Reduction of turbidity by adding bio coagulant-A sustainable approach

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Abstract. Improper management of human developmental activities such as industrialization and haphazard urban development deteriorating the quality parameters of Surface Water sources beyond the permissible limits. Turbidity in water, a major physical characteristic parameter is highly increasing due to the presence of suspended, colloidal, dissolved solids and making the water resources anaesthetic in condition. The chemical coagulants like Alum, Ferric Sulphate are widely used in turbidity treatment processes. Present study aimed sustainable approach to reduce turbidity by adding Neem (Azadirachta indica) leaf powder as bio coagulant along with Alum (Aluminum Potassium Sulphate). Laboratory investigation was done for the sample from Hussain sagar lake, Telangana, India and analysed the obtained turbidity results. Optimum dosage of neem leaf powder along with Alum has been determined by Jar Test Apparatus to increase the efficiency of treatment. The dose of bio coagulant used was 0.1 to 1gr per Litre. It has been observed that the bio coagulant is efficient in reducing turbidity upto 94.8% when it was added with reduced dosages of Alum. This paper explains sustainable method of reducing turbidity by using neem leaf powder as bio coagulant along with Alum.

Keywords Turbidity, Coagulant, Azadirachta indica, Alum, Ferric Sulphate, Jar Test Apparatus

1. Introduction

Water is a precious natural resource and 3/4th of globe is occupied by the same. Population explosion, indiscriminate utilization of fertilizers, unplanned urban growth and improper handling of waste water are leading to deteriorate the quality characteristics of water resources. Among the physical water quality characteristics, turbidity indicates the presence of suspended, colloidal, dissolved solid levels in the water thereby it imparts color and odor to surface water bodies. The widely used Chemical coagulants in water treatment processes pose threat to human and aquatic lives as they produce high quantity of sludge and alter the quality characteristics of water. Turbidity can be reduced by a sustainable method using bio coagulants as they do not harm the aquatic eco system instead of adding high dosages of chemical coagulants. Bio coagulation is a modern treatment process which involves locally available natural materials to treat turbidity efficiently. As a part of present study, the Neem (Azadirachta indica) leaf powder is added to reduced dosage of a widely used chemical coagulant, Aluminium Potassium Sulphate in varying amounts. Hussain Sagar lake in Telangana, India which was used as a major source for drinking and agricultural practices during 1894 to 1930 but now it has been polluted by human developmental activities and reported higher turbidity levels was taken for laboratory investigation. Devanathan, Dhakshin kumar M , Dinesh M , Dinesh S K , Sinduja N from SRM Valliammai Engg College, Chennai (2020) from their comparative study of different bio coagulants concluded that the bio coagulants are efficient in low to medium turbid water by reducing BOD (150mg/l to 99 mg/l), Total Solids (8000 mg/l to 2000mg/l) by using neem leaf as a coagulant and COD(44mg/l to 9.6mg/l) by using banana pith as coagulant. Also recommended that New coagulant processing technique such as composite polymerization and impregnation method can be incorporated in producing coagulants with enhanced capability [1]. Muhammad B. Ibrahim, Muhammad S. Sulaiman and Sadiq Sani(2015) analyzed the physico chemical characteristics and binding capacity of Neem Leaf Powder by SEM with EDX, FTIR Spectroscopy and concluded that NLP can be an effective, low cost adsorbent for removing Congo Red and Methyl Orange in aqueous solution[2].Md Asrafuzzaman, A.N.M.Fakhruddin from
Jahangirnagar University, Dhaka, Bangladesh and Md.Alamgir Hossain from Dhaka (2011) Water Supply and Sewerage Authority investigated and reduced turbidity to 95.89% in synthetic organic turbid water by adding locally available natural materials such as Moringa Oleifera, Cicer arietinum, Dolichos lab [3]. Anju S and K.Mophin-Kani from UKFCET(2016), India evaluated that the use of alternative coagulant such as orange peel and neem powder brought turbidity of Dairy wastewater from 53NTU to 4NTU without reducing PH [4]. Dr.DuraiArulneyam and Dr.R.Premsudha from TKR College of Engineering And Technology , Meerpet, Hyderabad, Telangana, India (2018) found that the parameters such as pH, Electrical Conductivity, total Suspended Solids, Total Dissolved Solids, BOD, COD, Total Nitrogen, Total Phosphorous were extremely high in Hussain Sagar Lake and reduced to desirable limits after the treatment [5]. Rubinis, Balamurugan p, Shanmugapriya k from M.Kumaraswamy College of engineering, Karur, India (2019) explored the usage of cactus and neem leaf powder as alternative coagulants whose efficiency was 50 to 60% and when natural coagulant was added with Alum, the efficiency was increased to 95 to 96% in waste water from MKCE college [6]. Sankeet K.V, Asha Rani N.R from Alliance University, Bengaluru (2021) utilized Neem leaf powder as a natural coagulant for industrial waste water treatment and concluded that reduction of 49% of turbidity, 34% of Total hardness, 54% of chlorides, 35% of residual chlorine have been achieved efficiently[7]

