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Use of Cactus Powder as Natural Coagulant in Turbidity Removal of Water

by

Bal Krishna Aryal

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

____

Iswar Man Amatya, Supervisor
Assoc. Professor
Department of Engineering, Central Campus Pulchowk
Institute of Engineering

____

Mr. Nanda Khanal
External Examiner

____

Iswar Man Amatya, Program Coordinator
Associate Professor
MSc in Environment Engineering Program
Department of Civil Engineering, Central Campus, Pulchowk
Institute of Engineering

____

Date

ABSTRACT

Coagulation is an important water treatment process used to reduce water turbidity. In this study, the effectiveness of a natural macromolecular coagulant derived from a cactus species for turbidity removal from natural water were evaluated using jar test. Initial turbidity values measured at 25-300 NTU was reduced by as much as 93%. For continuous flow the 0.9m distance seems to be enough for turbidity removal by using cactus powder. It was indicated that the coagulant did not have a considerable effect on final pH of the water. The amount of cactus added was well correlated with the final turbidity. High turbidity removal determined in this study indicates that *cactus opuntia* has the potential to be utilized for surface water treatment applications.

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LIST OF ABBREVIATIONS

ADF	-	Acid Detergent Fiber
ADL	-	Acid Detergent Lignin
CP	-	Crude Protein
IOE	-	Institute of Engineering
NARC	-	Nepal Agricultural Research council
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 I

1.0 INTRODUCTION

1.1 Background

Water is undoubtedly the most essential resource for mankind's survival. However, during the recent development of the country, water pollution has become such an inevitable and yet serious problem. More and more pollutants have been emitted into the water and contaminated our water resources. The 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. Towards providing safe and clean water supply to consumers is no longer an easy task, especially with stringent water quality regulations.

Most of the water supply projects in the country are running without any treatment. Only a small number of water supply projects, less than one dozen 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. According to authorities at the Nepal Water Supply Corporation (NWSC), water quality is especially poor during the rainy season when high levels of rainfall stimulate sediment re-suspension, increasing turbidity from 10 NTU (Nephelometric Turbidity Units) in the dry season to as high as 1500 NTU in the rainy season. 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 (source: http://akvopedia.org/wiki/Natural_coagulation_/_Flocculation). There is a variety of natural coagulants used around the world, depending on the availability. Among them the cactus species plant is also prevalent in South Asia also and has been traditionally used in some parts also.

1.2 Rationale of the Study

Coagulant plays an important part in areas of water treatment. But some kinds of inorganic coagulant that are used widely have disadvantages such as large dosage, low effect and harmful to human body, and synthetic organic coagulant has disadvantages of high price and toxicity, so their application was limited . Natural macromolecular coagulants as cactus powder shows bright future and are concerned by many researchers because their abundant source, locally availability, innocuity, multifunction, biodegradation and easy preparation procedure.

Cactus has received great degree of attention in recent years because it contains many nutritious and medicinal components such as protein, amylose, malic acid, resin, vitamin and cellulose. Studies indicated that cactus has similar properties to seeds of *Moringa oleifera* , so it has potential as a coagulant.

In Nepal, Cactus itself considered as of no use in water treatment process. It can be seen in boundary walls, rocky areas and neglected land area too. It has bright future of large-scale application, but the development of cactus application is now still limited in laboratory. It has also found out that the powder of cactus functioned much better as coagulant aid then a primary coagulant. The best performance of turbidity removal is by utilizing the combination of alum as primary coagulant and cactus solution as coagulation aid. Other benefits were discovered in utilizing the cactus powder as coagulant aid. It can add in forming bigger and denser flocs which eventually lead to faster settling time. It doesn't contribute the pH reduction to the treated surface water. As a result of the higher turbidity removal, other parameters such as total suspended solids, nitrate and Iron concentration showed positive reaction in surface water.

1.3 Objectives of the Study

The main objective of the study is:

- to determine the use of cactus powder on turbidity removal of water

The specific objectives of this study are:

- to determine the optimum dose in batch and continuous flow
- to determine the comparative performance of cactus powder with respect to alum

1.4 Limitations of the Study

The limitations of this study are listed below:

- Effect of micro organism in cactus powder has not been considered in the study.
- 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 includes the data observed and measurements during lab tests and their analysis and presentation terms as results and discussions.

Chapter V includes conclusions and recommendations regarding the whole study so that it will help for further research and study of the same nature.

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

CHAPTER II

2.0 LITERATURE REVIEW

2.1 Turbidity

Turbidity of water is caused by suspended matter, such as clay, silt, 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 for three major reasons i) aesthetic b) filterability c) disinfection. 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.

2.2 Elemental Analysis of Cactus

A cactus is a member of the plant family *Cactaceae* within the order Caryophyllales. The word "cactus" derives, through latin from the ancient Greek words a name originally used for a spiny plant whose identity is not certain. Cacti are native to the Americas, ranging from Patagonia in the south to parts of western Canada in the north—except for *Rhipsalis baccifera*, which also grows in Africa , Sri Lanka, India as well as Nepal. Most cacti live in habitats subject to at least some drought. Many live in extremely dry environments as well as cold, even being found in the Atacama Desert, one of the driest places on earth. Cacti show many adaptations to conserve water. Most species of cacti have lost true leaves, retaining only spines (source: https://en.wikipedia.org/wiki/Cactus). Cactus plants can grow in humidity conditions. The best practice is to simply let mother nature do the watering for it. If the weather has been hot and dry and the plants look limp or are beginning to droop indicates it needs water. Cactus plants grown in the ground don't need much fertilizer but they benefit from spring applications of compost or a liquid fertilizer designed for bulb or vegetable use (source : http://www.bhg.com/gardening/flowers/perennials/growing-cactus-plants-in-cold-climates).

Elemental analysis of cactus was carried out to provide a elemental compositions of the cactus with as determined by Ndabigengesere *et al.* (1995). In this study, it was determined that cactus opuntia contained 2.3% nitrogen, 29.4% carbon and 1.7% hydrogen.

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 2.1.

