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Removal of Turbidity and Effectiveness as Disinfectant of Water Using Eco-friendly Methi Seed Powder

by
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A THESIS

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The undersigned certify that they have read, and recommended to the institute of engineering for acceptance, a mid-term thesis report entitled "**Removal of Turbidity and Effectiveness as Disinfectant of Water Using Eco-Friendly Methi Seed Powder**" submitted by Mr Ushes Shrestha in partial fulfillment of the requirement for the degree of Master of Science in Environmental Engineering.

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ABSTRACT

Coagulation-Flocculation followed by sedimentation and filtration is the most commonly used water treatment process. Synthetic coagulant has both health and economic problems especially in developing countries. Natural and herbal coagulants have been used in developed countries since last centuries. This research was carried out to confirm the effectiveness of powder extracted from dried *Trigonella foenum graecum* seeds, a cheap, readily available local coagulant and readily biodegradable natural product. This work investigates on performance of methi seed powder (*Trigonella foenum graecum*) in removing turbidity at optimum dose. The quality of water was analysed and compared with alum treated water. 1.0M NaCl extract was found to be more efficient than that of aqueous extract in turbidity removal. The turbidity removal efficiency using 1.0 M NaCl extract was measured upto 95%. For continuous flow 0.9 m distance seems to be enough for turbidity removal using methi seed powder. The coagulant did not have considerable effect on final pH of the water. Methi can be used as coagulant but suitable for turbidity 20-150 NTU and flow rate about 3.5 liter/minute. The aqueous extract of methi seed powder did not show the disinfectant properties and therefore cannot be used at field. High turbidity determined in this study indicates that *Trigonella foenum graecum*, a natural coagulant, can be potentially viable substitute to alum in treatment of water.

Keywords: Natural coagulant, Methi seed powder, Turbidity removal, Disinfection, Water treatment

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Ushes Shrestha

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LIST OF ABBREVIATIONS

CP	-	Crude Protein
IOE	-	Institute of Engineering
M	-	Molarity
MPN	-	Most Probable Number
NaCl	-	Sodium Chloride
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
SS	-	Suspended Solids
TA	-	Total Ash
WHO	-	World Health Organization
%	-	Percentage
l	-	Liters
gm	-	Gram
mg	-	Milli-Gram
ml	-	Milli-Liters

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The explosive growth of the world's human population and subsequent water and energy demands have led to an expansion of standing surface water (Vara, 2012). The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses. In the developing countries access to safe water is crucial issue because water related diseases are one of the major health problems globally. About 75% of the present world lives in developing countries out of which 1.2 billion people still lack of safe drinking water and more than 6 million children die from diarrhea every year. About 84% of the populations without access to an improved source of drinking water live in rural areas of developing countries (Firdissa *et* al., 2015). The unhygienic handling of water and transport action can contaminate previously safe or treated water. The consumption of high quality of water in itself is an important factor and paramount significance for improving public health. This is of special importance in developing countries like our country Nepal where the quality of water even in the city areas is not above suspicion. The desire for better quality of water has placed the water treatment process in center stage.

The studies done by authorities at the Nepal Water Supply Corporation (NWSC), shows the poor water quality during rainy season ranging 10 NTU (Nephelometric Turbidity Units) in the dry season to 1500 NTU in the rainy season. Developing countries like Nepal are facing potable water supply problems due the lack of financial resources and technical personnel. The cost of water treatment is increasing. The quality of river water contains suspended and colloidal particles caused by land development and high storm runoff during the rainy seasons especially in Nepal. During the rainy seasons the turbidity level increases and consequences for water treatment increases which leads to high cost of treatment. As a result, the drinking water that reaches the consumer is not properly treated.

One of the most important steps during the conventional treatment process is coagulation/flocculation which serves mainly for the removal of suspended solids (including colloidal micro particles) and natural organic matter. Nearly all the colloidal impurities in natural water are negatively charged and hence, these systems may be stable as a result of mutual electrical repulsions (V.Jadhav and S.Mahajan, 2013). The process of chemical coagulation and flocculation is commonly used to remove suspended impurities and turbidity from water and chlorination is done for the disinfection of water. According to the coagulation and flocculation theory, colloidal destabilization can be achieved by adding cations that interact specifically the negative colloids and reduce (or neutralize) their charge (Peavy and Rowe, 1985). Alum is the most widely used coagulant in the treatment of water but its use increases the almunium concentration in treated water. A high concentration concentration of almunium is also of concern because of its adverse effects on health. Almunium intake into the body has been linked with several neuropathological diseases including percentile dementia and Alzheirmer's disease (V.Jadhav and S.Mahajan, 2013).

In many rural communities of developing countries water clarification methods like flocculation, coagulation, and sedimentation often impractical because of the high cost of equipment and low availability of chemical coagulants. Natural plant extracts have been used for water purification for many centuries and Egyptians inscription afforded the earliest recorded knowledge of plant materials used for water treatment, dating back perhaps to 2000BC in boiling and filtration. In recent years there has been considerable interest in the development of usage of natural coagulants which can be produced extracted from microorganism animal or plant tissues. These coagulants should be biodegradable and presumed to be safe for human health. In addition, natural coagulants produce readily biodegradable matter and less volume sludge that amounts only 20-30% that of alum (Megersa *et* al., 2014). It has been found that some natural coagulant can replace Aluminium Sulphate (Alum) which is used widely all over the world.

Due to these concerns of the chemicals used in the treatment of water the alternative to these chemicals need to be identified. The methi seed can be such natural product which has multifunction. It has the coagulant as well as disinfectant property. So this proposal is focusing on removal of turbidity along with disinfection of water using the natural eco-friendly methi seed powder. This will help identifying the alternative natural products like methi (fenugreek seed) which is grown locally in farms and in the forest of Nepal.

1.2 Rationale of the Study

Due to the disadvantages of chemical, inorganic, synthetic coagulants like large dosage, likely harmful to human well-being, high price and toxicity, the application of such coagulants and disinfectants should be minimized. Natural coagulant as fenugreek is an eco-friendly without any side effects and many researchers are investigating possibilities of this natural product. Excess of chlorine is carcinogenic and harmful to human health so alternative to chlorination need to be explored. The methi seed can both act as a natural coagulant as well as natural disinfectant. Methi has been used for medicinal, herbal purposes. It has the multiple benefits, so methi could be the good option for the drinking water treatment supply. The researchers are concerned about methi seed due to

a) Local availability
b) Abundant source
c) Economic
d) Eco- friendly
e) Multifunction
f) Biodegradation

Fenugreek has received a great degree of attention in recent years because it contains medicinal properties and many studies had been done in the disinfection of water using this product. Various studies indicated that methi containing crude protein, Fat, Fiber, Carbohydrates and Ash having coagulation properties similar to other natural coagulants. So it has potential as a natural coagulant.

In Nepal, Fenugreek, locally called Methi has been used for the medicinal, herbal purposes, cooking purposes. Methi is being used for controlling blood pressure, diabetes and other medical purposes. Methi can be found in the forest and terai areas of Nepal. It could have large-scale application, but the development of fenugreek application is still limited in laboratory. It has also established that the powder of fenugreek seed functioned as a coagulant as well as a disinfectant agent.

1.3 Objective of the Study

The main objective of the study is:

a) To evaluate the efficiency of natural bi-product derived from methi *(Trigonella foenum graecum)* seed for turbidity removal along with disinfection of water.

The specific objective of the study is

a) To detect the effect of variations in turbidity, pH and effectiveness as disinfectant on dosage of methi seed powder.
b) To evaluate at optimum operating conditions.

1.4 Limitations of the Study

Limitations of the study are:

a) The natural material may contain organic matter and there is always possibility of deterioration and biodegradation if the solution prepared is not used timely.
b) Treated water by methi may contain odour and color which may not be aesthetically acceptable.
c) The turbidity removal and disinfection by methi powder is suitable only for small treatment plant.
d) The test for disinfection will be limited for batch reactor and coliform only.

1.5 Organization of the Report

The report is divided into five chapters.

a) Chapter I: Introduction

   Introduction includes brief background about drinking water and drinking water treatment, rationale of the study, objective of the study and limitation of the study.

b) Chapter II: Literature Review

   This chapter deals with the brief literature review from secondary sources relating to the area of the study.

c) Chapter III: Methodology

   This chapter includes the detail about the methodology that was followed during the study.

d) Chapter IV: Results and Discussion

   This chapter shows the results obtained during the study period.

e) Chapter V: Conclusion and Recommendation

   This chapter contains conclusion of the research and further recommendation for similar researchers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Fenugreek (*Trigonella foenum graecum*): An overview

Fenugreek (*Trigonella foenum- graecum*) is a plant from the family of Leguminosae that grows annually and widely cultivated in the Mediterranean countries in Asia. The dried seeds have been traditionally used in India, China, Egypt, and in some parts of the Europe for their beneficial health such as galactogouge, antibacterial, antiflammatory, insulinotropic, and rejuvenating properties. Pleasantly bitter and slightly sweet fenugreek seeds which are available in whole and ground forms are used as a source of flavouring for foods including curry powders, spice, blends and teas. The seeds have horny and relatively large layer of white and semi-transparent endosperm encircling central hard, yellow embryo (Khorsidian *et* al., 2015).

2.2 Elemental Analysis of Fenugreek Seeds

Wonderful functional and medicinal values of fenugreek are attributed to the chemical composition (20-25% protein, 45-50% dietary fiber, 20-25% mucilaginous soluble fiber, 6-8% fixed fatty acids and essential oil, and 2-5% steroidal saponins, Moreover, some minor components such as alkaloids (trigonolline, cholin, gentianine, carpaine, etc), free unnatural amino acids (4-hydroxyisoleucine), and individual spirostanols and furastanols like diosgenin, gitogenin and yamogenin have also been identified and determined as the main components for its various biological effects (Khorsidian *et* al., 2015).

2.3 Mechanism of Turbidity Removal in Drinking Water

2.3.1 Turbidity removal mechanism

The one of the important processes that involves in conventional water treatment is Coagulation with flocculation at which the desired objectives can be achieved. Those substances which are capable of removing colloidal impurities from water may be defined as Coagulants. The purpose of coagulation is to turn the small particles of color, turbidity and bacteria into large flocs, and therefore it precipitates easily (Spellman Frank and Joanne, 1999). It is presented in Figure 2.1.

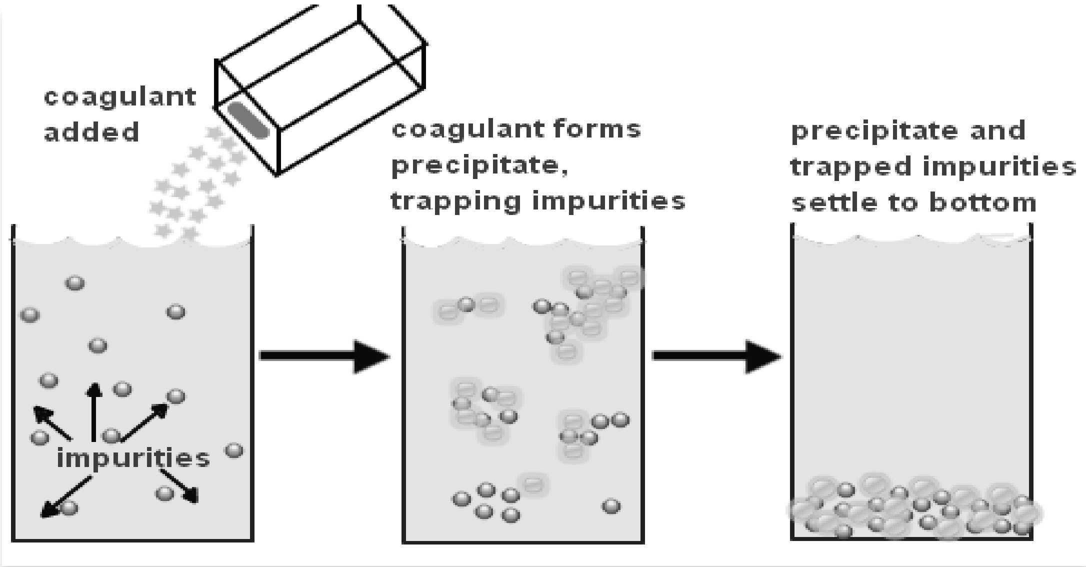


Figure 2.1: Coagulation process

Treatment to water to remove turbidity is essential for both large and small scale production of drinking water. The removal of turbidity in water treatment is essential because it is vehicle for undesirable organic and inorganic contaminants, taste, odour, and colour imparting compounds and pathogenic organisms. The turbidity of water often results from the presence of colloidal particles that have a net negative charge. Thus electrostatic forces prevent them from agglomerating, making it impossible to remove by plain sedimentation without the aid of coagulants (Addo Mariam Marimax, 2011).

The high cationic charge of these two metals salts makes them effective for destablizing colloids. They act by neutralizing the negative charge of the stable colloidal particles. Coagulants enhance particle collision and agglomeration of neutral particles to form dense flocs that can settle easily. Destabilization of colloidal particles in water is accomplished via adsorption and charges neutralization, adsorption and inter-particle bridging, enmeshment in a precipitate and double layer compression (Nancy Jotham, 2008).

2.3.2 Polyelectrolytes

Polyelectrolytes are water soluble organic polymers consisting of repeating units of smaller molecular weights chemically combined to form larger molecules of colloidal size each carrying electrical charges or ionized groups. They can be either natural or synthetic and can be used as both primary coagulants and coagulant aids. Polyelectrolyte primary coagulants are cationic with high charge density and low molecular weight, while synthetic polyelectrolyte coagulant aids have relatively high molecular weights and facilitate flocculation through inter-particle bridging (Addo Mariam Marimax, 2011).

However, they are not readily available and also costly for most part of the developing world. Natural polyelectrolytes such as water soluble proteins released form crushed seed of fenugreek are potential alternatives to synthetic polyelectrolytes. The merits of natural polyelectrolytes over synthetic include safety to human health, biodegradability and wide effective range of flocculation for various colloidal suspensions (Addo Mariam Marimax, 2011).