1.1. Problem statement
Hussain Sagar Lake popularly known as largest man-made lake in Asia located at Hyderabad, Telangana, India and is situated at 17° 22’ northern latitude and 78° 29’ of eastern latitude built on Musi river by Hussain Shah Wahi, under ruling of Ibrahim Quli Qutub Shah in the year 1562. The storage volume at spill level is 28.6 × 106 m3, average depth at full capacity is 5.2 m and the road bund level is 5.18 m (Kora, 2017). In addition to storm water, rapid residential and industrial growth in its catchment area, the lake is fed by four major drains nalas, which act as feeding channels. A million litres per day (MLD) of domestic sewage and solid waste is discharged into the lake through (13.3MLD) Balkapur, (6MLD) Banjara, (70MLD) Kukatpally and (5.7MLD) Picket nalas (Sridhar, 2015). As a result, turbidity of lake water is reported above permissible limits making the lake anaesthetic in condition. figure 1 illustrates the Hussain Sagar Lake and collected water samples shown in figure 2.

1.2. Research Significance
Extensive utilization of Alum can alter the physical, chemical properties of lake water causing threat to human beings. Natural bio coagulant utilization as an emerging technology to increase turbidity reduction efficiency as well as decrease the pollution threat. There is a lot of scope in finding many more naturally available bio coagulants for improving water quality characteristics without posing harm to the environment.

1.3. Objectives of present study are
• To assess turbidity levels of Hussain Sagar Lake water.
• To identify the optimum dosage of chemical coagulant, Alum.
• To determine optimum dosage of natural coagulant, Azadirachta indica adding with reduced dosage of Alum.
• To compare the efficiency of chemical coagulant with natural coagulant.
2. Experimental program
The program has been designed to investigate the quality characteristics such as pH and Turbidity of Hussain Sagar Lake. Water samples were collected from Hussain Sagar Lake. Neem (Azadirachta indica) leaf powder was utilized along with Alum (Aluminium Potassium Sulphate) for the sustainable removal of turbidity.

2.1. Materials
2.1.1. Coagulants
a) Alum. Alum also known as Potash Alum (Aluminium Potassium Sulphate-KAl(SO₄)₂·12H₂O), a colorless astringent compound is a hydrate resulted from the combination of anhydrous aluminium sulphate with 12 mol. eq of water. It is widely used as a coagulant from ancient times. It is added in water purification processes where it combines with colloidal particles in water, neutralizes their electrical charges and clump them together which can be removed easily thereafter. Alum is a pH dependent coagulant, needs alkaline condition to give appropriate results. As flocs growth depends on pH, mixing conditions, it is suitable to have pH of water from 5.8 to 6.5. American Water Works Association (AWWA) recommends aluminium standards should not exceed 0.05ppm or mg/l and USEPA also recommends its level should not be more than 0.2 ppm. If it exceeds the limit, it causes throat swelling, skin ulcers, Alzheimers and cancer in human beings. 5gr of Alum is added with 500ml of distilled water to prepare alum solution where 1ml is equal to 10mg of alum.

b) Azadichta indica. Commonly called as Neem tree and Indian lilac belongs to Meliaceae family is widely available in Indian subcontinent. It is a natural herb known for its pesticidal and insecticidal properties. Neem leaves contain protein (7.1%), carbohydrates (22.9%), minerals, calcium, phosphorus, vitamin C, carotene etc. But they also contain glutamic acid, tyrosine, aspartic acid, alanine, praline, glutamine and cystine like amino acids, and several fatty acids (dodecanoic, tetradecanoic, elcosanic, etc.

