CERTIFICATION OF APPROVAL

Municipal Wastewater Treatment by Sequencing Batch Reactor

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 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.

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ABSTRACT

The report presents municipal wastewater treatment using Biological process by Sequencing Batch Reactor (SBR). The aim of the study is to investigate the SBR on the removal of organic compound and nutrient namely nitrogen and phosphorus. Lab scale SBR model with the presence of anoxic-aeration state was operated in 5 state of cycle in SBR which are the Filling, React, Settle, Decant and Idle period. Effluent discharged during the Decant state have resulted a high quality effluent with low concentration of COD, TSS and ammonia and nitrate. The removal of COD, TSS, ammonia and nitrate was 69.4%, 47.67%, 86.07% and 59.16% respectively. The optimum parameter was evaluated based on the performance at various rates. Hydraulic Retention Time (HRT) of the SBR cycle at 17.22 hours results in the optimum removal reduction of nitrogen.

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1.0 INTRODUCTION

1.1 Background of Study

Malaysia's sewerage industry has evolved over the last half a century. Prior to the country's independence in 1957, there was no known treatment exists for the treatment of sewage. Pre-independence era for sewage treatment is limited to latrines systems only; as the urban development is just started to grow and the rural development is limited to village houses in turn the overall population density at that time never warranted any kind of treatment system for sewage as the nature is still accepting generated sewage (*Rahman Abdul Abdullah, 2006*).

Post independence era concentrated on providing treatment by primitive method as pit and bucket latrines, over hanging latrines and direct discharge to rivers and seas. The need for proper sanitation arose when the country developed and moved from agriculture to an industry-based economy. In the 1960s, sewage treatment systems in the form of individual septic tanks (IST) and poor flush systems were introduced (*Rahman Abdul Abdullah, 2006*). Small communal septic tanks engaging mainly primary treatment such as communal septic tanks (CST) and Imhoff tanks (IT) started developing.

A decade later in 1970s, as the population growth doubled the production sewage is also doubled but the existing systems were incapable to treat the large production of sewage. Therefore, new technology was introduced to carry out biological treatment process in the form of oxidation ponds systems with natural means of treatment. This system required large land area for the treatment to be effective. As the oxidation pond concept became popular in the urban area; it helps the industry by introducing connected services for the first time in Malaysia (*Rahman Abdul Abdullah, 2006*). This is the turning point for much bigger centralized concepts as we can witness in the greater Kuala Lumpur capital areas.

The combination of biological treatment and connected services give way to the mechanization of sewerage treatment technology in late 1980s and 1990s. The industry

1.3 Objective & Scope of Study

The objectives to be achieved by the end of this project are:

- To investigate the operations required in conducting the Sequential Batch Reactor (SBR) treatment and so to obtain its optimum performance.
- To study the appropriate parameters of the biological process and all the reaction involves.
- To conduct the water quality analysis of municipal wastewater effluent as food for the biological process of specific feeding state.

The scope of works involves a detail review of SBR operations design and including the testing for municipal wastewater effluent. The effluent concentration and composition was determined and the water sample would be taken at the same day when the experiment was conducted.

2.0 LITERATURE REVIEW

2.1 Introduction

Wastewater is sewage, stormwater and water that have been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both **residential** and **nonresidential** sources *(National Small Flows Clearing House, 1997)*.

2.2 Residential Wastewater

Although the word *sewage* usually brings toilets to mind, it actually is used to describe all types of wastewater generated from every room in a house. In the U.S., sewage varies regionally and from home to home based on such factors as the number and type of water-using fixtures and appliances, the number of occupants, their ages, and even their habits, such as the types of foods they eat *(National Small Flows Clearing House, 1997)*. However, when compared to the variety of wastewater flows generated by different nonresidential sources, household wastewater shares many similar characteristics overall.

There are two types of domestic sewage: blackwater, or wastewater from toilets, and graywater, which is wastewater from all sources except toilets. Blackwater and graywater have different characteristics, but both contain pollutants and disease-causing agents that require treatment.

However, some areas in the U.S. permit the use of innovative systems that safely recycle household graywater for reuse in toilets or for irrigation to conserve water and reduce the flow to treatment systems *(National Small Flows Clearing House, 1997)*.

2.3 Non-residential Wastewater

Nonresidential wastewater in small communities is generated by such diverse sources as offices, businesses, department stores, restaurants, schools, hospitals, farms, manufacturers, and other commercial, industrial, and institutional entities. Stormwater is a nonresidential source and carries trash and other pollutants from streets, as well as pesticides and fertilizers from yards and fields *(National Smalls Flows Clearing House, 1997)*.

Because of the variety of nonresidential wastewater characteristics, communities need to assess each source individually or compare similar types of nonresidential sources to ensure that adequate treatment is provided. For example, public restrooms may generate wastewater with some characteristics similar to sewage, but usually at higher volumes and at different peak hours. The volume and pattern of wastewater flows from rental properties, hotels, and recreation areas often vary seasonally as well.

Laundries differ from many other nonresidential sources because they produce high volumes of wastewater containing lint fibers. Restaurants typically generate a lot of oil and grease. It may be necessary to provide pretreatment of oil and grease from restaurants or to collect it prior to treatment, for example, by adding grease traps to septic tanks.

Wastewater from some nonresidential sources also may require additional treatment steps. For example, stormwater should be collected separately to prevent the flooding of treatment plants during wet weather. Screens often remove trash and other large solids from storm sewers. In addition, many industries produce wastewater high in chemical and biological pollutants that can overburden onsite and community systems. Dairy farms and breweries are good examples-communities may require these types of nonresidential sources to provide their own treatment or preliminary treatment to protect community systems and public health *(National Small Flows Clearing House, 1997)*.

2.4 Fundamental Concept

The wastewater treatment is a process to reduce pollutant in the water. It could be applied for fresh water to purify it to become suitable for human use, or could be applied for sewage and used water to treat it before disposal into the sea or reuse it for irrigation purposes. The treatment could be done by mechanical process, biological process and advanced treatment (physico-chemical process).

2.5 Principal of Wastewater Management Issues

The wastewater is a liquid waste generated from different sources like households, economic enterprises and agriculture. It may be disposed in different ways with or without treatment, and in some cases this type of wastewater are reused in agriculture and forest activity.

The pollutants in wastewater vary depending on the source of wastewater. The household wastewater contains organic pollutant, but the manufacturing wastewater contains heavy metals *(Amman Khamis Raddad, 2005)*. The wastewater is classified by sources depending on economic activities such as:-

- Agriculture, forestry and fishing
- Mining and quarrying
- Manufacturing Industries
- Production and distribution of electricity
- Construction
- Households
- Commercial and others

2.6 Wastewater Treatment

Increasing in urban populations and production growth generally boost large amount of volume for the wastewater distribution. In large parts of the world, substantial amounts of discharges for domestic sewage and industrial effluents are still untreated or not treated properly according to its required standard. And in urban areas with sewage treatment plants, the treatment capacities are often far exceeded by the rapid pace of urban growth and development *(Amman Khamis Raddad, 2005)*.

Wastewater treatment plants act as the natural self-purification of water. The quality of treated wastewater is largely dependent on the type of treatment technology used. In primary (mechanical) treatment, only settleable materials are separated from wastewater, and the remainder is released again without further treatment. In secondary (biological treatment), organic material is mineralized through the action of bacteria; the net result is that the BOD is decreased. In advanced treatment, nutrient are removed.

The main function of biological method is to remove biodegradable matter. Thus, the important variable to record is the quantity of BOD in the influent entering the plant and the quantity released by the plant in the treated effluent. The difference constitutes an important measure of the treatment efficiency. Whereas a properly functioning biological treatment plant may remove as much as 90% of BOD, a primary treatment plant may remove only about 30%.

2.7 Total Wastewater Treatment

Wastewater treatment is a process of rendering wastewater fit to meet applicable environmental standards or other quality norms for recycling or reuse. Three broad type of treatment are distinguished; which are, mechanical, biological and advanced. For the purpose of calculating the total amount of treated wastewater, volumes reported should be shown only under the highest volume to which the plant was subjected. Wastewater treated mechanically as well as biologically should be shown under biological treatment, and wastewater treatment treated in accordance with all three types should be reported under advanced treatment.

2.8 Type of Wastewater Treatment Process

I. Mechanical Treatment Process

Mechanical treatment is a process of physical and mechanical nature which results in decanted effluents and separate sludge. Mechanical processes are also used in combination and/or in conjunction with biological and advanced unit operation.

