

Impact of sludge produced from drinking water plants on groundwater and its treatment by a natural polymer

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Abstract: The main aim of this work is to utilize the sludge water through treatment of the water turbidity and residual aluminum to prevent the seepage of the aluminum into the groundwater. Cross-linked chitosan was used as coagulant to remove turbidity and adsorb aluminum ions from the sludge water. The effect of several variables on the rate of gelation of chitosan glutaraldehyde system for maximum residual turbidity and aluminum removal from sludge water were studied. FT-IR spectrum was used as a tool to confirm the formation of cross-linked chitosan from pure chitosan using glutaraldehyde. A set of jar test experiments were conducted to find the optimal cross-linker concentration and coagulant dosage. The obtained results demonstrated that coagulation/flocculation process can assure turbidity removal from low to high turbidity waters effectively (10-18NTU), using relatively low doses of cross-linked chitosan (0.6-0.8 ppm). The results showed that turbidity removal is dependent on pH, coagulant dosage, and cross-linking degree as well as initial turbidity of water for both used coagulants. The highest turbidity removal efficiency was 85.1-92.4% with maximum removal of aluminium of 95 % for cross-linked chitosan over the applied range of turbidity.

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Keywords: sludge water, turbidity, aluminium removal, cross-linked chitosan, glutaraldehyde, Water treatment.

1. Introduction:

The main water resources of Egypt are; Nile River and its stream, and groundwater. Nevertheless; there is a severe shortage of potable water, where the per capita in Egypt currently does not exceed 750 m³/year; less than the world's water line (1000m³/year) [UNFPA, 2001]. In Egypt; about 88 % of the drinking water is produced from traditional treatment of Nile river water. Despite, the most common coagulant in the treatment plants is aluminum sulfate (Alum), there is a huge amount of sludge (40,000m³/day) is produced during the treatment process. Turbidity and aluminum ion are the most components of the sludge water. It is known that; Al³⁺ is a suspected causative agent of neurological disorders such as Alzheimer's disease [Shiraki and Yase, 1991 & Petrik *et al.*, 2007]. During water treatment processes, aluminum undergoes various transformations which are affected by factors such as pH, temperature of water source, and initial turbidity of raw water [Gregory and Carlson, 2003]. Chemical precipitation, reverse osmosis, and absorption methods are used as an efficient techniques in aluminum removal from sludge water [Folkard, *et al.*, 2000]. The production of potable water from sludge water in water treatment plant usually requires the use of a coagulation/flocculation stage to remove turbidity in the form of

suspended and colloidal material. This process plays essential role in sludge water treatment by reducing turbidity, bacteria, algae, colour, organic compounds and clay particles. The presence of suspended particles would clog filters or reduce disinfection process, thereby significantly minimizing the risk of water borne diseases [Mackenzie and Cornwell, 1991 & Fatoki and Ogunfowokan, 2002]. With aluminium salts, there is a concern about residuals in the treated water and Alzheimer disease. So, in recent years, there has been considerable interest in the development of natural coagulants such as chitosan. By using natural coagulants, considerable savings in chemicals and sludge handling cost may be achieved [Diaz *et al.*, 1999]. In recent years, chitosan has been applied as coagulant in water treatment [Folkard *et al.*, 2000]. Chitosan is a weak base and is insoluble in water and in organic solvent; it is inexpensive, biodegradable and nontoxic [Qin *et al.*, 2006]. The effective coagulation for turbidity removal was achieved in sludge water when using much lower doses of chitosan [Roussy *et al.*, 2005]. Chitosan can adsorb heavy metal ions due to its high percentage of nitrogen (6.9%), amino and hydroxyl groups on their chemical structure act as chelating sites for metal ions absorption [Szygula, *et al.*, 2009]. The unpaired electron doublet of nitrogen on amino group is

responsible for the sorption of metal cations [Sun and Wang, 2006 and Guibal *et al.*, 2004]. Chitosan has the highest chelating ability among the natural polymers. Hence, much attention has been drawn to this polymer and to the possibilities of its modifying in order to improve its absorption performance.

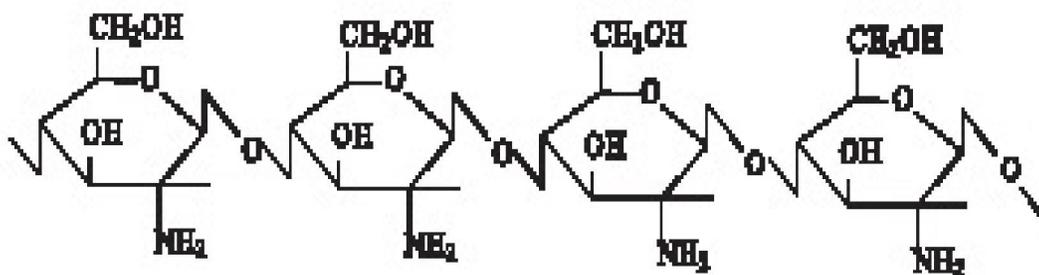
The current study aims to re-use of sludge water producing in vast amounts (15-20 %) depends on the efficiency of the plant and the physicochemical characteristic of the row water. The main component of this sludge is the aluminum ions that produced as a result of addition aluminum sulfate as coagulant in water treatment plants. The study depends on preparation of cross-linked chitosan glutaraldehyde beads and using it in removal of excess aluminum

from sludge water as well as using it as alternative to aluminum sulfate for removal all turbidity, suspended matter and the organic and inorganic compounds that present in raw water.

