



# Preparation of Carboxymethyl Cellulose-g-Poly (Acrylic Acid - 2-Acrylamido-2-Methylpropane Sulfonic Acid)/Attapulgate Superabsorbent Composite

Fathelrahman Mohammed Soliman, Wu Yang, Hao Guo, Mahgoub Ibrahim Shinger, Ahmed Mahmoud Idris, Emtenan Suliman Hassan

Key Lab of Eco-environment Related Polymer Materials of MOE, College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou, China

## Email address:

fathy.19867@gmail.com (F. M. Soliman)

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**Abstract:** An eco-friendly high-swelling superabsorbent composite CMC-g-poly(acrylic acid - 2-acrylamido-2-methylpropane sulfonic acid)/Attapulgate based on carboxymethyl cellulose (CMC) and inorganic clay Attapulgate (ATP) was prepared via a grafting copolymerization of acrylic acid (AA) and 2-acrylamido-2-methylpropanesulfonic acid (AMPS), using with N, N-methylenebisacrylamide (MBA) as a cross-linking agent, ammonium persulfate (APS) as an initiator and polyethylene glycol(PEG) as a phase transfer catalyst. The effects of polymerization conditions on the swelling ability of the superabsorbent composite were investigated. The results indicated that the prepared superabsorbent had high water absorbency. Saturated water absorbencies of the superabsorbent reached ( $864 \text{ g.g}^{-1}$ ) for distilled water and ( $72 \text{ g.g}^{-1}$ ) for 0.9 wt% NaCl aqueous solution respectively. The water absorbency of the composites was dependent on the pH of external solutions and used saline solutions.

**Keywords:** Superabsorbent Composite, Carboxymethyl Cellulose, Attapulgate, Swelling Behavior

## 1. Introduction

Superabsorbent composites are slightly crosslinked hydrophilic polymers with a three-dimensional network structure which are capable of absorbing and retaining large amount of water in a short time and retaining water under pressure. For their unique properties, these kinds of materials have attracted an amount of attention so far [1-3]. By virtue of the special characteristics, these materials have been abundantly used in the disposable diaper industry for the past 30 year. Their applications, at present, are still being expanded to more fields, such as agriculture [4, 5], biomedicine [6, 7], waste-water treatment [8, 9], biosensors [10], tissue engineering [11, 12] and so on. However, most of these Superabsorbents are expensive and/or environmentally toxic synthetic polymers [13]. To reduce the cost of production and to improve biocompatibility, renewable, eco-friendly and non-toxic, biodegradable, natural

polysaccharides and abundant inorganic clay minerals have attracted widespread attentions

Superabsorbents prepared with natural material, such as starch [14-16], sodium alginate [17], chitosan [18], guar gum [19], montmorillonite [20] and carrageenan [21] have been focused and used so far. Cellulose, as one of the most abundant natural polymers, possesses excellent biodegradability and biocompatibility. However, the strong intermolecular and intramolecular hydrogen bonds between the hydroxyl groups along the chain backbone not only limit the water solubility but also lead to the poor reactivity of cellulose. Carboxymethyl cellulose (CMC) is a representative cellulose derivative with carboxymethyl groups ( $-\text{CH}_2-\text{COONa}$ ) bonded to some of the hydroxyl groups on cellulose backbone. The polar carboxyl groups promise the cellulose solubility, chemical reactivity and strong hydrophilicity. So the application of CMC in superabsorbent fields has become more and more attractive and promising [22].

Along with the development of the Superabsorbents based

on clay composites in recent years, the preparation of organic-inorganic superabsorbent composite has received much attention, because of its relatively low production cost and high hydrogel strength. Many types of inorganic clay, such as attapulgite [23], montmorillonite [24, 25], kaolin [26], mica [27], bentonite and sericite [28], vermiculite [29], sepiolite [30] and diatomite [31], have been used for the preparation of superabsorbent composites. Attapulgit (ATP) is a kind of hydrated octahedral layered magnesium aluminum silicate absorbent mineral with lots of OH groups on its surface. It is expected that the amount of hydrophilic groups, as well as the network structure of the Superabsorbents, could be improved by introducing ATP micropowder into the carboxymethyl cellulose.

In this work, CMC-g-poly(AA-co-AMPS)/ATP superabsorbent composite was prepared by using a graft copolymerization of acrylic acid (AA) and 2-acrylamido-2-methyl propane sulfonic acid (AMPS) monomers onto the carboxymethyl cellulose (CMC) in the presence of attapulgit (ATP) using N,N-methylenebisacrylamide (MBA) as a crosslinker, ammonium persulphate (APS) as an initiator and polyethylene glycol (PEG) as a phase transfer catalyst in an aqueous solution. The water adsorption capacity of the hydrogel composite and its influence factors, such as the weight ratios of AA/AMPS, and CMC/ATP, the amounts of the crosslinking agent and the initiator, initial pH values of solution and salt concentrations, were investigated.

