



SYNTHESIS, CHARACTERIZATION AND SWELLING PROPERTIES OF POLY (ACRYLAMIDE-CL-CARBOXYMETHYLGUARGUM) HYDROGELS

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ABSTRACT

Hydrogel materials based on Polyacrylamide and Carboxymethylguargum (PAM-CI-CMG) were synthesized using potassium persulphate as initiator and N,N'methylenebisacrylamide as cross linking agent while analyzing the effect of concentrations of crosslinker and carboxymethylguargum on swelling behavior of PAM-CI-CMG hydrogel. To evaluate their structure-properties relationship, these were characterized by FTIR Spectroscopy, SEM, and DSC. Percent swelling was selected as a parameter for deciding the best hydrogel in each series of CMG concentration. The hydrogels showed appreciable swelling and the swelling exponent has been found to be in the range of 0.6 - 0.9, thus indicating non-fickian diffusion mechanism. These hydrogels were further studied for their swelling behavior as a function of temperature, pH, and electrolyte concentration. The results indicate that the percent swelling is directly proportional to the CMG concentration and inversely proportional to the concentration of crosslinker. The swelling behavior of synthesized hydrogels were found sensitive to swelling conditions such as temperature, pH, and [NaCl].

KEYWORDS: Carboxymethylguargum; Polyacrylamide; Hydrogel; Cross linking; Swelling behavior.

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INTRODUCTION

The modification of natural polymers is a promising method for the preparation of new polymeric hydrogel materials. Graft copolymerization of vinyl monomers on natural polymers is an efficient approach to achieve these materials. The present investigation aims to develop the hydrogels based on crosslinking of vinyl monomer (Acrylamide) and the biopolymer (Carboxymethylguar gum) and to study their swelling characteristic. Among various water-soluble polysaccharides, guar gum (GG) is one of the most important polysaccharides. Guar gum is a naturally occurring non-ionic polysaccharide derived from the Guar seed "*Cyamopsis tetragonolobus*". This leguminous plant is grown in India and is currently used as an edible item. It also finds application in various industries as viscosity builder and water binder. It is a member of the class of galactomannans, which consist of α (1–4)-linked β -D-mannopyranosyl backbone partially substituted at O-6 with α -D-galactopyranosyl side groups¹⁻⁴. Guar gum has been modified by derivatization, grafting and network formation to improve its properties for a wide spectrum of end applications. The grafting on Guar gum with acrylamide⁵⁻⁷, acrylic acid⁸⁻⁹, methacrylic acid¹⁰⁻¹², ethyl acrylate¹³, N-isopropylacrylamide¹⁴⁻¹⁵, acrylonitrile¹⁶, methyl acrylate¹⁷ and methyl methacrylate¹⁸⁻²⁰ has already been reported. Chemical modification of guar gum involves reaction of the hydroxyl groups on the anhydroglucose units and these reactions have been used to produce guar gum derivatives. Among the guar gum derivatives, carboxymethylguar gum (CMG) is very important because it covers a wide range of industrial applications. CMG is an anionic semi-synthetic guar gum derivative. It is available at economic rates and is also a water soluble commercial polysaccharide. The polysaccharide backbone is similar to guar gum, a galactomannan. Carboxymethylation of

guar gum was carried out by reacting guar gum with sodium monochlorate / monochloroacetic acid in presence of sodium hydroxide / sodium bicarbonate. The polar carboxyl group offers CMG a strong hydrophilic characteristic and so it can be used in the production of superabsorbent hydrogels. By virtue of the abundant –OH groups on the CMG chain, it can be easily modified through graft copolymerization with hydrophilic vinyl monomers²¹⁻²³. Polyacrylamide (PAM) grafted CMG was developed by conventional redox grafting and microwave assisted method and it was found that the later showed better flocculating properties²⁴. Graft copolymers of CMG and PAM were synthesized using ceric-ion induced solution polymerization technique which exhibited better flocculation properties²⁵. CMG was also grafted with methacrylic acid²⁶, methylacrylate²⁷, N,N'-dimethylacrylamide²⁸ and N-isopropylacrylamide²⁹. Polyacrylamide is a water-soluble polymer with a hydrophobic main chain and hydrophilic functional groups in side chains. Its swelling nature is not very sensitive to pH or to the presence of electrolytes. The role of amide functional group is to introduce the required ionic functionalities in the gel³⁰. Moreover polyacrylamide readily forms hydrogen bonds with water thus expected to be more water absorbent when copolymerized with biopolymer. In the present investigation, an attempt was made to synthesize hydrogel networks based on polyacrylamide and a biopolymer CMG using Potassium persulphate (KPS) as an initiator and N,N'-methylenebisacrylamide (N,N'MBA) as crosslinking agent. Different hydrogels were prepared by using different ratios of Acrylamide and CMG with varying concentrations of N,N'MBA. The swelling characteristics of these cross-linked hydrogels were investigated as a function of time, temperature, pH, and electrolyte concentrations.