2. Experimental:

2.1. Materials

Chitosan powder (M.W 161.16 & de-acetylation 93%), Scheme 1 was obtained from oxford Co., Indian. Acetic acid soln. (Conc. 100%) was purchased from Merck Co., Germany. Glutaraldehyde (50 % in aqueous) was purchased from Merck Co., Germany, Sodium hydroxide was purchased from ADWIA Company, Egypt.



Scheme 1: chemical structure of chitosan

2.2. Preparation of cross-linked chitosan gel (CLCG):

12 g of chitosan powder were putted in a measuring flask of 1 litter, and then 640 ml of acetic acid solution (1%) was slowly added with continuous stirring. The crosslinking of chitosan was carried out using slowly drop-wise addition of 12 ml glutaraldehyde (50%) with strong stirring, 100 ml of NaOH solution (5%) was added and the reaction mixture was stirred and stayed for 10 hour under basic conditions, The resulting product is filtered, and washed by distilled water 8 times.

2.3. Jar test experiments:

Experiments on residual turbidity and aluminum removal by coagulation / flocculation processusing CLCG were performed using a jar test apparatus (Fisher-Bioblock, France). A standardized set of stirring speeds, i.e., 200 rpm/ 15 min for rapid stirring and 30 rpm/ 20 min for slow stirring, was used for comparative purposes [Roussy *et al.*, 2005b]. The initial pH of the solution was measured and then adjusted to a determine value using diluted H₂SO₄ or NaOH solutions (0.1 M). The homogeneous sludge water was separated into several beakers; each contains 1000 ml, to which a specific weight of CLCG was added. The mixtures were then stirred at high velocity (200 rpm) for 15 min, after which the velocity was decreased to 30 rpm and maintained for 20 min.

The stirring was then stopped and the experiments were performed at room temperature. Following a settling time of 30 min, the samples were collected at the top of the settling. Then residual turbidity and aluminum concentration were measured.

2.4. Heavy metals analysis:

Aluminium ion concentration was determined by means of ICP-MS, using 1000 ppm Multi- elements stock solution for standard preparation.

2.5. Turbidity measurement:

The turbid meter instrument measures turbidity in the range 0.01 to 1100 NTU/FTU featuring auto ranging. The light source is an infrared LED (light emitting diode) with a wavelength of 860 nm. The emitted light is reflected by turbidity in the sample. The scattered light will be detected at an angle of 90° by a photodiode. The turbidimeter TB300 IR is factory calibrated with Formazin Primary Standard and does not require user calibration before use. The international Reference Standard for turbidity is a Formazin solution. Results related to these standards are indicated as Formazine Nephelometric Units, FNU.

2.6. Degree of swelling of CLCG:

To determine the percentage of water absorption placed samples of known weight of cross linked chitosan glutaraldehyde (g) into distilled water (ml) for different times at room temperature (25 °C). The

dry weight of the sample was recorded as W_d , and W_w the wet weight, with surface adsorbed water being removed by filter paper, the Swelling ratio was calculated by the following formula:

$$\text{Swelling ratio (\%)} = (W_w - W_d) / W_d * 100$$

2.7. Degree of cross-linking of CLCG in acetic acid solution:

The degree of cross-linking of CLCG is representative of a ratio of mass of cross-linked state (W_d) of CLCG to the whole mass of CLCG (W_t). The cross-linking degree of the obtained CLCG was determined by dissolving known weight of CLCG into acetic acid for different time (h) and then measuring the dry weight of pre-post-dissolved CLCG.

$$\text{Degree of cross linking (\%)} = W_d / W_t * 100$$

3. Results and discussions:

3.1. Fourier transform-infrared (FT-IR) spectroscopy:

Fourier Transform-infrared (FT-IR) spectroscopy is a diagnostic method for characterization of chitosan powder and cross-linked chitosan glutaraldehyde. The IR spectrum of the cross-linked chitosan glutaraldehyde (Fig. 1B) shows different characteristic peaks than that of the pure chitosan (Fig. 1A). A significant peak can be found at 1658cm^{-1} corresponding to the formation of imine bond (C=N), i.e. Schiff's base structure by the reaction of amino groups of chitosan and aldehyde groups of glutaraldehyde [Peng, *et al.*, 1994 & Bellamy *et al.*, 1980]. The characteristic peaks between 1548 and 1564cm^{-1} indicated the presence of $-\text{NH}_3^+$ groups in the swollen hydrogel. One important reason for the swelling is the formation of $-\text{NH}_3^+$ groups in the hydrogel at the environmental medium (pH, 3) below the acid dissociation constant (pKa) which is 6.3 for amino groups of chitosan. The

