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CHITOSAN APPLICATION FOR TREATMENT OF BENI- AMRANE'S WATER DAM

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Abstract: Chitosan is a biopolymer, biodegradable, non-toxic and widely abundant in nature. Our study presents an investigation on the application of this biopolymer in treatment of Beni- Amrane dam water by coagulation flocculation process. In this study, the raw water from Beni-Amrane dam characterized by high turbidity was treated using chitosan as primary flocculant and as coagulant aid with aluminum sulfate (alum). The performance of this process was evaluated by measuring the supernatant residual turbidity for various values of chitosan concentrations. The obtained results are in favor of chitosan. With low concentrations, chitosane used alone is able to reducing 85% of initial turbidity. In the case of using chitosane in combination with alum, highest turbidity removal (97 %) was carried out with 0. 15 mg/l of chitosan and 20 mg/l after 45 minutes of settling time. At this value, a very low residual aluminum (0, 02 mg/l) was registered. The organic carbon contribution on the turbidity coagulation flocculation performance is negligible because chitosan is used in small doses. Hence, chitosan could be used as natural coagulant aid for drinking water treatment with lowest risks of organic release. These properties, combined with its non-toxicity, make the chitosan as the best substitute to conventional synthetic polyelectrolytes used so far.

Keywords: chitosan, coagulation flocculation, dam water treatment

1. Introduction

Coagulation and flocculation is the important unit process in drinking water treatment. This process aims to produce water biologically and chemically safe for human consumption. Treated water should be aesthetically pleasing in terms of odor, appearance and taste. Coagulation allows by the injection and the scattering of chemical (coagulants) during relatively intense mixing to destabilize naturally occurring particles and macromolecules and/or to precipitate additional particles [1]. Flocculation permits, by the addition of synthetic or natural polymers in slant of slow mixture, to promote the aggregation and bind together the micro-flocs of destabilized particles into larger flocs that can be removed subsequently by sedimentation and/or filtration. However, the use of these chemicals, particularly aluminum, may have several environmental consequences: (a) human health implications such as Alzheimer and other disease with carcinogenic properties [2]; (b) production of big volumes of sludges [3]. Use of synthetic organic polymer coagulants such as polyacrylamides and polyamines are also problematic since they may be toxic under certain circumstances [4].

Recently, the use of environmentally friendly coagulants widened. They can be proposed as an important alternative for waters treatment. Natural organic polymers named biopolymers are naturally produced or extracted from animal, plants tissues or microorganisms. These biopolymers are no toxic for human health and are

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biodegradable. Their use as coagulants is advantageous because they are efficient in low dosage and therefore reduce sludge volume. Their impact on pH and alkalinity is insignificant [3].

Chitin and chitosan are two natural biopolymers. They have interesting properties as part of a strategy for water treatment and environmental protection. Chitin: a Poly (N-acétyl-D-glucosamin) is the second most abundant polymer in nature after cellulose. It is present in the exoskeleton of crustaceans in the marine arthropods, in some seaweed and yeasts [5]. Chitosan is a continuum of different copolymers of N-acetyl-D-glucosamine and glucosamine units. It differs from chitin by amine groups -NH2. In acidic medium, chitosan has more than one reactive center, through its functions and amino alcohol. Due to its biodegradability, no toxicity, its polyelectrolytic nature and its tendency to flocculation, chitosan is able to overcome the nuisances of traditional coagulants. According to its excellent properties, chitosan is recommended as suitable flocculants in many applications such as: solids suspensions from various food processing wastes [6], Silt River [7], latex particles [8], microorganisms [9], and the treatment of dyes in effluents [10]. Several studies [7], [11], [12], [13], [14], [15]…]have treated the effect of chitosan on the removal turbidity of turbid waters, but few ones who study the effectiveness of chitosan as a coagulant for drinking water treatment.

This research focuses on the study of chitosan efficiency as a biomaterial for drinking water treatment by coagulation flocculation process. For this propose, coagulation flocculation sedimentation tests were conducted in the laboratory using a conventional Jar Test. Water samples are collected from Boudouaou station of water treatment at about 30 km east of Algiers, the capital of Algeria. The performance of the coagulation flocculation was assessed by measuring the supernatant residual turbidity of the aqueous solution for various parameters, namely, chitosane and alum doses.