2.3.3 Protein structure of fenugreek seed

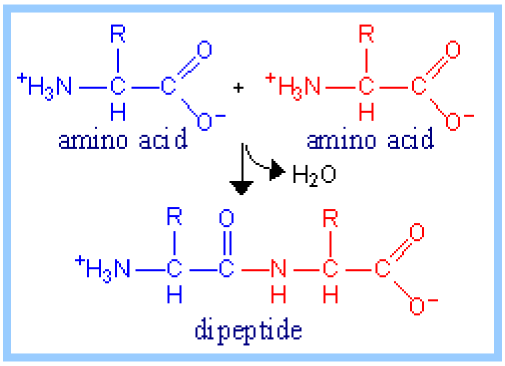


Figure 2.2: Protein structure of Fenugreek

Natural coagulants and disinfectants can be alternative to chemical and physical water treatment method. There are several biological agents, mainly plants, reported for its coagulation activity especially removal of microorganisms. The use of natural materials for treatment of drinking water in some parts of world has been recorded throughout human history. However, these natural materials have not been recognized or duly supported due to lack of knowledge on their exact nature and the mechanism by which they function. As a consequence, the natural materials have been unable to compete effectively with the commonly used water chemicals. There has been a resurgence of interest 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, synthetic organic polymers and disinfectants. They are reusing some of the by-products from natural coagulants in other enterprises (Addo Mariam Marimax, 2011). Most of the rural areas of developing countries depend on turbid water from rivers, non-perenial streams and natural rain ponds for domestic water supply, but they need to be treated. In india crushed seed of the nirmali tree (*strychnospotatorum*) have been used for centuries to clarify turbid water. Traditional water treatment using crushed or chopped *Maerua pseudo petalosa* (Kordala) root is practiced in some parts of developing countries. Knowledge on natural coagulants is widespread in many parts of the developing world and therefore there is potential for such knowledge to be used efficiently to maximize their performance through research. Studies have acknowledged that the most important plant families from which several genera are used traditionally for domestic water coagulation are Acanthaceae, Capparidaceae and papilionaceae (Nancy Jotham, 2008) Natural macromolecular coagulants show bright future and are concerned by many researchers because their abundant source, low price, innocuity, multifunction and biodegradation (Nik Azimatolakma, 2011).

Seeds of methi (*Trigonella foenum graecum*) contain materials that can act as effective natural coagulant. The natural coagulant present in *Trigonella foenum graecum* shows its coagulation efficiency at neutral PH. Further it was found that this natural coagulant is temperature and PH stable (Ramamurthy *et* al., 2012). Some natural coagulants like methi, guar seeds, bhindi seeds contained active constituents which are responsible for the coagulation mechanism and improving coagulant property (Amitkumar and Farooq, 2015).

The literature review reveals that there is hardly any research carried out exclusively for methi seed as a disinfectant agent. In general the literature indicates that methi is good antimicrobial agent. Apart from that there is hardly any specific details regarding its use as a disinfectant.

CHAPTER THREE

3.0 METHODOLOGY

This chapter includes laboratory setup, collection of sample and analysis of sample.

3.1 Laboratory Setup

The main concern of the study was to find out the removal efficiency of turbidity and disinfection for the water sample. The analysis was carried out at public health laboratory of IOE. Due to time constraint all the parameter could not be conducted.

3.2 Collection and Preparation of Methi Seed Powder

The seed of methi was collected from the city areas of Kathmandu Valley and was dried in the sun for 24 hours. Then it was grinded to fine powder using the hand grinder. Then it was sieved through 2 micron sieve to obtain fine powder.

3.3 Preparation of Methi Solution and Water Sample for Jar Test

First of all 10 gm of prepared powder was suspended in 1liter distilled water or NaCl (1.0M) solution and the suspension was stirred using a magnetic stirrer for 10 min to extract the coagulation active components. For the optimum dose condition different dose of prepared powder was suspended in NaCl (1.0M) solution and was stirred using a magnetic stirrer for 10 minutes to extract the coagulation active components and the solution was gravity filtered through rough filter paper.

The turbid water sample varying 20-300 NTU was prepared mixing mud slurry obtained from bottom of water tank of guard house near zero energy house with distilled water.

3.4 Preparation of Methi Solution and Water Sample for Disinfection

The aqueous solution was prepared mixing 10gm of prepared powder in 50ml of distilled water. And it was allowed to stand for 24 hours after which it was filtered using Whatman No.1 filter paper. Then the filtered sample was made up to volume using distilled water.

3.4.1 Preparation of sample

One liter of distilled water was taken in a beaker. Then water was mixed with water consisting of coliform bacteria. 100 ml of the contaminated water was measured with help of measuring cylinder and placed in a sampling bottle. Same procedure was repeated for three times. Then the disinfectant was added in the three sampling bottles while one of sampling bottle was kept as control. Then the sampling bottle was shaken and placed for 24 hour.

3.4.2 Preparation of media

7.72 gms of M-Lauryl Sulphate broth was taken and placed in a autoclaved 100 ml volumetric flask. Then 100 ml of distilled water was added on the volumetric flask and the flask was shaken till the media is dissolved completely. Then the flask was sterilized by autoclaving at 121 ºC for 15 minutes.

3.4.3 Preparation of petri plates

Petri plates were autoclaved and dried in oven. Then absorbent pads were placed in the petri plates. Then the M-Lauryl sulphate broth was added on the absorbent pad and it was saturated with the broth.

3.4.4 Membrane filtration and incubation

Vacuum flask apparatus was sterilized. Then the membrane filter was taken with the sterilized forcep and placed on the vacuum filter. Then the sample was poured on the vacuum flask and filtered. Then the membrane filter was picked from the vacuum filter with sterilized forcep and the placed on the absorbent pad saturated with medium and the petri plate was covered.

The petri plate was kept in room condition for 1 hour for acclimatization. The cultured bacteria water sample was used for the disinfection. This procedure was repeated for all the four samples. Then the petri plate was kept in incubator for 24 hours at 44 ºc.

3.4.5 Colony count

The petri plate was taken out of incubator. Then the cover was taken out and the petri plate was placed on the colony counter. The no of colony was calculated. Then the membrane filter was taken from the petri plate placed on the crucible basin and chromic acid was added on the crucible basin for killing of the bacteria.

3.5 Coagulation Test

3.5.1 Jar test

Coagulation efficiency of each seed extract was determined by jar test. The synthetic water sample (500 ml) was filled into the beakers (500ml) and mixed at 125 rpm at constant room temperature. Various doses of solution 0.5ml, 1ml, 1.5ml, 2ml, 2.5ml, 3ml were added into the beakers and were mixed for 1-2 minutes. The mixing speed was then reduced to 70 rpm and will be kept for another 30 min. Then the suspension was left for sedimentation. Then after certain interval of time clarified samples were collected from the top of beakers and turbidity was measured as TS (Turbidity of Sample). Turbidity was measured using a turbidimeter and it was expressed in Nephelometric Turbidity Units (NTU). Numbers of samples were taken and measured for tests about effect of fenugreek coagulant dosage. The various doses 10gm/l, 3gm/l, 1gm/l, 0.5gm/l, 1.5gm/l, 1.25gm/l solution was prepared respectively and were tested for the removal efficiency of turbidity of synthetic sample of water. The PH of initial sample water was taken and the again the final PH of treated water was taken. The optimum dose of methi solution was determined.

3.5.2 Continuous set up and procedure

In the experimental set up, a continuous flow laboratory unit was fabricated and used. It consists of coagulation dose tank, mixing tank and sedimentation tank. In the mixing tank the sample water and appropriate methi dose was constantly mixed with rotary mixer and then was sent to sedimentation tank which maintains the constant flow rate. Different settling time period 10, 20, 30, 40, 60, 90, 120 minute was chosen to calculate the different flow rate of 21.52, 10.76, 7.17, 5.38, 2.24, 1.68 liter/minute.

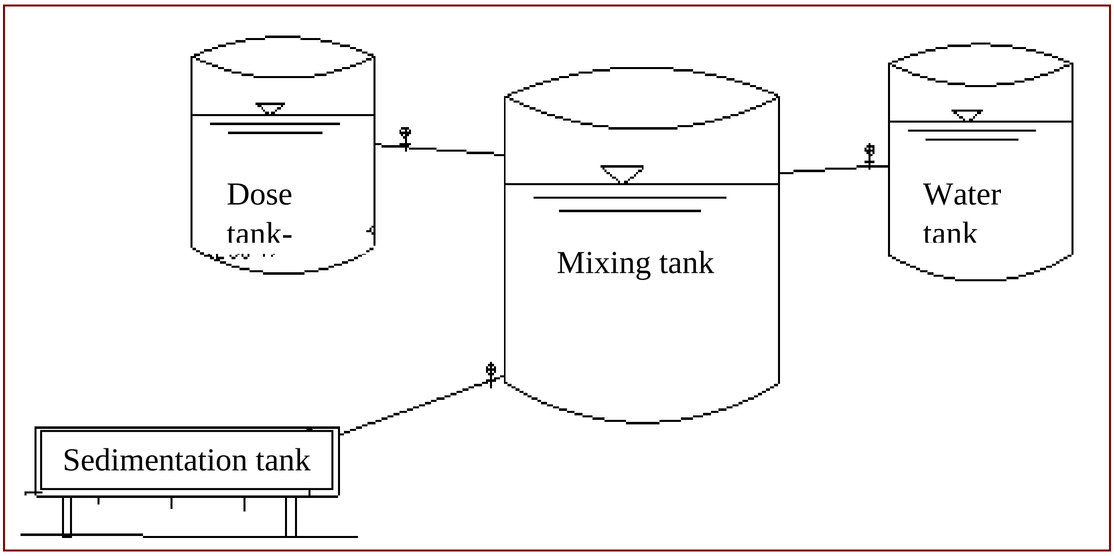


Fig 3.1: Set up for continuous flow

Sedimentation basin consists the size of volume 0.54 (3.75*0.41*0.35) cubic meters. It has both sides inlet as in Figure. It consists of the seven ports with in interval of 300mm. It has four sludge extraction outlets in the bottom of the sedimentation tank.

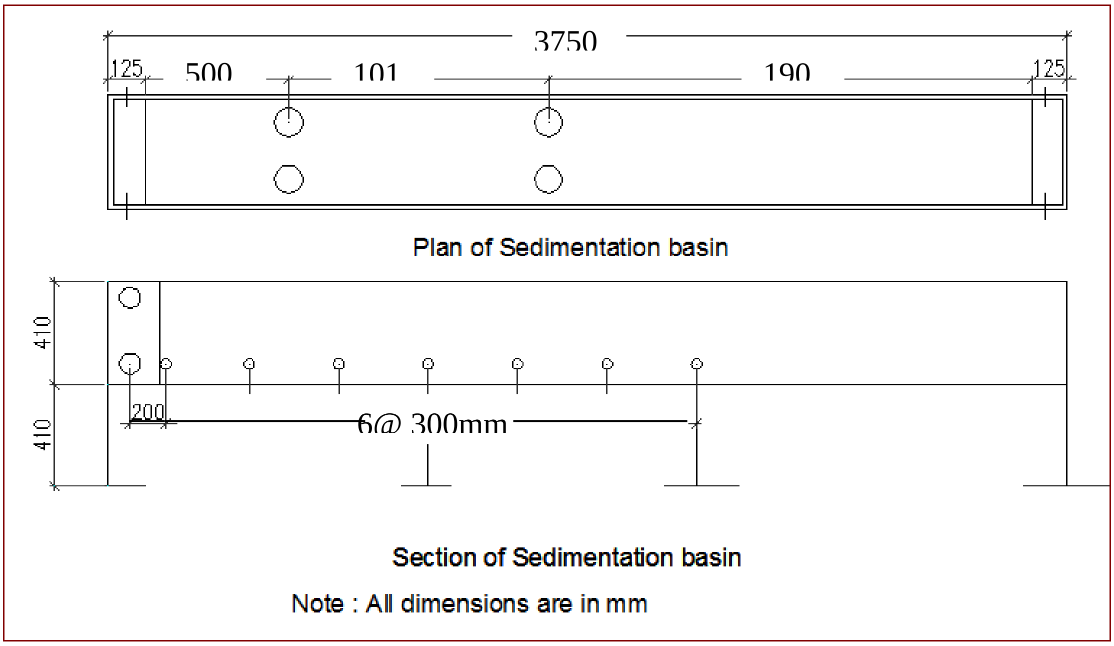


Fig 3.2 Plan and section of sedimentation tank

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

The results of turbidity removal of water by methi seed 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.

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 methi dose at the Public Health laboratory of IOE.

