Research Paper Environment

Process Investigation and Optimization of Coagulation and Flocculation

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ABSTRACT

Natural coagulants have been the focal research by many investigators through the last decade owing to the problems caused by the chemical coagulants. Optimization of process parameters is vital for the effectiveness of coagulation process. In the present study optimization of parameters like pH, dose of coagulant and mixing speed were studied using natural coagulant chitin. Jar test apparatus was used to perform the coagulation. The results showed that the removal of turbidity was up to 99% by both alum and chitin at lower doses of coagulant i.e 0.1 – 0.3g/L. The optimum conditions observed for alum and chitin were pH – 7, all pH ranges, coagulant dose – 0.1 – 0.4g/ L, 0.1 – 0.3g/L and mixing speed – rapid mixing at 100rpm for 10min and slow mixing 20rpm for 20 minutes. Hence it can be concluded that chitin can be used for treating water even with large seasonal variation in turbidity.

KEYWORDS

Introduction

Water is essential for human life, development and environment, but it is a finite and vulnerable resource which has quantitative limitations and qualitative vulnerability (Lalzad, 2007). Safe drinking water is essential to the health and welfare of a community, and water from all sources must have some form of purification before consumption. Various methods are used to make water safe and attractive to the consumer. The method employed depends on the character of the raw water. One of the problems with treatment of surface water is the large seasonal variation in turbidity (Mc Connachie et.al. 1999).

All waters, especially surface waters, contain both dissolved and suspended particles. Coagulation and flocculation processes are used to separate the suspended solids portion (turbidity) from the water. Most solids suspended in water possess a negative charge and, since they have the same type of surface charge, repel each other when they come close together. Therefore, they will remain in suspension rather than clump together and settle out of the water.

Naturally occurring coagulants are usually presumed safe for human health while there is a fear by using aluminum salts that may induce Alzheimer's disease (Martyn et.al., 1989). Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants (Ganjidoust et.al 1997; Kawamura 1991; Lee et.al. 1995). Recently, however, there has been a resurgence of interest in natural coagulants for water treatment in developing countries (Ndabigengesere and Narasiah, 1998).

To address these issues, the present work focuses on the understanding and optimisation of various parameters or factors that govern the process of coagulation by natural coagulants, so that environmental specialists can tailor its usage for a myriad of water contaminants. The focal coagulant in this study is a natural coagulant derived from non-plant sources such as chitin (widely produced from exoskeleton of crustaceans) is included in the present study.

Materials and Methods

Optimization of Coagulant Dosage, pH and Mixing Speed

The coagulant dosages for optimization were selected to be 0.1, 0.2, 0.3 and 0.4 g/l. The optimized dosages of coagulants were further examined at various pH conditions in order to test their efficiency and suitability at a wide range of pH i.e 6, 7 and 8. Further the studies were extended with optimizing mixing speed – rapid mixing at 100 mixing speed for 10 min and slow mixing at 30 mixing speed for 20 min; rapid mixing at 80 for 2 min and slow mixing at 20 for 20 min.

Natural Coagulant-Chitin

Chitin is one of the most abundant renewable biopolymer on earth that can be obtained as a cheap renewable biopolymer from marine sources (Feisal and Montarop, 2010). It is biocompatible, biodegradable and bio-absorbable (Muzzarelli, 1977).

Collection of Samples

For the present study the surface water samples were collected from two different sources in and around Visakhapatnam, i.e., Mudasarlova and P.M.Palem. The water samples were subjected to the following parameters both pre and post treatment with the two coagulants: pH, Turbidity, Conductivity, Colour, Hardness, Alkalinity and Chlorides

Result

Turbidity reduction is good at pH 7 at both mixing speed speed (100 for 5 min followed by 30 for 20 min and 80 for 2 min followed by 20 for 20 min) and in pH 8 only at 100 and 30 mixing speed by alum at all four doses but chitin showed a stability in reduction of turbidity in all the pH at both mixing speed at 0.1g/L and 0.2g/L doses which is more than 93% (Fig-1). Conductivity reduction is observed with chitin at pH 7 (both mixing speed) and at pH 8 (mixing speed 100, 30). Colour is reduced upto 90% with alum at pH 7 at both mixing

speed whereas chitin reduced more than 92% at the same pH at both mixing speed at all doses (Fig-2).

Decrease in alkalinity is 80% with alum at only 0.4g/L doses at pH 7 at mixing speed 80 and 20 and at pH 8 with both mixing speed. Chitin has succeeded to decrease alkalinity in both pH 6 and pH 7 in all the doses (Fig-3). Alum and chitin both are good in reduction of chlorides by 48% at pH 6 in both mixing speed at all doses (Fig-4). It is observed that total hardness reduction is good with chitin at pH 6 with both mixing speed and chitin is also good in reduction of calcium hardness at both pH 6 and 7 with both mixing speed at all doses.