2. Materials and methods

Before 1987, the drinking water of greater Algiers was provided by the Mazafran, Baraki, and Hamiz well fields. The amount of groundwater could no longer meet requirements. To address the shortage of drinking water in the region of Algiers, a new supply system was put into service from 1987 and was the mobilization of surface waters of Isser River. The treatment plant is located 8 km from the dam Keddara, between Boudouaou city and Ouled Moussa. It occupies an area of 17 hectares. It is part of the production system Keddara-Isser, treating water from Beni-Amrane, Keddara and Hamiz dams, and feeds an estimated population of 4 000000 inhabitants. Its processing capacity is 540.000 m^3 and storage capacity of 100.000 m^3.

In table 1, we present the properties relevant the characterising samples of Beni-Amrane raw water collected from the Boudouaou treatment plant. Samples were analyzed with minimal delay just after collection. No pretreatment was performed on any collected water samples, except for pH adjustment.

Table 1. The water quality collected from Boudouaou drinking water treatment plant

Paramètre	***Eau de Beni-Amrane***
Température (°C)	15 - 16
pH	7.90 – 8.5
Turbidité(NTU)	25 - 50
UV_{254nm}	0.080 – 0.141
Alcalinité (mg/l)	
Dureté totale (mg/l)	160 - 163
Dureté calcique (mg/l)	75 - 76
Dureté magnésique (mg/l)	85 - 87
Demande en chlore (mg/l)	2 – 2.5

Chitosan, purchased from Sigma ® C3646, was used in this study. It comes from a chitin shell crab and was characterized by a deacetylation degree (DD) of 85%. 100 mg of chitosan were dissolved in 1 ml of acetic acid (85% w/w) under agitation after hydrated overnight in 99 ml of demineralised water. The final polymer solution was maintained at pH 4. All agents used in the experiment were of laboratory grad

Performance of chitosan used alone and as coagulation aids with aluminum sulfate was evaluated through jar tests. Conventional Jar Test (Brand: Janke and Hunkeler) used in this study have 5 agitators with variable speed, and five trains equipped for every one with 1litre beaker.

As soon as, the flocculant was added to beakers, the solution was strongly mixed at 200 rpm for 3 minutes. This step is followed by a slow mixing (40 rpm) for 20 minutes. Thereafter, the solution was settled for 45 minutes to assess analytically the coagulation flocculation effectiveness; the supernatant of solution was removed from the top by siphoning. Turbidity was analyzed using a HACH Model 2100P. Turbidity is expressed in terms of the standard nephelometry method. UV_{254} absorption was determined in 3 replicates at a wavelength of 254 nm using a quartz cell and Shimadzu spectrophotometer model 2100. The pH of the solution was adjusted by the addition of solutions of HCl or NaOH at 0.1 N.

Coagulation flocculation tests concern first: the use of chitosan as natural primary coagulant added alone in an amount effective to form a floc in the drinking water, second: the use of chitosan as coagulant aid with aluminum sulfate. The main factors that have the purpose of this study are dosage of coagulant, pH, alkalinity, residual aluminium in treated water and the like.

3. Experimental results and discussion

Chitosan solubility is a very difficult parameter to control [17] that is why; it is one such important parameter which must be taken in account to study the chitosan efficiency. Chitosan is hydrophilic copolymer; it can dissolve in dilute organic or inorganic acid solutions.

In this study, acetic acid (AcOH), a common solvent, was chosen for this bioflocculant. After dissolution, the obtained solution was very clear; chitosan was completely soluble. The acid medium is used to solubilise and favors the ionization of amine groups in C_2 of D-glucosamine residues [16] - [17]. Their pKa is about 6.3 [17]. At pH below 4, chitosan acquired a high charge density [12]. Note that chitosan solubilization depends on the deacetylation degree. It is estimated that 87% of deacetylation allows a complete dissolution [18].

The main purpose of coagulation using chitosan in drinking water treatment from Beni-Amrane raw water is to recover turbidity. The efficiency of turbidity removal is an important parameter to check the efficiency of coagulation. First, Jar test ware conducted to study the chitosan performance used alone on turbidity removal of raw water of Beni-Amrane dam. Chitosan were added with dosage of 0.1, 0.2, and 0.3…. until 10 mg/l, respectively.

