STUDYING THE EFFECTS OF HEAD LOSS IN FILTRATION PROCESS OF PRECIPITATED IRON IN WATER

MOHAMMED FAIRUZ BIN ADZHARI

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JANUARY 2009

Studying The Effects of Head Loss in Filtration Process of Precipitated Iron in Water

by

Mohammed Fairuz Bin Adzhari

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JAN 2009

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Studying the Effects of Head Loss in Filtration Process of Precipitated Iron in Water

by

Mohammed Fairuz Adzhari

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi Petronas
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

(Dr. Amirhossein Malakahmad)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

Jan 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMMED FAIRUZ ADZHARI

ABSTRACT

This project is to study the effects of head loss in removing precipitated iron in water. It is also to calculate the best flow rate and performance, as well as to find out the backwashing time of pilot plant filter located in Concrete Technology Laboratory of Universiti Teknologi PETRONAS. The filtration column consists of clear acrylic columns with 250 mm diameter and 3.0 m height. The filter media is fine sand (350 to 800 micron meter) and gravels which 3 to 6 mm. 6 manometer tubes connected to 6 different port at the column was used to observe pressure change in the column. Filtration experiments had been done with different concentration of iron in water. For Run 1 with concentration of 3.6 mg/l, the head loss builds up after 20 minutes was 0.8 m. Iron concentration of 3.55mg/l was used for Run 2 and the head loss was 1.2 m, while Run 3, 5.75 mg/l iron concentration was used and the head loss at the end of 20 minutes was 0.3 m. These 3 experiments was done for only 20 minutes due to the limitation of sample volume. For run 4 and 5, the experiment been done until clogging time. Run 4 with 11.7 mg/l iron concentration causing the system to clog at minute 39 with 1.4 m of head loss while it only treat water at 0.04 $m^3/m^2/h$ at this point. Run 5 have a head loss of 1.4 m when the system was clog after 25 minutes of the run and only treat water at the rate of 0.09 $m^3/m^2/h$ at the end. Iron concentration of 21.2 mg/l was used for run 5. Experimental result shows that the filtration column will be clog and need backwashing process at total head loss of 1.4 m height since it treating water at undesirable rate.

ACKNOWLEDGEMENT

The project has been successful with the guidance of individuals and organization that contributed in achievement of this paper. Their assistance has been a valuable help in order to made the project complete with success.

First and foremost, I am deeply indebted to my supervisor Dr. Amirhossein Malakahmad whose help, stimulating suggestions and encouragement helped me, continuity dedicating his time in all the moment of research for and writing of this project.

I would like to express my gratitude to Civil Engineering Department of Universiti Teknologi PETRONAS (UTP) for providing the facilities to undertake this project which has contributed tremendously in enhancing the technical knowledge and gaining more.

My thanks also to Miss Nabila and Mr Kalaikumar a/l Vallyutham, providing the various seminars which guidance and advice received helped me a great deal during the completion of this project.

Lastly, I would like to take this opportunity to express my forgiveness for any party that had unintentionally not being mentioned above. Thanks to all parties who were involved in completing this successful project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Problem Statement

Nowadays, industrial sectors have widely developed for every and each country in the world. Most of the industrial sectors have produced various types of wastewater that may contents a lot of hazardous materials, including heavy metals. One of the examples is iron. Iron sometimes contained in wastewater or sewage discharged from photographic processing laboratories, metal-plating plants, factories for cementation or nitriding of steels, warehouses for fumigation of vegetables and fruits, smelteries by the cyanide process and others (Koichi et. al., 1985). The other example of industries that involve ferrous alloys and those that use iron salts, such as ink manufacture and tanneries, discharge iron- contaminated waters. These can pollute both surface and ground waters (Win et. al., 2002).

In groundwater, Fe and are present as Fe(II). This metal consumes chlorine in the disinfection process and promotes biofouling and microbiological induced corrosion in water networks. (Pacini et. al., 2005). Tekerlekopoulou et. al.(2006) mention that when iron and manganese are present in a water supply at concentrations exceeding the permitted limits, they are objectionable for the following reasons:

(a) their precipitation gives water a reddish and brown-black colour, respectively, when exposed to air,

(b) iron and manganese give water an unpleasant metallic taste,

(c) deposits of iron and manganese precipitate in the distribution system, reduce the pipe diameter and eventually clog the pipe.

High concentration of iron in groundwater is unsuitable for use as drinking water without appropriate treatment. A simple and widely applicable water treatment procedure is thus needed (Štembal et. al., 2004)

In Universiti Teknologi PETRONAS (UTP), Environmental Engineering courses will conduct lab experiments and demonstration to shows the practicality of theories studied in classroom. Filtering process by using granular media filtration column is included. However, the backwashing time of the designed column was always been done by estimation method, which is at the end of the demonstration. It is due to less data regarding the effects of head loss and water quality of the filtration column to produce an exact time for backwashing process. Due to this act, natural resource which is clean water been wasted just to clean a filtration column that probably can run for another demonstration without ant effects on its performance.

1.2 Objectives

1. To calculate flow rate in pilot plant filter
2. To finalise and determine the best time for the backwash process based on head loss with different Iron concentrations.

1.3 Scope of Study

The preliminary study for this project is to have the best way on managing the task given and to gather all the required information about the head loss in removing of iron wastewater using filtration pilot plant. By using proper apparatus, it is important to know the flow rate of the pilot plant filter while running. From the calculated flow rate, the performance of the pilot plant should be determined by comparing the pressure with water quality at the specific time. Resulted from the experiment that have been done, it is crucial to find out the best time for running backwashing process. The time of backwashing process will be selected based on head loss build up or based on filtered water quality. Prior to that, a several times of running the filter with different iron concentration are important to find the best time for backwashing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are numbers of studies regarding removing iron by filtration had been done by researchers. Ghaly et. al. (2007) had done the studies by using limestone and sandstone rocks for the treatment of landfill leachates containing 6.6 mg/L iron. They stated that this method had successfully removed iron and manganese where the filters removed on average a minimum of 97.60% of the iron from solution on daily basis sand. Smith *et al.* (1994) used limestone filters to treat contaminated groundwater containing iron concentration of 5 mg/L and reported final concentration of iron of 0.2 mg/L. Xu *et al.* (1997) conducted batch experiments using calcite and quartz grains as filter media and reported an iron removal efficiency of 99.8%. Sun conducted batch experiments in which limestone was used as a filter medium to treat an iron acid solution (27.9 mg/L) and reported an iron removal of 100% after 150 minutes. Aziz *et al.* (2004) reported 90% removal of iron by limestone filter from landfill leachate containing 19.5 mg/L iron.

2.2 Filtration

Removal of suspended solids by filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It is also a major part of most water treatment (Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009). Filtration involves the removal of particulate material suspend in a liquid by passing the liquid through a filter bed comprised of a granular or compressible filter medium (Metcalf & Eddy, 2004).

2.2.1 Type of Filtration

Historically, the first depth filtration process developed for the treatment of wastewater was the slow sand filter with typical filtration rates of 30 to 60 L/m²d (Metcalf & Eddy, 2004). This type of filter requires large filter areas. The top several inches of the sand has to be removed regularly, usually by hand due to the mass of growing material that collects in the filter. The sand removed is usually washed and returned to the filter. These filters are still in use in some small plants, especially in the western United States as well as in many developing countries. They may also be used as a final step in wastewater treatment (Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009).

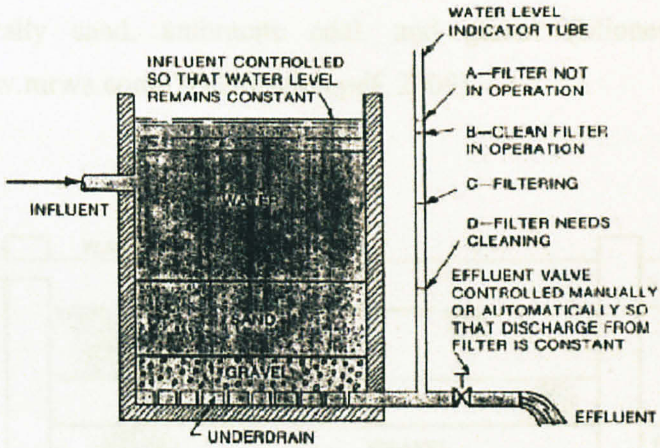


Figure 2.1: Gravity Filter Module

The rapid sand filter with typical filtration rates of 80 to 200 L/m²d was developed to treat larger volumes of water in a facility with a smaller footprint (Metcalf & Eddy, 2004). Rapid sand filters can accommodate filter rates 40 times those of slow sand filters. Filters in large plants are usually constructed next to each other in a row, allowing the piping from the sedimentation basins to feed the filters from a central pipe gallery. Some smaller plants are designed with the filters forming a square of four filters with a central pipe gallery feeding the filters from a centre well (Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009)

High rate filters, which operate at a rate three-to-four times that of rapid sand filters. In rapid sand filters, finer sand grains are at the top of the sand layer with larger grains farther down into the filter. As a result, the filter removes more suspended material in the first few inches of the filter. In the high rate filter, the media size decreases. The top layer consists of a coarse material with the finer material farther down, allowing the suspended material to penetrate deeper into the filter. The material in a filter bed forms layers in the filter, depending on their weight and specific gravities. In the coarse layer at the top, the larger suspended particles are removed first, followed by the finer materials. This allows for longer filter runs at higher rates than is possible with rapid sand filters. The media for this filter use a combination of different filter media, not just sand. The combinations vary with the application, but generally they are sand and anthracite coal. Multi-media or mixed-media filters use three or four different materials, generally sand, anthracite coal, and garnet (Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009).

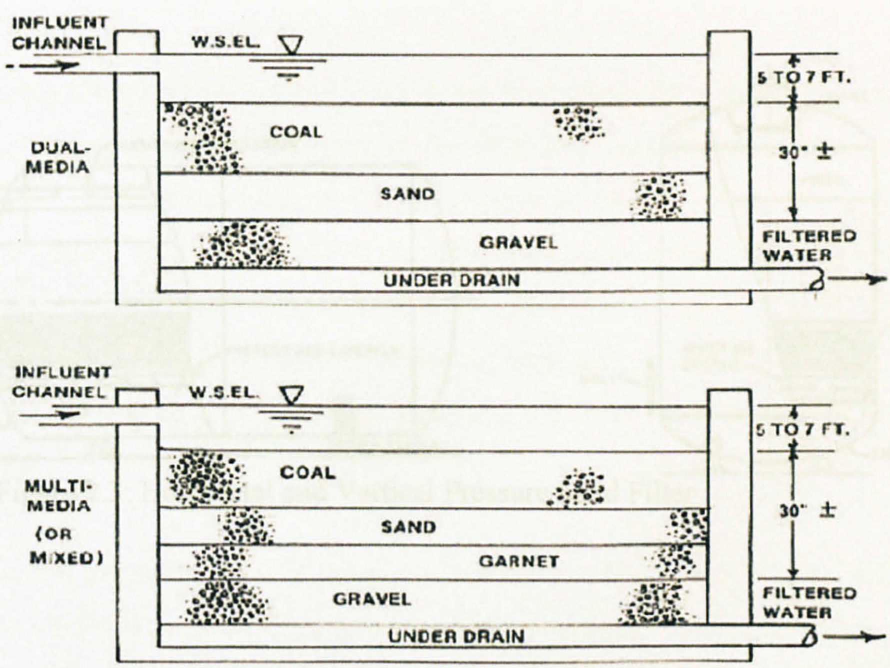


Figure 2.2: High Rate Filter Configuration

Another type of filter is pressure sand filter. Pressure sand filters is the type of filter that been used extensively in iron and manganese removal plants. A pressure sand filter is contained under pressure in a steel tank, which may be vertical or horizontal, depending on the space available. As with gravity filters, the media is usually sand or a combination of media and the rates are similar to gravity filters. It is commonly used for iron and manganese removal from groundwater, which is first aerated to oxidize the iron or manganese present, then pumped through the filter to remove the suspended material. Since water under pressure, air binding will not occur in the filter. However, pressure filters have a major disadvantage in that the backwash cannot be observed; in addition, cracking of the filter bed can occur quite easily, allowing the iron and manganese particles to go straight through the filter. When using pressure filters for iron and manganese removal, the operator must regularly measure the iron and manganese concentration of the filter effluent and backwash the filter before breakthrough occurs. Because of these limitations, pressure filters must not be used to treat surface water (Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009).