MATERIALS AND METHODS

2.1 Materials

Acrylamide (AM) (S.D. Fine Chemicals Mumbai India), Carboxymethylated guar gum (CMG) viscosity 3000 CPS at 25°C (Courtesy Hindustan Gum Ltd. India), N,N'-Methylene bisacrylamide (N, N'-MBA) (Merck, Germany), Potassium persulphate (KPS) (CDH, New Delhi India) were used as received. The other reagents used were all of analytical grade, and all solutions were prepared with triple distilled water.

2.2 Synthesis of Polyacrylamide-*cl*-Carboxymethylguargum (PAM-*Cl*-CMG) Hydrogel

A series of PAM-*Cl*-CMG hydrogels were synthesized by free radical copolymerization of Acrylamide (7×10^{-2} mole) and by varying the CMG concentration ([CMG]) (0 wt. %, 5 wt. %, 10 wt. %, 15 wt. % and 20 wt. %) with respect to AM. The concentrations of N, N'-MBA were varied from 0.5 to 2.5 wt. % with respect to AM (as stated in Table I), for each series of CMG concentration i.e. HG0 to HG4 in order to optimize the best hydrogel with respect to its swelling tendency. The synthesis conditions

and designation of hydrogels have been summarized in Table I. The reaction was carried out by dispersing predetermined amount of CMG in 50 mL AM solution and stirred for 2h in 250mL flat bottom flask. Different concentrations of N, N'-MBA solutions were made by dissolving desired amounts of N, N'-MBA (as stated in Table I) in 2-3 mL of distilled water and was added to above solution with constant stirring, then 0.05g KPS was also added and stirring was continued for further 1h, till a homogenous, viscous but fluid system was obtained. Subsequently the content of the flask was poured into test tubes and kept in water bath maintained at $65 \pm 1^\circ\text{C}$ for 2h. After copolymerization reaction, the hydrogel obtained was taken out by breaking the test tube and cut into small slices of about 0.5cm thick. These slices were then immersed in distilled water for 24h with intermittent stirring in order to remove any unreacted chemicals. Then the hydrogel pieces were kept at room temperature for 12h in open atmosphere and then dried in vacuum oven at 50°C till constant weight.

Table I
Details of synthesis conditions and designation of (PAM-CI-CMG) hydrogels.

Designation	Formulation	AM (g)	CMG (wt %)	N, N'MBA (wt %)	KPS (g)
HG 0(0.5)	PAM	5	0	0.5	0.05
HG 0(1)	PAM	5	0	1.0	0.05
HG 0(1.5)	PAM	5	0	1.5	0.05
HG 0(2)	PAM	5	0	2.0	0.05
HG 0(2.5)	PAM	5	0	2.5	0.05
HG 1(0.5)	(PAM-CI-CMG)	5	5	0.5	0.05
HG 1(1)	(PAM-CI-CMG)	5	5	1.0	0.05
HG 1(1.5)	(PAM-CI-CMG)	5	5	1.5	0.05
HG 1(2)	(PAM-CI-CMG)	5	5	2.0	0.05
HG 1(2.5)	(PAM-CI-CMG)	5	5	2.5	0.05
HG 2(0.5)	(PAM-CI-CMG)	5	10	0.5	0.05
HG 2(1)	(PAM-CI-CMG)	5	10	1.0	0.05
HG 2(1.5)	(PAM-CI-CMG)	5	10	1.5	0.05
HG 2(2)	(PAM-CI-CMG)	5	10	2.0	0.05
HG 2(2.5)	(PAM-CI-CMG)	5	10	2.5	0.05
HG 3(0.5)	(PAM-CI-CMG)	5	15	0.5	0.05
HG 3(1)	(PAM-CI-CMG)	5	15	1.0	0.05
HG 3(1.5)	(PAM-CI-CMG)	5	15	1.5	0.05
HG 3(2)	(PAM-CI-CMG)	5	15	2.0	0.05
HG 3(2.5)	(PAM-CI-CMG)	5	15	2.5	0.05
HG 4(0.5)	(PAM-CI-CMG)	5	20	0.5	0.05
HG 4(1)	(PAM-CI-CMG)	5	20	1.0	0.05
HG 4(1.5)	(PAM-CI-CMG)	5	20	1.5	0.05
HG 4(2)	(PAM-CI-CMG)	5	20	2.0	0.05
HG 4(2.5)	(PAM-CI-CMG)	5	20	2.5	0.05

2.3 Characterization

PAM, CMG and PAM-CI-CMG were characterized by the following techniques.

2.3.1 Fourier transforms infrared spectroscopy (FTIR)

FTIR spectra of PAM, CMG and PAM-CI-CMG were recorded in KBr pellets on Thermo scientific Nicolet 380 Spectrometer in transmittance mode to study the evidence of formation of PAM-CI-CMG hydrogels.

2.3.2 Scanning Electron Microscopy (SEM)

To investigate and compare the morphological structure of pure PAM and PAM-CI-CMG, SEMs of these polymers were recorded using Hitachi S3700N Scanning Electron Microscope.