Under the condition without controlling solution pH (7.8), the residual turbidities after jar-mixing/settling with various dosages of chitosan expressed as mg per liter of raw water were shows in Figure (2). It says that the residual turbidity reduced as the coagulation dosage increased. After the residual turbidity down to the lowest point, the increasing of chitosan dosage resulted an apparent increasing of residual turbidity. Indeed, in this, it is shown that the percentage removal of turbidity from raw water of Beni-Amrane dam was enhanced by increasing the chitosan concentration up to 0.15mg/l. Further increase in chitosan concentration reduced turbidity. The optimum concentration of chitosan for coagulation of Beni-Amrane raw water with initial turbidity (25-55 NTU) was found at 0.15mg/l for 87% of turbidity removal. It's clear that effective coagulation was achieved with much lower doses of chitosan than would be required for complete charge neutralization of particles, and this process was guided by the combined effects of electrostatic patch and bridging mechanisms. This coagulation process was fast; turbidity removal was achieved within 30 min at natural pH.

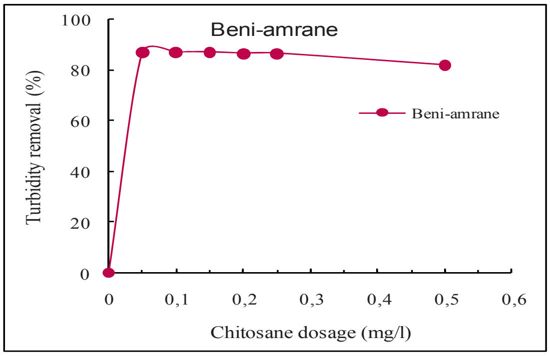

Fig. 1. Effects of chitosan addition on removal percentage of turbidity (%) at pH 7.8

This indicated that the coagulation mechanism of removing turbidity by chitosan can be explained as both the polymer bridging and the charge neutralization. When the chitosan dosage exceeded the saturation of polymer bridging or charge neutralization, the surplus chitosan has a tendency to destroy the polymer bridging between particles or to reverse the particle charge and to restabilize them, thereby exhibiting an increase in the residual turbidity.

At the second phase, the raw water of Beni-Amrane was treated by aluminum sulfate alone as primary coagulant for turbidity removal. We have chosen 45 minutes of time for settlement to evaluate alum performance. Figure 2 shows the results concerning alum dose effect (ranged from 10 to 60mg/l) on the evolution residual turbidity. It can be seen that the amount of alum increases with turbidity decrease. The better turbidity removal (2.10 NTU) occurs when the dose of alum solution reaches 40mg/l. above this dosage, the suspensions showed a tendency to re-stabilize. For this optimal dose a 0.5 mg/l of residual aluminum has been registered.

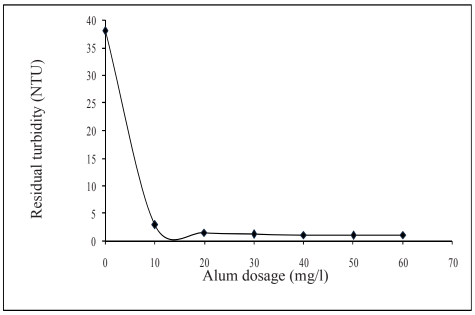

Fig. 2. Effect of various Aluminum sulfate dosages on turbidity removal from Beni-Amrane raw water (NTU) at actual pH (7, 8) and 30 minutes of settling time

Experiments of coagulation-flocculation were conducted again to test the chitosan used as aid coagulant with alum. It was tested in a concentration range from 0.05 to 0.3 mg/l. Alum sulfate (40 mg/l) was used as coagulant for this experiment. Optimal dose was determined on the basis of both turbidity removal and UV absorbance at 254 nm abatements.

In terms of these parameters, figure (3), (4) illustrate the characteristics giving the turbidity and UV absorbance at 254 nm variation as a function of the chitosan dose. It shows that the residual turbidity reduced as the chitosan dosage increased. After the optimum point corresponding to the lowest value of the residual turbidity, it’s perceived a slight increase in turbidity values with additional doses of chitosan.