In this operation a course material like plastics and wood are separated by lowering the water flow speed in large basins, sand and fine inorganic particles will settle, and periodically removed as sludge. Floating compounds like oils are skimmed of the surface of water. Mechanical treatment is understood to include at least such processes as sedimentation, flotation, and etc.

II. Biological Treatment Process

Biological treatment is a process which employs aerobic or anaerobic micro-organisms and result in decanted effluents and separated sludge containing microbial mass together with pollutants.

The anaerobic and aerobic microorganism oxidize the organic matter; as result of this process the fine minerals sludge will settle and the remaining fluid is discharge into a surface water body or alternatively reused.

Biological treatment processes are also used in combination and/or in conjunction with mechanical and advanced unit operations.

III. Advanced treatment Process

A process which is capable of reducing specific constituents in wastewater not normally achieved by other treatment options like Nitrogen (N), Phosphorus (P), pathogens and worm eggs is called an advanced treatment process.

Advanced treatment technology covers all unit operations which are not considered to be mechanical or biological. In wastewater treatment this includes e.g. chemical coagulation, flocculation and precipitation, break-point chlorination, stripping, mixed media filtration, micro-screening and selective flotation. Advanced treatment processes are also used in combination and/or in conjunction with mechanical and biological unit operations.

2.9 Water Quality

Water quality indicates the amount of condition and substance that affecting the quality of water. The categories are presented as below:-

- Physical condition
- General chemical condition
- Pathogens
- Oxygen consuming substances

- Nutrients
- Toxic substances
- Radioactive substances

2.10 Parameters in Water Quality

a) Oxygen Demand (BOD)

Amount of dissolved oxygen required by organisms for the aerobic decomposition of organic matter present in water. This is measured at 20 degrees Celsius (20°C) for a period of five days. The parameter yield information on the degree of water pollution with organic matter. Amount of oxygen required by bacteria to oxidize biodegradable organic matter under aerobic conditions. BOD is one of the most important indicators of water pollution

b) Dissolved Oxygen (DO)

Amount of gaseous oxygen (O_2) actually present in water expressed in terms of either of its presence in the volume of water (milligrams of O_2 per liter).

c) Chemical Oxygen Demand (COD)

COD is defined as the total quantity of oxygen required for the oxidation of organic pollutants into carbon dioxide and water. It is based upon the fact that all organic compounds, with a few exceptions, can be oxidized by the chemical action of strong oxidizing agents under acid conditions.

d) Total Dissolved Solids (TDS)

It is defined as the total weight of dissolved mineral constituents in water. Excessive amounts make the water unsuitable for drinking or for use in industrial processes.

e) Total Phosphorus (P or TP)

Sum of phosphorus compounds in water measured in terms of phosphorus. Phosphorus is an element that, while being essential to life as a key limiting nutrient factor, nevertheless contributes together with nitrogen to the eutrophication of lakes other bodies of water.

f) Total Nitrogen (TN)

Sum of inorganic and organic nitrogen compounds (excluding N_2) in water measured in terms of nitrogen. It is comprised of organic nitrogen, ammonia, nitrite and nitrate. The organic fraction consists of a complex mixture of organic compound including amino acids, amino sugars, and proteins. The compounds that comprise the organic fraction can be soluble or particulate. Nitrogen together with phosphorus can contributes to eutrophication of water bodies.

g) Feacal Coliform

Microorganisms found in the intestinal tract of human beings and animals. Their presence in water indicates faecal pollution rendering water unsuitable for drinking without prior treatment.

h) TKN (Total Kjeldahl Nitrogen)

The Total Kjeldahl Nitrogen is the sum of organic nitrogen; ammonia (NH3) and the ammonium (NH4) in biological wastewater treatment. TKN is determined in the same manner as organic nitrogen, except the ammonia is not driven off before the digestion step. It is named after Johan Kjeldahl. TKN is measured in milligrams per liter (mg/L). High measurement in TKN typically results from sewage and manure discharges to water body.

i) Total Solids (TS)

The term "total solids" is refers to the matter suspended or dissolved in water or wastewater and related to both conductance and turbidity. Total solids include both total suspended solid, the portion of total solid retained by a filter and total dissolved solids, the portion that passes through a filter.

j) Total Suspended Solids (TSS)

Total suspended solids are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

k) pH

pH is one of the important quality parameter of both natural water and wastewater. The usual mean of expressing hydrogen-ion concentration is as pH, which is defined as the negative logarithm of the hydrogen-ion concentration.

l) Turbidity

Turbidity is a measure of the light-transmitting properties of water, is another test used to indicate the quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. The measurement of turbidity is based on comparison of the intensity of light scattered by a sample to the light scattered by a reference suspension under the same conditions.

2.11 Sequencing Batch Reactor (SBR)

2.11.1 Introduction

SBRs are used all over the world and have been around since the 1920s. With their growing popularity in Europe and China as well as the United States, they are being used successfully to treat both municipal and industrial wastewater, particularly in area characterized low or having different flow patterns *(U.S. Environmental Protection Agency, 1999)*. Municipalities, resorts, casinos and a number of industries, including diary, pulp and paper, tanneries and textiles, are using SBRs as practical wastewater treatment alternatives.

Improvement in equipment and technology, especially in aeration devices and computer control systems, has made SBRs a viable choice over the conventional activated-sludge system. These plants are very practical for a number of reasons such as areas where there is an area of limited spaces, treatment takes place in a single basin instead of multiples basins, allowing in small area. Effective decanters will achieve a low total suspended solid value which is less then 10 miligrams per liter (mg/l) that eliminate the need for a separate clarifier *(Al-Rekabi, 2007)*.

The treatment cycle can also be adjusted to undergo few of condition such as anoxic, anaerobic and aerobic conditions in order to achieve biological nutrient removal which includes nitrification, denitrification and some for phosphorus removal. Biochemical Oxygen Demand (BOD) levels of less then 5 mg/L can be achieved consistently *(Al-Rekabi, 2007)*. Total nitrogen limits of less than 5 mg/L can be achieved by aerobic conversion of ammonia to nitrates (nitrification) and anoxic conversion of nitrate to nitrogen gas (denitrification) within the same tank. Low phosphorus limits of less than 2 mg/L can be attained by using a combination of biological treatment (anaerobic phosphorus absorbing organisms) and chemical agents (aluminium or iron salts) within the vessel and treatment cycle.

Wastewater discharge permits are becoming more severe and SBRs offer a cost-effective way to achieve lower effluent limits. Note that discharge limits that require a greater degree of treatment may need the addition of tertiary or an expansion of filtration unit following the SBR treatment phase.

The SBR system is a modern version of fill and draw system, consisting of one or more tanks which provide the function of waste stabilization and solids separation. The number of tank will varies in accordance to the sophistication of the control system. In biological wastewater treatment, each tank has several basic operational modes and periods. The periods are filling, react, settle, draw/decant and idle in a sequence of time. These operational modes can be modified depending on the operational strategies desired *(Al-Rekabi, 2007)*.

2.11.2 Common SBR Characteristics

Generally SBRs are a variation of the activated-sludge process. The different between SBR and the activated-sludge plants is, it combines all the treatment steps into a single basin, or tank whereas conventional facilities rely on multiple basins. In the most basic form, SBR system is a set of tanks that operate in a fill and draw basis. Each tank in the SBR system is filled during a discrete period of time and then operated as a batch reactor. After desired treatment, the mixed liquor is allowed to settle and the clarified supernatant and then drawn from the tank.

2.11.3 Period or Phase in SBR Cycle

The cycle of each tank in a typical SBR is divided into five discrete time period which is **Fill, Reach, Settle, Decant** and **Idle**. There are several types of fill and react periods, which may vary according to the aeration and mixing procedures. Sludge wasting may take place near the end of react or during settle, draw or idle time period. Central to SBR design is the use of a single tank for multiple aspects of wastewater treatment *(A-Rekabi, 2007)*.

- Fill

The influent to the tank may be either raw wastewater (screened) or primary effluent. It may either be pumped in or allowed to flow in by gravity. The feed volume is determined by number of factors including desired loading, detention time and expecting settling characteristics of the organisms. The time of fill depends on the volume of each tank, the number of tanks in operation, and the extent of diurnal variations in the wastewater flow rate. In general, any aeration system can be used such as diffused system, floating mechanically or jet. The ideal operation system, however, must be able to provide both a range of mixing intensities, from zero to complete agitation, and the flexibility of mixing without aeration. Level sensing devices, timers or in-tank probes can be used to switch the aerators and or mixers on and off as desired (for the measurement of either dissolved oxygen or ammonia nitrogen).

