

Synthesis, Applications and Swelling Properties of Poly (Sodium Acrylate-Coacrylamide) Based Superabsorbent Hydrogels

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Summary: Superabsorbent hydrogels constitute a group of polymeric materials with three-dimensional network structure, which can swell to absorb an enormous amount of water or aqueous solutions. This property enables various commercial applications of hydrogels such as water holding capability in agriculture and superabsorbent material for baby diapers. Several novel superabsorbent hydrogels based on acrylic acid-co-acrylamide copolymers were synthesized under variation of copolymer compositions through free radical polymerization. N,N'-methylenebisacrylamide (MBA) was used as a water soluble crosslinker and potassium persulphate (KPS) as an initiator. Effect of varying the copolymer composition, change in crosslinker concentration, and effect of environmental parameters (pH, temperature, and ion concentration) on both swelling capacity and swelling rate were examined. These gel shows maximum swelling at neutral pH-7, whereas increasing salt concentration in water decrease the swelling capacity. It was found interesting that an increase in crosslinker concentration from 0.020% to 0.16%, the swelling capacity decreases up to 70% while the swelling rate increases from 0.007g water/g dry hydrogel sec to 0.024g water/g dry hydrogel sec, respectively because there is a compromise exists between entropic spring forces between network connection points and the hydrostatic pressure of the water diffusing into the gels. Dynamic swelling curve obtained were fitted to the three different kinetic models namely Peleg's kinetic model, pseudo 1st order as proposed by Lagergen and pseudo 2nd order kinetics. All these models provided a good agreement with the experimental data; However on the bases of statistical parameters (RMSE, R² and X²) the Peleg's model was selected as the most appropriate model for this study. Analyzing rate constant for Peleg's models at different swelling temperatures disclosed that increasing temperature could only increase the swelling rate without affecting the swelling capacity of the hydrogels. Experimental values for rate constant k₁ of Peleg's model at different temperature shows a sharp decrease from 0.57545 at 30 °C to 0.1535 at 75 °C that contemplated the rate of swelling at 75 °C was 65% faster than that of 30 °C. The diffusion mechanisms in hydrogels were proven to be tailorable by increasing cross-linker concentration and temperature, leading towards the Fickian type diffusion behavior. The synthesized superabsorbent hydrogels were also tested for water retention applications in agriculture.

Keywords: Superabsorbent; Hydrogels; Hydrophilic polymer; Crosslinker; Monomer concentration.

Introduction

Superabsorbent hydrogels are lightly crosslinked polymers having hydrophilic nature due to which they can absorb and retain large amount of aqueous solution, and the captured fluid is hardly removable even when kept under pressure [1-6]. There are two characteristics of hydrogels; firstly, it absorbs water and secondly it retains the absorbed water for a long period, i.e., provides resistance to evaporation. The absorption arises from the hydrophilic functional groups in the polymeric substrate, which binds water to the hydrogel for a longer period, as the loosely crosslinked network prevents complete dissolution, but also limits the degree of swelling due to the stretch of the polymer chains between 2 crosslinking points opposing further water absorption [7-9].

These distinctive properties of hydrogels have led to its extensive applications in various areas. In the United States, the earliest applications of hydrogel were as a water retention agent, then in mid-1970s Japanese companies started utilizing hydrogels in personal care and hygienic products such as disposable diapers, sanitary napkins, or surgical pads [10]. In addition to healthcare products, they were also used as artificial additives for soil conditioning, as controlled release agents for agrochemicals or pharmaceuticals, in enhanced oil recovery, and other numerous other areas [1, 5, 11-14].

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Preferred attributes of superabsorbent hydrogels are (a) high capacity for swelling, (b) fast rate of swelling and (c) high strength of swollen gel. There is a tradeoff between these properties, which needs to be optimized for each application [15-17]. Various research works have been done in the area of superabsorbent hydrogels; for example, studies have investigated the effect of reaction parameters, particle size and salinity on swelling.

This paper reports a new preparation methodology and swelling characterization of poly (Sodium acrylate-co-acrylamide). The aim is to explore the swelling behavior of superabsorbent polymers (SAPs) corresponding to crosslink density, monomeric ratio and bath temperature variation. The SAPs by free radical solution polymerization of partially neutralized acrylic acid (AA) and acrylamide (AM). A water soluble crosslinker *N, N'* methylenebisacrylamide (MBA) and initiator potassium persulphate (KPS) were used in synthesis. The water retention capacity of synthesized SAPS is also studied in soil by growing plants.

Experimental

Materials

Anhydrous Acrylic Acid (AAA, Sigma Aldrich), MBA (Sigma Aldrich) were used as purchased, Acrylamide (AM, Mitsubishi) was recrystallized from methanol. KPS and NaOH (Dae-Jung) were used as received. All solutions were prepared in double distilled water. The water had a resistivity of $>10^{18}$ M Ω cm $^{-1}$. All the chemicals were reagent grade.