## 2. Experimental

### 2.1. Materials

Carboxymethyl cellulose (CMC, degree of substitution: 0.7, average molecular weight 250000), acrylic acid were distilled under reduced pressure before use. 2-acrylamido-2-methylpropanesulfonic acid (AMPS) and N, N-methylenebis acrylamide (MBA) were used without further purification. Ammonium persulfate (APS) was recrystallized from water. Attapulgit (ATP, SiO<sub>2</sub>: 55.6-60.5, Al<sub>2</sub>O<sub>3</sub>: 90-10.1, Fe<sub>2</sub>O<sub>3</sub>: 5.7-6.7, Na<sub>2</sub>O: 0.03-0.11, K<sub>2</sub>O: 0.96-1.30, CaO: 0.42-1.95, MgO: 10.7-11.35, MnO: 0.61, TiO<sub>2</sub>: 0.32-0.6, purchased from Zhongtian industry & trade Co. LTD, Mingguang, Anhui, China) was milled and passed through a 320-mesh screen before use. Hydrogen peroxide, sodium bicarbonate and sodium carbonate were of all analytical grades and purchased from Tianjin No. 6 Chemical Reagent Factory, China. Sodium chloride(NaCl), magnesium chloride(MgCl<sub>2</sub>), calcium chloride(CaCl<sub>2</sub>), ferric chloride (FeCl<sub>3</sub>·6H<sub>2</sub>O) and the other reagents were of analytical grade and used as received.

### 2.2. Preparation of the Hydrogels

A series of superabsorbent hydrogels CMC-g-poly (AA-co-AMPS)/ATP were prepared by the following procedure. In a 250 ml three-neck flask, distilled water of 30 mL was added to a mixture of 0.9 g of CMC, 0.03 g of PEG, and 0.03 g of Na<sub>2</sub>CO<sub>3</sub>, and the reaction mixture was stirred until they were dissolved completely. Then, 0.1 g of ATP was dispersed

into above solution under electromagnetic stirring in 5 min and ultrasonically agitated for 30 min. After that, 0.05 g of MBA, 0.09 g of APS, 0.93 g of AMPS, and 7.2 g of AA (neutralized with 8.2 mL of 8.0 mol/L NaOH solution) were added accompanied with electromagnetic stirring for 5 min. At last, 0.02 g of NaHCO<sub>3</sub> and 0.75 mg of H<sub>2</sub>O<sub>2</sub> were successively added and the mixture was slowly heated to 75°C on oil bath and kept for 3 h to finish the polymerization. After polymerization, the product was washed with excess distilled water for several times to remove any unreacted reactants. The depurative product was dried in an oven at 60°C until weight of the product was constant. A part of the dried hydrogel was used to observe morphology before and after salt adsorption by using SEM. Other was milled through a 200-mesh sieve for testing the adsorption Properties.

### 2.3. Measurement of Water Absorbency and Swelling Rate

0.05 g of the superabsorbent sample was immersed in excess distilled water (500 mL) at room temperature for 6 h to reach a swelling equilibrium. Swollen samples were then separated from unabsorbed water by filtering through a 100-mesh screen under gravity for 10 min and not blotting samples. Water absorbency of the superabsorbent composite in distilled water,  $Q_{eq}$ , was calculated using the following equation:

$$Q_{eq} = \frac{m_S - m_D}{m_D} \quad (1)$$

Where  $m_D$  and  $m_S$  are the weights of the dry sample and the swollen sample respectively.  $Q_{eq}$  was calculated as grams of water per gram of sample (g.g<sup>-1</sup>). Water absorbency of the sample in 0.9 wt% NaCl solution was tested according to the same procedure.

#### 2.3.1. Swelling at Various pHs

Individual solutions with acidic and basic pHs were prepared by diluting of NaOH (pH 13.0) or HCl (pH 1.0) solutions to achieve a desirable pH, respectively. The pH values were precisely checked by a pH meter. Then, 0.1 g of the dried hydrogel was used for the steady state swelling measurements according to Eq. (1).

#### 2.3.2. Swelling in Salt Solutions

Water absorbent capacity of the superabsorbent hydrogel was determined in various saline solutions (NaCl, MgCl<sub>2</sub>, CaCl<sub>2</sub> and FeCl<sub>3</sub>) with different concentration (0.1, 0.3, 0.5, 0.7, and 0.9 mol·L<sup>-1</sup>) according to the above method described for swelling measurement in distilled water.

#### 2.3.3. Water Retention Measurement

The water retention (WR) was determined by centrifuging the water-swollen hydrogels at 4000 rpm. The weight of the hydrogels was determined every 1 min for 10 time. The WR of the hydrogels was calculated according to Eq. (2).

$$WR(\%) = \frac{W_F}{W_C} \times 100\% \quad (2)$$

Where  $W_F$  is the weight of the fully swollen hydrogel and  $W_C$  is the weight of the hydrogel centrifuged for different times at 4000 rpm.