2.3.3 Differential Scanning Calorimetry (DSC)

Differential Scanning Calorimetric analysis of PAM, CMG and PAM-CI-CMG was performed using TA Instruments, Model Q20 to examine the thermal properties of the polymers. The DSC curves were recorded in the temperature range of 25 to 500°C at a heating rate of 10°C min⁻¹, under Nitrogen atmosphere.

2.4 Swelling behavior

Swelling studies of the polymeric hydrogel samples were carried out in distilled water by gravimetric method. The known weight of hydrogel samples were immersed in distilled water at 20±1°C and then these polymeric hydrogel samples were taken out at regular intervals, wiped with tissue paper to absorb extra surface water and weighed till equilibrium swelling was attained. The percent swelling (%S) was calculated by the equation: %S = (W_s - W_d) / W_d × 100 (1) Where W_d and W_s

are weights of dry and swollen hydrogels respectively. Percent swelling was selected as a parameter for deciding the best hydrogel in each series of CMG concentration. The super absorbent hydrogels so selected were further studied for their swelling behavior with respect to temperature, pH, [NaCl] and multivalent cations effect.

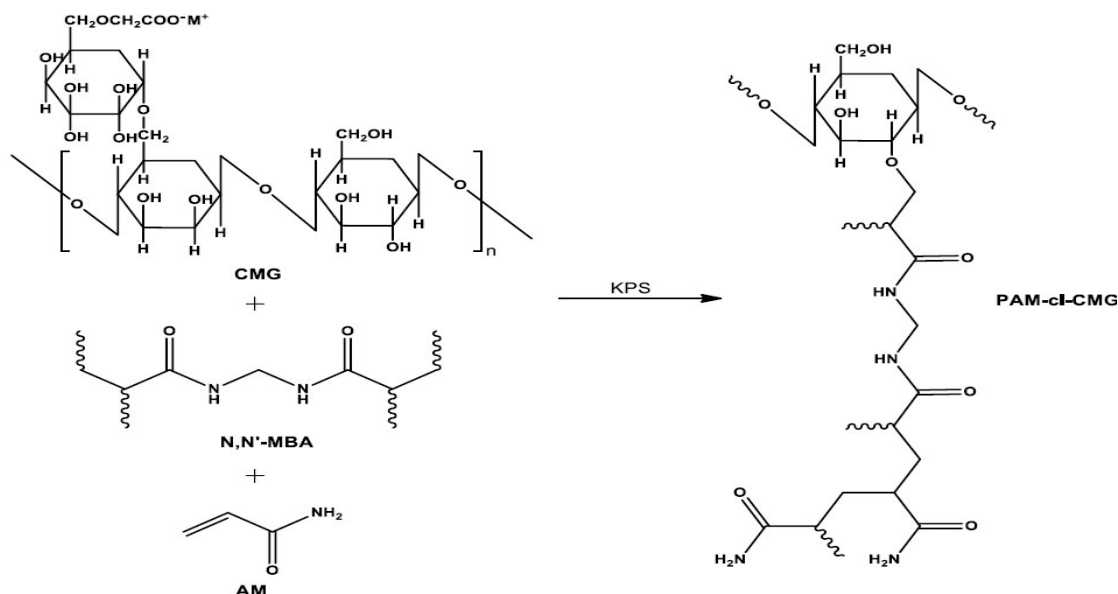
Analysis of Water uptake

The copolymeric hydrogel when immersed in distilled water, undergoes swelling due to the migration of water into pre-existing or dynamically formed spaces between the macromolecular chains. The portion of the water absorption curve with a fractional water uptake $(W_t/W_\infty) < 0.6$ for the optimized hydrogels are analyzed with the following equation. $F = W_t / W_\infty = kt^n$ (2) Where W_t is the mass of water absorbed at time t , W_∞ is the mass of water uptake at equilibrium, 'k' is gel characteristic constant and 'n' is swelling exponent describing the mode of the penetrant transport mechanism. The constants 'n' and 'k' may be calculated from the slopes and intercepts of the plots of $\ln(W_t/W_\infty)$ versus $\ln t$ from the experimental data. For a cylindrical gel, $n = 0.45-0.50$ corresponds to Fickian-type diffusion process (diffusion controlled), while $0.50 < n < 1.0$ indicates non-Fickian or

anomalous transport and $n = 1$ implies case II (relaxation controlled) transport.

RESULTS AND DISCUSSION

Crosslinking of AM onto CMG backbones was carried out using KPS as a radical initiator and N,N'MBA as a cross linker. The persulfate initiator was decomposed by heating to produce sulfate anion radicals, which extracted hydrogen atom/s from the hydroxyl groups of the CMG backbones to form macromolecular radicals on the substrates. The vinyl groups of AM were then reacted with the active radicals to form covalent bonds and simultaneously generate the new radicals that can process the chain propagation. Due to poly functionality of cross linker N,N'MBA ($\text{CH}_2=\text{CHCONHCH}_2\text{NHCOCH}=\text{CH}_2$), a macro radical with four reactive sites was formed which can be utilized for crosslinking both the PAM and CMG through its $-\text{OH}$ groups (as shown in Scheme I). These will finally result into the formation of three dimensional network of (PAM-CI-CMG) hydrogel. In order to study the effect of amounts of cross linker and CMG on the resulting hydrogels, polymeric networks of different [CMG] and [N,N'MBA] were synthesized.



