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# Use of Oak Bark Powder as Natural Coagulant in Turbidity Removal of Water

**by**

**Deepak Raj Bhatta**

**A THESIS**

**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING**

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**TRIBHUVAN UNIVERSITY**

# INSTITUTE OF ENGINEERING

**CENTRAL CAMPUS, PULCHOWK**

**DEPARTMENT OF CIVIL ENGINEERING**

The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **" Use of Oak Bark Powder as Natural Coagulant in Turbidity Removal of Water "** submitted by Mr. Deepak Raj Bhatta in partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering.

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# ABSTRACT

Coagulation is an important water treatment process used to reduce water turbidity. In this study, the effectiveness of a natural coagulant derived from an oak bark for turbidity removal was evaluated using jar test. Initial turbidity values of sample water were from 25-300 NTU which was reduced by as much as 96.6 % using dose of 2.5 ml from 77 mg/l and 96.1% using dose of 0.5 ml from 77 mg/l concentration of oak bark powder extract respectively. In continuous flow turbidity was varied from 25–300 NTU for which 1.5 m distance was enough for turbidity removal by using oak bark powder extract of 77 mg/l optimum dose. It was indicated that the coagulant did not have a considerable effect on final pH of the water. Different concentrations 76, 77 and 78 mg/l of oak bark extract added shows clear correlation with the final turbidity. High turbidity removal determined in this study indicates that oak bark has the potential to be utilized for water treatment applications for 25–300 NTU turbidity range.

## ACKNOWLEDGEMENT

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Deepak Raj Bhatta

069/MSE/r/904

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ADF | - | Acid Detergent Fiber |
| ADL | - | Acid Detergent Lignin |
| CP | - | Crude Protein |
| IOE | - | Institute of Engineering |
| NAST | - | Nepal Academy of Science and Technology |
| NDF | - | Neutral Detergent Fiber |
| NDWQS | - | Nepal Drinking Water Quality standard |
| NRC | - | National Research Council |
| NTU | - | Nephelometric Turbidity Units |
| NWSC | - | Nepal Water Supply Corporation |
| OM | - | Organic Matter |
| TA | - | Total Ash |
| WHO | - | World Health Organization |
| % | - | Percentage |
| gm | - | Gram |
| Kcal | - | Kilo calorie |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background

Drinking water is safe enough to be consumed by humans or used with low risk of immediate or long term harm. In most developed countries, the water supplied to households, commerce and industry meets drinking water standards, even though only a very small proportion is actually consumed or used in food preparation. Typical uses (for other than potable purposes) include toilet flushing, washing and irrigation. Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with disease vectors, pathogens or unacceptable levels of toxins or suspended solids. Drinking or using such water in food preparation leads to widespread acute and chronic illnesses and is a major cause of death and misery in many countries (WHO, 1996 ). Reduction of waterborne, water washed and water vector diseases is a major public health goal in developing countries like Nepal.

Actually there are several methods available for water treatment:

Pre-chlorination - for algae control and arresting any biological growth

- Aeration - along with pre-chlorination for removal of dissolved iron and manganese
- Coagulation- -to improve coagulation and for thicker floc formation
- Sedimentation - for solids separation, that is, removal of suspended solids Filtration - removing particles from water with help of filter media
- Desalination - Process of removing salt from the water
- Disinfection - for killing bacteria.

In developing country like Nepal, most of water treatments are not done sufficiently. This is due to the financial condition and lack of the knowledge of technologies. So for the developing countries like Nepal, there is the search for some low cost technologies methods for water treatment. Therefore there is need for cheaper, easier and sustainable options for water treatment.

Most of the water supply projects in the country are running without any treatment. Only a small number of water supply projects, very less water supply projects so far in the country have treatment plants. It is therefore evident that treated water is not available to the vast majority of the population in the country. Quality of water is not stable due to suspended and colloidal particles load caused by land development and high storm runoff during the rainy seasons especially in a country like Nepal. Even if treatment plants were built in some water supply projects, they did not run for long time due to the operational difficulties. Practical experience in existing water treatment plants in Kathmandu and other towns shows that conventional treatment plants are not only costly to operate and maintain but also demand skilled personnel. Khanal (2000) has reported the turbidity of some rivers of Nepal during the rainy season up to 300 NTU. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote re-growth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis throughout the world. Generally, coagulants are added to turbid water in order to destabilize particles and reduce inter-particle repulsion forces. Coagulation with extracts from natural and renewable vegetation has been widely practiced since recorded time.

## 1.2 Rationale of the Study

From ancient time turbidity in water due to the presence of suspended and colloidal impurities has been a challenge for the purpose of safe drinking water supply. Coagulant plays an important part in areas of water treatment. Inorganic coagulants that are used widely have disadvantages such as large dosage and harmful to human body, and on the other hand synthetic organic coagulant has disadvantages of high price and toxicity. Natural coagulants as oak bark powder shows bright future and may be alternate to inorganic coagulants and synthetic organic coagulants concerned by many researchers because of their abundant source, locally availability, multifunction, and low price.

Oak has received great degree of attention in recent years because it contains constituents capable of performing turbidity removal with coagulation with flocculation mechanism. In Nepal, Oak tree is deciduous and evergreen species extending from cool temperate to tropical latitudes and grows between 1700 m to 3800 m altitude all over Nepal but oak bark is not used for any commercial purpose. Oak tree is dominantly found in Humla and Jumla regions in Nepal. It doesn't contribute the drastic pH reduction to the treated water. Since it has turbidity removal efficiency up to 96.63% without using other coagulant for up to 300 NTU turbid water it can be used as a coagulant.

## 1.3 Objectives of the Study

The main objective of the study is:

- To determine the use of oak bark powder as a natural coagulant for turbidity removal of water.

The specific objectives of this study are:

- To determine the optimum dose of oak bark powder in batch and continuous flow
- To compare coagulation efficiency of oak bark powder and alum.

## 1.4 Limitations of the Study

The limitations of this study are listed below:

- Temperature variation within the day in the turbidity removal has not been considered in the study.

## 1.5 Organization of the Study

This report is organized into five chapters as:

Chapter I deals with introduction, rationale of the study, objectives of the study, and limitation of the study.

Chapter II describes the theories, which is related with the study. It contains relevant information and data available in past research, papers, journals etc.

Chapter III describes the methodology adopted for this research.

Chapter IV this chapter shows the results obtained during the study period.

Chapter V this chapter contains all conclusions and recommendations regarding the whole study so that it will help for future research and study of same nature.

The appendices contain some graphs, tables and outputs. It also contains different data used in the research works.

## CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Turbidity

Turbidity of water is caused by suspended matter, such as clay, silts, finely divided organic and inorganic matter soluble organic compounds and plankton and other microscopic organism. Turbidity expresses the optical property that causes light to scatter and absorb instead of transmitting it in a straight line. It is measured in Nephelometric turbidity unit (NTU). Turbidity is an important consideration in public water supplies turbid water has muddy or cloudy appearance and is aesthetically unattractive. The character and amount of turbidity depends on the type of soil over which the water has moved. WHO guideline has set the limiting turbidity value of 5 NTU for drinking water purpose (WHO, 2006)

Most of the water sources in Hilly and mountainous regions of Nepal are dependent on natural streams and rivers. Turbidity is among the fluctuating variable of the stream with respect to season. Khanal (2000) has reported the turbidity of some streams/rivers of Nepal during the rainy seasons as given in the Table 2.1 below.

Table 2. 1: Turbidity of typical stream sources

| S.N | Name of source | Location | Turbidity (NTU) |
|---|---|---|---|
| 1 | Sera | Panchkanya, Sunsari | 250 |
| 2 | Kadam | Kerabari, Morang | 300 |
| 3 | Solti | Mangalbare, Morang | 250 |
| 4 | Jharna | Satasidham, Jhapa | 190 |
| 5 | Kodku | Kodku, Lalitpur | 190 |

## 2.2 Analysis of Oak Bark

An oak is a tree in the genus Quercus of the beech family, Fagaceae. There are approximately 600 species of oaks. The common name "oak" may also appear in the names of species in related genera, notably Lithocarpus. The genus is native to the Northern Hemisphere, and includes deciduous and evergreen species extending from cool temperate to tropical latitudes in the Americas, Asia, Europe, and North Africa. Oak tree is widely spread in different areas of the world .North America contains the largest number of oak species, with approximately 90 occurring in the United States. Mexico has 160 species, of which 109 are endemic. The second greatest center of oak diversity is China, which contains approximately 100 species.

Oaks have spirally arranged leaves, with lobate margins in many species; some have serrated leaves or entire leaves with smooth margins. Many deciduous species are marcescent, not dropping dead leaves until spring. In spring, a single oak tree produces both male flowers (in the form of catkins) and small female flowers. The fruit is a nut called an acorn, borne in a cup-like structure known as acupule; each acorn contains one seed (rarely two or three) and takes 6–18 months to mature, depending on species. The live oaks are distinguished for being evergreen, but are not actually a distinct group and instead are dispersed across the genus.

In Nepal, Oak tree is deciduous and evergreen species extending from cool temperate to tropical latitudes. In western Nepal it is dominant whereas in central and eastern Nepal it tends to be confined to warmer drier south- facing slopes In the Humla-Jumla area it is dominant. In Nepal local name of oak tree is “Baanj”. There has been a resurgence of intrest in using naturally occurring alternatives to currently used coagulants for water treatment in developing countries mainly due to cost implications that are associated with inorganic chemicals and synthetic organic polymers (Mariam, 2011)

Oak bark contains the compound called as tannin. Tannin a general name given to large polyphenol compounds obtained from natural materials, for example bark and wood of trees such as Acacia, Castanea, or oak (Beltrán-Heredia *et al.*, 2010). There have been many reports on the use of tannin in medical field and as natural coagulant for water treatment. They are used in dairrhoea treatment; gum problems etc. Researchers have concluded that tannin is an excellent substitute to chemical coagulants. The effectiveness of tannin as a natural coagulant for water treatment is influenced by the chemical structure of tannins that are present within. The presence of phenolic groups in tannin clearly indicates its anionic nature since it is a good hydrogen donor. Fig.2.1 illustrates the schematic representation of basic tannin structure in aqueous solution and possible molecular interactions that induce coagulation. It is common knowledge that phenolic groups can easily deprotonate to form phenoxide which is stabilized via resonance. This deprotonation is attributed to delocalization of electrons within the aromatic ring which increases the electron density of the oxygen atom. This provides an indication that the more phenolic groups are available in a tannin structure, the more effective its coagulation capability.

The usage of natural coagulants derived from plant based sources represents a vital development in sustainable environmental technology since it focuses on the improvement of quality of life for underdeveloped communities(G. Vijayaraghavan *et al.*, 2011). Nonetheless, there are many pressing issues that are hindering process development of these coagulants, namely, absence of mass plantation of the plants that affords bulk processing, perceived low-volume market and virtually non-existent supportive regulation that Stipulates the quality of the processed coagulant .The last factor is especially vital since it is normally difficult for regulatory authorities to endorse a product for sale to the general public. In view of this, it is felt that application is currently restricted to small-scale usage and academic research stakeholders, particularly from the authorities. As such, it is always prudent for water treatment practitioners to select the most suitable natural coagulants and tailor them for specific proposes.