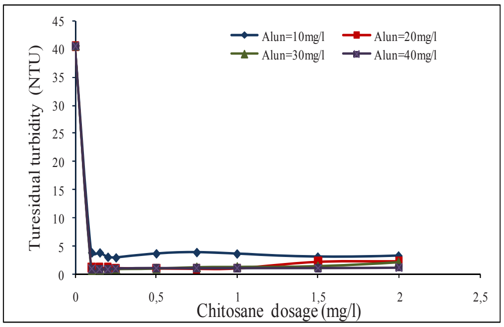

Fig. 3. Effect of various amounts of Aluminium sulfate and chitosan on turbidity removal from Beni-Amrane raw water

The use of chitosan in combination with Alum sulfate leads to an increase in the flocculation efficiency (97% after 45 minutes of settling) and to the formation of a denser flocs at lower chitosan concentration. The major turbidity decrease occurred in experiments carried out with 0.15 mg/l of chitosan.

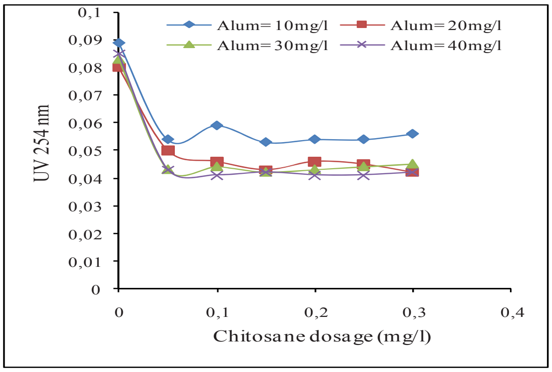

Fig. 4. UV_{254} variation alum and chitosane dosage for Beni-Amrane raw water coagulation

At the same value, UV absorbance at 254 nm decrease reaching the lowest value of the absorbance which is 0.04 nm equivalent to 51.76% of turbidity reduction for optimal dosages. It is noted also, that beyond the optimal point, the values of residual turbidity increases; this means that suspension tends to re-stabilizing. For this value, analysis of supernatant residual aluminum has been completed the. Results are represented in figure (5). A value of 0.2mg/l of Al3+ is noted. This results concord with that found by Bina and al. [19]. They have reported that the use of chitosan as aid coagulant in coagulation flocculation process decreases the residual Al3+ in treated water.

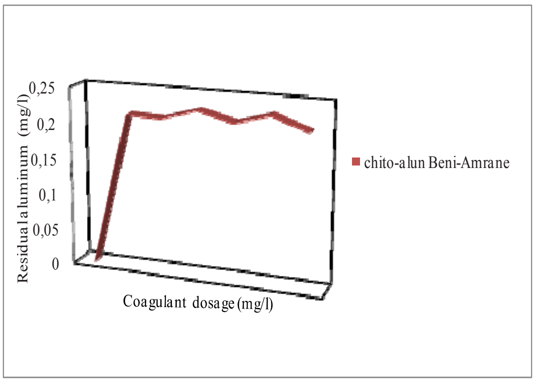

Fig. 5. Residual aluminum variation detected of Beni-Amrane raw water treatment

No change in pH was observed. According to the flocculation and sedimentation processes, we have observed the formation of flocs after the addition of the chitosan. They are bigger than those obtained with the chitosan used as primary coagulant. They were of rounded shapes, glued one to the other, forming in the middle of the backer a big ball. They settled well in less than 10 minutes. The final solution became very clear and very limpid. These results are in agreement with those found by Guibal [20]. Indeed, according to Roussy and al. [14], the ionic sulfate compounds have a significant effect on the chitosan's sorption. Although, it is reported that chitosan has a higher molecular weight in the presence of sulfates [20]. Van Duin and Hermans [21] justified there hypothesis by the fact that chitosan formed the large aggregates and could precipitate in the presence of sulfate. They also reported that taking into account the low dosage of chitosan in these experiments (less than 1 mg/l), the amount of introduced organic carbon remained was low enough (less than 0.8 mg/l) to make its contribution negligible for the coagulation flocculation performance. Thus, chitosan could be used as natural aid coagulant for drinking water treatment with the lowest risks of organic release.

4. Conclusion

Experiments were conducted to determine the chitosan ability as natural flocculant for drinking water treatment of raw water. Through these experiments, it was found that chitosan as primary has reduced considerably (87%) turbidity from Beni-Amrane raw water. the chitosan has more effectiveness (turbidity removal 97 %) in removing turbidity when it used as aid coagulant with aluminium sulphate as main coagulant. The chitosan efficiency was highly dependent on initial turbidity and on chitosan dosage. The organic carbon contribution on the coagulation flocculation performance is negligible because chitosan is used in small doses. Hence, chitosan could be used as natural aid coagulant for drinking water treatment with the lowest risks of organic release.

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