand for drying at 40°C in air and at 10°C in methanol, respectively. The dried samples were not grinded, but used as such for the water uptake study. The results of water uptake behavior of two samples, namely SAP(55)$_{air,40°C}$ and SAP (55)$_{MeOH,10°C}$ have been depicted in Figure 12. It is clear that the sample SAP (55)$_{MeOH,10°C}$ demonstrates greater water uptake (i.e., nearly 208 g/g), while the other sample SAP(55)$_{air,40°C}$ shows water absorbency of nearly 169 g/g. This suggests that the methanol dewatered sample shows relatively higher water uptake. The observed finding can be explained as follows.
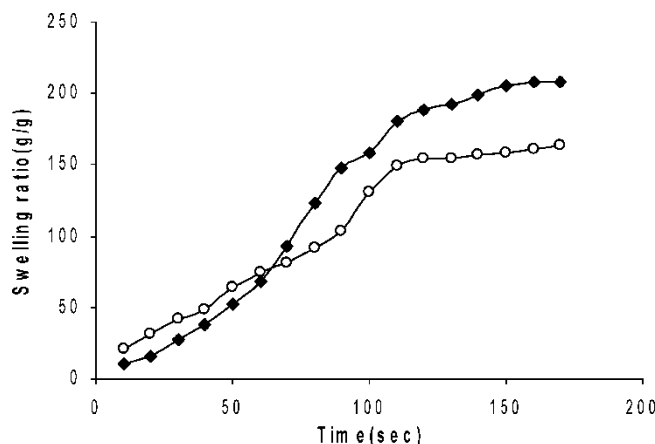
Figure 12. Swelling ratio as a function of time for the 'as-synthesized' foamy polymer network de-watered by keeping in methanol at 10°C ($\blacklozenge$) and in oven at 40°C ($\bigcirc$).

As is clearly mentioned in the Experimental section, NaHCO3 has been used in the present study as porogen. It leads to the formation of CO_2 bubbles. The bubbles are trapped in the viscous reaction mixture during the gelation and cause foam formation. Finally, a higher foamy mass is produced. Since this as-synthesized foamy structure is an elastic substance, the polymeric chains within the network are in the rubbery state. When this is immediately placed in a nonsolvent (i.e., methanol), the temperature of the gel (which was nearly 90°C at the time of synthesis) is reduced sharply to 10°C and the expanded chains are collapsed immediately. Under this condition, the macromolecular chains movement is immediately prohibited so that the chains and also the macroscopic layers are nearly fixed in their own positions without causing any damage to the foamy structure during drying through de-watering. In other words, the free volume within the porous structure is not decreased and the initial porosity, generated during the synthesis, is almost retained. Therefore, the sample $SAP(55)_{MeOH,10^\circ C}$ is a highly porous structure and shows greater water uptake. On the other hand, in the other sample $SAP(55)_{air,40^\circ C}$, which was allowed to be dried slowly in an oven at 40°C, there is some loss of porosity as the macromolecular chains get some time and have kinetic energy for movement. Therefore, the polymer chains approach a little closer to each other, thus reducing the free space within the matrix. This finally results in a less porous structure with decreased water absorbency.

Figure 12 also reveals one interesting fact. In the initial stage of swelling (i.e., up to nearly 60 s) the water uptake of the two samples does not differ much. It means water absorption takes place at nearly the same rate. Later on, water uptake increases in the methanol-dewatered sample, the cause of which has already been explained in the above paragraph. The initial, almost the same water uptake of the two different samples, might be due to the fact that initially the absorption occurs mainly through capillary action rather than conventional diffusion. Therefore, water enters into the porous networks through the capillary action only. Later on, in the more porous structure $SAP(55)_{MeOH,10^\circ C}$, the higher porosity provides a greater surface area of macro-molecular network to the invading solvent, thus causing greater chain relaxation in the swelling network. As a result, higher water uptake is observed in the sample
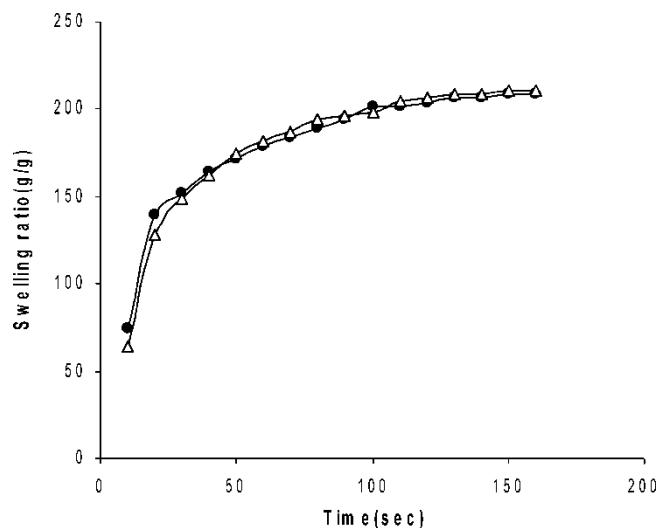
Figure 13. Swelling ratio as a function of time for the 150 μm sized particles of sample SAP (55) initially de-watered by keeping in methanol at 10°C (△) and in oven at 40°C (●), followed by grinding and sieving.