Synthesis

The methodology of copolymer synthesis involves the free radical solution polymerization technique which is composed of the following steps. The reactions were conducted in flask covered with cork equipped with magnetic stirrer and nitrogen line. Using appropriate dropping funnel acrylic acid was neutralized (up to 75%); then the acrylamide solution along with crosslinking agent (MBA) was mixed with partially neutralized acrylic acid; the final mixture was put into reaction vessel under nitrogen bubbling at room temperature. After 10 minutes KPS was added under constant stirring, and then temperature was slowly increased to $70\pm 1^\circ\text{C}$. When the viscosity of the mixture has increased sufficiently, the stirrer bar was stopped after 30-40min (gelation time).

Due to gel formation mechanism and simultaneous release of water, the reaction mixture became foamy or fluffy. The recovered solid mass

was brought to room temperature and cut into small pieces. The pieces from the vessel were transferred onto an aluminum foil and heated in a forced air recirculation oven at $60\pm 5^\circ\text{C}$ for 24 hours. Finally, the pieces were ground in a hammer-type mini grinder, leading to particle sizes around 200 μm .

Water-absorbency Measurement

A sieved sample of hydrogels ($0.5\text{g} \pm 0.001\text{g}$) was added to a 1000 ml vessel filled with distilled water. The sample was allowed to swell freely. Equilibrium swelling was achieved by allowing the hydrogels to absorb water for overnight. The amount of swelling of the swollen gels was measured by first filtering them through a 100-mesh screen, then the surface water was removed by sponge or polyurethane foam followed by weighing the obtained sample. To obtain a reliable value of absorption capacity, five measurements were averaged. The quantitative amount of swelling capacity (absorption capacity) was calculated as follows

$$Q = \frac{Q_{ss} - Q_{sd}}{Q_{sd}} \quad (1)$$

where,

Q = Maximum absorption capacity.

Q_{ss} = Swollen gel weight.

Q_{sd} = Dry hydrogel weight.

Characterization

Fourier transform infrared spectrometer (Nicolet 6700, Thermo Scientific, USA) was used for the spectroscopic analysis of the samples. Spectra in the wavenumber range of $4000\text{--}1000$ cm^{-1} were collected over 5 scans with a resolution of 2 cm^{-1} . For the preparation of the test specimens KBr-disk method was used after subsequent vacuum drying.

For analyzing the internal morphologies, the samples were gold-coated in a JUC-500 Magnetron Sputtering Device (JEOL, Tokyo, Japan), and a Field Emission Scanning Electron Microscope (FESEM, INSPECT F, FEI, the Netherlands) was used for the observation of the cross section of the samples.

Results and Discussion

Effect of Crosslinker Concentration

From Fig. 1 it can be deduced that by increasing crosslinker concentration, the absorption capacity decreases. Increase in cross-linker

concentration from 0.020% to 0.16%, the swelling capacity decreases up to 70% while the swelling rate increases from 0.007g water/g dry hydrogel sec to 0.024g water/g dry hydrogel sec, respectively. Increase in crosslinker concentration increases the crosslinker density of hydrogels, which bonds the polymer chains more tightly and resist the expansion of crosslinked network. This ultimately decreases the network volume as well as absorption capacity.

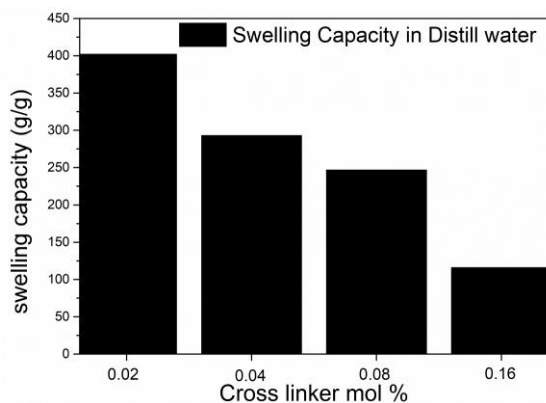


Fig. 1: Impact of Crosslinker Concentration on Swelling Capacity.

Effect of Monomer Ratio on Absorption Capacity

Table-1 shows that with increasing acrylamide concentration in the copolymer, there is an increase in absorption capacity, due to the increase in charge density in the network. Thus, the difference in the polarity between sodium acrylate and acrylic acid group suggests the possible segregation, thereby, affecting the chain packing and perhaps the free volume. Therefore, we observed an increase in absorption capacity as increased the acrylamide concentration in hydrogel.

Table-1: Effect of Change in Monomeric Ratio.

Polymer code	Monomers (g)		Crosslinker mol%	Swelling Capacity (g/g)
	Acrylic Acid	Acryl Amide		
S1	15	0	0.04	216
S2	10	5	0.04	242
S3	5	10	0.04	293

Reaction condition: initiator [KPS] = 0.2g, Temperature = 70±1 °C.