- React

Biological reactions during fill period are completed during react. As in fill, alternating condition of low dissolved oxygen concentrations such as mixed react and high dissolved oxygen concentrations such as aerated react may be required. If the liquid level remains at the maximum throughout react, sludge wasting can take place during this period as a simple means for controlling sludge age. By wasting during react, sludge is removed from the reactor as a means of maintaining and decreasing the solid volume. Time dedicated to react can be as high as 50% or more of total cycle time. The end of react may be dictated by a time specification (e.g. the time in react shall always be 1.5 hrs) or a level controller in an adjacent tank.

- Settle

In the SBR, solids separation takes place under quiescent conditions (i.e. without inflow or outflow) in a tank, which may have a volume more than ten times that of the secondary clarifier used for conventional continuous-flow activated sludge plant. This major advantage in the clarification process results from the fact that the entire aeration tank serves as the clarifier during the period when no flow enters the tank. Because all of the biomass remains in the tank until some fraction must be wasted, there is no need for underflow hardware normally found in conventional clarifiers. By way of contrast, mixed liquor is continuously removed from a continuous-flow activated sludge aeration tank and passed through the clarifiers only to have a major portion of the sludge returned to the aeration tank.

- Decant/ Draw

The withdrawal mechanism may take one of several forms, including a pipe fix at some predetermined level with the flow regulated by an automatic valve or pump. The time dedicated to draw can range from 5 to more than 30% of the total cycle time. The time in draw, however, should not overly extend because of possible problems with the rising sludge.

- Idle

The period between draw and fill is termed idle. Despite its name, this "idle" time can be used effectively to waste settled sludge. While sludge wasting can be as infrequent as once every 2 to 3 months, more frequent sludge wasting programs are recommended to maintain process efficiency and sludge settling.

2.11.4 Continuous-Flow System

SBR facilities commonly consist of two or more basins that operate in parallel but single basin configurations under continuous-flow conditions. In this modified version of the SBR, flow enters each basin on a continuous basis. The influent flow into the influent chamber, which has inlets to the react basin at bottom of the tank to control the entrance speed therefore, it will not agitate the settle solids. Continuous-flow systems are not true batch reaction because the influent is constantly entering the basin. Ideally, a true batch reactor SBR should operate under continuous flow only under emergency situations.

Plants that have been designed as continuous-inflow systems have been shown to have poor operational conditions during peak flows. Some of the major problems of continuous-inflow systems have been overflows, washouts, poor effluent, and permit violations *(Al-Rekabi, 2007)*.

2.11.5 Application SBR to Treat Various Wastewater

The Sequencing Batch Reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. A SBR operates in a true batch mode with aeration and sludge settlement both occurring at same tank. The major difference between SBR and conventional continuous-flow activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. In addition, the SBR system can be designed with the ability to treat a wide range of influent volumes whereas the continuous system is based upon a fixed influent flow rate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence *(Al-Rekabi, 2007)*.

SBRs produce sludge with good settling properties providing the influent wastewater is admitted into the aeration in a controlled manner *(Al-Rekabi, 2007)*. Control range from a simplified float and timer based system (Software basis) with a color graphics using either flow proportional aeration to reduce energy consumption and enhance the selective pressures for BOD, nutrient removal, and control of filaments *(Al-Rekabi, 2007)*. An appropriately designed SBR process is a unique combination of equipment and software. Working with automated control reduces the number of operator skill and attention requirement.

2.12 Comparison on Performance of SBR with Other Type of Sewerage Treatment Plants

A recent World Bank Report came out strongly in favor of stabilization ponds as the most suitable wastewater treatment system for effluent use in agriculture. Table 15 provides a comparison of the advantages and disadvantages of ponds with those of high-rate biological wastewater treatment processes. Stabilization ponds are the preferred wastewater treatment process in developing countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply *(FAO Corporate Document Repository)*

Table 2.1: Comparison Performance on Various Treatment Systems

	Criteria	Package Plant	Activated Sludge Plant	E.A.A.S.	Biological Filter	Oxidation Ditch	Aerated Lagoon	W.S.P.S.	SBR
Plant Performance	BOD Removal	F	F	F	F	G	G	G	G
	FC Removal	P	P	F	P	F	G	G	G
	SS Removal	F	G	G	G	G	F	F	G
	Helmith Removal	P	F	P	P	F	F	G	G
	Virus Removal	P	F	P	P	F	G	G	G
Economic Factors	Cheap & Simple Construction	P	P	P	P	F	F	G	P
	Simple Operation	P	P	P	F	F	P	G	G
	Land Requirement	G	G	G	G	G	F	P	G
	Maintenance Costs	P	P	P	F	P	P	G	P
	Energy Demand	P	P	P	F	P	P	G	G
	Sludge Removal Costs	P	F	F	F	P	F	G	F

(FAO Corporate Document Repository)

Key:

E.A.A.S. = Extended Aeration Activated Sludge

W.S.P.S. = Waste Stabilization Pond System

FC = Focal Coliform

SS = Suspended Solids

F = Fair

G = Good

P = Poor

2.13 Comparison on Effluent Treated by Activated-Sludge and SBR

The table below represents the treatment result of the Activated-Sludge Plant and a Sequential Batch Reactor Plant.

Table 2.2: Influent and Effluent Discharge by Pure-oxygen Activated Sludge

Parameters	Mean Influent	Mean Effluent	% Removal
Flow (mg/d)	6.60	5.98	-
BOD5 (mg/L)	339.00	10.50	96
COD (mg/L)	-	-	-
TSS (mg/L)	190.00	8.70	95
Ammonia Nitrogen (mg/L)	28.80	12.90	55
Nitrate (mg/L)	0.28	0.77	-175
Phosphorus (mg/L)	4.73	3.03	40

(United State Environmental Protection Agency, 2004)

Table 2.3: Influent and Effluent Discharge by Sequential Batch Reactor

Parameters	Mean Influent	Mean Effluent	% Removal
Flow (mg/d)	0.94	-	-
BOD5 (mg/L)	246.00	2.00	99
COD (mg/L)	-	-	-
TSS (mg/L)	230.00	3.00	99

Ammonia Nitrogen (mg/L)	23.90	0.50	98
Nitrate (mg/L)	-	-	-
Phosphorus (mg/L)	-	-	-

(Borough Nazareth, Pennsylvania, 1998)

From the data above, we can conclude that the effluent on the Sequential Batch Reactor produce the lowest concentration of BOD_5, TSS and ammonia. This shows that sequential batch has the high efficiency on removing organic matters although it is using the same influent constituents.

2.14 Comparison between the Process on Conventional Activated Sludge Plants with Sequential Batch Reactor

These are the common type of treatment plant used either by residential or industrial development which are the activated-sludge plant and the sequential batch reactor plant. The diagram shows the comparison process between these two different plants.