Scheme I
Schematic Synthesis of PAM-cl-CMG

3.1 Characterization

3.1.1 Fourier transforms infrared spectroscopy

The copolymerization was confirmed by comparing the FTIR spectra of CMG, PAM and PAM-cl-CMG as shown in figure I (a), (b) and (c) respectively. The evidence of crosslinking of polyacrylamide on CMG was obtained by analyzing the characteristic peaks of the functional groups present in the respective hydrogel materials. In the case of CMG (Fig.1a) important peaks were observed at 3436.5, 2920.4, 1022.2 and 1152 cm^{-1} due to associated O-H stretching, C-H stretching, C-O stretching of $-\text{CH}_2\text{OH}$ in primary alcohols and C-O-C stretching in ether respectively. The peaks observed in the spectrum of CMG at 1603.9 cm^{-1} and 1424.4 cm^{-1} represented asymmetric and symmetric stretch of $-\text{COO}^-$ group in the associated carboxylic acid salt. In

the spectrum of PAM-cl-CMG hydrogel (Fig.1c), the additional peaks diagnostic of the polymer cross-linked with CMG can be observed along with the peaks of CMG. The positions of the peaks are slightly shifted which can be attributed to the crosslinking of CMG to PAM. The spectra of PAM-cl-CMG have peaks at around 1650-1667.2 cm^{-1} which is associated to amide-I (CO stretching) and amide-II (NH stretching), the peaks at 1454-1458 cm^{-1} are due to NH and CN in plane bending of amide. In the FTIR spectra of (PAM-cl-CMG) hydrogels, O-H stretching band of hydroxyl group of CMG and N-H stretching band of amide group of PAM overlap with each other which can be observed at around 3413-3429.5 cm^{-1} . Consequently, it was concluded that the AM monomers were successfully cross linked onto the CMC backbones

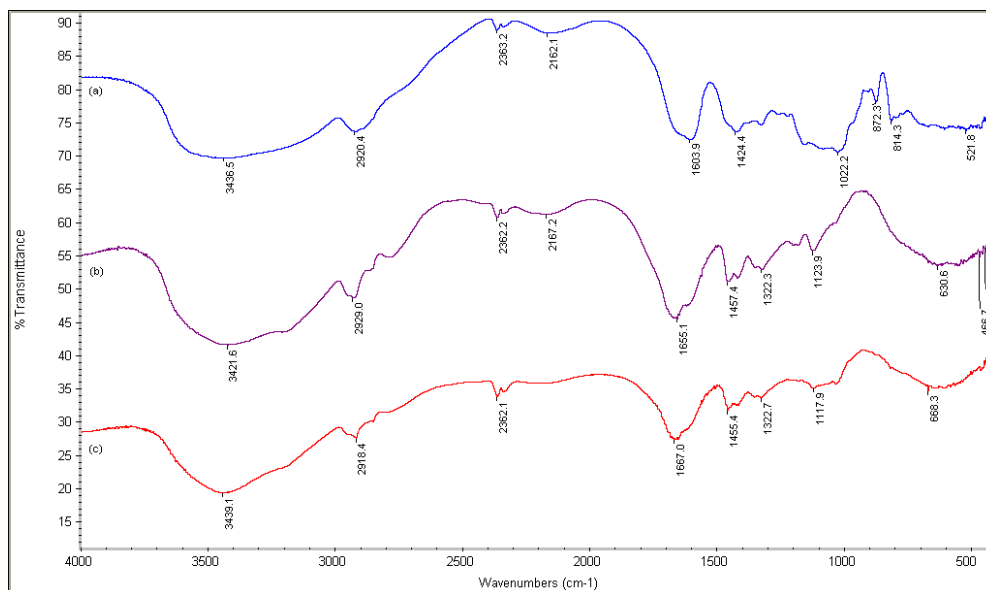


Figure I
FTIR Spectra of (a) CMG, (b) PAM and (c) PAM-cl-CMG

3.1.2 Scanning Electron Microscopy

The Scanning Electron Micrographs of PAM and PAM-Cl-CMG hydrogels are shown in figure II (a) and (b). SEM observations revealed that the pure PAM hydrogel had smooth and dense surface while PAM-Cl-CMG hydrogel had

an uneven and coarse surface with fibrillar structure. The presence of micro pores present on the surface support the higher swelling tendency of these cross-linked hydrogels (7783.5%) than PAM hydrogel (2224.35%).

