Removal of Water Turbidity by Different Coagulants

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ABSTRACT

During the last decade, there has been a concern about the relation between aluminum residuals in treated water and Alzheimer disease, and more interest has been considered on the development of natural coagulants. The present study aimed to investigate the efficiency of alum as a primary coagulant in conjunction with mallow, Arabic gum and okra as coagulant aids for the treatment of water samples containing synthetic turbidity of kaolin. Jar test experiments were carried out for initial raw water turbidities 100, 200 and 500 (NTU). The optimum doses of alum, mallow, Arabic gum and okra were 20, 2, 1 and 1 mg/L for100 NTU turbidity level, 35, 4, 2 and 3 mg/L , for 200NTU turbidity level and 50, 8, 10 and 8 mg/L for 500 NTU turbidity level, respectively. The optimum pH was 7 for alum, and 7.5 for mallow, Arabic gum and okra. The residual turbidity was 3.34 to 6.81 NTU by using alum as a primary coagulant with mallow, Arabic gum and okra, and pH values of the treated water by the natural coagulants were 6.1 to 7.01. The optimum dose of the natural coagulants in the present study has higher efficiency in removing high turbidity in comparison with low turbidity. Natural coagulant showed many advantages in coagulation/flocculation process. By using natural coagulants, considerable decreasing in $Al_2(SO_4)_3$ consumption, and Increasing in the rate of sedimentation can be achieved.

KEY WORDS: Coagulant, jar test, flocculation, kaolin, turbidity.

إزالة عكوره الماء باستعمال مخثرات مختلفة

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الخلاصة

خلال العقد الاخير،لقد كان هناك اهتمام حول العلاقة بين بقايا الالمنيوم في الماء المعالج ومرض الخرف المبكر (الزهايمر)،لذا ظهر اهتمام كبير في تطوير استخدام المخثرات الطبيعية في عمليات معالجة الماء. الدراسة الحالية تهدف الى تقييم كفاءة كل من الشب ومخثرات طبيعية هي الملوخية، الصمغ العربي ومخلفات البامية في معالجة عينات ماء تم تحضيرها باستعمال طين الكاؤلين.تم أجراء التجارب باستعمال جهاز فحص الجرة للماء و بمستويات عكورة 200,100و500 وحدة نفلومتر. الجرع المثلى كانت20، 2، 1 و 1 ملغم/لتر لمستوى العكورة 100وحدة نفلومتر ،35، 4، 2 و 3 ملغم/لتر لمستوى العكورة 200وحدة نفلومتر و50 ، 8 ، 10و 8 ملغم/لتر لمستوى العكورة 500وحدة نفلومتر للشب، الملوخية، الصمغ العربي و البامية. قيم ال pH المثلى كانت 7 للشب و 7,5 لكل من الملوخية، الصمغ العربي و البامية.العكورة المتبقية في الماء كانت ما بين 3,34الى 6,81وحدة نفلومتر،قيم ال pH للماء المعالج بالمخثرات الطبيعية كانت ما بين 6,1الى7,01. أثبتت التجارب أيضا ان المخثرات الطبيعية لها كفاءة أزاله عالية في مستوى العكورة 500وحدة نفلومترمقارنة بمستوى العكورة 100وحدة نفلومتر. المخثرات الطبيعية كانت مفيدة في عمليات التخثير والتلبيد متى ما تم استعمالها لوحدها كمخثرات رئيسية او مقترنة بالشب كمساعدات تخثير، فباستعمالها يمكن تحقيق ،تقليل في كمية الشب المستعملة ، وزيادة في نسبة الترسيب.