Discussion

Optimization of pH

The pH will not only affects the surface charge of coagulants, but also affects the stabilization of the suspension. Besides, the solubility of chitin in aqueous solution is influenced by pH value.

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 20 min. The reduction of turbidity and other parameters were observed to be good at pH 7. The results were in correlation with the studies done by Bina et.al. 2009. This finding is in agreement with other studies at optimum pH (Ebeling et al., 2003). The optimum pH was 7 and was similar to the obtained results by Divakaran (Divakaran and Pillai, 2002). The best performance of alum was observed at pH 7 over the selected range of turbidity but its performance decreased to some extent at pH values of 6 and 8. Coagulation efficiency of alum at pH 6 was almost close to that of at pH 7. The highest turbidity removal was attained at pH 7.

The relationship between the dosage, pH and turbidity reduction shows that the optimum dosage of chitin with respect to reduction in turbidity is smaller in acidic solutions. This phenomenon can be attributed to the increase in number of protonated amine groups on chitin at lower pH. Similar results were obtained when chitin / chitosan is used as a coagulant by Jill et.al, 1999, in their experiments where they stated that the destabilization of particles was enhanced by the increase in charged groups followed by charge neutralization, resulting in a decrease in optimum dosage.

The color removal patterns of both alum and chitin were observed to be good at neutral pH, further more chitin has shown moderate efficiency in removing color at both the acidic and basic pH ranges i.e at pH 6 and also 8.Further, highest removal of COD and color was found to be 68.8 and 47.0 % respectively using MSP. Moreover, highest removal of COD and color was found to be 64.7 and 42.8 % respectively using Chitin / chitosan. This may be as a result of re suspension of solids at this concentration. Furthermore, the high concentrations (>30.0 g L^{-1}) of the coagulant may be confer positive charges on the particle surface (a positive zeta potential), thus re dispersing the particles (Amudaet al., 2006).

It was also found that the reduction of alkalinity by chitin was quite moderate to low at pH 6 and 7 and the alkalinity was observed to be increased at pH 8. 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 (Roussy et al., 2005). 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, inter-particle bridging as well as hydrophobic flocculation (Li and Kegley, 2005).

Based on the results it is found that chitin has not considerable potential to be used in the treatment of hard waters, especially in medium and high turbidities. It can be seen that the removal of hardness decreased with increasing hardness values (Bina et.al, 2009). The presence of bivalent cations such as $Ca^{+2}$and Mg^{+2} increased the ion strength of solution and the destabilization. Chitin-fibers absorb calcium ions very selectively, forming a chelate. The amide groups involvement is very clear, and the hydroxy groups (either the C(6) or the C(2)) has been suggested to participate too. The selectivity seems to be caused by the chelation mechanism (Zikakis, 1984). Hence the optimum pH for alum was found to be 7, whereas chitin was substantially stable at all the given pH ranges.

Optimization of Mixing Time

Mixing period is very crucial for polymeric flocculent on their performance in flocculation. The trends that had been illustrated in Figures – 1, 2, 3 and 4 showed that the lesser agitation time resulted in the poor performance of chitin for binding and bridging (Mohd Ariffin et.al.), the collisions between the flocculants and suspended particles are low and lead to the lower flocculation rate. On the other hand, if the mixing time is too long, the flocculate chains tend to break and limiting the size of the flocs formed. The small size flocs are not dense to settle down in wastewater and thus, indirectly cause the sample to be turbid again.

The other physico-chemical parameters have also shown similar trends with these mixing rates and times. The results were parallel with the studies done by many researchers previously, even for the treatment of wastewaters. The highest removal of COD and color was found to be 75.6 and 52.8% respectively using SSP. Further, highest removal of COD and color was found to be 74.7 and 48.9% respectively using MSP. Moreover, highest removal of COD and color was found to be 69.6 and 42.8% respectively using Chitin / chitosan. Such results of removals with increasing flocculation time were reported earlier (Ebeling et.al. 2003; Omar et.al., 2008; Fu and Yu, 2007).

From this it can be resolved that the optimum mixing time for coagulation with both alum and chitin is rapid mixing at 100 rpm for 10min and slow mixing at 30 rpm for 20 min.

Effect of Coagulant Dose

Essentially, insufficient dosage or overdosing would result in the poor performance in flocculation. Therefore, it is significant to determine the optimum dosage in order to minimize the dosing cost and sludge formation and also to obtain the optimum performance in treatment (Patel and Vashi, 2013).

The optimum alum dosage was lower (0.1g L^{-1}) which was the lowest required dosage obtained the highest turbidity removal. The best performance of alum in removing turbidity from water was obtained at pH 7 following by pH 6. The coagulation efficiency of alum remained almost constant within the dosage range of 0.1 – 0.4g L^{-1} at pH range of 6-8. The results were in agreement with the report by Yukselen and Gregory, 2004. Turbidity removal efficiency was slightly decreased by increasing alum concentration from 40-50 mg L^{-1}, e.g., turbidity removal decreased from 97.1-95.7% at pH 6 (initial turbidity of 100 NTU). This reduction may be attributed to charge reversal and destabilization of colloidal particles due to overdosing as also suggested by Yukselen and Gregory (2004).