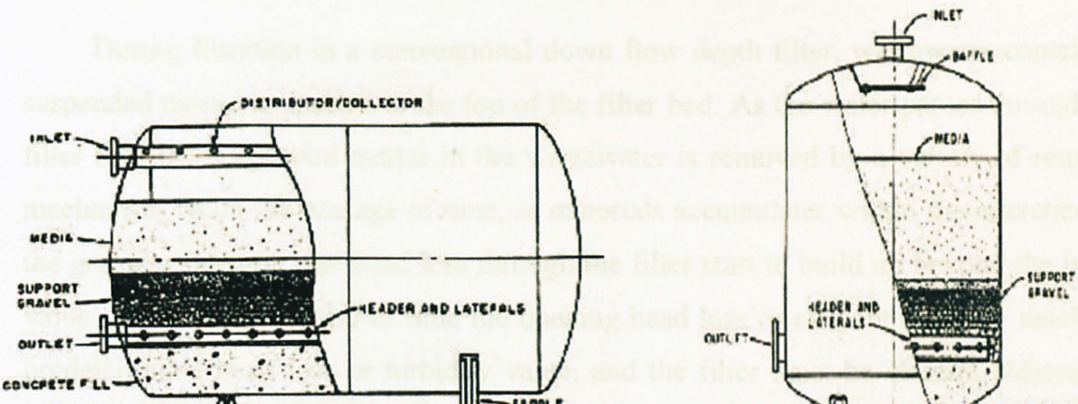


Figure 2.3: Horizontal and Vertical Pressure Sand Filter

2.2.2 Filter Medium

The filter used in the filtration process can be compared to a sieve or microstrainer that traps suspended material between the grains of filter media. The most important component of a filter is the medium. This medium must be of the appropriate size and ideally must be uniform . Small grain size tend to have higher head losses, while large grain sizes, although producing comparatively smaller head losses, are not as effective in filtering. For slow sand filters, the effective size ranges from 0.25 to 0.35 mm with uniformity coefficient ranging from 2 to 3 while for rapid sand filter, the effective size ranges from 0.45 mm and higher with uniformity coefficient ranging from 1.5 and lower. Effective size is defined as the size of sieve opening that passes the 10% finer of the medium sample. Uniformity coefficient is defined as the ratio of the size opening that passes 60% finer of the medium sample to the size of the sieve opening that passes 10% finer of the medium sample (Sincero & Sincero, 1996)

2.2.3 Backwashing

During filtration in a conventional down flow depth filter, wastewater containing suspended matter is applied to the top of the filter bed. As the water passes through the filter bed, the suspended matter in the wastewater is removed by a variety of removal mechanism. With the passage of time, as materials accumulates within the interstices of the granular medium, the head loss through the filter start to build up beyond the initial value . After some period of time the opening head loss or effluent turbidity reaches a predetermined head loss or turbidity value, and the filter must be cleaned (Metcalf & Eddy, 2004).

The end of the filter run is reached when the suspended solids in the effluent start to increase beyond an acceptable level, or when a limiting head loss occurs across the filter bed. Once of these condition is reached, the filtration phase is terminated and the filter must be cleaned (Metcalf & Eddy, 2004). The backwashed waters enters the bottom of the filter and flows upward until it overflows and goes to drains (Al-Jadhai,

2002) As long as backwashing is carried out regularly, the system can run for an indefinite period without any replacement or regeneration of growth media (Brian Gage et. al., 2001)

2.2 Head Loss

Head loss in a filter is a complex function of flow rate, pressure, influent suspended solids concentration, and characteristics of the suspended solids and filter media. It continuously varies with time and position in the bed (Droste, 1997). The motion of water through sand beds is just like the motion of water through a run pipe. Nevertheless, the form of friction head loss expression should remain the same (Sincero & Sincero, 1996).

According to Metcalf & Eddy (2004)

> The equation of head loss for the flow of clean water through a porous medium are derive from a consideration of the Darcy-Weisbach equation for flow in a closed conduit and dimensional analysis where the equation is

$$h = f\frac{LV^2}{D2g} \tag{2-1}$$

Where h = head loss

L = depth of filter

D = filter diameter

V = average velocity in filter

f = friction factor

Over the years several equations have been developed to describe the flow of clean water through a porous medium, such as Carman-Kozeny and Rose equation (Metcalf & Eddy, 2004).The Carman-Kozeny and Rose equation are summarise in Table 2-1 below

Equation	No.	Definition
Carman-Kozeny(Carman, 1937)		*Cd = coefficient of drag*
		D = grain size, m
$h = \frac{f}{\emptyset}\frac{1-\alpha}{\alpha^3}\frac{L}{d}\frac{v^2}{g}$	2-2	*Dg = geometric mean size*
		F = friction factor
$h = \frac{1}{\emptyset}\frac{1-\alpha}{\alpha^3}\frac{Lv^2}{g}\sum f\frac{p}{d_g}$	2-3	*G = gravity acceleration*
		H = head loss
$f = 150\,\frac{1-\alpha}{N_R} + 1.75$	2-4	*L = depth of filter bed*
		NR = Reynolds number
$N_R = \frac{\emptyset d v \rho}{\mu}$	2-5	*P = fraction of particles*
		V= superficial filtration velocity, m/s
		α = porosity
		μ = viscosity
Rose (Rose, 1945)		*ρ = density*
		Ø = particle shape factor
$h = \frac{1.0671}{\emptyset}C_d\frac{1}{\alpha^4}\frac{L}{d}\frac{v^2}{g}$	2-6	
$h = \frac{1.0671}{\emptyset}\frac{Lv^2}{\alpha^4 g}\sum C_d\frac{p}{d_g}$	2-7	
$C_d = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$	2-8	

Table 2.1: Summation of Head Loss Equation

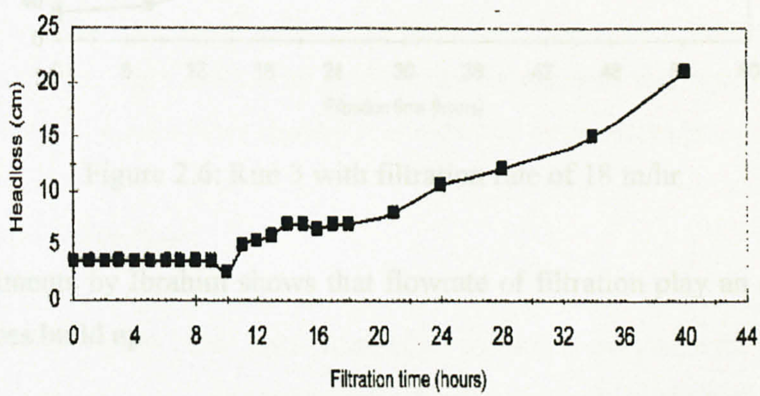
The summation term in Eqs. (2-3), and (2-7) is included to account for the strafication that occurs in filters. To account for strafication, the mean size of the material retained between successive sieve sizes is assume to correspond to the mean size of the successive sieves, assuming that the particles retained between sieve sizes are substantially uniform (Metcalf & Eddy, 2004). One of the different in Carman-Kozeny and Rose equation is that, Carman-Kozeny equation consider about the friction factor of the filter while Rose does not consider it. The definition of the shape factor is the ratio of the surface are of an equivalent sphere to the surface area of the particle, for particles of the same volume.

Boller et. al.(1994) had done a research regarding head loss in granular media filtration correspondent to particle characteristics. Larger media provides a lower initial head loss during filtration, but it appears that the rate of head loss will be larger due to lower densities of deposit Boller et. al.(1994). Larger media provide fewer pore spaces, and thus particulate capture will be less efficient causing greater distribution of the particulates throughout the filter column Boller et. al.(1994).

A research that had been done by Stevenson (1996), filters running at constant rate produce a linear increase in head loss with time. This characteristic is reproduced by the present model. Most of the head loss occurs within the fully clogged part of the bed and as this proceeds forward so the head loss increases.

Al-Jadhai, (2002) had done a studies regarding head loss related to flow rate and time runs of the experiment. Filtration rates of 4, 8 and 18 $m^3/m^2/hr$ were used for runs 1, 2 and 3, respectively and continued for 40, 100 and 53 hours respectively. For Run 1, the beginning of the head loss was about 3.5 cm. After 10hours of continued operation, the head loss increase to 25cm. Ibrahim believe that if won't achieve the head loss limit during the filtration cycle which is 24 hours

Figure 2.4: Run1 with filtration rate of 4m/hr



For Run 2, the initial head loss was 10 cm. The experiment was continued up to 100 hours; where the head loss reached about 2.25 m. For the run 2, the flow rate is as twice as run 1 which is 8 m/hr.

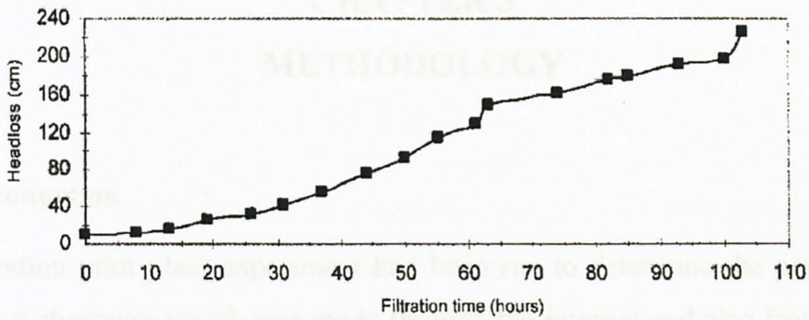


Figure 2.5: Run 2 with filtration rate of 8 m/hr

For Run 3, the initial head loss was 30 cm and the terminal head loss (i.e. 2.25 m) was reached in 53 hours. The variation of head loss in this run is shown in Fig. 3.

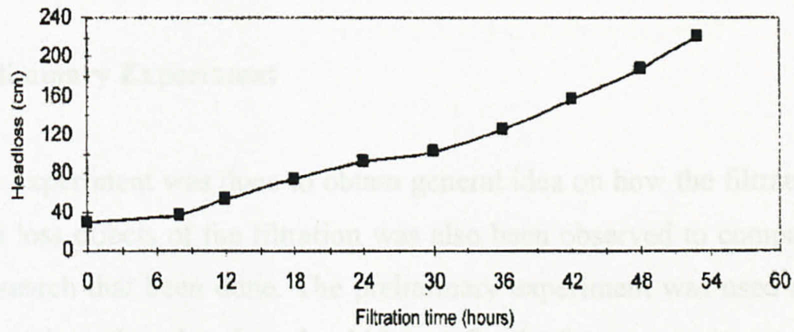


Figure 2.6: Run 3 with filtration rate of 18 m/hr

All the experiments by Ibrahim shows that flowrate of filtration play an important role for the head loss build up.

CHAPTER 3
METHODOLOGY

3.1 Introduction

Filtration pilot plant experiment had been run to determine the performance of the system. A thorough search was made through the internet and also from libraries to collect all available information regarding filtration concept and head losses and how to calculate it. The collections of basic knowledge regarding sand filtration are essential to know how the system functions theoretically before can be run experimentally. The result of research will be adopt and use when running the experiment and obtaining the result of experiment.

3.2 Preliminary Experiment

Preliminary experiment was done to obtain general idea on how the filtration pilot plant work. Head loss effects of the filtration was also been observed to compare the pattern with the research that been done. The preliminary experiment was used as the guiding experiment on how the pilot plant should be run for the future experiments.

3.3 Filtration Pilot Plant

The filtration pilot plant unit consists of a column packed with filter media, a transfer pump, sump tanks, a rotameter, a bank of manometer tubes and various valves for flow control sampling. The unit shall be suitable to investigate on:

- Effect of filtration run on total head loss
- Pressure drop profiles through filter bed
- Suspension concentration through filter bed
- Fluidization and backwashing operation.

This filtration column is made from clear acrylic with 250 mm diameter and 3.0 m height. The thick of the acrylic is 5 mm. The filter media is fine sand (350 to 800 micron meter) and gravels which 3 to 6 mm. For feeding tank, it can contain total capacity of 250 L and in cylindrical shape, while for effluent tank, it can carry the same volume but with rectangular shape. This system is equip with single impeller centrifugal pump with max capacity of 90L/min and can pump up to 20.7 m. The overall dimension for this system is 4.15 m with the depth and width 1.22m respectively. For this system, there are 6 tubes for manometer with height of 2m and pressure range from 0 to 1.0 bar. This manometer is to observe the pressure change in the system.

Figure 3.1: Filter media (sand)

Figure 3.2: Filter media (fine sand)

Figure 3.3: Filter media (gravel)

Figure shown below is the schematic drawing of the filtration pilot plant. It is important how the pilot plant element (manometer tube, sampling point, valves etc) connected to each other since it is the basics idea of the pilot plant workability procedure.