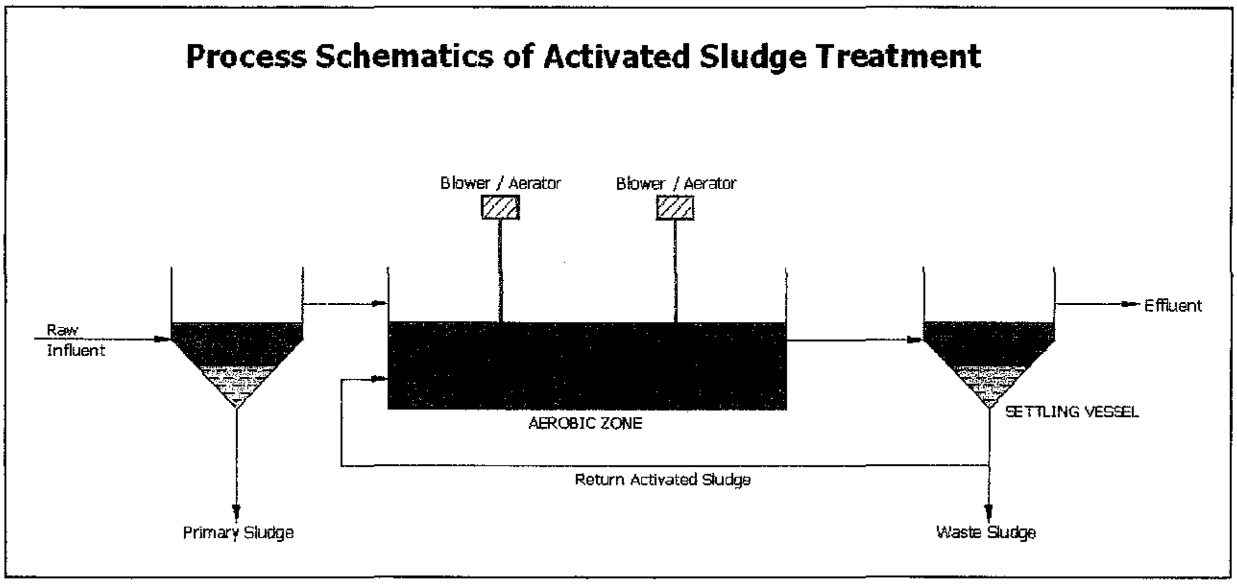


Figure 2.1: Process Schematic of Activated Sludge Treatment

Conventional Activated Sludge Plant

In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

Sequencing Batch Reactor Plant

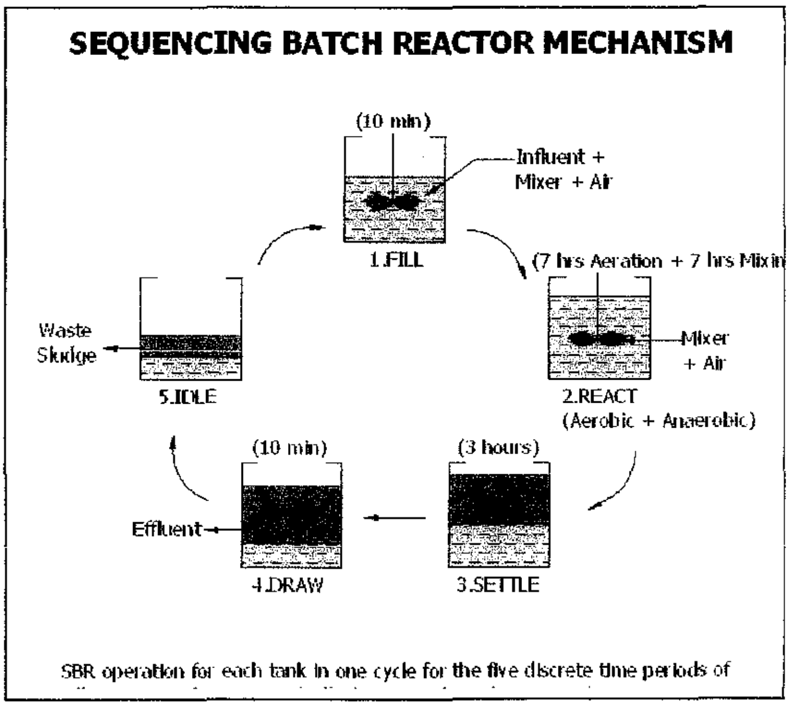


Figure 2.2: Mechanism of Sequential Batch Reactor *(Environmental Protection Agency)*

There are two major classifications of SBRs which are the intermittent flow (IF) or "true batch reactor," that employs all the steps (Refer Figure 2.2 and 2.3) and the continuous flow (CF) system, which does not follow these steps. It can be designed and operated to enhance removal of nitrogen, phosphorus and ammonia, in addition to removing TSS and BOD_5. The intermittent flow SBR accepts influent only at specified intervals and, in general, follows the five-step sequence.

Schematic Diagram of a Batch Reactor

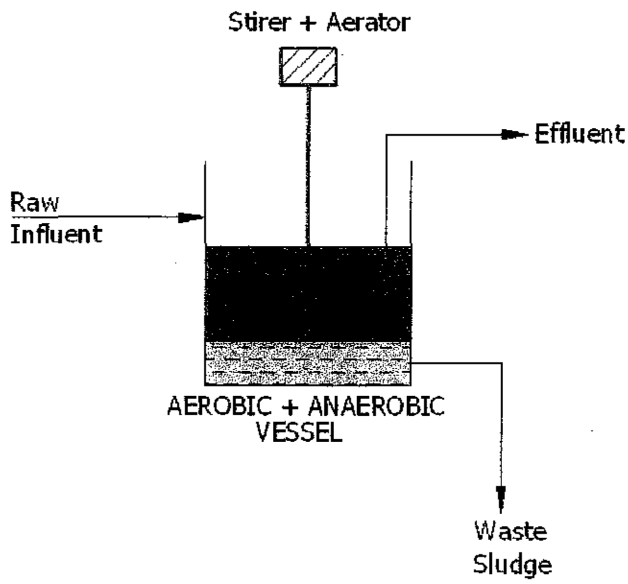


Figure 2.3: Schematic Diagram of a Batch Reactor

There are usually two IF units in parallel. Because this system is closed to influent flow during the treatment cycle, two to three units may be operated in parallel (Refer Figure 2.4), with one unit open for intake while the other runs through the remainder of the cycles. In the continuous inflow SBR, influent flows continuously during all phases of the treatment cycle. To reduce short-circuiting, a partition is normally added to the tank to separate the turbulent aeration zone from the quiescent area

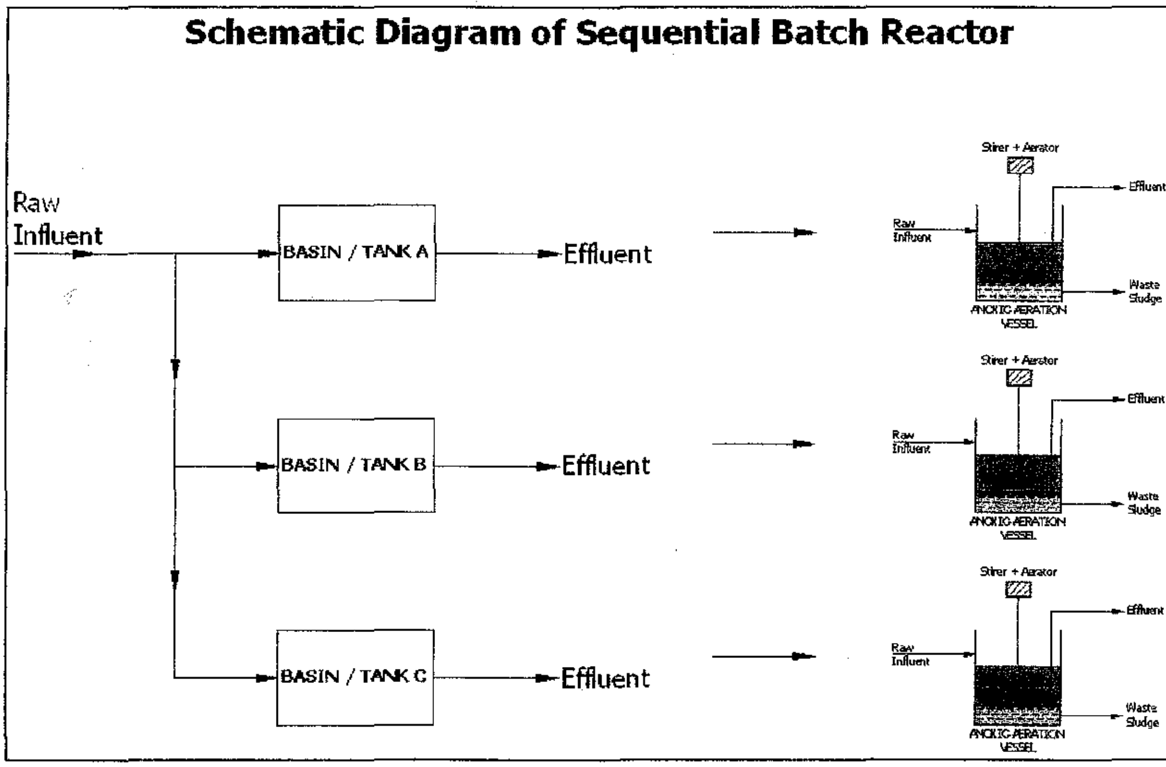


Figure 2.4: Showing the Mechanism of Sequencing for a Batch Reactor

2.15 Advantages and Disadvantages of SBR

Some advantages and disadvantages of SBRs are listed below:

Advantages *(T3, October 2006)*

- Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.
- Operating flexibility and control.
- Minimal requirement of land area.
- Potential capital cost savings by eliminating clarifiers and other equipment.

Disadvantages *(T3, October 2006)*

- A higher level of sophisticated is required (compared to conventional systems), especially for larger systems, of timing units and controls.

- A higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.
- Potential of discharging floating or settled sludge during the draw or decant phase with some SBR configuration.
- Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.
- Potential requirement for equalization after the SBR, depending on the downstream processes.

3.0 METHODOLOGY

The methodology conducted throughout the project is as follows:

- Fabricating the model for SBR laboratory scale.
- Parameter selection for the laboratory testing.
- Maintaining the sludge acclimatization during before preparing the tests.
- Laboratory analysis of sample effluents for domestic wastewater for measurement of water quality.