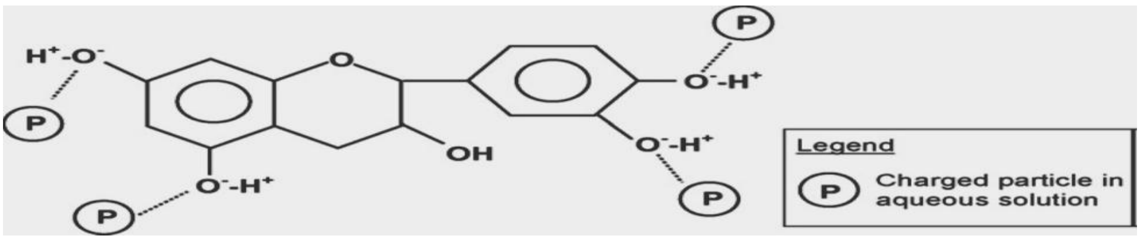



Figure 2. 1: Structure of constituent species of Tannin

**2.3 Reaction Mechanism: Coagulation with Flocculation**

Water is chemically treated to adjust pH, to remove solids, to disinfect water, to oxidize and to reduce dissolved elements.  Coagulation-flocculation is one of the important processes that involved in conventional water treatment, at which it is able to achieve such objectives. Coagulation may be defined as adding those substances which are capable of removing colloidal impurities from water. The purpose of coagulation is to turn the small particles of colour, turbidity and bacteria into large flocs, either as precipitates or suspended particles (Spellman *et al.*, 1999) .It is presented in Figure 2.2.

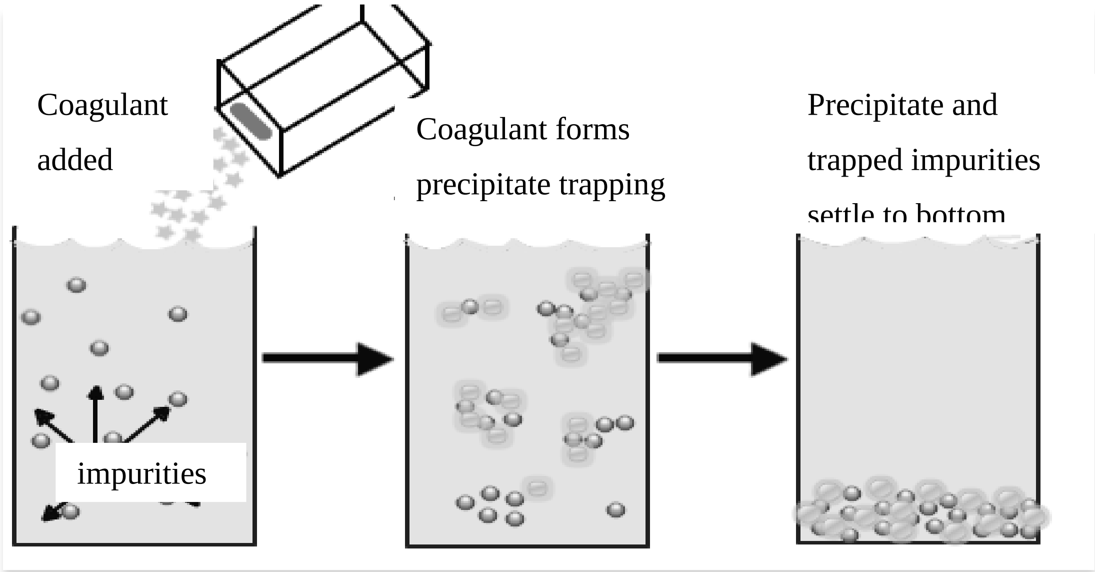



Figure 2. 2 : Coagulation with flocculation process

Aluminum salts are widely used as chemical coagulant in the water purification process all over the world. However, recent studies have raised doubts about the advisability of introducing aluminium into the environment, especially concerning about residuals in the treated water, large production of sludge volume and Alzheimer's disease (Ndabigengesere and Narasiah, 1998). There is also another problem of alum's reaction with natural alkalinity present in the water leading to a reduction of pH and low efficiency in coagulation in ambient temperature. Ferric salts and synthetic polymers have been used as alternatives but those chemicals can be a serious problem because of secondary contamination of drinking water with traces of toxic synthetic polymeric coagulants or residual iron and aluminum ions .Moreover many developing countries can hardly afford the costs as well as the low availability of such chemicals for water and wastewater treatment (Young *et al*, 2006). Natural coagulants of vegetable and mineral origin were in use in water and wastewater treatment before the advent of synthetic chemicals like aluminium, ferric salts (Ndabigengesere and Narasiah,1998).

# CHAPTER THREE

## 3.0 METHODOLOGY

The proposed study work was mainly focused to find out optimum dose of Oak bark powder for removal of turbidity in water by batch and continuous set up. The study was prepared in the laboratory of Environmental Engineering of IOE Pulchowk campus.

### 3.1 Material and Its Preparation

The botanical name of Oak tree used in the experiment was *Quercus semecarpifolia* .The constituents of Oak bark studied in Nepal Academy of Science and Technology laboratory is as in Table 3.1.

Table 3. 1: Constituent species of oak bark

| SN. | Description | | Unit | Remarks |
|---|---|---|---|---|
| 1. | English local name | Oak Bark | | |
| 2. | Botanical name | *Quercus semecarpifolia* | | |
| 3. | Organic matter (OM) | 89.32 | % | Total 100% |
| 4. | Total ash (T.ash) | 10.68 | % | |
| 5. | Tannin | 8.98 | gm | Per 100gm |
| 6. | Ether Extract (EE) | 2.32 | gm | |
| 7. | Non Detergent Fiber (NDF) | 44.58 | gm | |
| 8. | Acid Detergent Fiber (ADF) | 11.24 | gm | |
| 9. | Acid Detergent Lignin (ADL) | 3.38 | gm | |
| 10. | Ca(mg) | 0.69 | gm | Per 100gm |
| 11. | Energy | 39.80 | Kcal | Per 100gm |
| 12. | Volatile solid | 60.00 | gm | Per 100gm |

Oak bark was collected from the area of lakuri bhanjyang side of Lalitpur District. Firstly the undesired parts were removed via cutting and slicing. Then it was cut for the small pieces and dried for 24 hours at $80 \pm 5°C$ and milled and sieved to obtain the solids with the diameter of nearly 0.8 mm. The solid was used as raw coagulant to treat with synthetic water.

## 3.2 Experimental Set Up and Procedure

In the experimental set up, a Batch reactor laboratory treatment unit was arranged for which the jar test apparatus was performed for finding the optimum dose of coagulant.

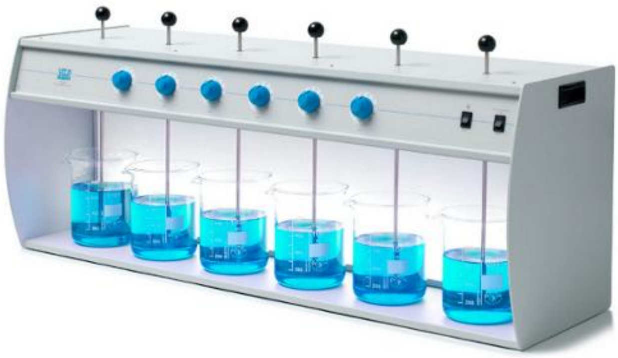


Figure 3. 1 : Jar test apparatus

A standard jar test apparatus was used in the coagulation test. Prepared water samples (500 ml) were stirred at 125 rpm for 2 min and coagulants was added into the samples during this time. Then the sample was stirred at 70 rpm for 30 min. After the agitation, the samples was stand for 30 min and then the turbidity sample was measured using a turbidity meter. Numbers of samples of various turbidity was taken and measured for tests about effect of oak bark powder coagulant dosage.

At first the mud slurry was taken from the bottom of the tank of the guard house near Zero energy house to prepare the turbid water of different units (i.e. 25 NTU , 50 NTU, 100 NTU, 150 NTU ,200 NTU, 250 NTU, 300 NTU). Different concentrations (i.e 76 mg/l, 77 mg/l, 78 mg/l) of oak bark extract were prepared by keeping calculated weight in 500 ml synthetic water and then stirred with magnetic stirrer. Then different volumes of that sample prepared (i.e 0.5 ml, 1 ml,1.5 ml ,2 ml,2.5 ml,3 ml) were added to the turbid water prepared with above process . A standard jar test apparatus was used in the coagulation test. Prepared different 6 water samples (500 ml) were stirred at 125 rpm for 2 min and 70 rpm for 28 min with different coagulant doses. Coagulant was added into the samples during this time. After the agitation, the samples were left for for 30 min and then the turbidity sample was measured using a turbiditimeter. Similarly pH of the samples was also measured. Numbers of samples of various turbidity was taken and measured for tests about effect of oak bark powder extract as coagulant dosage.

In the experimental set up, a continuous flow laboratory treatment unit was fabricated and used. It consists of water tank, tank with coagulation dose, mixing tank and sedimentation tank. In the mixing tank, sample water was stirred and sent to the sedimentation tank which maintains the constant flow rate. Different settling time period 10, 20, 30, 40, 50, 60, 90 and 120 minute was chosen to calculate the different flow rate of 21.52, 10.76, 7.17, 5.38, 4.30, 3.58, 2.24 and 1.68 liter/minute. Different distances in the sedimentation tank are taken for the observation of the effect in residual turbidity.

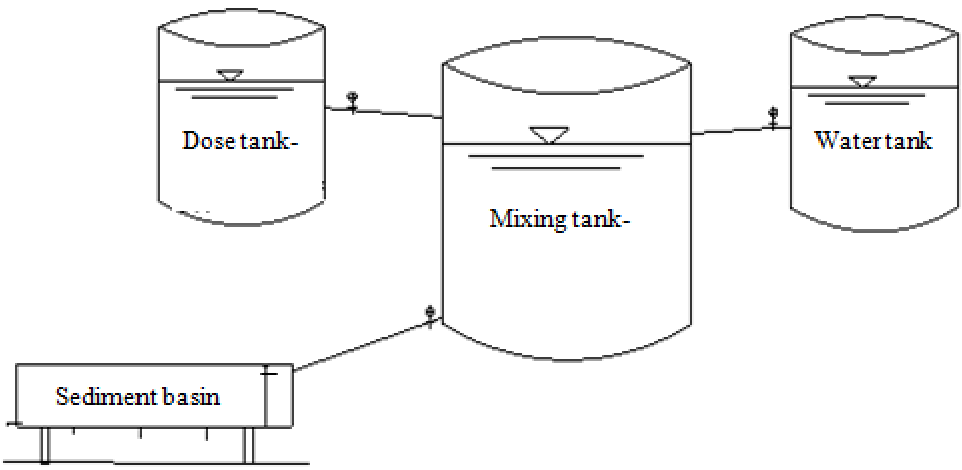



Figure 3. 2 : Set up for continuous flow

Sedimentation basin consists the size of volume (3.75*0.41 *0.35) $m^3$. It has both sides inlet as in the Figure 3.3.  It consists the seven ports with an interval of 350mm. It has four sludge extraction outlets in the bottom of the sedimentation tank.