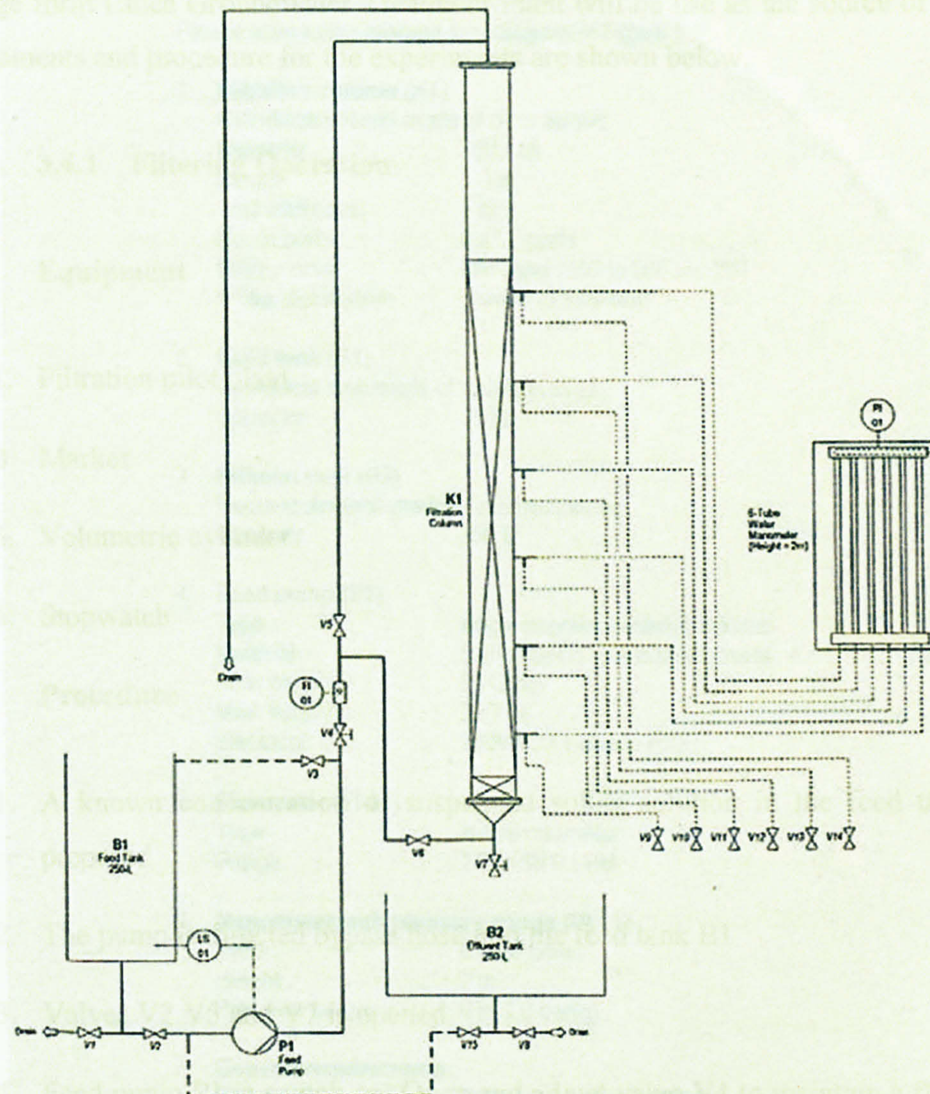


Figure 3.4: Schematic Plan of Filtration Pilot Plant

3.4 Filtration Experiment

Before running the experiment, filtration column had been backwashed first to ensure that the system is clean and ready to operate. Iron sludge will be mix with water to achieved the needed concentration of the precipitated iron in water. For this study, sludge form Chica Groundwater Treatment Plant will be use as the source of iron. The equipments and procedure for the experiments are shown below.

3.4.1 Filtering Operation

Equipment

1. Filtration pilot plant
2. Marker
3. Volumetric cylinder
4. Stopwatch

Procedure

1. A known concentration of suspended solids solution in the feed tank B1 is prepared
2. The pump is directed bypass hose into the feed tank B1
3. Valves V2 V5 and V7 is opened
4. Feed pump P1 is switch on. Open and adjust valve V4 to maintain a flow rate as determined during the general start-up procedures; q'
5. Start the timer at t=0
6. Perform the following procedures at 1 minute interval

I. Record the pressure measurements until at all 6 tubes in the manometer

II. Collect the effluent sample for 5 seconds

7. Samples are continuing taking and recording the pressure measurement until a sharp increase in head loss is observed. This is when the filter media has reached the breakthrough point

8. Feed pump P1 is switch off and valve V5 and V7 is immediately close

3.4.2 Backwashing Operation

After some period of time, the head loss will increase to a limitation value. At this time, the filter must be cleaned. For backwashing process, it is done by allowing clean water to flow through the column from the bottom upwards at a flow rate that will fluidize the filter media. Bed expansion and fluidization permit entrapped particles to become released and flushed upward and out of the media. Usually the degree of bed expansion is in the range of 20 to 50% of the static bed dept. it is important for the operator to aware the volume and flowrate of the water for backwashing process to avoid the media being flushed away together. The procedure of backwashing shown below

Procedure

1. Ensure that all valves are initially closed except bypass valve V3
2. Fill the effluent tank B2 with sufficient amounts of clean water
3. Direct the pump/s bypass hose into effluent tank B2
4. Direct the effluent hose to feed tank B1 to recover the backwashed fluid
5. Record the initial height of the static filter bed at the filtration column
6. Open valves V6 and V15
7. Switch on feed pump P1. Open and adjust valve V4 to obtain desired water flow rate

8. Allow clean water to flow upwards through the column and flood the top of the filter bed until it overflows to the feed tank B1
9. Increase the backwash flow rate until the filter media just begins to move
10. Increase the backwash flow rate until the bed expend. Maintain the flow rate and record the expended filter bed height
11. Stop the process when no suspended solids appears in the water flowing out from the top of the column
12. Switch off feed pump P1 and immediately close valve V6

3.5 Head Loss

For the measurement of the head loss and pressure drop, it is important to ensure that all the 6 manometer tubes are free from bubble. The sampling valves can be used to remove air bubbles along the flexible tubing connecting the column ports to the manometer. When the tubings are free from air bubbles, the pressure at each port can be measured by reading the water level at the respective manometer tube. Pressure drop or head loss for any two ports can be calculated by subtracting the respective water level. The total head loss can be approximated by the pressure drop between the highest and the lowest ports.To calculate the absolute pressure at each port in the filtration column, the following formula can be use:

$$P_n = P_G + \rho g(h_{M,n} - h_n) \qquad \text{3-1}$$

Where P_n = pressure at port n

P_G = pressure reading at gauge above manometers

$h_{M,n}$ = water level at manometer tube

h_n = height of port n at the column (measured from the zero level of the manometer tubes)

n = 1,2,3…,6

3.6 Flow rate Calculation

It is important to know the flowrate of the filtration experiments since it is affecting head loss. The flowrate of filtration process was taken from the effluent point of the column. As stated above in 3.4, the collected samples were taken for 5 seconds long. All the data collected for flowrate will divided with 5 to produce a data with unit of ml/sHowever, in the rule of thumb calculating flowrate, m/s were taken as the unit of flowrate. To convert from ml/s to m/s, equation below applied

$$v_2\left(\frac{m}{s}\right) = \frac{v_1\left(\frac{ml}{s}\right)}{10^6} \qquad 3\text{-}2$$

Where v_1 = flowrate in ml/s

v_2 = flowarate in m/s

3.7 Sieve Analysis

Sieve analysis is an additional experiment to have more information regarding the system since the most important component of filter is the medium itself. This experiment was analysed the medium of the filter whether it is uniformly distributed or not and whether it is effective size of media or not. The equipment needed and procedures related are shown below

Equipment:

1. Stack of Sieves including pan and cover
2. Coarse and fine medium sample
3. Mechanical sieve shaker
4. Balance
5. Oven

Procedure:

1. Take a representative oven dried sample of medium with calculated weight
2. Determine the mass of sample accurately. W_t (g)
3. Prepare a stack of sieves. Sieves having larger opening sizes placed above the ones having smaller opening. Make sure sieves are clean, if many soil particles are stuck in the openings try to poke them out using brush.
4. Weigh all sieves and the pan separately.
5. Pour the medium into the stack of sieves from the top and place the cover
6. Put the stack in the sieve shaker and fix the clamps, adjust the time on 10 minutes and get the shaker going.
7. Stop the sieve shaker and measure the mass of each sieve + retained soil.

The effective size is the size of sieve opening passes 10% finer of the sample medium while uniformity coefficient can be calculate by using equation below:

$$UC = \frac{d_{60}}{d_{10}} \qquad \text{3-3}$$

Where d_{60} = size pass 60% finer of the sample medium

d_{10} = size pass 10% finer of the sample medium

3.8 Data Analysis and Discussion

From the experiment, all the data collected was analysed. For the filtration experiment, data collected was analysed to obtain the head loss of the system, which showing the performance of the system. Discussion regarding the experiment will act as a postmortem when running another filtration experiment. Sieve analysis will give some additional information regarding the system media whether the media is effective or not.

CHAPTER 4

RESULT and DISCUSSION

4.1 Introduction

A preliminary filtration experiment had been done to have some overview on how this system functioning and to have the preliminary data to analyse. The preliminary experiment with 3.6 mg/l was then followed up bye another experiments with initial iron concentration of 3.55 mg/l, 5.75 mg/ 11.7 mg/l and 21.2 mg/l. All the results and discussions are shown below.

4.2 Filtration Experiment

4.2.1 Run 1

For this experiment, Iron concentration of 3.6 mg/l was prepared. The experiment was executed for 20 minutes. Within 1 minute interval, the flow rate of the experiment was taken and all manometer tubes reading was recorded. The average flowrate calculated for 20 minutes of experiment was 1.17 m/h

Figure 4.1 shows the recorded water level in manometer during the experiment. The figure also shows for tube 1, 2, 3, the reading was decreased while, 5, and 6, the readings were increased. For manometer tube 4, the changes are quite small and the reading was persistence. The data gathered below were used to calculate the pressure differences. Sudden increase or sudden decrease are shown in this figure. It was believed as the effects of opening the valve for sampling point, where the pressure will be affected.

Figure 4.1: Water level in manometer tube vs time for Run 1

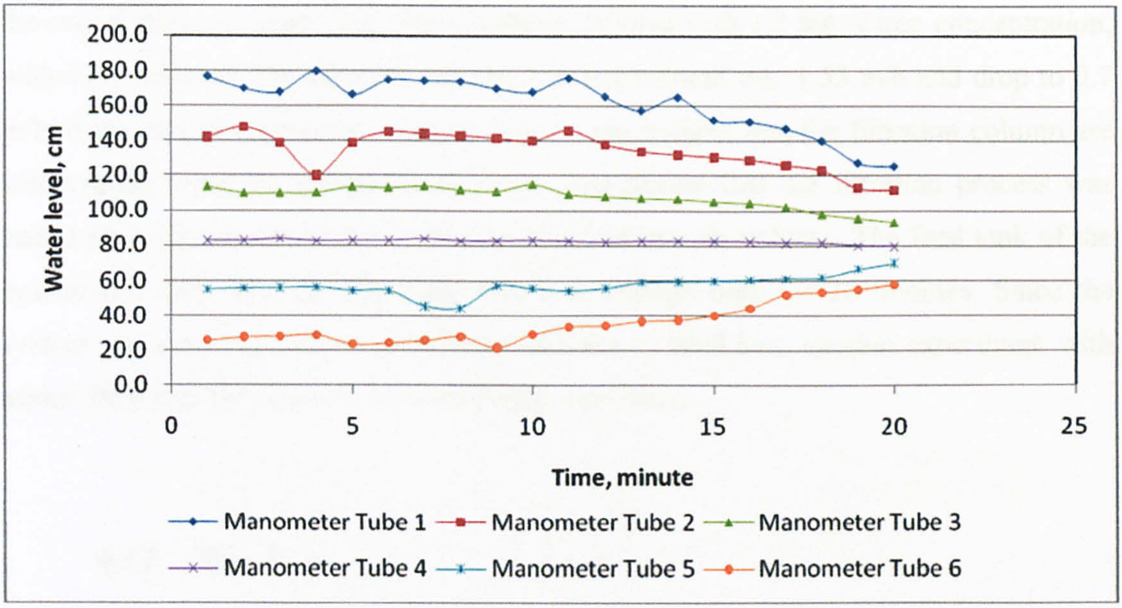


Figure 4.2 below is the calculated head loss with respect to time of running the experiment. From the graph shown, there is no significant increase of head loss while doing the experiment. However, the head loss start to build up at minute 10 of running the experiment. At the end of the experiment, total head loss was 0.8 m height.

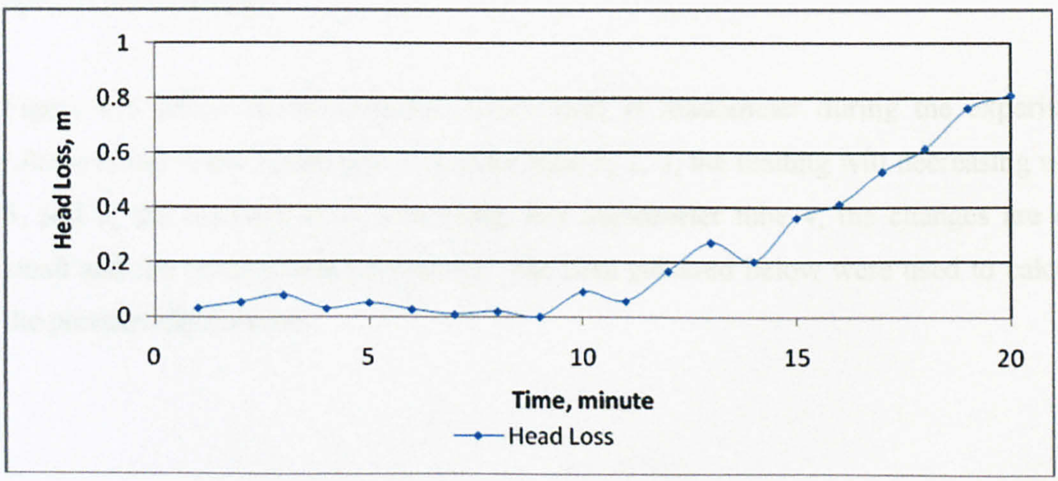


Figure 4.2: Graph of total headloss vs time for Run 1.

