Evaluation of Chitin as Natural Coagulant in Water Treatment

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Abstract: The use of synthetic coagulants is not regarded as suitable due to health and economic considerations. The present study was aimed to investigate the effects of alum as coagulant in conjunction with chitin as coagulant aid on the removal of turbidity, hardness and *Escherichia coli* from water. A conventional jar test apparatus was employed for the tests. The experiment was conducted at three different pH conditions of 6, 7 and 8. The dosages chosen were 0.5, 1, 1.5 and 2mg/l. The results showed that turbidity decrease provided also a primary *Escherichia coli* reduction. Hardness removal efficiency was observed to be 93% at pH 7 with 1mg/l concentration by alum whereas chitin was stable at all the pH ranges showing highest removal at 1 and 1.5mg/l with pH 7. At low concentration chitin showed marginally better performance on hardness. In conclusion, using natural coagulants results in considerable savings in chemicals and sludge handling cost may be achieved.

Keywords: Alum, Chitin, Coagulation & Turbidity.

1.   Introduction

The biosphere is increasingly exposed to pollution threats in spite of the global efforts to protect it. Anthropogenic activities are the significant and the dominant sources of these threats. The growing human needs and ceaseless drive to satisfy them have led to the production of varying forms of harmful wastes that ultimately rest in our aqua systems. The implication is that much of the water cannot be used without a form of treatment. This situation brings to the fore the needed impetus to focus on the challenges inherent in hydro management, especially in developing countries where discharge of effluents is common (1).

Access to safe drinking water is important as a health and development issue at a national, regional and local level. In some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, since the reductions in adverse health effects and health care costs outweigh the costs of undertaking the interventions (2).

About one billion people do not have healthy drinking water. More than six million people (about two million children) die because of diarrhea which is caused by polluted water. Developing countries pay a high cost to import chemicals including poly-aluminium chloride and alum (3, 4). This is the reason why these countries need low-cost methods requiring low maintenance and skill. Nowadays, poly-aluminium Chloride is widely used in water treatment plants all over the world. Poly-aluminium chloride and alum add impurities such as epichlodine are carcinogenic (5, 6). Aluminum is regarded as an important poisoning factor in dialysis encephalopathy. Aluminum is one of the factors which might contribute to Alzheimer disease (7, 8). Alum reaction with water alkalinity reduces water pH and its efficiency in cold water (9, 10). However, some synthetic organic polymers such as acrylamide have neurotoxicity and strong carcinogenic effect (5, 7). Natural macromolecular coagulants are promising and have attracted the attention of many researchers because of their abundant source, low price, multi-purposeness and biodegradation (9, 11 and 12). Okra, rice and Chitin are natural compounds which have been used for turbidity removal (13-15).

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2. Methodology

2.1 Water Samples and coagulants

Stage – 1: Initially two synthetic water samples with turbidity of 70 and 100 NTU were prepared and tested for the efficiency of the coagulants to remove their turbidity.

Stage – 2: In the next stage the same concentrations of the coagulants were tested on the surface water samples collected from a reservoir.

All the experiments were carried out at three different pH conditions – 6, 7 and 8.

2.2 Equipment

The equipment used for jar test experiments was a Cintex flocculator jar test apparatus with 4 beakers of 1.0l capacity each (Fig. 1). Each beaker was filled with 500ml of test water with identical turbidity. Different volumes of coagulant reagent were added to 4 beakers. Mixing of the coagulant with water was provided by flash mixing during approximately 3 minutes with propellers set at 120 rpm followed by slow mixing at 40 rpm during approximately 17 minutes. Then the propellers were stopped and the content of the jars left to settle for approximately 30 minutes. After sedimentation, samples were taken for water quality determination. For each coagulant and turbidity level, three identical jar tests were performed in order to obtain statistically reliable results.

Fig. 1. Jar Test Apparatus used in the experiment.

2.3 Measurements and Analytical methods

Turbidity, suspended solids, temperature, pH, EC (electrical conductivity), total dissolved solids (TDS) and bacteria were the water quality parameters measured. Turbidity was measured using a nephelometric turbidimeter. In order to, increase reliability of measurements, water turbidity readings was tripled and that of settled water, doubled and the average values used as reference values. The temperature was measured with a standard mercury thermometer (accuracy of ± 1°C) held for 1 minute in the water, and the observed values rounded to the nearest integer. pH and EC were measured using

handheld digital meters and TDS was measured by gravimetric analysis, suspended solids were also determined using standard procedures described in the APHA Standard Methods (2005).