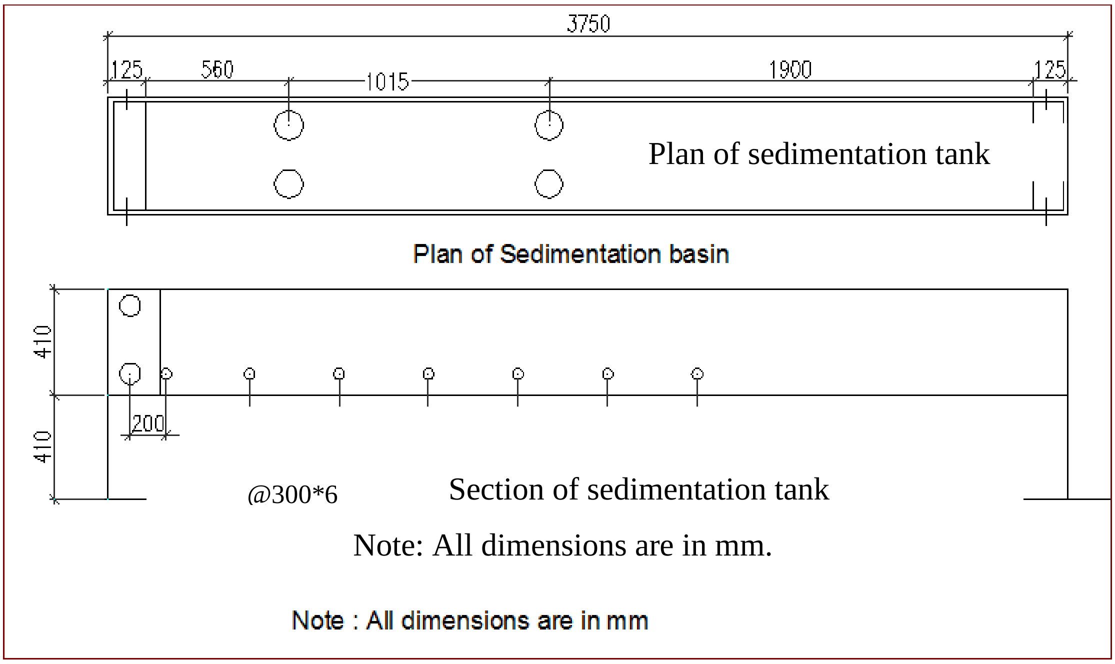



Figure 3. 3 : Plan and section of Sedimentation tank

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSIONS

The experiment results of turbidity removal of water by oak bark powder are presented in this chapter. The treatment process has to ensure that turbidity removal in the water sample is within the permissible limit 5 (10) NTU as prescribed by NDWQS in case of Nepal.

### 4.1 Laboratory studies

The initial turbidity around 25, 50, 100, 150, 200,250, and 300 NTU of water sample was treated by oak bark powder dose at the Environmental laboratory of IOE.

#### 4.1.1 Suspended stability test

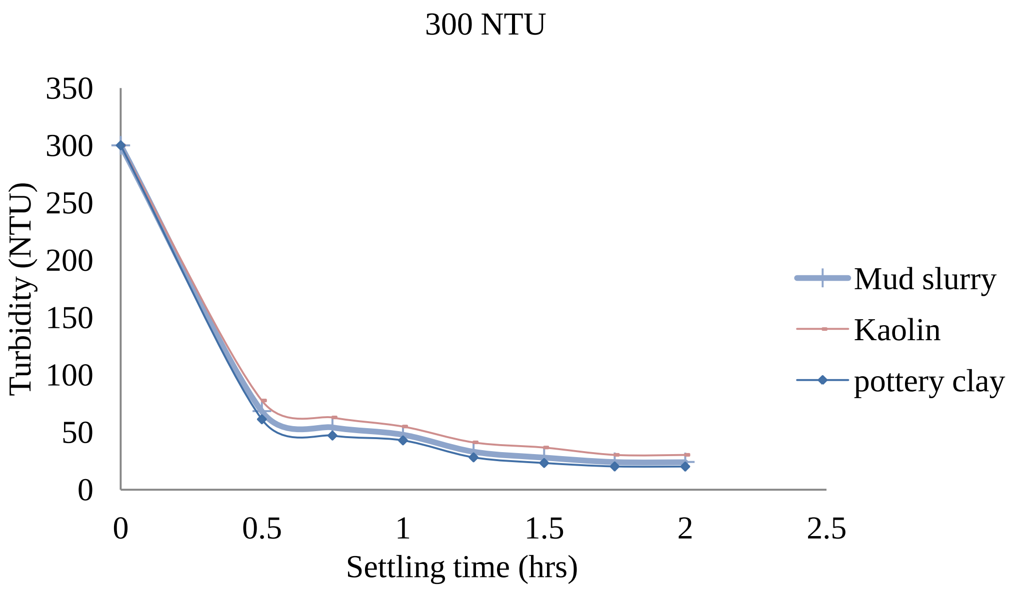



Figure 4. 1 : comparison of natural settling of mud slurry, kaolin and pottery clay

Suspension stability test for the mud slurry, kaolin and local pottery clay was conducted in the laboratory. The turbidity vs. settling time is shown above. It shows that kaolin is more stable than other two materials. However kaolin is expensive and is imported .The mud slurry can substitute kaolin for preparing the model as it deflects more realistic field situation. Actually above graph clearly depicts that from 300 NTU to 20.2 NTU the particles are suspended particles and the remaining particles are colloidal particles which are of concerned as the coagulation and flocculation mechanism only removes the colloidal particles.

Actually while using the turbid water, at first the turbid water was kept in the bucket and left for about 30 minutes in still condition. While doing so the suspended particles settled down at the bottom and only the upper part water of that bucket was used for doing the experiments. It is necessary to do that because the coagulation with flocculation mechanism removes only the colloidal particles and it is necessary to see the results in colloidal particles.

### 4.1.2 Batch study for synthetic water without using coagulant

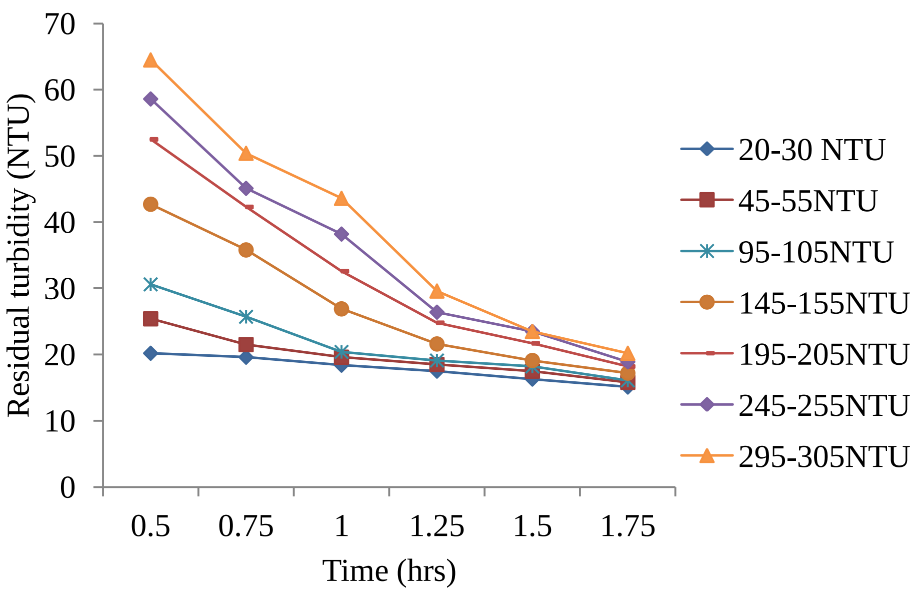


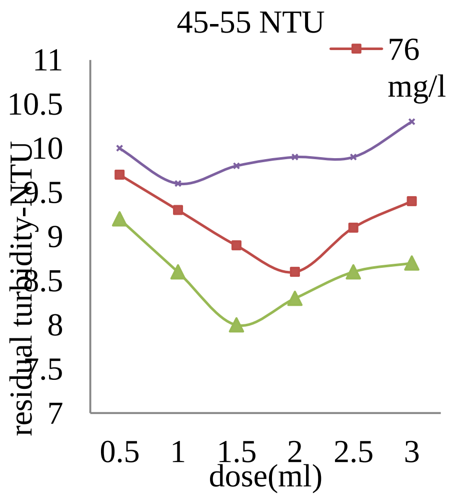

Figure 4. 2 : Turbidity profile of Synthetic water without using coagulant

The average initial turbidity of 25, 50, 100, 150, 200 and 250 NTU synthetic water with mud slurry sample was stirred in jar test for thirty minutes and it was settled for the period of 0.5, 0.75, 1.0, 1.25, 1.5 and 1.75 hours for each turbidity ranges. For the range of 20-30 NTU the residual turbidity becomes 20.2 NTU up to the settling time period of half hour while it becomes lowers up to the 18.4 NTU for the settling time period of 1 hours and 16.3 NTU for 1 hr 30 minutes. For the range of 45–55 NTU the residual turbidity becomes 25.4 NTU up to the settling time period of half hour while it becomes lowers up to the 19.6 NTU for the settling time period of 1 hours and 17.5 NTU for settling time of 1 hours and 30 minutes.. From the Figure 4.1 we can see that as the settling time increases the value of the residual turbidity is decreasing. By adding coagulant we can see that the residual turbidity level further decreases to lower value. Some portion of the turbidity is removed by plain sedimentation while some portion is removed by coagulation with flocculation mechanism. Hence we can observe that turbidity reduction using coagulant addition is more efficient than without adding coagulant.