Based on the result, it is shown that within 20 minutes of experiments with initial iron concentration of 3.6 mg/l, the system is still in good condition for filtering process. At the end of the experiment, the filter produces effluent with 1.2 mg /s iron concentration, with 67% removal. For flowrate, minute 1 of experiment was 1.53 m/h and drop to 0.7 m/h at the end of experiment. Due to that, it was believe that the filtration column are still treating water at acceptable flowrate. The reason that the filtration process was ended after 20 minutes is due to the limitation of sample volume. The feed tank of the system can only hold for 250 liters which is enough only for 20 minutes. Since the system was not clog, and no significant increase in head loss, another experiment with higher flow rate but same iron concentration was done.

4.2.2 Run 2

For this experiment, Iron concentration of 3.55 mg/l was prepared. The experiment was executed for 20 minutes. Within 1 minute interval, the flow rate of the experiment will be taken and all manometer tubes reading will be recorded. The average flowrate calculated for 20 minutes of experiment was 1.76 m/h. This flowrate also is the highest at the current situation (iron concentration of 3.55 mg/l) since all the valves had been open to the maximum.

Figure 4.3 below is the recorded water level in manometer during the experiment. Likewise run 1, the figure also shows for tube 1, 2, 3, the reading will decreasing while, 5, and 6, the readings were increasing. For manometer tube 4, the changes are quite small and the reading was persistence. The data gathered below were used to calculate the pressure differences.

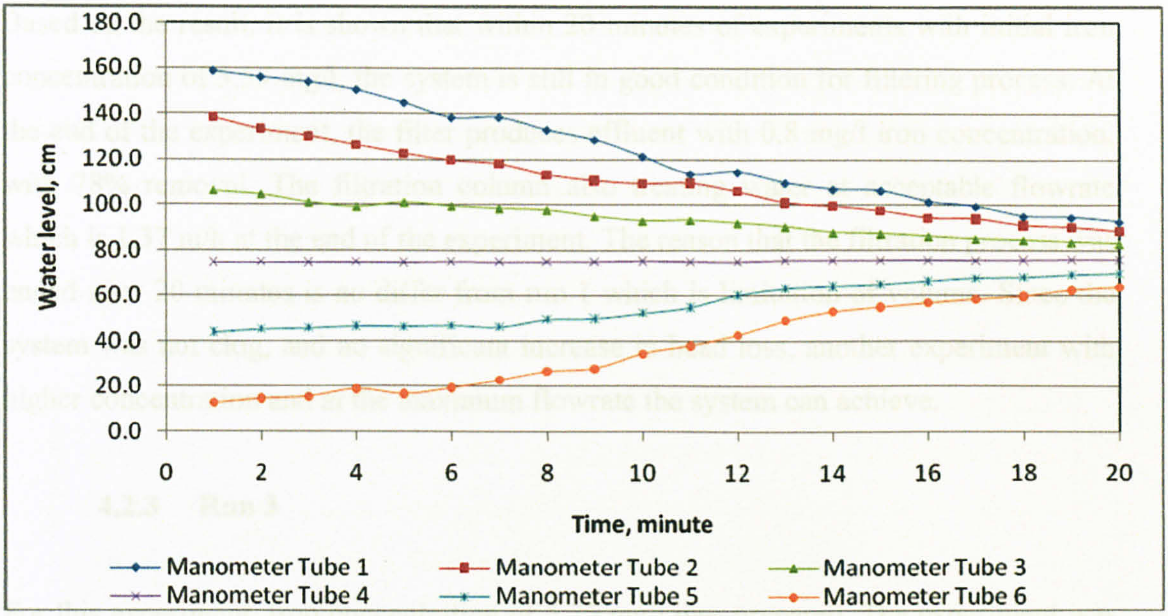


Figure 4.3: Water level in manometer tube vs time for Run 2

Figure 4.4 below is the calculated head loss with respect to time of running the experiment. From the graph shown, there is no significant increase of head loss with total head loss of 1.2 m at the end of the experiment. The head loss increase gradually within time, and still filtering water at average flowrate. At the end of filtration, the flow rate recorded was 1.37 m/h, giving a small decrease compare to minute 1 of filtering which is 1.77 m/h.

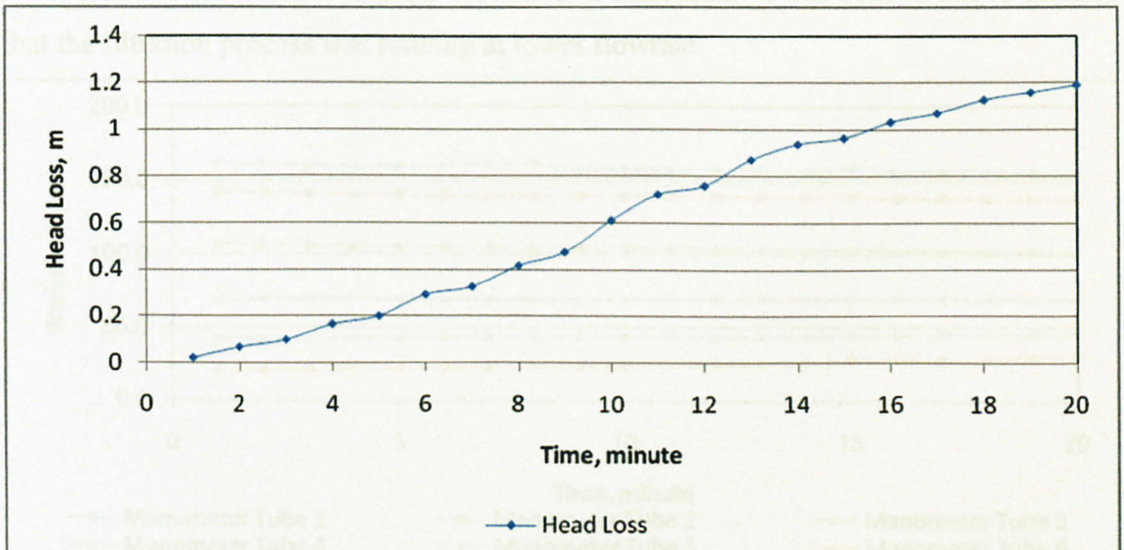


Figure 4.4: Graph of total headloss vs time for Run 2.

Based on the result, it is shown that within 20 minutes of experiments with initial iron concentration of 3.55 mg/l, the system is still in good condition for filtering process. At the end of the experiment, the filter produces effluent with 0.8 mg/l iron concentration, with 78% removal. The filtration column also treating water at acceptable flowrate which is 1.37 m/h at the end of the experiment. The reason that the filtration process was ended after 20 minutes is no differ from run 1 which is limitation of volume. Since the system was not clog, and no significant increase in head loss, another experiment with higher concentration and at the maximum flowrate the system can achieve.

4.2.3 Run 3

For this experiment, Iron concentration of 5.75 mg/l was prepared. The experiment was executed for 20 minutes. Within 1 minute interval, the flow rate of the experiment will be taken and all manometer tubes reading will be recorded. The average flowrate calculated for 20 minutes of experiment 1.17 m/h. Even thou the valve been open maximum, the flowrate was dropping compare to Run 2 which is 1.78 m/h. this is believe as the effect of filtering mechanism on higher concentration

Figure 4.5 below is the recorded water level in manometer during the experiment. The reading shows that there was small decreased or increased. It was believe due to the fact that the filtration process was running at lower flowrate.

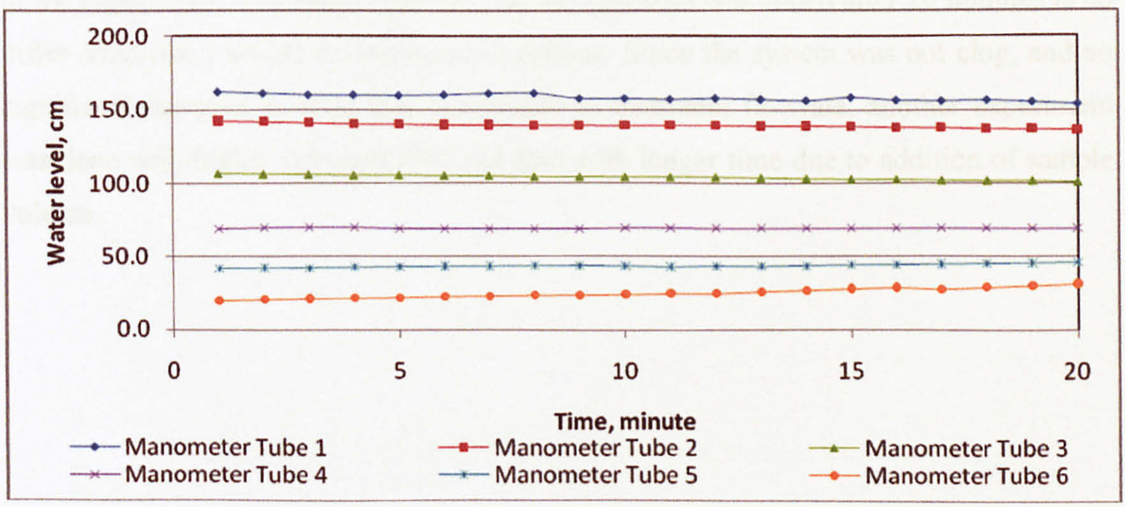


Figure 4.5: Water level in manometer tube vs time for Run 3

Figure 4.6 below is the calculated head loss with respect to time of running the experiment. From the graph shown, there is no significant increase of head loss with total head loss of 0.25 m at the end of the experiment. The head loss increase gradually within time, and still filtering water at average flowrate.

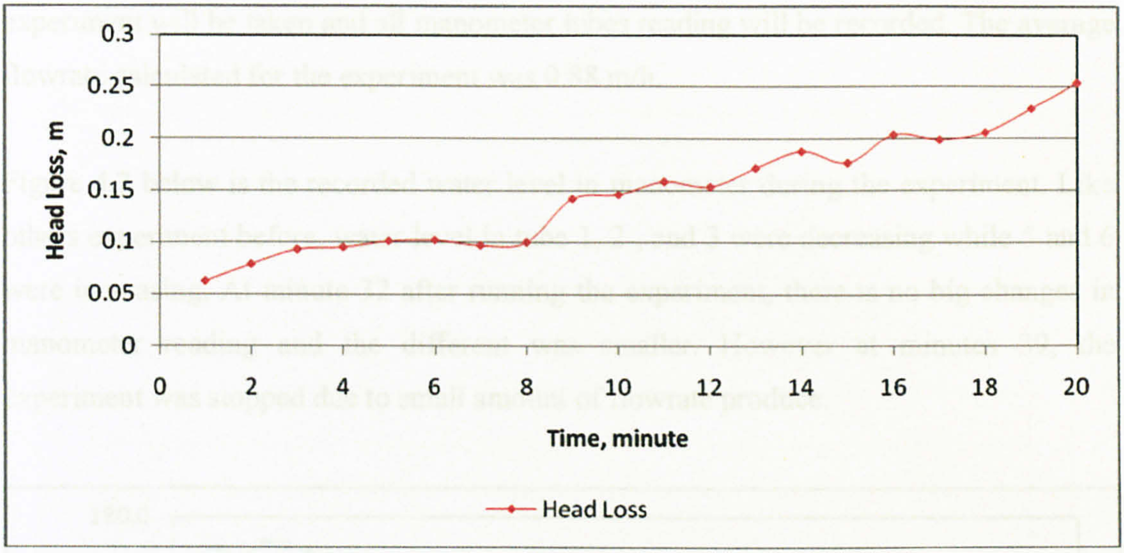


Figure 4.6: Graph of total head loss vs time for Run 3

Based on the result, it is shown that within 20 minutes of experiments with initial iron concentration of 5.75 mg/l, the system is still in good condition for filtering process. The filtration column also treating water at acceptable flowrate which is 0.99 m/h at the end of the experiment. The reason that the filtration process was ended after 20 minutes is no differ from run 1 which is limitation of volume. Since the system was not clog, and no significant increase in head loss nor reduce in treatment flowrate, another experiment was done with higher concentration and also with longer time due to addition of sample volume.

4.2.4 Run 4

For this experiment, Iron concentration of 11.7 mg/l was prepared. The experiment was executed until the system clogged. Within 1 minute interval, the flow rate of the experiment will be taken and all manometer tubes reading will be recorded. The average flowrate calculated for the experiment was 0.88 m/h.

Figure 4.7 below is the recorded water level in manometer during the experiment. Like others experiment before, water level in tube 1, 2 , and 3 were decreasing while 5 and 6 were increasing. At minute 32 after running the experiment, there is no big changes in manometer reading and the different was smaller. However at minutes 39, the experiment was stopped due to small amount of flowrate produce.