4.1.1 Batch study for synthetic water without using coagulant

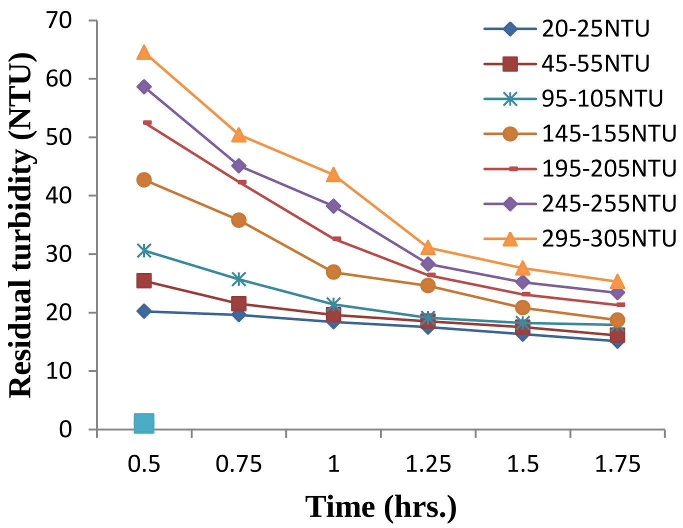


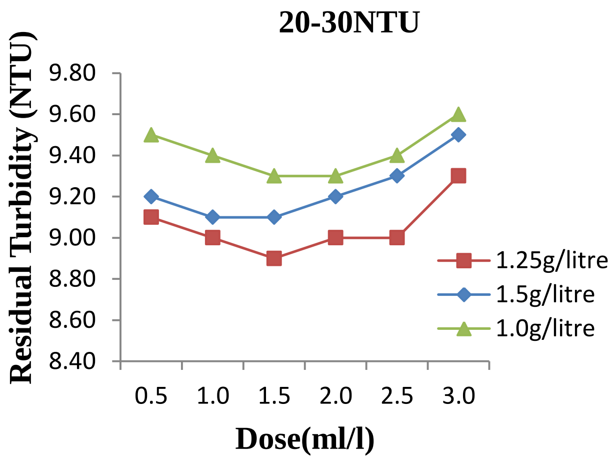
Figure 4.1 Turbidity profile of Synthetic water without using coagulant

The average initial turbidity of 50, 100, 150, 200,250 and 300 NTU synthetic water sample at an interval with 50NTU were 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 20-30NTU the residual turbidity becomes 20.2 NTU up to the settling time period of one hour while it lowers up to the 15.1 NTU for the settling time period of 1.75 hours. For the range of 45-55NTU the residual turbidity becomes 25.4 NTU up to the settling time period of one hour while it drops up to the 16.1NTU for the settling time period of 1.75 hours. For the range of 95-105 NTU the residual turbidity becomes 30.6 NTU up to the settling time period of one hour while it becomes gets to the 17.9 NTU for the settling time period of 1.75 hours. Similarly for the range of 295-300NTU, the residual turbidity becomes 25.3 NTU. From the Figure 4.1 it can be concluded that the maximum reduced level of turbidity becomes up to the 15.1NTU of average initial turbidity 20-30 NTU without using coagulant.

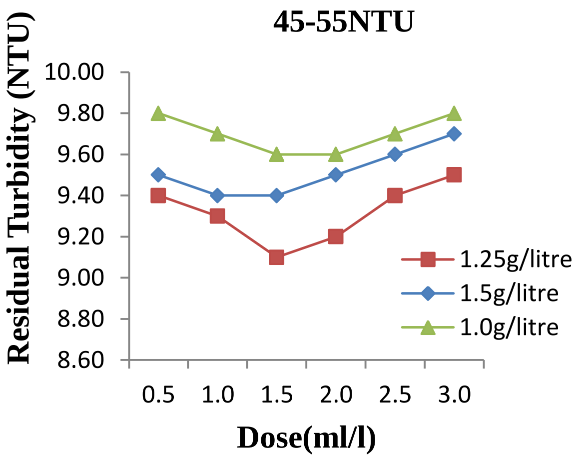
4.1.2 Batch study for methi dose

The average initial turbidity of 25, 50, 75, 100, 150, 175, 200,250, 275 and 300 NTU water sample at an interval with 25NTU treated with various dose from the concentrations of 1.0, 1.25 and 1.5 g/liter are plotted as in Figure 4.2. From the Figure 4.2(a) the reduced level of turbidity of 20-30NTU treated with the dose of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml taken from the concentration of 1.25g/liter of 1M NaCl extract found to be 9.1, 9.0, 8.9, 9.0, 9.0 and 9.3NTU respectively.

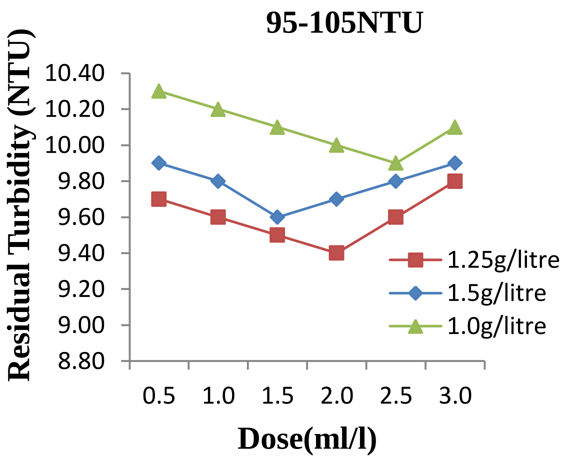
Thus it indicates that turbidity level reduces upto the dose of 1.5 ml and no further effect in the turbidity with the increase of dose. Similarly for the concentration of 1.5 g/liter the optimum removal efficiency occurs at the dose of 1.0ml and for the concentration of 1.25 g/liter the optimum removal efficiency occurs at the dose of 1.5 ml. The turbidity level increases beyond the dose of 1.5 ml. Hence it can be concluded that for the turbidity 20-30 NTU the optimum removal efficiency occurs at the dose of 1.5 ml taken from the concentration of 1.25 g/liter. Similarly from the Figure 4.2(b) it was found that the optimum removal efficiency occurs at the dose of 1.5ml taken from the concentration of 1.25 g/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 1.25g/liter.


20-30NTU
Residual Turbidity (NTU)
9.80
9.60
9.40
9.20
9.00
8.80
8.60
8.40
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

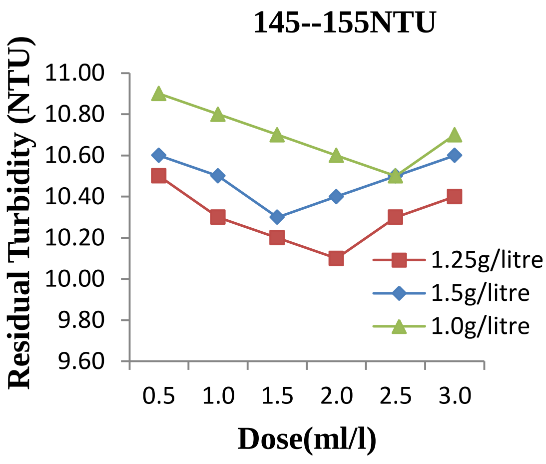
4.2 (a)


45-55NTU
Residual Turbidity (NTU)
10.00
9.80
9.60
9.40
9.20
9.00
8.80
8.60
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

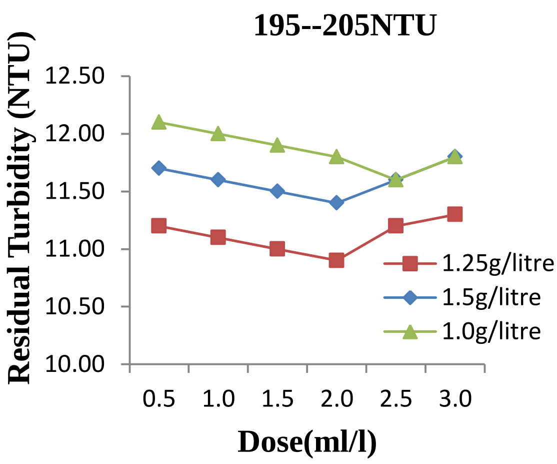
4.2 (b)


95-105NTU
Residual Turbidity (NTU)
10.40
10.20
10.00
9.80
9.60
9.40
9.20
9.00
8.80
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

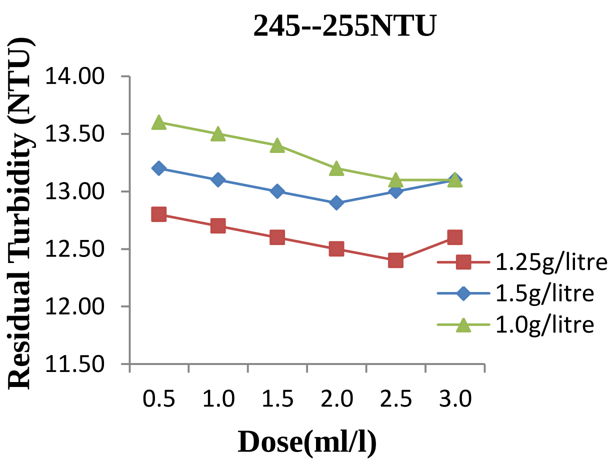
4.2 (c)


145--155NTU
Residual Turbidity (NTU)
11.00
10.80
10.60
10.40
10.20
10.00
9.80
9.60
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

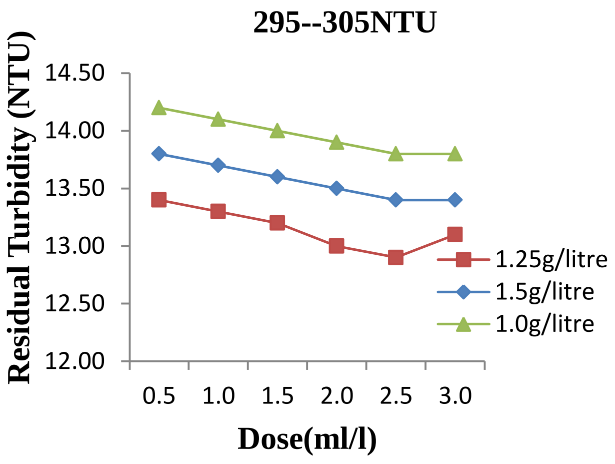
4.2 (d)


195--205NTU
Residual Turbidity (NTU)
12.50
12.00
11.50
11.00
10.50
10.00
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

4.2 (e)


245--255NTU
Residual Turbidity (NTU)
14.00
13.50
13.00
12.50
12.00
11.50
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)
1.25g/litre
1.5g/litre
1.0g/litre

4.2 (f)



4.2 (g)

Figure 4.2: Turbidity profile of synthetic water for average initial turbidity (a) 25 (b) 50, (c) 100, (d) 150, (e) 200, (f) 250, and (g) 300 NTU at batch

For more than average 100 NTU the efficiency of turbidity removal increases and hence it can be concluded that the optimum removal efficiency occurs at the dose of 1ml to 3ml ml taken from the concentration of 1.25g/liter. As the influent turbidity increases the turbidity removal efficiency is going to increase 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 shows the plot of residual turbidity versus dose of Alum. For different turbidity 25, 50, 100, 150, 200, 250, 300 NTU different dose 10, 15, 20, 25, 30, 35 mg/liter has been applied for the influent turbidity. From the figure it is evident that the optimum turbidity removal efficiency varied form 10-35mg/liter depending upon the turbidity of water. The more turbidity the more optimum dose of Alum is required.

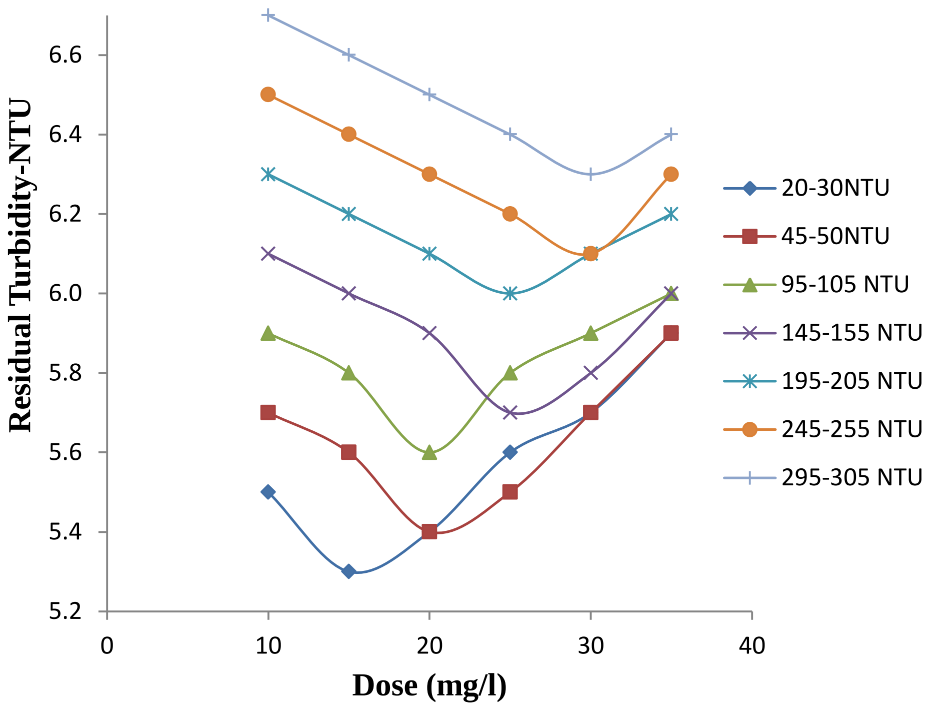
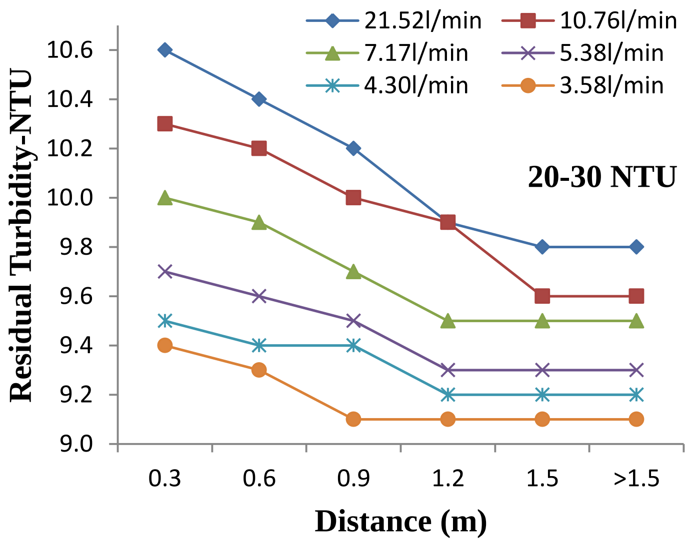