#### 2.4. Characterization

IR spectra of the samples were measured using a Thermo Nicolet NEXUS TM spectrophotometer with KBr pellets. The micrographs were obtained using a Scanning Electron Microscopy (SEM) (JSM-5600LV, JEOL, Ltd.). Before SEM observation, all samples were fixed on aluminum stubs and coated with gold. Thermal stability was studied on a Perkin-Elmer TGA-7 thermogravimetric analyzer (Perkin-Elmer Cetus Instruments, Norwalk, CT), with a temperature range of 25–70°C at a heating rate of 10°C.min<sup>-1</sup> using dry nitrogen purge at a flow rate of 50 ml.min<sup>-1</sup>.

### 3. Results and Discussion

#### 3.1. Mechanism of Hydrogel Formation

The superabsorbent hydrogel was prepared by a graft copolymerization of AA and AMPS onto CMC in the presence of the cross-linking agent MBA and ATP, the initiator APS. Persulfate initiator decomposed under heating to produce sulfate anion radicals that abstracted hydrogen atoms from the hydroxyl groups of the carboxymethyl cellulose to form alkoxy radicals on the substrate. As a result, this redox system resulted in active centers capable of radically initiating the polymerization of AA and AMPS, leading to a graft copolymer. The end vinyl groups of the crosslinker MBA might react synchronously with polymer chains during the chain propagation. The copolymer comprised a crosslinked structure. ATP in the polymerization reaction can also be considered as a cross-linking agent [32]. The proposed mechanism for the grafting and chemically crosslinking reactions was outlined in Fig. 1.