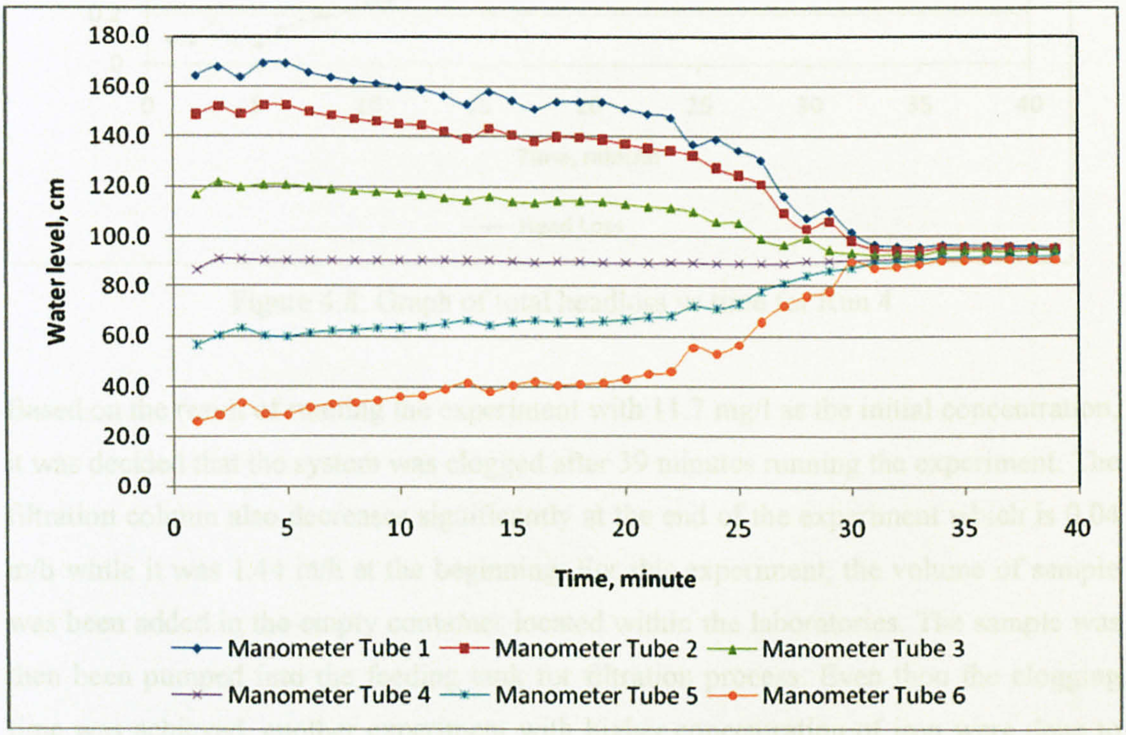


Figure 4.7: Water level in manometer tube vs time for Run 4

Figure 4.8 below is the calculated head loss with respect to time of running the experiment. From the graph shown, the head loss had a significant increase start from minute 25 of the experiment. Start from minute 32, the head loss build up rate was decreasing significantly and the head loss calculated almost linear after that. It was believed that the system was already clogged and the experiment had been stop after that.

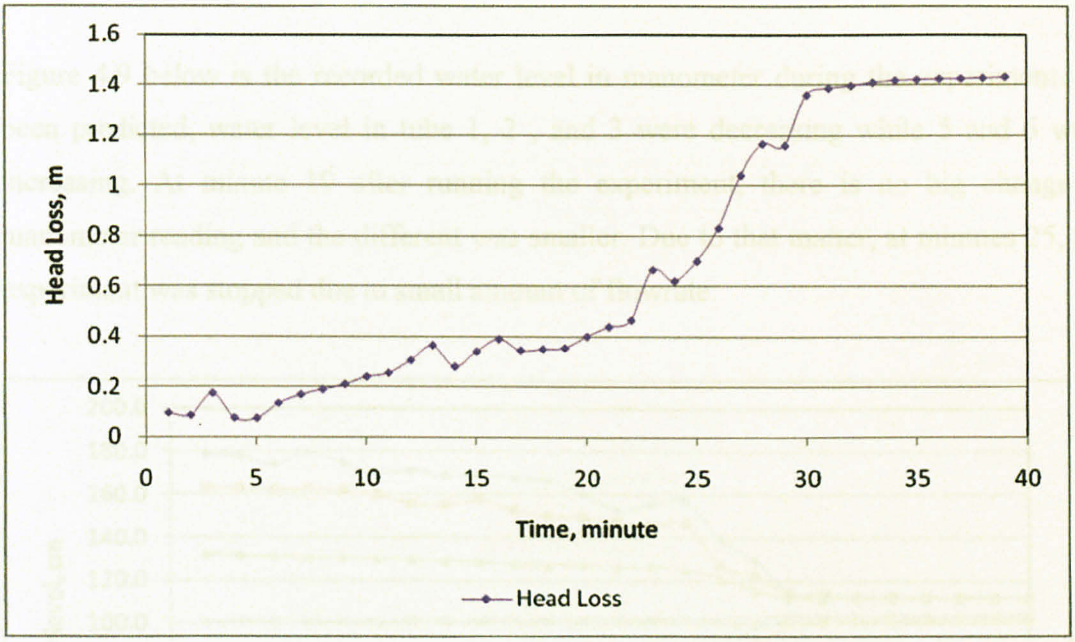


Figure 4.8: Graph of total headloss vs time for Run 4

Based on the result of running the experiment with 11.7 mg/l as the initial concentration, it was decided that the system was clogged after 39 minutes running the experiment. The filtration column also decreases significantly at the end of the experiment which is 0.04 m/h while it was 1.44 m/h at the beginning. For this experiment, the volume of sample was been added in the empty container located within the laboratories. The sample was then been pumped into the feeding tank for filtration process. Even thou the clogging time was achieved, another experiment with higher concentration of iron were done to check the correlativeness of the head loss effects when the system is clogged.

4.2.5 Run 5

For this experiment, Iron concentration of 21.2 mg/l was prepared. The experiment was executed until the system clogged. Within 1 minute interval, the flow rate of the experiment will be taken and all manometer tubes reading will be recorded. The average flowrate calculated for the experiment was 0.77 m/h, meets the prediction that the flow rate should be lower that experiment done before, which is 0.88 m/h.

Figure 4.9 below is the recorded water level in manometer during the experiment. As been predicted, water level in tube 1, 2 , and 3 were decreasing while 5 and 6 were increasing. At minute 19 after running the experiment, there is no big change in manometer reading and the different was smaller. Due to that matter, at minutes 25, the experiment was stopped due to small amount of flowrate.

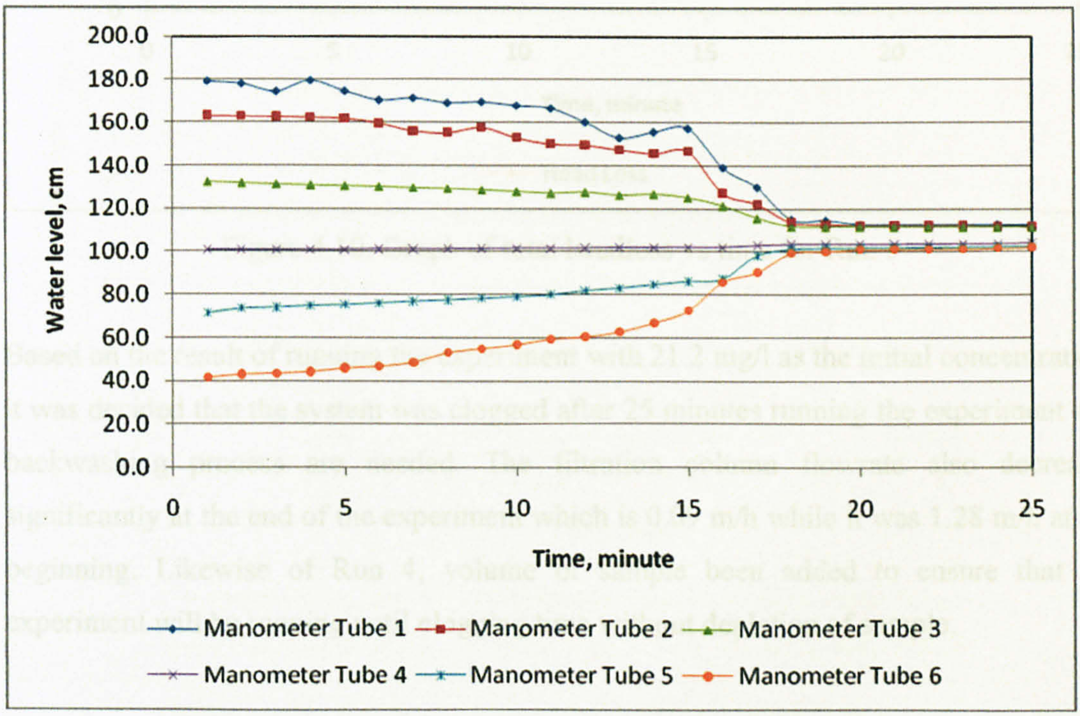


Figure 4.9: Water level in manometer tube vs time for Run 5

Figure 4.10 below shown the calculated head loss with respect to time of running the experiment. From the graph shown, the head loss had a significant increase start from minute 15 of the experiment. Start from minute 19, the head loss build up was decreasing significantly and the head loss calculated almost linear after that. It was believed that the system was already clogged and the experiment had been stop after that.

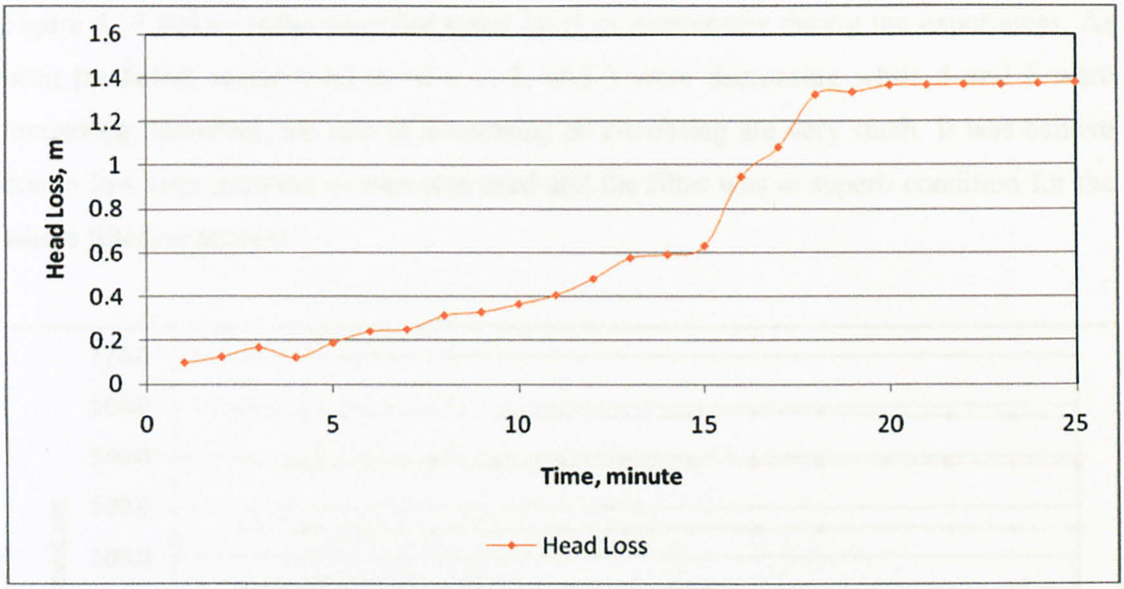


Figure 4.10: Graph of total headloss vs time for Run 5

Based on the result of running the experiment with 21.2 mg/l as the initial concentration, it was decided that the system was clogged after 25 minutes running the experiment and backwashing process are needed. The filtration column flowrate also decreases significantly at the end of the experiment which is 0.09 m/h while it was 1.28 m/h at the beginning. Likewise of Run 4, volume of sample been added to ensure that the experiment will be running until clogging time without depletion of sample.

4.2.6 Run 6

For this experiment, Iron concentration of 2.07 mg/l was prepared. The experiment was executed for 14 minute. Within 1 minute interval, the flow rate of the experiment will be taken and all manometer tubes reading will be recorded. The average flowrate calculated for the experiment was 1.48 m/h.

Figure 4.11 below is the recorded water level in manometer during the experiment. As been predicted, water level in tube 1, 2, and 3 were decreasing while 5 and 6 were increasing. However, the rate of decreasing or increasing are very small. It was believe due to low concentration of iron was used and the filter was in superb condition for the whole filtering process.

