FILTRATION: EFFECT OF SAND PARTICLES ARRANGEMENT ON WATER QUALITY

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CERTIFICATION OF APPROVAL

Filtration: Effect of Sand Particle Arrangement on Water Quality

by

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CERTIFICATION OF ORIGINALITY

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

SARINA BT TUKIMAN

ABSTRACT

Water filtration is a process for separating suspended or colloidal impurities from water by passage through a porous medium, usually a band of sand or others. Water fills the pores (open spaces) between the sand particles and the impurities are left behind either clogged in the open spaces or attached to the sand itself. It is well known that the arrangement of the sand bed determines the quality of the water filtered.

In this research, the equipment use is the Filterability Index Unit (FIU). Different types of sand bed arrangement with various sand particles sizes will be used to remove impurities or suspended solids. The first experiment using paddy field sample water and the second experiment using UTP River sample water.

In general, the main objective of this experiment is to propose the best sand bed arrangement for water filtration process. During the filtration, the data for volumetric and the flowrate is taken into account in order to calculate its specific cake filter resistance and filter medium resistance. The filtrate is tested for its quality measurement. From the result obtained, the first sand bed arrangement (larger particles to small particles, from top to bottom) is proposed as the best sand bed arrangement for sand filtration due to the lowest COD and smallest specific filter cake resistance.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND NOMENCLATURES

ABBREVIATIONS

FIU	Filterability Index Unit
UTP	Universiti Teknologi PETRONAS
FYP	Final Year Research Project
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
TOC	Total Organic Carbon
EPA	Environment Protection Agency

NOMENCLATURES

α	specific filter cake resistance
R_m	filter medium resistant
μm	micrometer
m	meter
kg	kilogram
$K_2Cr_2O_7$	Potassium Dichromate
CO_2	Carbon Dioxide
t	time
V	volume
L	liter
min	minutes
mg	milligram
P	pressure
C_s	slurry concentration
μ	viscosity
A	area of the filter unit

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Screening will remove larger suspended solids from water, and sedimentation following chemical coagulation will remove most of the residual suspended matter. However, there will usually remain some fine floc particles and other suspended matter. To remove the particles, to reduce still further the bacterial content of the water, and to ensure the production of clear and attractive water, filters are used.

Water filtration is a process for separating suspended or colloidal impurities from water by passage through a porous medium, usually a band of sand or others. Water fills the pores (open spaces) between the sand particles and the impurities are left behind either clogged in the open spaces or attached to the sand itself. It is well known that the arrangement of the sand bed determines the quality of the water filtered.

In this research, different types of sand bed arrangement with various sizes will be used to remove impurities or suspended solids. For the first experiment using paddy field water, the sand bed arrangements are as below:

1) from top to bottom, large particles to small particles (1000μm, 700μm, 500μm)
2) from top to bottom, small particles to large particles (500μm, 700μm, 1000μm)
3) mixing of the sand

For the second experiment using water from UTP River, the sand bed arrangements are as below:

1) from top to bottom, large particles to small particles (700μm, 500μm, 300μm)
2) Mixing of the sand

The objectives is to measure the filterability characteristics of a given suspension performance of a standard water quality test, to determine the specific filter cake resistant α (m/kg) and the filter medium resistant R_m (1/m) for different arrangement of sand bed. The sample water before filtration and the filtrate is tested for COD. Based on the result and findings, the best sand arrangement can be deduced.

1.2 Problem Statement

1.2.1 Problem identification

Water filtration is a process for separating suspended or colloidal impurities from water by passage through a porous medium, usually a band of sand or others. Water fills the pores (open spaces) between the sand particles and the impurities are left behind either clogged in the open spaces or attached to the sand itself. It is well known that the arrangement of the sand bed determines the quality of the water filtered.

1.2.2 Significant of the project

The project carried out has significant effects for those who going to study water treatment using sand filtration. Basically, all the data, calculation, and discussion in this project will be used as a standard parameter for researchers to make their own studies about the quality comparison for water treatment using different sand bed arrangement in filtration.

CHAPTER 3
LITERATURE REVIEW AND THEORY

3.1 Type of filter

Screening will remove the larger suspended solids form water, and sedimentation following chemical coagulation will remove most of the residual suspended matter. However, there will usually remain some fine floc particles and other suspended matter. To remove them, to reduce still further the bacterial content of the water, and to ensure the production of clear and attractive water, filters are used.

Essentially a filter consists of a bed of granular material to remove suspended solid form the water, with devices to maintain a uniform rate of flow through the bed and with provisions for reversing the direction of flow of water periodically to wash accumulated solids from the filter medium.

In municipal water-treatment practice, sand filters are employed almost exclusively, though some plants utilize finely crushed anthracite coal instead of sand for the filter medium.

There are two general types of sand filters in use for water purification. They are classified as slow sand filters and rapid sand filters. They differ primarily in the rate at which they operate, but there are also essential differences in theory and in operation. The rapid sand filters are further classified as gravity filters and pressure filters.

In rapid sand filtration, the water is passed downward through the sand at relatively high velocity and the rate is carefully controlled. After passing through the sand bed and a supporting layer of gravel, the water is collected by an underdrainage system and discharged into a clear well from which it is drawn for consumption.
Pretreatment by coagulation and sedimentation is essential in order to remove as much as possible of the suspended matter, thus lessening the load on the sand bed, because of the

high rate, the sand bed tends to clog rather quickly and must be washed frequently. This accomplished by reversing the flow of the water through the gravel layer and the sand bed. Clear water for washing is supplied by a special pump. The dirty water resulting from washing overflows into wash-water troughs and is discharged through drains into a sewer for disposal.

Pressure filters have the same general characteristics as rapid sand of the gravity type filters and operate in the same way. The filter media and the underdrains are contained in a steel tank, and the water is pumped through the filter. Preliminary treatment is essential if the water is turbid or contains appreciable amounts of suspended matter. A variation of the pressure filter employing sand is the diatomite filter, which utilizes diatomaceous earth as a filtering medium.

In a slow sand filter the water is passed through the sand layer at a low velocity. Pretreatment is often advantageous but is not essential unless the water is turbid. Cleaning is required only at long interval of time if the water is relatively clear. It is accomplished by removing a thin surface layer of the sand.

3.2 The sand bed

Also the sand particles must be fairly uniform and of proper size. Fine sand tends to clog quickly and requires frequent washing. Very coarse sand permit the passage of some suspended solids and perhaps also more bacteria. Crushed anthracite coal, when used, conforms generally to applicable specifications for sand. Filter sand is classified in regard to its size and uniformity by means of two properties called the effective size and the uniformity coefficient. The requirements in regard to these properties apply also to anthracite media.

3.3 Loss of head

As water is passed through a filter, suspended material is deposited on top of the bed and in the upper layers of the sand. This material increases the resistance to the flow of water through the sand.

When the filter unit is first put into services, the loss of head is comparatively small, whereas, after an operating period of 20 to 30 hours it may be quite large. When the loss becomes too great, the filter is washed. In operation, loss of head is indicated by gages which measure the difference between the surface of the water over the filter and the piezometric pressure on the filter outlet.

3.4 Washing the filter

A filter unit is washed when the filtering medium has become so dirty that the maximum gravity head is required to force the water through the bed. The purpose of washing is to remove from the filter bed all suspended matter that has collected on and in the sand. Washing is accomplished by reversing the flow of water through the filter, but using a much higher rate.

3.5 Rapid sand filter

Even relatively large variations in bacterial pollutional loads can be handled in a well-designed and well- operated plant. Rapid sand filters are also effective in the removal of turbidity, if preparation of the water for filtration has been adequate and they are effective for algae removal.

Unless special treatment such as activated carbon or pre-chlorination is provided, such filter will not ordinarily remove tastes and odors. In lime-soda softening plants, rapid sand filters may be used after coagulation and sedimentation. However, some structural and operating modifications are necessary.

3.6 Pressure filter

Pressure filters are rapid sand filters contained in an airtight cell. Because the container is tight, this filter may be placed on a pressure line. Hence, the only loss of head is that required to force the water through the filter. Repumping is not required, as is the case with gravity filters.

Pressure filters are used principally for swimming pools and for small installation for public water supply. The principal objection to their use for public water supplies is the difficulty in providing adequate space for coagulation and sedimentation. It is, therefore, impractical to use a pressure filter where turbid water is to be treated. However, where the water is regularly clear and chlorination is provided after filtration, a pressure filter may be used.

3.7 Slow sand filter

Slow sand filters do not normally utilize coagulation to prepare the water for filtration. Usually they are employed only for relatively clear waters and have a low bacterial count of that have been clarified by storage or sedimentation.

Bacterial removals are of 98 percent. Slow sand filters are efficient in removing tastes and odors. Slow sand filters are efficient in removing tastes and odors. A slow sand filter has an additional advantage, it is simple to operate.

3.8 Primary treatment before filtration

Sedimentation and coagulation are important in that these processes prepare waters for filtration and proper preparation of the water is necessary to ensure efficient and trouble-free performance of filters. The aim in both design and operation of a treatment plant should be to combine the several treatment processes into an effective and economical whole.

3.8.1 Plain Sedimentation

Impoundment of surface water in a storage reservoir for a considerable time results in clarification which is sometimes sufficient treatment. More often, however, such storage is a preliminary step to further treatment. Clarification of the water by storage results not only from sedimentation, but also from sunlight and aeration. Plain sedimentation usually has little effect in removing the very small particles suspended in the water, but the larger and heavier particles do settle. The extent of settlement depends on the particles size and the velocity of flow of the water.

Where the water is drawn form a highly turbid source, pretreatment basins may be utilized to remove much of the turbidity and provide water that is relatively uniform in quality.

3.8.2 Sedimentation by Coagulation

In order to remove the very fine particles of suspended matter in the water, it is common practice to add a chemical, called a coagulant, to the water. This coagulant forms as a flow, attracting finely divided particles and the colloidal mater in the water into groups or aggregates that are more easily removed by sedimentation.

The ability of suspended matter in water to settle depends largely on the size and specific gravity of the particles, but it is also influenced by the temperature of the water. The colder the water, the more viscous it is, and the grater the friction that must be overcome by the particle in settling. [*Modern Municipal Water Softening Practices, 1995*]

3.9 Effective porosity

Porosity is one of the most important physical input parameters in hydrologic or contaminant transport studies. Soils contain particles of different types and sizes. Space between particles, called pore space, determines the amount of water that a given volume of soil can hold. Porosity is the measure of how much water a soil can contain, or in other words, the pore space ratio to the whole volume. The effective porosity is the volume of pore space through which fluid flow can effectively take place divided by the total volume of the sediment or rock. The effective porosity is commonly used because some of the pores within a porous media may be isolated or "dead-end" space which will not contribute to the ability of the medium to transmit water or other fluids. The relationship between effective porosity and total porosity depends on the sizes and shapes of the grains within the porous media, and on the packing arrangement or fabric of the sediment. The more tightly particles are packed; the tendency for the material to allow water to flow through it is reduced.[*Kraus, Mineralogy; an introduction to the study of minerals and crystals, 1959*]

3.10 BOD

Characteristics of wastewater in general can be broadly divided into four categories:

1. Physical
2. Inorganic chemicals
3. Organic chemicals
4. Toxicity

The physical characteristics such as quantities of dissolved solids and suspended solid, temperature, color and quantities of inorganic chemicals such as iron and ammonia present are all readily measured by various standard techniques. However, the measurement of organic pollution is less straightforward and it is usually based on the oxygen demand of the sample.