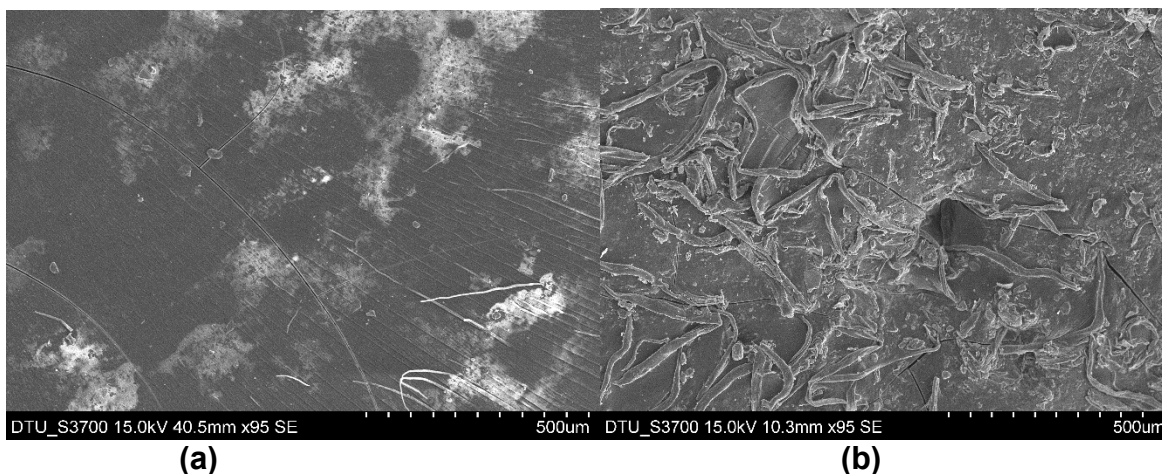


Figure II
SEM images of (a) PAM (b) PAM-Cl-CMG

3.1.3 Differential Scanning Calorimetry (DSC)

DSC curves of CMG, PAM hydrogel and PAM-Cl-CMG hydrogel are shown in figure III (a), (b) and (c). The initial endothermic peaks observed at temperatures 107°C, 94°C and 93°C can be attributed to the evaporation of

water, respectively in above polymers. In case of PAM and CMG, the thermal degradation is taking place at 288°C and 460°C while in case of PAM-Cl-CMG, it corresponds to the temperature of 258°C. Thus the degradation temperature of crosslinked polymeric hydrogel decreased from 288°C (for pure PAM

hydrogels) to 258°C (for PAM-CI-CMG) hydrogel. This implies that the crosslinking of

PAM with CMG decreased the thermal stability of the PAM-CI-CMG hydrogel.

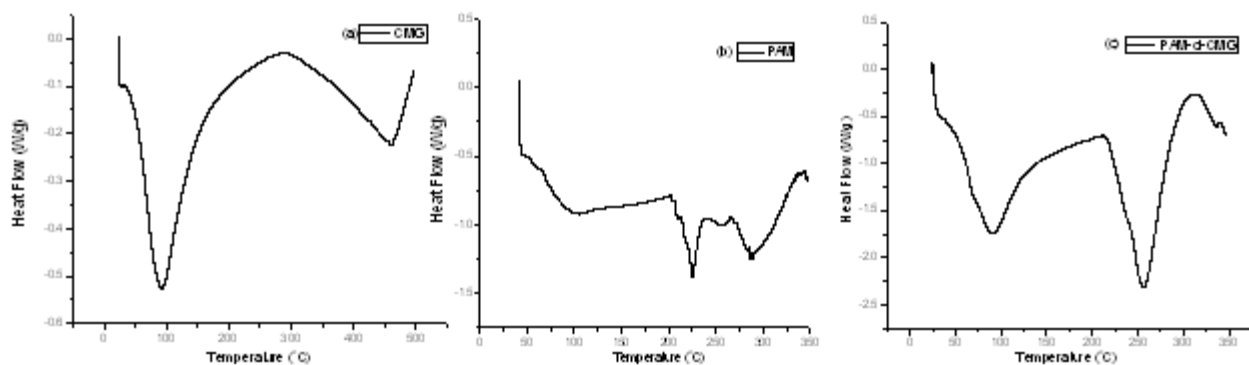


Figure III
DSC curves of (a) CMG, (b) PAM and (c) PAM-CI-CMG 20 wt%

3.2 Swelling behavior

PAM and PAM-CI-CMG hydrogels synthesized by varying the concentrations of crosslinker (N,N'MBA) and CMG were evaluated for their swelling capabilities.

3.2.1 Equilibrium swelling studies

The effect of different concentrations of CMG and N, N'MBA on equilibrium swelling was studied as a function of time in neutral swelling medium at $20 \pm 1^\circ\text{C}$. It was observed that percent swelling (%S) increases with time till swelling equilibrium was attained as shown in figure IV (a) to (e). Similar results were also reported by Singh and coworkers (2007)³¹. The polymeric hydrogels with highest swelling in each series of [CMG] (Fig. IV f) were selected as best candidates for swelling studies as a function of temperature, pH and in multivalent salt solutions.

