Treatment of Grey Water for Toilet Flushing Use

by

Naizaitul Husna binti Abd. Razi

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Chemical Engineering Programme
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Approved by,

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TRONOH, PERAK

JUNE 2004

CERITIFICATION 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.

NAIZAITUL HUSNA BINTI ABD. RAZI

ABSTRACT

This study is the preliminary study on treating grey water for toilet flushing use. Due to the increment number of students in Universiti Teknologi PETRONAS (UTP), the accommodations are also increased. This will result the increasing need of water use, in future. Thus, the recycling of grey water is recommended to overcome the problem. The recycled grey water will be use for toilet flushing system in UTP student's village. The main objective of the study is to find ways to treat grey water as of to reduce high-quality fresh water supply for toilet flushing purpose and to propose a grey water recycling system. Besides that, an economic study on using grey water for toilet flushing use was done. This project consists of two parts, which are to analyze the wastewater before and after treatment and to find the best treatment method using the available equipment in UTP by conducting a laboratory work. Based on the findings from the experiment, treatment methods are proposed to treat the grey water for toilet flushing use in UTP. Then, a brief economics analysis is required to check on cost and water saving if the treatment system is implemented in UTP. The methodology used for treatment of grey water including the experimental work that available in the UTP laboratory which is Coagulation and Flocculation, Sequencing Batch Reactor (SBR) and Chlorination. Other methods used are to analyze the parameters before and after the treatment. Results obtained from the experiment shown that the coagulation and flocculation treatment is the suitable method to treat turbidity of the grey water. The 70 mg/L alum dosages at pH 6.5 are the optimum value determined in order to reduce the turbidity. SBR treatment has shown a reduction in BOD for 1-hour time and chlorination method is able to reduce the MPN of total coliform with optimum chlorine dosage at 28 mg/L. The cost study analysis shows that the water consumption and water bill saving is by 87 % and 84%, respectively.

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ABBREVIATIONS AND NOMENCLATURES

BOD	Biological Oxygen Demand
BOD_5	5-days Biological Oxygen Demand
SBR	Sequencing Batch Reactors
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
MPN	Most Probable Number
NTU	Nephelometric Turbidity Unit
E. coli	Escherichia coli
MMF	Multimedia filter
RBC	Rotating Biological Contactor
UV	Ultraviolet
NaOCl	Sodium Hypochlorite
$Ca(OCl)_2$	Calcium Hypochlorite
$Al_2(SO_4)_3$	Aluminium Sulphate (Alum)

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Any water that has been used in the home, except water from toilets is called *grey water.* Depending on its use, grey water can require less treatment than black water and contains fewer pathogens. Black water is water that has been mixed with waste from the toilet. It requires biological or chemical treatment and disinfection before re-use. Black water should only be re-used outdoors. Treated grey water can be re-used for indoor purpose such as toilet flushing and clothes washing, both of which are significant consumers of water. However in this study, the treatment of grey water will be concentrated for toilet flushing purpose.

Water from recycling systems should fulfill four criteria: *hygienic safety, aesthetics, environmental tolerance and technical and economical feasibility* (*Nolde & Dott, 1991*). In Germany, the classification of household wastewater into black water and grey water is almost unknown and both terms are not yet defined. Here "Grey Water" means the low polluted wastewater from bathtubs, showers, hand washing basins and washing machines excluding wastewater from the kitchen and the toilet flushing system. (*Nolde, 1999*).

Recycling of grey water for toilet flushing purpose will give more advantages, which are:

- Reduce water bills.
- Use less water resources (potable water).
- Cut down the amount of pollution going into the waterways.
- Help save money on new infrastructure for water provision and wastewater treatment.

1.2 PROBLEM STATEMENT

This study is the preliminary study on treating grey water for toilet flushing use. Due to the increment number of students in Universiti Teknologi PETRONAS (UTP), the accommodations are also increased. This will result the increasing need of water use, in future. Thus, the recycling of grey water is recommended to minimize or overcome the problem. The recycled grey water will be used for toilet flushing system in UTP student's village. This concept can reduce the need to use potable water for non-potable applications with the water efficiency being used twice before disposal to wastewater treatment.

The treatment of grey water for toilet flushing use should be further discussed since this method can give a good benefit to UTP. This study will analyze the best treatment method for grey water treatment plant in UTP.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objectives of Study

The objectives of the study are listed as below:

1) To find ways to treat grey water as of to reduce high-quality fresh water supply for toilet flushing purpose.
2) To do an economic study on using grey water for toilet flushing use.
3) Propose a Grey Water Recycling System based on findings.

1.3.2 Scope of Study

This project consists of two parts, which are to analyze the wastewater before and after treatment and to find the best treatment method using the available equipment in UTP by conducting a laboratory work. Based on the findings from the experiment, treatment methods are proposed to treat the grey water for toilet flushing use in UTP. Then, a brief economics analysis is conducted to check on cost and water saving if the treatment system is implemented in UTP.

Conducting Laboratory Work

Laboratory works are conducted to treat and analyze the grey water before and after the treatment process. Types of sample taken are from the shower bath and hand basin produced from the student's village in Village 4. The analysis of the parameters is done together with the treatment before and after in order to see the effectiveness of the treatment method used.

Analyzing Cost Study

The cost and water saving is analyzed in order to see the effectiveness of the recycling grey water for toilet flushing. The analysis may result that after implementing the grey water treatment, a reduction in fresh water usage and not pay too much water bill can be achieved.

1.4 FEASIBILITY OF THE PROJECT WITHIN THE SCOPE AND TIME FRAME

As this study is one semester project, the treatment of grey water is done based on simple treatment that has been used for water and wastewater in general. The treatment can be carried out on grey water because it doesn't have much contaminant and constituents rather than other type of wastewater which need special treatment for them. If further studies are conducted for this project, it can be implemented in UTP and also for residential house as it can cut cost rather than using potable water for the toilet flushing. Therefore, this study only includes all the objectives and project scopes stated in Section 1.3.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 GREY WATER

2.1.1 What is Grey Water?

Grey water is a household wastewater that comes from the bath, shower, bathroom wash basins, clothes washing machine, laundry trough and kitchen sink. Its characteristics will vary according to the number of household occupants, their age, lifestyle, health and water use patterns. Grey water may contain some faecal contamination, bacteria, parasites and viruses washed from the body and clothes. Pathogenic micro-organisms are a normal part of the gut. This means that all forms of grey water are capable of transmitting disease. It needs to be properly managed to minimize health risk and degradation of the environment.

2.1.2 The Benefits of Grey Water Recycling

It is a waste to use potable water for non-potable applications. Grey water reuse is a part of the fundamental solution to many ecological problems and will probably remain essentially unchanged in the future. The advantages of grey water recycling are:

a) Lower fresh water use.

Grey water can replace fresh water, saved water bill and increase the effectiveness of water supply in regions where irrigation is needed. Residential water use is almost evenly split between indoor and outdoor. All type of water except water from toilet could be recycled outdoors, achieving the same result with significantly less water diverted from nature.

b) Less strain on failing septic tank or treatment plant.

Grey water use greatly extends the useful life and capacity of septic systems. For municipal treatment systems, decreased wastewater flow means higher treatment effectiveness and lower costs.

c) Grey water treatment in topsoil is highly effective.

Grey water is purified to a spectacularly high degree in the upper, most biologically active region of the soil. This protects the quality of natural surface and ground waters.

d) Less energy and chemical use.

Less energy and chemicals used are due to the reduced amount of both freshwater and wastewater that needs pumping and treatment. For those providing their own water or electricity, the advantage of a reduced burden on the infrastructure is felt directly.

e) Reclamation of otherwise wasted nutrients.

Loss of nutrients through wastewater disposal in rivers or oceans is a subtle, but highly significant form of erosion. Reclaiming nutrients in grey water helps to maintain the fertility of the land.

2.1.3 Grey Water Quality Guideline

The findings in water quality guideline provide the basis for an interim monitoring tool for indirect water reuse systems, where the focus in this study is on toilet flushing system. The indirect use classification is not very extensive because activities such as toilet flushing do not require as high a standard as potable water use since it is not ingested or used for body contact. Water quality is monitored using typical physical, chemical and biological parameters. Most of these parameters were discussed at the Ottawa '99 Protocol Round Table (*Cate Soroczan, 1999*). For this study, the existing monitoring guidelines for treated reused water for toilet flushing are criteria developed by following Canada Mortgage and Housing Corporation Toilet Reuse Pilot Project Ottawa Water Reuse Criteria. All the criteria are presented in the table below.

Table 1.1: Light grey water criteria for toilet flushing.

Parameter	**Light Grey Water Criteria for Toilet Flushing**
Total Suspended Solid	10 mg/L
Coliform	20 MPN/100 mL (Drinking water standard)
Turbidity	20 NTU
Colour	30 Pt-Co
Iron	1.0 mg/L
Manganese	0.5 mg/L
Biological Oxygen Demand	5 – 30 mg/L

Source: Research Report "Water Quality Guideline and Water Monitoring Tools for Residential Water Reuse System", 1999.

2.2 TREATMENT METHOD

In treating the grey water, there are several general methods that are normally used to treat water and wastewater. The selection of the treatment is based on the critical parameters which contains in the grey water. Generally, the treatment of wastewater is divided into three parts; physico-chemical treatment, biological treatment and disinfection treatment.

In the physico-chemical treatment, the physical unit operation is combined with the chemical unit processes, where the chemical reactions occur. The principle chemical unit processes include chemical precipitation, chemical oxidation and chemical coagulation. Method that normally being used for water and wastewater treatment is coagulation and flocculation, where the mixing and flocculation are combined with the chemical coagulation to enhance the treatment process.

Biological treatment in wastewater is essential as the biodegradable constituents in the wastewater are much higher rather than other types of water. There are many methods that can be used for biological treatment. Methods that most of wastewater treatment plant used are anaerobic digester, rotating biological contactor (RBC), activated sludge, sequencing batch reactor (SBR) etc. In this study, sequencing batch reactor has been chosen to reduce the BOD content in grey water.

The last treatment before the water can be used is a disinfection treatment. In the wastewater, diseases can be caused by these waterborne microorganisms such as bacterias, viruses and cysts, if the water is not disinfected properly. Disinfection methods is most commonly accomplished by the used of; *chemical agents, physical agents, mechanical agents, mechanical means and radiation.* Due to the availability and simplicity of the chemical agents, the chlorination method is concentrated in this study.

2.2.1 Physico-Chemical Treatment (Coagulation and Flocculation)

In wastewater treatment operations, the processes of coagulation and flocculation are employed to separate suspended solids from water. Although the terms coagulation and flocculation are often used interchangeably, or the single term "flocculation" is used to describe both; they are, in fact, two distinct processes.