الكلمات الرئيسية:المخثرات،جهاز فحص الجرة،التلبيد، الكاؤلين، العكورة

1. INTRODUCTION

Growing population, increased economic activity and industrialization have not only created an increased demand for fresh water but also resulted in severe misuse of natural resources. Water resources all over the world are threatened not only by over exploitation and poor management but also by ecological degradation. About 1.2 billion people still lack safe drinking water and more than 6 million children die from diarrhea in developing countries every year. In many parts of the world, river water highly turbid is used for drinking purposes. World Health Organization (WHO) has set the guideline value for the residual turbidity in drinking water at 5 Nephelometric Turbidity units (NTU) (Connachie, et. al. 1999). As identified by the United States Environmental Protection Agency (USEPA), turbidity is a measure of the cloudiness of water; it is used to indicate water quality and filtration effectiveness. High turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria in the water. These organisms can cause symptoms such as nausea, cramps, diarrhoea and headaches, other microorganisms are associated with outbreaks and background rates of diseases in developing countries worldwide (Mackenzie and Cornwell, 1991; Fatoki and Ogunfowokan, 2002). Developing countries pay a high cost to import chemicals including polyaluminium chloride and alum (Ghebremichael, 2004) for water purification. This is the reason why these countries need low cost methods requiring low maintenance and skill for purification. Inorganic coagulants such as alum in combination with lime have been conventionally used for turbidity removal from surface waters. The sludge formed from such treatment poses disposal problems because of its aluminum content, tend to accumulate in the environment and also because of its large volume (Divakaran and Pillai, 2001). This development led to cost effective, easier and environmental friendly processes for water clarification. Natural organic polymer has been used for more than 200 years in India, Africa and China as effective coagulants and coagulants aids at high water turbidities (Connachie, et.al. 1999). These natural organic polymers are comparative to the synthetic polymer containing acrylamide monomers, no human health danger and less expensive over to the conventional chemical used. The aim of this work is to evaluate the performance of alum and natural coagulants (mallow, Arabic gum and okra) for removing the turbidity of raw water.

2. MATERIALS

2.1 Synthetic Water Preparation

For the coagulation experiments, samples of turbid water were prepared by adding kaolin into distilled water. A weight of 10 g of kaolin powder was added to one liter of distilled water. Suspension solution was kept at room temperature for 24 h and was completely mixed for 20 minutes by an electrical blender. The suspension solution was kept in a stable condition for 4 hours in order to settle coarser particles. From this stock solution, desired experimental turbidities of 100 NTU, 200 NTU and 500 NTU were generated.

2. 2 Coagulants Solutions Preparation

2. 2.1 Alum solution

Alum was prepared by dissolving 10 g of the $Al_2(SO_4)_3.18H_2O$ into one liter of distilled water and stirred well to produce 1% solution concentration. Thus each 1ml of this solution is equivalent to 10 mg of alum.

2. 2.2 Mallow solution

Fresh mallow was brought from the local market. The leaves, already separated from the stems, were dried under sun light, cleaned from dust materials, ground to produce a very fine powder by using a domestic blender then sieved to obtain a weight of 250 μm particles. A weight of 1g of this powder was added to 1L of distilled water and stirred well for 5 minutes then filtered through muslin cloth to produce a 0.1% solution concentration. Thus each 1ml of this solution is equivalent to 1 mg of this material. The composition of mallow per 100 g edible portion is: water 81.50 g, energy 235.00 kJ (56.00 Kcal), protein 4.40 g, fat 0.60 g, carbohydrate 11.30 g, fibre 2.10 g, Ca 532.00 mg, P 70.00 mg, Fe 0.70 mg, ascorbic acid 59.00 mg, β-carotene 385.00 μg, thiamin 0.25 mg, riboflavin 2.80 mg, niacin 0.20 mg (Labib et al., 1997).

2. 2.3 Arabic Gum Solution

Arabic gum was brought from the local market and grinded in to fine grains using a domestic blender. A weight of 1g of this powder was dissolved in 1L of distilled water and stirred well for 5 minutes, then filtered through muslin cloth to produce a 0.1% solution concentration. Therefore 1ml of this solution is equivalent to 1 mg of these materials. The gums contain a small amount of nitrogenous material. Their chemical compositions vary slightly with source, climate, season, age of the tree, etc. The gums consist of sugar, rhamnose , glucuronic acid arabinose and 4-O-methyl glucuronic acid, (Williams. and Phillips, 1998)