Swelling Kinetics at Different Crosslinker Concentrations

Swelling capacities of SAPs prepared with varying concentrations of crosslinker were investigated. The swelling kinetics can be analyzed by plotting relative rate of absorption (m_t/m_∞) against time. Where m_t and m_∞ denote the amount of solvent absorbed into the gel at time t and at infinite time,

respectively. From Fig. 2 it is clear that by increasing the crosslinker concentration absorption rate increases. The time dependence of water uptake as well as the equilibrium values can be easily understood from the following considerations. The polymers are very hydrophilic. If not crosslinked, water is a good solvent for them. Hence, they absorb water quickly, which in turn, however, leads to an increase in volume. In anhydrous state the SAPs are densely coiled up, so an increase in volume uncoils the polymers. Depending on the concentration of crosslinker, the distance between 2 network points varies. As coil diameter scale with approximately the square root of molar mass (\propto chain length) – depending on solvent quality, the possible amount of stretch that a polymer can undergo increases with the square of the molar mass between the randomly placed crosslinking points. As the stretched conformation of a polymer is the entropically least favored, reaching a completely stretched conformation is unlikely, as the force balance between the entropic spring forces – leading to a coiling up of the polymer segments – and the hydrostatic pressure of the water diffusing into the gels finds its equilibrium somewhat before complete stretch for the higher crosslinker concentration. Different kinetic models for swelling behavior of the hydrogel have been proposed by researchers namely Peleg's kinetic model [18], pseudo 1st order as proposed by Lagergen [19] and pseudo 2nd order kinetics, which were tested over the experimental results and their results are presented in Table-2 for the change in cross-linker concentration over time and in Table-3 for the effect of temperature over the swelling kinetics.

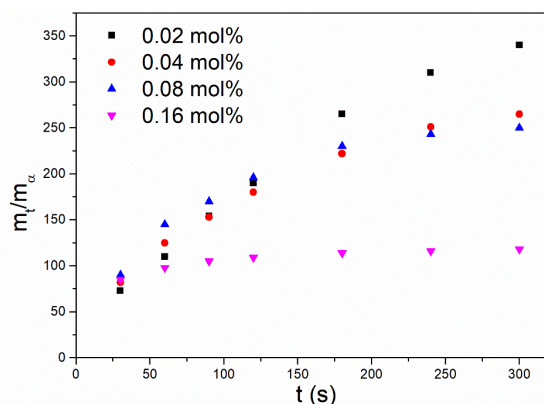


Fig. 2: Swelling Rates of SAPs with Different Crosslinker Concentration.

The two-parameter model proposed by Peleg for absorption of water over grains [18] is given by,

$$m_t = m_o \pm \frac{t}{k_1 + k_2 t} \quad (2)$$

where, m_o is the swelling rate at $t=0$ and m_t is at any other time t , k_1 and k_2 are the characteristic constants used in the model. For adsorption the sign convention for the model is “+” and for desorption the “-“ sign will be used. For the case of 1st order kinetics the model is of the form

$$\frac{dm_t}{dt} = k_{r1}(m_\infty - m_t) \quad (3)$$

where, m_∞ and m_t are swelling rate at infinite time and at time t , (g/g), k_{r1} is the rate constant. The equation can be simplified into a linear function

$$\log(m_\infty - m_t) = \log(m_\infty) - \frac{k_{r1}}{2.303} t \quad (4)$$

The second order kinetics were approximated by the equation [20],

$$\frac{dm_t}{dt} = k_{r2}(m_\infty - m_t)^2 \quad (5)$$

Applying boundary conditions after integration of the equation the relation takes the form

$$\frac{t}{m_t} = \frac{1}{k_{r2}m_\infty^2} + \frac{1}{m_\infty} t \quad (6)$$

The statistical analysis was performed via Statistica6.0 employing Levenberg-Marquardt approach. The parameters (RMSE, R^2 and X^2) were calculated for the estimation of error in the experimental and models used, where:

$$X^2 = \frac{\sum_{i=1}^N (SR_{ex,i} - SR_{pr,i})^2}{N - z},$$

$$RMSE = \left[\frac{1}{N} \sum_{i=1}^N (SR_{ex,i} - SR_{pr,i})^2 \right]^{1/2} \quad (7)$$

Table-1: Rate constants and statistical analysis of the effect of crosslinker conc over swelling rate.

Peleg's Model					
Cross-Linker (mol%)	K_1	K_2	R^2	RMSE	X^2
0.02	0.78986	4.46E-04	0.20707	0.029908	0.003419111
0.04	0.57892	0.00238	0.98178	0.017912	0.00071296
0.08	0.40853	0.00322	0.97368	0.031386	0.002277887
0.16	0.31284	0.01164	0.99994	0.003715	4.5E-05
Pseudo 1 st Order Model					
Cross-Linker (mol%)	K_{r1}	R^2	RMSE	X^2	
0.02	0.00953442	0.94086	0.037377	0.004114481	
0.04	0.0112156	0.95874	0.029527	0.00272412	
0.08	0.01420951	0.98536	0.027036	0.002484285	
0.16	0.01458	0.97339	0.056026	0.005659	
Pseudo 2 nd Order Model					
Cross-Linker (mol%)	K_{r2}	R^2	RMSE	X^2	
0.02	1.77928E-05	0.71444	0.098815	0.01684088	
0.04	5.0233E-05	0.9087	0.074342	0.00925308	
0.08	8.29153E-05	0.9584	0.054041	0.005012395	
0.16	8.39251E-05	0.9977	0.028974	0.001384	

Table-2: Rate constants and statistical analysis of the effect of temperature over swelling rate.