Finely dispersed solids (colloids) suspended in wastewaters are stabilized by negative electric charges on their surfaces causing them to repel each other. Since this prevents these charged particles from colliding to form larger masses called flocs, they do not settle. To assist in the removal of colloidal particles from suspension, chemical coagulation and flocculation are required. These processes usually done in sequence are a combination of physical and chemical procedures. Chemicals are mixed with wastewater to promote the aggregation of the suspended solids into particles large enough to settle or be removed.

Coagulation is the destabilization of colloids by neutralizing the forces that keep them apart. Cationic coagulants provide positive electric charges to reduce the negative charge (zeta potential) of the colloids. As a result, the particles collide to form larger particles (flocs). Rapid mixing is required to disperse the coagulant throughout the liquid. Care must be taken not to overdose the coagulants as this can cause a complete charge reversal and restabilize the colloid complex. The most widely used coagulant is aluminium sulphate (alum – $Al_2(SO_4)_3.H_2O$). Alum reacts with the alkalinity in the water to produce insoluble aluminium hydroxide floc ($Al(OH)_3$) according to equation (1).

$$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2 \quad (1)$$

The insoluble aluminium hydroxide is a gelatinous floc that settles slowly through the wastewater, sweeping out suspended material and producing other changes. The reaction is analogous when magnesium bicarbonate is substituted for calcium salt. (*Metcalf and Eddy, 2003*).

Flocculation is the action of polymers to form bridges between the flocs and bind the particles into large agglomerates or clumps. Bridging occurs when segments of the polymer chain adsorb on different particles and help particles aggregate. An anionic flocculant will react against a positively charged suspension, adsorbing on the particles and causing destabilization either by bridging or charge neutralization. In this process, it is essential that the flocculating agent is added slowly and mixed gently to allow for contact between the small flocs and to agglomerate them into larger particles. The newly formed agglomerated particles are quite fragile and can be broken apart by shear forces during mixing. Care must also be taken not to overdose the polymer, as doing so will cause settling/clarification problems. Anionic polymers themselves are lighter than water. As a result, overdosing will increase the tendency of the floc to float and not settle.

2.2.2 Biological Treatment (Sequencing Batch Reactors)

The sequencing batch reactors (SBR) is a fill-and-draw activated sludge system for wastewater treatment which is an effective method to remove BOD and nitrification. (*Metcalf and Eddy, 2003*). The BOD removal efficiency is generally 85 to 95 percent. (*EPA, 1999*). In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components and then discharged. Equalization, aeration and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions.

SBR Process Cycles

The operation of an SBR is based on the fill-and-draw principle which consists of the following five basic steps: **Idle**, **Fill**, **React**, **Settle** and **Draw**. (*EPA, 1999*). For industrial wastewater applications, treatability studies are typically required to determine the optimum operating sequence. For most municipal wastewater treatment plants, treatability studies are not required to determine the operating sequence because municipal wastewater flowrates and characteristic variations are usually predictable and most municipal designers will follow conservative design approaches.

The **Idle** step occurs between the Draw and Fill steps, during which treated effluent is removed and influent wastewater is added. The length of the Idle step varies depending on the influent flowrate and the operating strategy. Equalization is achieved during this step if variable idle times are used. Mixing to condition the biomass and sludge wasting can also be performed during the Idle step, depending on the operating strategy.

Influent wastewater is added to the reactor during the **Fill** step. There are two variations used for the Fill step and any or all of them may be used depending on the operating strategy: *Anoxic Fill* and *Aerated Fill*. During *Anoxic Fill*, the influent wastewater is distributed throughout the settled sludge through the influent distribution manifold to provide good contact between microorganisms and the substrate. The influent can be either pumped in or allowed flowing in by gravity. Most of this period occurs without aeration to create an environment that favours the procreation of microorganisms with good settling characteristics. Aeration begins at the beginning of this period. *Aerated Fill* is classified by aerating the contents of the reactor to begin the aerobic reactions completed in the React step. This initiates the feast period. Feast is when the microorganisms have been contact with the substrate and a large amount of oxygen is provided to facilitate the substrate consumption. This period ends when the tank is either full or when a maximum time for filling is reached.

The biological reactions are completed in the **React** step. During this period aeration continues until complete biodegradation of BOD and nitrogen is achieved. After the substrate is consumed, famine stage starts. During this stage, some microorganisms will die because of the lack of food and will help reduce the volume of the settling sludge. The length of the aeration period determines the degree of BOD consumption.

Settle is typically provided under quiescent conditions in the SBR. Aeration is discontinued at this stage and solids separation takes place leaving clear, treated effluent above the sludge blanket. During this clarifying period no liquids should enter or leave the tank to avoid turbulence in the supernatant.

The **Draw** step uses a decanter to remove the treated effluent from approximately two feet below the surface of the mixed liquor by the floating solids excluding decanter. This removal must be done without disturbing the settled sludge.

Table 2.1: Some advantages and disadvantages of SBR.

Advantage	Disadvantage
• Equalization, primary clarification (in most cases), biological treatment and secondary clarification can be achieved in a single reactor vessel. • Operating flexibility and control. • Minimal footprint. • Potential capital cost savings by eliminating clarifiers and other equipment.	• A higher level of sophistication is required (compared to conventional systems), especially for larger systems of timing units and controls. • Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches and automated valves.

2.2.3 Disinfection (Chlorination)

Due to the undigested nature of the organic materials in grey water, microorganisms can grow and reproduce faster. The number of bacteria can actually increase in grey water within the first 48 hours of storage. Therefore, it is a must to make sure that the recycled grey water used for toilet flushing purposes are refrain from microorganisms.

Disinfection is used to ensure that any harmful bacteria are destroyed before wastewater release from the plant. Although several methods eliminate disease-causing microorganisms in water, chlorination is the most commonly used. The reason is that chlorine satisfies most of the requirements specified in Table 2.2 below.

Table 2.2: Characteristics of an ideal disinfectant. (*Metcalf and Eddy, 2003*)

Characteristic	Properties / response
Availability	Should be in large quantity and reasonably priced.
Deodorizing ability	Should deodorize while infecting.
Homogeneity	Solution must be uniform in composition.
Interaction with extraneous material	Should not be absorbed by organic matter other than bacterial cells.
Noncorrosive and nonstaining	Should not disfigure metals or stain clothing.
Nontoxic to higher forms of life	Should be toxic to microorganisms and nontoxic to humans and other animals.
Penetration	Should have the capacity to penetrate through surface.
Safety	Should be safe to transport, store, handle and use.
Solubility	Must be soluble in water or cell tissue.
Stability	Should have low loss of germicidal action with time on standing.
Toxic to microorganisms	Should be effective at high dilutions.

Chlorine has the added advantage of providing residual disinfections of the wastewater. This is because the chlorine residual that remains in the wastewater after chlorination continues to provide protection from the possibility of re-contamination by bacteria. (*TID-MS-02; October 2000*).

The principal chlorine compounds used at wastewater treatment plants are chlorine [Cl_2], sodium hypochlorite [NaOCl], calcium hypochlorite [$Ca(OCl)_2$] and chlorine dioxide [ClO_2]. Some of the plants have switched from chlorine gas to sodium hypochlorite due to safety concerns related to handling and storage of liquid chlorine.

Chlorine [Cl_2]

It can be present as a gas or a liquid. Chlorine gas is greenish yellow in colour. Chlorine is moderately soluble in water with a maximum solubility of about 1 % at 10°C (50°F). Chlorine is supplied as a liquefied gas under high pressure in containers varying in size. Although the use of chlorine for the disinfection of both potable water supplies and treated wastewater has been significance from a public health perspective, serious concerns have been raised of its continued use.

1. Chlorine is a highly toxic substance that is transported by rail and truck which may cause accident and potentially poses health risks to people surroundings if released by accident.
2. Chlorine reacts with organic constituents in wastewater to produce odourous compounds and byproducts.
3. Residual chlorine in treated wastewater effluent is toxic to aquatic life.

When chlorine in the form of Cl_2 gas is added to water, two reactions take place: hydrolysis and ionization. Hydrolysis may be defined as the reaction in which chlorine gas combines with water to form hypochlorous acid (HOCl):

$$Cl_2 + H_2O \leftrightarrow HOCl + H^+ + Cl^-$$

Ionization of hypochlorous acid to hypochlorite ion (OCl^-) may be defined as:

$$HOCl \leftrightarrow H^+ + OCl^-$$

Sodium Hypochlorite [NaOCl]

Also known as liquid bleach is only available as liquid and usually contains 12.5 to 17 % available chlorine at the time it is manufactured. Sodium hypochlorite can be purchased in bulk lots of 12 to 15 % of available chlorine or manufactured onsite. The solution decomposes more readily at high concentrations and is affected by exposure to light and heat. It is must therefore be stored in a cool location in a corrosion-resistant tank. The disadvantage of sodium hypochlorite is the chemical cost. The handling of sodium hypochlorite requires special design considerations because of its corrosiveness and the presence of chlorine fumes.

The reaction occurs in sodium hypochlorite:

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

Calcium Hypochlorite [Ca(OCl)$_2$]

It is available commercially in either a dry or a wet form. It contains at least 70 % available chlorine. In dry form it is available as an off-white powder or as granules, compressed tablets or pellets. Calcium hypochlorite granules or pellets are readily soluble in water, varying from about 21.5 g/100 ml at 0°C to 23.4 g/100 ml at 40°C. Because of its oxidizing potential, calcium hypochlorite should be stored in a proper storage conditions, the granules are relatively stable. It is more expensive than liquid chlorine, loses it available strength on storage and may be difficult to handle. Because it tends to crystallize, calcium hypochlorite may clog piping and valves.

The reaction occurs in calcium hypochlorite:

$$Ca(OCl)_2 + 2H_2O \rightarrow 2HOCl + Ca(OH)_2$$

CHAPTER 3
METHODOLOGY AND PROJECT WORK

3.1 SAMPLE COLLECTION METHOD

Samples are collected directly from the activities that contributed to the production of grey water. In this case, samples from the toilet sink and shower bath were collected. The samples from those two sources were mixed together. The collected samples were stored in black containers with capacity of approximately 1 L.

3.2 SAMPLING AND PRESERVATION METHOD

The contents of grey water samples can alter at different rates. As only a few parameters can be measured during collection, pretreatment or stabilization is often necessary. Correct sampling and storage are critical for accurate testing. Sampling devices and containers must be thoroughly clean to prevent carryover from previous samples. This allows tests to be carried out even after long periods of times have elapsed.