ionic $-\text{NH}_3^+$ groups formed cause the migration of counter ions into the hydrogel, thus changing the osmotic pressure of the network and inducing water transfer from the exterior buffer solution, resulting in the swelling of the hydrogel. Another significant peak at 1700cm^{-1} indicates the presence of carboxylic acid. As the hydrogel overcrowded at pH 7, the characteristic peak of $-\text{NH}_3^+$ at 1564cm^{-1} decreased, indicating the transition of $-\text{NH}_3^+$ to $-\text{NH}_2$ under neutral or alkaline conditions. The C=N bond of the Schiff's base structure at 1658cm^{-1} was still present in the hydrogel which is assumed to be the major covalent bond maintaining the 3-D structure of the hydrogel. A significant peak at 1564cm^{-1} was also observed, especially as the contraction time increased. Because of the instability of the imine bond (C=N) of the Schiff's structure, the hydrogen could undergo structural changes depending on reactant structure, temperature, and pH of the solution, especially when hydrolyzed at high pH [Carey and Sundberg, 1984]. The appearance of the new peak at 1564cm^{-1} indicates the structure transition from C=N to C—N. This transformation is more likely to occur under alkali condition of the surrounding media [Peng *et al.*, 1994]. The nucleophilic nitrogen of the amino group ($-\text{NH}_2$) attacks the carbon of the aldehyde, which displaces the oxygen of the aldehyde and results in the loss of one water molecule, thus forming the C=N bond, the Schiff's base. When the pH of the reaction environment is neutral or alkaline, it facilitates the formation of the $-\text{NH}_2$ of chitosan (pKa= 6.3), which is essential for the formation of Schiff's base. In an acidic environment, however, $-\text{NH}_3^+$ is more likely to form, which significantly decreases the nucleophilicity of nitrogen, thereby lowering the activity of the Schiff's base reaction.

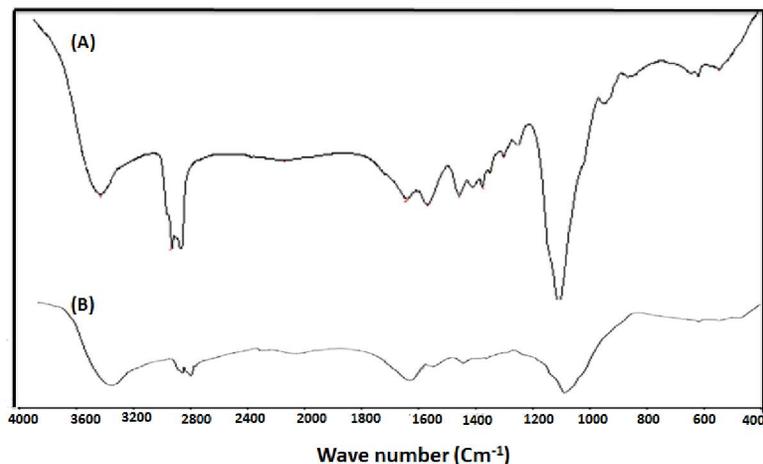


Fig (1) FTIR spectra of chitosan (A), and cross-linked chitosan glutaraldehyde (B)

3.2. Removal of residual turbidity and aluminium from sludge water

3.2.1. Effect of chitosan concentration:

Table 1 and Fig. 2 show the effect of chitosan concentration (1 – 4 wt. %) on the residual turbidity, aluminium removal and the observed scum at different doses. From the table, it is clear that; at low chitosan concentration (1%), high layer scum was formed in water surface and residual turbidity, aluminium removal were very low (Fig. 2 A and B), these are due to greatly decrease in chitosan concentration leading to decrease the active sites. So, cross-linking degree, charge density decreases and swelling degree increases [Roberts, *et al.*, 1989 & Kurita *et al.*, 2001] as shown in Fig. (2 C and D). At chitosan concentration (2%), no scum layer was formed in water surface. So, residual turbidity and aluminium removal greatly increased (Fig. 2 A and B), These are due to increase chitosan concentration leading to active sites increases, so cross-

linking and charge density increases, swelling degree decreases (Fig. 2C and D). Hence, the residual turbidity and aluminium removal increases [Roberts, *et al.*, 1989 & Berger *et al.*, 2004 & Li J, Jiao *et al.*, 2013]. At chitosan concentration (3&4%), high layer scum was formed in water surface. so, residual turbidity and aluminium removal greatly decreased (Fig. 1 A and B), this is due to greatly increase in chitosan concentration leading to active sites increases. So, cross-linking and charge density greatly increases (Fig. 2C and D). So, the accessibility to active sites decreases as a result of a more extensive three-dimensional network. Hence, residual turbidity and aluminium removal of water decreased [Ruiz *et al.*, 2000 & Mohd *et al.*, 2009]. So, 2% is the optimum chitosan concentration for maximum residual turbidity and aluminium removal at constant dose 0.8ppm as shown in table 1.