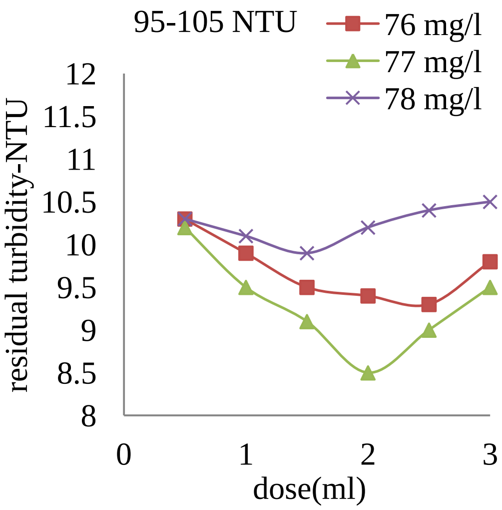
### 4.1.3 Batch study for synthetic water using oak powder dose as a natural coagulant

The average initial turbidity of 25, 50, 100, 150, 200 and 250 NTU water samples treated with different dose from the concentrations of 76 and 77 and 78 mg/liter are plotted as in Figure 4.2. From the Figure 4.2(a) for 20-30 NTU the reduced level of turbidity treated with the dose of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml taken from the concentration of 76 mg/liter concentration found to be 9.5, 9.0, 8.5, 8.3, 8.9 and 9.1 NTU respectively. Thus it indicates that turbidity level reduces up to the dose of 2 ml and no further effect in the turbidity with the increase of dose. Similarly for the concentration of 77 mg/liter the optimum removal efficiency occurs at the dose of 1.5 ml and for the concentration of 78 mg/liter the optimum removal efficiency occurs at the dose of 1.0 ml. Hence it can be concluded that for the turbidity 20-30 NTU or any other turbidity range, actually more the concentration of oak bark less is the dose of it required. Similarly from the Figure 4.2(c) 95-105 NTU, it can be concluded that the optimum removal efficiency occurs at the dose of 2.5 ml taken from the concentration of 76 mg/liter and 2ml for 77 mg/l and 1.5 ml for 78 mg/l .Therefore comparing the two figures 4.2(a) and 4.2(c), we can also see that as the turbidity value is increasing more is the dose of the coagulant required.

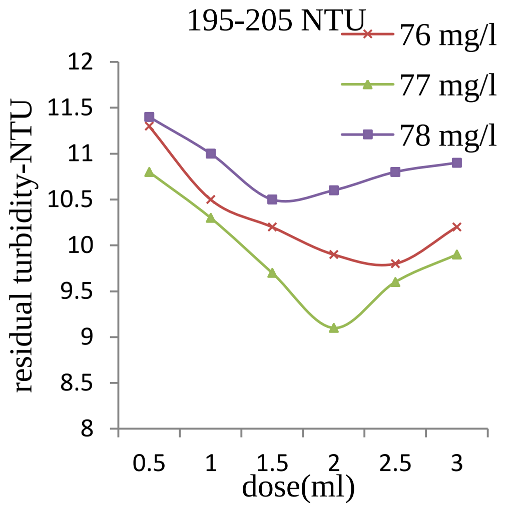
Actually, higher turbid water has higher amount of suspended and colloidal impurities thus it has more amount of negatively charged ions so to neutralize the higher amount of charged ions more concentration of the coagulant powder is required. Thus as the turbidity increases the dose of the prepared coagulant also increases. Similarly, with increase in the concentration of the oak bark powder it is seen that less amount of dose of the prepared sample is required. It is because of the fact that as the more concentration of the bark powder has already more amount of positive charged ions to itself now only small dose of the prepared samples would do the required coagulation process and vice versa . In conclusion, with increase in turbidity the dose also increases and vice versa. Similarly with increase in the dosage of the oak bark extract concentration the amount of the dose taken from the concentration also decreases and vice versa.


45-55 NTU
76
mg/l
11
10.5
10
9.5
9
8.5
8
7.5
7
residual turbidity-NTU
0.5
1
1.5
2
2.5
3
dose(ml)

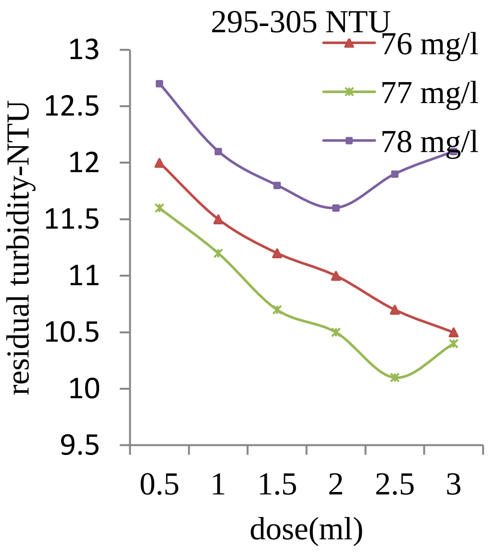
(a)


95-105 NTU
76 mg/l
77 mg/l
78 mg/l
12
11.5
11
10.5
10
9.5
9
8.5
8
residual turbidity-NTU
0
1
2
3
dose(ml)

(b)



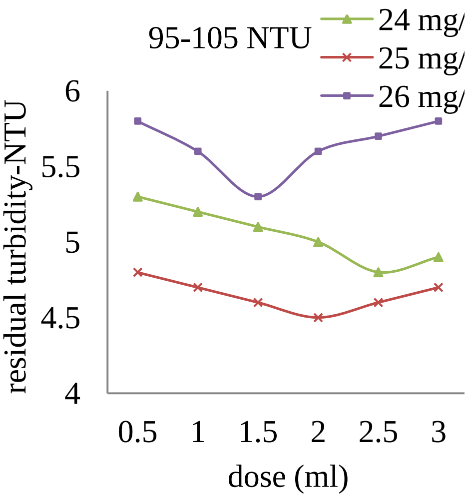

(c )



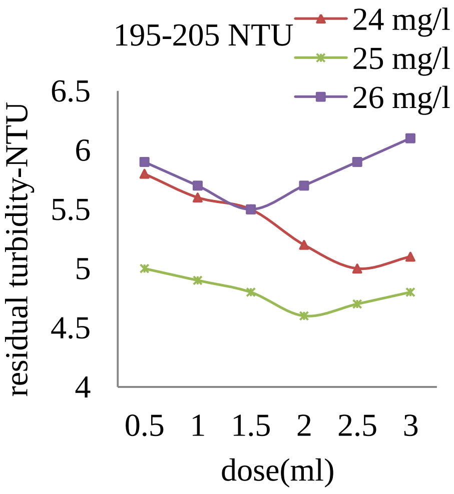

(d)

Figure 4.3: Turbidity profile of synthetic water for average initial turbidity (a) 50, (b) 100, (c) 200 and (d) 300 of oak bark powder dose at batch reactor.

### 4.1.4 Batch study for alum dose




(a)

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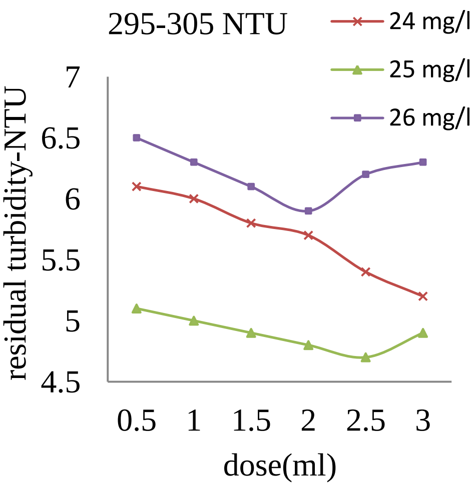
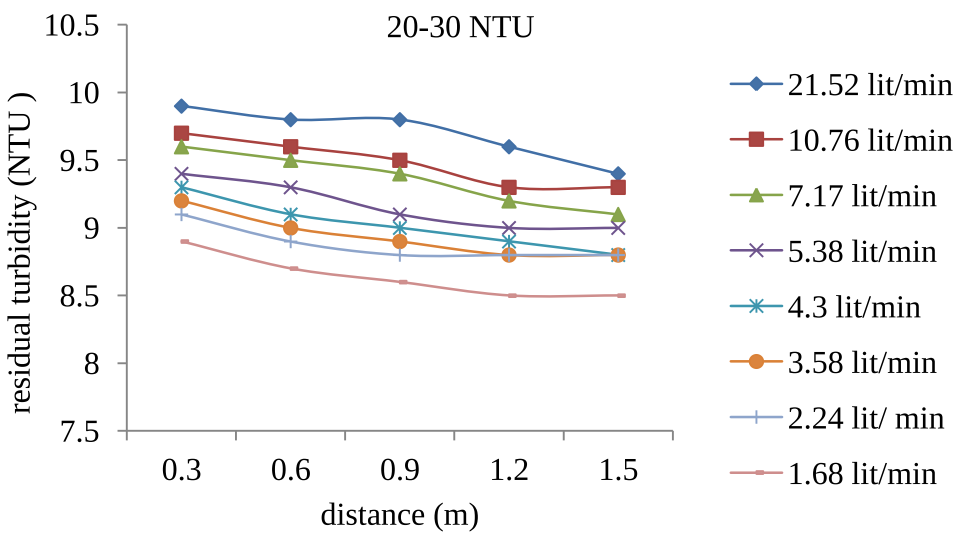


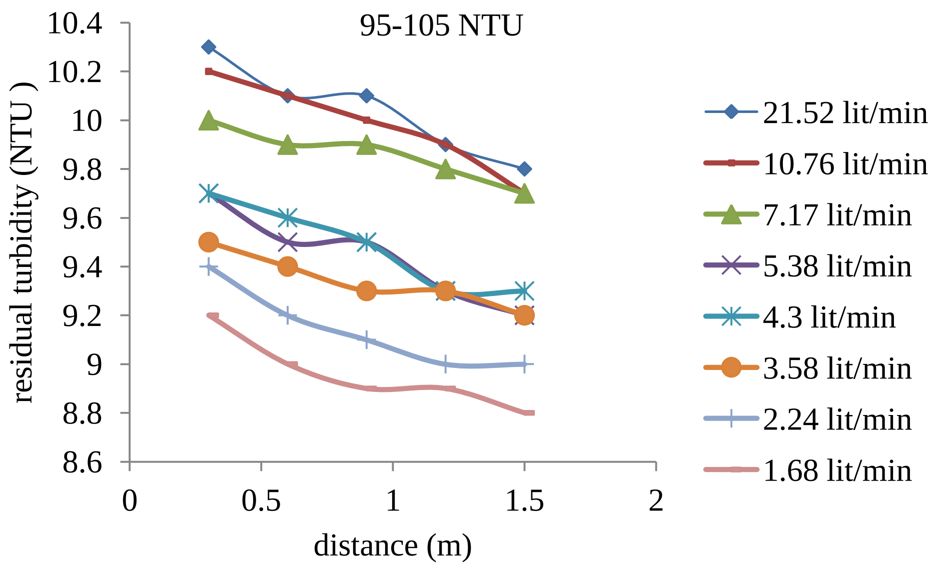

(c)

Figure 4.4: Turbidity profile of synthetic water for average initial turbidity (a) 100, (b) 200 and (c) 300 NTU of alum dose at batch reactor