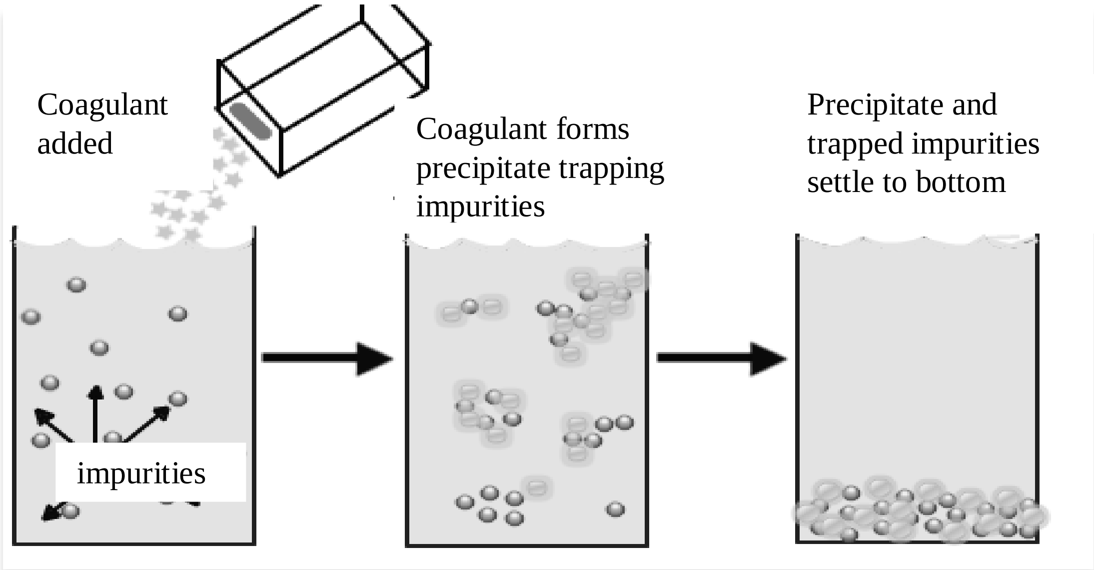


Figure 2.1 : Coagulation process

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). Some preliminary studies on cactus as alternative coagulant in water treatment have been done and the coagulation performance of cactus to act as natural macromolecular coagulant was positive. It has been used in Chile as well as Mexico as a water purifier . A study made in Cuba recently to compare the purifying capacity of cactus plant' mucilage with other traditional agents, $Al_2(SO_4)_3$. The author reported that Opuntia ficus-Indica when compared have behaviour similar to aluminium sulphate in water purifying . Cactus coagulant has its optimum dosage and pH when used to treat given water sample, and the coagulation effect was slightly influenced by temperature and alkalinity. When cactus was used to treat synthetic water and potable water resource, the effect was just a little worse than that of $AlCl_3.6H_2O$. The effect that cactus used with $AlCl_3.6H_2O$ synchronously to treat sewage water was better than that of cactus or $AlCl_3.6H_2O$ was used solely. So cactus could be used as a substitute of alum in water treatment (Sáenz *et. al*, 2001) . Previous studies however, have not determined whether such natural coagulants are economically and environmentally more acceptable than chemical coagulants. Recently there has been more interest in the subject of natural coagulants, especially to ease problems of water and wastewater treatment. Natural macromolecular coagulants show bright future and are concerned by many researchers because their abundant source, low price, innocuity, multifunction and biodegradation (Zhang *et. al,* 2006).

Similarly A study made on the Cactus Opuntia as natural Coagulant in turbid water treatment (Yin *et.al,* 2006) shows that powdered and dried cactus opuntia was very effective in removing turbidity from both estuarine and river waters as evident by the high removal efficiencies. It was also proven that the cactus powder did not have a significant effect on final pH of the waters as compared to chemical-based coagulants.

According to Miller and Fugate (2008), the ability *opuntia cactus* coagulation occurs through the mechanism of forming chemical bridges, through hydrogen bonds or dipole interactions. The flakes formed in the study are long and thin, mucilage derived from the common species of cactus, aloe vera and okra and the polygalacturonic acid component present in mucilage, as responsible for the formation of chemical bridges in flocculation as described in Figure 2.2.

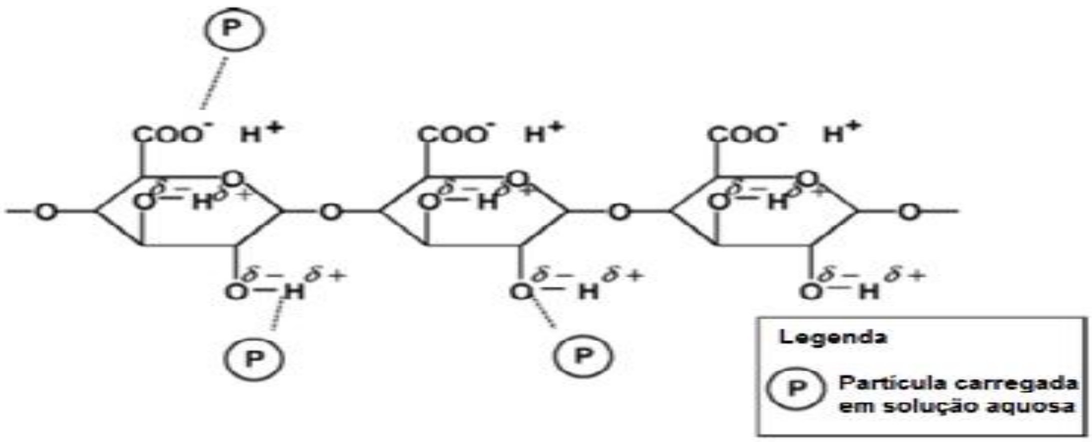


Figure 2.2 Structure of constituent spices of cactus

According to Vishalia and Karthikeyan (2014) the potentiality of *Cactus opuntia* (*ficus-indica*), as a coagulant for the treatment of simulated industrial water-based paint wastewater in terms of colour, chemical oxygen demand (COD) and turbidity was high as their study. The obtained results that were compared with conventional coagulant ferric chloride acknowledged that *Cactus opuntia* (*ficus-indica*) a natural, eco-friendly coagulant, could be a strong alternative to the conventional coagulant in the treatment of water-based paint wastewater.

According to Nharingo and Moyo M (2015) cactus has been explored for the biosorption and biocoagulation-flocculation of pollutants from wastewaters. The green technology involving Opuntia ficus-indica in wastewater decontamination has been scaling up from the laboratory scale to community pilot plants and eventually to industrial level. The main results obtained in the depollution of a variety of contaminated wastewaters using cactus show very high and promising pollutant maximum absorption capacities and removal percentages in the range 125.4-1000 mg/g and 0.31-2251.56 mg/g for the biosorption of dyes and metallic species respectively and removal % ranges of 50-98.7%, 11-93.62% and 17-100% for turbidity, chemical oxygen demand and heavy metals respectively by coagulation flocculation process.

Hence, the positive outcome of all the studies justifies further research on *cactus opuntia* as a natural macromolecular coagulant.

CHAPTER III

3.0 METHODOLOGY

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

3.1 Material and Its Preparation

The botanical name of cactus that used in the experiment was *Opuntia ficus-indica*. The constituents of studied cactus in National Agricultural Research Council (NARC) Nepal laboratory is as in Table 3.1.

Table 3.1 Constituents of cactus

SN.	Description		Unit	Remarks
1.	English local name	Nepali cactus		
2.	Botanical name	*Opuntia ficus Indica*		
3.	Organic matter (OM)	86.27	%	Total 100%
4.	Total ash (T.ash)	13.73	%	
5.	Crude Protein (CP)	5.98	gm	Per 100gm
6.	Ether Extract (EE)	1.5	gm	
7.	Non Detergent Fiber (NDF)	48.5	gm	
8.	Acid Detergent Fiber (ADF)	9.01	gm	
9.	Acid Detergent Lignin (ADL)	2.34	gm	
10.	Ca(mg)	1.64	gm	Per 100gm
11.	Energy	34.90	Kcal	Per 100gm
12.	Volatile solid	60.00	gm	Per 100gm

Cactus stem was collected from the area of Kathmandu Zone. 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 1.25 mm. The solid was used as raw coagulant to treat with synthetic water.

3.4 Experimental Set Up and Procedure

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.