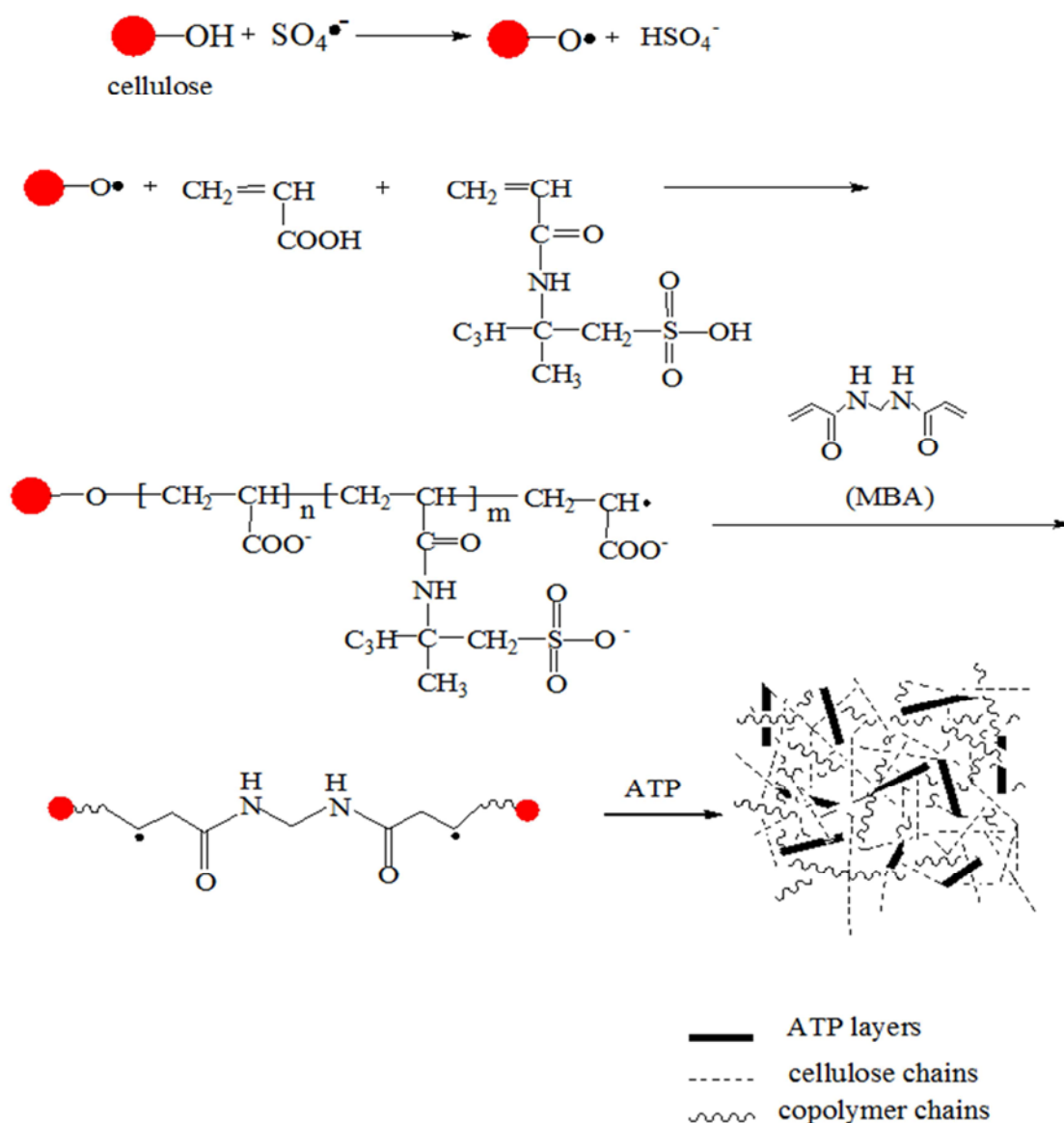


Fig. 1. Proposed reaction mechanism for synthesis of CMC-g-poly (AA-co-AMPS)/ATP superabsorbent hydrogel.

### 3.2. Characterization of the Superabsorbents

#### 3.2.1. FTIR Analysis

FT-IR spectra of ATP, CMC, CMC-g-poly (AA-co-AMPS), and CMC-g-poly (AA-co-AMPS)/ATP superabsorbent hydrogel were shown in Fig. 2. The three absorption bands of CMC at 1042, 1110 and 1140  $\text{cm}^{-1}$  assigned to stretching vibration of C–OH were obviously weakened after reaction (Fig. 2b–2d)). The characteristic bands assigned to C = O stretching of –COOH at 1623–1624  $\text{cm}^{-1}$ , asymmetric stretching of –COO<sup>−</sup> groups at 1548–1556  $\text{cm}^{-1}$  and symmetric stretching of –COO<sup>−</sup> groups at 1435–1427  $\text{cm}^{-1}$  appeared in the spectra of CMC-g-poly(AA-co-AMPS) and CMC-g-poly(AA-co-AMPS)/ATP (Fig. 2c and 2d). Moreover, The characteristic absorption peaks at 1397, 1027 and 626  $\text{cm}^{-1}$ , which were attributed to C–N stretching vibration of the amide, S–O stretching vibration of –SO<sub>3</sub>H, and C–S stretching vibration, could be observed in the spectrum of CMC-g-poly(AA-co-AMPS), which strongly suggested the existence of AMPS. These results indicated that AA and AMPS monomers were actually grafted onto the backbone of CMC.

In the spectrum (see Fig. 2a) of ATP, the (Al)O–H stretching vibration at 3613  $\text{cm}^{-1}$ , the (Si)O–H stretching vibration at 3545  $\text{cm}^{-1}$  and the –OH bending vibration at 1639  $\text{cm}^{-1}$  disappeared in the spectrum of the superabsorbent hydrogel (Fig. 2a and 2d). The absorption band of Si–O stretching vibration appeared at 1023  $\text{cm}^{-1}$  in the spectrum of CMC-g-poly (AA-co-AMPS)/ATP with a weakened intensity (Fig. 2d). These results indicated that –OH of ATP participated in the graft reaction with the monomers. Therefore, the superabsorbent hydrogel comprised a crosslink structure of CMC and ATP with side chains that carried carboxylate, carboxamide and sulfate.

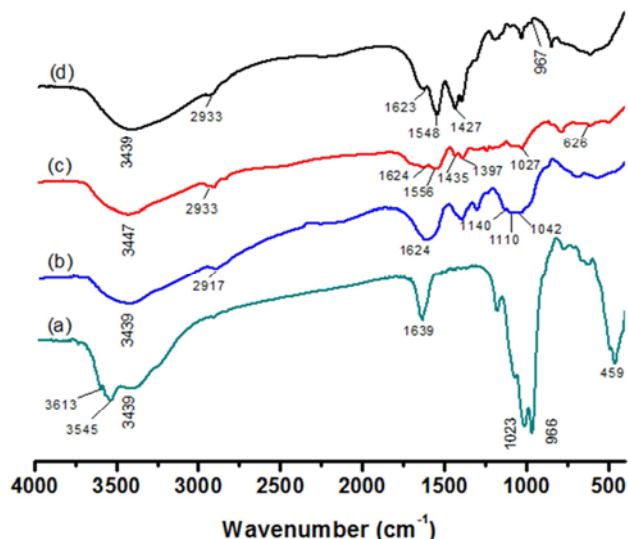


Fig. 2. FT-IR of (a) ATP, (b) CMC, (c) CMC-g-poly(AA-co-AMPS), (d) CMC-g-poly(AA-co-AMPS)/ATP.