The SBR model used in this study consisted of a single tank (batch) equipped with diffuser and decanter to draw the effluent sludge. The influent entered the tank by the gravity flow. The filling period was design for 10 minutes.

The parameters that evaluated during the experiment were; Mix Liquor Volatile Suspended Solid (MLVSS), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammonia Nitrogen (NH_3-N) and Nitrate. However, the most important part for this test was the measurement of nitrogen concentration that lies at the end of the experiment.

At the beginning before treatment was started, the first batch of effluent was prepared in the vessel and the tank was maintained and stabilized for acclimatization. The probation period was expected to be in several months before it can be used as a fully functional treatment plant which produced a high quality effluent that contain less concentration of COD, TSS, ammonia and nitrate (according to the discharge standard).

The primary phase for the laboratory work was to test the domestic wastewater effluent while the final phase of the experiment was conducted in order to measure the optimum parameters.

Laboratory Scale Test for SBR Model Used In the Experiment

SBR Configuration for Laboratory Scale Test

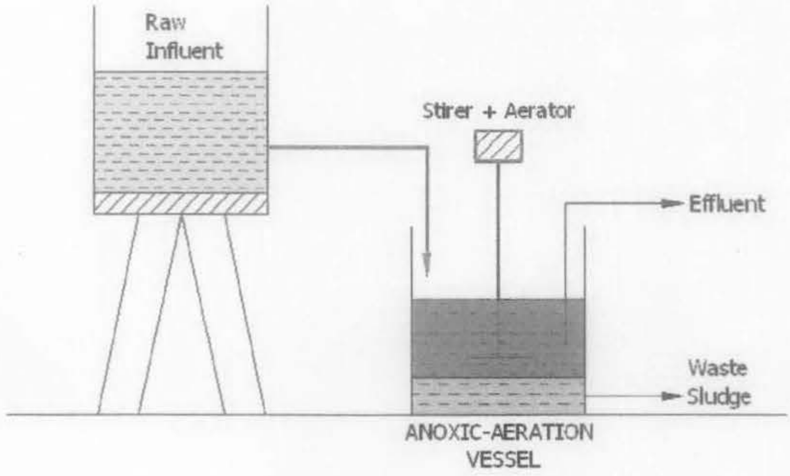
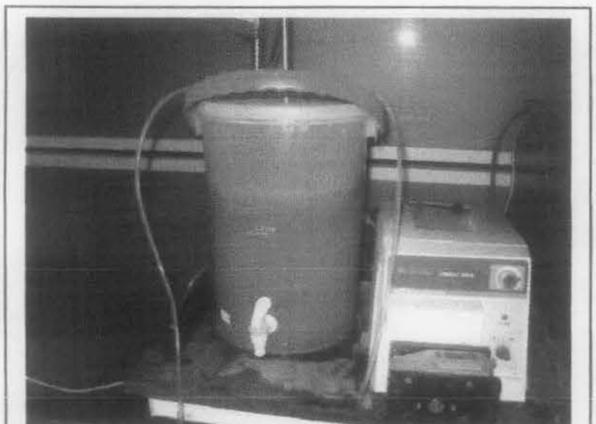


Figure 3.1: Laboratory Scale Test of SBR

3.1 SBR Cycle Process



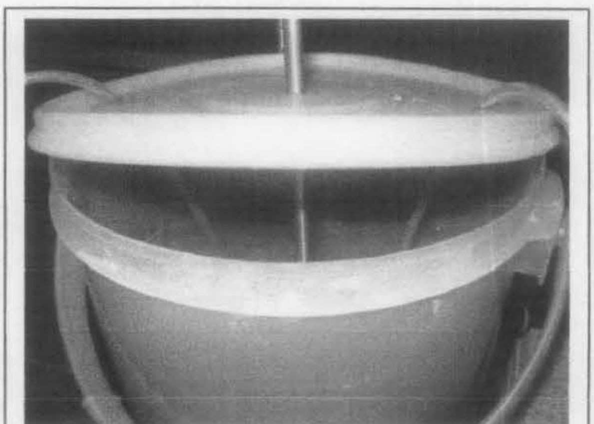


Figure 3.2: Aeration Process

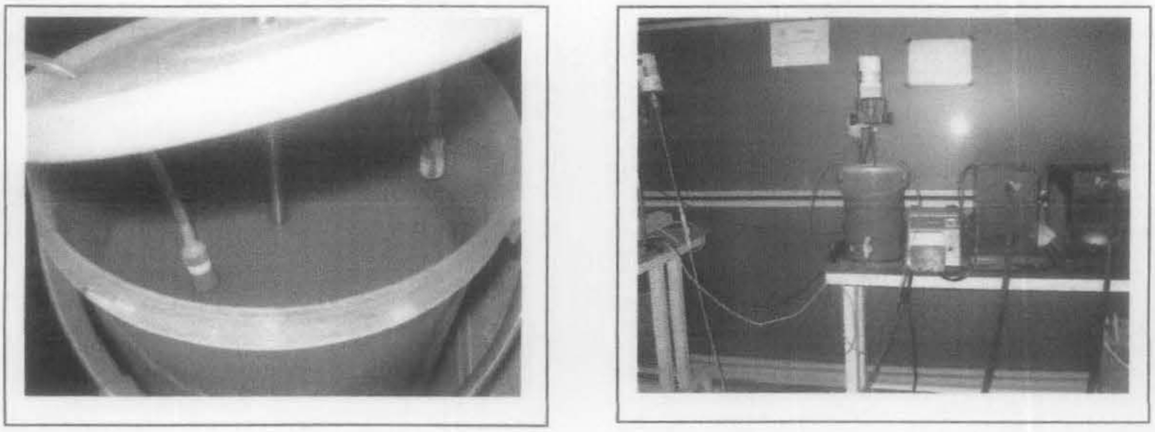


Figure 3.3: Anaerobic Process

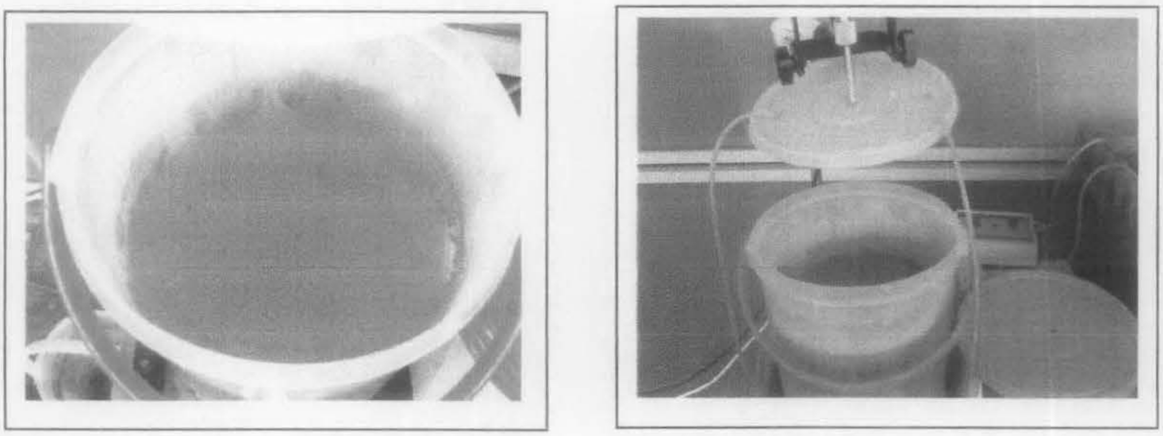


Figure 3.4: Settling Process

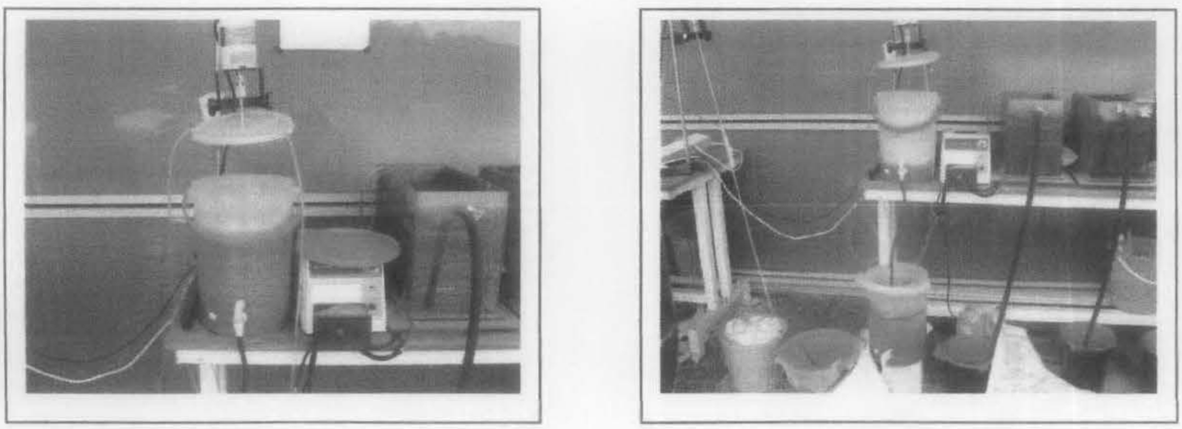


Figure 3.5: Decanting/ Discharging Effluent

3.2 Laboratory and Procedures of Work

3.2.1 Laboratory Scale Test for Sequential Batch Reactor

The work was started with the sludge measurement for the reactor in order to calculate the food to mass ratio and the soluble COD content for raw influent of municipal wastewater. The testing of sludge is carried out in the laboratory.