Once sample is taken, the constituents of the sample should be maintained in the same condition as when collected. When it is not possible to analyze collected samples immediately, samples should be preserved accordingly. Biological activity such as microbial respiration, chemical activity (i.e. precipitation or pH change) and physical activity (i.e. aeration or high temperature) must be kept to a minimum.

If the sample contains organic materials and favourable conditions for the development of micro-organisms, rapid change often occurs. In this case, stabilization is necessary. This is defined as blocking or delay biochemical process whereby the difference in content between the original and preserved sample should be less than 10%. Method of preservation includes cooling, pH control and chemical oxidation. The length of time that a constituent in wastewater will remain stable is related to the character of the constituent and the preservation method used.

For experiment of coagulation and flocculation and turbidity checking, the samples are collected in black plastic container. To obtain better results, the experiment should be started as soon as possible after samples collection. Otherwise, sample will be preserved at low temperature (4 ^{o}C) for no longer than 48 hours.

3.3 PROCEDURE IDENTIFICATION

Before starting the treatment experiments, the parameters of the grey water constituent are checked to record the values. After the treatment is done, the parameters are checked again to observe the reduction of the value whether it complies with the light grey water criteria for toilet flushing in Table 1.1. The treatment experiments are done in between the parameters checking.

3.3.1 Turbidity and pH Analysis

1. *Preparation for Analysis*

   The sample is shaken thoroughly to disperse the solids. After all the air bubbles has disappeared, the sample is poured into the turbiditimeter tube for test.

2. *Equipment and Apparatus*

   i. Turbiditimeter with 6 test cell tube.
   ii. pH meter.

3. *Experimental Procedure*

   The method is based upon a comparison of intensity of light scattered by the sample under defined conditions with the intensity of light scattered by the standard reference suspension. The experimental procedures to determine the turbidity level in the samples are listed as below:

a) A 20-mL of sample is red into the sample test cell.
b) By using soft cloth or tissue paper, the test cell is wiped to remove water spots and fingerprints.
c) The test cell is placed in the turbidity meter slot.
d) After a few seconds, the results can be obtained by reading the value displayed on the screen.

For pH checking:

a) Probe of the pH meter is dipped into the sample.
b) The results can be obtained by reading the value displayed on the screen after the reading stabilized.

3.3.2 Coagulation and Flocculation

The jar test is a common laboratory procedure used to determine the optimum operating conditions for water or wastewater treatment. This method allows adjustments in pH, variations in coagulant or polymer dose, alternating mixing speeds, or testing of different coagulant or polymer types, on a small scale in order to predict the functioning of a large scale treatment operation. A jar test simulates the coagulation and flocculation processes that encourage the removal of suspended colloids and organic matter which can lead to turbidity, odor and taste problems.

1. *Preparation for Analysis*

Three samples of grey water are prepared for three steps of experiments:

1 Step 1: Fresh grey water sample without altering the pH at various coagulant dose.
2 Step 2: Another fresh grey water sample with pH alteration with the optimum coagulant dose determined in Step 1.
3 Step 3: Fresh grey water sample corrected with the optimum pH in Step 2 at various coagulant dose again.

2. *Equipment and Apparatus*

i. A set of jar tester (refer to Appendices) with 6 paddles.
ii. 6 x 1-L beaker.
iii. Pipette.
iv. Measuring cylinder.

3. *Chemicals*

i. 1 % w/v aluminium sulphate (alum) – as coagulant dose.
ii. 1 % w/v calcium carbonate (lime) – pH alteration.
iii. 0.01 M sulfuric acid – pH alteration.

4. *Experimental Procedure*

a) The 1-L beaker is poured with 500-mL of sample for 6 beakers.
b) For Step 1, five different coagulant doses i.e. alum are drawn into each beaker. The remaining beaker is used as a control.
c) The stirrer speed is set at 150 rpm and the jar tester is started to rapid mixing for 1 minute.
d) After 1 minute, the stirrer speed is reduced to 30 rpm for slow mixing and this step is continued for 30 minutes.
e) The jar tester is turned off and the flocs formed are allowed to settle down for 1 hour.
f) Only 20-mL of sample is taken for turbidity test.
g) Step a) until f) are repeated for Step 2 with pH alteration and optimum alum dose and Step 3 with optimum pH at various alum doses to determine the final optimum alum dose.

3.3.3 5-Days Biological Oxygen Demand Analysis

1. *Preparation for Analysis*

Dilution method is used for the BOD_5 analysis. Prior to the experiment, sample dilution water is prepared using a BOD Nutrient Buffer Pillow for 3-L. The volume and range corresponding to the expected sample BOD have to be chosen. In this case, it is found that the BOD_5 contents grey water is around 480 mg/L. Therefore, the volume required during BOD_5 test is 3-mL.

Table 3.1: Measurable BOD using various dilutions of samples.

By direct pipetting into 300-mL bottles	
mL	**Range of BOD, mg/L**
0.02	30,000 – 105,000
0.05	12,000 – 42,000
0.10	6,000 – 21,000
0.20	3,000 – 10,500
0.50	1,200 – 4,200
1.0	600 – 2,100
2.0	300 – 1,050
5.0	120 – 420
10.0	60 – 210
20.0	30 – 105
50.0	12 – 42
100.0	6 – 21
300.0	0 – 7

Sources: Chapter 2, Constituents in Wastewater, "Wastewater Engineering, Treatment and Reuse," (Metcalf and Eddy, 1999).

2. *Equipment and Apparatus*

i. 300-mL BOD bottles.
ii. DO meter and BOD probe.
iii. Aluminium foil.
iv. BOD incubator.

3. *Chemicals Reagent*

i. BOD Nutrient Buffer Pillows (for 3-L).

4. *Experimental Procedure*

The BOD concentration in most wastewaters exceeds the concentration of dissolved oxygen (DO) available in an air-saturated sample. Therefore, it is necessary to dilute the sample before incubation to bring the oxygen demand and supply into appropriate balance. Because bacterial growth requires nutrients such as nitrogen, phosphorous and trace metals, these are added to the dilution water, which is buffered to ensure that the pH of the incubated sample remains in a range suitable for bacterial growth. Complete stabilization of a sample may require a period of incubation too long for practical purposes; therefore 5 day has been accepted as the standard incubation period.

a) Sample dilution water is prepared using BOD Nutrient Buffer Pillows for 3-L.
b) After determining the required sample for the BOD range, 3-mL of sample is transferred into the 300-mL BOD bottles.
c) Each bottle is filled with the dilution water. The dilution water is allowed to flow slowly to prevent bubbles from forming.
d) Once stopped, the bottles are inverted several times to mix the sample with the dilution water.
e) The initial value of DO is determined using a DO meter with BOD probe.

f) An aluminium foil is placed over the lip of each bottles and placed in an incubator at 20 ± 1°C for 5 days.

g) When the 5 day incubation is complete, the final value of DO is determined again using DO meter with BOD probe.

h) The value of BOD can be calculated using standard methods approved by EPA.

3.3.4 Sequencing Batch Reactor

1. *Preparation for Analysis*

   2 beakers of 600-mL of grey water are prepared. Approximately 60 mL of water sample from waste water pond (contains bacteria) are mixed together with the grey water for inoculation.

2. *Equipment and Apparatus*

   i. Jar tester.
   ii. 2 x 1-L beaker.
   iii. Air pumps with tubes.

3. *Chemical Reagent*

   i. Water sample from waste water pond (which contains bacteria).

4. *Experimental Procedure*

   The operating principles of SBR have 5 basic steps: Idle, Fill, React, Settle and Decant. However, in this experimental set-up only 3 steps can be done: Fill, React and Settle due to the limitations of the equipment availability. The parameter that needs to be considered in this experiment is time for sample reactions.

   a) 60-mL of water sample which contains bacteria is filled for both beakers.

b) The air pump is on to aerate the sample about 15 minutes. At the same time, the sample is stirred at 20 rpm for slow mixing.

c) While the sample is mixed and aerated, the beaker is filled slowly with influent grey water.

d) After filling process, the water is left for reaction to occur. The first beaker is set for 1 hr and second is set for 1 ½ hr.

e) After the required time for reaction has finished, the air pump is stopped and the water is left again to settle down about half an hour.

3.3.5 Total Coliform Analysis

1. *Preparation for Analysis*

Sterilized bottles are prepared before an experiment can be conducted. The sample is shaken thoroughly to disperse the solids.

2. *Chemical Reagent*

i. Pack of Colilert powder nutrient.

3. *Equipments and Apparatus*

i. Incubator.
ii. IDEXX Quanti-Tray/2000.
iii. Colilert test kit.
iv. Quanti-Tray Sealer.

4. *Experimental Procedure*

Most Probable Number (MPN) methods are used for the presumptive identification, confirmation and enumeration of indicator bacteria. Indicator bacteria that can be determined are total coliforms and E. coli which may produce colour and fluorescence.

a) The 100-mL of sample is poured into the sterilized bottle and one pack Colilert powder nutrient is added into the sample.

b) By shaking the sterilized bottle, the nutrient is dissolved in the sample.

c) The sample is poured into the tray.

d) The tray is sealed and placed into the oven at 35 °C ± 0.5 °C for 24 hours.

e) After 1 day incubation, the MPN can be determined by counting the number of positive large and small wells and using the MPN table.

3.3.6 Chlorination

1. *Preparation for Analysis*

Before the chlorination can be conducted, the analysis of chlorine residual must be conducted first to meet the chlorine demand and provide residual disinfection. Thus, there will be no excess chlorine content in the water. The chlorine residual should be done before and after the chlorination treatment.

2. *Equipments and Apparatus*

i. Jar tester.
ii. 5 x 1-L beaker.
iii. Pipette.
iv. Hach DR 4000 Spectrophotometer.
v. Total chlorine test kit.

3. *Chemical Reagent*

i. DPD Total Chlorine Reagent Powder Pillows.
ii. Sodium Hypochlorite (10 % Cl_2) – chlorine dosage.

4. *Experimental Procedure*

a) Before the start of chlorination treatment, 10-mL sample is taken for total chlorine test and 100-mL is taken for total coliforms test.

b) 5 of 1-L beakers are filled with grey water sample and the sodium hypochlorite is filled at different dosage.

c) The jar tester is on and the sample is mixed together at 150 rpm speed for about 15 minutes.

d) Sample from each beakers are taken again for re-testing with total chlorine and total coliforms after the chlorination treatment process.