An important effect of leachates or wastewater entering a river can be the removal of oxygen from that river by bacteria, as they break down the organic compounds they have. In severe organic pollution the river may be completely denuded of oxygen with drastic effects on aquatic life. Thus the measurement of oxygen demand of a leachate or wastewater can give an estimate of the organic pollution potential.

Techniques for measuring the oxygen demand of wastewaters can be divided into three categories:

1. Biochemical
2. Chemical
3. Instrumental

Biochemical techniques use bacteria to oxidize the organic material and the loss of oxygen due to bacterial activity can be measured as in the biochemical oxygen demand test, BOD.

The BOD is often adopted as the standard test for measuring oxygen demand. It is expressed as the milligrams of oxygen required by the microorganisms due to oxidation of organic matter in a liter of water.

In the standard test, a sample of the leachate or a dilution of it is incubated at 20°C for five days (BOD5). A blank sample shows how much the dissolved oxygen in the diluting water decreases with time.

The dilution waster is seeded with bacteria, typically by adding a few mililiters of sewage works effluent, and some inorganic nutrients.

Precaution must be taken to ensure that the bacterial seed is appropriate for the sample, otherwise the bacteria must be acclimatized to the sample.

The oxidation of ammonia to nitrite and nitrate by bacteria may occur during the test. If the oxygen used by this process is not to be included in the BOD test, then a small quantity of allyl thiourea (ATU) can be added and this will inhibit the nitrifying bacteria.

Although the BOD test is often adopted as the standard test for measuring oxygen demand it has several major disadvantages. These include an accuracy of less than plus/minus 10%, a five day wait for completion of the test, and the fact that the results can be seriously affected by chemicals that inhibit bacterial activity.

3.11 COD

For COD test, chemical agents is used to oxidize the organic material, and the difference between the original concentration of oxidizing agents and that which remains after a given contact time with the sample is a measure of the oxygen demand of the sample.

The most common chemical technique is the chemical oxygen demand, COD. The COD of a natural water or wastewater is measured by adding the sample to a mixture of concentrated sulphuric acid and potassium dichromate, $K_2Cr_2O_7$, together with silver sulphate. Mercuric sulphate is also added to combine with chlorides which otherwise would precipitate the silver catalyst as silver chloride. The mixture is boiled for two hours, much more convenient than the five days of the BOD test.

The COD value is normally higher than the BOD value because more organic matter can be oxidized in these chemicals than are biodegradable in the BOD test. A low BOD5/COD ratio (e.g. 0.1) for a leachate may indicate the presence either of organic matter that are hard to biodegrade or of toxic material inhibiting the BOD results. Instrumental techniques use thermal oxidation of the organic material with subsequent measurement of the gases produced.

3.12 TOC

The total organic carbon, TOC, is an instrumental method in which a small quantity of the liquid sample or a dilution of it is injected into a stream of air into the instrument. The water is vaporized and the organic matter oxidized to carbon dioxide, CO2. The concentration of carbon dioxide in the gas stream is measured by an infra-red device.

Alternatively, the carbon dioxide may be reduced in a catalytic column to methane, CH4. The methane concentration can then be measured. This technique is more complex but may be more accurate at low concentrations of organic matter.

The BOD, COD and TOC may all give different values for some sample and an understanding of the relevance of these measurements can give an insight into the nature of the leachate sample.[Sawyer, Mc Carty and Parkin, *Chemistry for Environmental Engineering, 2003*]

3.13 General theory for COD

In environmental chemistry, the chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. It is expressed in mg/L, which indicates the mass of oxygen consumed per liter of solution.

COD is based on the fact that nearly all organic compounds can be fully oxidized to carbon dioxide with a strong oxidizing agent under acidic conditions. The amount of oxygen required to oxidize an organic compound to carbon dioxide, ammonia, and water is given by:

$$C_nH_aO_bN_c + \left(n + \frac{a}{4} - \frac{b}{2} - \frac{3}{4}c\right) O_2 \rightarrow nCO_2 + \left(\frac{a}{2} - \frac{3}{2}c\right) H_2O + cNH_3$$

In contrast to biochemical oxygen demand (BOD) — another common measure of water-borne organic substances — the process of measuring COD causes the conversion of all organic matter into carbon dioxide. For this reason, one limitation of COD is that it cannot differentiate between levels of biologically active organic substances and those that are biologically inactive. One major advantage of COD, however, is that it can be measured in a fraction of the time required by BOD: while BOD takes 5-7 days to determine, COD requires just 3 hours.

For many years, the strong oxidizing agent potassium permanganate (KMn04) was used for measuring chemical oxygen demand. Measurements were called oxygen consumed from permanganate, rather than the oxygen demand of organic substances. Postassium permanaganate's effectiveness at oxidizing organic compounds varied widely, and in many cases BOD measurements were often much greater than results from COD measurements. This indicated that potassium permanganate was not able to effectively oxidize all organic compounds in water, rendering it a relatively poor oxidizing agent for determining COD.

Since then, other oxidizing agents such as ceric sulfate, potassium iodate, and potassium dichromate have been used to determine COD. Of these, potassium dichromate (K2Cr2O7) has been shown to be the most effective: it is relatively cheap, easy to purify, and is able to nearly completely oxidize almost all organic compounds. Potassium dichromate is a strong oxidizing agent under acidic conditions. (Acidity is usually achieved by the addition of sulfuric acid.)

Most commonly, a 0.25 N solution of potassium dichromate is used for COD determination, although for samples with COD below 50 mg/L, a lower concentration of potassium dichromate is preferred.

In the process of oxidizing the organic substances found in the water sample, potassium dichromate is reduced (since in all redox reactions, one reagent is oxidized and the other is reduced), forming Cr^{3+}. The amount of Cr^{3+} is determined after oxidization is complete, and is used as an indirect measure of the organic contents of the water sample.

Because COD measures the oxygen demand of organic compounds in a sample of water, it is important that no outside organic material be accidentally added to the sample to be measured. To control for this, a so-called blank sample is required in the determination of COD (and BOD, for that matter). A blank sample is created by adding all reagents (e.g. acid and oxidizing agent) to a volume of distilled water. COD is measured for both the water and blank samples, and the two are compared. The oxygen demand in the blank sample is subtracted from the COD for the original sample to ensure a true measurement of organic matter.

Some samples of water contain high levels of oxidizable inorganic materials which may interfere with the determination of COD. Because of its high concentration in most wastewater, chloride is often the most serious source of interference. Prior to the addition of other reagents, mercuric sulfate can be added to the sample to eliminate chloride interference.

The following table lists a number of other inorganic substances that may cause interference. The table also lists chemicals that may be used to eliminate such interference, and the compounds formed when the inorganic molecule is eliminated.

Inorganic molecule	Eliminated by	Elmination forms
Chloride	Mercuric Sulfate	Mercuric chloride complex
Nitrate	Sulfamic acid	N_2 gas
Ferrous iron	Sulfamic acid	-
Sulfides	Sulfamic acid	-

3.14 Fecal Coliform and its effect

Fecal Coliform bacteria indicate the presence of sewage contamination of a waterway and the possible presence of other pathogenic organisms. Bacteria are single-celled organisms that can only be seen with the aid of a very powerful microscope. Bacteria can be found everywhere- in air, water, and soil, even in and on your own body. They can benefit us by recycling wastes, helping nitrogen-fixing plants to grow, and by making certain types of food. They may harm us by causing diseases and food spoilage. Of environmental concern are the many types of coliform bacteria

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Eschericia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. Bacteria reproduce rapidly if conditions are right for growth. Most bacteria grow best in dark, warm, moist environments with food. Some bacteria form colonies as they multiply which may grow large enough to be seen. By growing and counting colonies of fecal coliform bacteria from a sample of stream water, we can determine approximately how many bacteria were originally present.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. Fecal coliform bacteria can enter rivers through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated human sewage. Individual home septic tanks can become overloaded during the rainy season and allow untreated human wastes to flow into drainage ditches and nearby waters. Agricultural practices such as allowing animal wastes to wash into nearby streams during the rainy season, spreading manure and fertilizer on fields during rainy periods, and allowing livestock watering in streams can all contribute fecal coliform contamination.

At the time this occurs, the source water may be contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. Some waterborne pathogenic diseases include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively. While these bacteria do not directly cause disease, high quantities of fecal coliform bacteria suggest the presence of disease causing agents. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. During high rainfall periods, the sewer can become overloaded and over flow, bypassing treatment. As it discharges to a nearby stream or river, untreated sewage enters the river system. Runoff from roads, parking lots, and yards can carry animal wastes to streams through storm sewers.

Fecal coliform like other bacteria can usually be killed by boiling water or by treating with chlorine. Washing thoroughly with soap after contact with contaminated water can also help prevent infections. Gloves should always be worn when testing for fecal coliform.

Fecal-coliform testing is one of the nine tests of water quality that form the overall water-quality rating in a process used by the EPA (Environment Protection Agency). This test requires a very careful set of sterile procedures, as well as expensive equipment and a five-day test. Less expensive screening techniques are available for use by the trained student.

Untreated fecal material, such as contains fecal coliform, adds excess organic material to the water. The decay of this material depletes the water of oxygen. This lowered oxygen may kill fish and other aquatic life. Reduction of fecal coliform in wastewater may require use of chlorine and other disinfectant chemicals. Such materials may kill the fecal coliform and disease bacteria. They also kill bacteria essential to the proper balance of the aquatic environment, endangering the survival of species dependent on those bacteria. So, higher levels of fecal coliform require higher levels of chlorine, threatening those aquatic organisms.

The Coli Chrome' 2 redigel medium is a new and patented formulation for water testing. It contains a sugar linked to a dye which, when acted on by the enzyme Beta-galactosidase, turns the colony a red color. Similarly, there is a second sugar linked to a different dye which, when acted on by the enzyme Beta-glucuronidase, turns an E. coli colony a light blue or blue-green color. Because E. coli produces both Beta-galactosidase and Beta-glucuronidase, the colony grows with a purple color (red + blue). The combination of these two dyes makes possible the unique ability to use one test to differentiate and quantify coliforms and E. coli. Because E. coli is a member of the coliform group, add the number of purple colonies to the number of red colonies when counting coliforms.

The method used in this class (Environmental Science) employs the Coliscan gel method. Colonies, which have the blue or blue-green color, are not exhibiting any Beta-galactosidase activity (which is evidenced by the red color). Because of this, they are not considered to be either coliforms or E. coli and therefore should be ignored when counting coliform or E. coli colonies. Colonies that are white are exhibiting neither color-causing enzyme, and should also be ignored.

Colonies on the surface of the plate are exposed to the medium on only the underside of the colony. This causes these colonies to appear with much less of the indicator color. E. coli colonies may only have a slight purple tinge to them, and it may appear only in the center of the colony with the remainder of the colony being white. Coliforms on the surface may be light pink or white with just a bit of red in the center.