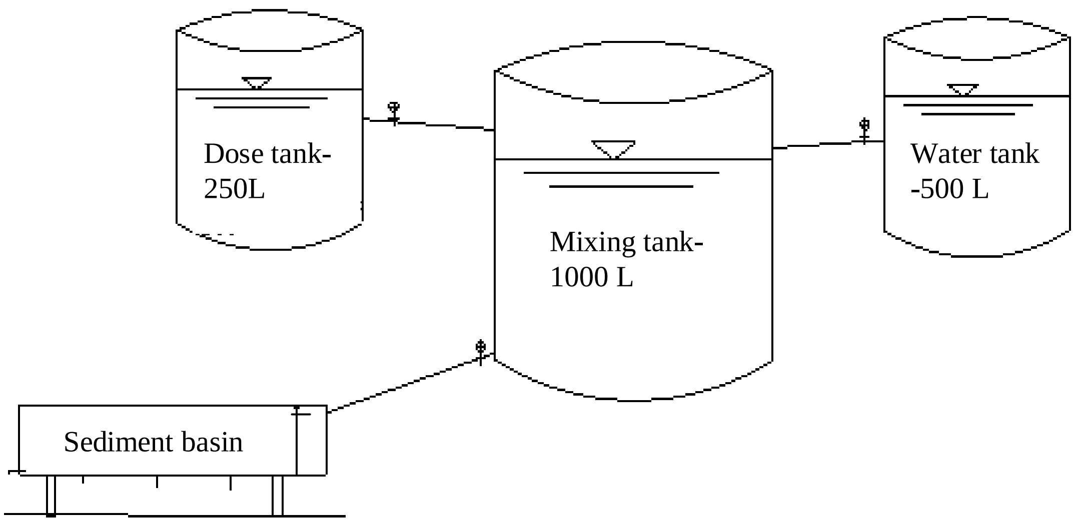
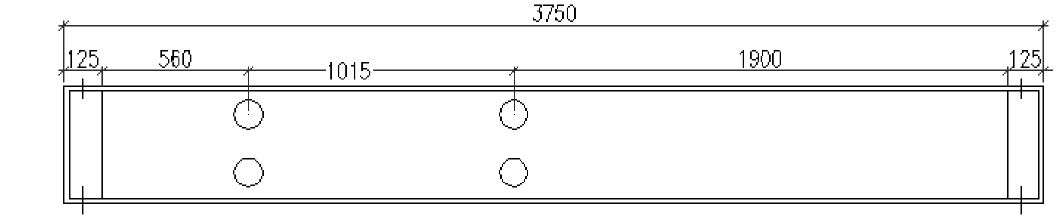
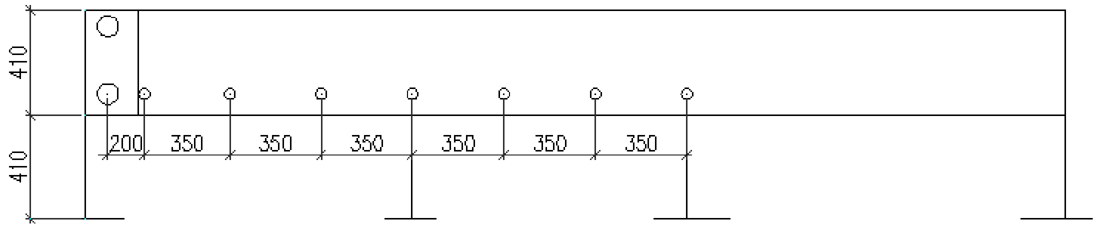


Figure 3.1 Set up for continuous flow

Sedimentation basin consists the size of volume 0.21 (3.75*0.41 *0.35) m^3. It has both sides inlet as in the Figure 3.2. It consists the seven ports with an interval of 350mm. It has four sludge extraction outlets in the bottom of the sedimentation tank.



Plan of sedimentation tank



Section of sedimentation tank

Note : All dimensions are in mm.

Figure 3.2 Plan and section of Sedimentation tank

A standard jar test apparatus was used in the coagulation test. Prepared water samples (500 ml) was 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 cactus coagulant dosage.

CHAPTER IV

4.0 RESULTS AND DISCUSSIONS

The experiment results of turbidity removal of water by cactus 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 Coagulant Dose

The initial turbidity around 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275 and 300 NTU of water sample was treated by cactus and alum dose at the Environmental laboratory of IOE.

4.1.1 Batch study for synthetic water without using coagulant

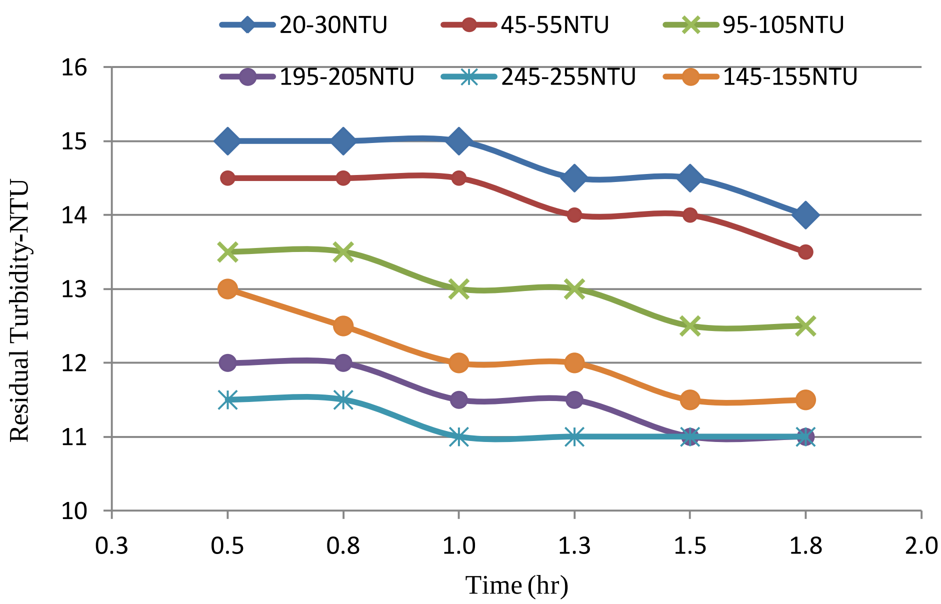


Figure 4.1 Turbidity profile of Synthetic water without using coagulant

The average initial turbidity of 25, 50, 100, 150, 200 and 250 NTU synthetic water sample at an interval with 25NTU 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 15 NTU up to the settling time period of one hour while it becomes lowers up to the 14 NTU for the settling time period of 1.75 hours. For the range of 45-55 NTU the residual turbidity becomes 14.5 NTU up to the settling time period of one hour while it becomes lowers up to the 13.5 NTU for the settling time period of 1.75 hours. Similarly for the range of 95-105 NTU the maximum residual turbidity becomes 12.5 NTU. Similarly for the range of 245-255 NTU, the residual turbidity becomes 11.0 NTU. From the Figure 4.1 it can be conclude d that the maximum reduced level of turbidity becomes up to the 11.0 NTU of average initial turbidity 245-255 NTU without using coagulant.

4.1.2 Batch study for cactus dose

The average initial turbidity of 25, 50, 100, 150, 200 and 250 NTU water sample at an interval with 25NTU treated with different dose from the concentrations of 0.5,1.0 and 1.5 mg/liter are plotted as in Figure 4.2. From the Figure 4.2(a) 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 0.5 mg/liter concentration found to be 9.5, 9.0, 8.5, 8.5, 8.0 and 8.0 NTU respectively.

Thus it indicates that turbidity level reduces upto the dose of 2.5 ml and no further effect in the turbidity with the increase of dose. Similarly for the concentration of 1.0 mg/liter the optimum removal efficiency occurs at the dose of 2.0ml and for the concentration of 1.5 mg/liter the optimum removal efficiency occurs at the dose of 2.0 ml. The turbidity level increases beyond the dose of 2.5ml. Hence it can be concluded that for the turbidity 20-30 NTU the optimum removal efficiency occurs at the dose of 2.0 ml taken from the concentration of 1.5 mg/liter. Similarly from the Figure 4.2(b) it can be concluded that the optimum removal efficiency occurs at the dose of 2.0 ml taken from the concentration of 1.5 mg/liter and beyond that removal efficiency of turbidity decreases for the 45-55 NTU. For the range of 95-105 NTU the maximum turbidity removal efficiency occurs at the dose of 2.0 ml taken from the concentration of 1.5mg/liter.