3.4 ECONOMIC STUDY

According to one of the objectives, the cost economic study has to be conducted in order to see the cost and amount of fresh water saving by recycling the grey water for toilet flushing use. The method used in doing the analysis is by calculating the total amount of UTP's water bill for first four months and the average water bill is determined. The estimation of water usage and bill rate can also be determined by dividing the number of people staying in the UTP. The estimation is done as per person per day basis in order to simplify the calculation. From these results, the estimation for toilet flushing capacity and the amount of grey water produced per person per day can be determined.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DISCUSSION ON SAMPLE TAKEN

The raw sample grey water that was used in this experiment is from bath shower and hand-washing basin. This is because the grey water produced is low-polluted compared to kitchen waste. Further, wastewater from kitchen waste is heavily polluted physically with food particles, oils, fats and other highly pollutant waste. It is often more polluted than black water or raw sewage. As of the solid food particles and fats can solidify, kitchen wastewater may cause blockage in a recycling system unless treated or removed from other sources of grey water. Kitchen wastewater is chemically polluted as it is also contains detergents and cleaning agents from dishwasher. The wastewater produced is very alkaline and it may be harmful to soils as its characteristics may alter in the longer term.

4.2 EXPERIMENT 1: COAGULATION AND FLOCCULATION

- *Results and Discussion on 3-stages of Coagulation and Flocculation.*

Generally, the first part of wastewater treatment is to do a physico-chemical treatment process. In the treatment of grey water, the experiment of coagulation and flocculation is done in order to treat the turbidity of water. The most important parameter that need to be emphasized in this discussion is dosage of coagulant (in this case, alum is used) and also pH for an optimum conditions. The optimum conditions for coagulation are determined as often as possible using a simple procedure known as the jar test *(Solt and Shirley, 1991)*. This measures the effect of different combinations of the coagulant dose and pH, which are the most important factors in the process. The jar test allows a comparison of these different combinations under standardized conditions after which the turbidity and pH of the supernatant (clarified water) are measured.

The experiment involves three separate sets of jar tests. The first stage of the experiment is to determine the optimum coagulant dose without pH alteration. According to Figure 4.1, the optimum alum dosage is at 60 mg/l (60 ppm) with the lowest turbidity of 8.3 NTU.

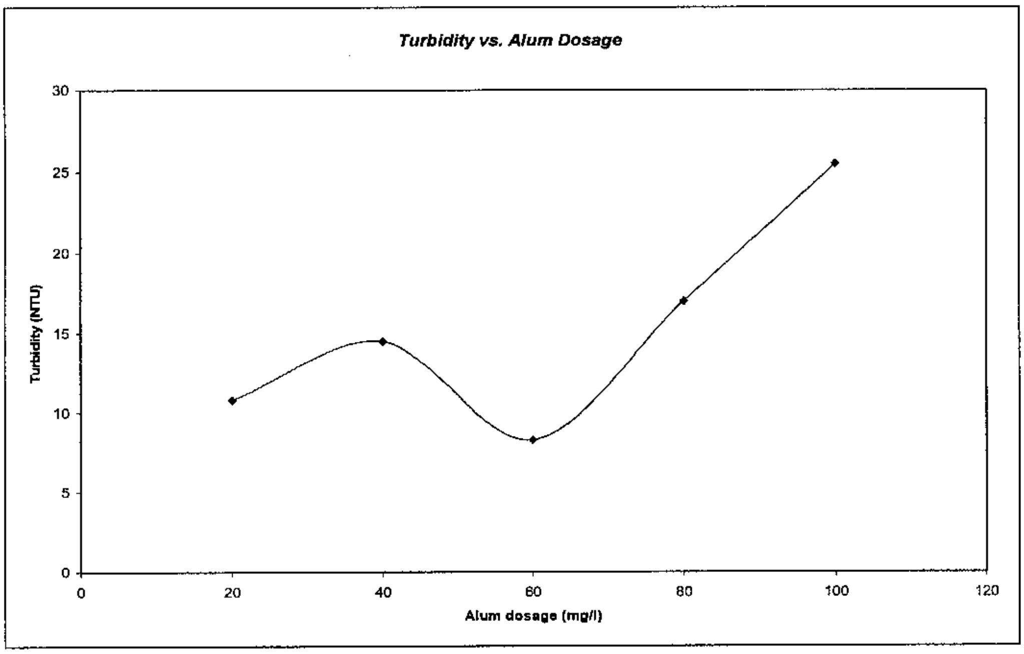


Figure 4.1: Determination of optimum alum dosage without pH alteration.

The second stage of the experiment is continued with pH alteration ranging from 6.0 to 7.0 and the alum dosage is constant at 60 mg/l. Based on Figure 4.2, the optimum pH determined is at 6.5 with the lowest turbidity of 5.7 NTU.

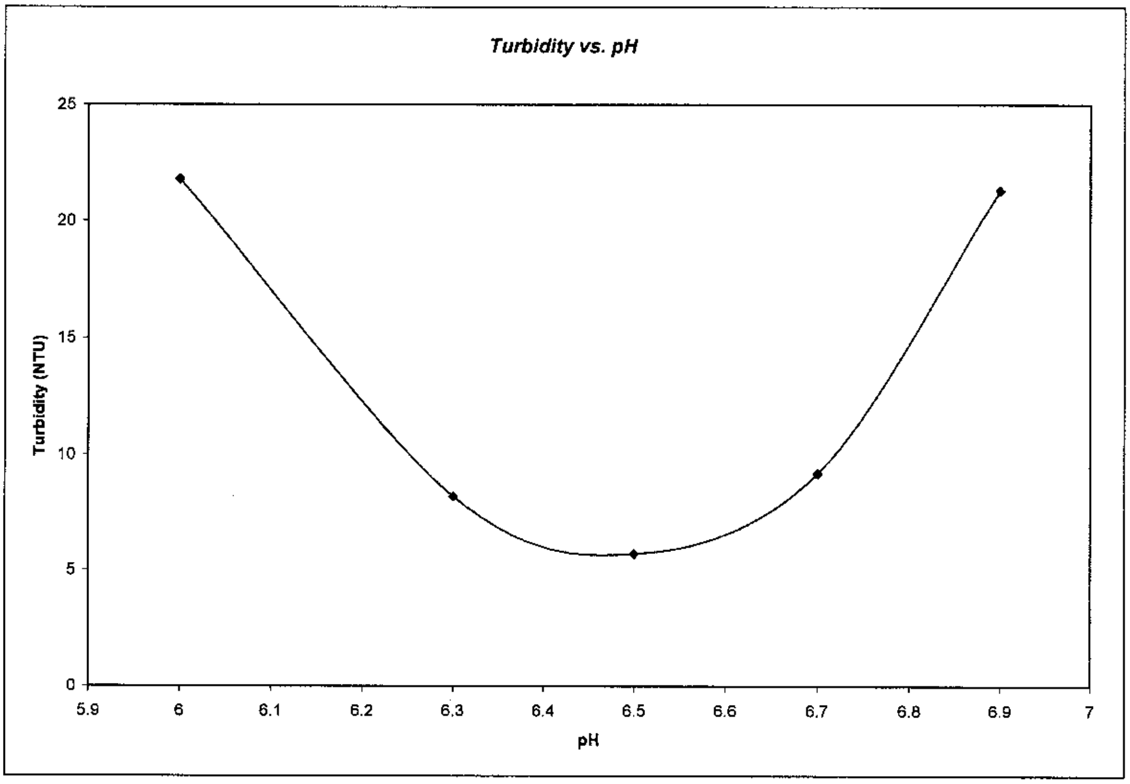


Figure 4.2: Determination of optimum pH with optimum alum dosage at 60 mg/L.

The last stage of the experiment is to determine again the alum dosage by constant the pH value at 6.5. Referring to Figure 4.3, the optimum alum dosage is at 70 mg/L with the lowest turbidity of 9.2 NTU.

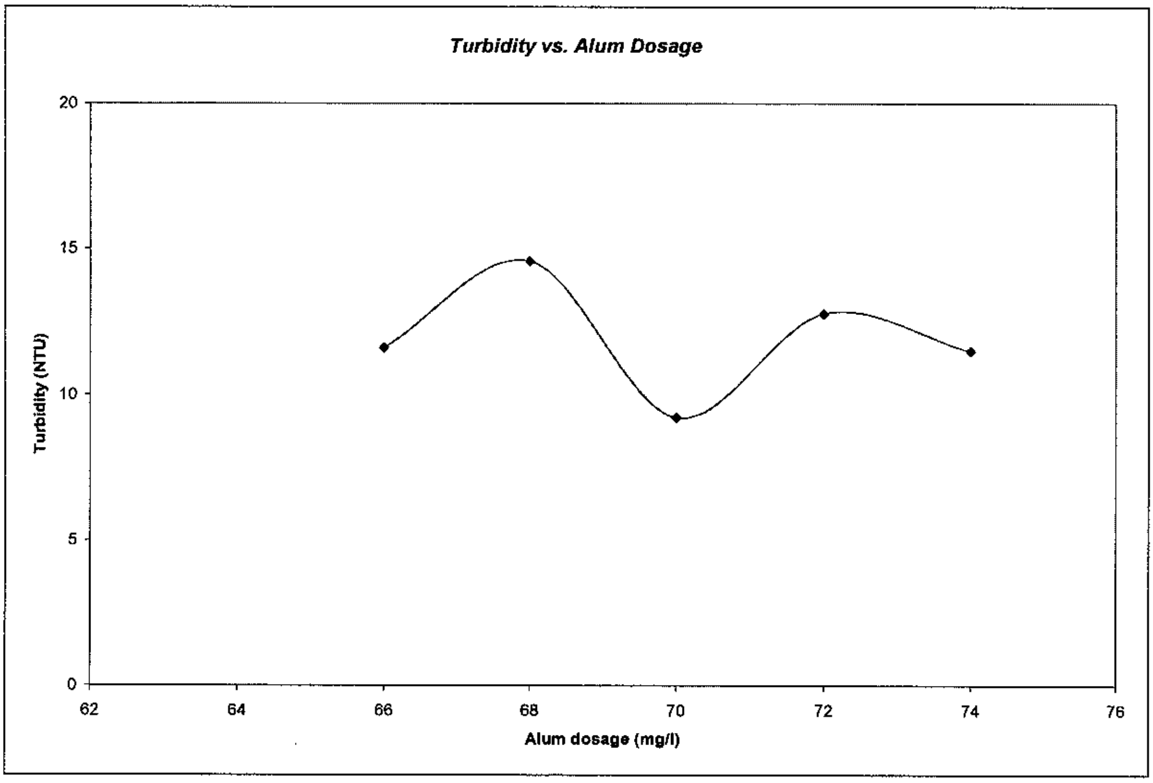


Figure 4.3: Determination of optimum alum dosage with optimum pH at 6.5.