i) Neem Leaf powder (NLP)as an adsorbent followed by coagulant. Neem Leaf Powder functions by means of adsorption mechanism followed by charge neutralization or polymeric bridging effect [1]. NLP can be a potential, low cost adsorbent as It has been considered from Muhammad B. Ibrahim Muhammad S. Sulaiman and Sadiq Sani [2] that the NLP was analyzed its morphological characteristics by Scanning Electronic Microscopy (SEM) and declared that the adsorbent was assemblage of fine particles without fixed shape and size and also consists mainly C and O, small amounts of Ca, Mg, K, P, S determined by using Energy-dispersive X ray(EDX) Spectroscopy. Percentage moisture< ash content < organic matter contents of the NLP were reported. NLP can be an effective adsorbent as it attains effective binding mechanism onto the biomass which has been determined by Fourier Transform Infra Red(FTIR) Spectrocopy. As turbidity is caused by suspended, colloidal and dissolved solids in water, colloidal particles will not be settled by plain sedimentation process in water treatment works due to electrostatic charges of particles. Neem Leaf Powder is an efficient adsorbent and coagulant as it contains positively charged proteins soluble which adheres the particle, neutralize their charges and causes the formation of floc which can be easily removed thereafter.

ii) Preparation of Neem Leaf Powder
Neem leaves were collected from nearby sources of Medchal, Telangana, India and washed thoroughly with distilled water to remove dust and impurities from them. Then the leaves were dried under the sun for 4 to 5 days and ground to make them in powder form. The resulted powder was then sieved by 90
micron sieve which was ready to utilize as a bio coagulant for the experiment. Potash alum and Neem leaf powder is shown in figure 3.

**Figure 3.** Potash alum and Neem leaf powder

2.2. **Methodology and test procedures**

2.2.1. **Grab Sampling.** A 50-litre sample was collected by grab sampling method where the sample represents holistic characteristic, concentration and measurement of Hussain Sagar Lake at a point of specific time. Care has been taken that there is no gas above the sample and also checked the retention of physical, chemical and biological parameters without any change in it as per IS 3025-1(1987) [8]. pH was determined by digital pH meter in the laboratory by calibrating it with standard buffer solutions pH4, pH7 and pH9.2. figure 4 shows the pH meter and Nephelometric Turbidity meter.

Turbidity measures the ability of light transmittance of water. Turbidity imparts anaesthetic color to water due to the presence of suspended, colloidal and dissolved solids. The test conducted according to IS 3025-10(1984) [9] by nephelometric turbidity meter which works on the principle of capturing scattered light from the solution and was calibrated by Hexamethylene Tetramine and Hydrazine solution. The resulted turbidity is expressed in terms of Nephelometric Turbidity Unit (NTU).

Physical and chemical characterization of Hussain sagar lake before and after the treatment with mixed coagulant is illustrated in Table1.

2.2.2. **Jar Test.** Jar test was conducted to obtain the optimum dosages of Alum, Neem leaf powder, Neem leaf solution and their combinations as per IS 3025-50 [10]. As there was lower pH investigated in lake water from pH determination, Sodium bicarbonate was used to raise pH to 6.3 for increasing alum efficiency. Homogenous Hussain Sagar Lake water sample was taken in 14 jars of litre capacity each. 5gm of Alum is dissolved in 500ml distilled water to prepare Alum solution where 1ml was equal to 10mg. 2ml to 28ml of varied concentrations of alum from above solution were added to jars accordingly. Set the paddles at the midst of samples as shown in figure 5. Run the paddles at a speed of 100 rotations per minute for 1 minute and slowed down the paddles at a speed of 30-40 rotations per minute for 30 minutes. Turned off the Jar Test Apparatus and kept the samples without disturbance for 10 minutes so that the floc formed during the process can be settled. The small amounts of water from each jar were tested for their turbidity in NTU. The concentration of samples and turbidity were plotted in the graph.

**Figure 4.** pH meter and Turbidity meter
The dosage sample which has shown the least turbidity was considered as optimum dosage of Alum coagulant respectively.

3. Results and discussions

3.1. Turbidity and pH value.
Turbidity and pH values along with other physicochemical characteristics of the Hussain Sagar lake water before and after treatment with mixed coagulant have been determined as per the guide lines of IS 3025-10(1984)\(^9\) and compared with permissible limits(IS 10500:2012) as given in Table 1.