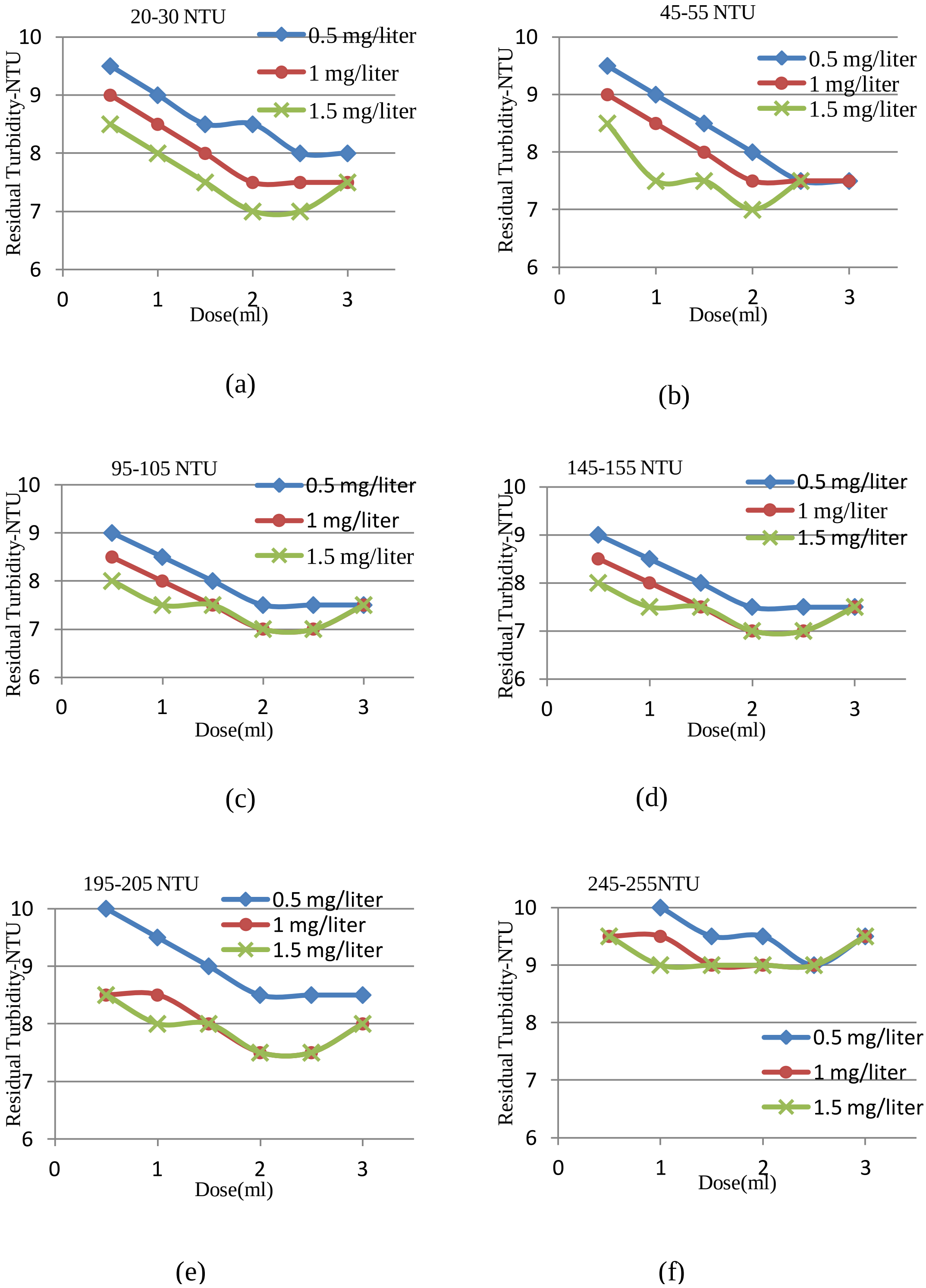


Figure 4.2: Turbidity profile of synthetic water for average initial turbidity (a) 25,(b) 50, (c)100, (d)150, (e) 200 and (f) 250 NTU at batch

For more than average 100NTU the efficiency of turbidity removal decreases and hence it can be concluded that the optimum removal efficiency occurs at the dose of 2.0ml taken from the concentration of 1.5mg/liter. As the influent turbidity increases the turbidity removal is going to decrease but it is more effective up to the range of average initial turbidity 100 to 150NTU.

4.1.3 Batch study for alum dose

Figure 4.3 shows the plot of residual turbidity versus dose of the alum. For different turbidity 25, 50, 100, 200 and 300NTU the different dose 10, 15, 20, 25, 30, 35mg/liter has been applied for each influent turbidity. From the Figure 4.3, it can be concluded that the optimum turbidity removal efficiency occurs at 25mg/liter dose of alum.

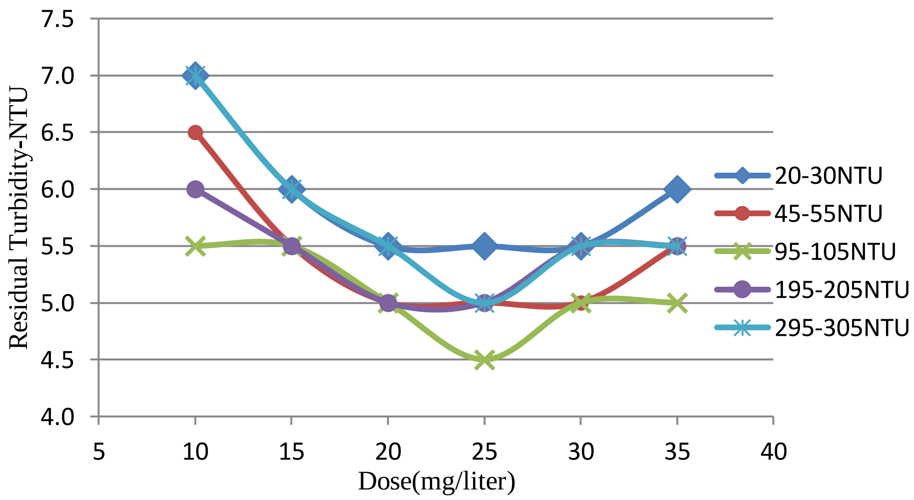


Figure 4.3 Turbidity profile of synthetic water by alum for initial turbidity 25, 50 , 100, 200 and 300 NTU at Batch

4.1.4 Continuous flow for cactus dose treatment

From the Figure 4.4 the turbidity profile has been drawn for the flow rate of 21.52, 10.76, 7.17, 5.38, 4.30, 3.58, 2.24, 1.68 l/min. The sampling points are fixed at the distance of 0.3, 0.6, 0.9, 1.2 and 1.5m from the inlet of sedimentation tank.