Peleg's Model					
Temperature (°C)	K_1	K_2	R^2	RMSE	X^2
30	0.57545	0.00111	0.90694	0.011122	0.00110058
50	0.33038	0.00162	0.98	0.005492	0.00307393
75	0.1535	0.00214	0.99078	0.006127	0.000382435
Pseudo 1 st Order Model					
Temperature (°C)	K_{r1}	R^2	RMSE	X^2	
30	0.0097647	0.94414	0.036864	0.00706745	
50	0.0094423	0.9811	0.013765	0.00217873	
75	0.02312212	0.86939	0.105395	0.09861731	
Pseudo 2 nd Order Model					
Temperature (°C)	K_{r2}	R^2	RMSE	X^2	
30	4.0416E-06	0.97897	0.002759	0.00026708	
50	9.6745E-06	0.99222	0.00288	0.00014444	
75	3.23493E-05	0.99298	0.004839	0.000205227	

The values $SR_{ex,i}$ and $SR_{pr,i}$ are actually the experimental and the predicted model values of the swelling rates. N and z are the number of data points recorded and the number of constants used in the model for the prediction of the experimental values [21].

In Peleg model the first constant k_1 is inversely related to the speed at which water absorption by the gels occurs, while the second constant k_2 is inversely related to its capacity to absorb water [22, 23]. From the results presented in Fig. 3 it can clearly be seen that the value of constant k_1 decreases with increasing amount of cross-linker, ranging from 0.78986- 0.31284 for 0.02% and 0.16%, respectively. This implied higher rate of water uptake with increase in amount of cross-linker while decreasing the swelling capacity as evident by higher k_2 values. The numerical values of capacity constant k_2 for the synthesized hydrogels was found as 4.46E-04 at 0.02% cross-linker and 0.01164 at 0.16% cross-linker, this increasing trend of capacity constant is correlated to decrease in swelling capacity [18].

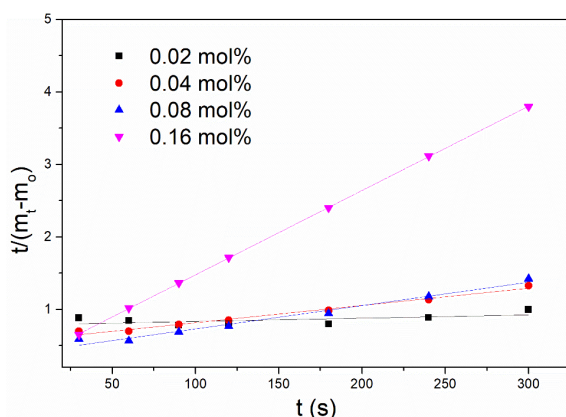


Fig 1: Peleg's model prediction to the experimental data.

Similar behavior could also be predicted by testing obtained results through pseudo-first order kinetic model and pseudo-second order kinetic model presented in Fig. 4 and 5 respectively. As shown in Table-2, the rate constant (k_{r1} & k_{r2}) of pseudo-first order and pseudo-second order models are proportional to the amount of cross-linker used indicating the increase in swelling rate with increase in amount of cross-linker. All three empirical models tested in this study are in good agreement with the experimental results. From the investigation of statistical parameters (RMSE, R^2 and X^2) the best suitable models that describe the swelling behavior

was one with high values of the coefficient of determination (R^2), the least values of the root mean square error (RMSE) and reduced chi-square (χ^2). It was observed that R^2 value is approx. to "1", whereas χ^2 and RMSE values are minimum for Peleg's model as predicted over the experimental range shown in Table-2. It turned out from the statistical analyses that the Peleg's model can be considered as the most appropriate.

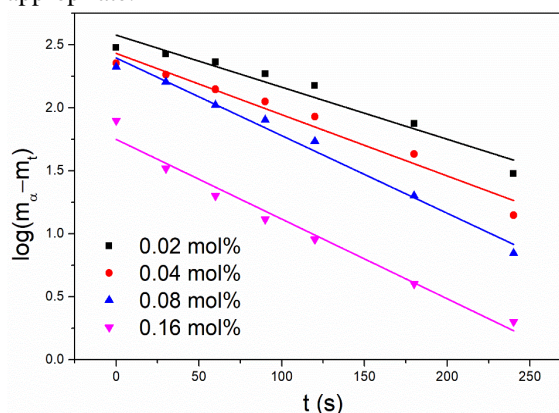


Fig. 2: 1st order model prediction to the experimental data

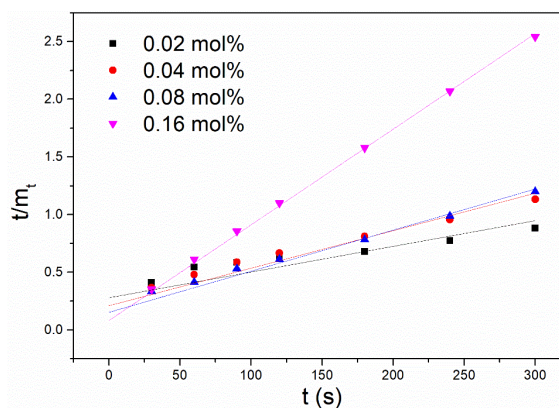


Fig 3: 2nd order model predictions to the experimental data.