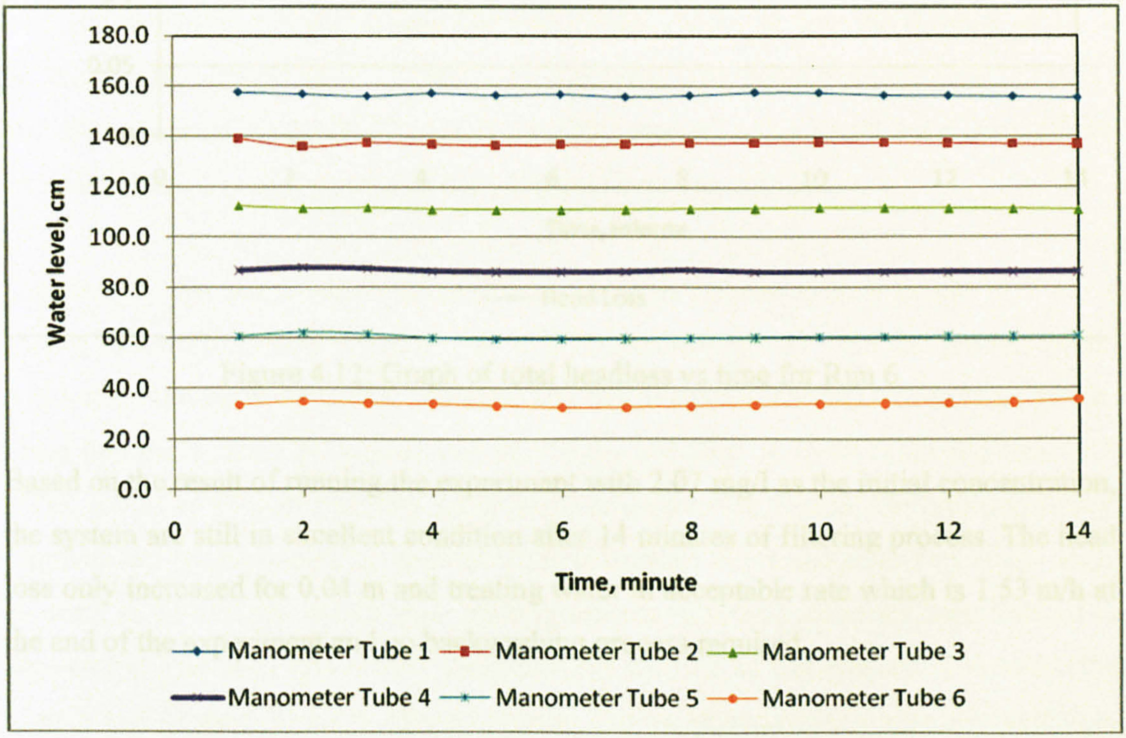


Figure 4.11: Water level in manometer tube vs time for Run 6

Figure 4.12 below shown the calculated head loss with respect to time of running the experiment. From the graph shown, the head loss build up ratio was very small. After 14 minutes of filtration process, the head loss increase only for 0.04 m, from 0.25 m initially to 0.29m at the end. The buildup rate of head loss was small due to small increase of pressure in the filter. It is based on the fact that precipitated iron retain in filter per minutes are too small, causing only small increase in pressure.

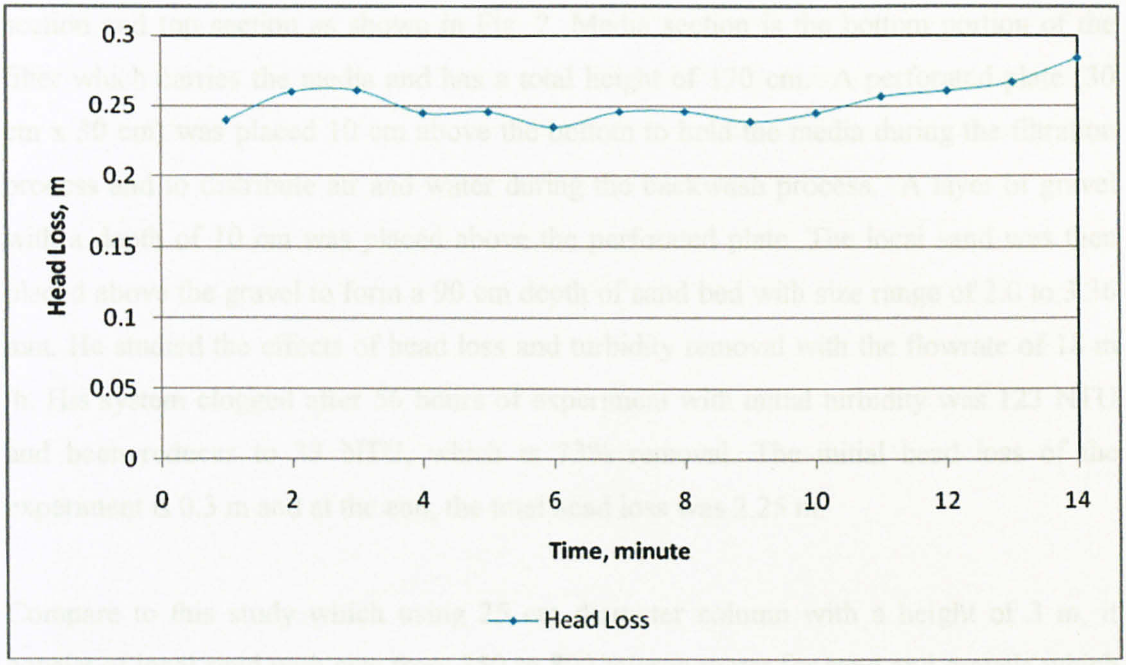


Figure 4.12: Graph of total headloss vs time for Run 6

Based on the result of running the experiment with 2.07 mg/l as the initial concentration, the system are still in excellent condition after 14 minutes of filtering process. The head loss only increased for 0.04 m and treating water in acceptable rate which is 1.53 m/h at the end of the experiment and no backwashing process required.

4.2.7 Comparison

Comparison of this experiment with other study was made. It is to compare the performance of this filter with others. Al-Jadhai, I.S. study entitles Pilot-Plant Study of the Tertiary Filtration of Wastewater Using Local Sand was choose. His pilot plant consist of The pilot filter has a square section of 30 cm x 30 cm and a height of 3.75 m. It is made of 10 mm thick clear Plexiglass. It has three sections; media section, trough section and top section as shown in Fig. 2. Media section is the bottom portion of the filter which carries the media and has a total height of 170 cm. A perforated plate (30 cm x 30 cm) was placed 10 cm above the bottom to hold the media during the filtration process and to distribute air and water during the backwash process. A layer of gravel with a depth of 10 cm was placed above the perforated plate. The local sand was then placed above the gravel to form a 90 cm depth of sand bed with size range of 2.0 to 3.36 mm. He studied the effects of head loss and turbidity removal with the flowrate of 18 m /h. His system clogged after 56 hours of experiment with initial turbidity was 123 NTU and been reduces to 33 NTU, which is 73% removal. The initial head loss of the experiment is 0.3 m and at the end, the total head loss was 2.25 m.

Compare to this study which using 25 cm diameter column with a height of 3 m, it consist of local sand with size from 350 to 800 micron meter for sand and gravels which 3 to 6 mm. The depth of sand is 180 cm while for gravel, the height recorded was 14 cm. From this study, the filter experiment had initial turbidity of 75.44 NTU and treat to 2 NTU, which is 97% of turbidity removal. It is believe the reason why the percentage removal was high compare to Ibrahim study is because the media size. This study using as small as 350 micron meter sand, causing more precipitated materials been trapped in the system. The head loss of this study initially was 0.1 m and was at 1.4 m when the system was clogged which is after 39 minute. For the phenomena, it also believe due to the sand size of this study use. The void between the media are smaller and can only retain small figure of precipitated materials, causing the system get clogged earlier.

4.3 Sieve Analysis

Figure 4.13 below shows the sieve analysis that had been done for the filter media. From the graph shown, the effective size, d_{10} is 0.25. The uniformity coefficient is 3.6. From this result, it is shown that the filter medium are not effective for rapid sand filtration, but effective if the system fall under slow sand filter type. The effective medium size for rapid sand filter should be above 0.45 with the uniformity coefficient below 1.5. This might be the reason of low flowrate of this system. It was believed that supplier was not following standard requirement of rapid sand filter media specification. Rectification of the media should be done to ensure that this filtration system with better efficiency.

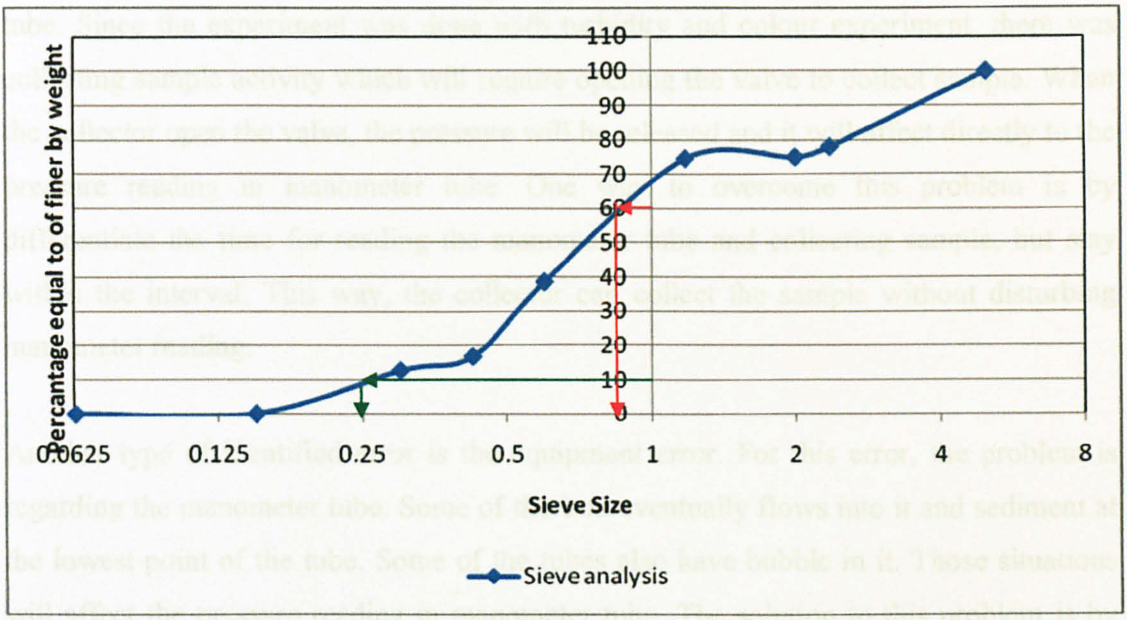


Figure 4.13: sieve analysis of the media

4.4 General Discussion

Since the preliminary experiment to Run 6, errors were always being part of the experiment. Basically there are many types of errors but in most cases experience shown that the biggest source of error is human error. As for this type of error, one of the mistakes is when reading the manometer tube. The observer should maintain reading the water level at the water meniscus. By doing so, it will reduce the percentage of error that occur. Then another problem is related to collecting sample and reading manometer tube. Since the experiment was done with turbidity and colour experiment, there was collecting sample activity which will require opening the valve to collect sample. When the collector open the valve, the pressure will be released and it will affect directly to the pressure reading in manometer tube. One way to overcome this problem is by differentiate the time for reading the manometer tube and collecting sample, but stay within the interval. This way, the collector can collect the sample without disturbing manometer reading.

Another type of identified error is the equipment error. For this error, the problem is regarding the manometer tube. Some of the iron eventually flows into it and sediment at the lowest point of the tube. Some of the tubes also have bubble in it. Those situations will affect the pressure reading in manometer tube. The solution to this problem is by cleaning and removes the precipitated iron in the tube by disconnecting it form the column before start the experiment. For the bubble problem, sampling valves can be use to remove any air trapped inside the tube and it need to be done before the experiment start. There is also equipment error while doing sieve analysis which is stuck sand in the stack sieve. This will affect the weight reading of the stack sieve.

Besides of error that occurred, it was a main problem that causing the experiment can be done for only 20 minutes. The feeding tank of the experiment can only cater a maximum of 250 L. This problem was the cause Run 1 to 3 can be done only for 20 minutes. However, for Run 4 and 5, the experiment can run longer since the problem was solved. The way to solved the problem is by mixing extra sample in empty container available in the laboratory before being pumped into the feeding tank. However, the advantages of mixing in the container is that manual water circulation need to be done in the container to avoid suspended of precipitated iron and effecting the experiment.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the experiment been done, calculating flowrate was achieved. A typical approach of method being used to obtain the flowrate which is took the effluent sample for a constant of time *t*, and the collected volume was divided with time, producing requested flowrate. From the calculated flowrate, the performance of the filter, which is head loss in this study, was observed. All the data recorded was analyse and documented. The objective to study the performance of filter in calculated flowrate was achieved. For the final objective which is to finalise and determine the best time for the backwashing process based on head loss for different Iron concentration, is also achieved for Run 4 and 5. For Run 4, initial iron concentration of 11.7 mg/l was used causing the system clogged at minute 30 of the process, while for Run 5, with 21.2 mg/l iron concentration causing the system to be clogged at minute 25 of the process. The reason that the other 3 run is not achieved was because of limitation of influent volume, which the feed tank of the system can only cater for 250 L maximum, enough for an average of 20 minutes run. While for Run 4 and 5, the problem was solved and the volume of influent was added up.

5.2 Recommendation

Based on the experiments and discussion, a few recommendations were decided. The recommendations regarding the filtration column are list below which is:

1. The feed tank for the system is small compare to the size of the filter where the filter bed height is 1.8 meter height. A few more containers will be need based on the time that the filter wants to be run. A smaller different pump to transfer the water for other containers to the feed tank will be good.
2. Modifications on manometer tube and sampling tube should be done. Both of the tubes are connected together from 1 port. For sampling, there is no problem at all with the configuration, but for the head loss reading from manometer, this configuration is a problem. When sample being taken, then pressure at the port will be affected, thus affecting the manometer reading, causing equipment type of error. To solve this, installing a valve to manometer tube will control the pressure different and reducing errors. Another solution is to install both tube at different port at the column.
3. Rectification on flowmeter should be made to ease calculation influent flowrate. The flowmeter was not functioning due to water surge phenomena.