2. 2.4 Okra Solution

Okra powder was prepared by collecting the waste agriculture resulted from minimizing the pod, dried in sun light, cleaned from dust materials, grinded in to a fine powder using a domestic blender, then sieved through 250 µm sieve. A weight of 1gm of this powder was added to 1L distilled water, and stirred well for 5 min, and then filtered through muslin cloth to produce a 0.1% solution concentration, thus each 1ml of this solution is equivalent to 1 mg of this materials. The composition of okra per 100 g edible portion is: water 81.50 g, energy 235.00 kJ (56.00 Kcal), protein 4.40 g, fat 0.60 g, carbohydrate 11.30 g, fibre 2.10 g, Ca 532.00 mg, P 70.00 mg, Fe 0.70 mg, ascorbic acid 59.00 mg, β-carotene385.00 µg, thiamin 0.25 mg, riboflavin 2.80 mg, niacin 0.20 mg, (A1-Wandawi, 1983)

3. EXPERIMENTAL PROCEDURE

A conventional jar test apparatus, the Phipps and Bird Six-Paddle Stirrer, was employed for the tests, with six 1.5 L square jars, called as Gator Jars. All tests were carried out with 1L samples. The experiments were carried out by using synthetic water having 100, 200 and 500 NTU turbidities. The optimum dose of alum, mallow, Arabic gum and okra for turbidity removal was determined, (Sulaymon et al., 2009). The procedure was as follows:-

-Different type and concentration of coagulants were added to synthetic water with different turbidities. The suspensions were stirred rapidly (200 rpm) for 1 min to ensure adequate mixing.

- Rapid mixing followed by slow mixing (30 rpm) for 15 min were performed to achieve collisions and aggregate of particles. The suspension was then allowed to settle for 40 min, and then a sample drawn at 6 cm depth from the supernatant for turbidity and pH measurements.

Optimum dosage that leads to meet the standard turbidity level within the range (7-5) NTU was selected, (Hoontrakul, 2006). Measurements of pH and turbidity were carried out with pH mater (Multi 340i WTW) and turbidity meter (Hi 98703 HANNA). A single batch-settling test was carried out on kaolin slurry. The test was achieved by using 407 mg of kaolin clay per liter then; different types and concentrations of coagulants were added. The suspensions were stirred rapidly followed by slow mixing then allowed to settle for 40 min. The interface between clear liquid and suspended solid was observed at different periods of time (5, 10, 20, 30, 40 min). The data were treated by plotting the height of the interface (Z) as a function of time (t). From this plot the value of V_L is the slope of the curve at $t= t_L$ eq. (1) can be obtained.

$$V_L= \frac{Z_i - Z_l}{t_l} \quad (1)$$

By using eq. (2) the corresponding concentration C_L can be obtained.

$$C_L Z_i = C_0 Z_0 \quad (2)$$

In this test C_0=407mg/L, Z_0=13.5cm, and by using eq. (3) C_L value can be obtained.

$$C_L = \frac{(C_o Z_o)}{Zi} = \frac{5495}{Zi} \left(\frac{\text{mg}}{\text{L}}\right) \quad (3)$$

Where:-

Z_0= initial height of the interface, in this test Z_0=13.5cm.

C_0= initial solids concentration in this test C_0=407mg/l.

V_L = slope of the curve.

Z_i = height of the interface at time t.

C_L = solids concentration.

From equation (3), the settling velocity V_L as a function of solids concentration C_L was obtained, (Foust, et.al. 2004).

4. Results and Discussions

4.1 Optimum Coagulants Doses

Experiments were conducted to find the optimum coagulants doses for alum, mallow, Arabic gum, and okra as primary coagulants by fixing the initial water turbidities at 100, 200 and 500NTU. Also experiments were carried out by using mallow, Arabic gum and okra as coagulant aids with alum in binary, ternary and quartery combinations.

4.1.1 Single Coagulant Experiments

The effect of different dosages of alum and the selected coagulants on the removal of turbidity is presented in figures (1, 2, 3, and 4) respectively.