Diffusion Mechanism

The diffusion mechanism was analyzed for the synthesized polymeric superabsorbent material and presented in Fig. 6 for cross linker concentration changes and in Fig. 7 for the effect of temperature on the diffusion mechanism respectively. It is difficult to propose a universal model that accurately describes the diffusion mechanism and to calculate diffusion coefficients. The model used to describe the diffusion process in this work is based on Fick's law [24]:

$$\frac{dc}{dt} = D \frac{(d^2c)}{(dx^2)} \quad (8)$$

The following useful equation was used to determinate the nature of diffusion in the hydrogels [25].

$$\frac{m_t}{m_\infty} = kt^n \quad (9)$$

where, m_t and m_∞ denote the amount of solvent diffused in to the gel at time (t) and at infinite time (t_∞), respectively, k is a constant related to the structure of the network and n is a characteristic exponent of the transport mode of the solvent [26].

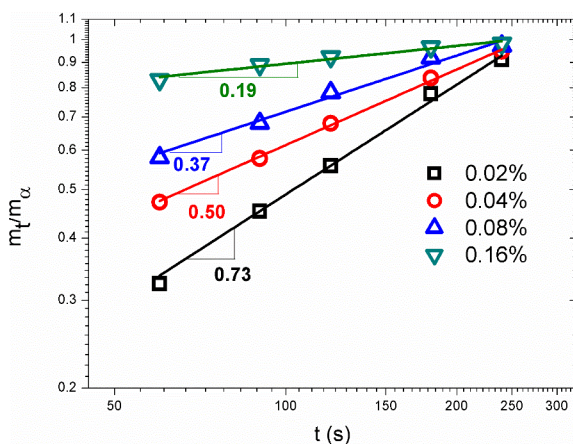


Fig. 4: Diffusion Mechanism at different cross-linker concentration

Depending on the relative rates of diffusion and polymer chains relaxation three classes of diffusion mechanisms were observed. Type I: Fickian diffusion mechanism in which rate of diffusion is much less than that of relaxation of the changes ($n < 0.5$), Type II: Diffusion in which the diffusion is very rapid compared with the relaxation processes ($n = 1$), Type III: Non-Fickian or anomalous diffusion which occurs when the diffusion and relaxation rates are comparable ($0.5 < n < 1$) [27]. From the analysis of the diffusion mechanism in Fig. 6 it is quite obvious that the increase in the cross-linker concentration decreases the value of “n” in a pattern viz $0.02 > 0.04 > 0.08 > 0.16$ respectively, which shows that the greater the concentration of cross-linker the better is the approximation to Fickian diffusion. The effect of temperature over the diffusion rate dictates that the increase in temperature results in small value of the slope obtained from the log-log plot in Fig. 7 thus drifting inside the Fickian diffusion range.

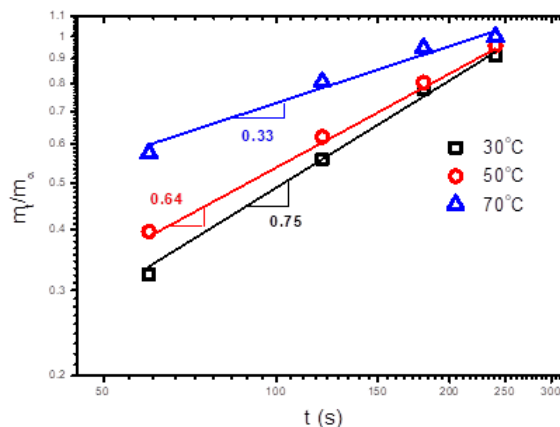


Fig. 5: Diffusion mechanism at different bath temperatures for sample S3

Absorption Capacity in Saline Solution

The effect of ionic solution on swelling can be concluded from Fig. 8, the swelling capacity almost decreases with the same trend for all salt or crosslinker concentrations having an overall decreasing impact for increasing salt or crosslinker concentration. For single crosslinker concentration, increasing the salinity decreases the swelling capacity.