The new USEPA coliform rule requires major monitoring changes by the drinking water industry. The testing requirements for drinking water are markedly increased. Not only is the number of routine coliform tests increased, especially for the smaller utilities, but also a new regulation requires automatic repeat testing from all sites that show a total coliform positive.

The current USEPA recommendations for body-contact recreation is fewer than 200 colonies/100 mL; for fishing and boating, fewer than 1000 colonies/100 mL; and for domestic water supply, for treatment, fewer than 2000 colonies/100 mL. The drinking water standard is less than 1 colony/ 100ml. [*Water supply and Waste Disposal, 1989*]

CHAPTER 4
METHODOLOGY/ PROJECT WORK

4.1 Methodology of study

Filtration process is usually used to remove harmful pollutants from domestic and industrial liquid waste to make it safe to return to the environment. In filtration, suspended solid particles in a fluid is removed by setting up a pressure difference that causes fluid to flow through small holes which block the passage of the large particles; these, in turn , build up as a porous cake.

The first objective of this experiment is to measure the filterability characteristics of a given suspension performance of a standard water quality test. Second is to determine the specific filter cake resistant α (m/kg) and the filter medium resistant R_m (1/m) for different arrangement of sand bed in order to determine the filterability index. The third objective is to test the samples for COD test.

Overall, the main objective of this experiment is to propose the best sand bed arrangement for water filtration based on the result of the experiment.

For the first experiment using paddy field water sample, the sand bed arrangements are as below:

- Exp 1: large particles to small particles, from top to bottom (1000μm, 700μm, 500μm)
- Exp 2: small particles to large particles, from top to bottom (500μm, 700μm, 1000μm)
- Exp 3: Mixing of the sand

For the second experiment using water from UTP River, the sand bed arrangements are as below:

- Exp 1: large particles to small particles, from top to bottom (700µm, 500µm, 300µm)
- Exp 2: Mixing of the sand

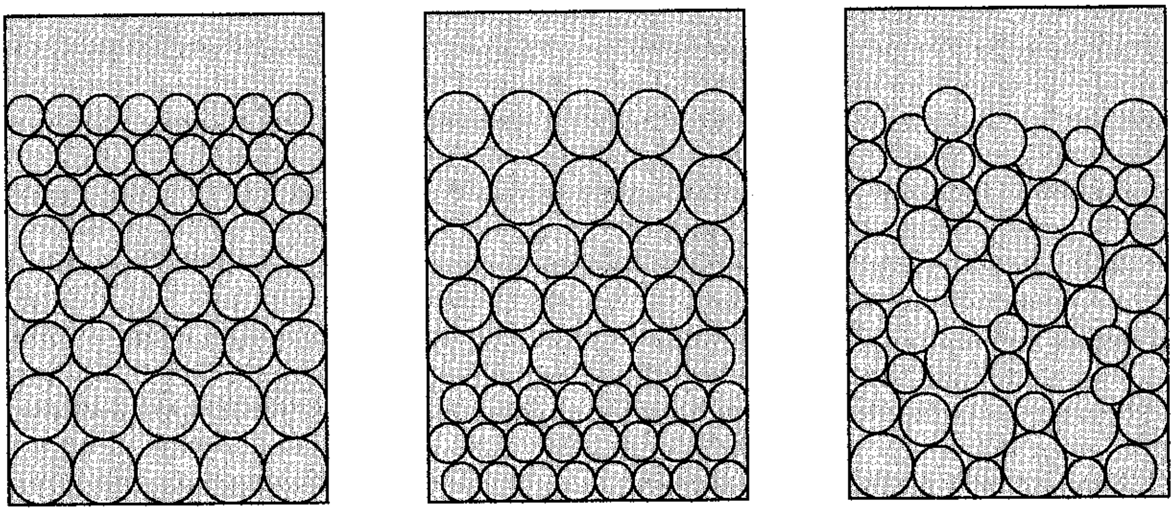

Figure 4.1: Different sand bed arrangement with various sand particles

4.2 Equipment/ Tool required

The tools/ equipment/ software required for the experiments are:

1. FIU connected with pc
2. Different size of sand particles (1000µm, 700µm and 500µm)
3. Paddy field sample water and UTP river sample water
4. Oven
5. Spectrometer for COD test
6. Thermoreactor
7. COD vial (High Range and Low Range)

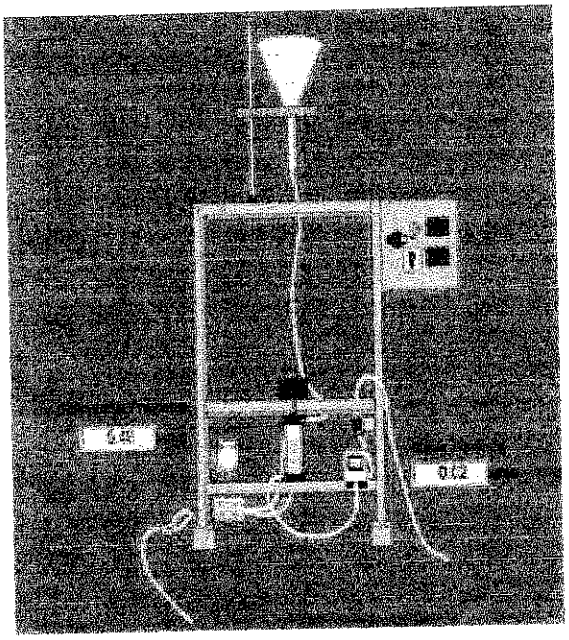

Figure 4.2: Filterability Index Unit Diagram

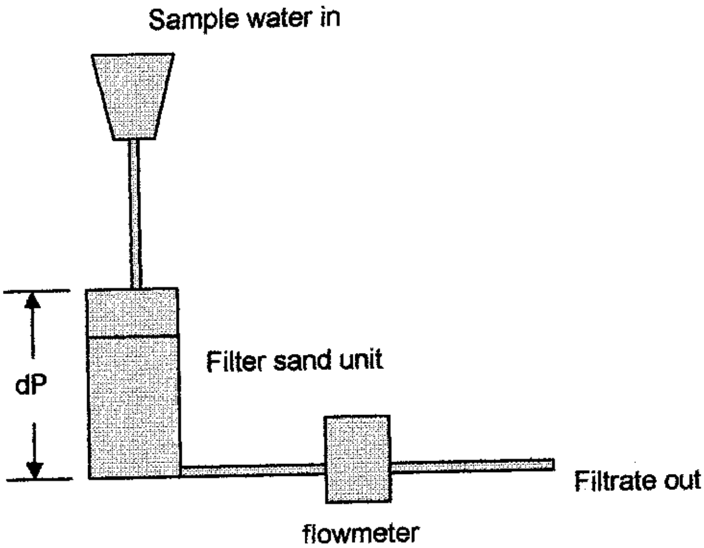

Figure 4.3: Simplified diagram for Filterability Index Unit

4.3 Experiment Procedures

1. Dismantle the filtration column in order to fill it up with sand
2. Ensure that the filter mesh is clean and not damaged
3. Fill up the filtration column with sand up to 8 cm, about ¾ full

   First Experiment

   - Exp 1: large particles to small particles, from top to bottom (1000μm, 700μm, 500μm)
   - Exp 2: small particles to large particles from top to bottom, (500μm, 700μm, 1000μm)
   - Exp 3: Mixing of the sand

   Second Experiment

   - Exp 1: large particles to small particles, from top to bottom (700μm, 500μm, 300μm)
   - Exp 2: Mixing of the sand

4. Assemble the column and tighten it firmly, but make sure the mesh is not folded anywhere as this will result in leaks
5. Raise the funnel to the marked height (1200 mm)
6. Fill up the filterability index unit with clean water through the funnel at the top of the apparatus with valves closed. Make sure that all the air bubble trapped along the inlet hose that connect to the funnel has been released
7. Fully open the needle valve (outlet valve) in order to fill up the equipment system with clean water.
8. Then, open the ball valves that attached to the OP transmitter in order to release the air trapped inside the equipment system
9. Closed all the valves after ensuring all the air trapped are released and make sure that the water level had been set to the lowest level in the inlet hose
10. Then, fill up the filterability index unit apparatus with the sample water through the inlet funnel

11. Put the outlet hose of the apparatus into a beaker to collect the filtered water.
12. The filterability index unit is now ready for experiment
13. Switch on the control panel. Check that all the indicator display is on
14. Turn on the computer, and let the OAS software load up
15. Open the needle valve (outlet valve) to 0.5 L/min and click on the start button in the DAS software when the flow meter reading is stable. The software will record measurements automatically
16. Close the needle valve (outlet valve) after all the sample finish
17. Take 100 ml of the collected water (filtrate) and put it into oven to dry the concentration in order to determine the slurry concentration, C_s
18. Take 2 ml of collected water and do the COD test
19. From the data obtained, plot the graph of (t/v) vs v
20. After finish the experiments, empty the filtration column, use plenty of clean water to flush the equipment and leave the place spotless
21. Repeat the experiment using different sample water and provide a comparison discussion

CHAPTER 5
RESULT AND DISCUSSION

5.1 Experimental Result

FIRST EXPERIMENT: PADDY FIELD WATER SAMPLE

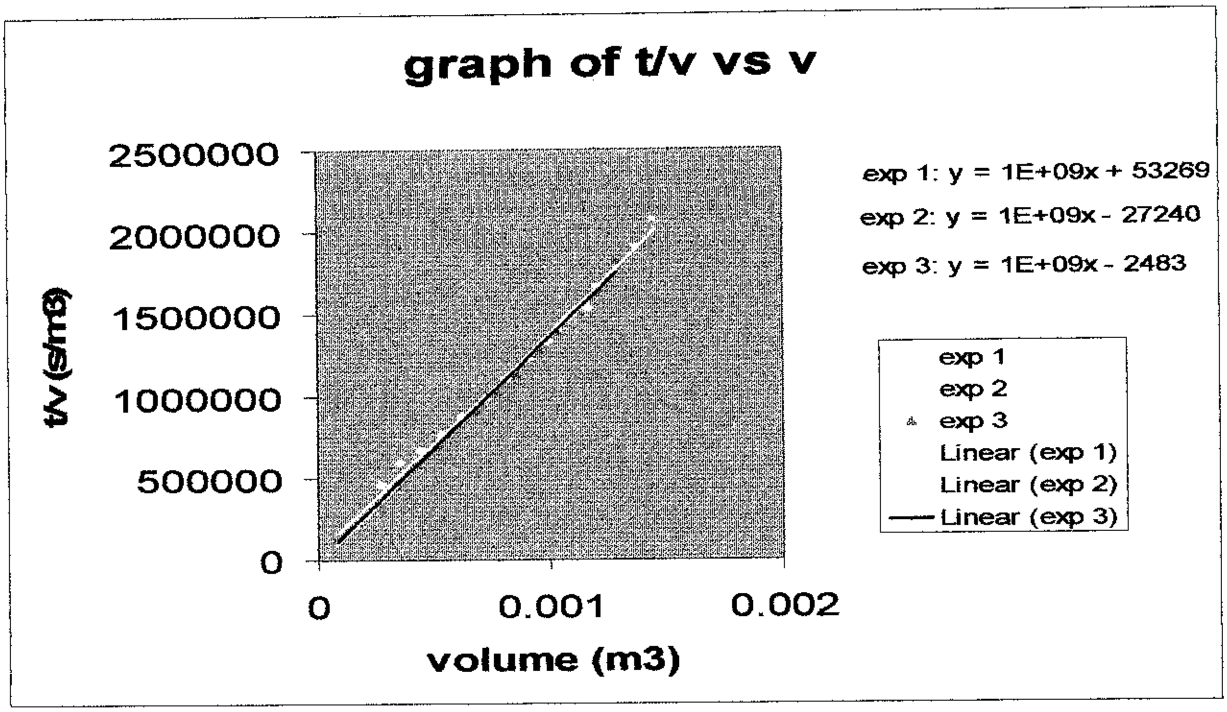

Figure 5.1: Combination of graph t/v vs v for first experiment

Refer Appendix C for calculation (first experiment)

Exp 1: first sand bed arrangement

Large particles to small particles, from top to bottom (1000μm, 700μm, 500μm)

$R_m = 1.678 \times 10^8 \ m^{-1}$

$\alpha = 1.249 \times 10^{11}$ m/kg

Exp 2: second sand bed arrangement

Small particles to large particles from top to bottom, (500μm, 700μm, 1000μm)

$R_m = -9.077 \times 10^7 \, m^{-1}$

$\alpha \; = 1.322 \times 10^{11}$ m/kg

Exp 3: third sand bed arrangement

Mixing sand

$R_m = -1.353 \times 10^7 \, m^{-1}$

$\alpha \; = 2.162 \times 10^{11}$ m/kg

COD result

Below is the COD test for the filtrate of the samples and the samples before filtration to compare and find the result for the best sand bed arrangement.