Examining figure (1), it is clear that as the alum dose increased, the removal efficiency of turbidity increased. The decrease in turbidity might be attributed to the fact that as metal hydroxide precipitation increased, the sweep floc efficiency became higher, and therefore final turbidity value became lower because colloid particles were captured in metal hydroxide floc structure. At coagulant dose lower than 10(mg/L), the floc did not appear since the coagulant was not adequate to compress the double layer of the colloid particles or the metal hydroxides precipitation decreased, which resulted in lower efficiency of sweep floc mechanism with small size flocs formation. High dose of the coagulant in the suspension caused charge stabilization of colloid particles, due to the adsorption of counter ions (in this case was AL^{+3}). Increase in dose of alum (more than 80 (mg/L)) raised the turbidity because the excess adsorption of the counter ions caused the charge of colloid particles to become positive (i.e. re-stabilization of the colloid particles), which had resulted in the separation of the particles due to electrostatics repulsions and in low floc appearance. Dosage was one of the most important parameters that have been considered to determine the optimum condition for the performance of mallow, Arabic gum and okra in coagulation and flocculation. Examining figures 2, 3, and 4 it is clear that, as the dose increased, the removal efficiency of turbidity from the test solution also increased, but after the optimum dose, a decreasing trend in removal was seen. The behavior could be explained by the fact that the optimal dose caused larger amount of solid to aggregate and settle, but more than the optimal amount of flocculent would cause the aggregated particles to re-disperse in the suspension and would also disturb particle settling.

Moreover, in high turbid solution (500 NTU) the removal efficiency of turbidity was the highest as compared to low (100NTU) and moderate (200 NTU) turbid solutions. The present results showed that mallow, Arabic gum and okra have higher efficiency in removing high turbidity in comparison with low turbidity. Also it should be noted that the coagulant aid dosage in comparison to alum dosage is very low. This finding is in agreement with results obtained by Patale, (Patale and Parikh, 2010). The experimental results are listed in Table 1.

4.1.2Combination Coagulants Experiments

4.1.2.1 Binary Combination

The combination of alum as a primary coagulant with another coagulant aid (mallow, Arabic gum and okra) for raw water with initial turbidity levels 100, 200 and 500 NTU were carried out and tabulated Table 1 (A).

4.1.2.2 Combination Ternary Combination

The combination of alum as a primary coagulant with another coagulant aid (mallow, Arabic gum and okra) for raw water with initial turbidity levels 100, 200 and 500 NTU were carried out and tabulated Table 1 (B).

4.1.2.3 Quartery Combination

The combination of alum as a primary coagulant with another coagulant aid (mallow, Arabic gum and okra) for raw water with initial turbidity levels 100, 200 and 500 NTU were carried out and tabulated Table 1(C).

The residual turbidities versus dosses for binary, ternary, and quartery combinations are shown in figures 5, 6, and 7 respectively.

4.2 Optimum Coagulants pH

Figure (8) shows the optimum pH of alum, mallow, Arabic gum and okra.

Examining figure (8), it is clear that, the optimum pH values for alum was 7 and was similar to the obtained results by Divakaran, (Divakaran and Pillai, 2002). And for mallow, Arabic gum and okra were 7.5, 7.5, and 7.5, respectively. Also it is clear from the previous figures that the natural coagulants have less sensitivity to the change in pH, so these natural coagulants can work at range wide of pH. This finding is in agreement with other studies at optimum pH (Lin *et al.*, 1971; Ebeling *et al.*, 2003). pH was adjusted with 0.1 M H_2SO_4 and 0.1M NaOH.

4.3 Settling Velocity

Figure (9) shows the settling rate-concentration relationship by using alum, mallow, Arabic gum and okra as primary coagulants.

From figure (10), it is clear that there was an improvement in the flocs settling velocity when mallow, Arabic gum and okra were used as coagulants aids in conjunction with alum as compared to alum alone. These coagulants make larger flocs with aluminum flocs in the water by bridging mechanism, finally settling them down and can be easily removed from turbid water; the experimental results are listed in Table 2

5.CONCLUSIONS

Based on the results of the experiments and tests conducted in this research, the following conclusions were found:-

1-The optimum doses of alum, mallow, Arabic gum and okra were 20, 2, 1 and 1 mg/L for100 NTU turbidity level, 35, 4, 2 and 3 mg/L for 200NTU turbidity level and 50, 8, 10 and 8 mg/L for 500 NTU turbidity level, respectively.