#### 3.2.2. Thermogravimetric Analysis

Fig. 3 showed the effect of introduced ATP on the thermal

stability of the nanocomposite and it could be seen that the weight-loss rate of CMC-g-poly (AA-co-AMPS)/ATP was obviously slower than that of CMC-g-poly (AA-co-AMPS). At the initial stage, the weight loss about 20 wt% from 240 – 355°C for CMC-g-poly(AA-co-AMPS) and about 14 wt% from 183 – 306°C for CMC-g-poly(AA-co-AMPS)/ATP were respectively ascribed to the dehydration of saccharine rings and the breaking of C–O–C bonds in the chain of CMC[33]. The weight loss about 26 wt% from 355 – 420°C for CMC-g-poly (AA-co-AMPS) and about 19 wt% from 306–412°C for CMC-g-poly(AA-co-AMPS)/ATP might be due to elimination of the water molecule from the two neighboring carboxylic groups of the grafted chains. The weight losses about 53 wt% from 431 to 494°C for CMC-g-poly(AA-co-AMPS) and about 41 wt% from 412 to 500°C for CMC-g-poly(AA-co-AMPS)/ATP derived from the breakage of AA-co-AMPS chains and the destruction of crosslinked network structure. CMC-g-poly(AA-co-AMPS)/ATP composite exhibited slower weight-loss, which indicated the incorporation of ATP improved the thermal stability of the hydrogel.

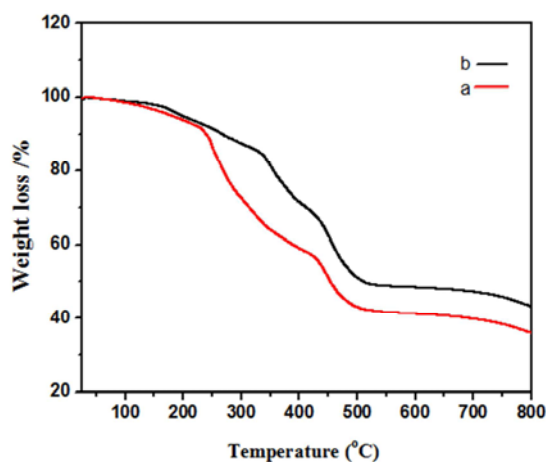
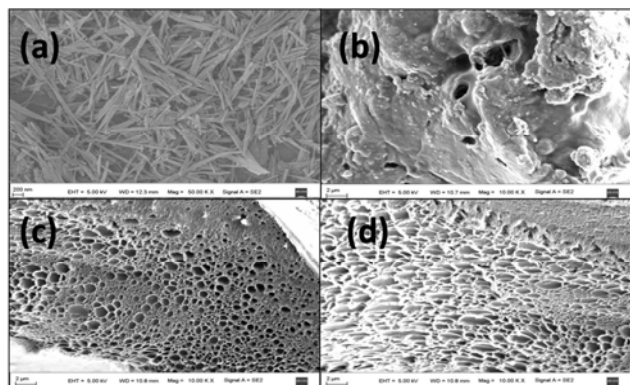


Fig. 3. TGA curves of CMC-g-poly (AA-co-AMPS) (a) and CMC-g-poly (AA-co-AMPS)/ATP (b).

#### 3.2.3. Scanning Electron Microscopy

Hydrogel microstructure is considered to be one of the most important properties for this material. This porous microstructure brings about an increased surface area and capillary effect. The surface morphology of the CMC-g-poly (AA-co-AMPS)/ATP hydrogel was obviously different from of CMC-g-poly (AA-co-AMPS). It could be observed that the cross-linked CMC-g-poly (AA-co-AMPS) (Fig. 4b) displayed a porous structure with a few of large pores. However, for hydrogel containing ATP (Fig. 4c), the pore size became smaller and the pore number became more. The CMC-g-poly (AANA-co-AMPS)/ATP hydrogel exhibited a larger specific surface area, implying that the grafted hydrogel had higher adsorption capacity. The microstructure of pure ATP clays was flaky (Fig. 4a), but when they were embedded within CMC-g-poly (AA-co-AMPS) composites, no flocculation of ATP particles could be observed (Fig. 4c). It could be also seen from (Fig. 4c) that the ATP

microparticles dispersed uniformly in the CMC-g-poly (AA-co-AMP)/ATP superabsorbent composite. It was the reaction of ATP with the monomers that changed the structure of polymeric network of the traditional superabsorbent materials [34, 35], and further improved the water absorbency. Fig.4d showed the surface of CMC-g-poly (AANA-co-AMPS)/ATP hydrogel after salt adsorption, the micrograph of the hydrogel before and after salt adsorption displayed an obvious structural change.



**Fig. 4.** SEM images of ATP (a), CMC-g-poly (AA-co-AMPS)(b), CMC-g-poly(AA-co-AMPS)/ATP(c) and (d) CMC-g-poly(AA-co-AMPS)/ATP after salt adsorption.