3. Results and Discussion

In the initial stage of the experiment, the two coagulants alum and chitin were tested against synthetic turbid samples with 70 and 100 NTU.

The effectiveness of alum, commonly used as a coagulant, is severely affected by low or high pH. In optimum conditions, the white flocs were large and rigid and settled well in less than 10 min. This finding is in agreement with other studies at optimum pH (16, 17). The optimum pH was between 7-7.5 and was similar to the obtained results by Divakaran (18). At high turbidity, a significant improvement in residual water turbidity was observed. The supernatant was clear after about 20 min. settling. Flocs were larger and settling time was lower. The results showed that above optimum dosage, the suspensions showed a tendency to re-stabilize according to Fig. 2a, b the optimum dosage of alum is 1mg/l for both the turbid samples and the optimum pH is observed to be 7.
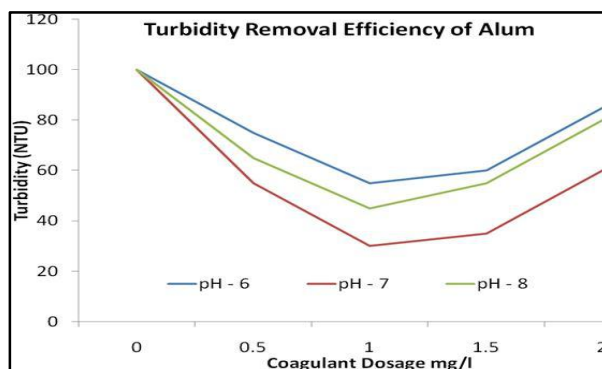

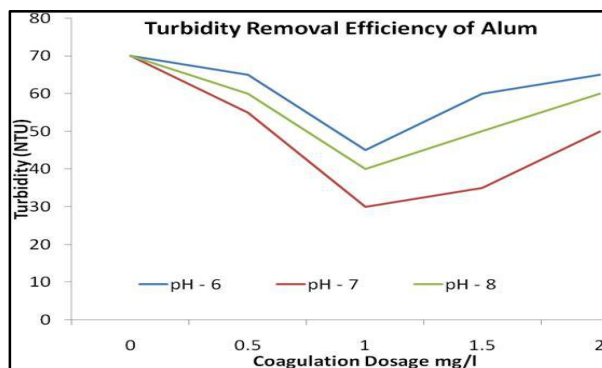**Fig. 2a. Turbidity removal efficiency of alum with initial turbidity 70 NTU.**

Fig. 2b. Turbidity removal efficiency of alum with initial turbidity 100 NTU.

According to Fig. 3a, b the optimum dosage of chitin is 1.5mg/l for 100 NTU solution and not much

difference was observed between pH 7 and 8 both the turbid samples and the optimum pH is observed to be 7 for both 70 and 100 NTU samples.
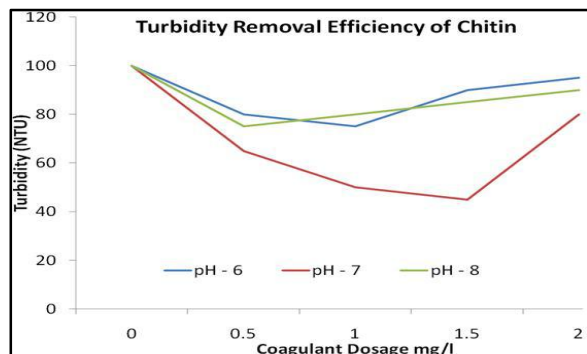

Fig. 3a. Turbidity removal efficiency of chitin with initial turbidity 100 NTU.
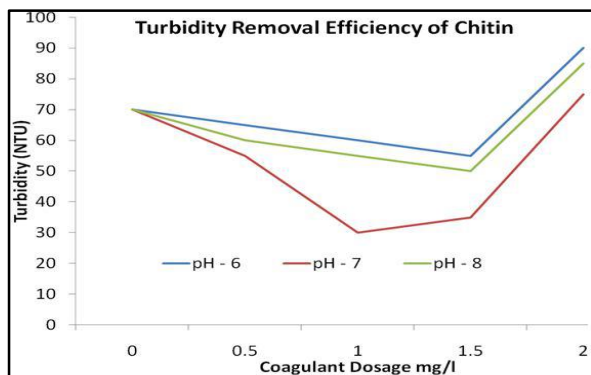

Fig. 3b. Turbidity removal efficiency of chitin with initial turbidity 70 NTU.