2-The optimum pH values for all the four coagulants (alum, mallow, Arabic gum and okra) were 7, 7.5, 7.5 and 7.5, respectively.

3-Using mallow, Arabic gum and okra as coagulant aids with alum (in binary, ternary and quartery combinations) cause the formation of flocs more quickly and increase the rate of sedimentation.

4- Natural coagulants (when used as primary coagulants) seem to be more effective at higher turbidity levels.

5- Natural coagulant significantly reduced the required dosage of alum between 15 to 30%, thereby reducing costs of treatment.

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Table 1. The percentages of the coagulant doses.

A

Sample No.	Coagulants
1	85% of alum dose+15% one of (mallow, gum okra) dose
2	70% of alum dose+30% one of (mallow, gum okra) dose
3	55% of alum dose+45% one of (mallow, gum okra) dose
4	40% of alum dose+60% one of (mallow, gum okra) dose
5	25% of alum dose+75% of one (mallow, gum okra) dose
6	10% of alum dose+90% one of (mallow, gum okra) dose

B

Sample No.	Coagulants
1	85% of alum dose+7.5% two of (mallow, gum okra) dose
2	70% of alum dose+15% two of (mallow, gum okra) dose
3	55% of alum dose+22.5% two of (mallow, gum okra) dose
4	40% of alum dose+30% two of (mallow, gum okra) dose
5	25% of alum dose+37.5% two of (mallow, gum okra) dose
6	10% of alum dose+45% two of (mallow, gum okra) dose

C

Sample No.	Coagulants
1	85% of alum dose+5% of mallow, gum and okra doses
2	70% of alum dose+10% of mallow, gum and okra doses
3	55% of alum dose+15% of mallow, gum and okra doses
4	40% of alum dose+20% of mallow, gum and okra doses
5	25% of alum dose+25% of mallow, gum and okra doses
6	10% of alum dose+30% of mallow, gum and okra doses