### 3.3. Effects of the Experimental Conditions on Water Absorbency

#### 3.3.1. Effect of the Crosslinker Content

The water absorbency as a function of MBA content, for crosslinked CMC-g-poly (AA-co-AMPS)/ATP was investigated (Fig. 5a). As shown in Fig. 5a, the water absorbency sharply decreased with increasing of the crosslinker content. The swelling ratio reached the highest,  $864 \text{ g.g}^{-1}$  when the MBA weight ratio was 0.2 wt%. When the crosslinker content was  $< 0.2 \text{ wt\%}$ , the absorbent composite was semi-soluble so that the water absorbency could hardly be measured. The results might be due to the fact that the network of the superabsorbent composite could not be formed efficiently, because of few crosslink points when the crosslinker content was too low. Contrarily, the excess crosslinkers resulted in a generation of more crosslink points, which in turn caused the formation of an additional network and decreased the space left for water to enter. The results were congruous with Flory's network theory [36] and similar observations had been reported by others [37, 38].

#### 3.3.2. Effect of Amount of the Initiator

The effect of the initiator amount on the water absorbency of CMC-g-poly (AA-co-AMPS)/ATP composite was shown in (Fig. 5b). The water absorbency increased with APS amount increasing from 0.25 to 0.75 wt% and then decreased with further increasing of APS amount. When the initiator amount was lower than the optimum value, the CMC macromolecular radical sites at which the monomer could be initiated could not be adequately formed. As a result, the process of the chain transfer reaction influenced the growth

of grafting polymer chains so that a regular 3 dimensional network was difficult to form when APS amount was too low. However, an excess of APS would produce too much more free radical species to accelerate the termination reaction of radicals and to increase the effective crosslinking density in the polymeric network of superabsorbent composite. As a result, the water absorbency decreased with the increase of APS amount beyond the optimum value.

#### 3.3.3. Effect of the Monomer Ratio

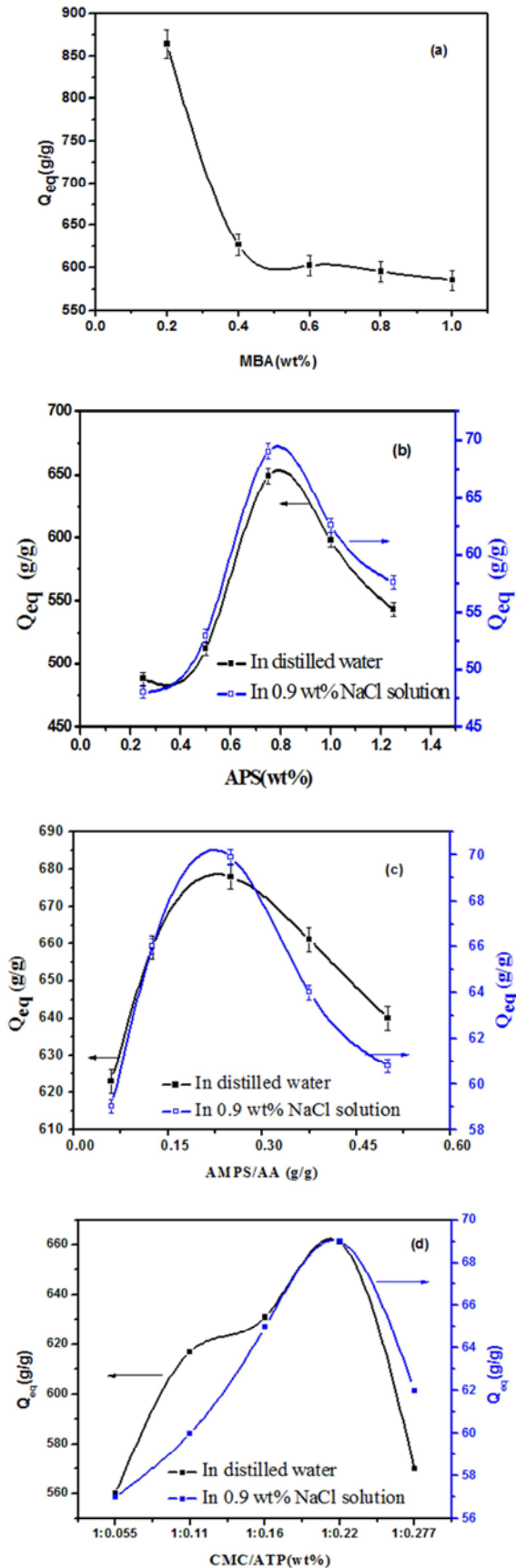
The effect of AMPS/AA weight ratio on the swelling ratio of the CMC-g-poly (AA-co-AMPS)/ATP superabsorbent hydrogels was shown in (Fig.5c). The maximum swelling ratios ( $678 \text{ g.g}^{-1}$  in distilled water and  $72 \text{ g.g}^{-1}$  in 0.9 wt% NaCl solution) were obtained at the 0.25 (g/g) ratio of AMPS/AA. The increase of the swelling ratio with increasing weight ratio of AMPS/AA from 0 to 0.25(g/g) could be attributed to the increase of hydrophilic groups, such as  $-\text{CONH}-$ ,  $-\text{CONH}_2-$ , and  $-\text{SO}_3\text{H}$  in the network.  $-\text{SO}_3^-$  groups associated to AMPS presented better affinity than  $-\text{COO}^-$  group of AA. But When the ratio became more than 0.25(g/g), the water absorbency and swelling ratio decreased sharply. This indicated that the hydrophilic monomer grafted onto CMC chains would decrease with continually increasing AMPS/AA weight ratio.