Table (1): Effect of chitosan concentrations on the turbidity and aluminium removal

Chitosan conc. (%)	Chitosan dose (g)	Residual turbidity (NTU)	Residual alum. (ppm)	Observation
1%	0.3	8.19	0.438	High scum layer
	0.4	7.51	0.427	High scum layer
	0.5	6.95	0.415	High scum layer
	0.6	6.80	0.406	High scum layer
	0.7	6.04	0.392	High scum layer
	0.8	4.78	0.374	High scum layer
2%	0.3	5.33	0.275	No scum layer
	0.4	4.62	0.259	No scum layer
	0.5	4.32	0.212	No scum layer
	0.6	2.94	0.188	No scum layer
	0.7	2.16	0.106	No scum layer
	0.8	2.04	0.081	No scum layer
3%	0.3	5.83	0.365	Medium scum layer
	0.4	6.42	0.373	Medium scum layer
	0.5	6.47	0.381	Medium scum layer
	0.6	7.53	0.384	Medium scum layer
	0.7	8.41	0.390	Medium scum layer
	0.8	9.73	0.395	Medium scum layer
4%	0.3	11.5	0.461	High scum layer
	0.4	12.8	0.478	High scum layer
	0.5	13.5	0.484	High scum layer
	0.6	13.8	0.492	High scum layer
	0.7	14.9	0.514	High scum layer
	0.8	16.2	0.528	High scum layer

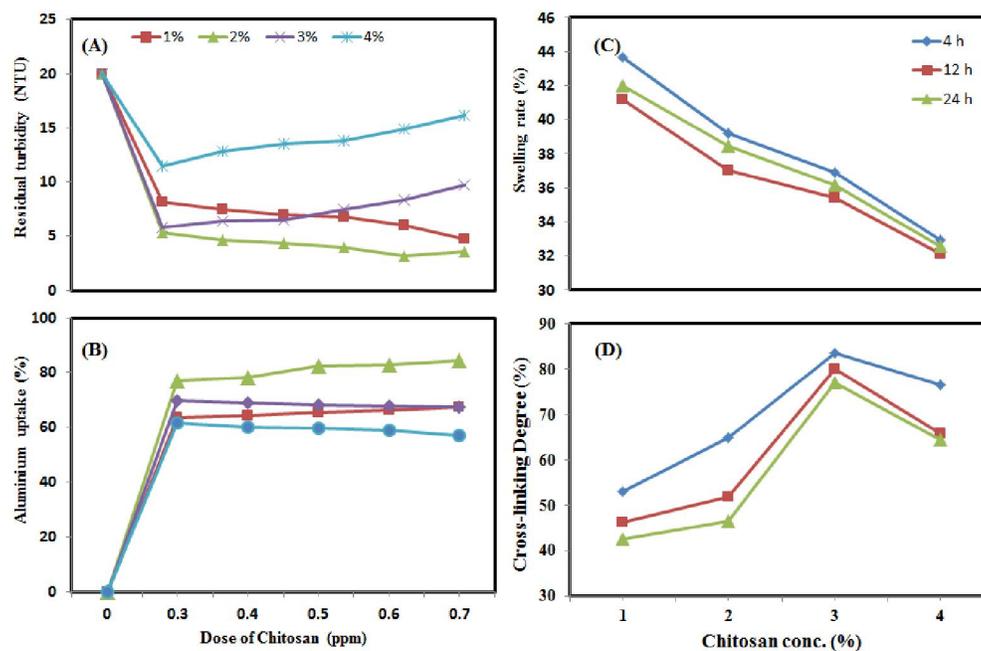


Figure 2: Effect of chitosan concentration on A) Residual turbidity removal (NTU), B) Aluminium uptake (ppm), C) Degree of swelling (%) and D) Degree of cross-linking (%).