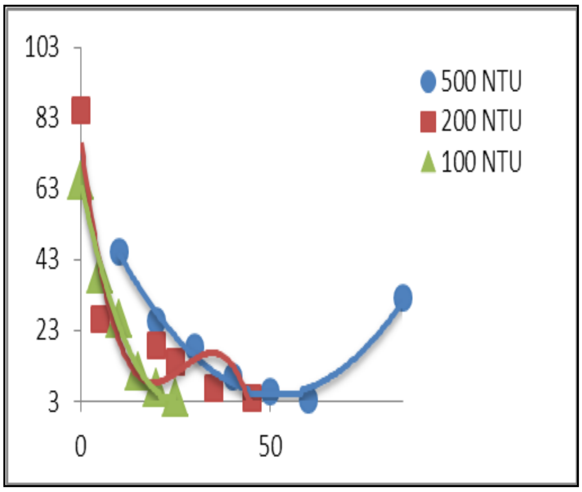

Fig. 1 Plot residual turbidity vs. alum dose

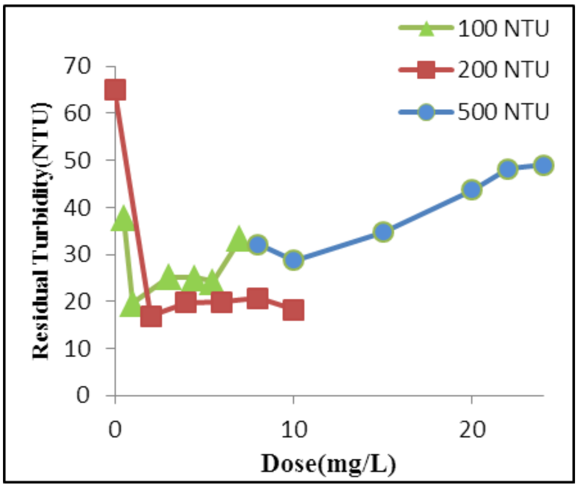

Fig. 2 Plot residual turbidity vs. Arabic gum dose

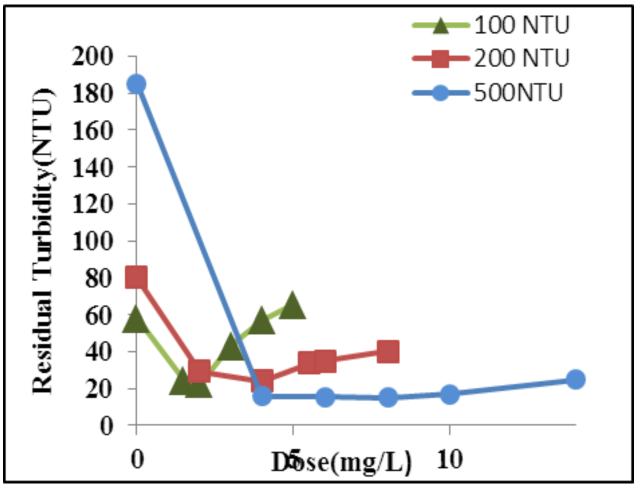

Fig. 4 Plot residual turbidity vs. mallow dose

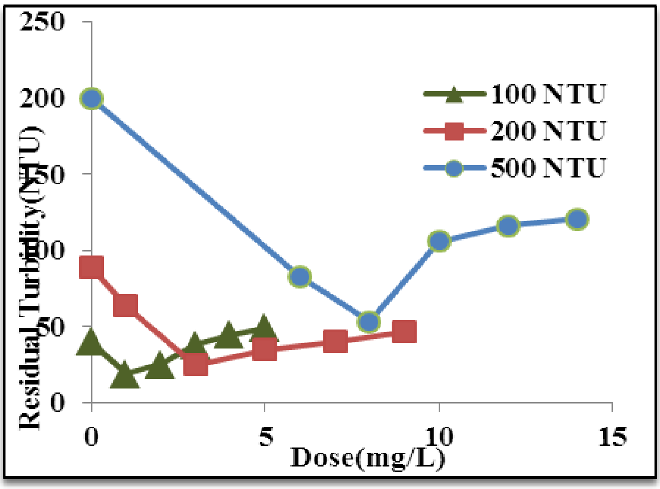

Fig. 3 Plot residual turbidity vs. okra dose

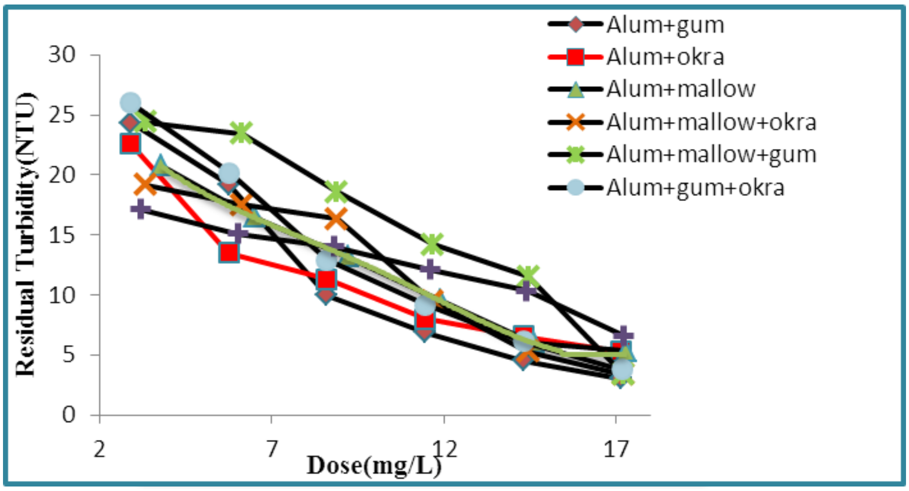

Fig. 5 Plot residual turbidity vs. dose of alum in conjunction with mallow, Arabic gum and okra for raw water with initial turbidity100 NTU.