Table 5.1: COD result for first experiment

Experiment	COD before filtration	COD after filtration
1	52 mg/L	43 mg/L
2	52 mg/L	46 mg/L
3	52 mg/L	46 mg/L

SECOND EXPERIMENT: UTP RIVER WATER SAMPLE

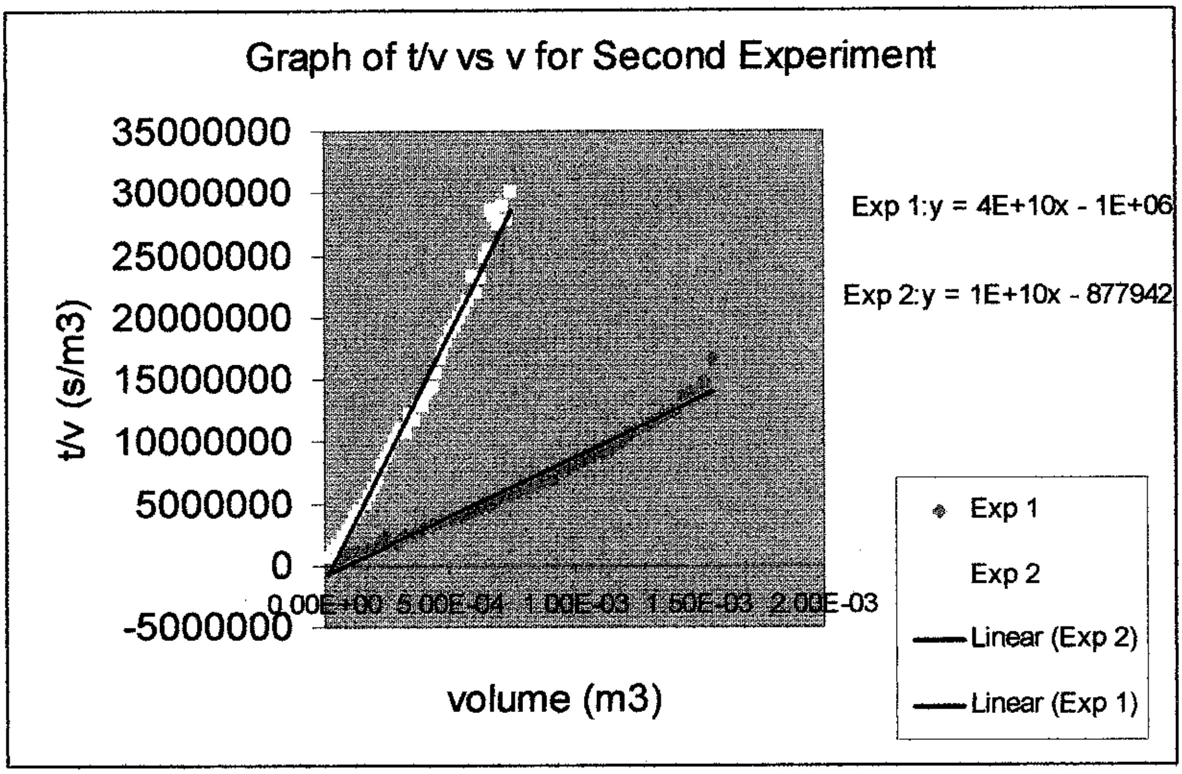

Figure 5.2: Combination of graph t/v vs v for second experiment

Refer Apendix C for calculation (second experiment)

Exp 1: first sand bed arrangement

Large particles to small particles, from top to bottom (700μm, 500μm, 300μm)

$R_m = -7.98 \times 10^9 \text{ m}^{-1}$

$\alpha = 3.60 \times 10^{12}$ m/kg

Exp 2: second sand bed arrangement (mixing sand)

$R_m = -9.08 \times 10^9 \text{ m}^{-1}$

$\alpha = 1.44 \times 10^{13}$ m/kg

COD result

Table 5.2: COD result for second experiment

Experiment	COD before filtration	COD after filtration
1	14 mg/L	6 mg/L
2	14 mg/L	11 mg/L

5.2 Discussion

In filtration, suspended solid particles in a fluid of liquid or gas are physically removed by using a porous medium that retains the particles as a separate phase or cake and passes the clear filtrate. The suspended solid particles can be very fine, very rigid or plastic particles, spherical or very irregular in shape, aggregates of particles or individual particles. The valuable product may be the clear filtrate from the filtration or the solid cake. In some cases, complete removal of the solid particles is required, in other cases only partial removal. In this experiment, the valuable product is the clarified water (clear filtrate) as the experiment is carried out to improve the clarity of clear filtrate.

The feed or slurry solution may carry a heavy load of solid particles or a very small amount. Student used paddy field water and UTP river sample as the slurry solution. While the filter unit for the filtration is sand bed arrangement which is arranged in different way; from larger particles to small particles, small particles to larger particles and mixing sand particles. The sand is first separated to its particle sizes using Sieve Shaker. The filter unit can be readily demounted to change the sand. This unit and all tubing connections are transparent so that the operation can be observed and air bubbles avoided. Air bubble trapped must be released before doing the experiment to make it a constant pressure. The equipment used for the filtration is Filterability Index Unit (FIU). Figure 5.3 shows the FIU equipment. All the data for the flowrate, pressure and time taken can be obtained from the OAS software provided.

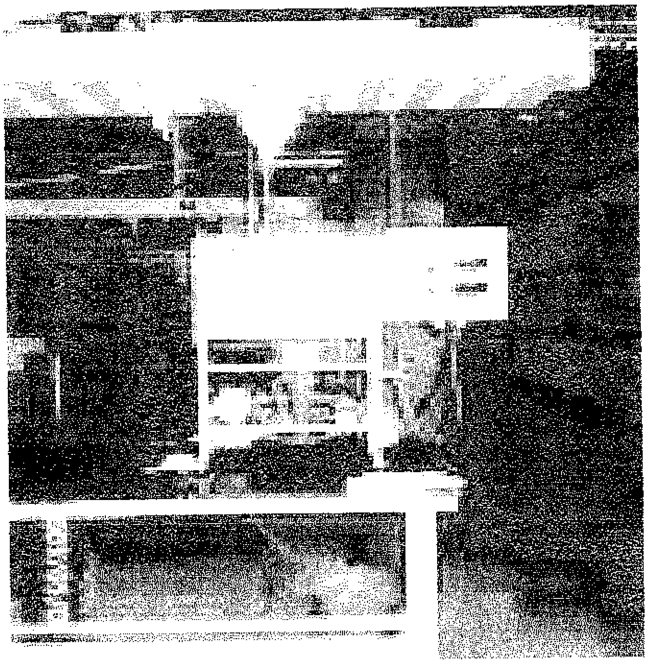

Figure 5.3: Filterability Index Unit

The paddy field sample water and UTP river water sample contains the suspended particles. The passage of the particles is blocked by the small openings in the pores of the unit filter; sand. The solid particles build up in the form of a porous filter cake as the filtration proceeds. This cake also acts as a filter for the suspended particles. As the filter cake builds up, resistance to flow also increase. Thus, the volumetric flow rate would decrease. [*Separation Process Principle, 1998*]

The smaller the pores at the top of the sand filter unit will increase the forming of filter cake thus will decrease the flow rate of filtration and can clog the flow of the sample water. From the experiment result, comparing those sand bed arrangements, the first sand bed arrangement gives smaller specific filter cake resistance,α. Meaning that, sand arrangement from larger particles to smaller particles (from top to bottom) can reduce the cake forming. But then, at the same time it has better ability to block the particles of suspended solids and gives better quality of filtration.

The behavior of a filter can be expressed by the equation

$$\frac{dt}{dV} = \frac{1}{Q} = \frac{\alpha.\mu.C}{A^2.\Delta P}.V + \frac{\mu.R_m}{A.\Delta P}$$

And if we plotted graph of t/v vs v, the equation became

$$\frac{t}{v} = \left[\frac{\mu\alpha C_s}{2A^2 P}\right]V + \frac{\mu R_m}{AP}$$

The equation shows that the filtration process depends on the specific filter resistance of filter cake (α), filter medium resistance (R_m), slurry concentration C_s, viscosity of the solution (μ) and other factors. This equation is used to predict the variation in flow or pressure with time at the filter from knowledge of α and R_m. [*Separation Process Principle, 1998*]