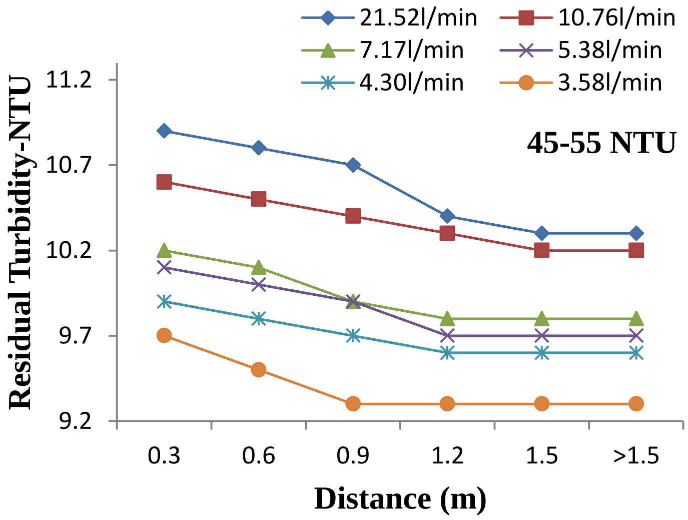
Figure 4.3: Turbidity profile of synthetic water by Alum for initial turbidity 25, 50, 100, 150, 200, 250 and 300 NTU at Batch

4.1.4 Continuous flow for methi dose treatment

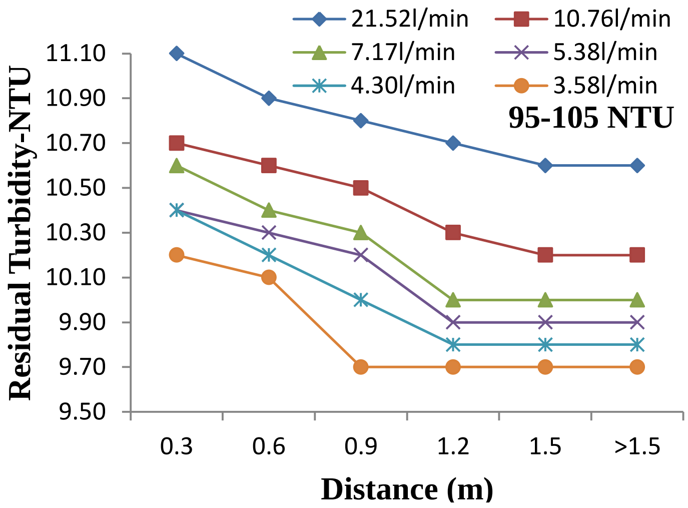
From the figure the turbidity profile has been drawn for the flow rates of 21.52, 10.76, 7.17, 5.38, 4.30, 3.58, 2.24, 1.68 l/min. The sampling points are fixed at the distance of 0.3, 0.6, 0.9, 1.2 and 1.5m form the inlet of sedimentation tank.



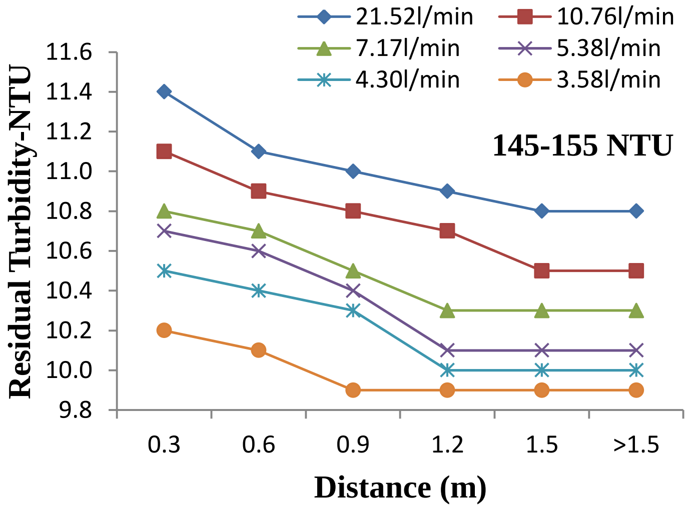
4.4 (a)



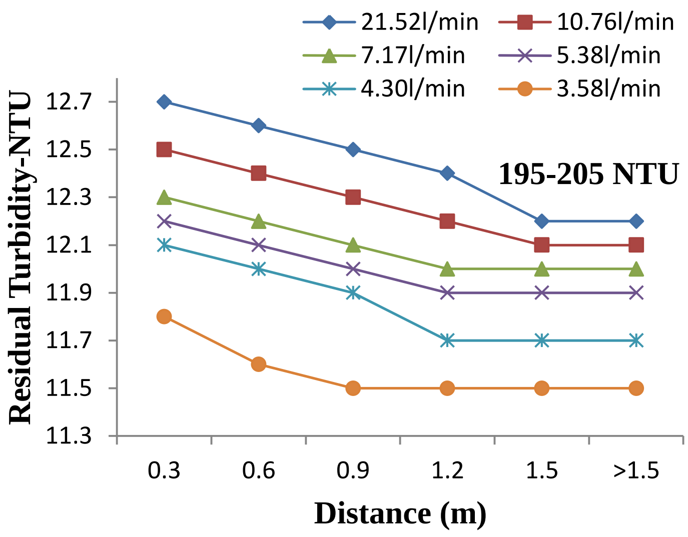
4.4 (b)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
95-105 NTU
Residual Turbidity-NTU
11.10
10.90
10.70
10.50
10.30
10.10
9.90
9.70
9.50
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

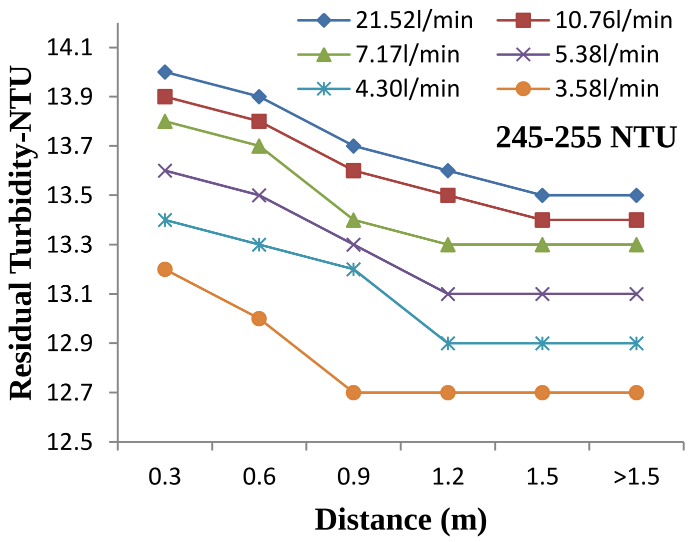
4.4 (c)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
145-155 NTU
Residual Turbidity-NTU
11.6
11.4
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

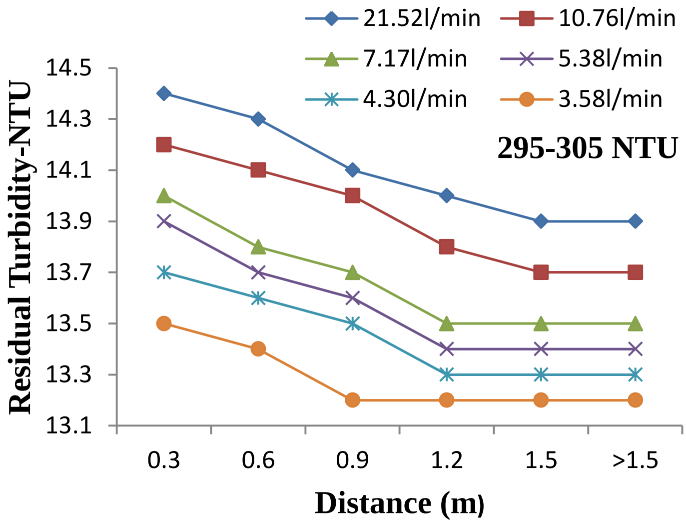
4.4 (d)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
195-205 NTU
Residual Turbidity-NTU
12.7
12.5
12.3
12.1
11.9
11.7
11.5
11.3
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

4.4 (e)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
245-255 NTU
Residual Turbidity-NTU
14.1
13.9
13.7
13.5
13.3
13.1
12.9
12.7
12.5
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

4.4 (f)



4.4 (g)

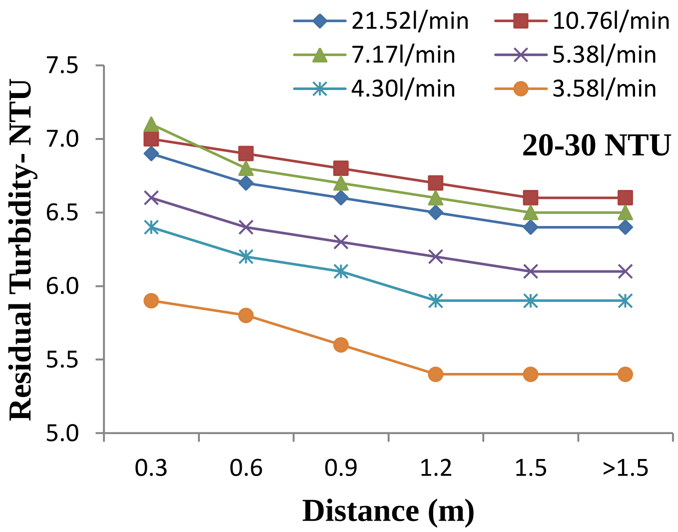
Figure 4.4 Turbidity profile of water using methi dose for initial turbidity (a) 25, (b) 50, (c) 100, (d) 150, (e) 200, (f) 250, and (g) 300 for continuous flow

The maximum turbidity removal occurs at the flow rate of 3.58l/min. For the lower than 3.58l/min flow, the turbidity removal efficiency almost remains same. For the 20-30 NTU the optimum turbidity removal efficiency occurs at distance of 0.9m for the flow rate of 3.58l/min. From the Figure it can be inferred that for the flow rate 10.76 l/min and lower than this flow rate the residual turbidity occurs below 10 NTU which is acceptable range for NDWQS. Similarly for the 45-55 NTU and 95-105 NTU the optimum turbidity removal efficiency occurs at distance of 0.9 m for the flow rate of 3.58l/min. For the flow rate 7.17l/min and lower than this flow rate the residual turbidity is within the range of NDWQS. For the turbidity range 145-155 NTU the optimum turbidity removal efficiency occurred same as 3.58 l/min. For the flow rate 4.30 l/min and lower than this flow rate the residual turbidity is within the range of NDWQS. For the average turbidity 20-150 NTU the 0.9 m seems to be enough for turbidity removal within NDWQS using methi powder.

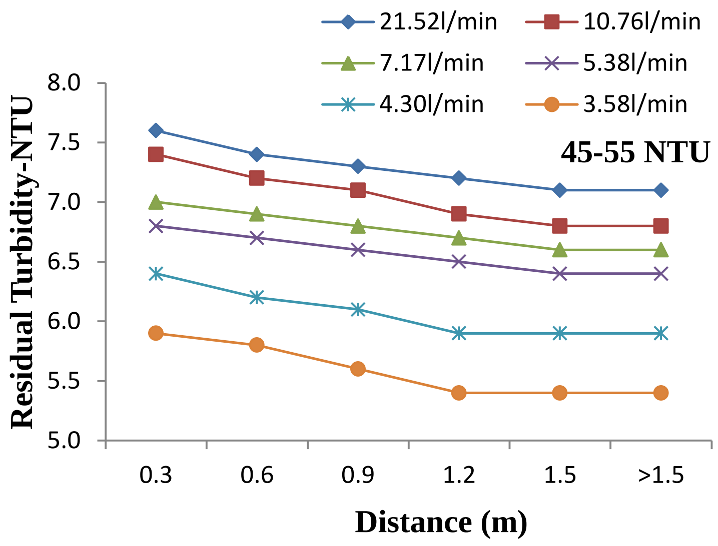
4.1.5 Continuous flow for alum dose treatment

From the figure 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, 1.5 m from the inlet of sedimentation tank.

The plotted data shows that for the 21.52 and 10.76 l/minute flow rate, the maximum turbidity occurred at the distance of 1.5m. Similarly for flow rates 7.17, 5.38, 4.30 l/minute the maximum turbidity occurred at distance of 1.2m. For flow rate 3.58, 2.24 and 1.68 l/minute the maximum turbidity removal occurred at the distance of 0.9 m. It can be concluded that for the different initial turbidity of the 20-30, 45-55, 95-105, 145-155, 195-205 and 295-305 NTU the maximum turbidity removal efficiency occurs at the flow rate of 3.58l/min or lower than that. Therefore, it can be concluded that the maximum residual turbidity lowers upto the range of 5 NTU for the flow rate of 3.58 l/min.