In the second stage of the experiment, the two coagulants alum and chitin were tested for their efficiency on raw surface water samples, whose physicochemical parameters are presented in the Table – 1.

Table 1. Physicochemical parameters of the raw surface water.

S.No.	Parameter	Value
1	Turbidity (NTU)	4.1
2	pH	6-8
3	Total Hardness	2150
4	*E.coli*	positive

From Fig. 4 a,b it is observed that the turbidity removal of alum at pH 8 was greater with a dose of 0.5mg/l, even though it has not shown any notable reduction for 1 and 1.5mg/l dosages and there was change of note again at dose 2mg/l. The pH 7 was observed to be more or less even at all the doses. pH 6 was the least efficient among all. WHO recommends that if turbidity is more than 5 NTU, some treatment is necessary to remove the turbidity before the water can be effectively disinfected with chlorine (19). The use of

alum as a coagulant for water treatment often leads to higher concentrations of aluminum in the treated water than in the raw water itself. There is now abundant evidence that aluminum may cause adverse effects on the nervous system (20). In the USEPA survey of 186 water utilities, it was found that after coagulation with Al^{+3} salts, the Al^{+3} concentration in the treated water varied from 0.01 to 2.37mg/L (21). The USEPA promulgated a secondary maximum contaminant level range of 0.05 to 0.2mg/L for residual Al^{+3} (22). Our results correlate with the studies conducted by Yarahmadi *et al*., 2009 (23).
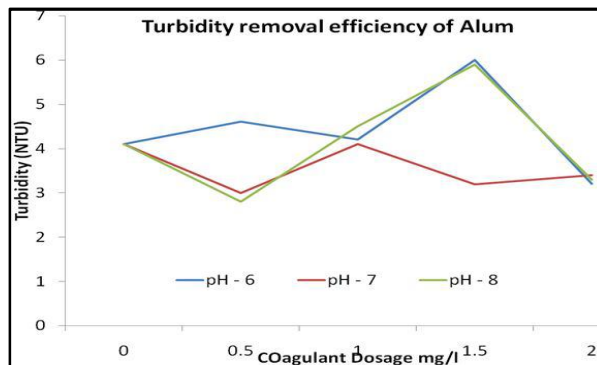

Fig. 4a. Turbidity removal efficiency of alum in raw surface water.
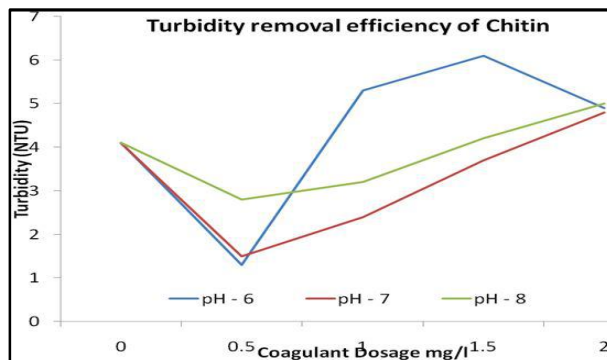

Fig. 4b. Turbidity removal efficiency of chitin in raw surface water.

From the results of chitin, it is understood that it is very effective at lower doses at all the pH ranges while a higher input of coagulant has reduced its efficiency towards reduction in turbidity. This property of chitin tolerance to various pH ranges offers a good alternative to the chemical coagulants. In order to decrease the residual Al^{+3} concentration in treated water and possible adverse effects of aluminum in drinking water on human health, Chitin as coagulant may be used.

The use of chitin as a coagulant flocculation process with less dose is effective in reducing turbidity without filtration, irrespective of initial turbidity. An improvement in the floc size when chitin was used as a coagulant aid in conjunction with alum as compared to either Chitin or alum alone was observed by Bina *et al*., 2009 (24). They have also observed that chitin

significantly reduced the required dosage of alum between 50 to 87.5%, thereby reducing costs of treatment.