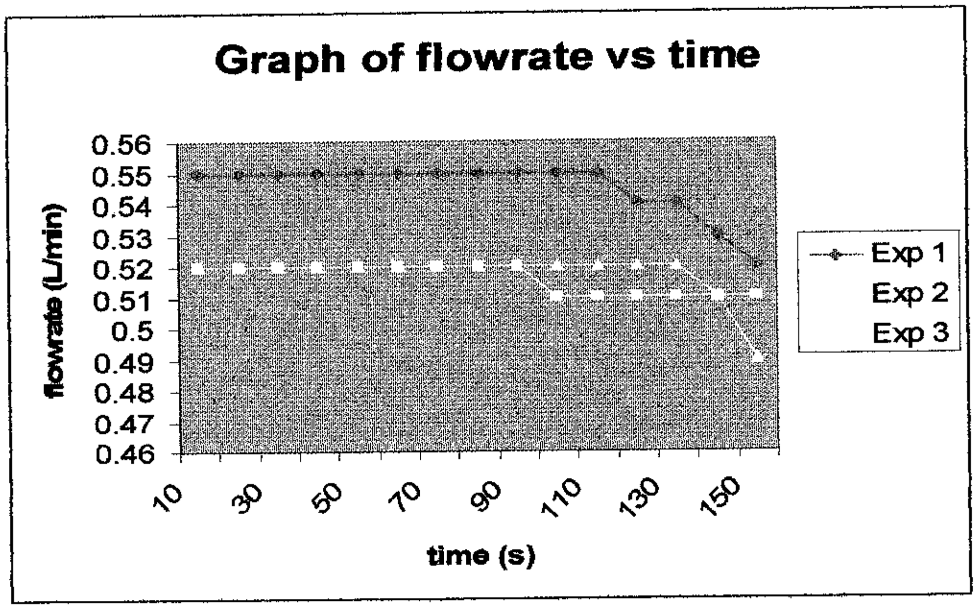

Figure 5.4: Combination of graph flowrate vs time for first experiment

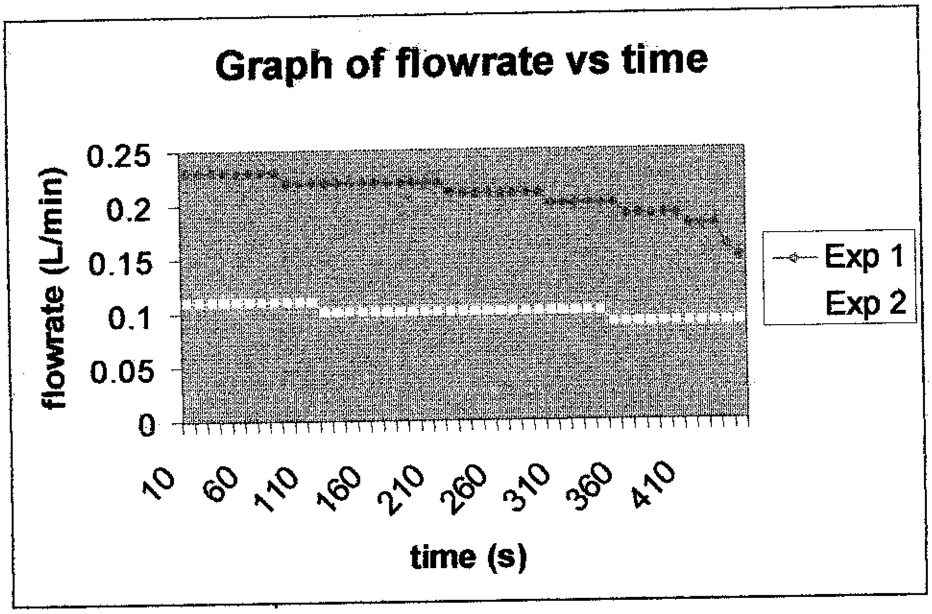

Figure 5.5: Combination of graph flowrate vs time for second experiment

Graph of flow rate (q) versus time (t) is plotted in the experiment (refer figure 5.4 and 5.5). As the observation, the flow rate is fluctuated at the same value for an interval before it drops. The constant value of the flow rate happens because the other variables except resistances are set constant throughout the experiment.

Figure 5.4 and 5.5 show that for both experiments; first experiment and second experiment, filtration for the first sand bed arrangement gives higher value of flowrate. This is because of the porosity of the sand bed. As for others sand bed, the pores between the sand particles is small, thus gives resistance to the sample water to flow through it and cause its low flowrate. After certain time, the flowrate starts to decrease. The decrement of flow rate is caused by the porous cake resistance that is forming over time. Thus, this resistance of flow is determined as specific filter cake resistance.

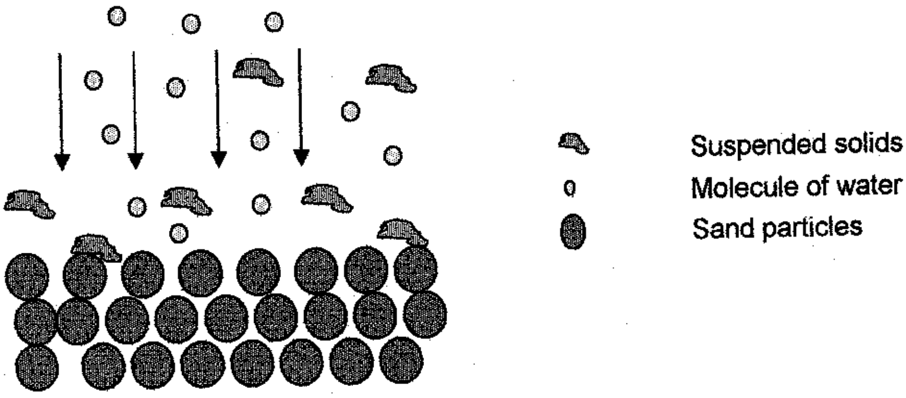

Figure 5.6 water flows together with suspended solids

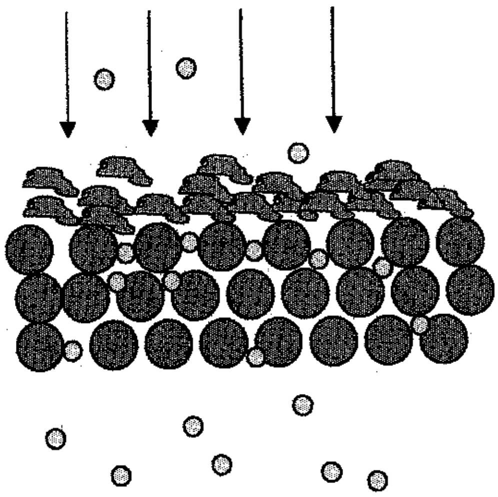

Figure 5.7: Formation of cake build-up

Figure 5.6 and 5.7 shows the formation of cake build up. The water flows together with suspended solids. The suspended solid that clog on top of the filter sand tend to build up during the filtration. The resistance of flow due to this cake build up is called specific filter cake resistance, α. From the result, the specific filter cake resistance, for the first sand bed arrangement which is from larger particles to smaller particles (from top to bottom) gives the smallest value. Means the resistance of flowrate due to porous of cake formed is small. In this case, the quality of the filtration with small α is better compared to other sand bed arrangement. Larger α will give higher tendency for the sand bed to clog in a short time period of filtration.

The chemical Oxygen Demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality. It is expressed in mg/L, which indicates the mass of oxygen consumed per liter of solution. In terms of COD test, the first sand bed arrangement also gives the best result because it can decrease the COD of the sample water to the lowest compared to other sand bed arrangement. Thus we know, lower COD is good for the quality of water.

However, this research experiment can be further improved in order to get the better parameter of water quality measurement. For recommendation, the filtrate collected can be tested for feacal coliform, TOC, turbidity, pH and conductivity. Better equipment should be used and it is highly recommended that this experiment is done by more than one person. This is due to the time constraint between filtration experiment and quality water test such as COD. In order to get more accurate result, water quality test must be done immediately after the filtrate is obtained.

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APPENDICES

APPENDIX A: EXPERIMENTAL DATA

APPENDIX B: EXPERIMENTAL GRAPH

APPENDIX C: EXPERIMENTAL CALCULATION

APPENDIX A

EXPERIMENTAL DATA

Data for First Experiment

Table 1.1: Data for time taken and volumetric flowrate for Exp 1

Time taken (s)	Flowrate (L/min)
10	0.55
20	0.55
30	0.55
40	0.55
50	0.55
60	0.55
70	0.55
80	0.55
90	0.55
100	0.55
110	0.55
120	0.54
130	0.54
140	0.53
150	0.52

Table 1.2: Data for time taken and the volumetric flowrate for Exp 2

Time taken (s)	Flowrate (L/min)
10	0.52
20	0.52
30	0.52
40	0.52
50	0.52
60	0.52
70	0.52
80	0.52
90	0.52
100	0.51
110	0.51
120	0.51
130	0.51
140	0.51
150	0.51

Table 1.3: Data for time taken and volumetric flowrate for Exp 3

Time taken (s)	Flowrate (L/min)
10	0.52
20	0.52
30	0.52
40	0.52
50	0.52
60	0.52
70	0.52
80	0.52
90	0.52
100	0.52
110	0.52
120	0.52
130	0.52
140	0.51
150	0.49

Table 1.4: Data for time and volume of filtrate collected for Exp 1

t(s)	V (m^3)	t/v (s/m^3)	ΣV (m^3)
10	0.0000863	115870	0.0000863
20	0.0000869	230150	0.0001732
30	0.000086	348840	0.0002592
40	8.7E-06	459770	0.0002679
50	0.0000848	589620	0.0003527
60	0.0000899	667410	0.0004426
70	0.000092	760870	0.0005346
80	9.2E-05	869570	0.0006266
90	0.000092	978260	0.0007186
100	0.0000903	1107420	0.0008089
110	0.00009	1222220	0.0008989
120	0.0000899	1334820	0.0009888
130	0.0000881	1475600	0.0010769
140	0.0000877	1536350	0.0011646

Table 1.5: Data for time and volume of filtrate collected for Exp 2

t(s)	V (m^3)	t/v (s/m^3)	ΣV (m^3)
10	0.000086	116280	0.000086
20	0.000086	232560	0.000172
30	0.000086	348840	0.000258
40	0.000086	465120	0.000344
50	0.000088	568180	0.000432
60	0.000086	697670	0.000518
70	0.000086	813950	0.000604
80	8.6E-05	930230	0.00069
90	0.000086	1046510	0.000776
100	0.000086	1162790	0.000862
110	8.6E-05	1279070	0.000948
120	0.000086	1395350	0.001034
130	0.000085	1524030	0.001119
140	8.4E-05	1666670	0.001203

Table 1.6: Data for time and volume of filtrate collected for Exp 3

t(s)	V (m^3)	t/v (s/m^3)	ΣV (m^3)
10	0.000082	121950	0.000082
20	0.000086	232560	0.000168
30	0.000086	348840	0.000254
40	0.000086	465120	0.00034
50	0.000086	581400	0.000426
60	0.000086	697670	0.000512
70	0.0000844	829380	0.0005964
80	8.8E-05	909090	0.0006844
90	0.000088	1022730	0.0007724
100	0.0000862	1136360	0.0008586
110	8.6E-05	1276100	0.0009446
120	0.000086	1395350	0.0010306
130	8.6E-05	1511630	0.0011166
140	8.6E-05	1627910	0.0012026

Data for second experiment

Table 2.1: Data for time taken and volumetric flowrate for Exp 1

Time taken (s)	Flowrate (L/min)
10	0.23
20	0.23
30	0.23
40	0.23
50	0.23
60	0.23
70	0.23
80	0.23
90	0.22
100	0.22
110	0.22
120	0.22
130	0.22
140	0.22
150	0.22
160	0.22
170	0.22
180	0.22
190	0.22
200	0.22
210	0.22
220	0.21
230	0.21
240	0.21
250	0.21
260	0.21
270	0.21
280	0.21
290	0.21
300	0.2
310	0.2
320	0.2
330	0.2
340	0.2
350	0.2
360	0.19
370	0.19
380	0.19