However, the curve shown in Figure 4.1 and 4.3 is not similar to the one in the literature as shown in the Figure 4.4. This could be due to the alteration of pH during the experiment. The pH meter in the laboratory is not very accurate because the equipment has not been calibrated before being used. Other than that, for the coagulation process to be effective, the additional help of polymer in the coagulant dose may increase the efficiency of the experiment.

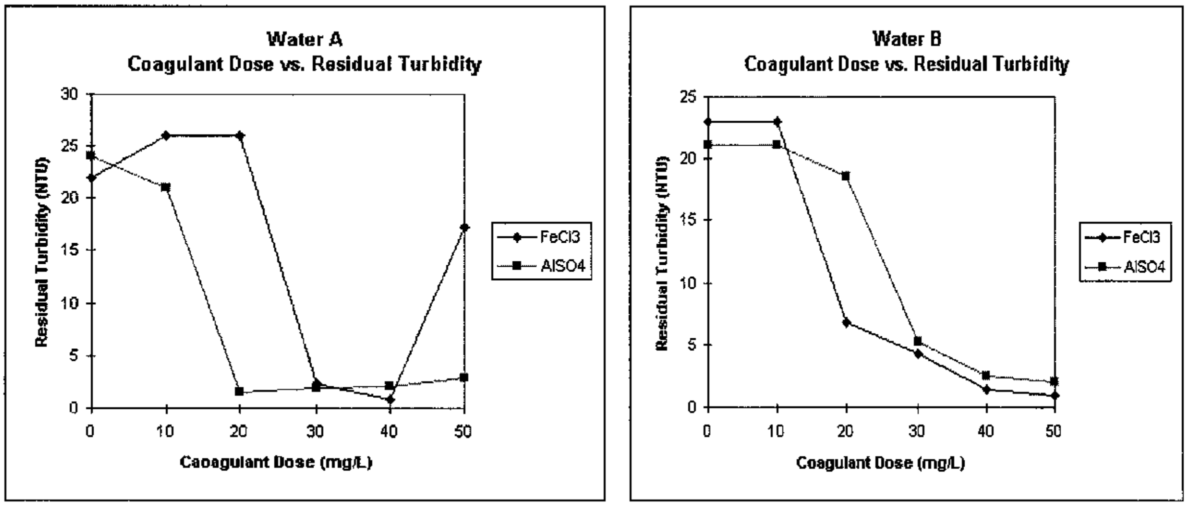


Figure 4.4: Graph of coagulant dose against residual turbidity for different coagulants.

Sources: Water Treatment Primer, CE 4124: Environmental Information Management Civil Engineering Department, Virginia Tech.

Based on the analysis of the turbidity before and after the coagulation and flocculation treatment, the turbidity has been reduced. Therefore, the coagulation and flocculation can be said to be the most suitable method to reduce the turbidity with the optimum conditions determined.

4.3 EXPERIMENT 2: SEQUENCING BATCH REACTOR

- *Results and Discussion on BOD_5 Analysis on Sequencing Batch Reactor (SBR).*

The second part of the experiment is a biological treatment process. The treatment process that has been chosen is Sequencing Batch Reactor (SBR) which is an effective method to reduce BOD. Before the SBR treatment, the BOD reading is at 237 mg/L which is around the estimated BOD value for grey water, 480 mg/L. After the experiment, two different times are varied at 1-hr and 1½-hr and the BOD reading result as 233 mg/L and 251 mg/L, respectively.

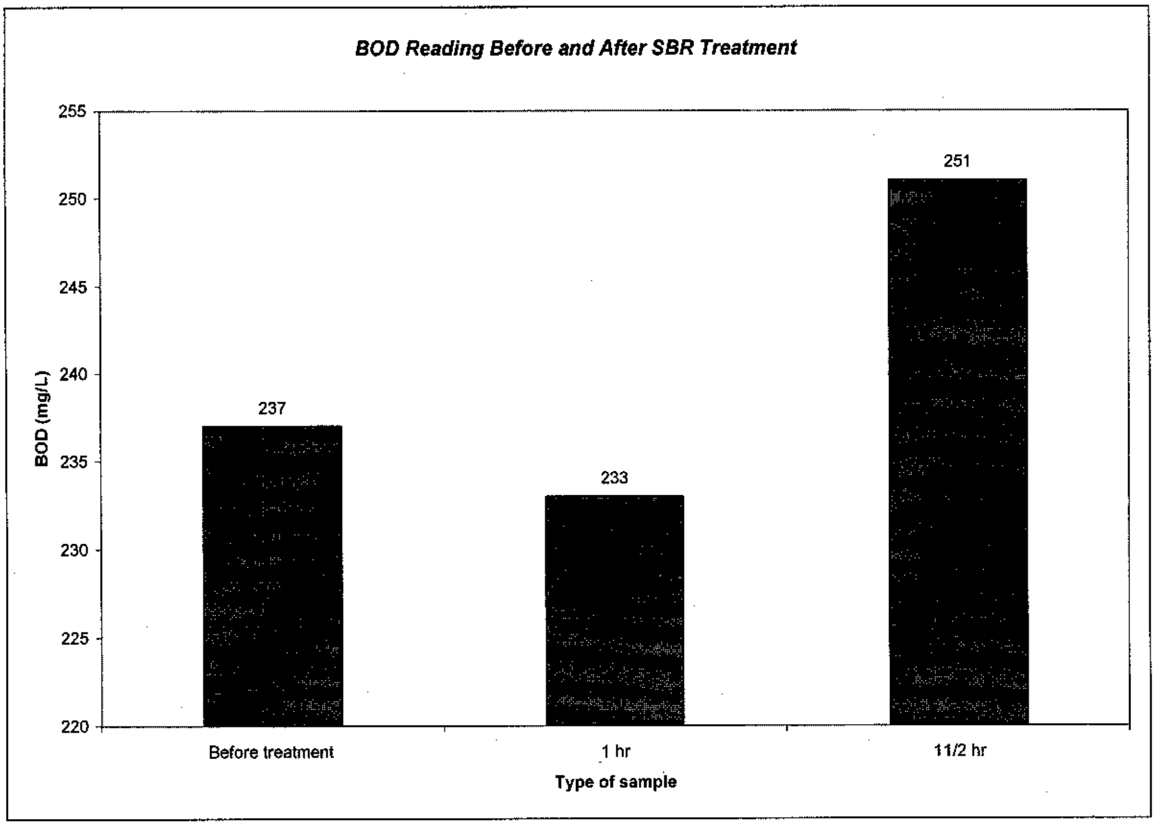


Figure 4.5: BOD reading before and after the SBR treatment.

From this result, the 1-hr has shown reduction in BOD. However, it still cannot comply with grey water criteria for toilet flushing because the BOD reading is much higher than the light grey water criteria for toilet flushing as per Table 1.1. Even though the 1-hr time can reduce the BOD, but the difference in value between before and after the SBR treatment is not high enough to achieve the objective of the experiment.

In theory, the SBR aerobic react times may range from 1.0-hr to 3.0-hr *(WEF,1998)*. The reduction of BOD can only be achieved at the optimum time, which is 1-hr but when it extends to 1 ½-hr, the BOD has increased to a higher value. The reaction time should be at optimum 1-hr or at least 3-hr. If the reaction times drop within the range, the BOD reduction cannot be achieved.

There are many reasons that can contribute to the inaccuracy of the results. The BOD_5 analysis is done for this study because it is the shortest time that can be used. However, the analysis should be done with very high quality water for the dilution method. The sample taken must not be stored more than 48 hours if it is not being used for the analysis. The sample should be used as immediately as it is being collected. Due to the limitation of using the equipment and time constraint, the procedure has not been followed properly.

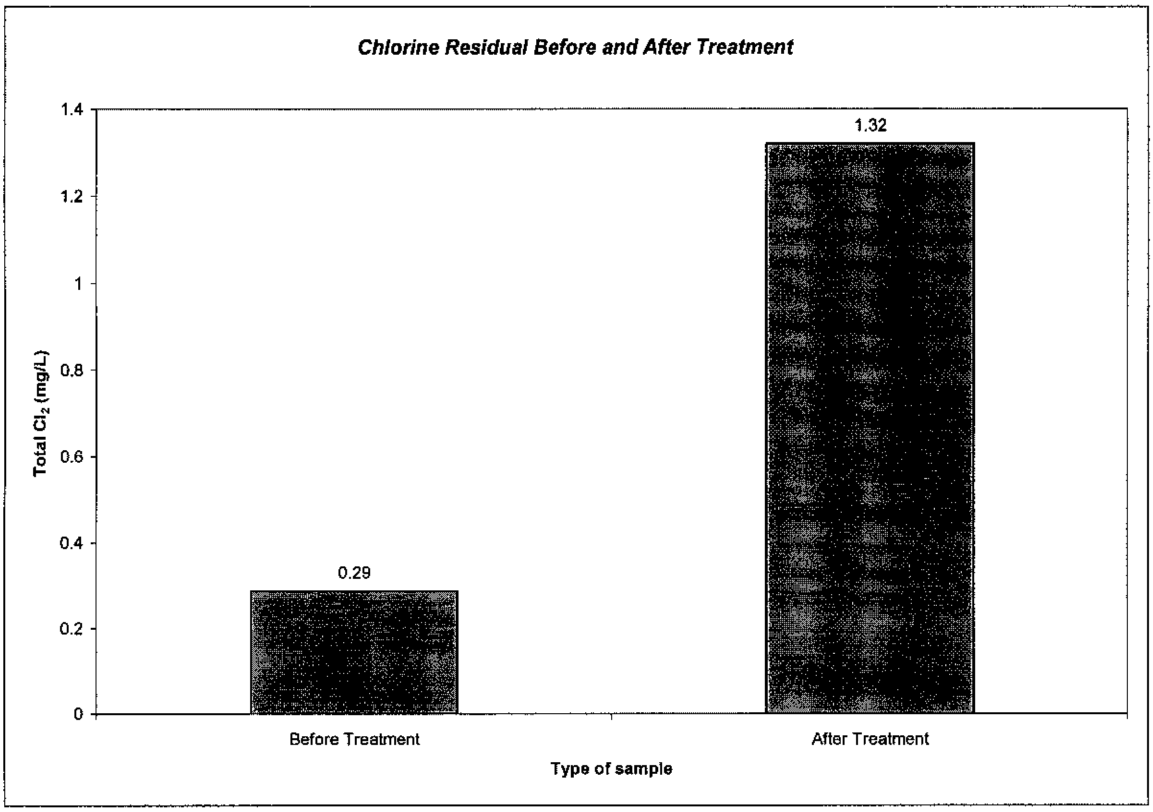
Another factor is the equipment error while doing the experiment. This experiment was done on bench scale by self-arrangement without following the real scale. Other than that, lack of suitable equipment to run this experiment could be one of the causes. As a result, the results from this experiment may not be accurate.