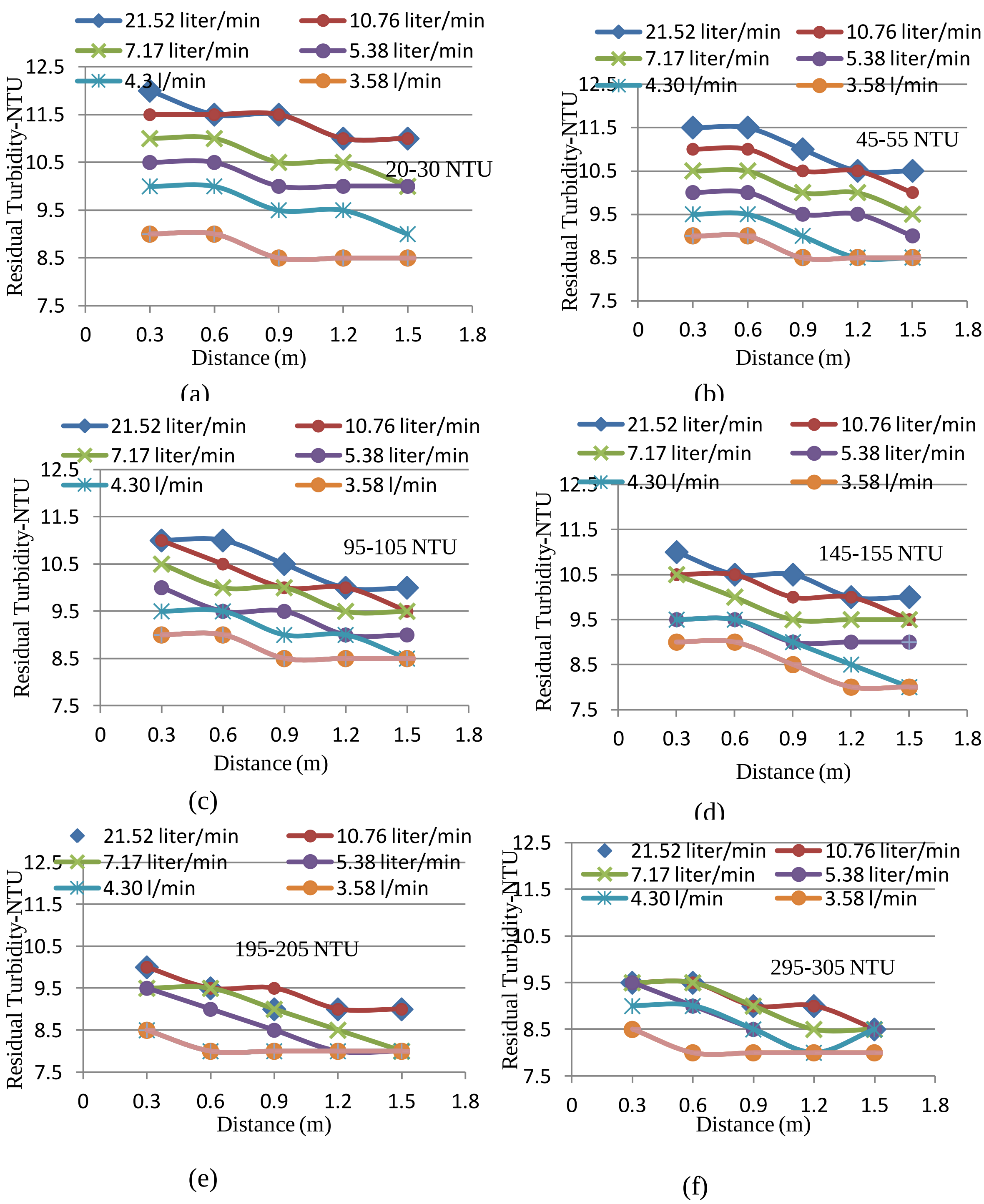


Figure 4.4 : Turbidity profile of synthetic water for initial turbidity (a) 25,(b) 50, (c)100, (d)150, (e) 200 and (f) 250 NTU for continuous flow

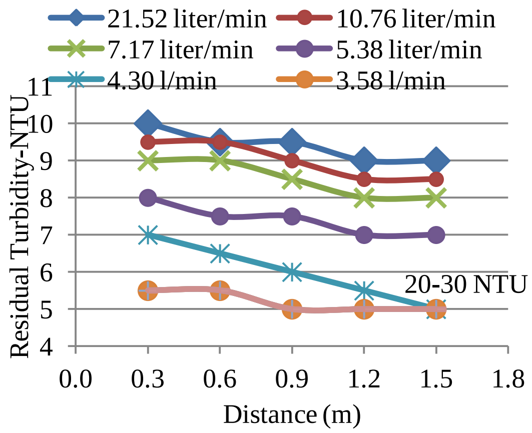
For the range of 20-30 NTU the maximum turbidity removal occurs at the flow rate of 3.58 l/min. For the lower then 3.58 l/min flow, the turbidity removal efficiency remains same or decreases with the respective distance.

Similarly for 45-55 NTU the optimum turbidity removal efficiency occurs at.distance of 0.9m for the flow rate of 3.58l/min. For the lower turbidity at the same flow rate, the turbidity removal efficiency does not increase with respective distance.From the plotted data as in Figure 4.4 it can be concluded that for the flow rate 7.17 l/min and lower than this flow rate the residual turbidity occurs below 10NTU which is acceptable range for NDQS. For the turbidity range of 95-105NTU the maximum turbidity removal efficiency occurs for the flow rate of 3.58 l/min and for the same flow rate the turbidity can be lowered upto 8.0NTU . For the initial turbidity range of 195-200NTU and 295-305NTU, it can be concluded that the residual turbidity occurs below the range of NDQS . For average influent turbidity 20 to 100NTU,the 0.9m distance seems to be enough for turbidity removal within NDQS using cactus powder.

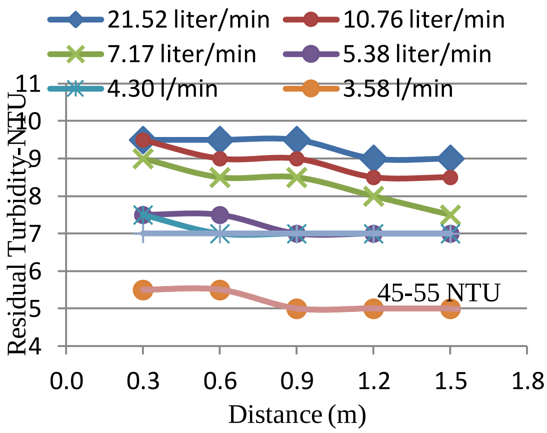
4.1.5 Continuous flow for alum dose treatment

From the Figure 4.5 the turbidity profile has been drawn for the flow rate of 21.52, 10.76, 7.17, 5.38, 4.30, 3.58, 2.24, 1.68 l/min. The sampling points are fixed at the distance of 0.3, 0.6, 0.9, 1.2 and 1.5m from the inlet of sedimentation tank.

The plotted data shows that for 21.52 liter/minute flow rate, the maximum turbidity removal was occurred at the distance of 1.2 m. Similarly for 10.76 liter/minute flow rate the maximum removal of turbidity occurred at 1.2m.Similarly for 7.17 liter/minute flow rate the maximum removal of turbidity occurred at the distance of 1.2m. Similarly for 5.38 liter/minute flow rate the maximum removal of turbidity occurred at the distance of 1.2m. The plotted data shows that for 4.30 liter/minute flow rate , the maximum turbidity removal was occurred at the distance of 1.5 m. Similarly for 3.58 liter/minute flow rate the maximum removal of turbidity occurred at 0.9m.Similarly for 2.24 liter/minute flow rate the maximum removal of turbidity occurred at the distance of 0.9m. Similarly for 1.68 liter/minute flow rate the maximum removal of turbidity occurred at the distance of 0.9m. For the initial turbidity within the range of 20-30 NTU the residual turbidity occurs within the acceptable limit of NDWQS standard for any flow rate. From the plotted data of different initial turbidity of the 45-55, 95-105, 145-155, 195-205 and 295-305 NTU it can be concluded that the maximum turbidity removal efficiency occurs for the flow rate of 3.58l/min or lower than that. Again it can be concluded that the maximum residual turbidity lowers upto the range of 5.0 NTU for the flow rate of 3.58l/min.



(a)



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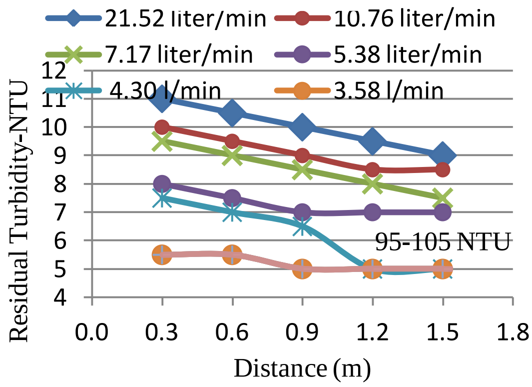
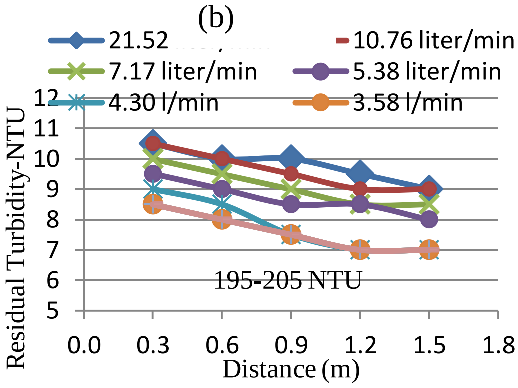
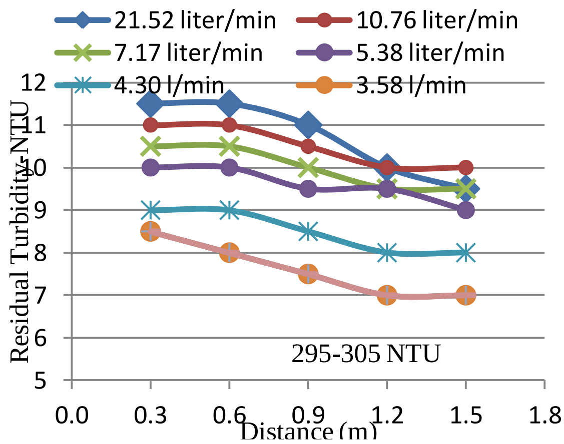