#### 3.3.4. Effect of ATP Content

The influence of CMC/ ATP weight ratio on water absorbency of the superabsorbent hydrogel was shown in (Fig.5d). It was obvious that ATP content was an important factor influencing water absorbency of the hydrogel. The water absorbency increased from 560 to  $661 \text{ g.g}^{-1}$  with CMC/ATP weight ratios increasing from 1:0.055 to 1:0.22. The maximum water absorbency ( $661 \text{ g.g}^{-1}$ ) was obtained at weight ratio of CMC/ATP of 1:0.22.

This trend was attributed to the facts that ATP possessed strong water adsorption and the active  $-\text{OH}$  groups of ATP could react with the  $-\text{OH}$ ,  $-\text{SO}_3\text{H}$ , and  $-\text{COOH}$  groups of the polymeric chains. In addition, ATP contained a lot of cations, and these ions could easily disperse into the superabsorbent composite polymeric network, which enhanced hydrophilicity of the superabsorbent composite and also made it swell more easily [24]. Another reason for ATP acquiring higher water absorbency was that the network was relatively loose and the capillarity was more evident, which accelerated the penetration of water molecules into the polymeric network. As a result, the water absorbency could be enhanced by introducing moderate amount of ATP. The decreasing tendency of water absorbency with the further increase of ATP content might be because the ATP could act as an additional cross-linking point in the polymeric network to decrease the elasticity of polymers. Additionally, the hydrophilicity of ATP was also lower than the polymeric chains, so that the osmotic pressure decreased gradually with increasing ATP content, which resulted in the shrinkage of the superabsorbent composite.

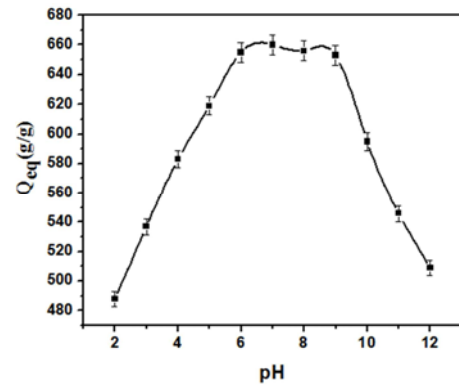




**Fig. 5.** Effect of the experimental conditions including crosslinker amount (a), initiator amount (b), monomer ratio(c) and ATP content (d) on water absorbency. Reaction temperature: 75°C, and reaction time: 3hr

### 3.3.5. Effect of pH

Prepared CMC-g-poly (AA-co-AMPS)/ATP, containing carboxylate, carboxamide, and sulfonate groups, was a typical anionic-type superabsorbent. Fig.6 showed its swelling behavior. As shown in Fig.6, the superabsorbent exhibited a significant swelling change in a wide range of pHs. The swelling ratio of the superabsorbent hydrogel increased sharply in the pH 2–6 range and then decreased in the pH 9–12 range. In acidic medium (pH <6), the carboxylate and sulfonate groups on the polymeric chain could turn into carboxylic acid and sulfonic acid groups. At higher pH (6.0–9.0), nearly all of the  $-\text{COOH}$  and  $-\text{SO}_3\text{H}$  groups were converted to  $-\text{COO}^-$  and  $\text{SO}_3^-$ . Consequently, the hydrogen-bonding interaction was eliminated and the electrostatic repulsion among the anionic groups increased in relatively higher pH. So the polymer network tended to swell more and kept higher swelling ratios. The swelling ratio decreased in the basic solutions (pH > 9) was due to the “charge screening effect” of the counter ions ( $\text{Na}^+$ ). Similar swelling-pH dependencies had been reported in the case of other hydrogel systems [39].



**Fig. 6.** Effect of external pH on the water absorbency of the hydrogel.

### 3.3.6. Effect of the Saline Solution

The water absorbency ratios of the hydrogel in aqueous solutions of NaCl,  $\text{MgCl}_2$ ,  $\text{CaCl}_2$ , and  $\text{FeCl}_3$  of various concentrations were shown in Fig. 7. The water absorbency decreased with the increase of the concentration of all four salt solutions. This decrease in water absorbency with increasing of the ionic strength of salt solutions could be attributed to a decrease of the osmotic pressure generating from ion concentration difference between the gel and aqueous phase, which resulted in shrinkage of the network. In addition, as shown in Fig. 7, for a given concentration of salt solution, the water absorbencies in NaCl,  $\text{MgCl}_2$  solution were far higher than those in  $\text{CaCl}_2$  and  $\text{FeCl}_3$  solutions. The absorbency decreased with the increased metal cation activity (from  $\text{Na}^+$  to  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$  and  $\text{Fe}^{3+}$ ) [40]. This tendency may be due to the fact that the coordination of the carboxylate groups induced the formation of intramolecular and intermolecular complexes, which resulted in an increase in the crosslink density of the network [41]. As a result, the water absorbency decreased considerably in the order:  $\text{NaCl} > \text{MgCl}_2 > \text{CaCl}_2 > \text{FeCl}_3$ .