4.4 EXPERIMENT 3: CHLORINATION

- *Results and Discussion on Total Coliform and Chlorine Residual Analysis on Chlorination.*

In the disinfection stage, chlorination has been chosen due to its simplicity and the availability of the chemicals in the laboratory. Sodium hypochlorite is used as a chlorine dosage in this treatment. The analysis used before and after the chlorination treatment is total chlorine for residual chlorine measurement and MPN method for total coliform. According to Figures 4.6 and 4.7, the residual chlorine value has increased from 0.29 mg/L to 1.32 mg/L because the addition of chlorine during the disinfection process. On the other hand, the MPN of total coliform has shown a reduction after the chlorination treatment, which is from 298.4 reduce to 133.78 MPN/100 mL.

Figure 4.6: Total chlorine reading before and after the treatment.



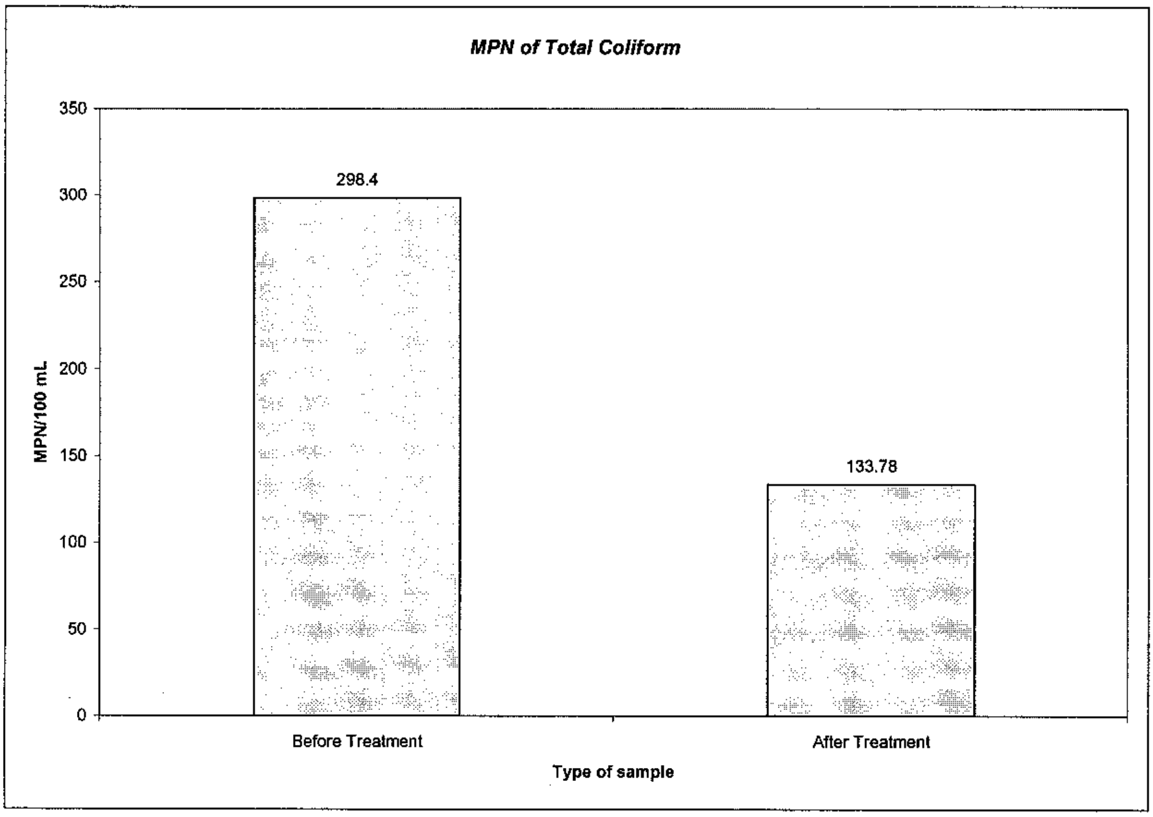


Figure 4.7: MPN reading before and after the treatment.

In the chlorination process, 5 different dosages of sodium hypochlorite are used in order to determine the optimum chlorine dosage. Referring to Figures 4.8 and 4.9, for 20 mg/L chlorine dosage, the MPN is high but the residual chlorine is lower. As the chlorine dosage increases, the MPN decreased but the residual chlorine increased. The increasing number of chlorine residual may due to the addition of chlorine dosage.

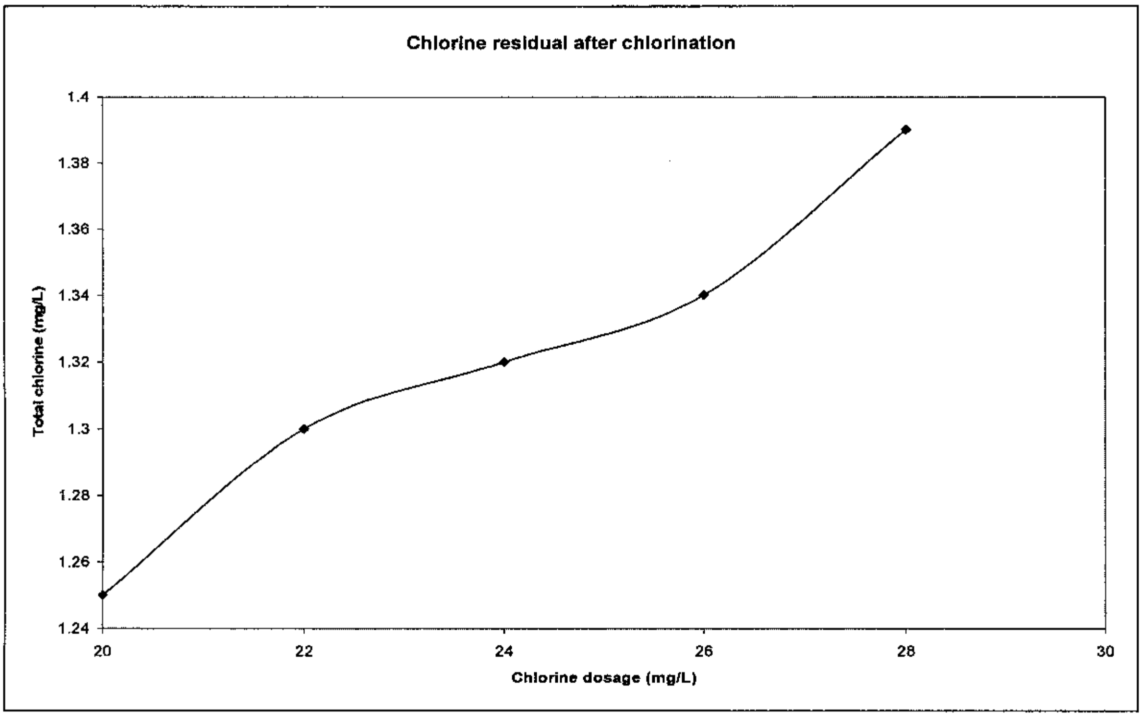


Figure 4.8: Chlorine residual after treatment.

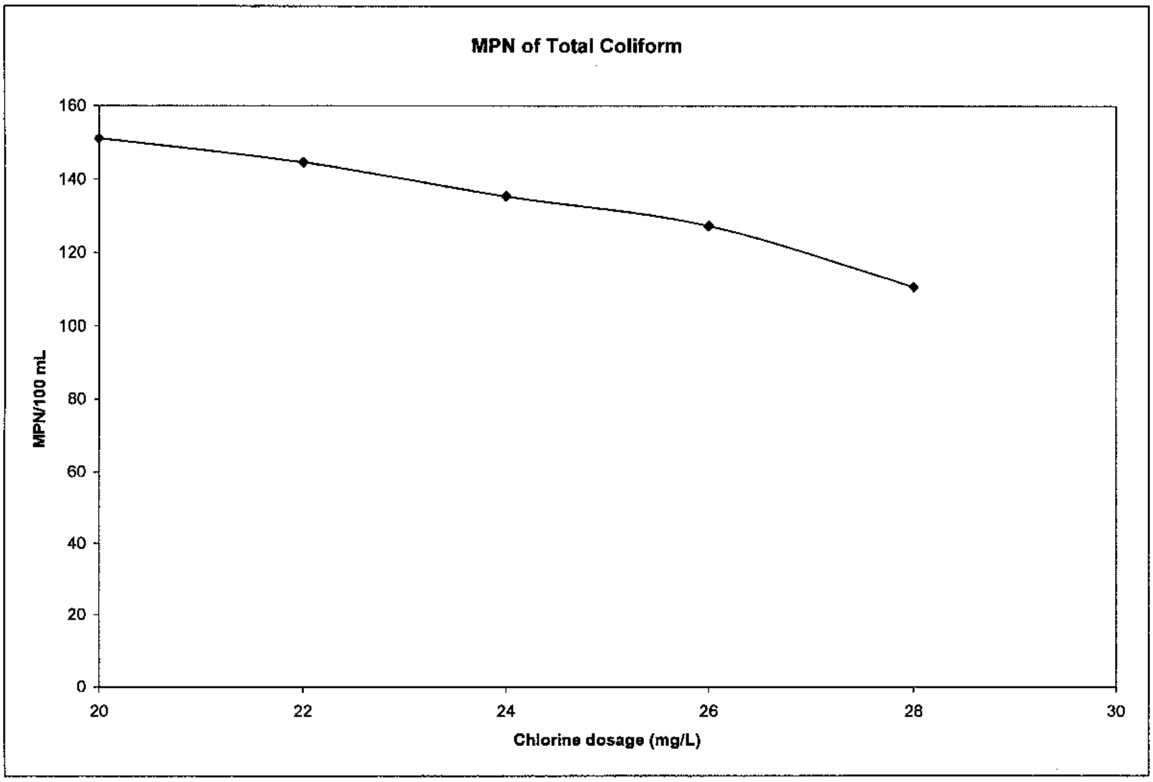


Figure 4.9: Determination of optimum chlorine dosage.

The maintenance of residual chlorine (combined or free) for the purpose of wastewater disinfection is complicated because free chlorine not only reacts with ammonia but also is a strong oxidizing agent. The term "breakpoint chlorination" is the term applied to the process whereby enough chlorine is added to react with all oxidizable substances such that if additional chlorine is added it will remain as free chlorine. The main reason for adding enough chlorine to obtain free chlorine residual is that effective disinfection can usually be assured.