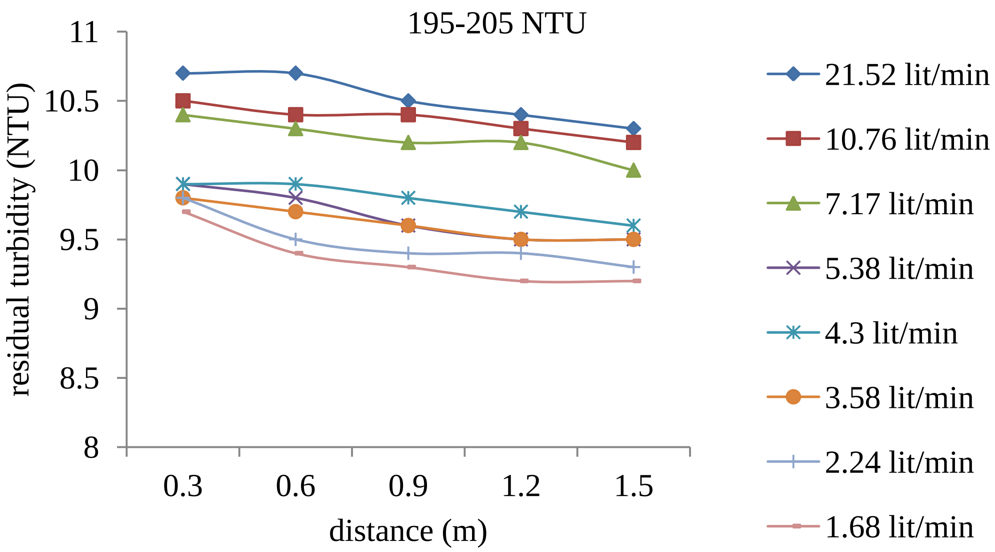
### 4.1.5 Continuous flow for oak powder dose treatment



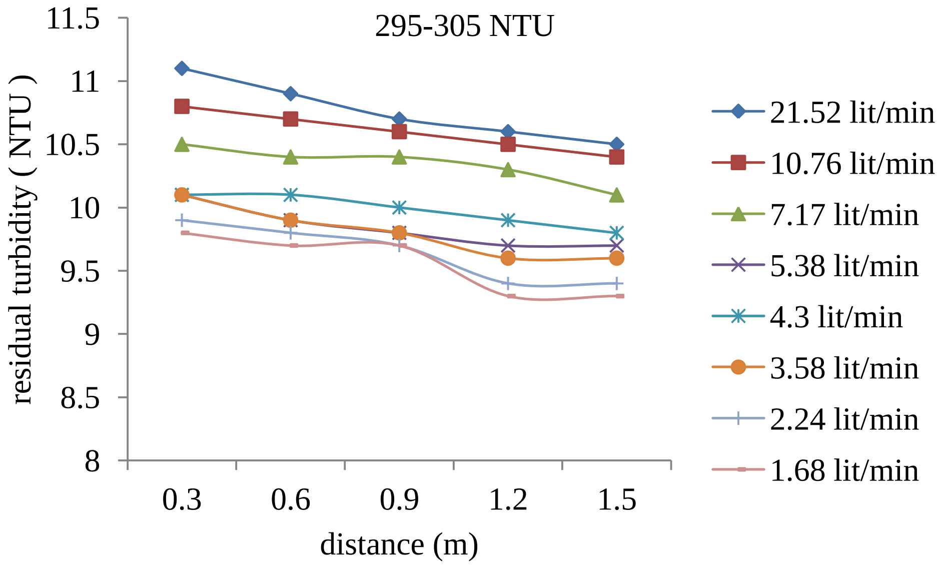

(a)




(b)



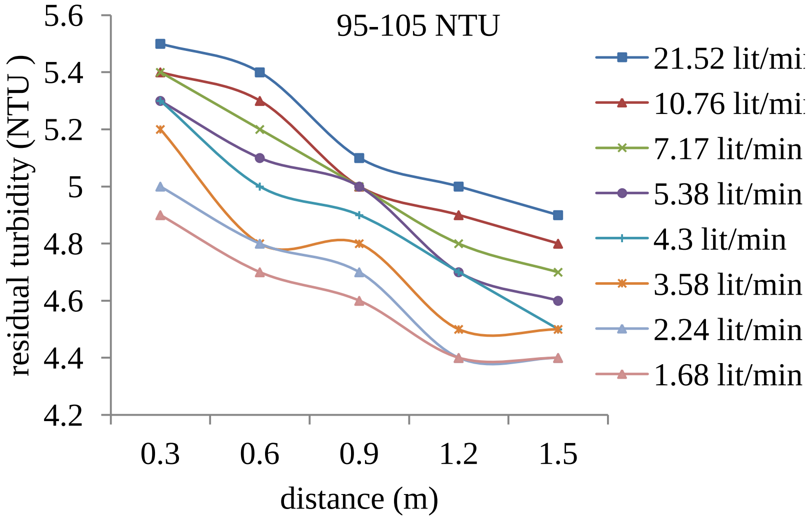

(c)



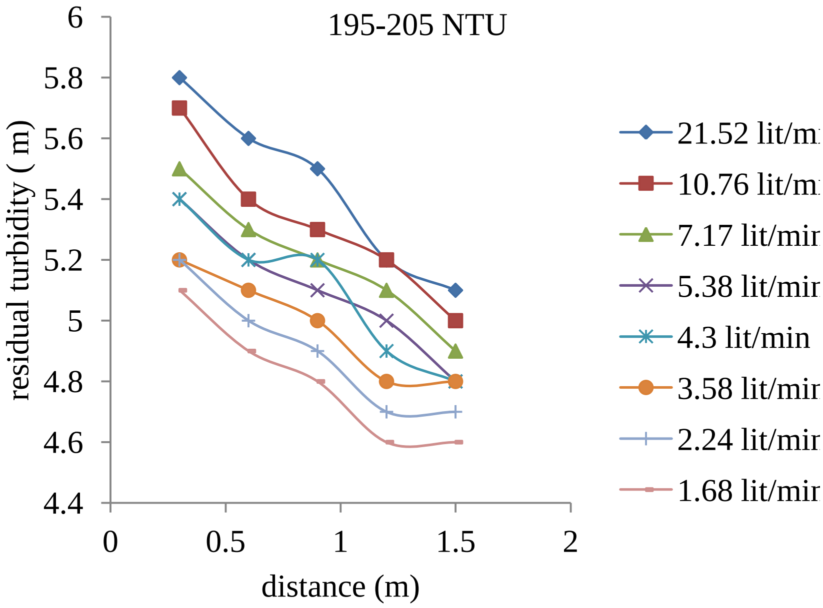

(d)

Figure 4.5: Turbidity profile of synthetic water for initial turbidity (a) 25, (b) 100 and (c) 200 and (d) 300 NTU for continuous flow.

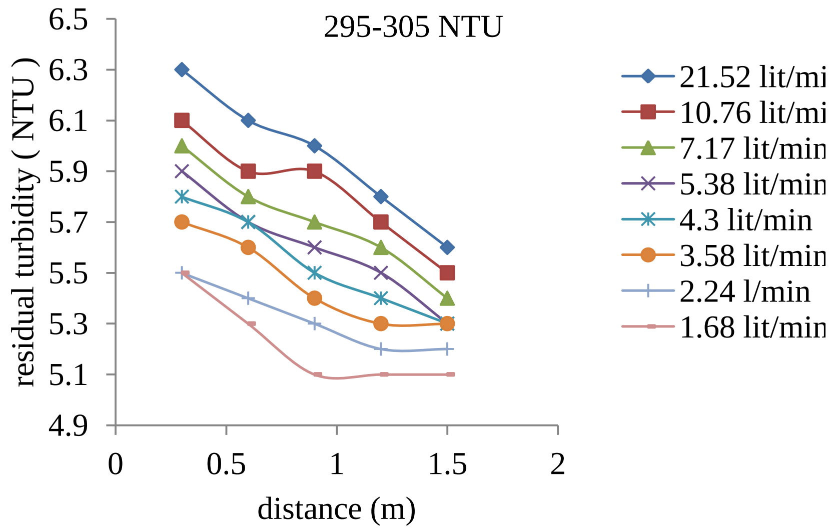
### 4.1.6 Continuous flow for alum dose treatment




(a)




(b)




(c)

Figure 4. 6: Turbidity profile of synthetic water for initial turbidity (a) 100, (b) 200 and (c) 300 NTU treated with alum for continuous flow

Actually, higher turbid water has high amount of the negative charged particles because of which it requires high amount of positive charged particles to form floc. From Annex D, in the continuous flow where oak bark is used as a coagulant dose it can be seen that for the same discharge of 21.52 lit/min for 25 NTU of initial turbidity the residual turbidity is 9.4 NTU and for 50 NTU of initial turbidity the residual turbidity is 9.8 NTU.

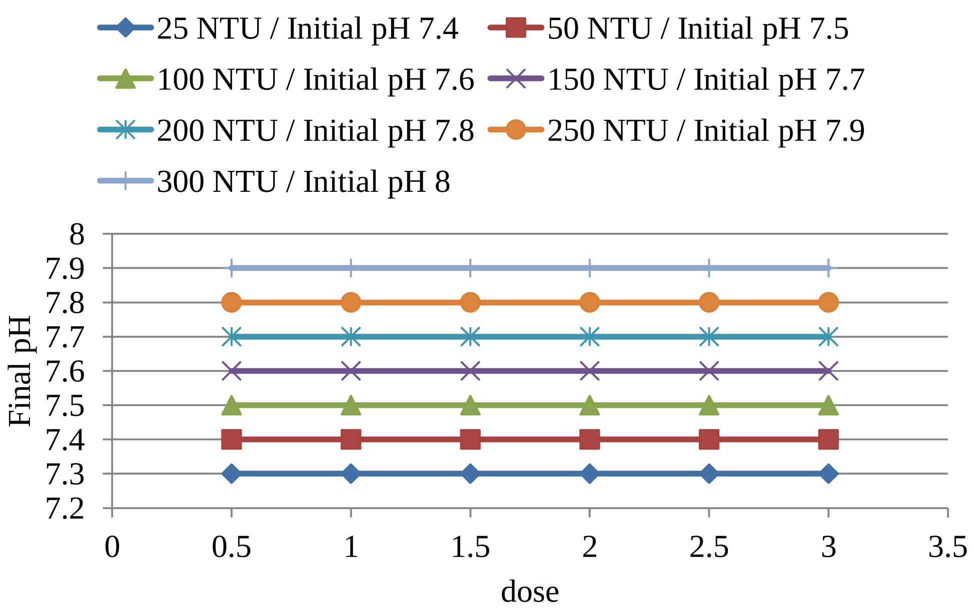
Similarly as the distance in the sedimentation tank is increasing the residual turbidity value is decreasing or turbidity removal is increasing. Actually as the distance increases the turbid water mixed with the required coagulant dose gets more time of contact for forming the floc and more amount of it is settled so turbidity removal is directly proportional to the distance up to the certain value after which it remains constant as seen in the Annex D and Annex E. In Annex D , For 300 NTU initial turbidity for the flow discharge of 1.68 lit/min the residual turbidity is 10.1 NTU, 9.9 NTU, 9.8 NTU,9.6 and 9.6 NTU for the respective distances of 0.3m, 0.6m, 0.9m ,1.2m and 1.5m . From this data it is clear that turbidity removal is directly proportional to the distance up to certain limit after which it becomes constant.