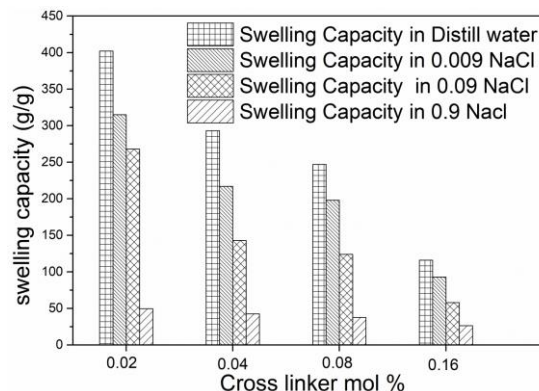


Fig. 6: Effect of ionic solution on swelling capacity.

This effect is mainly because of the presences of excessive ionic charge groups in the polymer network which balances the concentration difference between polymer network and the saline water restrict the water penetration in to a network.

Swelling Kinetics for Different Solvent Temperatures

By increasing the solvent temperature there is a remarkable increase in swelling rate or dynamic swelling. At higher temperature, kinetic energy of water molecule increases and, which results in faster diffusion. Chain entanglement of polymer quickly disappears. As a result of these two phenomena,

faster absorption rate at higher solvent temperature were observed. The effect of solvent temperature on dynamic swelling can be concluded from Fig. 9, which shows these effects for sample S3. For the other samples, the effect was found to be comparable.

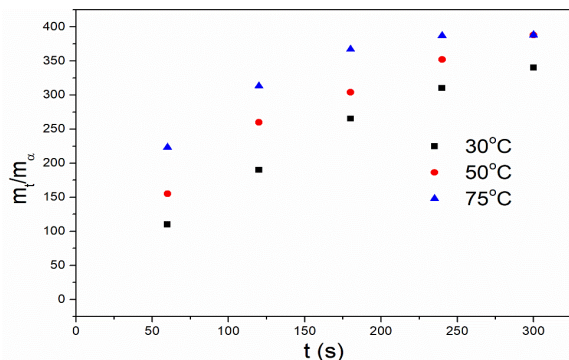


Fig. 7: Temperature effect over swelling rate for sample S3.

To describe the swelling kinetics of hydrogels at different temperature (30, 50 and 75 °C), the experimental data analyzed by above all three kinetic models are presented in Fig. 10-12 respectively.

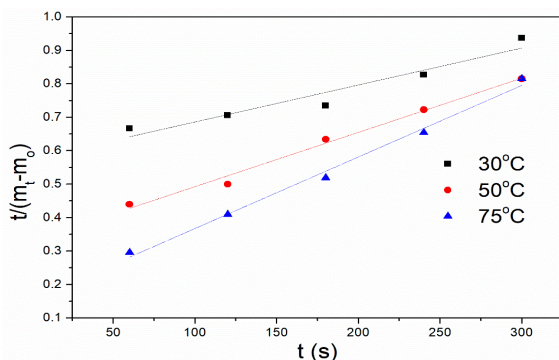


Fig. 8: Peleg's model prediction to the experimental data

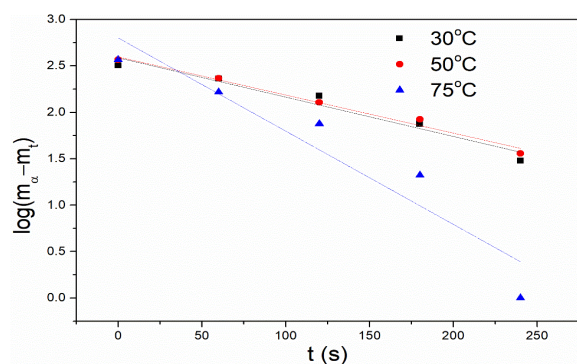


Fig. 9: 1st order model prediction to the experimental data.

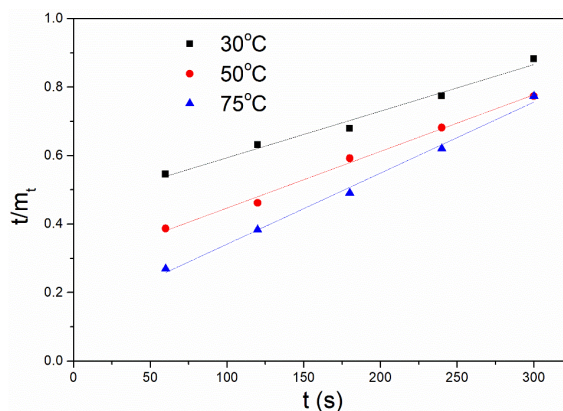


Fig. 10: 2nd order model predictions to the experimental data.

The rate constant and the statistical parameters (RMSE, R^2 and X^2) of the models are estimated, compared and reported in Table 3. The data obtained from Fig 9 for the Peleg model showed rate constant k_1 values are inversely related with temperature, increase in bath temperature decrease the rate constant thus increasing the rate of swelling. From all the calculated values for rate constant k_1 at different temperature the lowest value found was 0.1535 at 75 °C that contemplated the fastest rate of swelling at this temperature.