The stepwise phenomena that result when chlorine is added to wastewater containing oxidizable substances and ammonia can be explained by referring to Figure 4.10. Theoretically, this is the graph that should be plotted in determining the optimum chlorine dosage with respect to the reduction of MPN. At the breakpoint (point C), most of the chloramines is formed before the breakpoint is oxidized with continued addition of chlorine. Continued addition of chlorine passing the breakpoint will result in a directly proportional increase in the free available chlorine (unreacted hypochlorite).

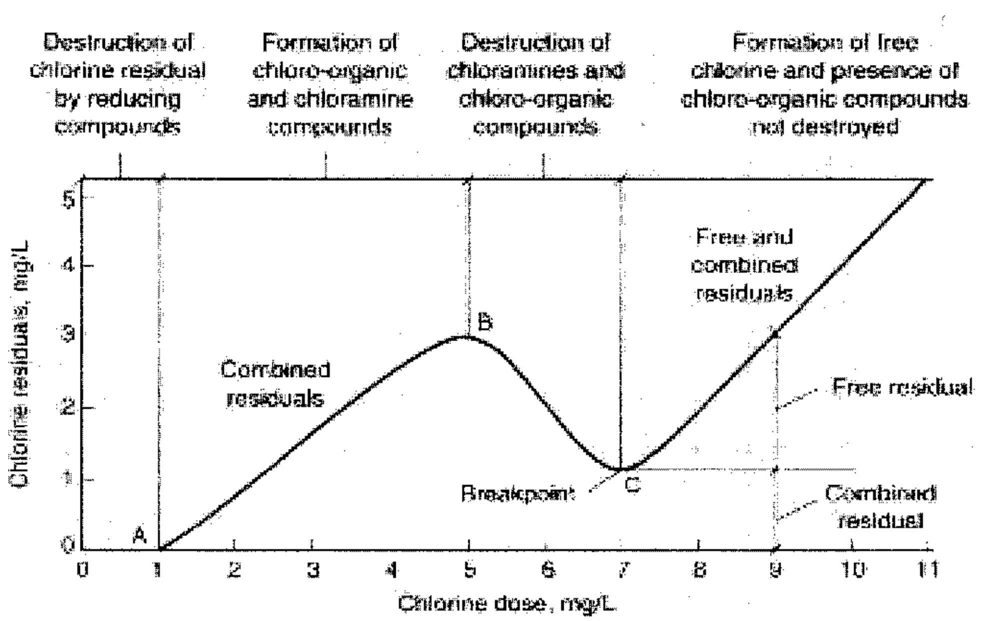


Figure 4.10: Generalized curve obtained during breakpoint chlorination of wastewater. *(Metcalf and Eddy, 2003).*

Referring to Table 1.1, the grey water criteria for toilet flushing, the total coliform should be at drinking water standard which is 20 MPN/100-mL. The lowest MPN value obtained from this experiment is 110.7 at 28 mg/L of chlorine dosage. The reduction cannot be achieved might due to expired date of the powder nutrient for analyzing the total coliform. Because of the time constraint and the limitation of using the equipment, the experiment had to go on in order to achieve the objective of the study.

4.4 ECONOMIC STUDY ANALYSIS

- *Results and calculation on economic study.*

It is estimated that UTP accommodates approximately 8500 peoples which comprise students, lecturers, staffs and other workers. Below are the first 4-months of UTP's water bill:

Table 4.1: Data for first 4-months of UTP's water bill.

Month	Amount (RM)
January 2004	93234.80
February 2004	83542.80
March 2004	93055.20
April 2004	81178.90
Total	*351011.70*

Based on the total amount of the first 4-months water bill:

Average water bill = Total amount / 4-months

= RM 351011.70 / 4-months

= RM 87752.93

Estimation of water bill rate: For usage of 1 m^3 = RM 0.50.

At average water bill per month = RM 87752.93 / RM 0.50

= 175505.86 m^3 is used in UTP.

For 1 person per month basis = (RM 87752.93 / 8500)

= RM 10.32 is the amount he/she should pay.

= (175505.86 m^3 / 8500)

= 20.65 m^3 is the amount he/she has been used.

At one day basis = (20.65 m^3 / 30 days)

= 0.68 m^3 is used (RM 0.34)

A person is estimated to use the toilet seven times per day. Thus, in one day a person has used = 0.01 m^3 x 7 times per day

= 0.07 m^3 amount of toilet flushing used.

= (0.07 m^3 x RM 0.50)

= RM 0.04 amount he/she should pay for toilet flushing.

About 0.68 m^3 of fresh water has been used per day including toilet flushing activities. However, 0.07 m^3 has been used for toilet flushing. Therefore, the amount of grey water produced is 0.61 m^3. By implementing grey water recycling system, the amount of fresh water used for toilet flushing only RM 0.04 (0.07 m^3 x RM 0.50). However, without implementing grey water recycling system, a person has to pay RM 0.25 of fresh water used for toilet flushing because the estimation of 7 times using toilet per day. After grey water treatment, the 0.68 m^3 of treated grey water will be stored in the grey water storage tank in order to use for toilet flushing. Approximately, 8.7 times of treated grey water can be used for toilet flushing. The amount of water in the storage will be saved by estimating the toilet usage at 7 times a day. Thus, the use of fresh water can be reduced and also the water bill. The total saving by implementing this recycle grey water system is:

Percent saving = (0.61 m^3 / 0.68 m^3) x 100 %

= <u>89.7 %.</u>

In terms of money, by subtracting the amount of water bill before and after implementing the grey water recycling system:

One day basis = [(before – after) / before] x 100 %

= [(RM 0.25 – RM 0.04) / RM 0.25] x 100 %

= 84 % is percent saving.

- *Discussion*

Grey water systems are used for one or more of these reasons: 1) a shortage of water supply or sewage facilities, 2) code requirements or 3) favourable economics. The first two rationales are easy to understand. However, the economics of grey water systems are somewhat more complex. Clearly, grey water systems can reduce the incoming fresh water requirement and the sewage generated by a building, thus, saving money by reducing utility charges. *(Lehr, 1986).*

Based on the economic study analysis, a person is estimated to use water at 0.68 m^3 or approximately 680 L per day and the amount of water that the person should pay is RM 0.34. It is estimated that toilet flushing capacity is about 10 L (0.01 m^3) per 1 toilet bowl A person is estimated to use the toilet seven times per day. Thus, a person would use 0.07 m^3 of water to flush the toilet. If the grey water recycling system is implemented, the percent saving in terms of fresh water usage is about 87 % whereas in terms of water bill is about 84 %. Furthermore, this can also reduce the amount of waste water entering the septic tank and the waste water treatment plant load.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Generally, the treatment of grey water for toilet flushing use has met its first objective by conducting three main experiments. The first part of the experiment, which is Coagulation and Flocculation is to reduce turbidity of the grey water comply with grey water criteria for toilet flushing. The analysis after the treatment has shown the turbidity value is lowest than grey water criteria at 20 NTU. The optimum coagulant dose and pH has been determined, which is 70 mg/L and 6.5, respectively.

The second part of the experiment is Sequencing Batch Reactor (SBR) which is used to reduce Biological Oxygen Demand (BOD). The analysis of BOD_5 was carried out before and after the SBR treatment in order to see the reduction. After the SBR analysis, the 1-hour time has shown reduction on BOD_5 but the 1 1/2-hour time has increased more than before the analysis. Further, the value of BOD_5 after the SBR treatment does not comply with the referred toilet flushing standard. Still, this treatment of method can be considered as an alternative to reduce BOD.

The last part of the experiment is Chlorination by using sodium hypochlorite as a chlorine dosage. Before the chlorination treatment, the residual chlorine analysis was carried out to see the content of chlorine in the grey water. The residual chlorine analysis was conducted by total chlorine experiment. Initially, the value of total chlorine before the chlorination treatment is low but after the treatment it has increased due to the addition of chlorine. The MPN of total coliform before the chlorination treatment showed a high value but after the treatment, the MPN has reduced. Five different chlorine dosages have been used in order to find the optimum dosage. The highest chlorine dosage, 28 mg/L can be considered as the optimum dosage because of the lowest MPN value.

The brief economic analysis has also been conducted at the end of the project work. This is to see the cost and water consumption savings if the grey water recycling system is implemented in UTP. The analysis only includes the amount of water bill and its relation to the usage of fresh water. Based on the analysis, the saving is up to 87 % in terms of fresh water consumption and 84 % in terms of water bill. Therefore it is assumed that a person may not have to pay too much bill and less fresh water will be used if the grey water recycling system is implemented.

5.2 RECOMMENDATION

5.2.1 Recommendation on Grey Water Recycling System.

Based on the findings and conclusion made from the experiment conducted, a grey water recycling system can be recommended. A simple grey water recycling system which is shown below may be implemented due to the increase of student in the future. This can reduce the use of fresh water from Jabatan Bekalan Air and the recycled water can be used for toilet flushing purpose.

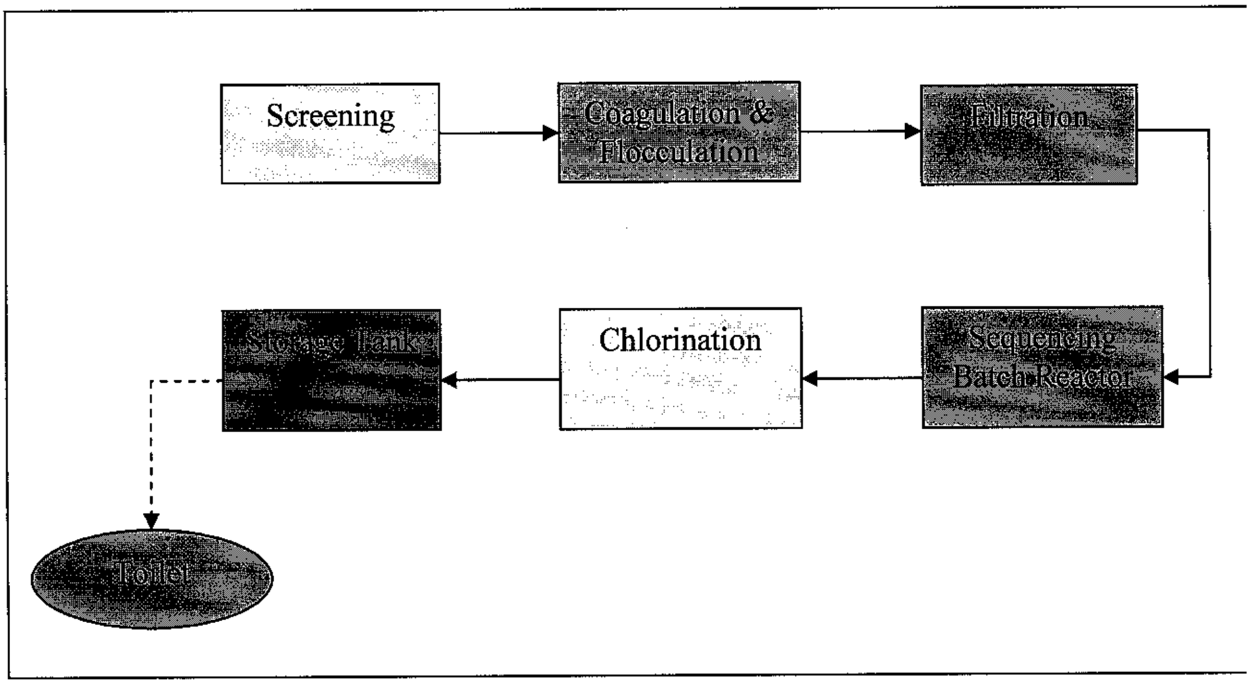


Figure 5.1: Proposed grey water recycling system.