Diffusion mechanism

The swelling exponent 'n' calculated from the slopes of the plots of $\ln(W_t/W_\infty)$ versus $\ln t$ indicating the type of solvent diffusion for these highest swelled hydrogels are found to be in the range of 0.6-0.9. Hence, the diffusion of water into these hydrogels has a non-Fickian (anomalous) character. This is generally explained as a consequence of the slow relaxation rate of the polymer matrix.

3.2.2 Effect of [N, N'MBA] on swelling behavior

As can be observed from figure IV (a) to (e), the optimized value for N,N'MBA concentration with respect to maximum swelling was 0.5wt% for HG0 to HG4. Thus the optimum crosslinking conducive to maximum swelling was obtained with 0.5wt% [N,N'MBA] for HG0 to HG4 and after increasing [N,N'MBA] the network structure became denser resulting in decrease in swelling capacity. This is due to incorporation of more crosslinking agents which resulted in decrease in hydrophilic group number and swelling as compared to its low cross linker counterpart. Moreover the crosslinking hinders the mobility of polymeric chains and thus lowers the swelling of hydrogels.³² Similar results were also reported for polymeric hydrogels containing PAM³³. It is remarkable to note that only a very small addition of cross linker brings abrupt transition from liquid to gel state during hydrogel synthesis. It was observed that absence of cross linker in the polymerization recipe resulted into formation of non-consistent jelly like product indicative of formation of linear polymeric chains. However, with increase in cross linker concentration from 0.5wt% to 2.5wt%, the firmness of hydrogel increased and its elasticity decreased due to formation of cross-linked structure.

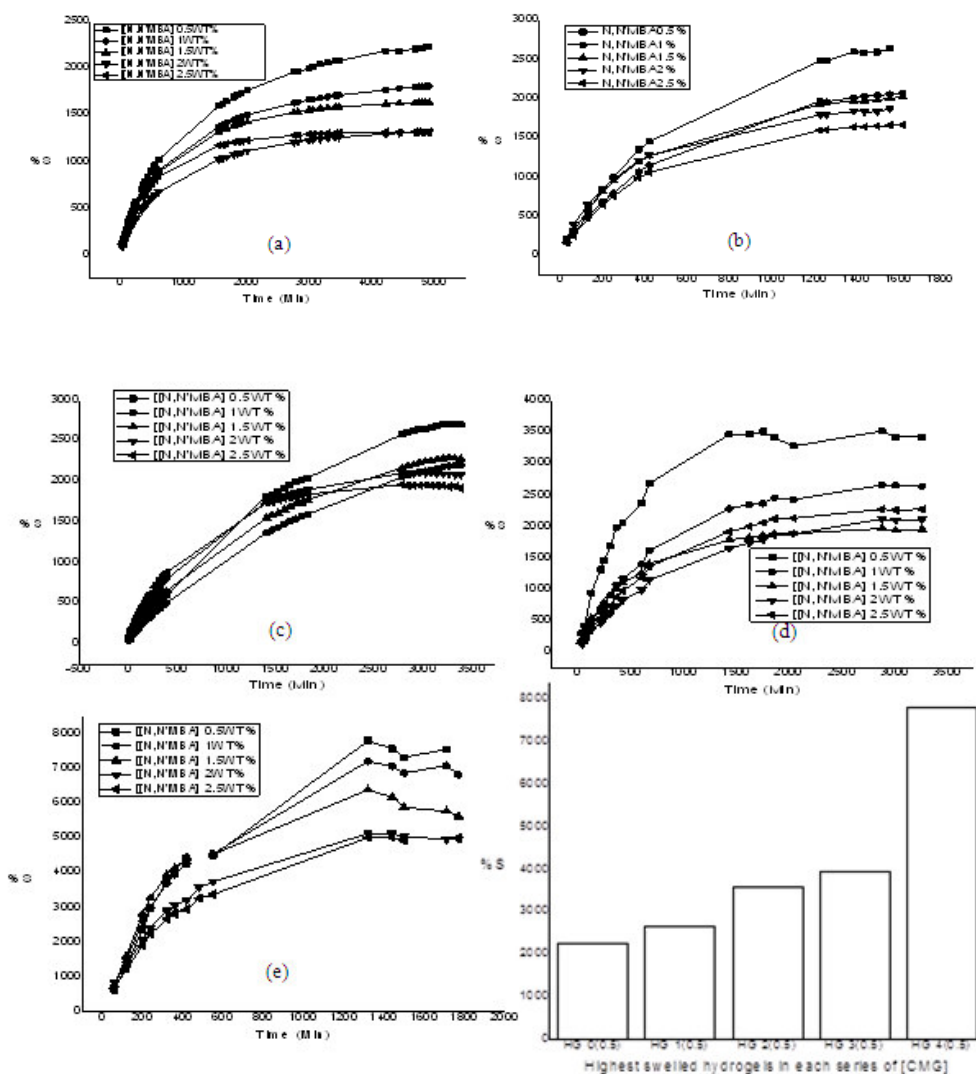


Figure IV

Percent swelling of: (a) PAM with 0.5 to 2.5 wt% [N,NMBA], (b) PAM-cl-CMG 5wt% with 0.5 to 2.5 wt% [N,NMBA], (c) PAM-cl-CMG 10wt% with 0.5 to 2.5 wt% [N,NMBA], (d) PAM-cl-CMG 15wt% with 0.5 to 2.5 wt% [N,NMBA], (e) PAM-cl-CMG 20wt% with 0.5 to 2.5 wt% [N,NMBA]