3.2. Optimum dosage of Alum
Jar test was conducted to determine the optimum dosages of coagulants to evaluate the turbidity of lake water. Alum solution dosage of 2 to 28 ml with an increment of 2 ml from the Alum solution (5gr of Alum into 500ml distilled water) was added to the samples to determine turbidity. Test results are given in Table 2.

The least turbidity of 5.7 NTU was observed at 24ml of alum solution where alum dosage is calculated as 240mg per litre. The turbidity removal efficiency was observed to be 70.9%. Figure 6 illustrates the Alum dosage variations.

3.3. Optimum dosage of Neem Leaf Powder (NLP)
Neem leaf powder of 0.1 to 1.0 gm. with an increment of 0.1gm was added to the jars with homogenous sample for conducting Jar test. Least turbidity 6.9NTU was observed at the dosage of 0.8gm of NLP in 1litre of sample which has been considered as optimum dosage of bio coagulant as shown in figure 7. The turbidity removal efficiency was achieved to be 64.7% from the experiment. The observations are shown in the Table 3.

3.4. Optimum dosage of Neem leaf Solution (NLS)
0.8gm of NLP was dissolved in 1lt of Distilled water to prepare Neem Leaf solution where 1ml is equal to 0.8mg of NLP. Varying dosages 2ml to 12ml of NLS have been added to the jars of 1lt capacity each for determining optimum dosage of NLS in lake water. The least turbidity 7.2NTU was observed at the dosage of 6ml (4.8mg) of NLS which has been considered as optimum dosage of coagulant shown in figure 8. The turbidity removal efficiency was achieved to be 63%. The observations are shown in Table 4.

3.5. Optimum dosage of mixed coagulant (NLS+Alum).
Varying dosages 2ml to 14ml of Alum solution were added to the constant dosage of 6ml of NLS to the jars containing one litre of lake water sample each. Paddles were set at the midst of sample and stirred at the speed of 120 rotations per minute for 2 minutes for rapid mixing and slowed down to 40 rotations per minute for 30 minutes. Jar test Apparatus was switched off and jars were kept without disturbance. The turbidity of each jar was measured with nephelometric turbidity meter for various dosages shown in Table 5. Optimum dosage of mixed coagulant (NLS+Alum) is illustrated in figure 9.
Table 1. Quality Characteristics of Hussain Sagar lake Water sample

| Quality Characteristics | Before Coagulation | After Coagulation | Permissible limits (IS 10500:2012) |
|-------------------------|--------------------|-------------------|-----------------------------------|
| pH                      | 4.84               | 7.5               | 6.5 to 8.5                        |
| Turbidity (NTU)         | 19.6               | 1.0               | <5                                |
| Total Solids (mg/L)     | 3124               | 380               | 2000                              |
| Alkalinity (mg/L)       | 212                | 164               | 200(as CaCO3)                     |
| Total Hardness ((mg/L)  | 310                | 187               | 200(as CaCO3)                     |
| BOD (mg/L)              | 59.8               | 6.7               | 3                                 |
| COD (mg/L)              | 128                | 35.3              | 10                                |
| DO (mg/L)               | 1.34               | 3.2               | >4                                |
| Nitrates (mg/L)         | 84                 | 34.1              | 45                                |

NTU: Nephelometric Turbidity Unit

Table 2. Optimum dosage of Coagulant-Alum

| Alum dosage (ml/L) | Turbidity (NTU) |
|--------------------|-----------------|
| 0                  | 19.6            |
| 2                  | 15.6            |
| 4                  | 13.3            |
| 6                  | 12.5            |
| 8                  | 11.6            |
| 10                 | 11.1            |
| 12                 | 10.8            |
| 14                 | 8.7             |
| 16                 | 7.5             |
| 18                 | 7.1             |
| 20                 | 6.6             |
| 22                 | 5.7             |
| 24                 | 6.9             |
| 26                 | 8.3             |
| 28                 | 9.1             |

Table 3. Optimum dosage of Bio coagulant-(NLP)

| NLP-dosage (gm/L) | Turbidity (NTU) |
|-------------------|-----------------|
| 0.0               | 19.6            |
| 0.1               | 15.2            |
| 0.2               | 13.6            |
| 0.3               | 12.8            |
| 0.4               | 10.5            |
| 0.5               | 9.7             |
| 0.6               | 8.8             |
| 0.7               | 7.2             |
| 0.8               | 6.9             |
| 0.9               | 8.3             |
| 1.0               | 9.1             |