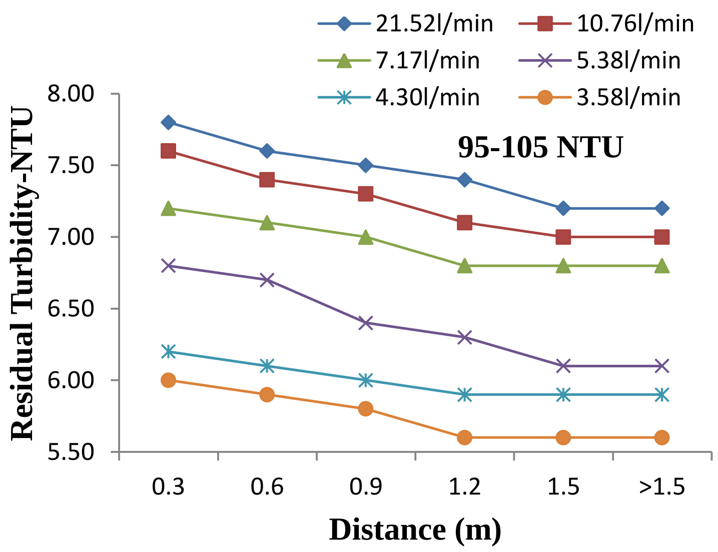


4.5 (a)



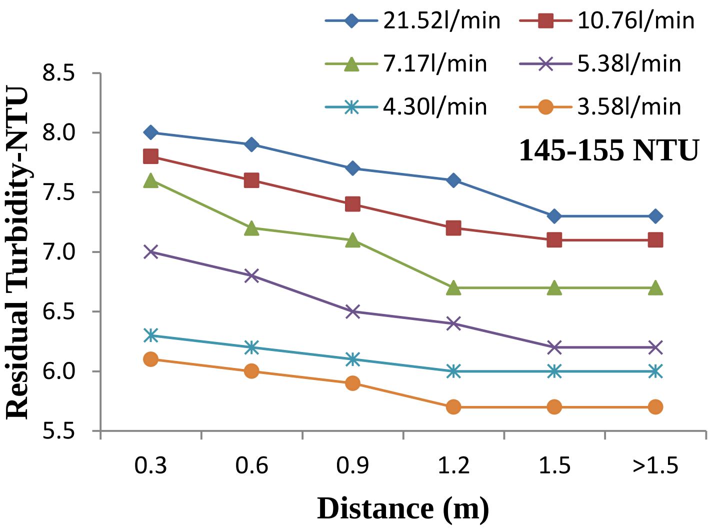
21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
45-55 NTU
Residual Turbidity-NTU
8.0
7.5
7.0
6.5
6.0
5.5
5.0
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

4.5 (b)

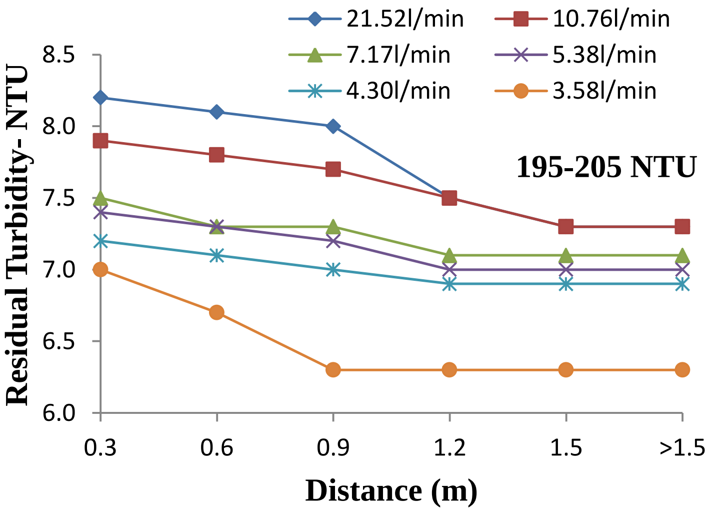


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
95-105 NTU
Residual Turbidity-NTU
8.00
7.50
7.00
6.50
6.00
5.50
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

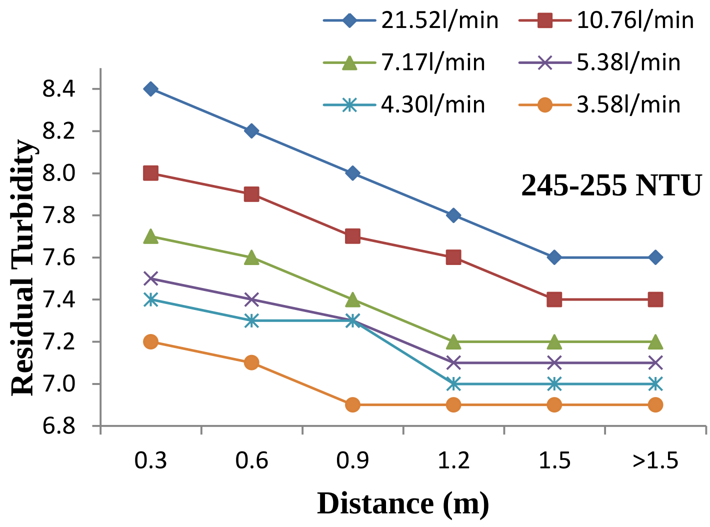
4.5 (c)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
145-155 NTU
Residual Turbidity-NTU
8.5
8.0
7.5
7.0
6.5
6.0
5.5
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

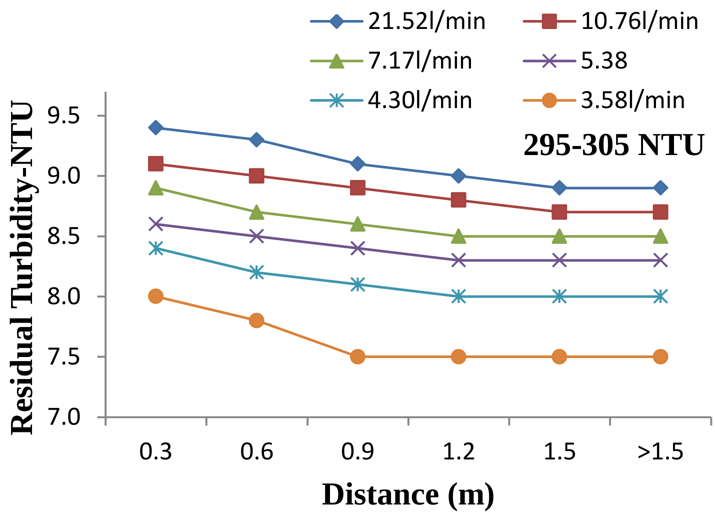
4.5 (d)


21.52l/min
10.76l/min
7.17l/min
5.38l/min
4.30l/min
3.58l/min
195-205 NTU
Residual Turbidity- NTU
8.5
8.0
7.5
7.0
6.5
6.0
0.3
0.6
0.9
1.2
1.5
>1.5
Distance (m)

4.5 (e)



4.5 (f)



4.5 (g)

Figure 4.5: Turbidity profile of water using alum dose for average initial turbidity (a) 25, (b) 50, (c) 100, (d) 150, (e) 200, (f) 250 and (g) 300 NTU at continuous

4.2 Effect of pH

The profile was drawn for the various turbidity samples of 50, 100, 150,200, 250 and 300 NTU without any coagulant for synthetic water as in Figure 4.6. The pH was measured for each average initial turbidity samples and it was applied to the methi dose 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ml. Then the final pH was measured.

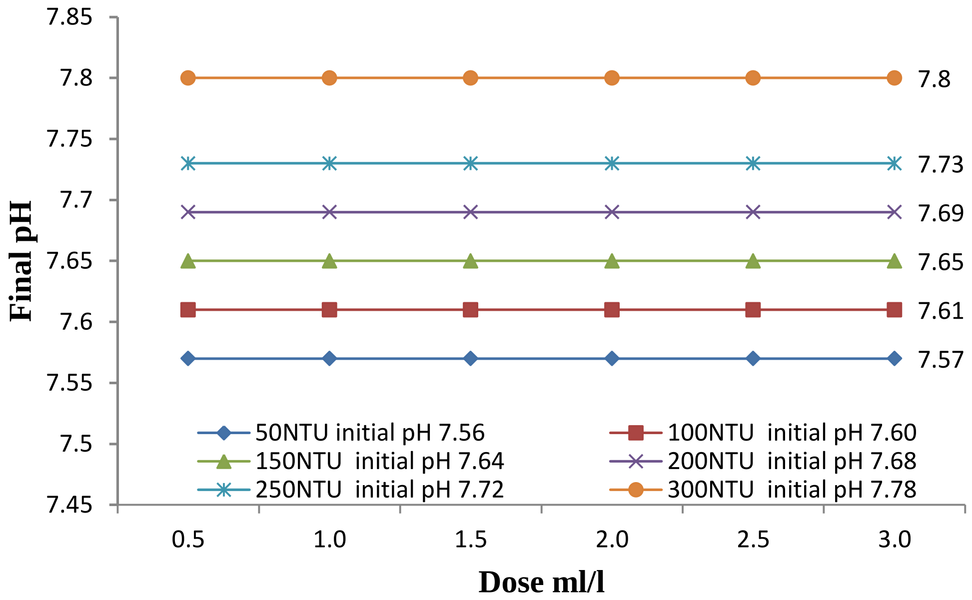


Figure 4.6 Variation of pH profile of synthetic water without any coagulant for initial turbidity 50, 100, 150, 200, 250 and 300 NTU.

The amount of pH slightly decreases than initial pH after the treatment by methi. It occur 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 1.25 g/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 final pH was measured.

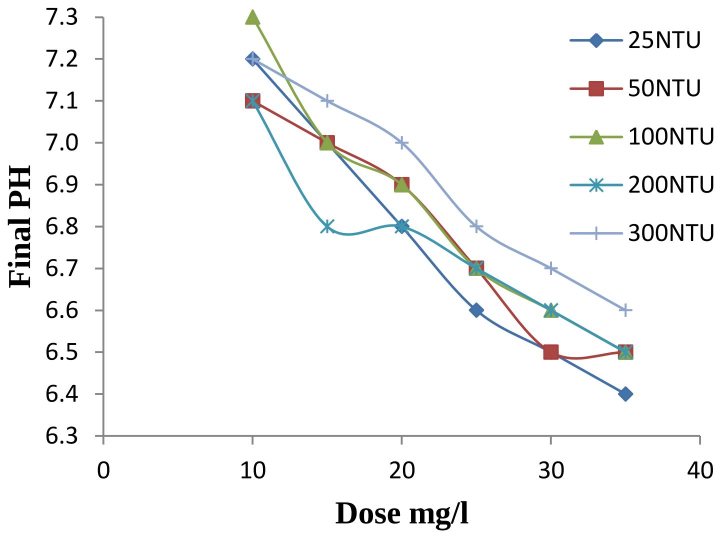
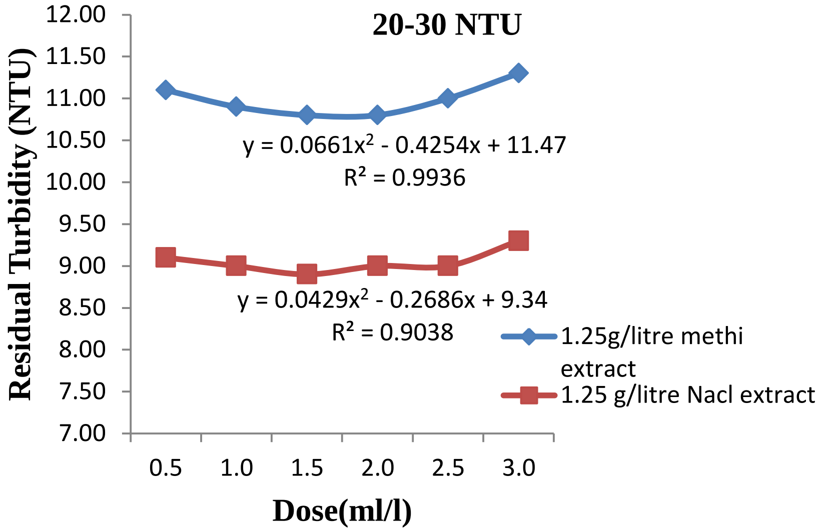


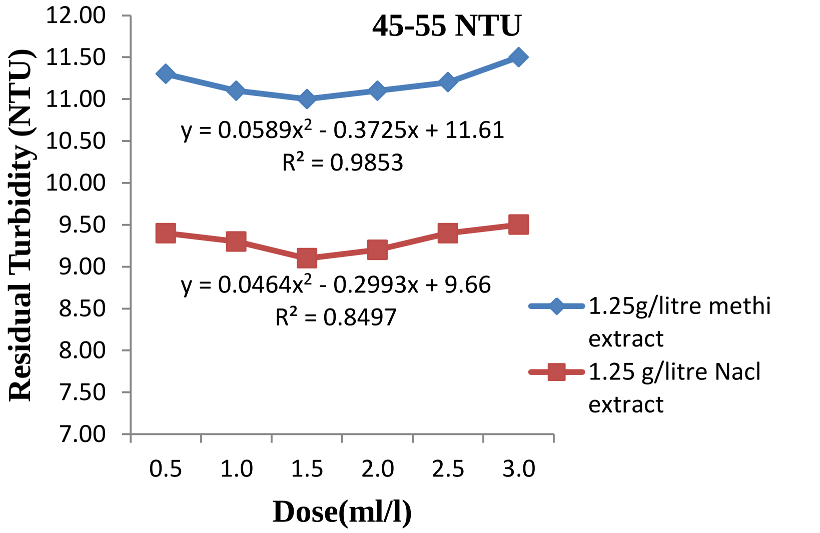
Figure 4.7: Variation of pH of synthetic water by alum for initial turbidity 25, 50, 100, 150, 200, 250 and 300 NTU at Batch.

For the average initial turbidity of 25 NTU the mixing of alum dose of 10 mg/l reduces the pH up to 7.0. While the further increase of alum dose of 35 mg/l reduces the pH upto 6.4. Similarly for the other average initial turbidity the addition of alum dose significantly reduced the pH. Thus it can be concluded that the addition of alum dose reduces pH.4.3 comparison of 1.0M NaCl extract and water extract at optimum dose.