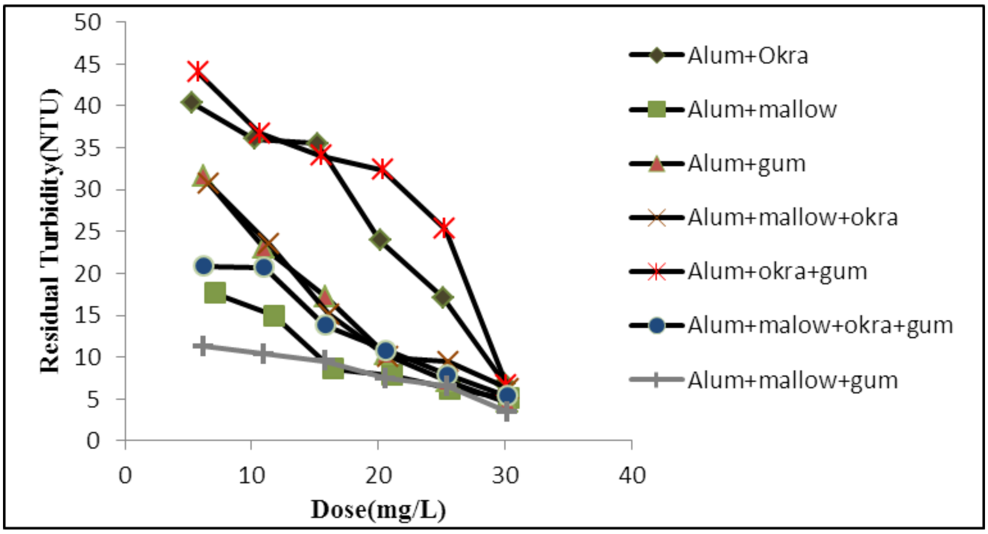

Fig. 6 Plot residual turbidity vs. dose of alum in conjunction with mallow, Arabic gum and okra for raw water with initial turbidity200 NTU.

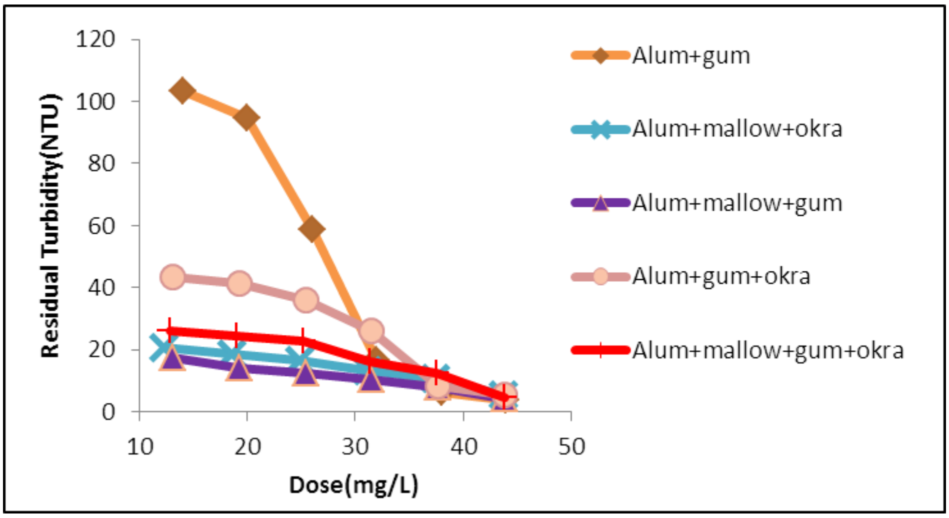

Fig. (7) Plot residual turbidity vs. dose of alum in conjunction with mallow, Arabic gum and okra for raw water with initial turbidity500 NTU.