As the discharge varies for the same turbidity there is the variation in the residual turbdity. In Annex D, for the same initial turbidity of 300 NTU, for discharge 21.52

lit/min the residual turbidity is 11.1 NTU whereas for discharge 10.76 lit/min the residual turbidity is 10.8 NTU while observing at the constant distance of 0.3m.

### 4.1.7 Effect of pH

The profile was drawn for the various initial turbidity of 25, 50, 100, 200 and 250 NTU without any coagulant for synthetic water as in Figure 4.6. The pH was measured for each average initial turbidity and it was applied to the Oak bark dose 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml .Then the final pH was measured




.

Figure 4. 7: Variation of pH profile of synthetic water without any coagulant for initial turbidity 25, 50, 100, 200,250 and 300 NTU.

The amount of pH slightly decreases than initial pH after the treatment by oak bark powder. It does no difference by adding the different dose of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml taken from the concentration of 76, 77 and 78 mg/liter concentration.

### 4.1.8 Alum vs. oak bark powder in Batch

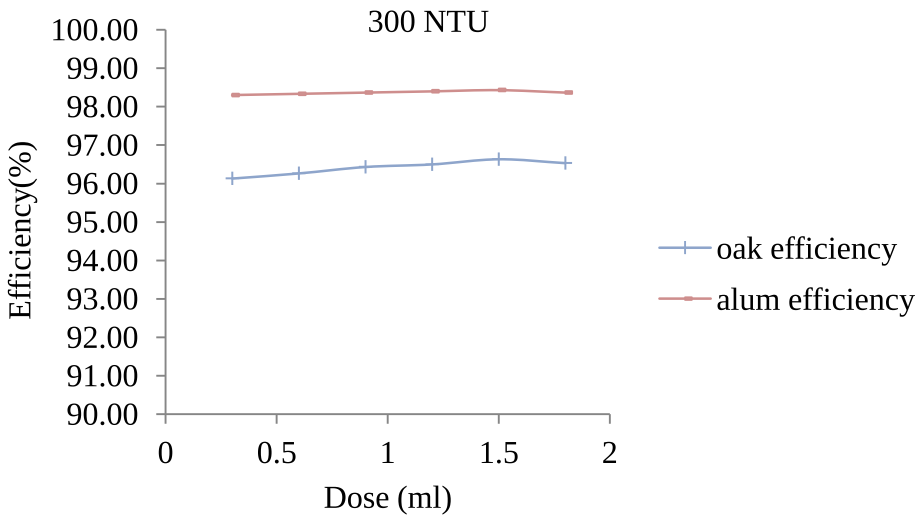



Figure 4.8: Efficiency comparison of Alum vs. oak powder in Batch

### 4.1.9 Alum vs. oak bark powder in continuous flow

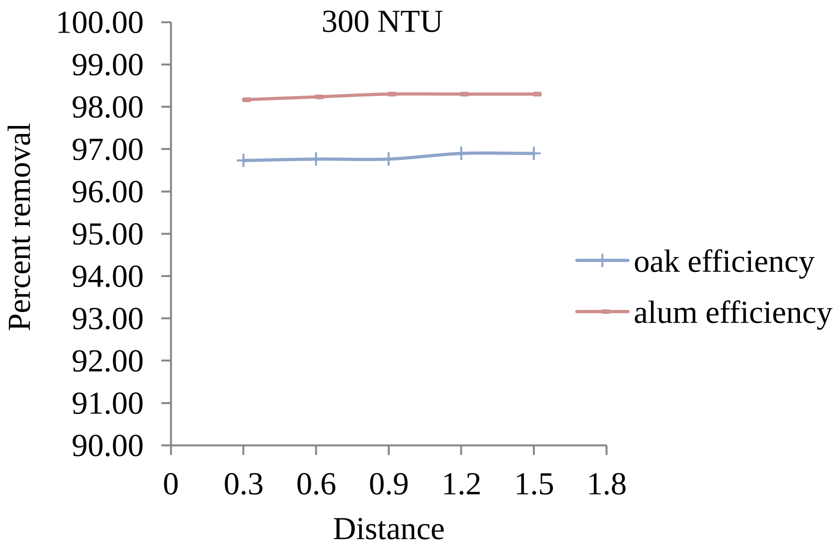



Figure 4.9: Efficiency comparison of Alum vs. Oak powder in continuous flow

Using Alum as a coagulant, initial turbidity is reduced to 4.7 NTU while using oak bark powder as a coagulant it is reduced to 10.1 NTU. It clearly shows the removal efficiency of 98.43 % and 96.63 % respectively. Since the required final turbidity is in the range of NDWQS oak bark powder can be used as a primary coagulant.

## 4.2 Economic Analysis

For the economic analysis, sample of specific turbidity was tested in the batch reactor at the optimum dose of oak bark powder and compared the cost involved it with the optimum dose of aluminium sulphate (alum).The optimum dose of the aluminium sulphate in synthetic water was determined by the jar test method. The settling time was maintained the same. The cost analysis is presented as in Table 4.1.

Table 4. 1 : Cost comparison of oak bark powder and alum dose

| SN. | Description | Alum | Oak | Remarks |
|---|---|---|---|---|
| 1. | Optimum dose | 25mg/l | 77 mg/l | |
| 2. | Unit rate | NRs 560/Kg | NRs 30/Kg | |
| 3. | Cost of coagulant to treat 1 L of water sample | NRs 0.014 per litre<br>=1 Rupees per 71.42 litre | NRs 0.00231 per litre<br>=1 Rupees per 432.9 litre | |

From the above comparison it is concluded that for turbidity removal through oak bark treatment is cheaper than the use of alum.

# CHAPTER FIVE

## 5.0 CONCLUSIONS AND RECOMENDATIONS

### 5.1 Conclusions

Based on the study conducted the following conclusions can be drawn:

- The optimum dose for the turbidity removal by oak bark powder extract is found to be at the dose of 2 ml taken from the concentration of 77 mg/liter of the oak bark powder dose in batch test.
- The maximum turbidity removal efficiency for continuous flow by oak bark powder is found to be effective at the flow rate of 1.68 liter/minute from the continuous flow for oak bark powder dose treatment.
- As per the results, it can be concluded that the turbidity can be lowered up to the 8.5 NTU by the oak bark powder dose for 25 NTU and up to 9.3 NTU for 300 NTU in the continuous flow which is within the range of NDWQS standard.
- Oak bark powder for the turbidity removal is found to be more economic than use of Alum. In addition of cost, final pH of water is in the range of NDWQS, so the use of oak bark powder for the removal of turbidity in Nepalese context may be alternate coagulant substituent.

### 5.2 Recommendations

The recommendations made from the study are:

- The further study is recommended for the influence of temperature.
- The further study is recommended for microbial contaminations/growth because of organic coagulant.

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# APPENDICES

**A: Calculation of different flow rate**

The calculation of different flow rate has been calculated as below.

For time $t_1$ =10 min

Here length of sedimentation tank is 1.5m.

v= 1.5/10=0.15m/min

Area, a= 0.41m*0.35m

Discharge, q= 0.41*0.35*v=0.1435v

For velocity $v_1$ =0.15m/min,

q = 0.1435*0.15=21.52liter/min

Similarly, for time $t_2$=20min

q= 10.76liter/min

Similarly, for time $t_3$=30min

q= 7.17liter/min

Similarly, for time $t_4$=40min

q= 5.38liter/min

Similarly, for time $t_5$=50min

q= 4.30liter/min

Similarly for time 60min, 90min and 120min the flow rate calculated as 3.58 liter/min, 2.24 liter/min and 1.68 liter/min respectively.

**B: Batch study for oak powder dose**

For 76 mg/liter concentration

Fixed parameters: Sample volume: 500ml, stirring time 30 minute,

Dose 0.5, 1.0, 1.5, 2, 2.5.and 3 ml

| Initial turbidity :20-30NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :45-55NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :95-105NTU , Initial pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) |
| 9.5 | 62 | 9.7 | 80.6 | 10.3 | 89.7 |
| 9 | 64 | 9.3 | 81.4 | 9.9 | 90.1 |
| 8.5 | 66 | 8.9 | 82.2 | 9.5 | 90.5 |
| 8.3 | 66.8 | 8.6 | 82.8 | 9.4 | 90.6 |
| 8.9 | 64.4 | 9.1 | 81.8 | 9.3 | 90.7 |
| 9.1 | 63.6 | 9.4 | 81.2 | 9.8 | 90.2 |

| Initial turbidity :145-155NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :195-205NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity : 245-255NTU , pH:7.70,Final pH:7.6 | | Initial turbidity : 295-305NTU , pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) |
| 11.1 | 92.6 | 11.3 | 94.4 | 11.4 | 95.4 | 12 | 96.0 |
| 10.2 | 93.2 | 10.5 | 94.8 | 10.9 | 95.6 | 11.5 | 96.2 |
| 9.7 | 93.5 | 10.2 | 94.9 | 10.8 | 95.7 | 11.2 | 96.3 |
| 9.6 | 93.6 | 9.9 | 95.1 | 10.6 | 95.8 | 11 | 96.3 |
| 9.5 | 93.7 | 9.8 | 95.1 | 10.4 | 95.8 | 10.7 | 96.4 |
| 10 | 93.3 | 10.2 | 94.9 | 10.3 | 95.9 | 10.5 | 96.5 |

For 77 mg/liter concentration

Batch study for oak powder dose

Fixed parameters: Sample volume : 500ml, Stirring time 30 minute,

Dose 0.5,1.0,1.5,2,2.5.and 3 ml

| Initial turbidity :20-30NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :45-55NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :95-105NTU , Initial pH:7.60,Final pH:7.5 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency (%) |
| 9 | 64 | 9.2 | 81.6 | 10.2 | 89.8 |
| 8.5 | 66 | 8.6 | 82.8 | 9.5 | 90.5 |
| 7.9 | 68.4 | 8 | 84 | 9.1 | 90.9 |
| 8.1 | 67.6 | 8.3 | 83.4 | 8.5 | 91.5 |
| 8.6 | 65.6 | 8.6 | 82.8 | 9 | 91 |
| 8.7 | 65.2 | 8.7 | 82.6 | 9.5 | 90.5 |

| Initial turbidity :145-155NTU , Initial pH:7.60,Final pH:7.5 | | Initial turbidity :195-205NTU , Initial pH:7.60,Final pH:7.5 | | Initial turbidity : 245-255NTU , pH:7.50,Final pH:7.4 | | Initial turbidity : 295-305 NTU , pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency (%) | Residual turbidity NTU | Efficiency (%) |
| 10.5 | 93 | 10.8 | 94.6 | 11.4 | 95.4 | 11.6 | 96.1 |
| 10 | 93.3 | 10.3 | 94.9 | 11 | 95.6 | 11.2 | 96.3 |
| 9.3 | 93.8 | 9.7 | 95.2 | 10.5 | 95.8 | 10.7 | 96.4 |
| 8.7 | 94.2 | 9.1 | 95.5 | 10.4 | 95.8 | 10.5 | 96.5 |
| 9.3 | 93.8 | 9.6 | 95.2 | 10 | 96.0 | 10.1 | 96.6 |
| 9.5 | 93.7 | 9.9 | 95.1 | 10.2 | 95.9 | 10.4 | 96.5 |