(c)



(d)



(e)

Figure 4.5: Turbidity profile of synthetic water for initial turbidity (a) 25, (b) 50,(c) 100, (d) 150, (e) 200 and (f) 250 NTU treated with alum for continuous flow

4.2 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 cactus dose 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml .Then the final pH was measured .

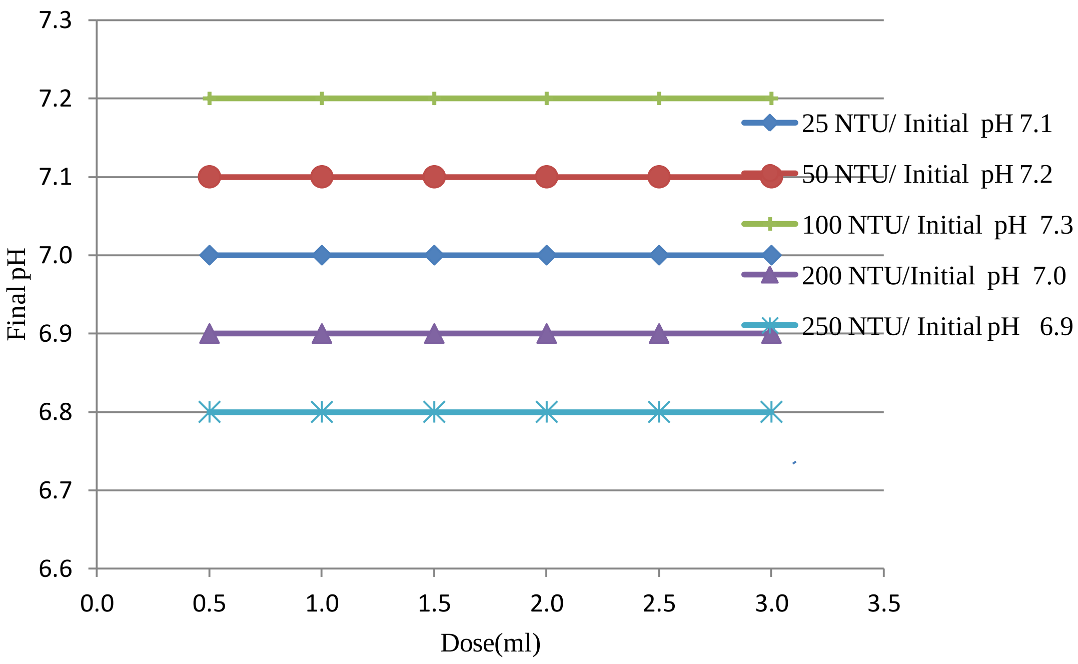


Figure 4.6 Variation of pH profile of synthetic water without any coagulant for initial turbidity 25, 50, 100, 200 and 250 NTU

The amount of pH slightly decreases then initial pH after the treatment by cactus. It occurs no difference adding the different dose of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml taken from the concentration of 1.5 mg/liter.

Figure 4.7 shows that the plot between the variation of alum dose and final pH. The pH of average initial turbidity was measured and the different alum dose was applied and then the final pH was measured.

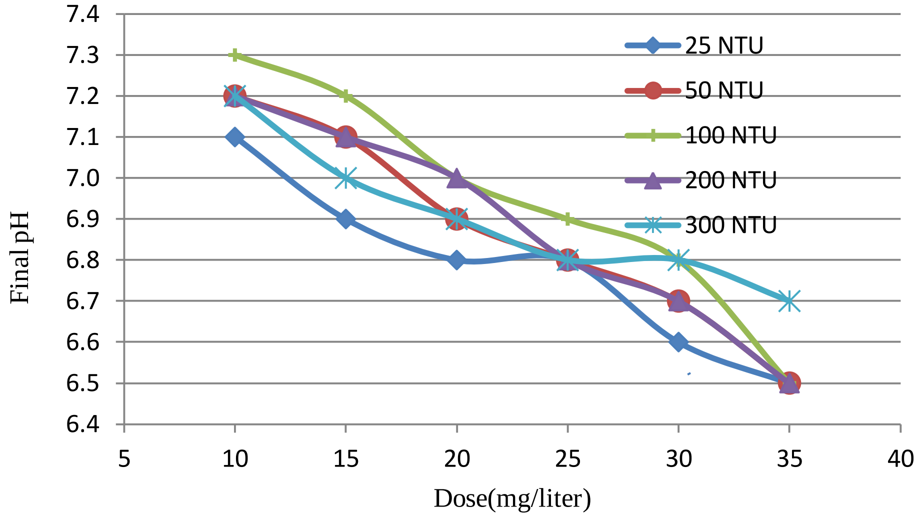


Figure 4.7 Variation of pH profile of synthetic water by alum for initial turbidity 25 , 50 , 100, 200 and 300 NTU at Batch

For average initial turbidity of 25 NTU the mixing of alum dose 15 mg/liter reduces the water pH up to 6.9. While the further increase of alum dose of 35mg/liter reduces the pH up to 6.5. Similarly for the other average initial turbidity the addition of alum dose has reduced the pH significantly. Thus it can be concluded that the addition of alum dose reduces the pH.

4.3 Economic Analysis

For the economic analysis, sample of specific turbidity was tested in the batch reactor at the optimum dose of cactus 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 cactus and alum dose

SN.	Description	Cactus	Alum	Remarks
1.	Cost for 500gm	Rs. 500	Rs. 280	
2.	Amount reducing 200NTU to 7.5NTU	0.003mg	0.025mg	
3.	Total Cost reducing turbidity 200NTU to 7.5NTU of 500ml prepared synthetic water	=Rs. 0.003*500/500000 = Rs. 0.000006 per 500ml = Rs. 1.2 per 100000 liter	=Rs. 0.025*280/500000 =Rs. 1.4 per 100000 liter	

From the above comparison it is concluded that for turbidity removal through cactus treatment is more efficient than the use of alum.

CHAPTER V

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 cactus powder found to be 2ml taken from the concentration of 1.5mg/liter from the batch study for cactus dose.
- The maximum turbidity removal efficiency for continuous flow by cactus powder found to be effective at the flow rate of 3.58 liter/minute from the continuous flow for the cactus dose treatment.
- As per the results, it can be concluded that the turbidity can be lowered up to the 8.0 NTU by the cactus powder in the continuous flow which is within the range of NDWQS standard.
- As per the economic analysis the coagulation method by cactus powder for the turbidity removal is found to be less cost in comparison to the use of Alum, final pH of water is in the range of NDWQS ,so the use of cactus powder for the removal of turbidity in Nepalese context is more effective in comparison to the Alum.

5.2 Recommendations

The recommendations made from the study are:

- The further study is recommended for the influence of temperature conditions.
- It is recommended to study for the cactus dose effect in the micro organism.
- It is recommended to study by using combined effect of cactus and alum in turbidity removal.