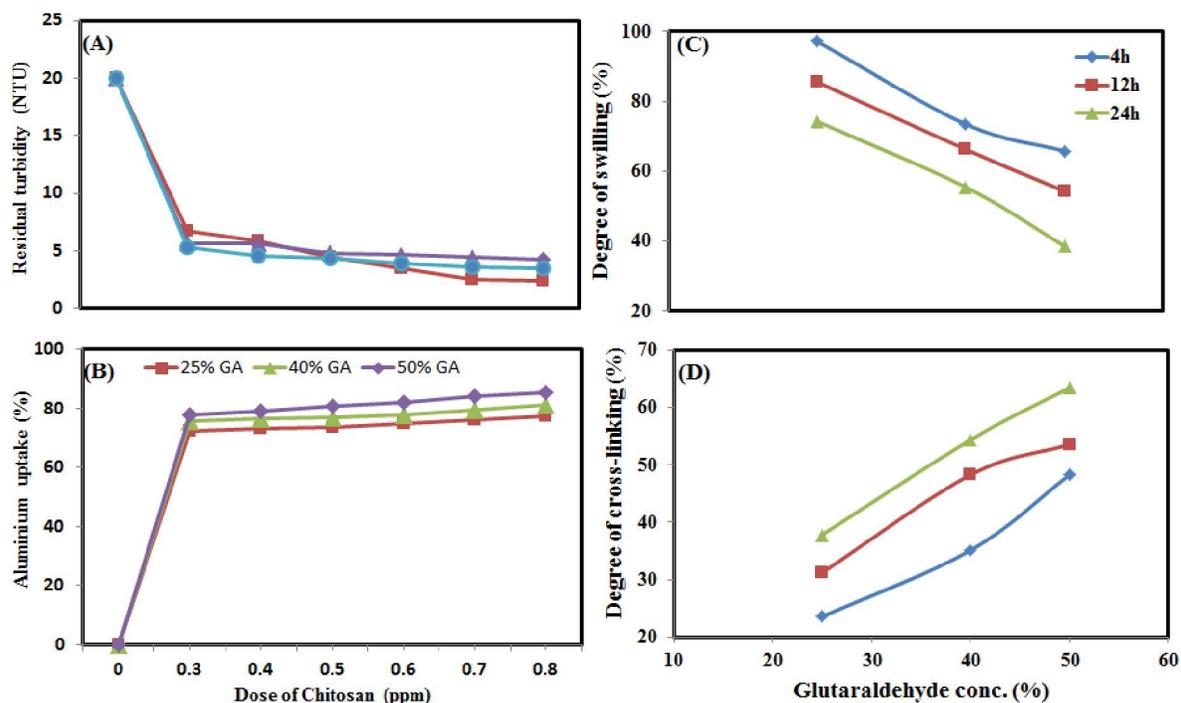
3.2.2 Effect of glutaraldehyde (GA) concentration

The crosslinking agent has a significant effect on the adsorption properties of chitosan beads because the chemical structure of the chitosan beads depends on the nature of the crosslinking agent and the degree of crosslinking [Chiou and Li, 2003 & Yoshizuka K, Lou Z, Inoue K, 2000]. The selectivity of chitosan beads depends strictly on the crosslinking density, and the diffusion of pollutants in surface of chitosan beads becomes slower as the crosslinking density increases. At higher degree of crosslinking, the beads have lower swelling capacities. The accessibility to active sites decrease as a result of a more extensive three-dimensional network [Shifan *et al.*, 2000] and an increase in the hydrophobic character. Although crosslinking enhances polysaccharide resistance against acid, alkali and chemicals it involves a loss in the chain flexibility, a reduction of the mobility of chelating groups and their accessibility, and as a result causes a significant decrease in pollutant uptake efficiency and adsorption capacities of the adsorbent. **Table 2, and figure 3** illustrate the effect of varying glutaraldehyde concentrations (25- 50%) on the rate of chitosan cross-linking for maximum residual turbidity, aluminium removal and the observed scum. From the table, it is clear that; at low concentration of

GA(25%), high layer scum was formed; this is due to degree of cross-linking decreased, therefore, charge density and active sites also decreased. Hence, residual turbidity and aluminium uptake decreased [Chiou and Li, 2003] as shown in (Fig. 3 A and B). But degree of swelling decreases with increasing cross-linking degree as shown in (fig. 3C and D). At moderate concentration of GA(40%) medium layer scum was formed in water surface leading to moderate increase of turbidity and aluminium in treated water [Yoshizuka *et al.*, 2000] as shown in (Fig. 3 A and B), these is due to degree of cross-linking increased, therefore, charge density and active sites also increased, so, aluminium uptake increases. At high concentration of GA solution (50%), no scum layer was formed in water surface. Hence, no increases turbidity and aluminium in treated water as shown in (Fig. 3A and B), Increase rate of cross-linking of chitosan leading to cross-linking degree increases, active sites of amino groups in surface of chitosan beads increases, swelling rate decreases and accessibility of pollutants are available [Chiou and Li, 2003], as shown in (Fig. 3 C and D). So, the optimum GA concentration for maximum residual turbidity and heavy metals removal at conc. 50% in which no scum layer was formed in water surface.

Table (2): Effect of glutaraldehyde concentrations on residual turbidity and aluminium removal

Glutaraldehyde conc. (%)	Dose of chitosan (ppm)	Residual turbidity (NTU)	Residual alum (ppm)	Observation
25%	0.3	6.75	0.331	High scum layer
	0.4	5.88	0.325	High scum layer
	0.5	4.46	0.318	High scum layer
	0.6	3.54	0.304	High scum layer
	0.7	2.57	0.289	High scum layer
	0.8	2.41	0.274	High scum layer
40%	0.3	5.69	0.294	Low scum layer
	0.4	5.62	0.283	Low scum layer
	0.5	4.84	0.278	Low scum layer
	0.6	4.64	0.265	Low scum layer
	0.7	4.43	0.246	Low scum layer
	0.8	4.21	0.225	Low scum layer
50%	0.3	5.33	0.267	No scum layer
	0.4	4.62	0.253	No scum layer
	0.5	4.32	0.234	No scum layer
	0.6	3.94	0.215	No scum layer
	0.7	3.61	0.192	No scum layer
	0.8	3.54	0.178	No scum layer