REFERENCES

Al-Jadhai, I.S., 2002, Pilot Planr Study of the Tertiary Filtration of Wastewater Using Local Sand, Department of Civil Engineering, College of Engineering, King Saud University

Aziz, H.A., Yusoff M.S., Adlzan M.N., Adnam N.H. and Alias S., 2003. Physico Chemical Removal of Iron From Semi-Aerobic Landfill Leachate by Limestone Filter, Elsevier Ltd.

Boller, M.A. and Kavanaugh M.C., 1994, Particle Characteristic and Head Loss Increase In Granular Media Filtration, Pergamon Press

Department of Environmental Malaysia 1981, Environmental Quality (Sewage And Industrial Effluents) Regulations 1979

Droste, R.L., 1997, Theory and Practice of Water and Wastewater Treatment, John Wiley & Sons, Inc.

Ghaly A.E., Kamal M.A., Mahmoud N.S. and Cote R., 2007, Treatment of Landfill Leachate using Limestone/Sandstone Filters Under Aerobic Batch Conditions, Science Publications.

Koichi T., Keiko T., Seiji Y., 1985, US Patent 4530768 - Method For The Disposal Of Waste Water Containing Iron-Cyanide Complexes.

Lenntech Water treatment & air purification Holding B.V, 2008, http://www.lenntech.com/elements-and-water/iron-and-water.htm

Metcalf & Eddy, Inc. 2004, Wastewater Engineering Treatment and Reuse, McGraw Hill

Minnesota Rural water Association, www.mrwa.com/OP-Filtration.pdf, 2009, Filtration.

Pacini, V.A., Ingallinella, A.M., Sanguinetti, G., 2005, Removal of Iron and Manganese Using Biological Roughing Up Flow Filtration Technology, Elsevier Ltd.

Sincero, A. P. & Sincero, G. A., 1996, Environmental Engineering A design Approach, Prentice Hall.

Smith, K.S., G.S. Plumlee and W.H. Ficklin, 1994. Predicting Water Contamination From Metal Mines and Mining Waste.

Štembal, T., Marki´, M., Ribiˇ ci´ N. , Briški, F., Sipos, L., 2004, Removal of ammonia, iron and manganese from groundwater of northern Crotia, Elsevier Ltd.

Tekerlekopoulou, A.G. and Vayenas, D.V. 2006, Ammonia, Iron And Manganese Removal From Potable Water Using Trickling Filters, Elsevier Ltd.

Weiner, R.F. and Matthews, R.A., 2003 Environmental Engineering, Butterworth Heineman.

Win D.T., Than M.M., and Tun S. 2002, Iron Removal from Industrial Waters by Water Hyacinth, Faculty of Science and Technology, Assumption University, Bangkok, Thailand

Xu, C.Y., F.W. Schwartz and S.J Traina, 1997. Treatment of Acid Mine Water with Calcite and Quartz Sand.

Yunus A. Çengel & John M. Cimbala, 2006, Fluid Mechanics Fundamentals and Application. McGraw Hill.

APPENDICES

APPENDIX 1

Gantt Chart

Gantt Chart for FYP I

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of Project Topic	■														
	- Propose topic															
	- Confirmation of topic selection															
2	Preliminary Research Work		■	■												
	- Data selection															
	- Identify Material and Researches				■	■										
	- Literature review					■	■	■	■	■	■	■	■	■	■	■
3	Submission of Preliminary/Progress Report						●									
4	Project Work				■	■	■	■								
5	Project work and Researches continue								■	■	■	■	■			
	- Practical/Laboratory work												■	■	■	■
8	Submission of Interim Report Final Draft												●			
9	Oral Presentation															●

● Suggested milestone

■ Process

Gantt Chart for FYP II

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continue															
	- Practical/Laboratory work															
2	Submission of Combined Progress Report						●									
3	Project Work Continue															
	- Practical/Laboratory work															
4	Poster Exhibition											●				
5	Submission of Dissertation (soft bound)												●			
6	Oral Presentation															●

● Suggested milestone

Process

APPENDIX 2

Table of Data

Run 1

Time, minute	Water Level in Manometer Tube, cm					
	1	2	3	4	5	6
0 (initial)	110.0	109.5	109.0	109.0	109.0	109.0
1	177.0	142.0	113.5	83.0	55.2	25.6
2	170.0	148.0	110.0	83.0	55.8	27.6
3	168.0	139.0	110.0	84.0	56.0	28.1
4	180.0	120.0	110.2	82.8	56.5	28.9
5	166.5	138.5	113.5	83.0	54.3	23.7
6	175.0	145.0	113.0	83.0	54.4	24.3
7	174.5	144.0	114.0	84.0	45.4	25.6
8	174.0	143.0	111.8	82.8	44.5	27.9
9	170.0	141.5	111.0	82.8	57.0	21.9
10	168.0	140.0	115.0	83.0	55.5	29.3
11	176.0	146.0	109.4	82.5	54.3	33.8
12	165.5	138.0	108.0	82.0	55.6	34.3
13	157.5	134.0	107.0	82.5	59.0	36.8
14	165.0	132.0	106.5	82.5	59.6	37.5
15	152.0	130.5	105.0	82.4	60.0	40.3
16	151.0	129.0	104.0	82.3	60.5	44.4
17	147.0	126.0	102.0	81.6	61.5	52.3
18	140.0	123.0	97.8	81.5	61.8	53.4
19	127.0	113.0	95.4	80.0	66.9	55.1
20	125.0	112.0	93.1	79.5	70.2	57.8

Water level in manometer tube 1 to 6 with respective time

Time, minute	Pressure, kg/ms^2			Total headloss h_L, m
	P1	P6	ΔP	
1	101043	104378.4	3335.4	0.034
2	107910	102416.4	5493.6	0.056
3	109872	101925.9	7946.1	0.081
4	98100	101141.1	3041.1	0.031
5	111343.5	106242.3	5101.2	0.052
6	103005	105653.7	2648.7	0.027
7	103495.5	104378.4	882.9	0.009
8	103986	102122.1	1863.9	0.019
9	107910	108008.1	98.1	0.001
10	109872	100748.7	9123.3	0.093
11	102024	96334.2	5689.8	0.058
12	112324.5	95843.7	16480.8	0.168
13	120172.5	93391.2	26781.3	0.273
14	112815	92704.5	20110.5	0.205
15	125568	89957.7	35610.3	0.363
16	126549	85935.6	40613.4	0.414
17	130473	78185.7	52287.3	0.533
18	137340	77106.6	60233.4	0.614
19	150093	75438.9	74654.1	0.761
20	152055	72790.2	79264.8	0.808

Calculated pressure difference, and total headloss

Run 2

Time, minute	Water Level in Manometer Tube					
	1	2	3	4	5	6
0 (initial)	110.0	109.5	109.0	109.0	109.0	109.0
1	158.5	138.5	106.4	74.7	44.0	12.5
2	155.9	133.4	104.8	74.8	45.4	14.5
3	153.8	130.5	101.3	74.7	45.9	15.5
4	150.4	126.5	99.3	74.8	46.8	18.9
5	144.7	122.7	101.3	74.7	46.7	16.7
6	138.3	119.7	99.7	75.0	47.2	19.4
7	138.4	118.1	98.6	74.8	46.5	22.9
8	133.0	113.4	98.0	74.9	49.7	26.7
9	128.6	110.8	95.3	75.0	50.1	28.1
10	121.4	109.4	93.1	75.3	52.4	34.6
11	113.7	109.7	93.4	75.1	55.0	38.1
12	114.5	106.0	92.1	75.0	60.5	42.6
13	109.8	101.0	90.5	75.5	63.4	49.1
14	107.0	99.5	88.0	75.5	64.3	53.0
15	106.4	97.5	87.5	75.6	65.0	55.0
16	101.5	94.2	86.3	75.6	66.5	56.9
17	99.5	93.9	85.2	75.7	67.9	58.6
18	95.1	91.1	84.7	75.8	68.3	60.0
19	94.7	90.2	83.7	76.0	69.4	62.7
20	92.8	88.5	83.0	76.0	70.0	64.0

Water level in manometer tube 1 to 6 with respective time

Time, minute	Pressure, kg/ms^2			Total headloss hL, m
	P1	P6	ΔP	
1	119191.5	117229.5	1962	0.02
2	121742.1	115267.5	6474.6	0.066
3	123802.2	114286.5	9515.7	0.097
4	127137.6	110951.1	16186.5	0.165
5	132729.3	113109.3	19620	0.2
6	139007.7	110460.6	28547.1	0.291
7	138909.6	107027.1	31882.5	0.325
8	144207	103299.3	40907.7	0.417
9	148523.4	101925.9	46597.5	0.475
10	155586.6	95549.4	60037.2	0.612
11	163140.3	92115.9	71024.4	0.724
12	162355.5	87701.4	74654.1	0.761
13	166966.2	81324.9	85641.3	0.873
14	169713	77499	92214	0.94
15	170301.6	75537	94764.6	0.966
16	175108.5	73673.1	101435.4	1.034
17	177070.5	72005.4	105065.1	1.071
18	181386.9	70632	110754.9	1.129
19	181779.3	67983.3	113796	1.16
20	183643.2	66708	116935.2	1.192

Calculated pressure difference, and total headloss

Run3

Time, minute	Water Level in Manometer Tube					
	1	2	3	4	5	6
0 (initial)	96.4	96.4	96.4	96.4	96.4	96.4
1	162.0	142.5	107.0	69.0	42.0	20.3
2	161.0	142.0	106.6	69.5	42.3	20.9
3	160.0	141.3	106.2	69.5	42.2	21.3
4	160.0	140.5	105.8	69.6	42.5	21.5
5	159.8	140.5	105.9	69.0	42.9	21.9
6	160.3	140.0	105.7	69.0	43.1	22.5
7	161.2	140.0	105.3	69.0	43.2	22.9
8	161.4	139.8	104.8	69.0	43.5	23.4
9	157.5	139.8	104.6	69.0	43.7	23.7
10	157.5	139.5	104.5	69.5	43.6	24.1
11	156.9	139.5	104.4	69.6	43.1	24.8
12	157.6	139.5	104.4	69.4	43.7	25.0
13	157.0	139.2	104.0	69.4	43.4	26.2
14	156.3	139.2	103.5	69.4	43.9	27.1
15	158.3	138.8	103.2	69.4	44.3	28.0
16	156.5	138.0	102.9	69.4	44.5	28.9
17	156.0	137.9	102.3	69.4	44.9	27.9
18	156.5	137.0	102.0	69.5	45.3	29.1
19	155.4	136.8	101.9	69.4	45.7	30.3
20	154.0	136.4	101.2	69.5	46.1	31.4

Water level in manometer tube 1 to 6 with respective time

Time, minute	Pressure, kg/ms^2			Total headloss hL, m
	P1	P6	ΔP	
1	115758	109577.7	6180.3	0.063
2	116739	108989.1	7749.9	0.079
3	117720	108596.7	9123.3	0.093
4	117720	108400.5	9319.5	0.095
5	117916.2	108008.1	9908.1	0.101
6	117425.7	107419.5	10006.2	0.102
7	116542.8	107027.1	9515.7	0.097
8	116346.6	106536.6	9810	0.1
9	120157.1964	106242.3	13914.8964	0.141844
10	120172.5	105849.9	14322.6	0.146
11	120761.1	105163.2	15597.9	0.159
12	120074.4	104967	15107.4	0.154
13	120663	103789.8	16873.2	0.172
14	121349.7	102906.9	18442.8	0.188
15	119387.7	102024	17363.7	0.177
16	121153.5	101141.1	20012.4	0.204
17	121644	102122.1	19521.9	0.199
18	121153.5	100944.9	20208.6	0.206
19	122232.6	99767.7	22464.9	0.229
20	123606	98688.6	24917.4	0.254