Comparing the values of capacity constant k_2 at different temperature, no significant difference was found regarding hydration temperature. The k_2 values for Peleg model are found as 0.00111 at 30 °C, 0.00162 at 50 °C and 0.00214 at 70 °C. It can be deduce from experimental observation that increasing temperature could only increase the swelling rate without affecting the swelling capacity of the hydrogels, this finding is in agreement with the previously reported results published elsewhere [28].

Pseudo-first order and pseudo-second order kinetic models tested were also depicted the similar trend of increase in swelling rate with increase in temperature presented in Fig 11 and Fig 12 respectively. From the results given in Table 3 it can be seen that the values of rate constant (kr_1 & kr_2) increases linearly with temperature. The highest value of kr_1 obtained is found as 0.02312212 and for kr_2 is 3.23493E-05 at a solvent temperature of 75 °C, elucidate the claim of increase in swelling rate with increase in temperature [29]. Predicting the kinetic behavior by comparing the determination of coefficient, reduced chi-square, and root mean square error values of three models, it was concluded that the Peleg's model represents swelling characteristics better than the others.

Furthermore, this trend suggests that the solvent quality of SAP in water does not change significantly as a function of temperature as would be the case for polymers with a lower critical solution temperature such as poly-N-isopropylacrylamide [30]

Effect of pH on Swelling Capacity

The effect of change in environmental pH on swelling capacity has been investigated. Fig 13 shows for sample S1 that at low pH swelling capacity decreases, because the polymer shrinks and become hydrophobic, thus, decrease in the degree of ionization decreases the swelling ratio.

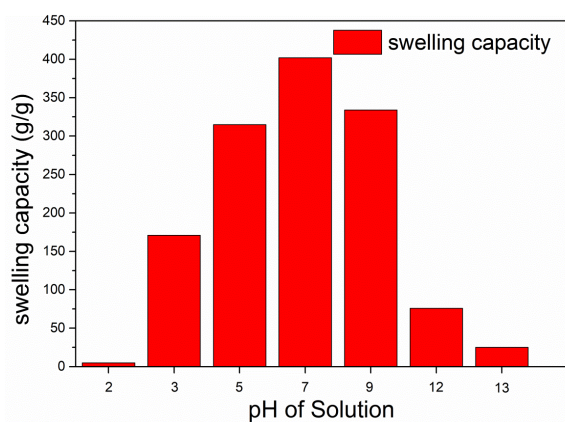


Fig. 11 Effect of change in environmental pH on swelling capacity

At higher pH, charge screening effect plays a role in minimizing the swelling capacity. Presence of excess Na^+ ions shields the

carboxylate anions and prevents effective anion-anion repulsion. Hence, it is clear that maximum swelling can only be achieved at neutral pH.

FTIR Analysis

To understand the formation and crosslinking of SAP prepared by solution polymerization of AA and AM copolymer FTIR analysis was conducted Fig. 14 shows the IR spectra of copolymer hydrogels.

In spectrum of copolymer the peak observed at 3443 cm^{-1} and 3193 cm^{-1} correspond to O-H hydroxyl and N-H amide stretching, respectively. The absorbance at 2929 cm^{-1} assigned to C-H stretching of acrylate group. The peak at 1659 cm^{-1} is assigned to carbonyl (-C=O) group. The absorbance at 1557 cm^{-1} is attributed to sodium acrylate -COONa group and peak at 1173 cm^{-1} correspond to carboxylate -COO^- group.

Scanning Electron Microscope

The SEM micrographs in Fig. 15 (a) and (b) show the samples in an un-swelling state showing a coil in folded structure. The average particle sizes of the hydrogels tested were in the range of $200\text{ }\mu\text{m}$ refers to the large number of convoluted layers at the surface providing a large surface area as can be seen in the sample. In SEM it was clearly observed that the sample has porous layers surfaces convoluted at 75X magnification.