3.2.3 Effect of [CMG] on swelling behavior

The swelling behavior of copolymeric hydrogels is influenced by hydrogel composition, especially due to the presence of ionic moieties in either of the constituents. In the present study since one of the copolymeric constituents was CMG which is ionic in nature, it influences the swelling behavior of PAM-Cl-CMG hydrogel as is evident from figure IV (a) to (e). This behavior is attributed to the fact that as the [CMG] increases from 0 wt. % to 20 wt. %, the COO⁻ groups along the macromolecular chains also

increase with simultaneous increase in number of counter ions (Na⁺) within the gel phase, causing an enhancement in the chain relaxation due to the repulsion among similar charged groups (i.e. COO⁻ groups). Moreover osmotic swelling pressure also increased due to the increase in free counter ions (i.e. Na⁺) in the gel phase. Thus these two factors contribute towards the increased percent swelling of PAM-Cl-CMG hydrogels with an increases in [CMG]. Absence of these driving forces for diffusion of

water into the polymeric matrix of non-ionic hydrogel (HG0) causes it swell to less extent as compared to PAM-CI-CMG hydrogels (HG4) at the same temperature of the swelling medium. Similar results were also reported by Bajpai & Johnson (2005) for the swelling of copolymer of Acrylamide and Sodium acrylate³³.

3.2.4 Percent swelling as a function of temperature

The swelling behavior of polymer network is influenced by the temperature of the swelling medium. The increase in the temperature of the swelling medium is usually accompanied by the increase in the swelling rate of the hydrogels due to increased kinetic energy of solvent molecules. In the present study, the effect of temperature on swelling behavior of highest swelled hydrogels (best candidates) in each series of [CMG] was investigated at temperatures ranging from 20°C to 45°C. The results thus obtained (Fig. V a) clearly show that with an increase in temperature, percent swelling also increased. This temperature responsive swelling behavior is attributed to the fact that the rise in temperature causes the breaking of hydrogen bond and other secondary forces of attraction resulting in an increase in intermolecular spaces. It may also be due to hydrolysis of network chains at high temperature which ultimately result in increased swelling of the hydrogels owing to the formation of charged groups on hydrolysis. Therefore the hydrolysis of AM units are responsible for the increased swelling of these hydrogels at elevated temperatures³⁴.

3.2.5 Percent swelling as a function of pH

It was observed from figure V (b) that percent swelling was greatly affected by changing the pH of swelling media. In order to investigate the effect of varying pH on swelling behavior of hydrogel samples, the best candidate hydrogels in each series of [CMG] were swollen in different solutions of pH 2, 4, 6, 8, 10 and 12. The different pH solutions were made by diluting standard solutions of HCl (pH 2) and NaOH (pH 12) in order to reduce the effect on swelling behavior by increased ionic strength caused due to the additional ions through buffer

solution. In the present study, the swelling capacity of PAM-CI-CMG hydrogels increased from pH 2 to 6 but it decreased at pH 8 and then further showed increasing trend from pH 10 to 12. The least water uptake at lower pH may be attributed to the protonation of COO⁻ which caused decrease in anionic-anionic repulsion resulting in shrinkage of PAM-CI-CMG hydrogel samples. Since the pKa value of the carboxylic group is about 4.7, these groups present in CMG undergo ionization above pH 4.7 and may favor enhanced water uptake due to anion-anion repulsion. However at pH 7-8, hydrogen bonding may exist between COO⁻ or COOH and probably carboxamide group of PAM which resulted in drop in percent swelling³⁵. Further, hydrolysis of network chains seems to be responsible for rise in swelling at pH 10 and 12. Thus % S was higher in pH 12 swelling medium than in distilled water and lower pH swelling media. The percent swelling values for HG4 (0.5) in pH 2, distilled water and pH 12 swelling media are 2268.46%, 7783.5% and 10156.08% respectively. This behavior was not observed with pure PAM hydrogel which exhibited almost linear graph up to pH 10 but at pH 12, the percent swelling marginally increased which may again be due to hydrolysis of network chains. This confirms the fact that PAM is insensitive to change in pH of swelling media but on polymerization with CMG, percent swelling increased drastically. These observations indicate that these PAM-CI-CMG hydrogels are pH sensitive and thus have a potential applications in drug delivery devices and metal ion adsorption.