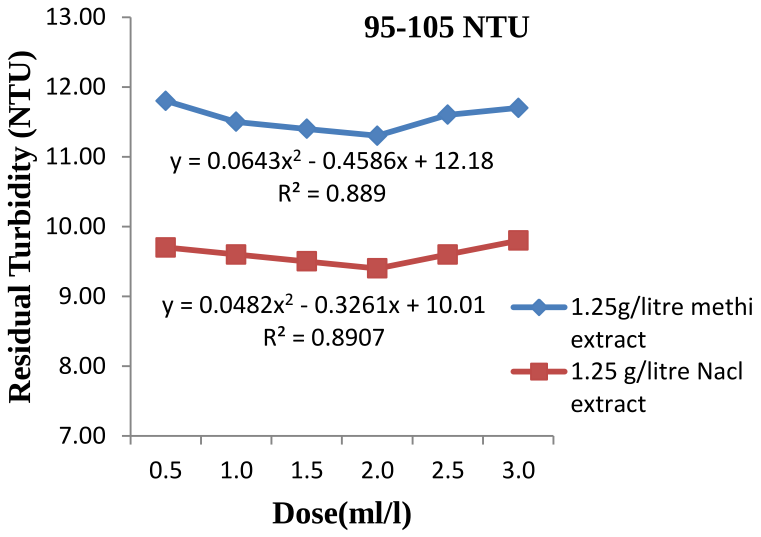
4.3 Comparison of 1.0M NaCl Extract and Water Extract at Optimum Dose



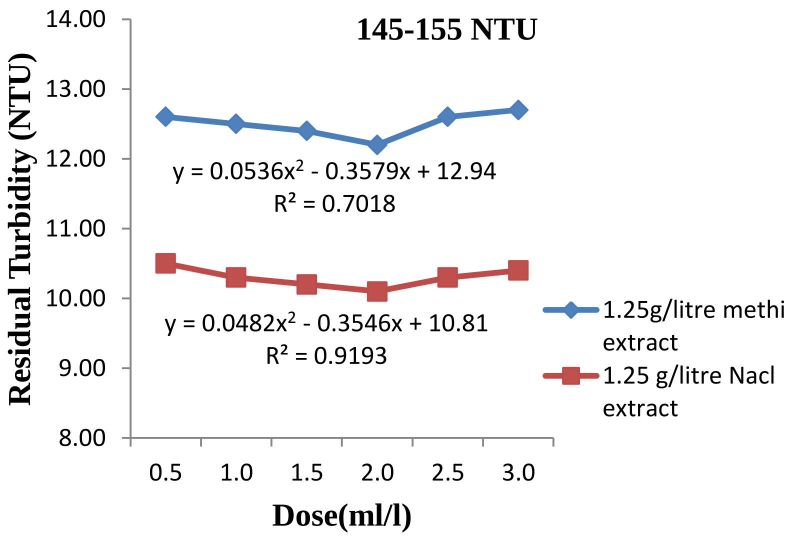
4.8 (a)



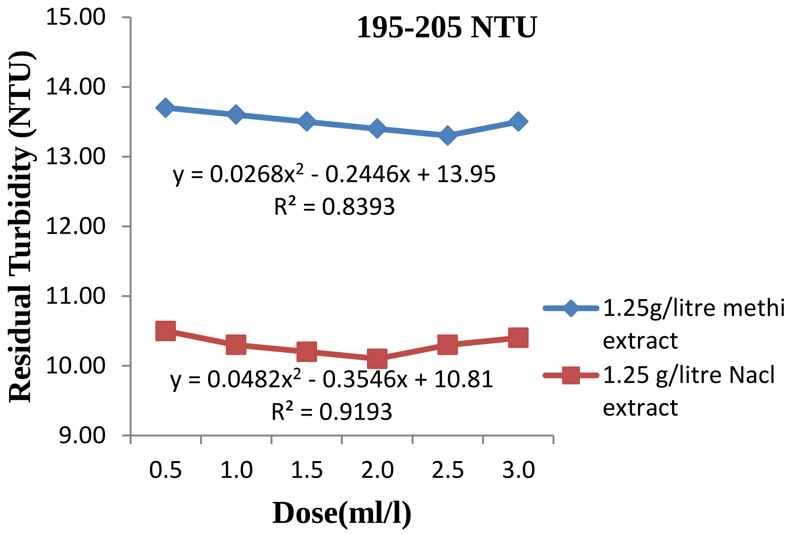
4.8 (b)


95-105 NTU
Residual Turbidity (NTU)
13.00
12.00
11.00
10.00
9.00
8.00
7.00
y = 0.0643x² - 0.4586x + 12.18
R² = 0.889
y = 0.0482x² - 0.3261x + 10.01
R² = 0.8907
1.25g/litre methi extract
1.25 g/litre Nacl extract
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)

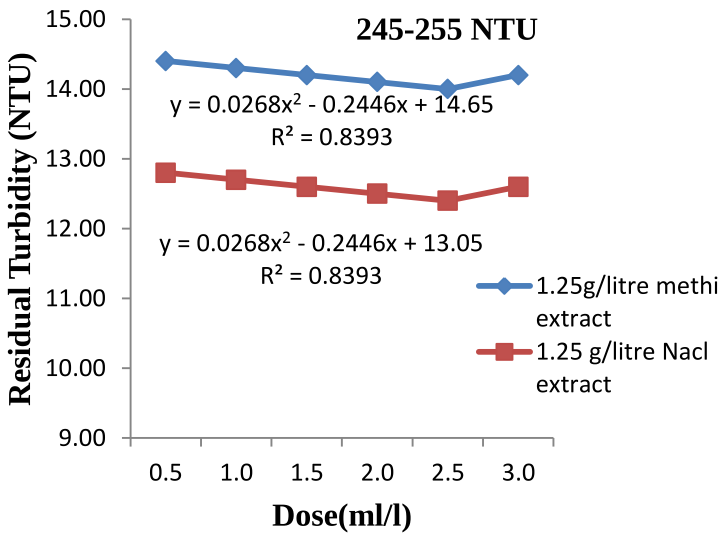
4.8 (c)


145-155 NTU
Residual Turbidity (NTU)
14.00
13.00
12.00
11.00
10.00
9.00
8.00
y = 0.0536x² - 0.3579x + 12.94
R² = 0.7018
y = 0.0482x² - 0.3546x + 10.81
R² = 0.9193
1.25g/litre methi extract
1.25 g/litre Nacl extract
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)

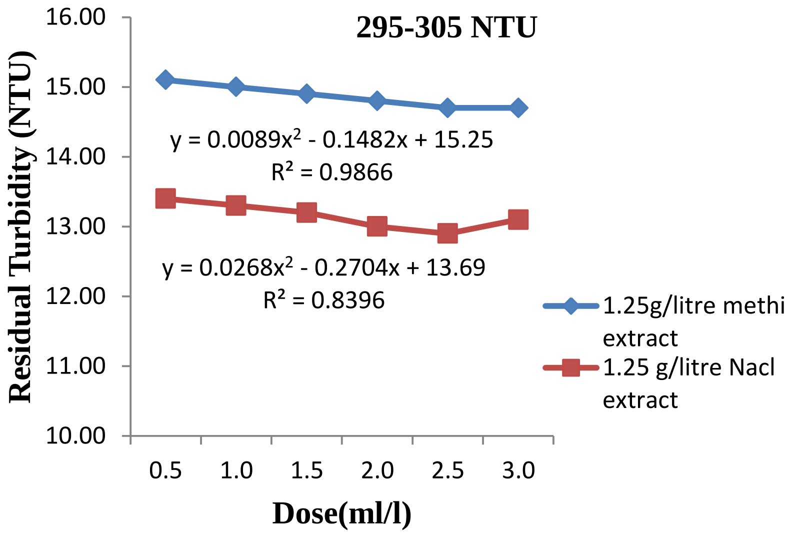
4.8 (d)


195-205 NTU
Residual Turbidity (NTU)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
y = 0.0268x² - 0.2446x + 13.95
R² = 0.8393
y = 0.0482x² - 0.3546x + 10.81
R² = 0.9193
1.25g/litre methi extract
1.25 g/litre Nacl extract
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)

4.8 (e)


245-255 NTU
Residual Turbidity (NTU)
15.00
14.00
13.00
12.00
11.00
10.00
9.00
y = 0.0268x² - 0.2446x + 14.65
R² = 0.8393
y = 0.0268x² - 0.2446x + 13.05
R² = 0.8393
1.25g/litre methi extract
1.25 g/litre Nacl extract
0.5
1.0
1.5
2.0
2.5
3.0
Dose(ml/l)

4.8 (f)



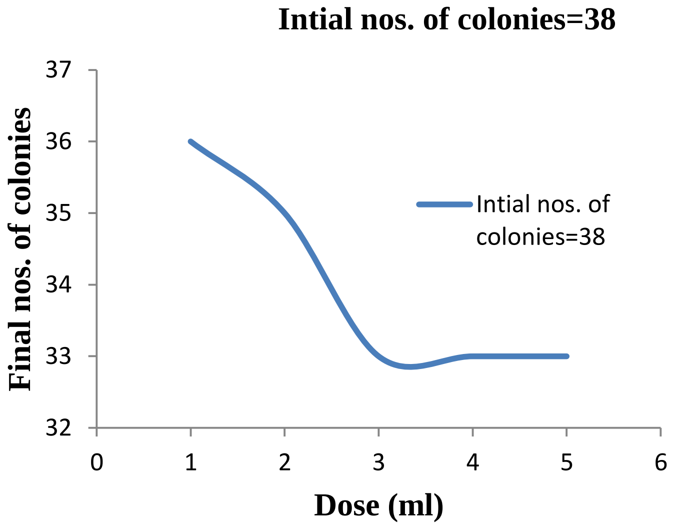
4.8 (g)

Figure 4.8 Comparison of NaCl extract and water extract for turbidity removal for (a) 25, (b) 50, (c) 100, (d) 150, (e) 200, (f) 250, and (g) 300 NTU at optimum dose.

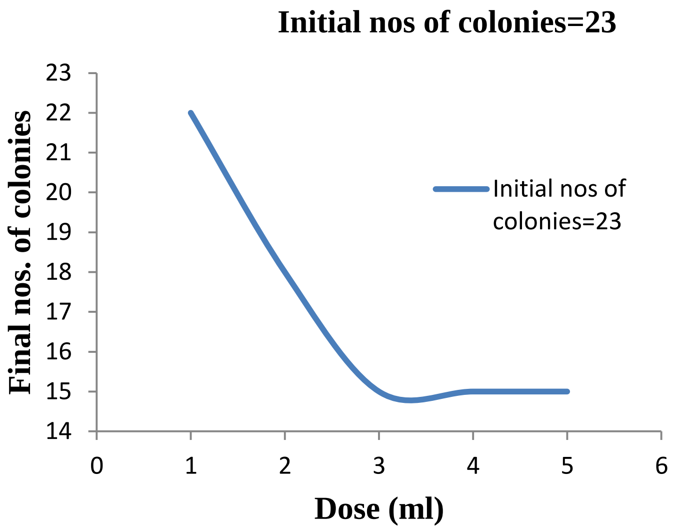
The NaCl extract shows the higher efficiency compared to that of water extract. The result shows that the NaCl extract increased the coagulant property. The result has shown the NaCl extract optimized the protein content of methi seed powder.

4.4 Effectiveness as Disinfectant of Methi Dose

The aqueous solution of methi dose was not seen effective for the disinfection. The flow chart shows the effectiveness of methi seed powder as disinfectant.



(a)



(b)

Figure 4.9 Effectiveness as disinfectant of aqueous methi dose.

The various concentrations of methi 1ml, 2.5ml, 5ml, 7.5ml and 10ml were taken for the study. The study for the contact time 24 hours (which is maximum contact time for the drinking water supply) the initial number of colonies 38 and 22 were reduced only to 33 and 15 respectively for the 5ml or above concentrations. Similarly in the spread test method the result found was also not effective.

4.5 Cost Analysis

Sample of specific turbidity was tested in the batch reactor at the optimum dose of methi seed powder and compared with the optimum dose of almunium sulphate (alum). The optimum dose of the almunium sulphate in the water was determined by the jar test method. The settling time was maintained same as of methi dose. The cost analysis has been presented as in Table no 4.1.

Table 4.1 Cost Comparison of methi and alum dose.

SN	Description	Methi seed	Alum	Remarks
1.	Cost for 500gm	Rs. 100	Rs 300	
2.	Average optimum dose per 500 ml	0.0375	0.025	
3.	Total cost of average optimum dose of prepared sample	=Rs. (0.0375*100)/500000 =Rs. 0.0000075 per liter =Rs. 0.75 per 100000 liter	=Rs. (0.025*300)/500000 =Rs. 0.0007 per lire =Rs. 1.5 per 100000 liter	

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the research work the following conclusions can be drawn:

1. The optimum dose for the turbidity removal by methi dose was found to be 1.5ml, 1.5ml, 2ml, 2ml, 2.5ml, 2.5ml and 3ml taken from the concentration of 1.25g/litre for 25NTU, 50NTU, 100NTU, 150NTU, 200NTU, 250NTU and 300 NTU respectively.

2. The efficiency of 1.0M NaCl extract is higher than that of aqueous extract of methi dose for the removal of turbidity.

3. The maximum turbidity removal efficiency for continuous flow by methi dose is found to be effective at the flow rate of 3.5 liter/minute.

4. The maximum turbidity can be lowered up to 9.0 NTU by the methi dose in the continuous flow which is within the range of NDWQS standard.

5. The study shows the turbidity removal for the range of 25-150 NTU is within the range of NDWQS standard.

6. The economic analysis shows coagulation method by methi powder for the turbidity removal is found to be less as compared to the cost of Alum, final PH of water is in the range of NDWQS, so use of this methi powder for the removal of turbidity is more effective.

7. For the disinfection, methi dose for the removal of *E-coli* is found to be less effective at 1ml, 2.5ml, 5ml, 7.5ml and 10ml taken form concentration of 10gm per 50ml solution.

5.2 Recommendations

The recommendations made for the study are:

1. Methi can be used as a coagulant. But it is suitable for turbidity 20-150 NTU and flow rate about 3.5 liter/minute.

2. Aqeous methi is not effective disinfectant and therefore cannot be applied in the field when other research works indicate otherwise.

5.3 Further Studies Suggested

1. The further study is suggested for the influence of temperature conditions.

2. The combined study of Alum and methi in turbidity removal is suggested.

3. It is suggested to study the effect of methi in other micro-organisms.

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3. Benti Firdissa, Abebe Beyene, Argaw Ambelu, and Moga Mergessa Teshome Soromessa, 2015, "Experimental Evaluation on Comparative Performance of Native Plant species in removing turbidity and Microbial Load for Household Water Treatment." *Journal of Natural Sciences research*, vol.5, pp. 53.