Figure 5.1 shows the overall of grey water recycling system. Screening is one of the pretreatment processes which are the main important process in the wastewater treatment. The purpose of screening is to trap any large particle that can be separated physically. Sometimes, chemicals may be added to raw wastewater before entering the next units for odour control and to improve settling characteristics of the solids. Screening process is required to prevent damage to equipment, pipe clogging and to increase efficiencies in down stream processes.

From the screening process, the effluent will be channeled to the coagulation and flocculation unit. The purpose of coagulation and flocculation is to reduce the turbidity of the water. Coagulation step is necessary to concentrate the fine particles into flocs, which can be removed by filter. Basically, alum is used as a coagulant, which allows the microscopic suspended particles that create the colour in water, to lose their positive charge and "floc" together into larger clumps. Difficulties with coagulation often occur because of slow settling precipitates or fragile flocs that are easily fragmented under hydraulics forces in basins and filter. Polymers are recommended to be used as a coagulant to agglomerate destabilizes particles by chemical joining and bridging.

The flocs which have been produced will be removed by filter. The simple filtration unit can be sand bed filter or multimedia filter (MMF). Both have same functions which is to trap sludge or any large particles that still cannot be trapped during screening process. In sand bed filtration, the media is filled with different layers of sand and gravel. In MMF, the media particles are filled by the small voids. For both filters, when they are saturated with the sludge, the filter can be backwashed to remove the sludge in the bed.

For BOD removal, sequencing batch reactor (SBR) is one of the simplest methods that can be used. Different from activated sludge, in which the sludge is recycled back, the SBR only requires one or two contact tanks. The fill and reaction of the process can occur in one tank. Other recommended method that can be used is rotating biological contactors (RBC). The RBC consists of a series of disks mounted over a shaft that rotates slowly.

The disks are spaced so that effluent and air can enter the space. The biological growth of micro-discs receives alternating exposures to organics and the air. The excess growth of microorganism becomes detached and therefore the effluent requires clarification.

The last treatment process is a disinfection unit which is used to treat water free from microorganisms. Even though the recycling grey water system is not for potable use and only for toilet flushing, it is very important to make sure that the level of bacteria and coliform present is low. In the proposed grey water recycling system, chlorination has been chosen for disinfection due to its simplicity and availability. In addition, chlorine is inexpensive, easy to control, generally safe to use, and adapts to municipal or private systems. However, chlorination may cause residual byproduct which may harm human health. Other recommended method that can be used without using any chemicals are ultraviolet radiation (UV), ozonation, boiling and pasteurization. UV is the most popular method that is highly recommended nowadays. The advantages of using UV disinfection:

- Uses light to kill microorganisms.
- Effective in killing both bacteria and viruses.
- Requires low doses.
- Not depend on pH and temperature.
- Provides no residual disinfection.

However, for UV to be effective, the water should not be cloudy or turbid as this will reflect and scatter much of the UV light, shielding some bacteria in the wastewater from the light and living them unharmed.

5.2.2 Recommendation on Experiments Done.

The experiment that had been conducted had dealt with a lot of problems. Most of the equipment that needs to be used is not enough and sometimes student have to queue to take turn. This would delay the time for the student to do the experiment. There is some equipment that has not been well-calibrated before it can be used for the experiment. As a result, the results obtained might not accurate and do not follow the theory or standards. Sometimes, the chemical reagents used were also out of date. This would also produce inaccurate results.

The recommendation that can be highlighted here is to ensure that the equipment should be enough for a student conduct his/her final year project. Prior to the experiment, the equipment must be calibrated first. This will prevent the student from doing the experiment so many times to get the accurate results. The chemical reagents should also be checked for its expiry date. It should be checked earlier so that the chemical reagents can be ordered much earlier.

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APPENDICES

APPENDIX I: EXPERIMENTAL DATA OBTAINED FROM THE EXPERIMENT.

Table A.1: Turbidity and pH data before treatment.

Beaker	**pH**	**Turbidity (NTU)**
1	11.14	34.8
2	11.33	32.7
3	11.45	35.4
4	11.35	32.4
5	11.59	37.7
6 (Control)	11.56	34.0

Table A.2: Turbidity data, alum dosage and pH value after treatment.

Beaker	***Stage 1 (without altering pH)***		***Stage 2 (with optimum alum dosage at 60 mg/L)***		***Stage 3 (with optimum pH at 6.5)***	
	Turbidity (NTU)	**Alum dosage (mg/L)**	**Turbidity (NTU)**	**pH**	**Turbidity (NTU)**	**Alum dosage (mg/L)**
1	10.8	20	21.8	6	11.59	66
2	14.5	40	8.2	6.3	14.55	68
3	**8.3**	**60**	**5.7**	**6.5**	**9.2**	**70**
4	17	80	9.2	6.7	12.76	72
5	25.5	100	21.3	6.9	11.47	74

Conclusion: pH = 6.5 and alum dosage = 70 mg/L.

(Note: Beaker 6 is not included in the results because it is being used as a control.)

Table A.3: BOD_5 reading before and after treatment.

Bottle	Before Treatment (mg/L)	After Treatment (mg/L)	
		1-hr	1 ½-hr
B1	240	214	233
B2	235	237	272
B3	235	249	247
Average	*237*	*233*	*251*

Table A.4: MPN and Total Chlorine reading before treatment.

Tray	MPN/100 mL	Total Chlorine (mg/L)
1	194.7	0.29
2	263.1	0.29
3	437.4	0.29
Average	*298.4*	*0.29*

Table A.5: MPN and Total Chlorine after treatment.

Tray	Chlorine Dosage (mg/L)	MPN/100 mL	Total Chlorine (mg/L)
1	20	151.0	1.25
2	22	144.5	1.30
3	24	135.4	1.32
4	26	127.3	1.34
5	28	110.7	1.39
Average		*133.78*	*1.32*

APPENDIX II: FIGURES OF JAR TESTER APPARATUS FOR COAGULATION AND FLOCCULATION EXPERIMENT.

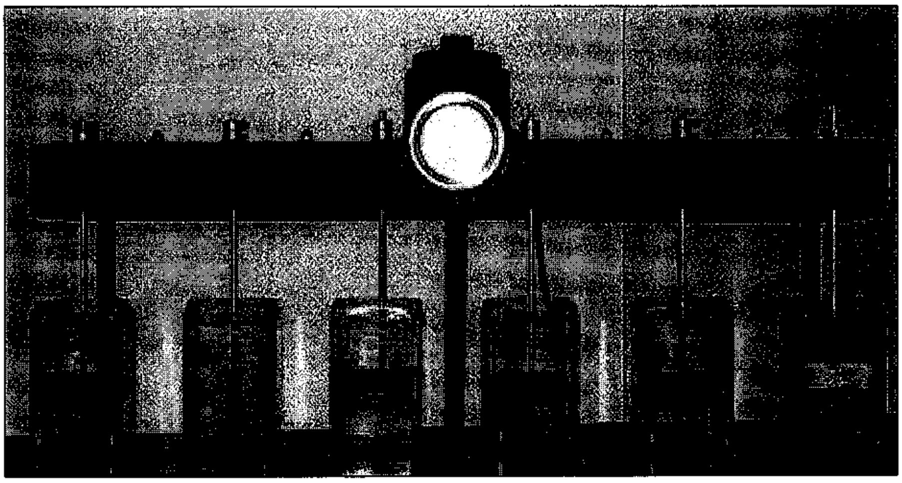

Figure A.6: Photo of jar tester apparatus.

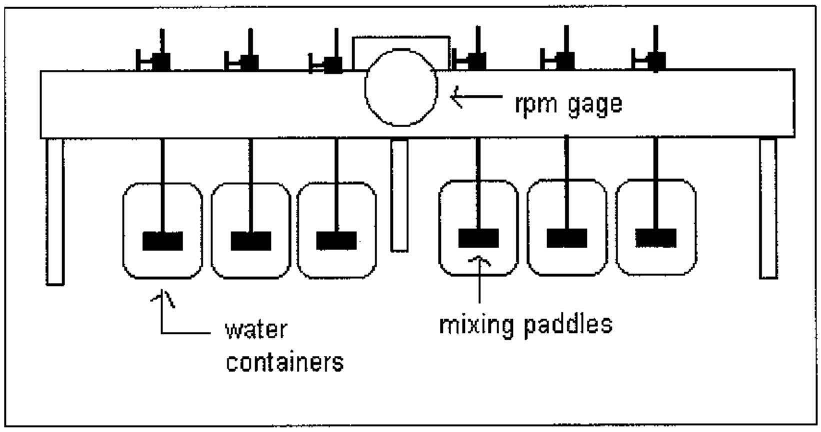

Figure A.7: Diagram of jar tester apparatus.

APPENDIX III: GANTT CHART.

Table A.8: Gantt chart for study of Treatment of Grey Water for Toilet Flushing Use.

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Selection of Project Topic																			
2	First Meeting with Supervisor																			
	- Asking information about the topic - Get some reading materials																			
3	Preliminary Research																			
	- Literature review/background - Defining the objectives - Project planning																			
4	*Submission of Preliminary Report*																			
5	Project Work																			
	- Laboratory work																			
6	*Submission of Progress Report*																			
7	Project Work continue																			
	- Laboratory work - Analyze data and findings - Analyze brief economics study - Find conclusion																			
8	*Pre-Exhibition (Pre-EDX)*																			
9	*Submission of First Dissertation Draft*																			
10	*Submission of Dissertation Final Draft*																			
11	*Oral Presentation and Submission of Hardbound Copy of Project Dissertation*																			