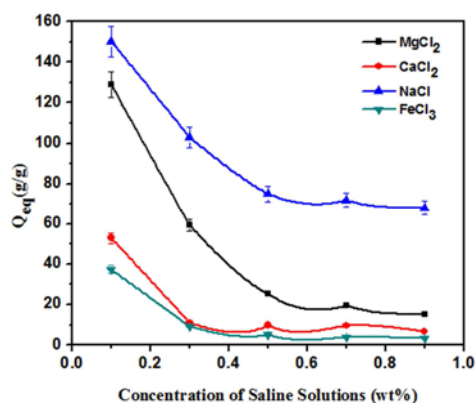


Fig. 7. Effect of different salt solution on the water absorbency of the hydrogel.

### 3.3.7. Effect of ATP Content on Water Retention

Effect of ATP content on water retention was presented in Fig.8. From Fig. 8 it could be seen that water retention of the hydrogel decreased with the centrifuging time increasing. The water retentions for CMC-g-poly(AA-co-AMPS)/ATP superabsorbent hydrogels with various ATP/CMC weight ratios of 0.05, 0.1, 0.15, and 0.2 were 74, 70, 65, and 50% respectively, when they were centrifuged at 4000 rpm for 10 min. All swollen superabsorbent composite samples showed high water retention ability and could keep more than 50% of

the distilled water after centrifuged at 4000 rpm for 10 min.

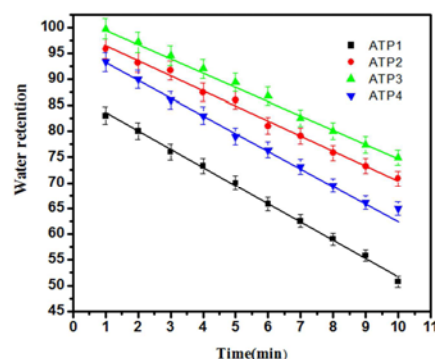


Fig. 8. Effect of ATP contents on water retention of the hydrogel.

### 3.4. Comparison of the Prepared High-Swelling Superabsorbent Hydrogels with Reported Absorbents

A comparison of high-swelling superabsorbent composite of the prepared superabsorbent hydrogels CMC-g-poly (AA-co-AMPS)/ATP with reported absorbents was given Table 1. The superabsorbent had high water absorbency as comparable with that of the other adsorbents. Therefore, considering the low cost and conventional use of this superabsorbent composite, it could be used as potential water-manageable materials for various applications.

Table 1. Comparison of high-swelling superabsorbent composite of the prepared superabsorbent hydrogels with reported absorbents was given Table 1.

Water absorbency	Water absorbency	Solution	References
CMC-g-poly(AA-co-AMPS) superabsorbent hydrogel	540 g/g	78g/g in 0.9wt% NaCl solution	[42]
Organic-inorganic composite superabsorbent	680 g/g	53g/g in 0.9wt% NaCl solution	[40]
(CTS-g-PAA/ATP) superabsorbent	159.6 g/g	42.3g/g in 0.9wt% NaCl solution	[18]
(CTS-g-PAA/SH) superabsorbent	183 g/g	41g/g in 0.9wt% NaCl solution	[43]
CMC-g-p(AA-co-AM-co-AMPS)/MMT	680.2 g/g	.....	[44]
kappa-carrageenan-g-poly acrylic acid	789 g/g	.....	[45]
CMC-g-p(AA-co-AMPS)/APT superabsorbent composite	864 g/g	72g/g in 0.9 wt% NaCl solution	This work

## 4. Conclusion

Eco-friendly CMC-g-poly(AA-co-AMPS)/ATP superabsorbent hydrogel was synthesized, the hydrogel product comprised a crosslink structure of ATP and CMC with side chains that carried an amount of hydrophilic groups including carboxylate, carboxamide and sulfate, high water absorbency and excellent water retention under load. The maximum equilibrium swelling ratios of the hydrogel in distilled water and 0.9 wt% sodium chloride solutions were up to 864 g.g<sup>-1</sup> and 72 g.g<sup>-1</sup>, respectively. The cation and concentrations of the saline solutions had a remarkable influence on the water absorbency of the hydrogel. The superabsorbent hydrogel could be used as potential water-manageable materials for various applications.

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