390	0.19
400	0.19
410	0.18
420	0.18
430	0.18
440	0.16
450	0.15

Table 2.2: Data for time taken and volumetric flowrate for Exp 2

Time taken (s)	Flowrate (L/min)
10	0.11
20	0.11
30	0.11
40	0.11
50	0.11
60	0.11
70	0.11
80	0.11
90	0.11
100	0.11
110	0.11
120	0.1
130	0.1
140	0.1
150	0.1
160	0.1
170	0.1
180	0.1
190	0.1
200	0.1
210	0.1
220	0.1
230	0.1
240	0.1
250	0.1
260	0.1
270	0.1
280	0.1

290	0.1
300	0.1
310	0.1
320	0.1
330	0.1
340	0.1
350	0.09
360	0.09
370	0.09
380	0.09
390	0.09
400	0.09
410	0.09
420	0.09
430	0.09
440	0.09
450	0.09
460	0.09
470	0.09
480	0.09
490	0.09
500	0.08
510	0.08
520	0.08
530	0.08
540	0.08
550	0.08
560	0.08
570	0.08
580	0.08
590	0.07
600	0.07

Table 2.3: Data for time taken and volume of filtrate collected for Exp 1

t(s)	v(m^3)	t/v (s/m^3)	ΣV (m^3)
10	3.28E-05	304878	3.28E-05
20	3.42E-05	584795.3	0.000067
30	0.000034	882352.9	0.000101
40	0.000034	1176471	0.000135
50	3.73E-05	1340483	0.000172
60	0.000038	1578947	0.00021
70	0.00003	2333333	0.00024
80	0.000046	1739130	0.000286
90	0.000038	2368421	0.000324
100	3.74E-05	2673797	0.000362
110	3.65E-05	3013699	0.000398
120	0.000036	3333333	0.000434
130	3.76E-05	3457447	0.000472
140	0.000038	3684211	0.00051
150	3.8E-05	3947368	0.000548
160	3.77E-05	4244032	0.000586
170	0.000036	4722222	0.000622
180	3.76E-05	4787234	0.000659
190	3.61E-05	5263158	0.000695
200	3.6E-05	5555556	0.000731
210	0.000036	5833333	0.000767
220	0.000036	6111111	0.000803
230	3.6E-05	6388889	0.000839
240	3.57E-05	6722689	0.000875
250	3.58E-05	6983240	0.000911
260	0.000034	7647059	0.000945
270	0.000034	7941176	0.000979
280	3.4E-05	8235294	0.001013
290	0.000034	8529412	0.001047
300	0.000034	8823529	0.001081
310	0.000034	9117647	0.001115
320	0.000034	9411765	0.001149
330	3.33E-05	9909910	0.001182
340	3.23E-05	10526316	0.001214
350	0.000032	10937500	0.001246
360	0.000032	11250000	0.001278
370	0.000032	11562500	0.00131
380	0.000032	11875000	0.001342
390	0.000032	12187500	0.001374
400	3.18E-05	12578616	0.001406
410	0.00003	13666667	0.001436

420	0.00003	14000000	0.001466
430	0.00003	14333333	0.001496
440	2.98E-05	14765101	0.001526
450	2.7E-05	16666667	0.001553

Table 2.4: Data for time taken and volume of filtrate collected for Exp 2

t(s)	v(m^3)	t/v(s/m^3)	Σv(m^3)
10	0.0000171	584795.3	0.0000171
20	0.000018	1111111	0.0000351
30	0.000018	1666667	0.0000531
40	0.000018	2222222	0.0000711
50	0.000018	2777778	0.0000891
60	0.000018	3333333	0.0001071
70	0.000018	3888889	0.0001251
80	0.000018	4444444	0.0001431
90	0.000018	5000000	0.0001611
100	0.0000179	5586592	0.000179
110	0.0000177	6214689	0.0001967
120	0.0000172	6976744	0.0002139
130	0.000016	8125000	0.0002299
140	0.000016	8750000	0.0002459
150	0.000016	9375000	0.0002619
160	0.000016	10000000	0.0002779
170	0.000016	10625000	0.0002939
180	0.0000163	11042945	0.0003102
190	0.0000178	10674157	0.000328
200	0.0000164	12195122	0.0003444
210	0.000018	11666667	0.0003624
220	0.0000172	12790698	0.0003796
230	0.000018	12777778	0.0003976
240	0.0000173	13872832	0.0004149
250	0.0000175	14285714	0.0004324
260	0.0000167	15568862	0.0004491
270	0.0000162	16666667	0.0004653
280	0.0000161	17391304	0.0004814
290	0.0000161	18012422	0.0004975
300	0.000016	18750000	0.0005135
310	0.000016	19375000	0.0005295
320	0.000016	20000000	0.0005455
330	0.000016	20625000	0.0005615

340	0.000016	21250000	0.0005775
350	0.000015	23333333	0.0005925
360	0.0000164	21951220	0.0006089
370	0.000016	23125000	0.0006249
380	0.0000154	24675325	0.0006403
390	0.0000153	25490196	0.0006556
400	0.000014	28571429	0.0006696
410	1.46E-05	28082192	0.0006842
420	0.0000153	27450980	0.0006995
430	0.0000149	28859060	0.0007144
440	1.59E-05	27672956	0.0007303
450	0.000015	30000000	0.0007453

APPENDIX B
EXPERIMENTAL GRAPH

Graph for first experiment

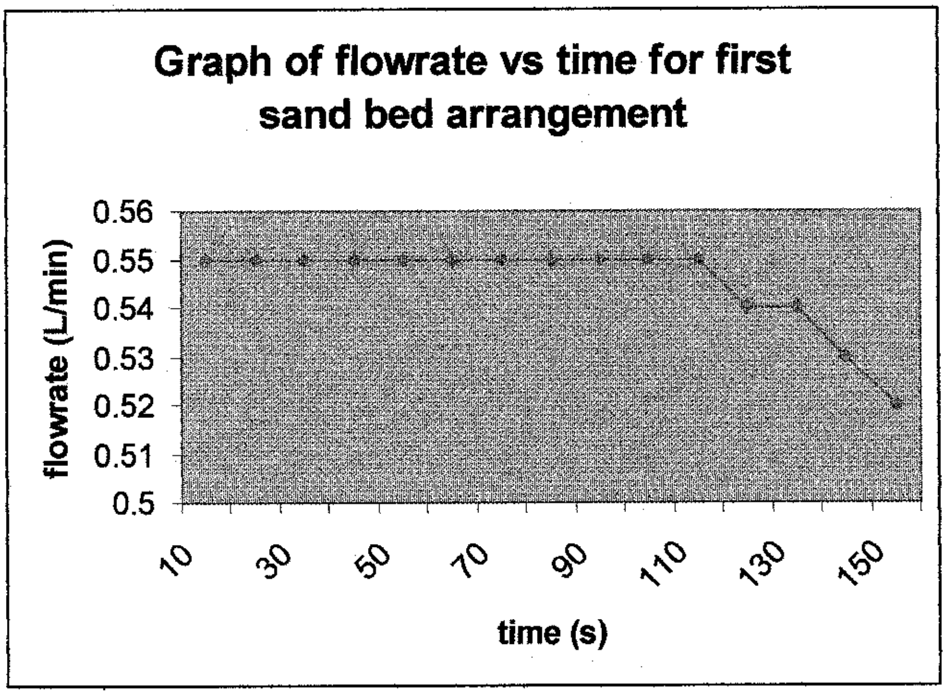

Figure 1.1: graph of flowrate vs time for Exp 1 (first sand bed arrangement)

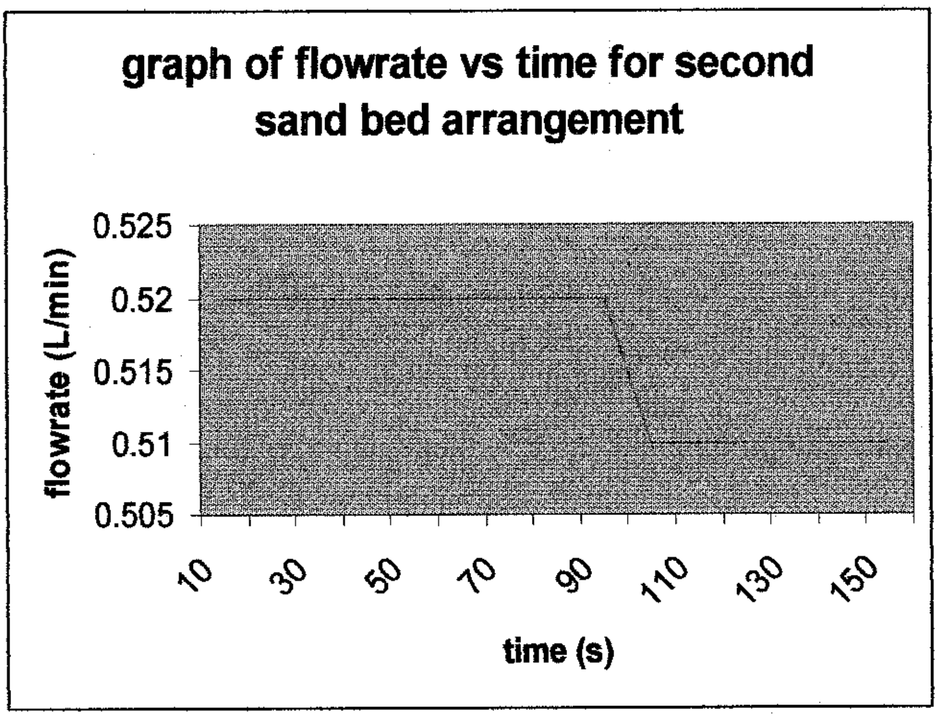

Figure 1.2: graph of flowrate vs time for Exp 2 (second sand bed arrangement)

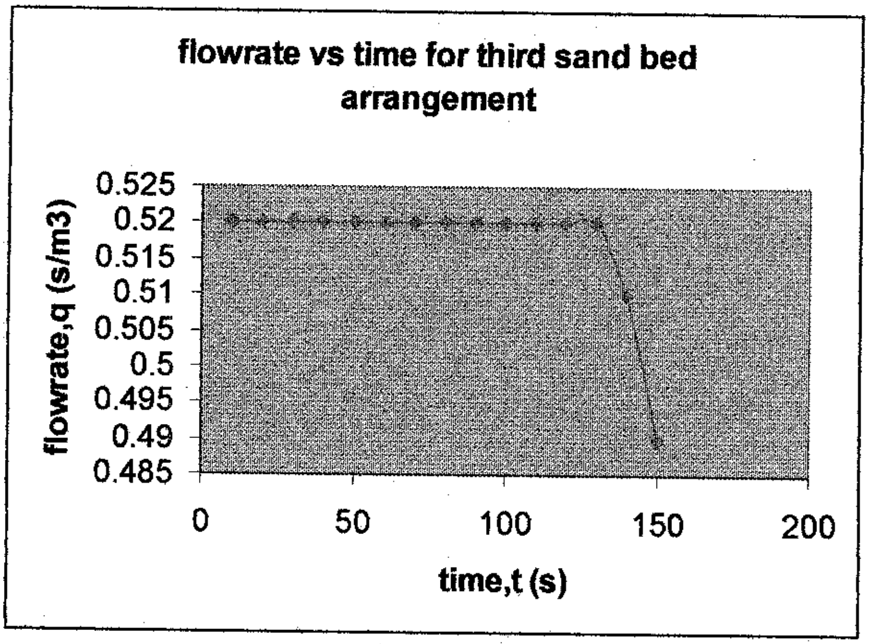

Figure 1.3: graph of flowrate vs time for Exp 3 (mixing sand)