SAP(55)$_{MeOH,10°C}$. In this way, it may be concluded that the method of de-watering plays a significant role in deciding water absorbing capacity of the SAPs.

However, in a later experiment, the samples SAP(55)$_{MeOH,10°C}$ and SAP(55)$_{air,40°C}$ were grinded to fine particles, sieved through a mesh to get 400 μm sized particles, and their water absorption was studied as a function of time (see Figure 13). It was actually amazing to see that the two swelling profiles almost coincided with each other, thus showing the same water uptake behavior of two samples. This may simply be due to the fact that although the two as-synthesized foamy structures had a different degree of porosity due to different mode of dewatering, but grinding of the two samples may have destroyed the macropores within the networks and when they are sieved to get the same sized particles, they show almost the same water absorbency. This suggests that the water uptake behavior of grinded and sieved super absorbent particles is independent of mode of de-watering process. These results, however, do not match with those obtained by other workers (20), who obtained different water absorbency of the grinded superabsorbent particles that were dewatered and dried through different methods. Finally, it may be concluded that superpores generated within the polymer materials due to evolution of CO_2 gas during the gelation process may probably be destroyed when the resulting foamy hydrogel matrix is grinded. However, the micropores within the particles remain and cause enhancement in water uptake of SAPs particles. This fact has already been confirmed previously (20).

Conclusions

From the above study, it is concluded that water absorbency of SAPs depends upon the degree of crosslinking, degree of neutralization of monomer acid, amount of initiator and volume of polymerization mixture. The SAP with a higher acid content shows a greater water retention capacity. The presence of transition metal ions in the swelling

media cause a sharp volume phase transition which explores the possibilities of their being used for fast removal of metal ions from domestic and industrial effluents. The water absorption of finally grinded particles is found to be independent of the mode of dewatering of the foamy hydrogel mass. The fast water uptake, low water-loss tendency of highly crosslinked polymer, and higher water retention capacity of polymer with higher charged contents are also the same significant outcomes of this study and they may be helpful in preparing superabsorbents with designable properties

References

1. Oxely, H., Corkhill, P.H., Fitton, J.H., and Tighe, B. (1993) *Biomaterials*, 21: 1.
2. Sriamornsak, P., Thirawong, N., and Puttipipatkhachorn, S. (2004) *AAPS Journal*, 6 (3): 1.
3. Qiu, Y. and Park, K. (2003) *AAPS Pharm. Sci. Technol.*, 4 (4): 406.
4. Bajpai, S.K. and Jhonson, S. (2005) *React. Funct. Polym.*, 62: 271.
5. Galaev, I.V. and Mattiasson, B. (1999) *Trends Biotechnol.*, 17: 335.
6. Jeong, B., Bae, Y.H., Lee, D.S., and Kim, S.W. (1997) *Nature*, 388: 860.
7. Raju, M.P. and Raju, K.M. (2001) *J. Appl. Poly. Sci.*, 80: 2635.
8. Dutkiewicz, J.K. (2002) *J. Biomed. Mater. Res.*, 63: 373.
9. Buchhlz, F.L. and Graham, T. (1998) *Modern Superabsorbent Polymer Technology*; Wiley-VCH: New York; Vol. 152, 1.
10. Po, R. (1994) *J. Macromol. Sci-Rev. Macromol. Chem. Phys.*, 34 (4): 607.
11. Bajpai, S.K., Bajpai, M., and Sharma, L. (2006) *J. Macromol. Sci. Pure Appl. Chem.*, 43 (3): 507–524.
12. Chen, X.P., Shan, G.R., Huang, J., Huang, Z.M., and Weng, Z.X. (2004) *J. Appl. Polym. Sci.*, 92: 619.
13. Liu, Z.S. and Remple, G.I. (1997) *J. Appl. Polym. Sci.*, 64: 1345.
14. Li, A., Wang, A., and Chen, J. (2004) *J. Appl. Polym. Sci.*, 92: 1596.
15. Qin Cao, L., Xu, S., Feng, S., and Wang, J. (2005) *J. Appl. Polym. Sci.*, 96: 2392.
16. Elliot, J.E., Macdonald, M., Nie, J., and Bowman, C.N. (2004) *Polymer*, 45: 1503.
17. Omidian, H., Hashimi, S.A., Sammes, P.G., and Meldrum, I. (1999) *Polymer*, 40: 1753.
18. Horkay, F., Tasaki, I., and Basser, P.J. (2001) *Biomolecules*, 2 (1): 195.
19. Zhou, W., Yao, K., and Kurth, M.J. (1997) *J. Appl. Polym. Sci.*, 64: 1001.
20. Kabiri, K. and Zohuriaan-Mehr, M.J. (2004) *Macromolecular Materials and Engineering*, 289: 653.