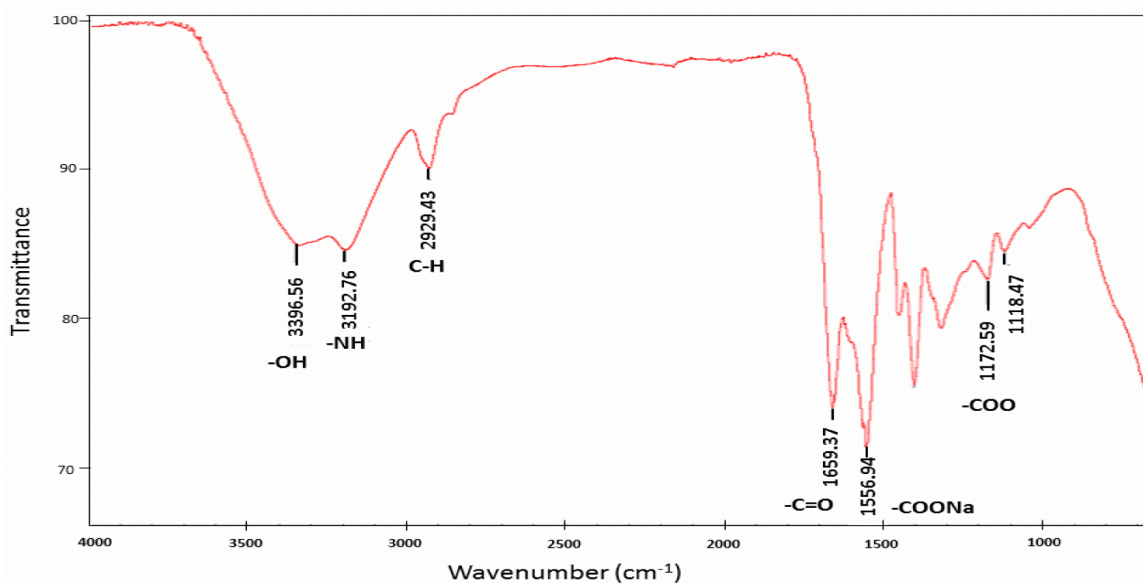


Fig 12: FTIR Spectra of Superabsorbent Polymer

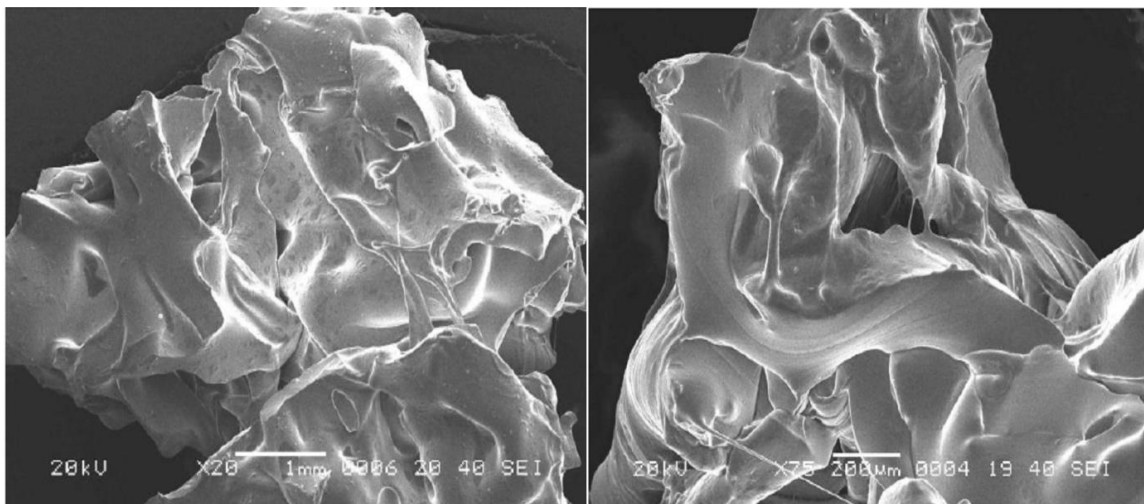


Fig. 13: SEM Images of SAP for x20 and x75 Magnifications.



Fig. 14: Effect on Plant Growth with and without SAP.

Water Retention of SAP

The water retention capability of SAP has led it to be applied for agricultural area for effective utilization of water in arid areas. The testing of SAP as a water retention agent was accomplished in small pots by growing the plant with and without SAP. Equal amount of soil (500g) was used 1% (w/w) SAP

was used in one pot equal amount of water (350 ml) were used initially. Results show that water retention capacity of soil with SAP was 10 days, while that of soil without SAP was only 3 days as portrayed in Fig. 16. The plant with the SAP sample grows 5 cm high in these 10 days. This shows that SAPs are quite helpful agents in effective utilization of water in

agriculture as well as in wetland soil capacity enhancement used for wastewater treatment.

Hence, it is clear that a lower crosslinker concentration limits chain stretch and, thus, swelling slower than a higher crosslinker concentration.

Conclusion

A series of novel superabsorbent polymers were synthesized in aqueous solution by free radical polymerization with acrylic based monomer and MBA as crosslinker. Effect of reaction variables (crosslinker density, monomer ratio, bath temperature and effect of pH) was investigated. Swelling capacity of SAPs was measured in distilled water as well as in ionic and pH solution. It was found interesting that increasing crosslinker concentration certainly increases the swelling speed. These gel shows maximum swelling at neutral pH-7, whereas increasing salt concentration in water decrease the swelling capacity. In order to determine the effect of cross-linker and temperature on swelling kinetics of the hydrogels, three different kinetic models were examined, and all these models provided a good agreement with the experimental data; However on the bases of statistical parameters (RMSE, R² and X²) the Peleg's model was selected as the most appropriate model for this study. Analyzing rate constant for Peleg's models at different swelling temperatures revealed that increasing temperature could only increase the swelling rate without affecting the swelling capacity of the hydrogels. The diffusion mechanisms in hydrogels were proven to be tailorable by increasing cross-linker concentration and temperature leading towards the Fickian type diffusion behavior. Water retention capacity of SAP indicates its application in agriculture, especially in arid areas. These finding for a commercialized product SAP are very interesting and useful to specify its application areas and usability.

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