**Fig. 3:** Effect of glutaraldehyde concentration on A) Residual turbidity removal (NTU), B) Aluminium uptake (%), C) Degree of swelling (%) D) Degree of cross-linking (%)

3.2.3. Effect of acetic acid (Ac) concentration

Increase acetic acid concentration lead to pH decreases. Hence, the charge density of cross-linked chitosan glutaraldehyde beads and therefore the cross-linking density decreases, which lead to swelling rate increases. Moreover, swelling is favoured by the protonation and repulsion of amino groups of chitosan glutaraldehyde. If the pH decrease is too large and the medium become more acidic, dissociation of ionic linkages and dissolution of the network can occur due to repulsion protons of amino groups [Shu, *et al.*, 2001 & Mi, *et al.*, 1999 & Jayakumar, *et al.*, 2010], leading to a fast aluminium and turbidity release [Shu and Zhu, 2002]. If the pH increases, the protonation of CLCG beads decreases and induces an increase of the crosslinking density, allowing swelling. If the pH becomes too high and the medium become more alkaline, amino groups of chitosan are neutralized and ionic crosslinking is inhibited [Draget, *et al.*, 2002 & Pivarčiová, *et al.*, 2014]. If the crosslinking density becomes too small, interactions are no longer strong enough to avoid dissolution [Mi, *et al.*, 1997]. Moreover, a covalently Cross-linked hydrogel does not exhibit swelling in basic conditions and as the crosslinking density not vary in a covalently cross-linked hydrogel, swelling is less declared but dissolution is avoided. Aluminium adsorption increases with increase pH of the solution till reaching the maximum value of adsorption at pH (5-6). The lower adsorption of metal ions in strong acidic pH solution at lower pH mainly due to the electrostatic repulsion between the positively metal ions in the medium and the positively charges in highly acidic solution (H^+) which accumulate on the surface of chitosan beads, The amino groups in chitosan beads are easily form protonation, reducing the number of active sites available for the adsorption of heavy metal ions. This leads to an electrostatic repulsion of the different aluminium ions. So, the competition existed between protons and the metal ions for adsorption sites and adsorption capacity was decreased. Hence, the repulsion prevents the approach of the metal ions to the chitosan surface. While low acidic PH solution and at higher pH (5-6), the adsorption of heavy metal ions increases due amino groups are free from protonation. Hence, electrostatic repulsion decreases. So, decreases positive charge density allowing the metal ions to approach from surface of chitosan which result in higher adsorption values. The adsorption mechanism may be partially replaced by a chelation mechanism on the amino groups of chitosan beads. Further increase in the pH value more than 5 would transform the dissolved metal into precipitated