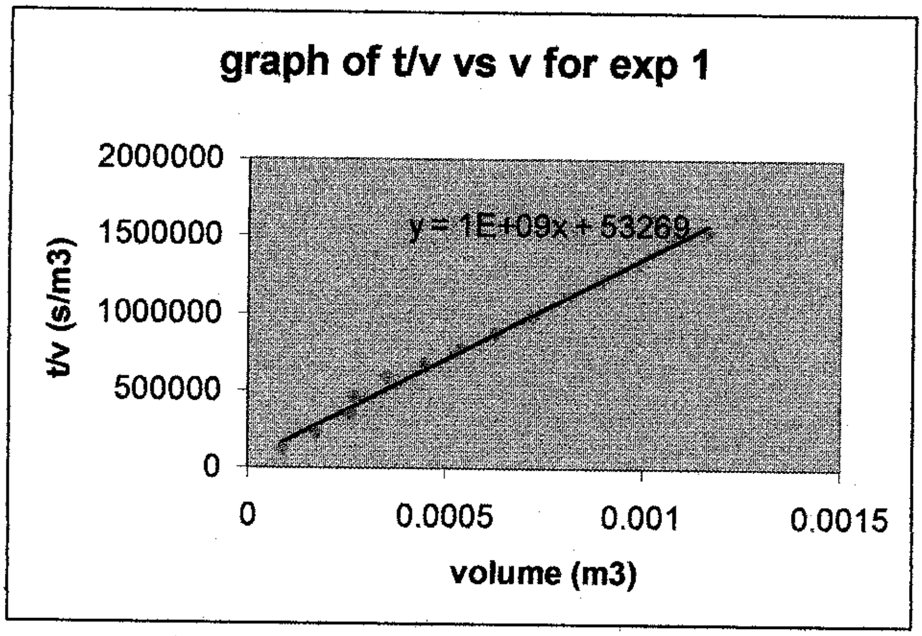

Figure 1.4: graph of t/v vs volume for Exp 1

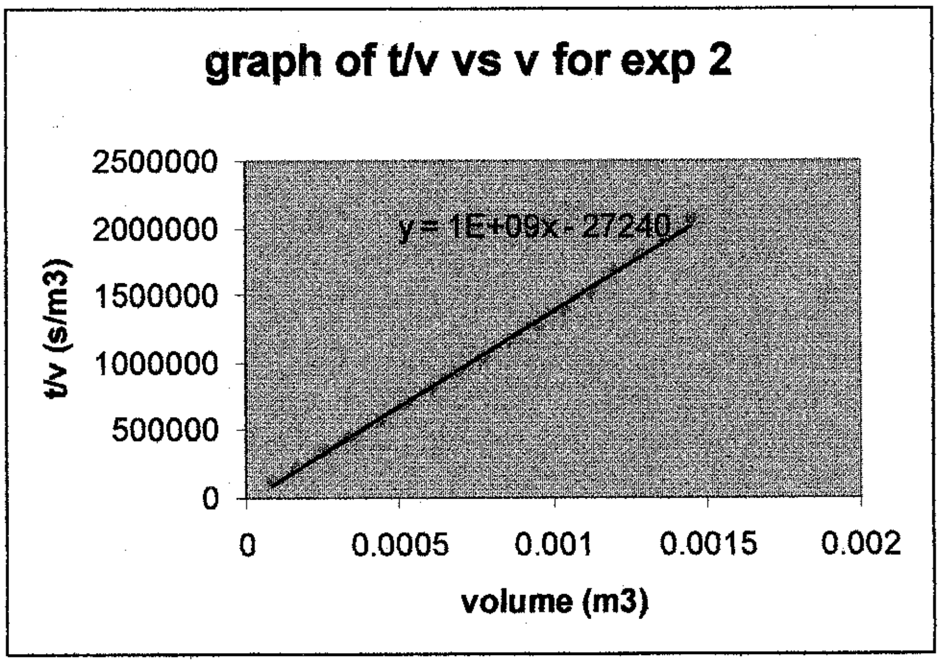

Figure 1.5: graph of t/v vs volume for Exp 2

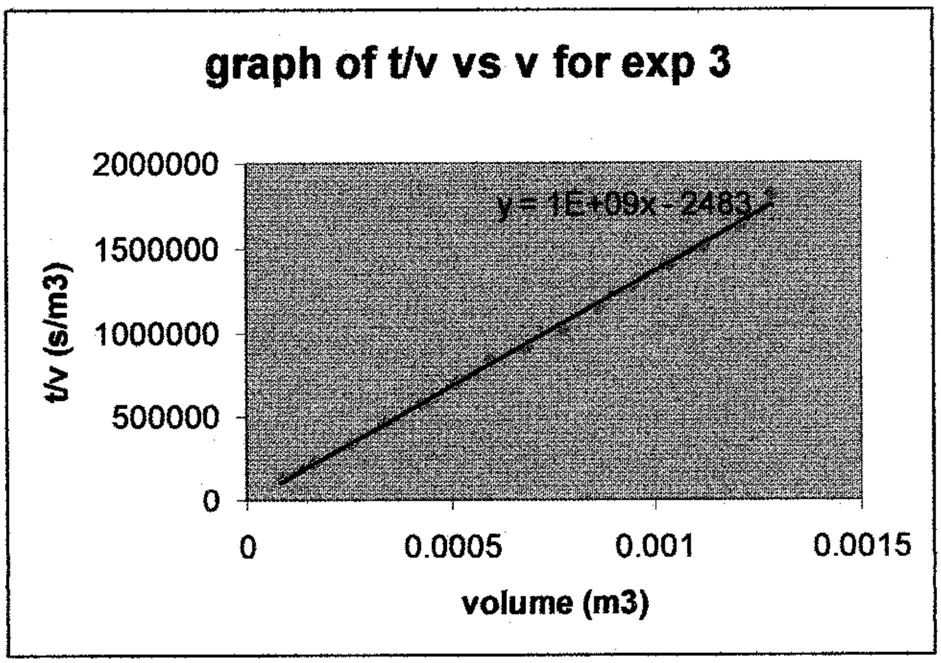

Figure 1.6: graph of t/v vs volume for Exp 3

Graph for second experiment

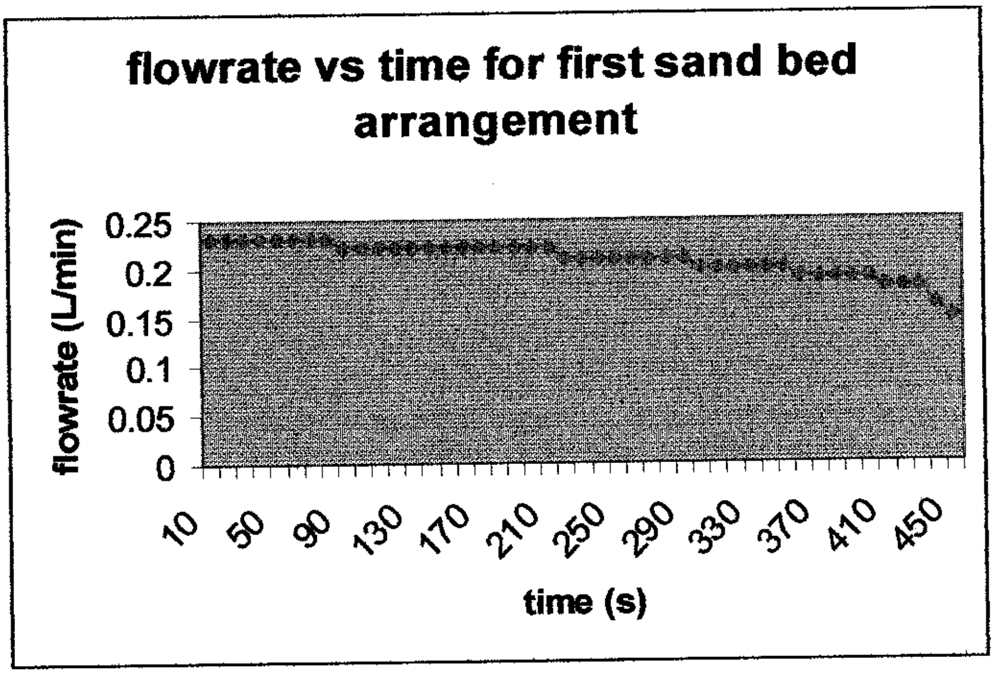

Figure 2.1: graph of flowrate vs time for Exp 1 (first sand bed arrangement)

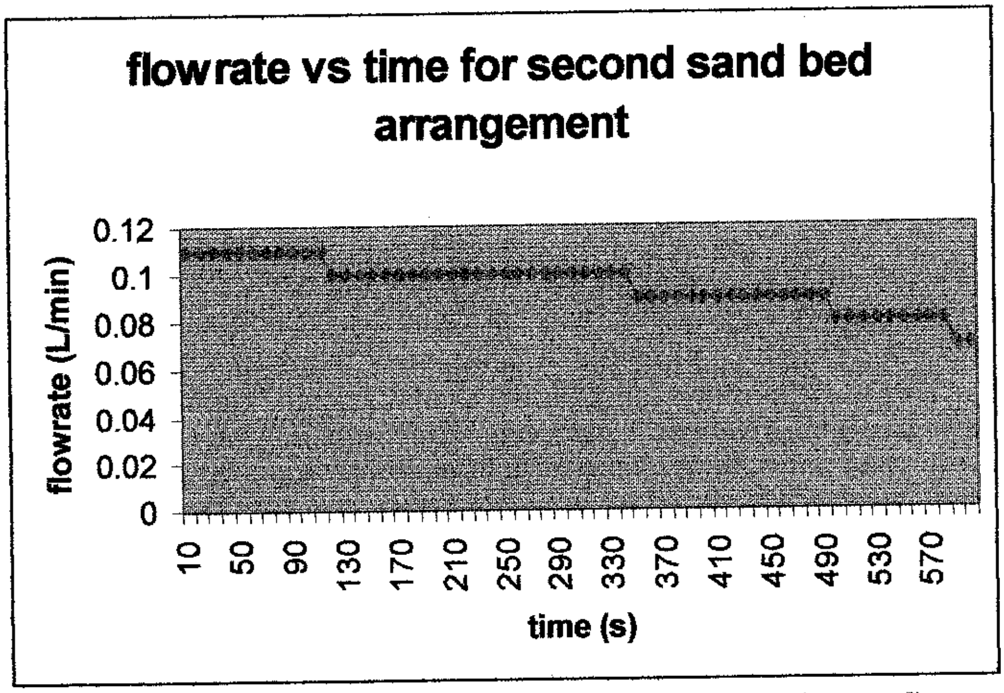

Figure 2.2: graph of flowrate vs time for Exp 2 (mixing sand)