NLP: Neem Leaf Powder

Table 4. Optimum dosage of Bio coagulant Solution-(NLS)

| NLS-dosage (ml/L) | Turbidity (NTU) |
|-------------------|-----------------|
| 0.0               | 19.6            |
| 2                 | 12.2            |
| 4                 | 9.6             |
| 6                 | 7.2             |
| 8                 | 8.3             |
| 10                | 8.8             |
| 12                | 9.1             |

NLS: Neem Leaf Solution

Table 5. Optimum dosage of NLS along with Alum

| Alum (0-14ml)+NLS 6ml | Turbidity (NTU) |
|-----------------------|-----------------|
| 0                     | 19.6            |
| 2                     | 11.4            |
| 4                     | 7.8             |
| 6                     | 4.9             |
| 8                     | 1.0             |
| 10                    | 3.8             |
| 12                    | 4.6             |
| 14                    | 5.1             |

Figure 6. Alum dosage variation
The turbidity of Hussain Sagar Lake water has been reduced to 1NTU was observed at 8ml (80mg) of Alum solution along with 6ml (4.8mg) of NLS. The turbidity removal efficiency of this method was identified to be 94.8%. Experimental setup with least turbidity values are shown in figure 10.
3.6. Coagulants efficiency.

Higher turbidity removal efficiency 94.8% was achieved by NLS along with Alum, where as individual efficiencies of Alum and NLS were observed 70.9% and 63% respectively. The percentage efficiencies of coagulants were illustrated in figure 11.

![Figure 10. Least turbidity values](image)

**Figure 10.** Least turbidity values

![Figure 11. Removal efficiency of coagulants](image)

**Figure 11.** Removal efficiency of coagulants

3.7. Sludge Management. Sludge can be treated to reduce its weight by sludge thickening process. Sludge can be dried under the sun and added to a landfill. As the sludge formed from mixed coagulant treatment is rich in nutrients, important nutrients can be recovered and used as fertilizer. Neem Leaf Powder can reduce microbial population efficiently so that sludge is free from harmful microbes can be used in agricultural practices.

3.8. Comparison of results with other studies

The present study results were compared with the previous experimentations, which is illustrated in Table 6.

**Table 6.** Comparative statement of present and previous studies

| Previous study                  | Water Sample          | Bio coagulant used                  | Reduction of Turbidity(NTU) |
|---------------------------------|-----------------------|------------------------------------|----------------------------|
| Rubini S, Balamurugan P, Shunmugapriya.K[6] | Kitchen used Waste water | Neem Leaf solution Opuntia Solution Opuntia Powder & Alum Alum &Neem Leaf Powder | 90 to 38.5 90 to 32.1 90 to 3.5 90 to 4.1 |
| Anju S and K.Mophin-Kani[4]     | Dairy Waste water     | Neem Leaf Powder Orange Peel Powder Alum | 260 to 4 260 to 8 260 to 3 |
| Present Study                   | Hussain sagar lake water | Alum Neem Leaf Solution Alum+Neem Leaf Solution | 19.6 to 5.7 19.6 to 7.2 19.6 to 1 |
4. Conclusion.
From the above study, it has been observed that the chemical coagulants can be partially replaced with widely available natural coagulants such as Neem Leaf Powder.

1. Turbidity of Hussain Sagar Lake was reported higher levels as 19.6 NTU above permissible limits (5NTU).
2. When the Alum alone with higher concentration level was used, 70.9% of turbidity removal efficiency was obtained along with higher amount of sludge which can alter the characteristics of lake.
3. When the NLS was used alone, 63% of removal efficiency was observed with reduced amount of sludge.
4. When NLS along with reduced amounts of alum is utilized, 94.8% of turbidity removal efficiency was achieved without posing threat to the characteristics of lake water. So, it is concluded that the bio coagulant can be the best option as alternate coagulant in water treatment processes.
5. The nutrient rich sludge raised from bio coagulation(mixed coagulant) can be treated by sludge thickening, and used for land filling, composting and agricultural activities.

Recommendations
The author recommends the mixed coagulant (NLS+Alum) is appropriate to reduce the turbidity economically for the Hussain Sagar Lake water.

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