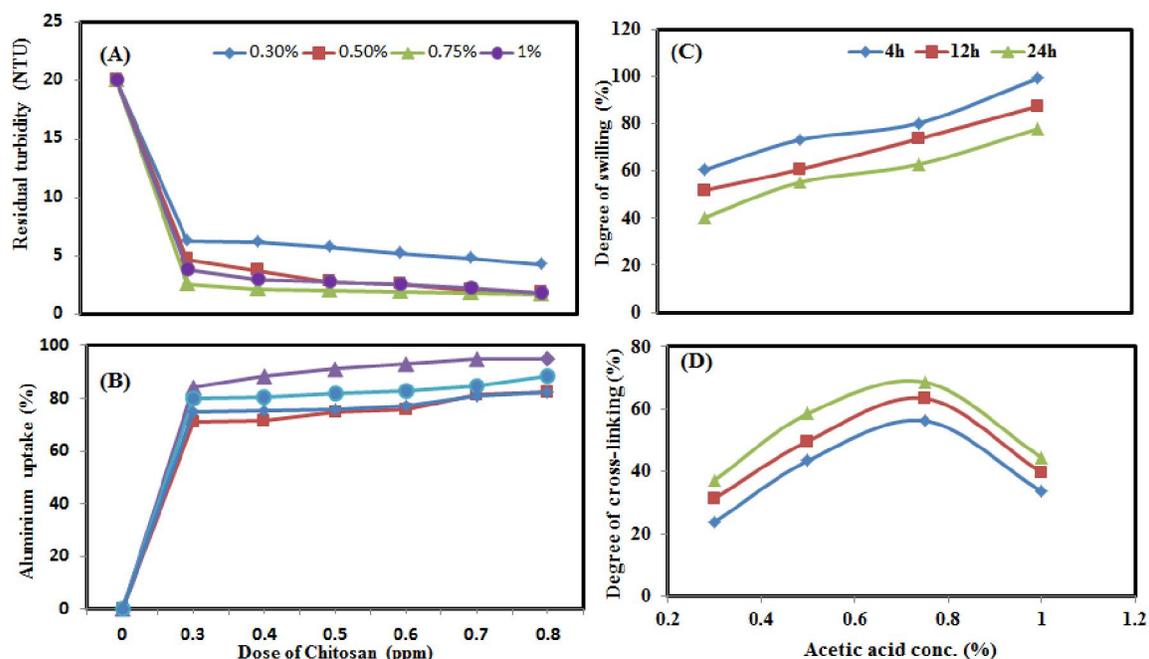
hydroxide form thus the adsorption capacity is decreased [Ngah *et al.*, 2002 & Sun and Wang, 2006 & Pivarčiová, *et al.*, 2014]. Table 4 shows effect of Acetic acid conc. (0.3 - 1%) on the rate of cross-linking of chitosan glutaraldehyde beads for maximum aluminium and residual turbidity removal (NTU), From table, it is shows that; as concentration of acetic acid solution(AC) increases, residual turbidity and aluminium removal of treated water decreases. This is due to at high acetic acid concentration more than 0.75%, the medium become more acidic. This leads to protonation of amine groups, so the charges density and cross-linking density of CLCG beads decreases. Hence, repulsion occur between protons (H^+) of amine groups in surface of CLCG beads and positive charges of aluminium ions [Shu, *et al.*, 2001, 2002 & Mi, *et al.*, 1999], therefore residual turbidity and aluminium removal decreases. Atacetic acid conc. 0.75%, the medium become less acidic. This leads to decrease protonation of amino groups in chitosan surface. So, no repulsion occurs between protons (H^+) of amine groups in surface of CLCG beads and positive charges of aluminium ions. Therefore, the active sites increases and pores of surface also increase. So, removal of residual turbidity and aluminium ions increases [K.I. Draget, *et al.*, 2002], as shown in Fig. (3 A and B). At low concentration of acetic acid (AC), less than 0.75%, the medium become very low acidic. This leadsto decreases dissolution of chitosan, so the charges density, cross-linking density and swilling rate of CLCG beads decreases as shown in Fig. 3 (C and D). Hence, surface area of CLCG beads decreases, therefore, the active sites decreases, pores of surface also decreases. So, removal of residual turbidity and aluminium decreases as shown in Fig. (3 A and B). Hence, the quality of treated water decreases [Mi, *et al.*, 1997]. So, the optimum acetic acid concentration for maximum residual turbidity and aluminium removal at acetic acid concentration 0.75%.

3.2.4. Effect of cross-linking time

Figure 5, shows the variation in both residual turbidity and aluminium uptake as a function of cross-linking time. From figure 5, it indicates that increase time of cross-linking of chitosan glutaraldehyde leads to increases removal of both residual turbidity and aluminum ions from sludge water. This is due to increase time of cross-linking leads to increase degree of cross-linking and charge density (lone pair of electrons). Therefore, active sites of amino groups in surface of chitosan beads increases and accessibility of pollutants are available [Chiou and Li, 2003 & Renault, *et al.*, 2009]. So the residual turbidity and aluminium ions removal increases.

Table (3): Effect of acetic acid concentrations on rate of cross-linking of chitosan glutaraldehyde beads for maximum residual turbidity and aluminium removal

Acetic acid conc. (%)	Dose of chitosan (ppm)	Residual turbidity (NTU)	Residual alum (ppm)	Observation
0.3%	0.3	6.3	0.350	scum layer
	0.4	5.6	0.343	scum layer
	0.5	4.8	0.302	scum layer
	0.6	3.8	0.292	scum layer
	0.7	3.4	0.223	scum layer
	0.8	3.2	0.210	scum layer
0.5%	0.3	4.65	0.190	No scum layer
	0.4	3.76	0.140	No scum layer
	0.5	2.75	0.107	No scum layer
	0.6	2.63	0.084	No scum layer
	0.7	2.0	0.061	No scum layer
	0.8	1.85	0.058	No scum layer
0.75%	0.3	5.81	0.241	No scum layer
	0.4	4.53	0.235	No scum layer
	0.5	3.17	0.215	No scum layer
	0.6	2.53	0.207	No scum layer
	0.7	2.10	0.185	No scum layer
	0.8	2.03	0.136	No scum layer
1 %	0.3	6.48	0.303	No scum layer
	0.4	5.37	0.296	No scum layer
	0.5	3.86	0.288	No scum layer
	0.6	2.79	0.275	No scum layer
	0.7	2.22	0.227	No scum layer
	0.8	2.30	0.213	No scum layer

**Fig.4:** Effect of acetic acid concentration on uptake (ppm) c) Degree of swelling (%)

a) Residual turbidity removal (NTU) b) Aluminium uptake (ppm) d) Degree of cross-linking (%)