Calculated pressure difference, and total headloss

Run 4

Time, minute	Water Level in Manometer Tube					
	1	2	3	4	5	6
0 (initial)	108.5	108.5	108.5	108.5	108.5	108.5
1	164.5	148.8	117.0	86.5	56.6	26.0
2	168.0	152.0	122.0	91.0	60.4	28.5
3	164.0	149.0	120.0	91.0	63.3	33.5
4	169.5	152.5	121.0	90.5	60.5	29.0
5	169.5	152.5	121.0	90.5	60.0	28.8
6	166.0	150.0	120.0	90.5	61.5	31.5
7	164.0	148.5	119.2	90.5	62.3	33.0
8	162.5	147.0	118.5	90.5	62.6	33.5
9	161.5	146.0	118.0	90.5	63.4	34.5
10	160.0	145.0	117.5	90.5	63.5	36.0
11	159.0	144.5	117.0	90.5	63.8	36.5
12	156.5	142.0	115.5	90.5	65.0	39.0
13	153.0	139.0	114.5	90.4	66.3	41.5
14	158.0	143.0	116.0	90.5	64.3	38.0
15	154.5	140.5	114.0	90.0	65.5	40.5
16	151.0	138.0	113.5	89.5	66.3	42.0
17	154.0	139.9	114.4	90.0	65.6	40.5
18	154.0	139.8	114.3	90.0	65.6	41.0
19	154.0	138.9	114.0	89.5	66.0	41.5
20	151.0	137.2	113.0	89.5	66.5	43.0
21	149.0	135.5	112.0	89.3	67.5	44.8
22	147.5	134.5	111.5	89.5	68.0	46.0
23	137	132.5	110	89.4	72	55.5
24	139.0	127.5	106.0	89.0	71.0	53
25	134.5	124.5	105.5	89.0	73.0	56.5
26	130.5	121.0	99.0	89.0	78.0	65.6
27	116.0	109.5	96.5	89.0	81.0	72.0
28	107.3	103.0	99.0	90.0	84.0	76.0
29	110.0	106.0	94.3	90.0	86.0	78.0
30	101.5	98.3	93.3	90.5	87.0	89.5
31	96.5	95.2	92.6	90.5	89.0	87.2
32	95.8	94.6	92.6	91.0	89.4	87.5
33	95.5	94.4	92.4	91.0	90.0	88.5
34	96.4	95.5	94.4	91.0	91.5	90.2
35	96.3	95.5	94.5	91.0	91.6	90.4
36	96.1	95.4	94.3	91.0	91.7	90.5
37	96.0	95.3	94.0	91.0	91.8	90.5
38	95.9	95.2	94.6	91.0	91.8	90.6
39	95.6	95.1	94.6	91.1	91.9	90.7

Water level in manometer tube

Time, minute	Pressure, kg/ms²			Total headloss hL, m
	P1	P6	ΔP	
1	113305.5	103986	9319.5	0.095
2	109872	101533.5	8338.5	0.085
3	113796	96628.5	17167.5	0.175
4	108400.5	101043	7357.5	0.075
5	108400.5	101239.2	7161.3	0.073
6	111834	98590.5	13243.5	0.135
7	113796	97119	16677	0.17
8	115267.5	96628.5	18639	0.19
9	116248.5	95647.5	20601	0.21
10	117720	94176	23544	0.24
11	118701	93685.5	25015.5	0.255
12	121153.5	91233	29920.5	0.305
13	124587	88780.5	35806.5	0.365
14	119682	92214	27468	0.28
15	123115.5	89761.5	33354	0.34
16	126549	88290	38259	0.39
17	123606	89761.5	33844.5	0.345
18	123606	89271	34335	0.35
19	123606	88780.5	34825.5	0.355
20	126549	87309	39240	0.4
21	128511	85543.2	42967.8	0.438
22	129982.5	84366	45616.5	0.465
23	140283	75046.5	65236.5	0.665
24	138321	77499	60822	0.62
25	142735.5	74065.5	68670	0.7
26	146659.5	65138.4	81521.1	0.831
27	160884	58860	102024	1.04
28	169418.7	54936	114482.7	1.167
29	166770	52974	113796	1.16
30	175108.5	41692.5	133416	1.36
31	180013.5	43948.8	136064.7	1.387
32	180700.2	43654.5	137045.7	1.397
33	180994.5	42673.5	138321	1.41
34	180111.6	41005.8	139105.8	1.418
35	180209.7	40809.6	139400.1	1.421
36	180405.9	40711.5	139694.4	1.424
37	180504	40711.5	139792.5	1.425
38	180602.1	40613.4	139988.7	1.427
39	180896.4	40515.3	140381.1	1.431

Head loss calculated

Run 5

Time, minute	Water Level in Manometer Tube					
	1	2	3	4	5	6
0 (initial)	119.5	119.5	119.5	119.5	119.5	119.5
1	179.5	163.2	132.5	100.6	71.4	41.5
2	178.3	163.0	131.9	100.6	73.6	42.9
3	174.6	162.7	131.4	100.7	74.1	43.4
4	179.8	162.4	131.0	100.8	74.9	44.1
5	174.9	161.9	130.7	100.9	75.3	45.8
6	170.6	159.7	130.3	101.1	76.1	46.7
7	171.6	156.2	129.8	101.1	76.9	48.6
8	169.4	155.3	129.4	101.2	77.5	52.9
9	169.8	157.8	128.7	101.3	78.2	54.8
10	168.1	153.1	127.9	101.5	79.0	56.7
11	166.8	150.2	127.1	101.5	79.9	59.4
12	160.4	149.7	127.6	101.6	81.8	60.4
13	153.2	147.5	126.2	101.9	83.0	62.7
14	155.9	145.6	126.7	101.9	84.6	66.9
15	157.6	146.7	125.1	102.0	86.1	72.5
16	139.4	127.3	121.4	102.0	87.2	86.0
17	130.1	122.3	115.8	102.9	98.2	90.4
18	115.3	113.8	111.7	103.4	101.1	99.5
19	114.9	112.8	111.6	103.4	101.6	100.3
20	112.9	112.1	111.6	103.5	101.7	101.3
21	112.8	112.1	111.5	103.5	101.8	101.3
22	112.8	112.1	111.5	103.6	101.9	101.5
23	112.8	112.1	111.5	103.7	102.1	101.5
24	112.7	111.9	111.5	103.8	102.3	101.8
25	112.6	111.9	111.4	104.1	102.4	102.2

Water level in manometer tube

Time, minute	Pressure, kg/ms²			Total headloss hL, m
	P1	P6	ΔP	
1	98590.5	88780.5	9810	0.1
2	99767.7	87407.1	12360.6	0.126
3	103397.4	86916.6	16480.8	0.168
4	98296.2	86229.9	12066.3	0.123
5	103103.1	84562.2	18540.9	0.189
6	107321.4	83679.3	23642.1	0.241
7	106340.4	81815.4	24525	0.25
8	108498.6	77597.1	30901.5	0.315
9	108106.2	75733.2	32373	0.33
10	109773.9	73869.3	35904.6	0.366
11	111049.2	71220.6	39828.6	0.406
12	117327.6	70239.6	47088	0.48
13	124390.8	67983.3	56407.5	0.575
14	121742.1	63863.1	57879	0.59
15	120074.4	58369.5	61704.9	0.629
16	137928.6	45126	92802.6	0.946
17	147051.9	40809.6	106242.3	1.083
18	161570.7	31882.5	129688.2	1.322
19	161963.1	31097.7	130865.4	1.334
20	163925.1	30116.7	133808.4	1.364
21	164023.2	30116.7	133906.5	1.365
22	164023.2	29920.5	134102.7	1.367
23	164023.2	29920.5	134102.7	1.367
24	164121.3	29626.2	134495.1	1.371
25	164219.4	29233.8	134985.6	1.376

Head loss calculated

Run 6

Time, minute	Water Level in Manometer Tube					
	1	2	3	4	5	6
0 (initial)	107.5	107.5	107.5	107.5	107.5	107.5
1	157.5	139.0	112.5	86.7	60.5	33.5
2	154.0	136.0	111.4	88.0	62.0	36.5
3	156.0	137.6	111.7	87.6	61.5	35.5
4	157.2	137.0	111.0	86.5	60.0	33.7
5	156.4	136.7	110.8	86.2	59.5	33.0
6	156.8	136.9	110.9	86.2	59.5	32.3
7	155.9	137.1	111.0	86.3	59.6	32.5
8	156.4	137.5	111.3	87.0	60.0	33.0
9	157.6	137.7	111.5	86.1	60.2	33.5
10	157.5	137.8	111.8	86.1	60.5	34.0
11	156.4	137.5	111.7	86.1	60.5	34.1
12	156.2	137.3	111.5	86.1	60.6	34.3
13	155.9	137.0	111.3	86.2	60.6	34.6
14	155.3	136.8	110.9	86.2	60.7	35.7

Water level in manometer tube

Time, minute	Pressure, kg/ms²			Total headloss hL, m
	P1	P6	ΔP	
1	120172.5	96628.5	23544	0.24
2	123606	93685.5	29920.5	0.305
3	121644	94666.5	26977.5	0.275
4	120466.8	96432.3	24034.5	0.245
5	121251.6	97119	24132.6	0.246
6	120859.2	97805.7	23053.5	0.235
7	121742.1	97609.5	24132.6	0.246
8	121251.6	97119	24132.6	0.246
9	120074.4	96628.5	23445.9	0.239
10	120172.5	96138	24034.5	0.245
11	121251.6	96039.9	25211.7	0.257
12	121447.8	95843.7	25604.1	0.261
13	121742.1	95549.4	26192.7	0.267
14	122330.7	94470.3	27860.4	0.284

Head loss calculated

Sieve Analysis

Total weight of sample, g	1027.93

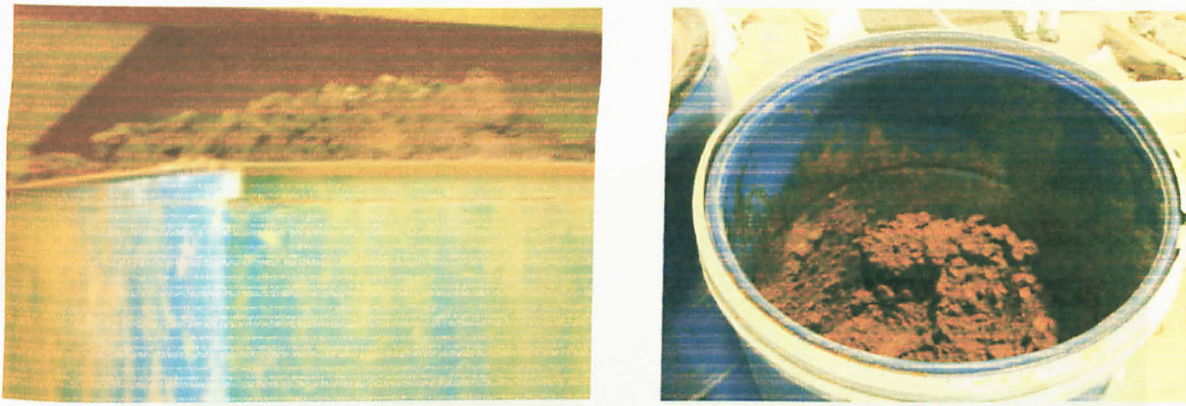
Total sample of media use

Sieve opening size, mm	Seive stack weight without sample	weight with sample	Weight of sample	% retain	%cumulative passing
5	0	0	0	0	100
2.36	388	614.3	226.3	22.02	77.98
2	432	462	30	2.92	75.07
1.18	350.6	355.5	4.9	0.48	74.59
0.6	329.6	843.1	369.1	35.91	38.68
0.425	347.9	601.5	224.9	21.88	16.80
0.3	285.3	341	41.6	4.05	12.76
0.15	161.3	322.1	130.9	12.73	0.02
0.063	321.2	321.3	0.1	0.01	0.01
0	393.7	393.9	0.2	0.01	0.00

Sieve analysis data

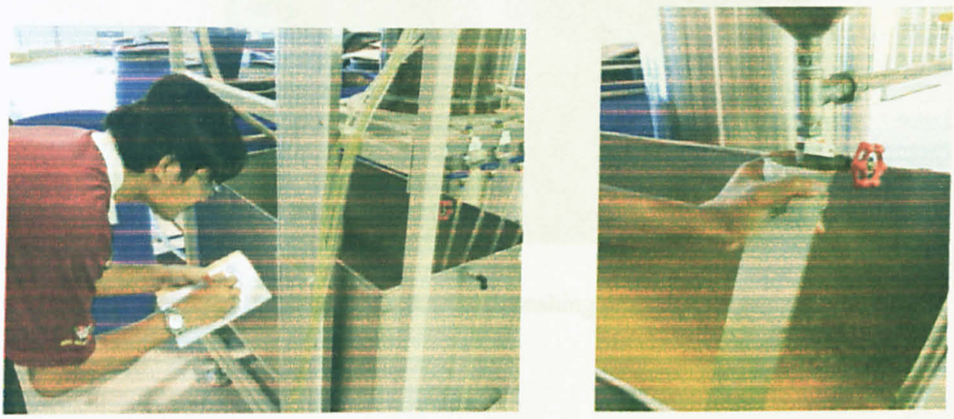
APPENDIX 2

Figures

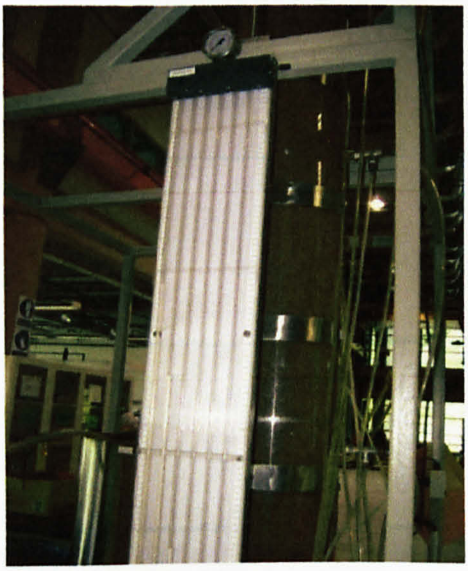


Iron sludge form Chicha Water Treatment Plant

Preparation of Sample



Data Gathering Process



Manometer tube

Backwash process, cleaning media from iron

Water level when backwashing process