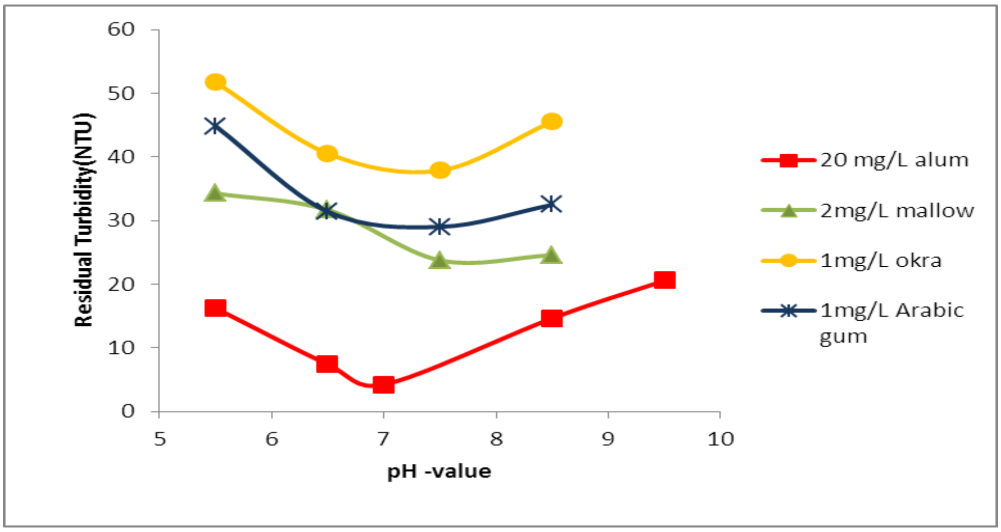

Fig. 8 Determination of optimum pH with initial turbidity 100NTU.

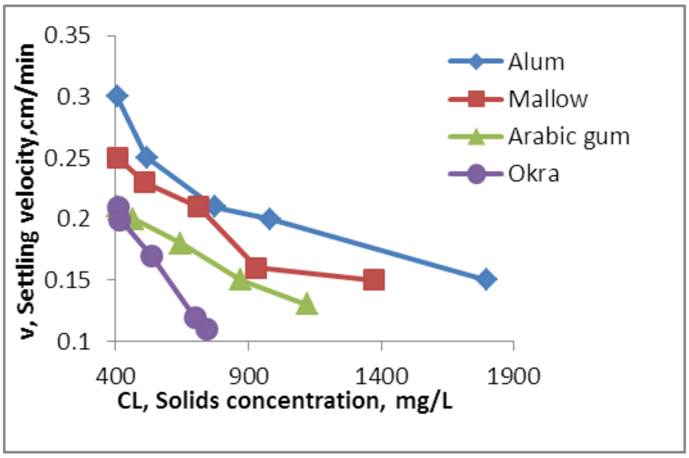

Fig. 9 Plot settling rate vs. concentration.

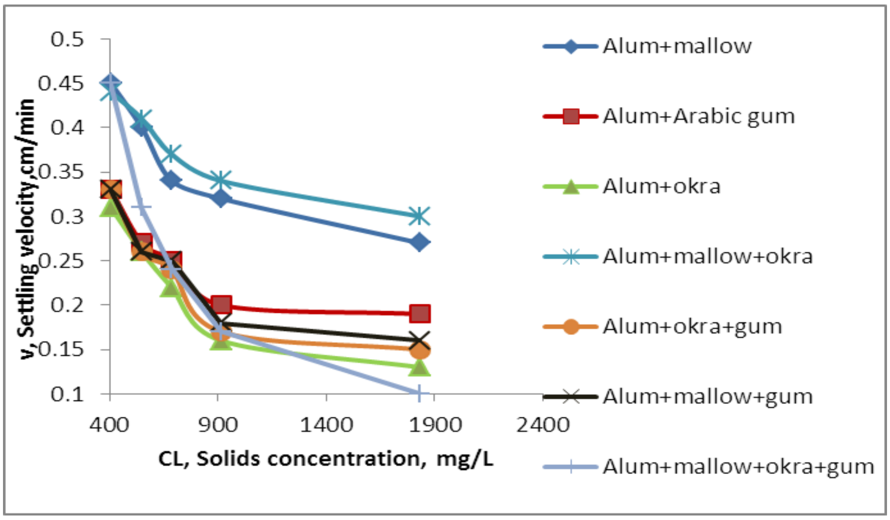

Fig. 10 Plot settling rate vs. concentration.