The objective for the experiment is to measure the nitrogen concentration of the influent after being treated by SBR model. The volume of reactor/ tank in the experiment was set to 14.3 liter and operated under the two phases of hydraulic retention time under ambient temperature of 20°C - 25°C.

The cycle time was operated in 12.22 hours and 17.22 hours of hydraulic retention time (HRT) and the cycle period are as below:

Period	12.22 Hours of HRT			17.22 Hours of HRT		
	On	Off	Duration	On	Off	Duration
Mixing	11:50 p.m.	4:50 a.m.	5 hrs	11.40 p.m.	6.40 a.m.	7 hrs
Settling	4:50 a.m.	6:50 a.m.	2 hrs	6.40 a.m.	10.40 a.m.	4 hrs
Waste	6:50 a.m.	7:00 a.m.	10 min	10.40 a.m.	10.50 a.m.	10 min
Fill	6:40 p.m.	6:50 p.m.	10 min	3.30 p.m.	3.40 p.m.	10 min
Aeration	6:50 p.m.	11:50 p.m.	5 hrs	4.40 p.m.	11.40 p.m.	7 hrs
		TOTAL	**12.22 hrs**		**TOTAL**	**17.22 hrs**

Table 3.1: Operation Time for Sequence Period of SBR Treatment

The influent volume which entered to the reactor was approximately about 8 liters of raw wastewater. After going through the cycle, the treated effluent was discharged after the sludge settle to the bottom of the reactor. The effluent then was tested in the laboratory for the measurement of the COD and Nitrogen concentration.

4.0 RESULT AND DISCUSSION

4.1 Results

4.1.1 Result for Mix Liquor Volatile Suspended Solids (MLVSS) Determination

Table 4.1: MLVSS Test (First Experiment)

		Mass (g)					
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper (105°C)	Foil + Filter Paper + Residue (550°C)	MLSS	MLVSS
1	50	1.1203	1.2870	1.2660	1.1206	210000	2908
2	50	1.3681	1.5260	1.5070	1.3687	190000	2766
3	50	1.2511	1.4230	1.3920	1.2516	310000	2808
Average	50	1.2465	1.4120	1.3883	1.2470	236667	**2827**

Table 4.2: MLVSS Test (Second Experiment)

		Mass (mg)					
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper (105°C)	Foil + Filter Paper + Residue (550°C)	MLSS	MLVSS
1	50	1.1633	1.3168	1.3151	1.1641	17000	3020
2	50	1.1831	1.3408	1.3383	1.1835	25000	3096
3	50	1.1330	1.2866	1.2848	1.1318	18000	3060
Blank	50	1.1244	1.2815	1.2788	1.1224	27000	3128
Average	50	1.1510	1.3064	1.3043	1.1505	21750	**3076**

Table 4.3: MLVSS Test (Third Experiment)

		Mass (mg)					
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper (105°C)	Foil + Filter Paper + Residue (550°C)	MLSS	MLVSS
1	50	1.1325	1.2845	1.2767	1.1318	78000	2898
2	50	1.1813	1.3375	1.3300	1.1815	75000	2970
3	50	1.1834	1.3362	1.3292	1.1841	70000	2902
4	50	1.1883	1.3451	1.3393	1.1896	58000	2994
5	50	1.0550	1.2066	1.2011	1.0545	55000	2932
Blank	50	1.1810	1.3383	1.3332	1.1809	51000	3046
Average	50	1.1536	1.3080	1.3016	1.1537	64500	**2957**

Table 4.4: MLVSS Test (Fourth Experiment)

		Mass (mg)					
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper (105°C)	Foil + Filter Paper + Residue (550°C)	MLSS	MLVSS
1	50	1.1504	1.3155	1.3090	1.1508	65000	3164
2	50	1.1258	1.2832	1.2759	1.1244	73000	3030
3	50	1.1196	1.2738	1.2696	1.1201	42000	2990
4	50	1.1235	1.2876	1.2834	1.1239	42000	3190
5	50	1.1730	1.3312	1.3273	1.1729	39000	3088
6	50	1.1830	1.3415	1.3386	1.1832	29000	3108
7	50	1.1546	1.3117	1.3097	1.1541	20000	3112

Average	50	1.1471	1.3064	1.3019	1.1471	40000	**3097**

4.1.2 Result for Soluble COD (sCOD) Determination

Table 4.5: sCOD Test (First Experiment)

No	Type of Effluent	Sample Size (ml)	COD Reading (mg/L)
1	Raw Wastewater	2	74
2	Raw Wastewater	2	141
3	Raw Wastewater	2	84
	Average	2	**100**

Table 4.6: sCOD Test (Second Experiment)

No	Type of Effluent	Sample Size (ml)	COD Reading (mg/L)
1	Raw Wastewater	2	63
2	Raw Wastewater	2	76
3	Raw Wastewater	2	103
4	Raw Wastewater	2	94
5	Raw Wastewater	2	85
	Average	2	**84**

Table 4.7: sCOD Test (Third Experiment)

No	Type of Effluent	Sample Size (ml)	COD Reading (mg/L)
1	Raw Wastewater	2	35
2	Raw Wastewater	2	68
3	Raw Wastewater	2	65
4	Raw Wastewater	2	70
5	Raw Wastewater	2	56
	Average	2	**58**

Table 4.8: sCOD Test (Fourth Experiment)

No	Type of Effluent	Sample Size (ml)	COD Reading (mg/L)
1	Raw Wastewater	2	90
2	Raw Wastewater	2	86
3	Raw Wastewater	2	92
4	Raw Wastewater	2	100
5	Raw Wastewater	2	75
6	Raw Wastewater	2	100
7	Raw Wastewater	2	99
	Average	2	**92**

Table 4.9: sCOD Test (Fifth Experiment)

No	Type of Effluent	Sample Size (ml)	COD Reading (mg/L)
1	Raw Wastewater	2	71
2	Raw Wastewater	2	157
3	Raw Wastewater	2	86
4	Raw Wastewater	2	112
5	Raw Wastewater	2	87
6	Raw Wastewater	2	183
7	Raw Wastewater	2	117
8	Raw Wastewater	2	107
	Average	2	**115**

After several testing made in the laboratory, the final result for both mix liquor volatile suspended solid, MLVSS (sludge) and the soluble COD (sCOD) were **3,097** mg/L and **100** mg/L respectively. The value of 100 mg/l is taken from the average value of the first experiment.

4.1.3 Result on COD Test

Table 4.10: COD (First Experiment) – 12.22 hours of HRT

No	Sample Size (mg/L)	COD (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	2	195	93	52.31
2	2	173	43	75.14
3	2	204	47	76.96
4	2	188	51	72.87
	Average	190	59	**69.32**

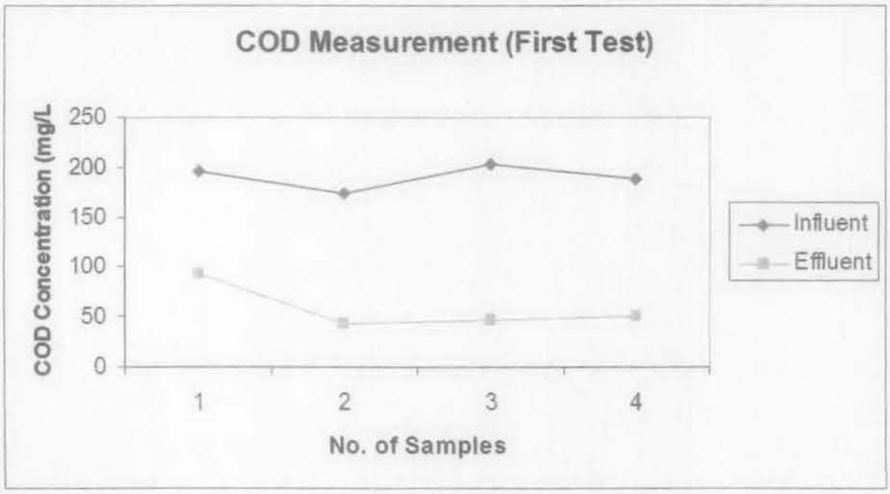


Figure 4.1: COD Measurement (First Test)

