Chapter 4

Flocculation of river silt using chitosan

4.1 Introduction

Removal of turbidity from river water is a problem confronting water treatment plants for producing potable water, especially during the dry season when silt is sucked into the pumping well. Alum, combined with lime, is commonly being used for clarifying water at present. The experience gained from our studies on the flocculation of kaolinite suspensions using chitosan was applied to this situation. In this study, the effectiveness of chitosan as a flocculant, when used alone, on the removal of turbidity due to river silt was examined at various concentrations of suspended particles and flocculant, and at different pH values. Samples of river silt collected from the Periyar River was resuspended and used in the laboratory studies, and the results were confirmed using natural turbid river water during the monsoon.

4.2 Materials and methods

4.2.1 Silt suspensions

Samples of naturally settled river silt were collected from shallow areas of the Periyar River near Aluva (Ernakulam District, Kerala, India). Raw silt was mixed with water and resuspended by rapid mechanical agitation. Portions of this suspension were withdrawn and diluted as necessary with tap water to obtain the
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turbidity required for the experiments. The tap water used for dilution had the following properties estimated as given in Standard Methods: pH 7.2 to 7.5, turbidity less than 1.0 NTU, total acidity = 0, total alkalinity 18 mg CaCO₃ per litre, total hardness 12 mg CaCO₃ per litre. The suspensions were prepared immediately before each set of experiments. The mass of suspended solid at each turbidity value was determined gravimetrically. The silt used consisted mainly of silica particles, with some adsorbed iron oxide. The volatile organic matter was estimated by heating the dry silt to 550°C [Standard Methods, 1995] and found to be 17.8 ± 1.0% of the dry mass.

Turbid water was collected from flooded Periyar River during heavy monsoon rainfall at the end of June, and at the end of August when monsoon was receding.

4.2.2 Chitosan solution

One hundred milligrams of chitosan powder was accurately weighed into a glass beaker and mixed with 10 mL of 0.1 M HCl solution and kept aside for about an hour to dissolve. The dissolution process was slow, and some amount of chitosan remained in the form of a thin gel even after this time. It was then diluted to 100 mL with tap water to obtain a solution containing 1.0 mg chitosan per mL of solution. As it was observed that chitosan solutions in acid medium undergo some change in properties over a period of time (section 3.4), the solutions were prepared fresh before each set of experiments.
4.2.3 Jar tests

Turbidity of silt suspensions were measured on a Systronics nephelometer model 131 calibrated according to the procedure recommended in Standard Methods. pH values of the suspensions were measured using a Systronics pH meter model 335. Flocculation was carried out on a six-spindle multiple stirrer unit with stainless-steel paddles. All tests were carried out at an ambient temperature of 28 ± 4°C.

The pH of test solution was adjusted by adding either 0.1 M HCl solution or 0.1 M sodium carbonate solution prior to adding the flocculant. It was thus ascertained that flocculation took place at the desired pH. The desired volume of chitosan solution was added to each test suspension and mixed thoroughly by stirring rapidly for five seconds. It was then stirred at a steady rate of 60 rpm for 30 minutes. The stirrer was then switched off and the flocs were allowed to settle undisturbed for 30 minutes. The samples for turbidity measurements were withdrawn using a pipette from a height of 5 cm below the surface.

Six replications of each test were carried out. The mean value obtained for residual turbidity and standard deviation from the six replications were computed.

4.3 Results and discussion

4.3.1 Relationship between silt concentration and turbidity

Determination of suspended silt concentration (in mg L⁻¹) gravimetrically gives a linear relationship with turbidity in NTU, as shown in Figure 4.1.
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Figure 4.1.

Relationship between mass of suspended river silt (dry mass) and turbidity produced.
4.3.2 Effect of pH on flocculation of river silt using chitosan

Tests were conducted as described, at pH values of 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0 and 9.0 ± 0.1 using a flocculant concentration of 1.0 mg L\(^{-1}\). The results are presented in Figure 4.2. From the figure, it is seen that chitosan produces appreciable reduction of turbidity only between pH 5 and 7.5. The final turbidities recorded show large variations between experiments at pH values close to 5.5 and 8. The maximum efficiency is observed at pH 7.0. About 90% removal of turbidity is achieved at this pH, without filtration, and the residual turbidity drops below 5 NTU. The flocs obtained are very coarse and settled almost completely in less than 5 minutes.