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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 cactus dose

For 1.0mg/liter concentration

Fixed parameters: Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3.5ml

Initial turbidity :20-30NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity :45-55NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity :95-105NTU , Initial pH:7.10,Final pH:7.0	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
9.0	91.0	9.0	91.0	8.5	91.5
8.5	91.5	8.5	91.5	8.0	92.0
8.0	92.0	8.0	92.0	7.5	92.5
7.5	92.5	7.5	92.5	7.0	93.0
7.5	92.5	7.5	92.5	7.0	93.0
7.5	92.5	7.5	92.5	7.5	92.5

Initial turbidity :145-155NTU , Initial pH:7.20,Final pH:7.10		Initial turbidity :195-205NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity : 245-255NTU , Initial pH:7.10,Final pH:7.0	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
8.5	91.5	8.5	91.5	11.0	89.0
8.0	92.0	8.5	91.5	10.0	90.0
7.5	92.5	8.0	92.0	9.0	91.0
7.0	93.0	7.5	92.5	9.0	91.0
7.0	93.0	7.5	92.5	9.0	91.0
7.5	92.5	8.0	92.0	9.0	91.0

For 0.5mg/liter concentration

Batch study for cactus dose

Fixed parameters: Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3.5ml

Initial turbidity :20-30NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity :45-55NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity :95-105NTU , Initial pH:7.10,Final pH:7.0	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
9.5	90.5	10.0	90.0	9.0	91.0
9.0	91.0	9.0	91.0	8.5	91.5
8.5	91.5	9.0	91.0	8.0	92.0
8.5	91.5	8.5	91.5	7.5	92.5
8.0	92.0	8.0	92.0	7.5	92.5
8.0	92.0	8.0	92.0	7.5	92.5

Initial turbidity :145-155NTU , Initial pH:7.20,Final pH:7.10		Initial turbidity :195-205NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity : 245-255NTU , Initial pH:7.10,Final pH:7.0	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
9.0	91.0	10.0	90.0	10.5	89.5
8.5	91.5	9.5	90.5	10.0	90.0
8.0	92.0	9.0	91.0	9.5	90.5
7.5	92.5	8.5	91.5	9.5	90.5
7.5	92.5	8.5	91.5	9.0	91.0
7.5	92.5	8.5	91.5	9.5	90.5

For 1.5mg/liter concentration

Batch study for cactus dose

Fixed parameters: Sample volume : 500ml, Stirring time 30 minute, Dose 0.5,1.0,1.5,2,2.5.and 3.5ml

Initial turbidity :20-30NTU , Initial pH:7.10,Final pH:7.0		Initial turbidity :45-55NTU , Initial pH:7.20,Final pH:7.1		Initial turbidity :95-105NTU , Initial pH:7.3,Final pH:7.2	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
8.5	91.5	8.5	91.5	8.0	92.0
8.0	92.0	8.0	92.0	7.5	92.5
7.5	92.5	7.5	92.5	7.0	93.0
7.0	93.0	7.0	93.0	7.0	93.0
7.0	93.0	7.0	93.0	7.0	93.0
7.5	92.5	7.5	92.5	7.5	92.5

Initial turbidity :145-155NTU , Initial pH:7.20,Final pH:7.10		Initial turbidity :195-205NTU , Initial pH:7.00,Final pH:6.9		Initial turbidity : 245-255NTU , Initial pH:6.9,Final pH:6.8	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
8.0	92.0	8.5	91.5	9.5	90.5
7.5	92.5	8.0	92.0	9.0	91.0
7.0	93.0	8.0	92.0	9.0	91.0
7.0	93.0	7.5	92.5	9.0	91.0
7.0	93.0	7.5	92.5	9.0	91.0
7.5	92.5	8.0	92.0	9.5	90.5

C: Batch study for alum dose

Fixed parameters: Sample volume : 500ml, Stirring time 30 minute, Dose 10,15,20,25,30 and 35mg/liter

Initial turbidity :20-30NTU			Initial turbidity :45-55NTU		
Final pH	Residual turbidity NTU	Removal %	Final pH	Residual turbidity NTU	Removal %
7.1	7.0	93.0	7.2	6.5	93.5
6.9	6.0	94.0	7.1	5.5	94.5
6.8	5.5	94.5	6.9	5.0	95.0
6.8	5.5	94.5	6.8	5.0	95.0
6.6	5.5	94.5	6.7	5.0	95.0
6.5	6.0	94.0	6.5	5.5	94.5

Initial turbidity :95-105 NTU			Initial turbidity :195-205NTU		
Final pH	Residual turbidity NTU	Removal %	Final pH	Residual turbidity NTU	Removal %
7.3	5.5	94.5	7.2	7.2	6.0
7.2	5.5	94.5	7.1	7.1	5.5
7.0	5.0	95.0	6.9	7.0	5.0
6.9	4.5	95.5	6.8	6.8	5.0
6.8	5.0	95.0	6.7	6.7	5.5
6.5	5.0	95.0	6.5	6.5	5.5

Initial turbidity :295-305 NTU		
Final pH	Residual turbidity NTU	Removal %
7.3	5.5	94.5
7.2	5.5	94.5
7.0	5.0	95.0
6.9	4.5	95.5
6.8	5.0	95.0
6.5	5.0	95.0

D: Continuous flow study for cactus dose

Data table for Turbidity profile of synthesis water for initial turbidity 25, 50, 100, 150, 200 and 250 NTU for continuous flow

Fixed parameters:

Sample point : 0.3,0.6,0.9,1.2,1.5m , Dose : 2ml, Settling time period :10 minute

Initial turbidity: 20-30NTU, Initial pH: 7.2, Final pH: 7.1

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 %
12.0	88.0	11.5	88.5	11.0	89.0	10.5	89.5
11.5	88.5	11.5	88.5	11.0	89.0	10.5	89.5
11.5	88.5	11.5	88.5	10.5	89.5	10.0	90.0
11.0	89.0	11.0	89.0	10.5	89.5	10.0	90.0
11.0	89.0	11.0	89.0	10.0	90.0	10.0	90.0.

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 %
10.0	90.0	9.0	91.0	9.0	91.0	9.0	91.0
10.0	90.0	9.0	91.0	9.0	91.0	9.0	91.0
9.5	90.5	8.5	91.5	8.5	91.5	8.5	91.5
9.5	90.5	8.5	91.5	8.5	91.5	8.5	91.5
10.0	90.0	9.0	91.0	9.0	91.0	9.0	91.0

Initial turbidity: 45-55NTU, Initial pH: 7.1, Final pH: 7.0

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 %
11.5	88.5	11.0	89.0	10.5	89.5	10.0	90.0

11.5	88.5	11.0	89.0	10.5	89.5	10.0	90.0
11.0	89.0	10.5	89.5	10.0	90.0	9.5	90.5
10.5	89.5	10.5	89.5	10.0	90.0	9.5	90.5
10.5	89.5	10.0	90.0	9.5	90.5	9.0	91.0

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 %
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
8.5	91.5	8.5	91.5	8.5	91.5	8.5	91.5
9.0	91.0	9.0	91.0	9.0	91.0	9.0	91.0

Initial turbidity: 95-105NTU, Initial pH: 7.1, Final pH: 7.0

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 %
11.0	89.0	11.0	89.0	10.5	89.5	10.0	90.0
11.0	89.0	10.5	89.5	10.0	90.0	9.5	90.5
10.5	89.5	10.0	90.0	10.0	90.0	9.5	90.5
10.0	90.0	10.0	90.0	9.5	90.5	9.0	91.0
10.0	90.0	9.5	90.5	9.5	90.5	9.0	91.0

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 %
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
8.5	91.5	9.0	91.0	9.0	91.0	9.0	91.0