For 78 mg/liter concentration

Batch study for oak powder dose
Fixed parameters: Sample volume : 500ml, Stirring time 30 minute,
Dose 0.5,1.0,1.5,2,2.5.and 3 ml

| Initial turbidity :20-30NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :45-55NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :95-105NTU , Initial pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) |
| 9.9 | 60.4 | 10 | 80 | 10.3 | 89.7 |
| 9.4 | 62.4 | 9.6 | 80.8 | 10.1 | 89.9 |
| 9.6 | 61.6 | 9.8 | 80.4 | 9.9 | 90.1 |
| 9.6 | 61.6 | 9.9 | 80.2 | 10.2 | 89.8 |
| 9.9 | 60.4 | 9.9 | 80.2 | 10.4 | 89.6 |
| 10.1 | 59.6 | 10.3 | 79.4 | 10.5 | 89.5 |

| Initial turbidity :145-155NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :195-205NTU , Initial pH:7.60,Final pH:7.5 | | Initial turbidity : 245-255NTU , pH:7.70,Final pH:7.6 | | Initial turbidity : 295-305 NTU , pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) |
| 11 | 92.7 | 11.4 | 94.3 | 12.1 | 95.2 | 12.7 | 95.8 |
| 10.5 | 93.0 | 11 | 94.5 | 11.5 | 95.4 | 12.1 | 96.0 |
| 10.2 | 93.2 | 10.5 | 94.75 | 11.3 | 95.5 | 11.8 | 96.1 |
| 10.4 | 93.1 | 10.6 | 94.7 | 10.8 | 95.7 | 11.6 | 96.1 |
| 10.6 | 92.9 | 10.8 | 94.6 | 11 | 95.6 | 11.9 | 96.0 |
| 10.7 | 92.9 | 10.9 | 94.55 | 11.6 | 95.4 | 12.1 | 96.0 |

**C : Batch study for Alum dose**

For 26 mg/liter concentration

Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3 ml

| Initial turbidity :95-105 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :195-205 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :295-305NTU , Initial pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) |
| 5.8 | 76.8 | 5.9 | 88.2 | 6.5 | 93.5 |
| 5.6 | 77.6 | 5.7 | 88.6 | 6.3 | 93.7 |
| 5.3 | 78.8 | 5.5 | 89 | 6.1 | 93.9 |
| 5.6 | 77.6 | 5.7 | 88.6 | 5.9 | 94.1 |
| 5.7 | 77.2 | 5.9 | 88.2 | 6.2 | 93.8 |
| 5.8 | 76.8 | 6.1 | 87.8 | 6.3 | 93.7 |

For 24 mg/liter concentration

Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3 ml

| Initial turbidity :95-105 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :195-205 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :295-305NTU , Initial pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) |
| 5.3 | 94.7 | 5.8 | 97.1 | 6.1 | 98 |
| 5.2 | 94.8 | 5.6 | 97.2 | 6 | 98 |
| 5.1 | 94.9 | 5.5 | 97.3 | 5.8 | 98.1 |
| 5 | 95 | 5.2 | 97.4 | 5.7 | 98.1 |
| 4.8 | 95.2 | 5 | 97.5 | 5.4 | 98.2 |
| 4.9 | 95.1 | 5.1 | 97.5 | 5.2 | 98.3 |

For 25 mg/liter concentration

Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3 ml

| Initial turbidity :95-105 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :195-205 NTU , Initial pH:7.70,Final pH:7.6 | | Initial turbidity :295-305NTU , Initial pH:7.70,Final pH:7.6 | |
|---|---|---|---|---|---|
| Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) | Residual turbidity NTU | Efficiency(%) |
| 4.8 | 95.2 | 5 | 97.5 | 5.1 | 98.3 |
| 4.7 | 95.3 | 4.9 | 97.6 | 5 | 98.3 |
| 4.6 | 95.4 | 4.8 | 97.6 | 4.9 | 98.4 |
| 4.5 | 95.5 | 4.6 | 97.7 | 4.8 | 98.4 |
| 4.6 | 95.4 | 4.7 | 97.7 | 4.7 | 98.4 |
| 4.7 | 95.3 | 4.8 | 97.6 | 4.9 | 98.4 |

**D: Continuous flow study for Oak dose**

Data table for Turbidity profile of synthesis water for initial turbidity 25, 50, 100, 200 and 300 NTU for continuous flow

Fixed parameters:

Sample point: 0.3, 0.6, 0.9, 1.2, 1.5m, Dose: 75 ml,

Initial turbidity: 20-30NTU, Initial pH: 7.7, Final pH: 7.6

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 9.9 | 60.4 | 9.7 | 61.2 | 9.6 | 61.6 | 9.4 | 62.4 |
| 9.8 | 60.8 | 9.6 | 61.6 | 9.5 | 62 | 9.3 | 62.8 |
| 9.8 | 60.8 | 9.5 | 62 | 9.4 | 62.4 | 9.1 | 63.6 |
| 9.6 | 61.6 | 9.3 | 62.8 | 9.2 | 63.2 | 9 | 64 |
| 9.4 | 62.4 | 9.3 | 62.8 | 9.1 | 63.6 | 9 | 64 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 9.3 | 62.8 | 9.2 | 63.2 | 9.1 | 63.6 | 8.9 | 64.4 |
| 9.1 | 63.6 | 9 | 64 | 8.9 | 64.4 | 8.7 | 65.2 |
| 9 | 64 | 8.9 | 64.4 | 8.8 | 64.8 | 8.6 | 65.6 |
| 8.9 | 64.4 | 8.8 | 64.8 | 8.8 | 64.8 | 8.5 | 66 |
| 8.8 | 64.8 | 8.8 | 64.8 | 8.8 | 64.8 | 8.5 | 66 |

Initial turbidity: 45-55 NTU, Initial pH: 7.7, Final pH: 7.6, Dose: 75 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 10.1 | 79.8 | 10 | 80 | 9.8 | 80.4 | 9.7 | 80.6 |
| 10 | 80 | 9.8 | 80.4 | 9.7 | 80.6 | 9.5 | 81 |
| 9.9 | 80.2 | 9.8 | 80.4 | 9.7 | 80.6 | 9.5 | 81 |
| 9.8 | 80.4 | 9.6 | 80.8 | 9.6 | 80.8 | 9.3 | 81.4 |
| 9.8 | 80.4 | 9.6 | 80.8 | 9.5 | 81 | 9.2 | 81.6 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 9.6 | 80.8 | 9.3 | 81.4 | 9.3 | 81.4 | 9 | 82 |
| 9.5 | 81 | 9.2 | 81.6 | 9.1 | 81.8 | 8.8 | 82.4 |
| 9.4 | 81.2 | 9.2 | 81.6 | 9 | 82 | 8.7 | 82.6 |
| 9.1 | 81.8 | 9 | 82 | 8.9 | 82.2 | 8.7 | 82.6 |
| 9.1 | 81.8 | 9 | 82 | 8.9 | 82.2 | 8.7 | 82.6 |

Initial turbidity: 95-105 NTU, Initial pH: 7.7, Final pH: 7.6, Dose : 100 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 10.3 | 89.7 | 10.2 | 89.8 | 10 | 90 | 9.9 | 90.1 |
| 10.1 | 89.9 | 10.1 | 89.9 | 9.9 | 90.1 | 9.8 | 90.2 |
| 10.1 | 89.9 | 10 | 90 | 9.9 | 90.1 | 9.6 | 90.4 |
| 9.9 | 90.1 | 9.9 | 90.1 | 9.8 | 90.2 | 9.5 | 90.5 |
| 9.8 | 90.2 | 9.7 | 90.3 | 9.7 | 90.3 | 9.5 | 90.5 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 9.7 | 90.3 | 9.5 | 90.5 | 9.4 | 90.6 | 9.2 | 90.8 |
| 9.6 | 90.4 | 9.4 | 90.6 | 9.2 | 90.8 | 9 | 91 |
| 9.5 | 90.5 | 9.3 | 90.7 | 9.1 | 90.9 | 8.9 | 91.1 |
| 9.3 | 90.7 | 9.3 | 90.7 | 9 | 91 | 8.9 | 91.1 |
| 9.3 | 90.7 | 9.2 | 90.8 | 9 | 91 | 8.8 | 91.2 |

Initial turbidity: 195-205 NTU, Initial pH: 7.7, Final pH: 7.6, Dose: 100 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 10.7 | 94.65 | 10.5 | 94.75 | 10.4 | 94.8 | 10.1 | 94.95 |
| 10.7 | 94.65 | 10.4 | 94.8 | 10.3 | 94.85 | 9.9 | 95.05 |
| 10.5 | 94.75 | 10.4 | 94.8 | 10.2 | 94.9 | 9.8 | 95.1 |
| 10.4 | 94.8 | 10.3 | 94.85 | 10.2 | 94.9 | 9.7 | 95.15 |
| 10.3 | 94.85 | 10.2 | 94.9 | 10 | 95 | 9.7 | 95.15 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 9.9 | 95.05 | 9.8 | 95.1 | 9.8 | 95.1 | 9.7 | 95.15 |
| 9.9 | 95.05 | 9.7 | 95.15 | 9.5 | 95.25 | 9.4 | 95.3 |
| 9.8 | 95.1 | 9.6 | 95.2 | 9.4 | 95.3 | 9.3 | 95.35 |
| 9.7 | 95.15 | 9.5 | 95.25 | 9.4 | 95.3 | 9.2 | 95.4 |
| 9.6 | 95.2 | 9.5 | 95.25 | 9.3 | 95.35 | 9.2 | 95.4 |

Initial turbidity: 295-305 NTU, Initial pH: 7.7, Final pH: 7.6, Dose: 125 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 11.1 | 96.30 | 10.8 | 96.40 | 10.5 | 96.5 | 10.3 | 96.57 |
| 10.9 | 96.37 | 10.7 | 96.43 | 10.4 | 96.5333 | 10.2 | 96.60 |
| 10.7 | 96.43 | 10.6 | 96.47 | 10.4 | 96.5333 | 10.1 | 96.63 |
| 10.6 | 96.47 | 10.5 | 96.50 | 10.3 | 96.5667 | 10.1 | 96.63 |
| 10.5 | 96.50 | 10.4 | 96.53 | 10.1 | 96.6333 | 9.8 | 96.73 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 10.1 | 96.63 | 10.1 | 96.63 | 9.9 | 96.70 | 9.8 | 96.73 |
| 10.1 | 96.63 | 9.9 | 96.70 | 9.8 | 96.73 | 9.7 | 96.77 |
| 10 | 96.67 | 9.8 | 96.73 | 9.7 | 96.77 | 9.7 | 96.77 |
| 9.9 | 96.70 | 9.6 | 96.80 | 9.4 | 96.87 | 9.3 | 96.90 |
| 9.8 | 96.73 | 9.6 | 96.80 | 9.4 | 96.87 | 9.3 | 96.90 |