4.3.3 Determination of optimal dosage of chitosan

As maximum efficiency of flocculation was around pH 7, experiments were conducted by varying the dosage of chitosan at this pH on silt suspensions having initial turbidities ranging from 10 to 160 NTU. Tests were run using 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 mg/L of chitosan. The results are presented in Figure 4.3. The lowest dosage with maximal efficiency was found to be 0.5 mg L\(^{-1}\). Above this dosage, the suspensions showed a tendency to restabilise.

4.3.4 Relationship between initial turbidity and dosage of chitosan

Results shown in Figure 4.3 indicate that effectiveness of chitosan in removing turbidity due to river silt is very much dependent on flocculant concentration.
Figure 4.2.
Effect of pH on removal of turbidity due to river silt.
initial turbidity = 40 NTU.
Whiskers indicate one standard deviation from six replications;
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Figure 4.3.

Effect of chitosan concentration on flocculation of river silt.

Whiskers indicate one standard deviation from six replications.
Irrespective of initial turbidity, 0.5 mg L\(^{-1}\) of chitosan lowers turbidity below 5 NTU. Beyond this dosage turbidity increases, probably due to restabilisation of suspended particles. When flocculant dosage reaches 0.75 mg L\(^{-1}\), complete restabilisation occurs for an initial turbidity of 10 NTU. This shifts to 1.5 mg L\(^{-1}\) for an initial turbidity of 20 NTU and for higher turbidities, the concentration required to restabilise completely is beyond the range examined here. Thus the dosage of chitosan required to restabilise the silt suspension depends on the concentration of suspended silt particles. Again, in the present study, it is observed that irrespective of initial turbidity, application of 0.5 to 1.0 mg L\(^{-1}\) of chitosan leaves a residual turbidity of only less than 5 NTU, before filtration, under test conditions (Figure 4.4). The chitosan dosage required to produce the lowest final turbidities increase very slightly with the concentration of suspended silt particles as can be seen from Figure 4.4. Starting with a turbidity value of 10 NTU, which is usually very difficult to clarify in conventional treatment using alum, a residual turbidity of about 2 NTU was obtained after flocculation and settling using chitosan.

It was also observed that at higher initial turbidities, flocs appear rapidly and grow to a larger size. The flocs are fibrous and stick to the stirrer or form large entangled mass resembling cobwebs.

4.4 Confirmation of results using naturally turbid river water

Results obtained in the laboratory studies using resuspended river silt were confirmed in experiments carried out using turbid raw water collected from Periyar
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Figure 4.4.

Effect of chitosan concentration on residual turbidity of river silt.

Whiskers indicate one standard deviation from six replications.
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Table 4.1.

Characteristics of water collected from Periyar River.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>June 2000</th>
<th>August 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.8</td>
<td>7.2</td>
</tr>
<tr>
<td>Average turbidity</td>
<td>36 NTU</td>
<td>26 NTU</td>
</tr>
<tr>
<td>Methyl orange alkalinity</td>
<td>4 mg CaCO₃ per litre</td>
<td>4 mg CaCO₃ per litre</td>
</tr>
<tr>
<td>Phenolphthalein alkalinity</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Total hardness</td>
<td>14 mg CaCO₃ per litre</td>
<td>10 mg CaCO₃ per litre</td>
</tr>
<tr>
<td>Calcium hardness</td>
<td>6 mg CaCO₃ per litre</td>
<td>4 mg CaCO₃ per litre</td>
</tr>
</tbody>
</table>
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Figure 4.5.
Effect of pH on flocculation of turbid river water
using 1 mg L$^{-1}$ chitosan
Figure 4.6.

Effect of chitosan concentration on flocculation

of turbid river water at pH = 7.0
River during flooding. Important parameters for the collected water are presented in Table 4.1. The effect of varying pH while keeping the flocculant concentration at 1 mg L\(^{-1}\) is shown in Figure 4.5. Effect of increasing flocculant dosage keeping the pH at 7 is shown in Figure 4.6. These agree well with the results for resuspended river silt shown in Figures 4.2 and 4.3.

4.5 Conclusion

About 90% of the turbidity due to river silt can be removed by chitosan at a pH of 7.0. Any addition of other chemicals for pH correction was not necessary. The final turbidity dropped below 5 NTU without filtration. The flocs were coarse and settled almost completely in less than 5 minutes. The optimum concentration of chitosan was found to be 0.5 to 1.0 mg per litre. In fact, the effectiveness decreased at higher concentrations due to restabilisation.