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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

The length of sedimentation tank is 1.5m.

v= 1.5/10=0.15m/min

Area, a=0.41m*0.35m

Discharge, q=0.4135*0.15*v=0.1435v

For velocity v_1=0.15m/min

q_1= 0.1435*0.15=21.52liter/min

Similarly, for time t_2= 20min

q_2=10.76 liter/min

Similarly, for time t_3= 30min

q_3=7.17 liter/min

Similarly, for time t_4= 40min

q_4=5.38 liter/min

Similarly, for time t_5= 50min

q_5=4.30 liter/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 methi dose

For 1.5g/liter 1M NaCl extract

Fixed parameters: Sample volume: 500ml, Stirring time 30 minute, Dose 0.5, 1.0, 1.5, 2, 2.5 and 3.0ml.

Initial turbidity :20-30NTU , Initial pH:7.54,Final pH:7.56		Initial turbidity :45-55NTU , Initial pH:7.56,Final pH:7.57		Initial turbidity :95-105NTU , Initial pH:7.60,Final pH:7.61	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
9.20	63.20	9.50	81.00	9.90	90.10
9.10	63.60	9.40	81.20	9.80	90.20
9.10	63.60	9.40	81.20	9.60	90.40
9.20	63.20	9.50	81.00	9.70	90.30
9.30	62.80	9.60	80.80	9.80	90.20
9.50	62.00	9.70	80.60	9.90	90.10

Initial turbidity :145-155 NTU , Initial pH:7.64,Final pH:7.65		Initial turbidity :195-205NTU , Initial pH:7.68,Final pH:7.69		Initial turbidity :245-255NTU , Initial pH:7.72,Final pH:7.73		Initial turbidity :295-305 NTU , Initial pH:7.78,Final pH:7.80	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
10.60	92.93	11.70	91.85	13.20	94.72	13.80	95.40
10.50	93.00	11.60	91.90	13.10	94.76	13.70	95.43
10.30	93.13	11.50	91.95	13.00	94.80	13.60	95.47
10.40	93.07	11.40	92.00	12.90	94.84	13.50	95.50
10.50	93.00	11.60	91.90	13.00	94.80	13.40	95.53
10.60	92.93	11.80	91.80	13.10	94.76	13.40	95.53

For 1.0g/liter 1M NaCl extract

Fixed parameters: Sample volume: 500ml, Stirring time 30 minute, Dose 0.5, 1.0, 1.5, 2, 2.5 and 3.0ml.

Initial turbidity :20-30NTU , Initial pH:7.54,Final pH:7.56		Initial turbidity :45-55NTU , Initial pH:7.56,Final pH:7.57		Initial turbidity :95-105NTU , Initial pH:7.60,Final pH:7.61	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
9.50	62.00	9.80	80.40	10.30	89.70
9.40	62.40	9.70	80.60	10.20	89.80
9.30	62.80	9.60	80.80	10.10	89.90
9.30	62.80	9.60	80.80	10.00	90.00
9.40	62.40	9.70	80.60	9.90	90.10
9.60	61.60	9.80	80.40	10.10	89.90

Initial turbidity :145-155 NTU , Initial pH:7.64,Final pH:7.65		Initial turbidity :195-205NTU , Initial pH:7.68,Final pH:7.69		Initial turbidity :245-255NTU , Initial pH:7.72,Final pH:7.73		Initial turbidity :295-305 NTU , Initial pH:7.78,Final pH:7.80	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
10.90	92.73	12.10	91.66	13.60	94.56	14.20	95.27
10.80	92.80	12.00	91.71	13.50	94.60	14.10	95.30
10.70	92.87	11.90	91.76	13.40	94.64	14.00	95.33
10.60	92.93	11.80	91.80	13.20	94.72	13.90	95.37
10.50	93.00	11.60	91.90	13.10	94.76	13.80	95.40
10.70	92.87	11.80	91.80	13.10	94.76	13.80	95.40

For 1.25g/liter 1M water extract

Fixed parameters: Sample volume: 500ml, Stirring time 30 minute, Dose 0.5, 1.0, 1.5, 2, 2.5 and 3.0ml

Initial turbidity :20-30NTU , Initial pH:7.54,Final pH:7.56		Initial turbidity :45-55NTU , Initial pH:7.56,Final pH:7.57		Initial turbidity :95-105NTU , Initial pH:7.60,Final pH:7.61	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
11.10	55.60	11.30	77.40	11.80	88.20
10.90	56.40	11.10	77.80	11.50	88.50
10.80	56.80	11.00	78.00	11.40	88.60
10.80	56.80	11.10	77.80	11.30	88.70
11.00	56.00	11.20	77.60	11.60	88.40
11.30	54.80	11.50	77.00	11.70	88.30

Initial turbidity :145-155 NTU , Initial pH:7.64,Final pH:7.65		Initial turbidity :195-205NTU , Initial pH:7.68,Final pH:7.69		Initial turbidity :245-255NTU , Initial pH:7.72,Final pH:7.73		Initial turbidity :295-305 NTU , Initial pH:7.78,Final pH:7.80	
Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %	Residual turbidity NTU	Removal %
12.60	91.60	13.70	90.88	14.40	94.24	15.10	94.97
12.50	91.67	13.60	90.93	14.30	94.28	15.00	95.00
12.40	91.73	13.50	90.98	14.20	94.32	14.90	95.03
12.20	91.87	13.40	91.02	14.10	94.36	14.80	95.07
12.60	91.60	13.30	91.07	14.00	94.40	14.70	95.10
12.70	91.53	13.50	90.98	14.20	94.32	14.70	95.10

C: Batch study for alum dose

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

Initial turbidity :20-30NTU , Initial pH:7.66			Initial turbidity :45-55NTU , Initial pH:7.68			Initial turbidity :95-105NTU , Initial pH:7.70		
Residual turbidity NTU	Removal %	PH	Residual turbidity NTU	Removal %	PH	Residual turbidity NTU	Removal %	PH
5.50	78.00	7.20	5.70	88.60	7.10	5.90	94.10	7.30
5.30	78.80	7.00	5.60	88.80	7.00	5.80	94.20	7.00
5.40	78.40	6.80	5.40	89.20	6.90	5.60	94.40	6.90
5.60	77.60	6.60	5.50	89.00	6.70	5.80	94.20	6.70
5.70	77.20	6.50	5.70	88.60	6.50	5.90	94.10	6.60
5.90	76.40	6.40	5.90	88.20	6.50	6.00	94.00	6.50

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

Initial turbidity :145-155NTU , Initial pH:7.66			Initial turbidity :195-205NTU , Initial pH:7.68			Initial turbidity :245-255NTU , Initial pH:7.70		
Residual turbidity NTU	Removal %	PH	Residual turbidity NTU	Removal %	PH	Residual turbidity NTU	Removal %	PH
6.10	95.93	7.20	6.30	96.85	7.10	6.50	97.40	7.00
6.00	96.00	6.90	6.20	96.90	6.80	6.40	97.44	6.80
5.90	96.07	6.80	6.10	96.95	6.80	6.30	97.48	6.70
5.70	96.20	6.70	6.00	97.00	6.70	6.20	97.52	6.60
5.80	96.13	6.50	6.10	96.95	6.60	6.10	97.56	6.60
6.00	96.00	6.50	6.20	96.90	6.50	6.30	97.48	6.40

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

Initial turbidity :195-305NTU , Initial pH:7.66		
Residual turbidity NTU	Removal %	PH
6.70	97.77	7.20
6.60	97.80	7.10
6.50	97.83	7.00
6.40	97.87	6.80
6.30	97.90	6.70
6.40	97.87	6.60

D: Continuous flow study for methi dose

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5 , >1.5, Dose 1.5ml

Initial turbidity :20-30NTU Initial pH:7.56,Final pH:7.57

Flow rate: 21.52l/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 %
10.60	57.60	10.30	79.40	10.00	86.67	9.70	87.07
10.40	58.40	10.20	79.60	9.90	86.80	9.60	87.20
10.20	59.20	10.00	80.00	9.70	87.07	9.50	87.33
9.90	60.40	9.90	80.20	9.50	87.33	9.30	87.60
9.80	60.80	9.60	80.80	9.50	87.33	9.30	87.60
9.80	60.80	9.60	80.80	9.50	87.33	9.30	87.60

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 %
9.50	93.67	9.40	81.20	9.40	81.20	9.40	81.20
9.40	93.73	9.30	81.40	9.30	81.40	9.30	81.40
9.40	93.73	9.10	81.80	9.10	81.80	9.10	81.80
9.20	93.87	9.10	81.80	9.10	81.80	9.10	81.80
9.20	93.87	9.10	81.80	9.10	81.80	9.10	81.80
9.20	93.87	9.10	81.80	9.10	81.80	9.10	81.80

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5, >1.5, Dose 1.5ml

Initial turbidity :45-55NTU Initial pH:7.60, Final pH:7.61

Flow rate: 21.52l/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 %
10.90	78.20	10.60	78.80	10.20	79.60	10.10	79.80
10.80	78.40	10.50	79.00	10.10	79.80	10.00	80.00
10.70	78.60	10.40	79.20	9.90	80.20	9.90	80.20
10.40	79.20	10.30	79.40	9.80	80.40	9.70	80.60
10.30	79.40	10.20	79.60	9.80	80.40	9.70	80.60
10.30	79.40	10.20	79.60	9.80	80.40	9.70	80.60

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 %
9.90	80.20	9.70	80.60	9.70	80.60	9.70	80.60
9.80	80.40	9.50	81.00	9.50	81.00	9.50	81.00
9.70	80.60	9.30	81.40	9.30	81.40	9.30	81.40
9.60	80.80	9.30	81.40	9.30	81.40	9.30	81.40
9.60	80.80	9.30	81.40	9.30	81.40	9.30	81.40
9.60	80.80	9.30	81.40	9.30	81.40	9.30	81.40

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5, >1.5 Dose 2ml
Initial turbidity :95-105NTU   Initial pH:7.64,Final pH:7.65

Flow rate: 21.52l/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 %
11.10	88.90	10.70	89.30	10.60	89.40	10.40	89.60
10.90	89.10	10.60	89.40	10.40	89.60	10.30	89.70
10.80	89.20	10.50	89.50	10.30	89.70	10.20	89.80
10.70	89.30	10.30	89.70	10.00	90.00	9.90	90.10
10.60	89.40	10.20	89.80	10.00	90.00	9.90	90.10
10.60	89.40	10.20	89.80	10.00	90.00	9.90	90.10

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 %
10.40	89.60	10.20	89.80	10.20	89.80	10.20	89.80
10.20	89.80	10.10	89.90	10.10	89.90	10.10	89.90
10.00	90.00	9.70	90.30	9.70	90.30	9.70	90.30
9.80	90.20	9.70	90.30	9.70	90.30	9.70	90.30
9.80	90.20	9.70	90.30	9.70	90.30	9.70	90.30
9.80	90.20	9.70	90.30	9.70	90.30	9.70	90.30

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5, >1.5 Dose 2ml
Initial turbidity :145-155NTU Initial pH:7.64, Final pH:7.65

Flow rate: 21.52l/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 %
11.40	92.40	11.10	92.60	10.80	92.80	10.70	92.87
11.10	92.60	10.90	92.73	10.70	92.87	10.60	92.93
11.00	92.67	10.80	92.80	10.50	93.00	10.40	93.07
10.90	92.73	10.70	92.87	10.30	93.13	10.10	93.27
10.80	92.80	10.50	93.00	10.30	93.13	10.10	93.27
10.80	92.80	10.50	93.00	10.30	93.13	10.10	93.27

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 %
10.50	93.00	10.20	93.20	10.20	93.20	10.20	93.20
10.40	93.07	10.10	93.27	10.10	93.27	10.10	93.27
10.30	93.13	9.90	93.40	10.00	93.33	10.00	93.33
10.00	93.33	9.90	93.40	9.90	93.40	9.90	93.40
10.00	93.33	9.90	93.40	9.80	93.47	9.80	93.47
10.00	93.33	9.90	93.40	9.80	93.47	9.80	93.47

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2,1.5, >1.5, Dose 2.5ml
Initial turbidity :195-205NTU Initial pH:7.72, Final pH:7.73

Flow rate: 21.52l/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 %
12.70	93.65	12.50	93.75	12.30	93.75	12.20	93.85
12.60	93.70	12.40	93.80	12.20	93.80	12.10	93.90
12.50	93.75	12.30	93.85	12.10	93.85	12.00	93.95
12.40	93.80	12.20	93.90	12.00	93.90	11.90	94.00
12.20	93.90	12.10	93.95	12.00	93.95	11.90	94.00
12.20	93.90	12.10	93.95	12.00	93.95	11.90	94.00

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 %
12.10	93.90	11.80	93.95	11.80	94.10	11.80	94.10
12.00	93.95	11.60	94.00	11.60	94.20	11.60	94.20
11.90	94.00	11.50	94.05	11.50	94.25	11.50	94.25
11.70	94.05	11.50	94.15	11.50	94.25	11.50	94.25
11.70	94.05	11.50	94.15	11.50	94.25	11.50	94.25
11.70	94.05	11.50	94.15	11.50	94.25	11.50	94.25

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5 , >1.5 Dose 2.5ml
Initial turbidity :245-255NTU Initial pH:7.72,Final pH:7.73

Flow rate: 21.52l/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 %
14.00	94.64	13.90	94.72	13.80	94.72	13.60	94.72
13.90	94.68	13.80	94.80	13.70	94.76	13.50	94.76
13.70	94.72	13.60	94.92	13.40	94.88	13.30	94.88
13.60	94.84	13.50	94.92	13.30	94.92	13.10	94.92
13.50	94.84	13.40	94.92	13.30	94.96	13.10	94.96
13.50	94.84	13.40	94.92	13.30	94.96	13.10	94.96