**E: Continuous flow study for alum dose**

Data table for Turbidity profile of synthesis water for initial turbidity 25, 50, 100, 200 and 300 NTU for continuous flow

Fixed parameters:

Sample point: 0.3, 0.6, 0.9, 1.2, and1.5m Dose: 100 ml

Initial turbidity: 95-105 NTU, Initial pH: 7.7, Final pH: 7.4

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 5.5 | 94.5 | 5.4 | 94.6 | 5.4 | 94.6 | 5.3 | 94.7 |
| 5.4 | 94.6 | 5.3 | 94.7 | 5.2 | 94.8 | 5.1 | 94.9 |
| 5.1 | 94.9 | 5 | 95 | 5 | 95 | 5 | 95 |
| 5 | 95 | 4.9 | 95.1 | 4.8 | 95.2 | 4.7 | 95.3 |
| 4.9 | 95.1 | 4.8 | 95.2 | 4.7 | 95.3 | 4.6 | 95.4 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 5.3 | 94.7 | 5.2 | 94.8 | 5 | 95 | 4.9 | 95.1 |
| 5 | 95 | 4.8 | 95.2 | 4.8 | 95.2 | 4.7 | 95.3 |
| 4.9 | 95.1 | 4.8 | 95.2 | 4.7 | 95.3 | 4.6 | 95.4 |
| 4.7 | 95.3 | 4.5 | 95.5 | 4.4 | 95.6 | 4.4 | 95.6 |
| 4.5 | 95.5 | 4.5 | 95.5 | 4.4 | 95.6 | 4.4 | 95.6 |

Initial turbidity: 195-205 NTU, Initial pH: 7.7, Final pH: 7.4, Dose: 100 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 5.8 | 97.1 | 5.7 | 97.15 | 5.5 | 97.25 | 5.4 | 97.3 |
| 5.6 | 97.2 | 5.4 | 97.3 | 5.3 | 97.35 | 5.2 | 97.4 |
| 5.5 | 97.25 | 5.3 | 97.35 | 5.2 | 97.4 | 5.1 | 97.45 |
| 5.2 | 97.4 | 5.2 | 97.4 | 5.1 | 97.45 | 5 | 97.5 |
| 5.1 | 97.45 | 5 | 97.5 | 4.9 | 97.55 | 4.8 | 97.6 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 5.4 | 97.3 | 5.2 | 97.4 | 5.2 | 97.4 | 5.1 | 97.45 |
| 5.2 | 97.4 | 5.1 | 97.45 | 5 | 97.5 | 4.9 | 97.55 |
| 5.2 | 97.4 | 5 | 97.5 | 4.9 | 97.55 | 4.8 | 97.6 |
| 4.9 | 97.55 | 4.8 | 97.6 | 4.7 | 97.65 | 4.6 | 97.7 |
| 4.8 | 97.6 | 4.8 | 97.6 | 4.7 | 97.65 | 4.6 | 97.7 |

Initial turbidity: 295-305 NTU, Initial pH: 7.7, Final pH: 7.5, Dose: 125 ml

| Flow rate : 21.52 l/min | | Flow rate : 10.76 l/min | | Flow rate : 7.17 l/min | | Flow rate : 5.38 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 6.3 | 97.90 | 6.1 | 97.97 | 6 | 98.00 | 5.9 | 98.03 |
| 6.1 | 97.97 | 5.9 | 98.03 | 5.8 | 98.06 | 5.7 | 98.10 |
| 6 | 98.00 | 5.9 | 98.03 | 5.7 | 98.10 | 5.6 | 98.13 |
| 5.8 | 98.07 | 5.7 | 98.10 | 5.6 | 98.13 | 5.5 | 98.17 |
| 5.6 | 98.13 | 5.5 | 98.17 | 5.4 | 98.20 | 5.3 | 98.23 |

| Flow rate : 4.30 l/min | | Flow rate : 3.58 l/min | | Flow rate : 2.24 l/min | | Flow rate : 1.68 l/min | |
|---|---|---|---|---|---|---|---|
| Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % | Residual turbidity NTU | Removal % |
| 5.8 | 98.07 | 5.7 | 98.10 | 5.5 | 98.17 | 5.5 | 98.17 |
| 5.7 | 98.10 | 5.6 | 98.13 | 5.4 | 98.20 | 5.3 | 98.23 |
| 5.5 | 98.17 | 5.4 | 98.20 | 5.3 | 98.23 | 5.1 | 98.30 |
| 5.4 | 98.20 | 5.3 | 98.23 | 5.2 | 98.27 | 5.1 | 98.30 |
| 5.3 | 98.23 | 5.3 | 98.23 | 5.2 | 98.27 | 5.1 | 98.30 |

**F : Natural settling**

| Time(hrs) | 0 | 0.5 | 0.75 | 1 | 1.25 | 1.5 | 1.75 | 2 |
|---|---|---|---|---|---|---|---|---|
| mud slurry (NTU ) | 300 | 68.3 | 54.3 | 47.9 | 33.1 | 28 | 24.1 | 24 |
| Kaolin(NTU) | 300 | 77.6 | 62.8 | 54.9 | 41.1 | 36.6 | 30.2 | 30.2 |
| pottery clay(NTU) | 300 | 61.2 | 47 | 42.8 | 28 | 23.1 | 20.1 | 20 |

**G: Batch study for synthetic water without using coagulant**

| Initial Turbidity(NTU) | | Settling time (hr) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.5 | 0.75 | 1 | 1.25 | 1.5 | 1.75 |
| 20-30 | Final Turbidity(NTU) | 20.2 | 19.6 | 18.4 | 17.5 | 16.3 | 15.1 |
| 45-55 | | 25.4 | 21.5 | 19.6 | 18.5 | 17.5 | 15.8 |
| 95-105 | | 30.6 | 25.7 | 20.4 | 19.1 | 18.2 | 16.1 |
| 145-155 | | 42.7 | 35.8 | 26.9 | 21.6 | 19.1 | 17.2 |
| 195-205 | | 52.5 | 42.3 | 32.6 | 24.8 | 21.7 | 18.2 |
| 245-255 | | 58.6 | 45.1 | 38.2 | 26.4 | 23.5 | 18.9 |
| 295-305 | | 64.5 | 50.4 | 43.6 | 29.6 | 23.5 | 20.2 |

**H : Alum Vs Oak bark powder**

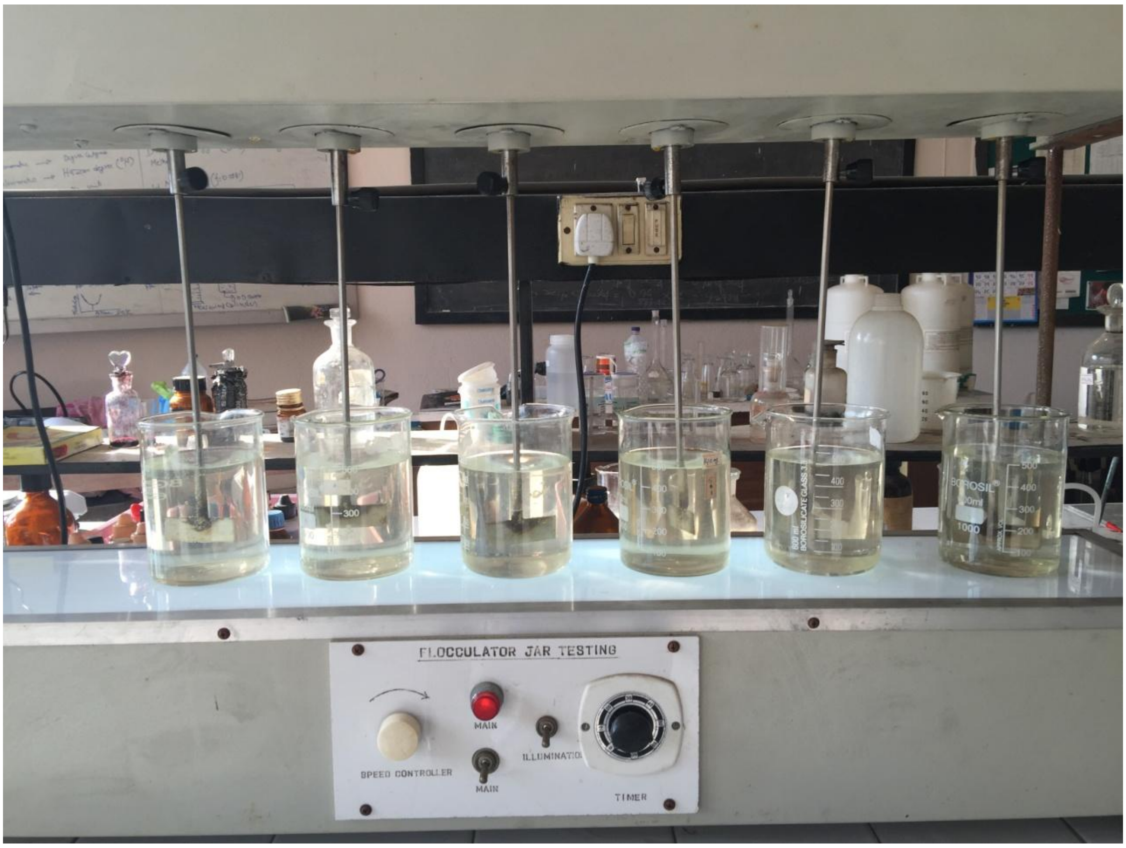
Dose : optimum dose for both Dose (ml) :0.5,1,1.5,2,2.5,3 ml

| Initial turbidity | Final Turbidity | | Efficiency | |
|---|---|---|---|---|
| Both | Oak | Alum | Oak | Alum |
| 300 | 11.6 | 5.1 | 96.13 | 98.30 |
| 300 | 11.2 | 5 | 96.27 | 98.33 |
| 300 | 10.7 | 4.9 | 96.43 | 98.37 |
| 300 | 10.5 | 4.8 | 96.50 | 98.40 |
| 300 | 10.1 | 4.7 | 96.63 | 98.43 |
| 300 | 10.4 | 4.9 | 96.53 | 98.37 |

# PHOTOGRAPHS

P1: Oak Bark

P2: Oak Bark in powder form




P3: Jar test before oak bark powder dose application

P4: Jar test after completion

P5: Continuous flow setup

P6: Application of rotating pump in mixing