In the present study, it was found that Chitin did not affect the alkalinity. The high content of amine groups in chitin provides cationic charge at acidic pH and can destabilize colloidal suspension to promote the growth of large, rapid-settling floc that can then flocculate (25). Because it is a long chain polymer with positive charges at natural water pH, it can effectively coagulate natural particulate and colloidal materials, which are negatively charged, through adsorption, charge neutralization, interparticle bridging as well as hydrophobic flocculation (26).
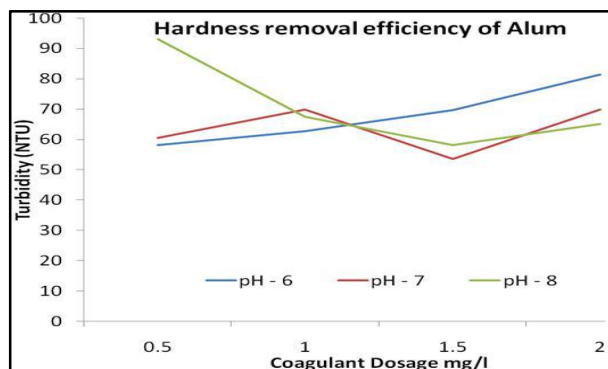

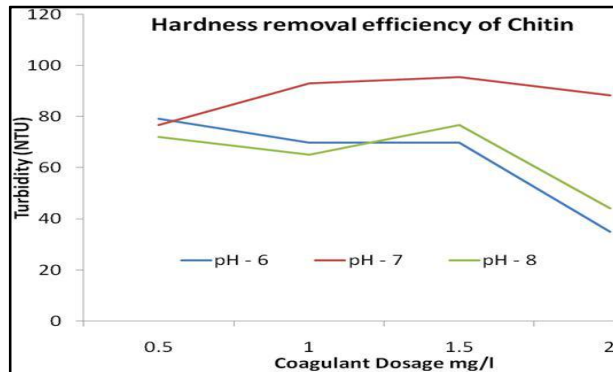**Fig. 5a.** Hardness removal efficiency of alum in raw surface water.

Fig. 5b. Hardness removal efficiency of chitin in raw surface water.

The effect of chitin aided coagulation on hardness is presented in Fig. 5a, b. It is observed that at varying pH ranges both the coagulants were effective at lower dosages, i.e., 0.5mg/l. A noteworthy property of chitin that was identified in the process is that it is stable along the varied pH. The maximum of hardness removal was obtained as 93.03% by alum at pH 8. Whereas chitin has resulted in an average reduction of hardness of about 76% in all the pH conditions at the lowest dosage of 0.5mg/l. Chitin was very effective at pH 7 with dosages of 1 and 1.5mg/l resulting in 93 and 95% removals of hardness.

E. coli is the best coliform indicator of fecal contamination from human and animal wastes. *E. coli*

presence is more representative of fecal pollution because it is present in higher numbers in fecal material and generally not elsewhere in the environment (27). The presence and absence of *E. coli* was tested with the help of the H_2S strip test. The water treated with chitin showed a negative result when compared to the raw sample (Fig. 6).

Fig. 6. *E. coli* removal efficiency of chitin in raw surface water before (left) and after (right) treatment.

Chitin as a natural coagulant aid showed antibacterial effect. Antimicrobial effects of water-insoluble Chitin were attributed to both its flocculation and bactericidal activities. A bridging mechanism has been reported for bacterial coagulation by Chitin (Roussy, 2005).

Chitin molecules can stack on the microbial cell surface, thereby forming an impervious layer around the cell that blocks the channels, which are crucial for living cells (28). It was found that when the samples were stored during 24 hours; regrowth of *E. coli* was not observed in all the samples. It should be noted that the test water contained no nutrient to support regrowth of *E. coli* and Chitin is not a nutrient source for it. Such findings have been previously reported by Bina (29).

4. Conclusion

The most significant property of chitin to withstand the variation in pH proves to be promising for its use as a coagulant. Conversely, it is also important to test its efficiency further in the form of blended and also need to track down the characteristics of the floc formed along with the in-depth analysis of chitin treated water samples for its traces and interactions with other parameters. Chitin shows good coagulating properties, and has many advantages compared to aluminum sulphate; it does not affect the pH, alkalinity or conductivity of the water. Chitin coagulation is a method that can be considered as a good, sustainable and cheap solution for smaller waterworks if the supply of chitin can be guaranteed. Complementary tests

should, however, be carried out in order to determine the impact of other parameters in raw water on treatment efficiency.

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