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 %
13.40	94.64	13.20	94.72	13.20	94.72	13.20	94.72
13.30	94.68	13.00	94.80	13.10	94.76	13.10	94.76
13.20	94.72	12.70	94.92	12.80	94.88	12.80	94.88
12.90	94.84	12.70	94.92	12.70	94.92	12.70	94.92
12.90	94.84	12.70	94.92	12.60	94.96	12.60	94.96
12.90	94.84	12.70	94.92	12.60	94.96	12.60	94.96

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5 , >1.5, Dose 3ml

Initial turbidity :295-305NTU Initial pH:7.84,Final pH:7.86

Flow rate: 21.52l/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 %
14.40	95.43	14.20	95.50	14.00	95.50	13.90	95.50
14.30	95.47	14.10	95.53	13.80	95.53	13.70	95.53
14.10	95.50	14.00	95.60	13.70	95.60	13.60	95.60
14.00	95.57	13.80	95.60	13.50	95.60	13.40	95.60
13.90	95.57	13.70	95.60	13.50	95.60	13.40	95.60
13.90	95.57	13.70	95.60	13.50	95.60	13.40	95.60

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 %
13.70	95.43	13.50	95.50	13.50	95.50	13.50	95.50
13.60	95.47	13.40	95.53	13.40	95.53	13.40	95.53
13.50	95.50	13.20	95.60	13.20	95.60	13.20	95.60
13.30	95.57	13.20	95.60	13.20	95.60	13.20	95.60
13.30	95.57	13.20	95.60	13.20	95.60	13.20	95.60
13.30	95.57	13.20	95.60	13.20	95.60	13.20	95.60

E. Continuous flow study for alum dose

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5, Dose 15mg/l
Initial turbidity :20-30NTU

Flow rate: 21.52l/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 %
6.90	72.40	7.00	72.00	7.10	71.60	6.60	73.60
6.70	73.20	6.90	72.40	6.80	72.80	6.40	74.40
6.60	73.60	6.80	72.80	6.70	73.20	6.30	74.80
6.50	74.00	6.70	73.20	6.60	73.60	6.20	75.20
6.40	74.40	6.60	73.60	6.50	74.00	6.10	75.60
6.40	74.40	6.60	73.60	6.50	74.00	6.10	75.60

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 %
6.40	74.40	5.90	76.40	5.90	76.40	5.90	76.40
6.20	75.20	5.80	76.80	5.80	76.80	5.80	76.80
6.10	75.60	5.60	77.60	5.60	77.60	5.60	77.60
5.90	76.40	5.40	78.40	5.40	78.40	5.40	78.40
5.90	76.40	5.40	78.40	5.40	78.40	5.40	78.40
5.90	76.40	5.40	78.40	5.40	78.40	5.40	78.40

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5 , Dose 20mg/l

Initial turbidity :45-55NTU

Flow rate: 21.52l/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 %
7.60	84.80	7.40	85.20	7.00	86.00	6.80	86.40
7.40	85.20	7.20	85.60	6.90	86.20	6.70	86.60
7.30	85.40	7.10	85.80	6.80	86.40	6.60	86.80
7.20	85.60	6.90	86.20	6.70	86.60	6.50	87.00
7.10	85.80	6.80	86.40	6.60	86.80	6.40	87.20
7.10	85.80	6.80	86.40	6.60	86.80	6.40	87.20

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 %
6.40	87.20	5.90	88.20	5.90	88.20	5.90	88.20
6.20	87.60	5.80	88.40	5.80	88.40	5.80	88.40
6.10	87.80	5.60	88.80	5.60	88.80	5.60	88.80
5.90	88.20	5.40	89.20	5.40	89.20	5.40	89.20
5.90	88.20	5.40	89.20	5.40	89.20	5.40	89.20
5.90	88.20	5.40	89.20	5.40	89.20	5.40	89.20

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5 , Dose 20mg/l
Initial turbidity :95-105NTU

Flow rate: 21.52l/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 %
7.80	92.20	7.60	92.40	7.20	92.80	6.80	93.20
7.60	92.40	7.40	92.60	7.10	92.90	6.70	93.30
7.50	92.50	7.30	92.70	7.00	93.00	6.40	93.60
7.40	92.60	7.10	92.90	6.80	93.20	6.30	93.70
7.20	92.80	7.00	93.00	6.80	93.20	6.10	93.90
7.20	92.80	7.00	93.00	6.80	93.20	6.10	93.90

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 %
6.20	93.80	6.00	94.00	6.00	94.00	6.00	94.00
6.10	93.90	5.90	94.10	5.90	94.10	5.90	94.10
6.00	94.00	5.80	94.20	5.80	94.20	5.80	94.20
5.90	94.10	5.60	94.40	5.60	94.40	5.60	94.40
5.90	94.10	5.60	94.40	5.60	94.40	5.60	94.40
5.90	94.10	5.60	94.40	5.60	94.40	5.60	94.40

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5, Dose 25mg/l

Initial turbidity :145-155NTU

Flow rate: 21.52l/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 %
8.00	94.67	7.80	94.80	7.60	94.93	7.00	95.33
7.90	94.73	7.60	94.93	7.20	95.20	6.80	95.47
7.70	94.87	7.40	95.07	7.10	95.27	6.50	95.67
7.60	94.93	7.20	95.20	6.70	95.53	6.40	95.73
7.30	95.13	7.10	95.27	6.70	95.53	6.20	95.87
7.30	95.13	7.10	95.27	6.70	95.53	6.20	95.87

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 %
6.30	95.80	6.10	95.93	6.10	95.93	6.10	95.93
6.20	95.87	6.00	96.00	6.00	96.00	6.00	96.00
6.10	95.93	5.90	96.07	5.90	96.07	5.90	96.07
6.00	96.00	5.70	96.20	5.70	96.20	5.70	96.20
6.00	96.00	5.70	96.20	5.70	96.20	5.70	96.20
6.00	96.00	5.70	96.20	5.70	96.20	5.70	96.20

Fixed parameters: Sampling point: 0.3, 0.6, 0.9, 1.2, 1.5, Dose 20mg/l
Initial turbidity :195-205NTU

Flow rate: 21.52l/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 %
8.20	95.90	7.90	96.05	7.50	96.25	7.40	96.30
8.10	95.95	7.80	96.10	7.30	96.35	7.30	96.35
8.00	96.00	7.70	96.15	7.30	96.35	7.20	96.40
7.50	96.25	7.50	96.25	7.10	96.45	7.00	96.50
7.30	96.35	7.30	96.35	7.10	96.45	7.00	96.50
7.30	96.35	7.30	96.35	7.10	96.45	7.00	96.50

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 %
7.20	96.40	7.00	96.50	7.00	96.50	7.00	96.50
7.10	96.45	6.70	96.65	6.70	96.65	6.70	96.65
7.00	96.50	6.30	96.85	6.30	96.85	6.30	96.85
6.90	96.55	6.30	96.85	6.30	96.85	6.30	96.85
6.90	96.55	6.30	96.85	6.30	96.85	6.30	96.85
6.90	96.55	6.30	96.85	6.30	96.85	6.30	96.85

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5 , Dose 20mg/l
Initial turbidity :245-255NTU

Flow rate: 21.52l/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 %
8.40	96.64	8.00	96.80	7.70	96.92	7.50	97.00
8.20	96.72	7.90	96.84	7.60	96.96	7.40	97.04
8.00	96.80	7.70	96.92	7.40	97.04	7.30	97.08
7.80	96.88	7.60	96.96	7.20	97.12	7.10	97.16
7.60	96.96	7.40	97.04	7.20	97.12	7.10	97.16
7.60	96.96	7.40	97.04	7.20	97.12	7.10	97.16

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 %
7.40	97.04	7.20	97.12	7.20	97.12	7.20	97.12
7.30	97.08	7.10	97.16	7.10	97.16	7.10	97.16
7.30	97.08	6.90	97.24	6.90	97.24	6.90	97.24
7.00	97.20	6.90	97.24	6.90	97.24	6.90	97.24
7.00	97.20	6.90	97.24	6.90	97.24	6.90	97.24
7.00	97.20	6.90	97.24	6.90	97.24	6.90	97.24

Fixed parameters: Sampling point: 0.3, 0.6,0.9, 1.2, 1.5, Dose 10mg/l
Initial turbidity :295-305NTU

Flow rate: 21.52l/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 %
9.40	96.87	9.10	96.97	8.90	97.03	8.60	97.13
9.30	96.90	9.00	97.00	8.70	97.10	8.50	97.17
9.10	96.97	8.90	97.03	8.60	97.13	8.40	97.20
9.00	97.00	8.80	97.07	8.50	97.17	8.30	97.23
8.90	97.03	8.70	97.10	8.50	97.17	8.30	97.23
8.90	97.03	8.70	97.10	8.50	97.17	8.30	97.23

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 %
8.40	97.20	8.00	97.33	8.00	97.33	8.00	97.33
8.20	97.27	7.80	97.40	7.80	97.40	7.80	97.40
8.10	97.30	7.50	97.50	7.50	97.50	7.50	97.50
8.00	97.33	7.50	97.50	7.50	97.50	7.50	97.50
8.00	97.33	7.50	97.50	7.50	97.50	7.50	97.50
8.00	97.33	7.50	97.50	7.50	97.50	7.50	97.50

F. PH variations

turbidity	initial PH	final PH
50	7.56	7.57
100	7.60	7.61
150	7.64	7.65
200	7.68	7.69
250	7.72	7.73
300	7.78	7.8

G. Relation of Turbidity of synthetic water with time.

Initial Turbidity(NTU)	Turbidity with time (hrs.)					
	0.5	0.75	1	1.25	1.5	1.75
20-30	20.2	19.6	18.4	17.5	16.3	15.1
45-55	25.4	21.5	19.6	18.5	17.5	16.1
95-105	30.6	25.7	21.4	19.1	18.2	17.9
145-155	42.7	35.8	26.9	24.6	20.8	18.7
195-205	52.5	42.3	32.6	26.4	23.1	21.3
245-255	58.6	45.1	38.2	28.3	25.2	23.4
295-305	64.5	50.4	43.6	31.1	27.6	25.3

H. Disinfection by methi dose

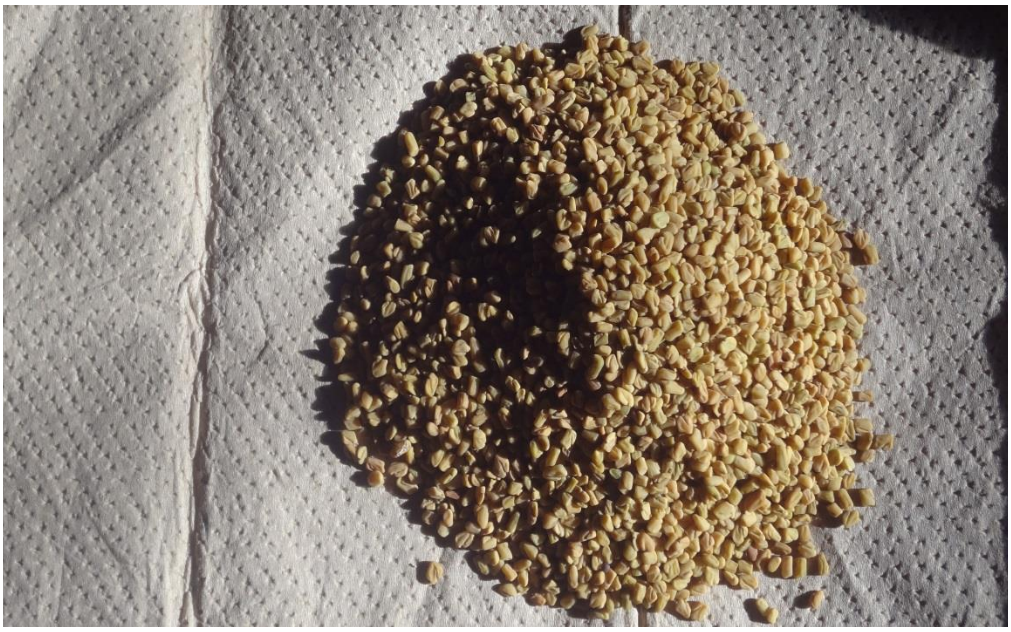
Time of Contact= 24 hours

sample	Raw water	1ml	2.5ml	5ml	7.5ml	10ml
No. of Colonies	38	36	35	33	34	34

Time of Contact= 24 hours

sample	Raw water	1ml	2.5ml	5ml	7.5ml	10ml
No. of Colonies	23	22	18	15	16	16

PHOTOGRAPHS



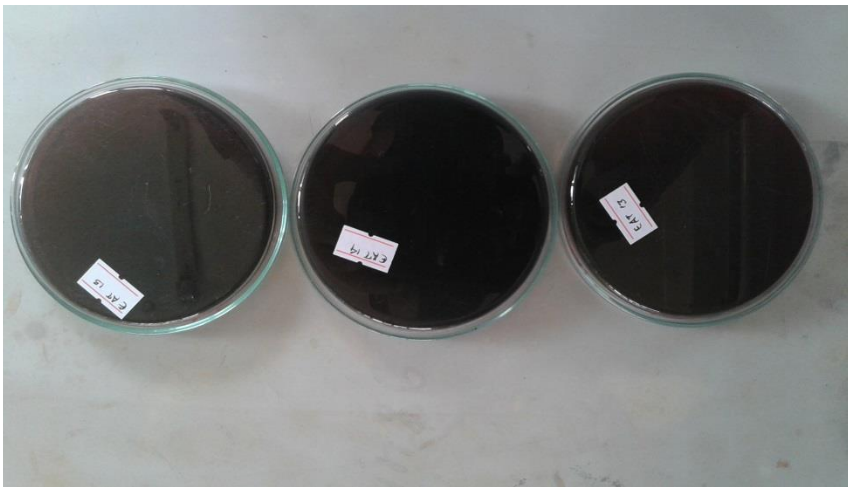
P1: Methi Seed Sample

P2: Methi in Powder Form

P3: Jar Test

P4: Continious Setup

P5: Membrane Filtration



P6: Petri Plates for Spread Plate Method