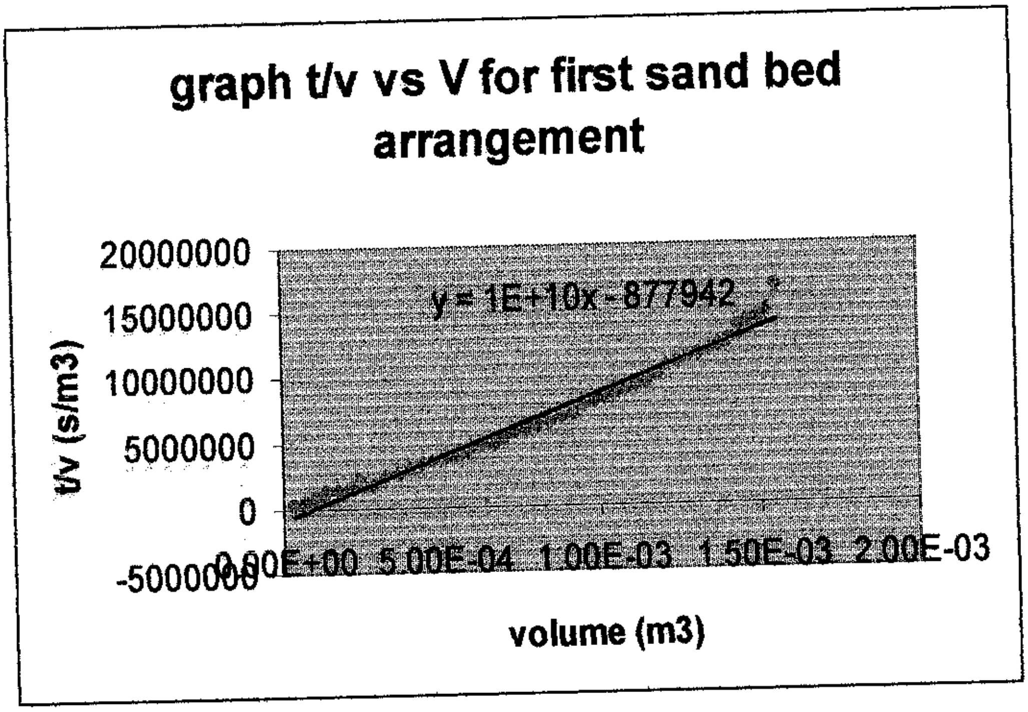

Figure 2.3: graph of t/v vs volume for Exp 1

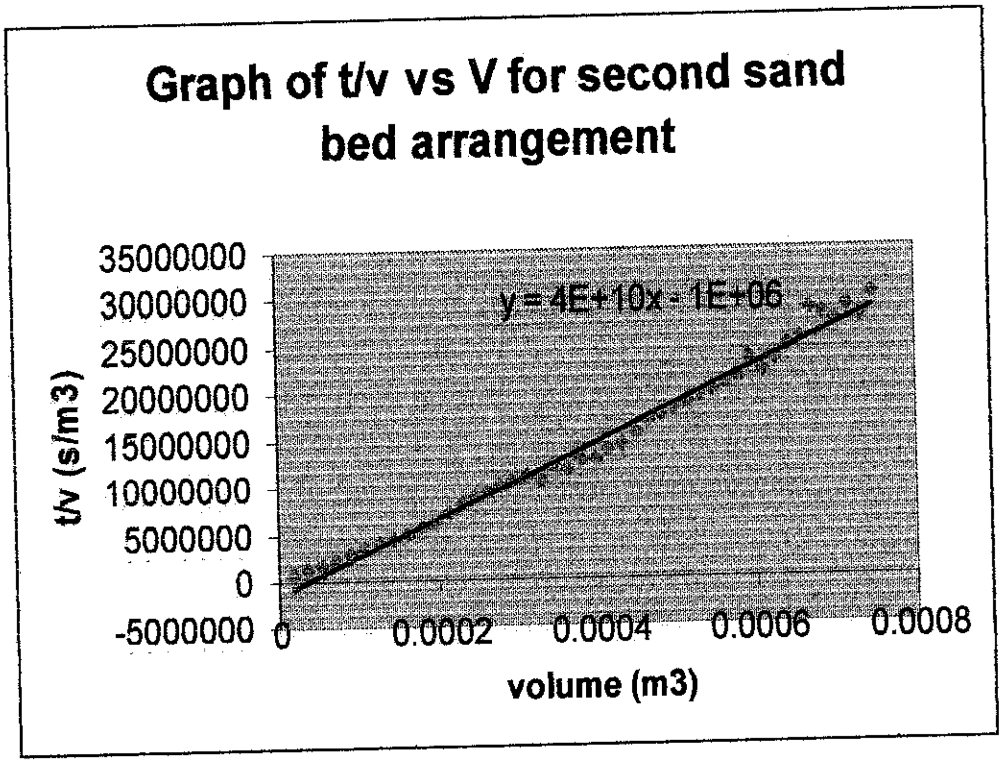

Figure 2.4: graph of t/v vs volume for Exp 2

APPENDIX C

EXPERIMENTAL CALCULATION

CALCULATION FOR FIRST EXPERIMENT

General equation for filtration (graph t/v vs V)

$$y = \frac{K_P}{2}x + B$$

$$where, B = \frac{\mu R_m}{AP}$$

$$\frac{K_P}{2} = \frac{\mu \alpha C_s}{2A^2 P}$$

Exp 1: first sand bed arrangement: large particles to small particles

(from top to bottom,1000μm, 700μm, 500μm)

μ = 8.93 x 10^{-4} kg/m.s

A of filter cylinder = 1.983 x 10^{-3} m^2

P drop across filter = 1418.65 Pa

From graph, $y = 1 \times 10^9 x + 53269$

$$B = \frac{\mu R_m}{AP}$$

$$53269 \frac{s}{m^3} = \frac{8.93 \times 10^{-4} kg}{m.s} \times \frac{R_m}{1.983 \times 10^{-3} m^2} \times \frac{m.s^2}{1418.65 kg}$$

$$R_m = 1.678 \times 10^8 m^{-1}$$

$$\frac{K_P}{2} = \frac{\mu\alpha C_s}{2A^2 P}$$

$$1\times10^9\,\frac{s}{m^6} = \frac{1}{2}\times\frac{8.93\times10^{-4}\,kg}{m.s}\times\frac{\alpha}{\left(1.983\times10^{-3}\,m^2\right)^2}\times\frac{0.1kg}{m^3}\times\frac{m.s^2}{1418.65kg}$$

$$\alpha = 1.249\times10^{11}\,\frac{m}{kg}$$

Exp 2: second sand bed arrangement: small particles to large particles

(from top to bottom, 500µm, 700µm, 1000µm)

$\mu = 8.93 \times 10^{-4}$ kg/m.s

A of filter cylinder = 1.983×10^{-3} m^2

P drop across filter = 1500.63 Pa

From graph, $y = 1\times10^9 x - 27240$

$$B = \frac{\mu R_m}{AP}$$

$$-27240\,\frac{s}{m^3} = \frac{8.93\times10^{-4}\,kg}{m.s}\times\frac{R_m}{1.983\times10^{-3}\,m^2}\times\frac{m.s^2}{1500.63kg}$$

$$R_m = -9.077\times10^7\,m^{-1}$$

$$\frac{K_P}{2} = \frac{\mu\alpha C_s}{2A^2 P}$$

$$1\times10^9\,\frac{s}{m^6} = \frac{1}{2}\times\frac{8.93\times10^{-4}\,kg}{m.s}\times\frac{\alpha}{\left(1.983\times10^{-3}\,m^2\right)^2}\times\frac{0.1kg}{m^3}\times\frac{m.s^2}{1500.63kg}$$

$$\alpha = 1.322\times10^{11}\,\frac{m}{kg}$$

Exp 3: third sand bed arrangement (mixing sand)

$\mu = 8.93 \times 10^{-4}$ kg/m.s

A of filter cylinder = 1.983×10^{-3} m^2

P drop across filter = 2454.68 Pa

From graph, $y = 1\times10^{9}x - 2483$

$$B = \frac{\mu R_m}{AP}$$

$$-2483\frac{s}{m^3} = \frac{8.93\times10^{-4}kg}{m.s}\times\frac{Rm}{1.983\times10^{-3}m^2}\times\frac{m.s^2}{2454.68kg}$$

$$Rm = -1.353\times10^{7}m^{-1}$$

$$\frac{Kp}{2} = \frac{\mu\alpha Cs}{2A^2P}$$

$$1\times10^{9}\frac{s}{m^6} = \frac{1}{2}\times\frac{8.93\times10^{-4}kg}{m.s}\times\frac{\alpha}{(1.983\times10^{-3}m^2)^2}\times\frac{0.1kg}{m^3}\times\frac{m.s^2}{2454.68kg}$$

$$\alpha = 2.162\times10^{11}\frac{m}{kg}$$

CALCULATION FOR SECOND EXPERIMENT

General equation for filtration (graph t/v vs V)

$$y = \frac{K_P}{2}x + B$$

$$where, B = \frac{\mu R_m}{AP}$$

$$\frac{K_P}{2} = \frac{\mu \alpha C_s}{2A^2 P}$$

Exp 1: first sand bed arrangement: large particles to small particles

(from top to bottom, 700μm, 500μm, 300μm)

μ = 8.93 x 10^{-4} kg/m.s

A of filter cylinder = 1.983 x 10^{-3} m^2

P drop across filter = 4089.480 Pa

From graph, $y = 1 \times 10^{10} x - 877942$

$$B = \frac{\mu R_m}{AP}$$

$$-877942 \frac{s}{m^3} = \frac{8.93 \times 10^{-4} kg}{m.s} \times \frac{R_m}{1.983 \times 10^{-3} m^2} \times \frac{m.s^2}{4089.48 kg}$$

$$R_m = -7.89 \times 10^9 m^{-1}$$

$$\frac{K_p}{2}=\frac{\mu\alpha C_s}{2A^2P}$$

$$1\times10^{10}\frac{s}{m^6}=\frac{1}{2}\times\frac{8.93\times10^{-4}kg}{m.s}\times\frac{\alpha}{\left(1.983\times10^{-3}m^2\right)^2}\times\frac{0.1kg}{m^3}\times\frac{m.s^2}{4089.48kg}$$

$$\alpha=3.60\times10^{12}\frac{m}{kg}$$

Exp 2: second sand bed arrangement: mixing sand

μ = 8.93 x 10^{-4} kg/m.s

A of filter cylinder = 1.983 x 10^{-3} m^2

P drop across filter = 4089.480 Pa

From graph, $y=4\times10^{10}x-1000000$

$$B=\frac{\mu R_m}{AP}$$

$$-1000000\frac{s}{m^3}=\frac{8.93\times10^{-4}kg}{m.s}\times\frac{R_m}{1.983\times10^{-3}m^2}\times\frac{m.s^2}{4089.48kg}$$

$$R_m=-9.08\times10^9m^{-1}$$

$$\frac{K_p}{2}=\frac{\mu\alpha C_s}{2A^2P}$$

$$4\times10^{10}\frac{s}{m^6}=\frac{1}{2}\times\frac{8.93\times10^{-4}kg}{m.s}\times\frac{\alpha}{\left(1.983\times10^{-3}m^2\right)^2}\times\frac{0.1kg}{m^3}\times\frac{m.s^2}{4089.48kg}$$

$$\alpha=1.44\times10^{13}\frac{m}{kg}$$