Table 4.11: COD (Second Experiment) – 12.22 hours of HRT

No	Sample Size (mg/L)	COD (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	2	176	68	61.36
2	2	205	87	57.56
3	2	179	70	60.89
4	2	198	41	79.29
	Average	190	67	**64.78**

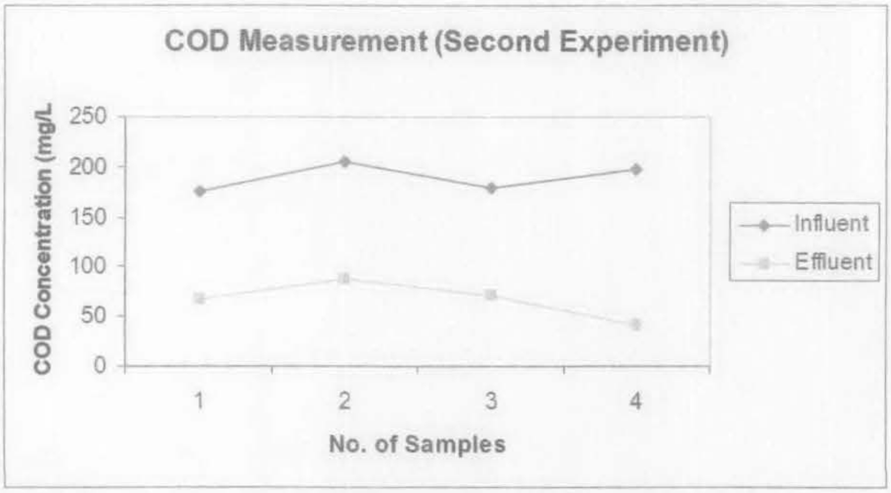


Figure 4.2: COD Measurement (Second Test)

Table 4.12: COD (Third Experiment) – 17.22 hours of HRT

No	Sample Size (mg/L)	COD (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	2	200	107	46.50
2	2	204	61	70.10
3	2	184	49	73.37
4	2	194	24	87.63
	Average	196	60	**69.40**

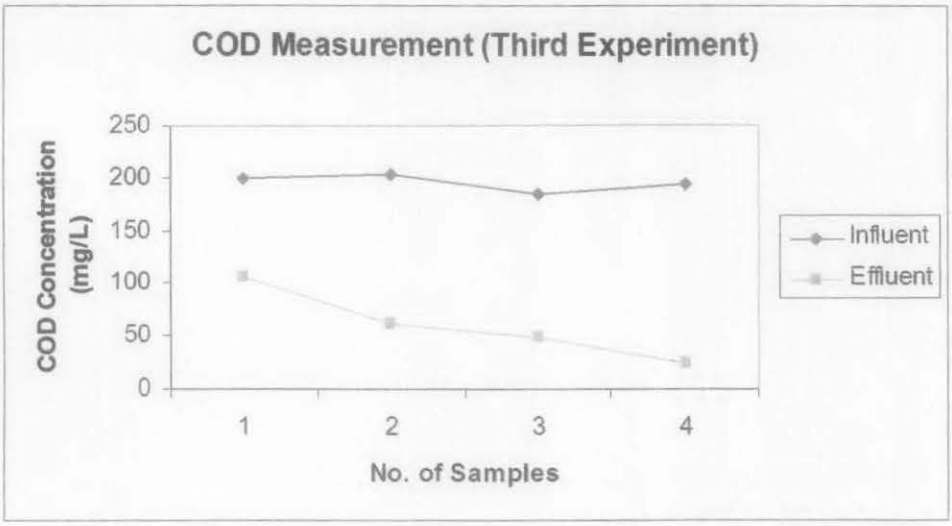


Figure 4.3: COD Measurement (Third Test)

Table 4.13: COD (Fourth Experiment) – 17.22 hours of HRT

No	Sample Size (mg/L)	COD (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	2	190	55	71.05
2	2	190	41	78.42
3	2	187	69	63.10
4	2	202	75	62.87
	Average	192	60	**68.86**

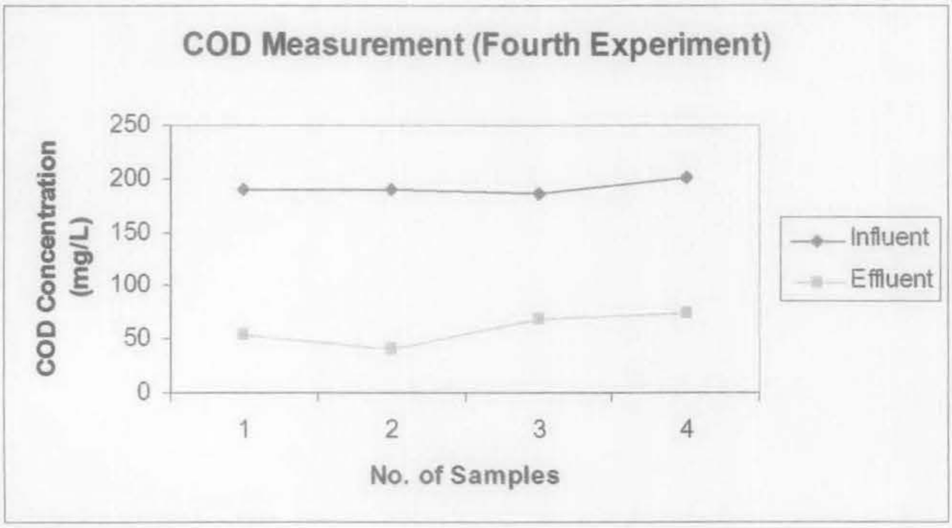


Figure 4.4: COD Measurement (Fourth Test)

4.1.4 Result on Nitrogen Test

Table 4.14: Nitrogen (First Experiment) – 12.22 HRT

No	Sample Size (ml)	Nitrogen Concentration (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	10	5.76	0.98	82.99
2	10	4.98	0.89	82.13
3	10	5.06	0.94	81.42
4	10	5.04	0.85	83.13
	Average	5.21	0.92	**82.42**

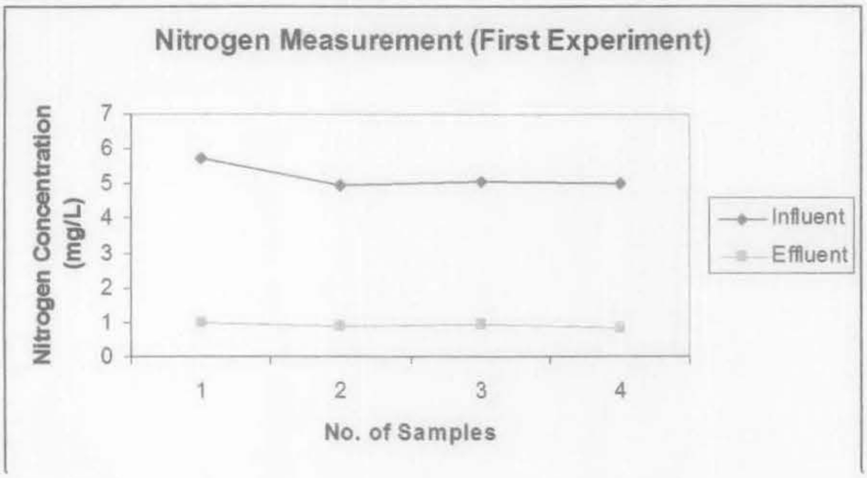


Figure 4.5: Nitrogen Measurement (First Test)

Table 4.15: Nitrogen (Second Experiment) – 12.22 HRT

No	Sample Size (ml)	Nitrogen Concentration (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	10	5.25	0.91	82.67
2	10	5.44	0.94	82.72
3	10	5.88	0.84	85.71
4	10	5.72	0.98	82.87
	Average	5.57	0.92	**83.49**