3.2.6 Percent swelling in saline and multivalent cation solutions

The effect of saline solution on the percent swelling of the best candidate hydrogel samples were investigated in 0.1M, 0.01M and 0.001M NaCl solution and to study the multivalent cation effect, these hydrogel samples were also subjected to swell in 0.1M CaCl₂ and 0.1M AlCl₃ solutions. Figure V(c) clearly shows that an increase in the concentration of NaCl caused decrease in percent swelling of hydrogels with [CMG] ≥ 10wt%. Thus the reduced water uptake in salt

solutions is often attributed to the decrease of osmotic pressure between the gel network and external solution due to increase in ionic strength and also due to the enhancement of screening effect of counter ions³⁶. However, the percent swelling for pure PAM and PAM-CI-CMG 5wt% hydrogels were not influenced by electrolyte concentrations which supports the fact that the swelling nature of PAM is not very sensitive to the presence of electrolytes.

Further percent swelling of these copolymeric hydrogels in different electrolyte solutions follow the order $Na^+ > Mg^{2+} > Al^{3+}$ as shown in figure VI for highest swelled hydrogel HG4 (0.5). Unlike monovalent cation, multivalent cations may form ionic crosslinks with anionic hydrophilic groups, which explains their reduced swelling tendency in $MgCl_2$ and $AlCl_3$ solution than in NaCl solution.

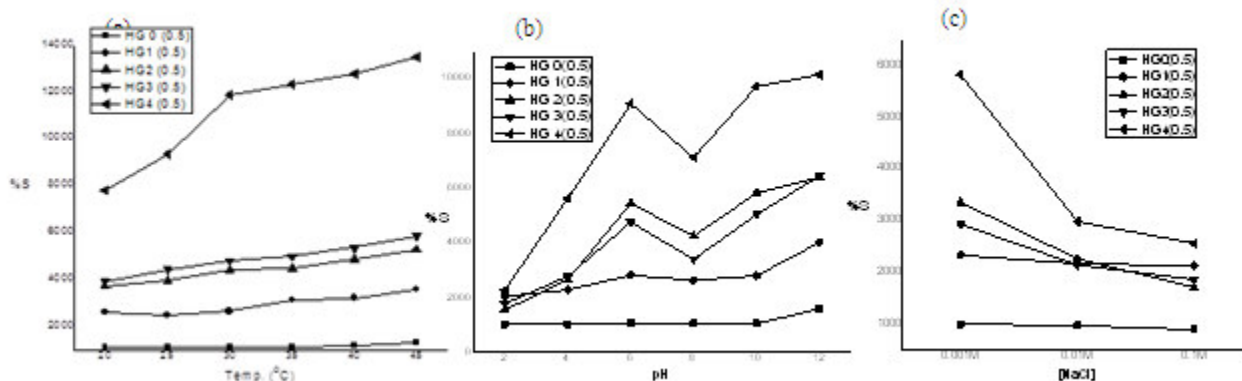


Figure V
 Percent swelling of best candidate hydrogels as a function of:
 (a) temperature, (b) pH and (c) [NaCl]

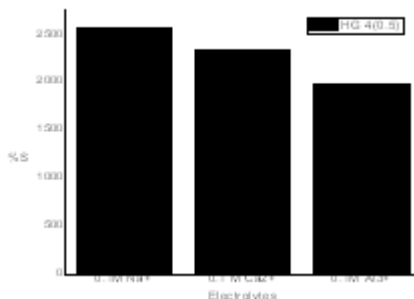


Figure VI
 Percent swelling of HG4 (0.5) in multivalent cation solutions.

CONCLUSION

Superabsorbent hydrogels based on natural polysaccharide CMG and AM were developed by free-radical copolymerization using N,N'MBA as crosslinking agent. The FTIR spectra demonstrated that the AM monomers were successfully cross-linked onto the CMC

backbones. SEM observations showed uneven, coarse and porous morphology of PAM-CI-CMG hydrogel, conducive to higher swelling tendency, while PAM hydrogels were comparatively smooth and least porous. The effect of reaction parameters, such as [CMG] and [N, N'MBA] on swelling behavior were investigated. The maximum percent swelling

(7783.5%) was achieved under the optimum reaction conditions, which were found to be: 20wt% [CMG], 0.5wt% [N, N'MBA] and 0.05g KPS. The swelling exponent 'n' values for the optimized hydrogels in each series of [CMG] were found to be above 0.5, hence indicating the diffusion mechanism to be Non-fickian (anomalous). Above all, the PAM-CI-CMG superabsorbent hydrogel showed improved swelling properties and smart pH, temperature and electrolyte responsivity. Therefore, CMG, when modified with acrylamide, resulted in the formation of the temperature, pH and electrolyte sensitive hydrogels and thus have potential to be used as metal ion adsorbents in

water enrichment technology. It is also concluded that due to the bio compatibility of synthesized polymeric hydrogels they can be used as potential candidate in drug delivery devices.

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