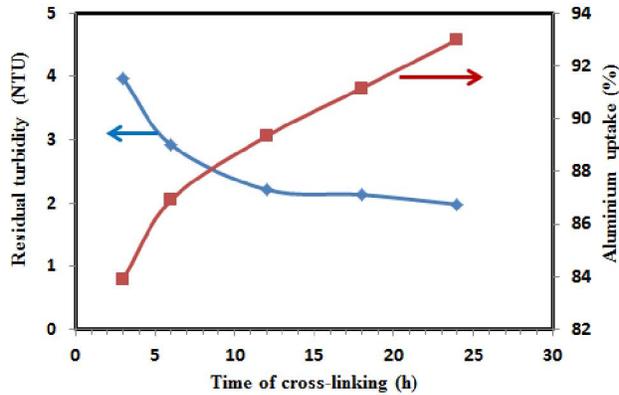


Fig. 5: Effect time of cross-linking on Residual turbidity removal (NTU) and Aluminium uptake (ppm)

3.3. Application of chitosan cross linked glutaraldehyde in aluminium ion and turbidity

removal in groundwater and treatment stations for drinking

From the aforementioned studies of the performance of synthetic chitosan cross-linked glutaraldehyde beads was used to study its efficiency in the environmental treatment of aluminum and turbidity in natural water in discharge of 10th Ramadan treatment station and groundwater samples surrounded the treatment station, Figure (6). Where the 15 -20% feed water discharged as sludge water producing depends on the efficiency of the plant and the physicochemical characteristic of the row water. Meanwhile this area beside the treatment is polluted by high aluminum concentration and high turbidity due to seepage water to the aquifer, table (4). It is clear that the synthesized chitosan cross linked shows high efficiency up to 100% in removal of Al³⁺ and turbidity. So the obtained results after treatment are low the permissible detection limits for drinking water, the results were obtained after 24hr.

Table (4): Al and turbidity removal of polluted water samples in discharge of 10th Ramadan treatment station and surrounded groundwater samples.

Sample location	Al ³⁺ before	Al ³⁺ after	Efficiency %	Turbidity before	Turbidity after	Efficiency %
10 th Ramadan treatment station						
Treatment Station	0.4199	0.0209	95	18	2.6	85.1
Store of station	0.258	0.0077	97	13	1.001	92.3
Groundwater samples						
1	0.0721	<0.005	99	1.9	0.017	99.1
2	0.098	<0.005	99	2.1	0.047	98.7
3	0.248	0.0034	98.6	3.3	0.059	98.2
4	0.261	0.0047	98.2	4.5	0.117	97.4

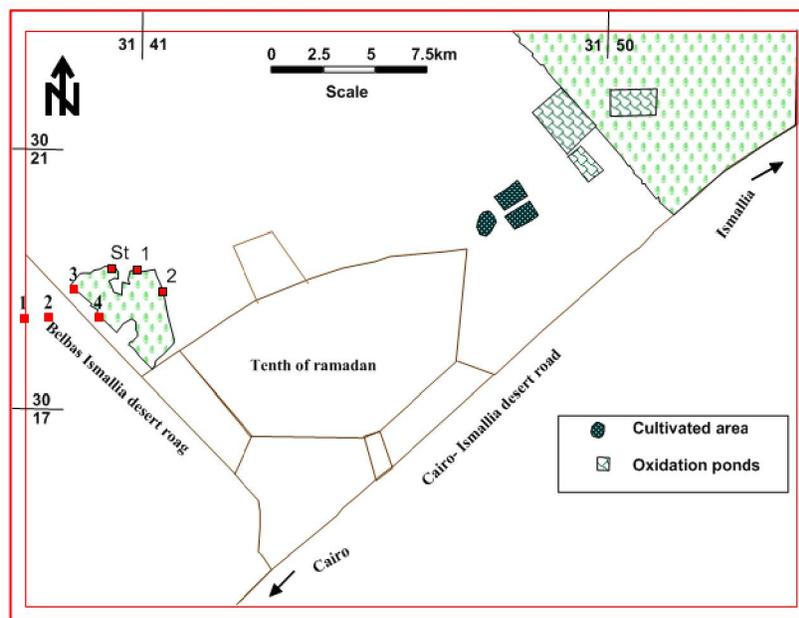


Fig. 6 location map of samples collected from the study area

Conclusions:

Chitosan is a biopolymer, biodegradable, biocompatible, non-toxic and abundant in nature. Our study presents an investigation on the application of this biopolymer in treatment of sludge water by coagulation flocculation process. The sludge water in water treatment plants contains high residual turbidity (10-18 NTU) and aluminum ions (>1.2 ppm). In this study, we use chitosan glutaraldehyde as flocculant agent to remove all water suspended, aluminum ions, and micro-organisms. The performance of this process was evaluated by measuring the supernatant residual turbidity and residual alum at different conditions of chitosan concentrations (1-4%), glutaraldehyde concentrations (25-50%), and acetic acid concentrations (0.3- 1%). The obtained results, indicates that chitosan can reduce >85% of initial turbidity and > 95% of initial residual alum in sludge water. The best conditions for maximum residual turbidity and aluminum removal and less than permissible limits occurs at dose 0.8 ppm of chitosan concentration 2%, glutaraldehyde concentration 50%, and acetic acid concentration 0.75%.

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