Initial turbidity: 145-155NTU, Initial pH: 7.2, Final pH: 7.1

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 %
11.0	89.0	10.5	89.5	10.0	90.0	9.5	90.5
11.0	89.0	10.5	89.5	10.0	90.0	9.5	90.5
10.5	89.5	10.0	90.0	9.5	90.5	9.0	91.0
10.0	90.0	9.5	90.5	9.5	90.5	9.0	91.0
10.0	90.0	9.5	90.5	9.0	91.0	9.0	91.0

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 %
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.5	90.5	9.0	91.0	9.0	91.0	9.0	91.0
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
8.5	91.5	8.0	92.0	8.5	91.5	8.0	92.0
8.0	92.0	8.5	91.5	8.0	92.0	8.5	91.5

E: Continuous flow study for alum dose

Data table for Turbidity profile of synthesis water for initial turbidity 25, 50, 100, 150, 200 and 250 NTU for continuous flow

Fixed parameters:

Sample point : 0.3,0.6,0.9,1.2,1.5m , Dose : 2ml, Settling time period :10 minute

Initial turbidity: 20-30NTU, Initial pH: 7.2, Final pH: 6.9

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 %
10.0	90.0	9.5	90.5	9.0	91.0	8.0	92.0
9.5	90.5	9.5	90.5	9.0	91.0	7.5	92.5
9.5	90.5	9.0	91.0	8.5	91.5	7.5	92.5
9.0	91.0	8.5	91.5	8.0	92.0	7.0	93.0
9.0	91.0	8.5	91.5	8.0	92.0	7.0	93.0

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 %
7.0	93.0	5.5	94.5	5.5	94.5	5.5	94.5
6.5	93.5	5.5	94.5	5.5	94.5	5.5	94.5
6.0	94.0	5.0	95.0	5.0	95.0	5.0	95.0
5.5	94.5	5.0	95.0	5.0	95.0	5.0	95.0
6.0	94.0	5.5	94.5	5.5	94.5	5.5	94.5

Initial turbidity: 45-55NTU, Initial pH: 7.2, Final pH: 6.9

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 %
9.5	90.5	9.5	90.5	9.0	91.0	7.5	92.5

9.0	91.0	9.0	91.0	8.5	91.5	7.5	92.5
9.0	91.0	9.0	91.0	8.5	91.5	7.0	93.0
8.5	91.5	8.5	91.5	8.0	92.0	7.0	93.0
8.5	91.5	8.5	91.5	7.5	92.5	7.0	93.0

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 %
7.5	92.5	5.5	94.5	7.0	93.0	5.5	94.5
7.0	93.0	5.5	94.5	7.0	93.0	5.5	94.5
7.0	93.0	5.0	95.0	7.0	93.0	5.0	95.0
7.0	93.0	5.5	94.5	7.5	92.5	5.0	95.0
7.5	92.5	6.0	94.0	8.0	92.0	5.5	94.5

Initial turbidity: 95-105NTU, Initial pH: 7.1, Final pH: 6.9

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 %
11.0	89.0	10.0	90.0	9.5	90.5	8.0	92.0
10.5	89.5	9.5	90.5	9.0	91.0	7.5	92.5
10.0	90.0	9.0	91.0	8.5	91.5	7.0	93.0
9.5	90.5	8.5	91.5	8.0	92.0	7.0	93.0
9.0	91.0	8.5	91.5	7.5	92.5	7.0	93.0

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 %
7.5	92.5	5.5	94.5	5.5	94.5	5.5	94.5
7.0	93.0	5.5	94.5	5.5	94.5	5.5	94.5
6.5	93.5	5.0	95.0	5.0	95.0	5.0	95.0
5.0	95.0	5.0	95.0	5.0	95.0	5.0	95.0
5.5	94.5	5.5	94.5	5.5	94.5	5.5	94.5

Initial turbidity: 195-205NTU, Initial pH: 7.0, Final pH: 6.8

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 %
10.5	89.5	10.5	89.5	10.0	90.0	9.5	90.5
10.0	90.0	10.0	90.0	9.5	90.5	9.0	91.0
10.0	90.0	9.5	90.5	9.0	91.0	8.5	91.5
9.5	90.5	9.0	91.0	8.5	91.5	8.5	91.5
9.0	91.0	9.0	91.0	8.5	91.5	8.0	92.0

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 %
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
8.5	91.5	8.0	92.0	8.0	92.0	8.0	92.0
7.5	92.5	7.5	92.5	7.5	92.5	7.5	92.5
7.0	93.0	7.0	93.0	7.0	93.0	7.0	93.0
7.5	92.5	7.5	92.5	7.5	92.5	7.5	92.5

Initial turbidity: 295-305NTU, Initial pH: 7.1, Final pH: 6.9

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 %
11.5	88.5	11.0	89.0	10.5	89.5	10.0	90.0
11.5	88.5	11.0	89.0	10.5	89.5	10.0	90.0
11.0	89.0	10.5	89.5	10.0	90.0	9.5	90.5
10.0	90.0	10.0	90.0	9.5	90.5	9.5	90.5
9.5	90.5	10.0	90.0	9.5	90.5	9.0	91.0

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	Removal	Residual	Removal	Residual	Removal	Residual	Removal

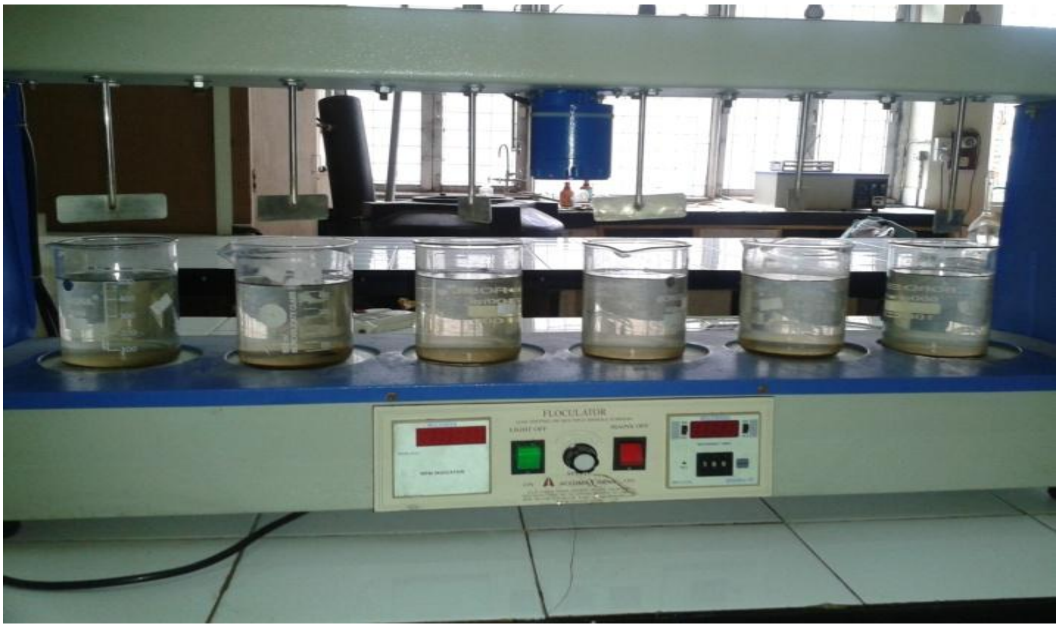
turbidity NTU	%	turbidity NTU	%	turbidity NTU	%	turbidity NTU	%
9.0	91.0	8.5	91.5	8.5	91.5	8.5	91.5
9.0	91.0	8.0	92.0	8.0	92.0	8.0	92.0
8.5	91.5	7.5	92.5	7.5	92.5	7.5	92.5
8.0	92.0	7.0	93.0	7.0	93.0	7.0	93.0
8.0	92.0	7.5	92.5	7.5	92.5	7.5	92.5

PHOTOGRAPHS

P1: Cactus sample plants

P2: Cactus in powder form

P3: Jar test before cactus application



P2: Jar test after completion