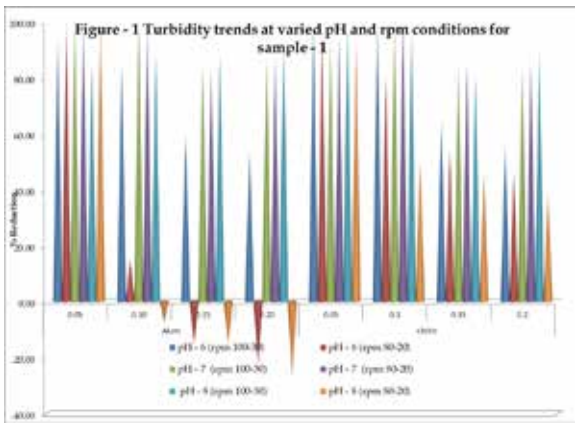
The results suggest that the dosage of chitin from 0.1g to 0.4 g/L was good for coagulation at varied conditions of pH and mixing speed and time. Though the reduction efficiencies with respect to various parameters was good at 0.3 and 0.4 g/L at elevated or alkaline pH conditions, the lower dosages also yielded considerably good results.

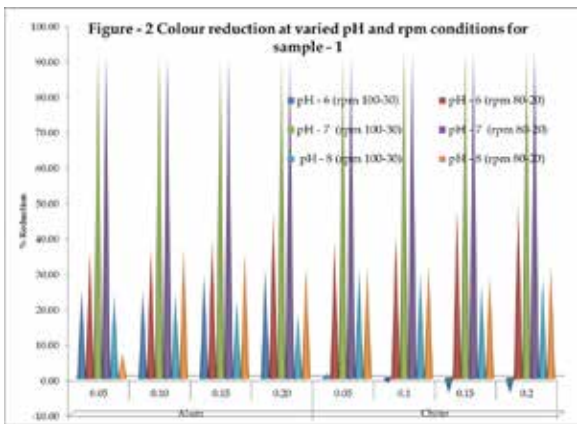
From the investigations steered by various researchers it has been observed that the addition of chitosan contributes to TOC increase in the solution that could affect the coagulation mechanism. According to the test by Bina et.al., 2009 in their studies taking into account the low dosage of chitosan in these experiments (systematically less than 1 mg/L), the amount of organic carbon introduced remained was low enough (less than 0.8 mg/L) to make its contribution negligible on the coagulation-flocculation performance. However,

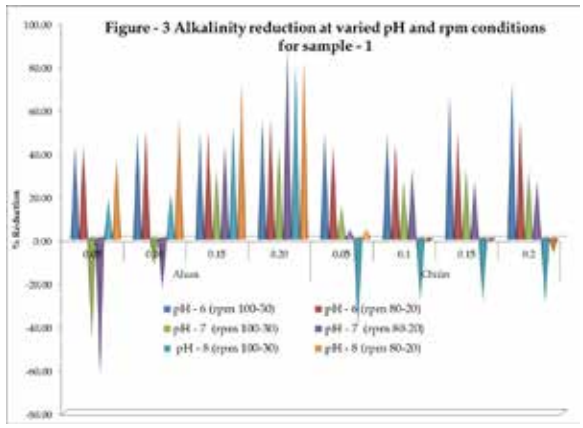
no clear correlation was found between the TOC level of the water samples and their flocculation behaviour. The results showed that chitosan could be used as natural coagulant aid for drinking water treatment with the lowest risks of organic release.

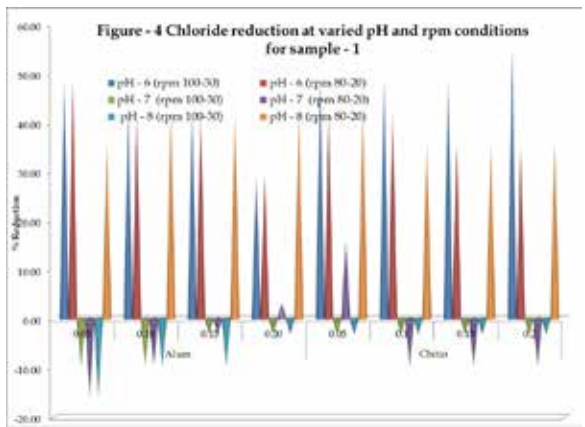
Conclusion

Hence it is concluded that chitin have properties that are of interest in water treatment. It is a remarkable chelation agents and heavy metal trap. It has the ability to coagulate a variety of small particles including colloidal size particles from water.









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