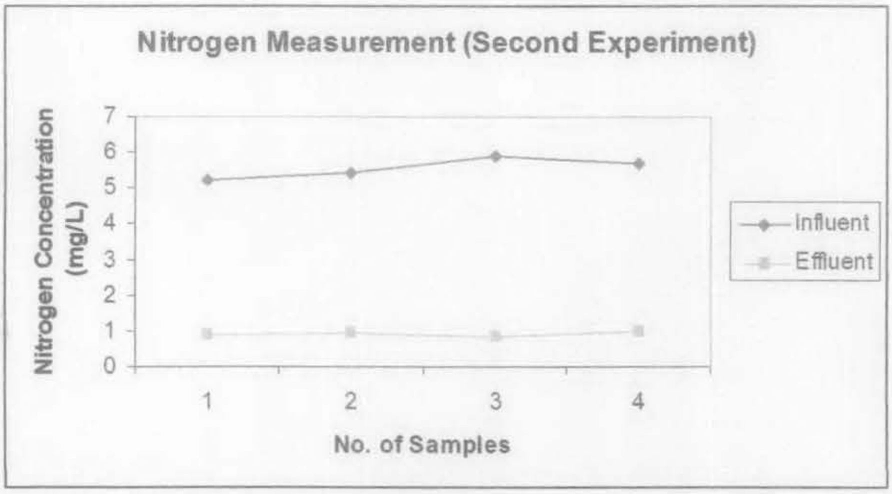


Figure 4.6: Nitrogen Measurement (Third Test)

Table 4.16: Nitrogen (Third Experiment) – 17.22 HRT

No	Sample Size (ml)	Nitrogen Concentration (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	10	5.06	0.75	85.18
2	10	5.54	0.81	85.38
3	10	5.12	0.84	83.59
4	10	5.43	0.79	85.45
	Average	5.29	0.80	**84.90**

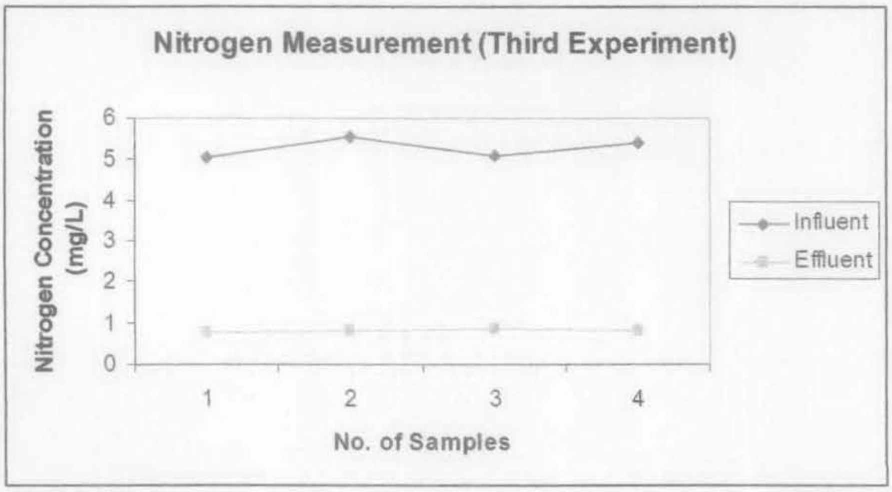


Figure 4.7: Nitrogen Measurement (Third Test)

Table 4.17: Nitrogen (Fourth Experiment) – 17.22 HRT

No	Sample Size (ml)	Nitrogen Concentration (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	10	5.61	0.73	86.99
2	10	5.78	0.89	84.60
3	10	5.22	0.77	85.25
4	10	5.18	0.65	87.45
	Average	5.45	0.76	**86.07**

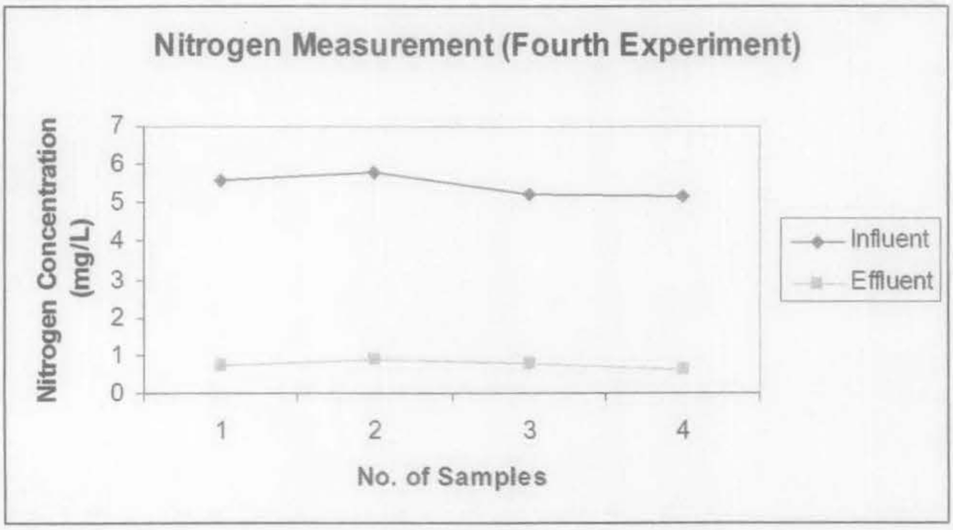


Figure 4.8: Nitrogen Measurement (Fourth Test)

4.1.5 Result on Nitrate Test

Table 4.18: Nitrate – 17.22 hours of HRT

No	Sample Size (ml)	Nitrate Concentration (mg/L)		Percentage Reduction (%)
		Influent	Effluent	
1	10	17.4	5.4	68.97
2	10	9.0	5.6	37.78
3	10	13.3	4.7	64.66
4	10	11.5	3.5	69.57
5	10	12.7	6.5	48.82
6	10	8.9	3.1	65.17
	Average	12.1	4.8	**59.16**

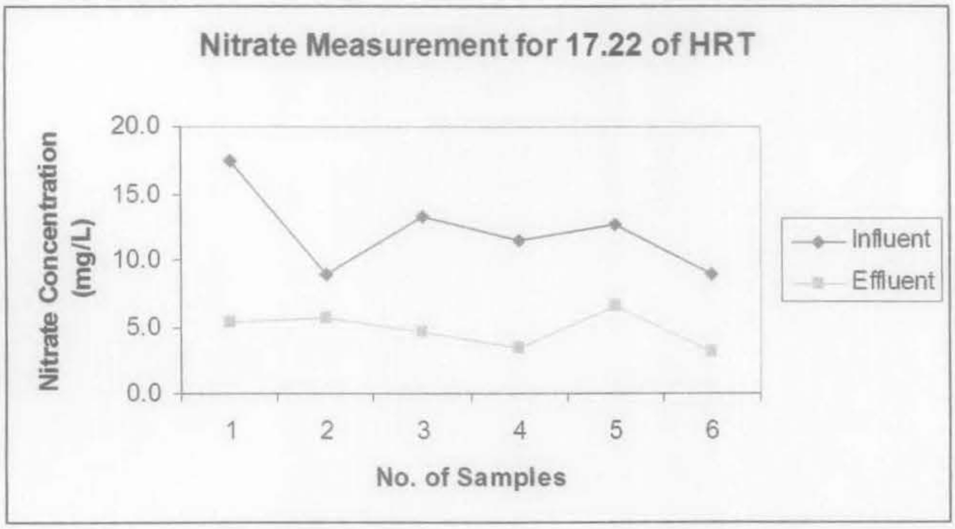


Figure 4.9: Nitrate Measurement

4.1.6 Result on TSS Test

Table 4.19: TSS (Influent) – 17.22 hours of HRT

	Effluent	Mass (mg)			
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper + Residue (105°C)	TSS
1	50	1.2003	1.3515	1.3449	58
2	50	1.1229	1.2741	1.2700	90
3	50	1.1214	1.2724	1.2680	70
4	50	1.1310	1.2827	1.2787	56
5	50	1.1791	1.3323	1.3298	70
6	50	1.1756	1.3252	1.3230	62

Table 4.20: TSS (Effluent) – 17.22 hours of HRT

	Influent	Mass (mg)			
No	Sample Size (ml)	Foil	Foil + Filter Paper	Foil + Filter Paper + Residue (105°C)	TSS
1	50	1.1830	1.3471	1.3387	30
2	50	1.1794	1.3408	1.3332	36
3	50	1.1842	1.3400	1.3332	46
4	50	1.1904	1.3471	1.3407	34
5	50	1.2391	1.3940	1.3876	40
6	50	1.1240	1.2779	1.2727	24

Table 4.21: Percentage Reduction of TSS Concentration

No	TSS Concentration (mg/L)		Percentage Reduction (%)
	Influent	Effluent	
1	58	30	48.28
2	90	36	60.00
3	70	46	34.29
4	56	34	39.29
5	70	40	42.86
6	62	24	61.29
Average	68	35	**47.67**

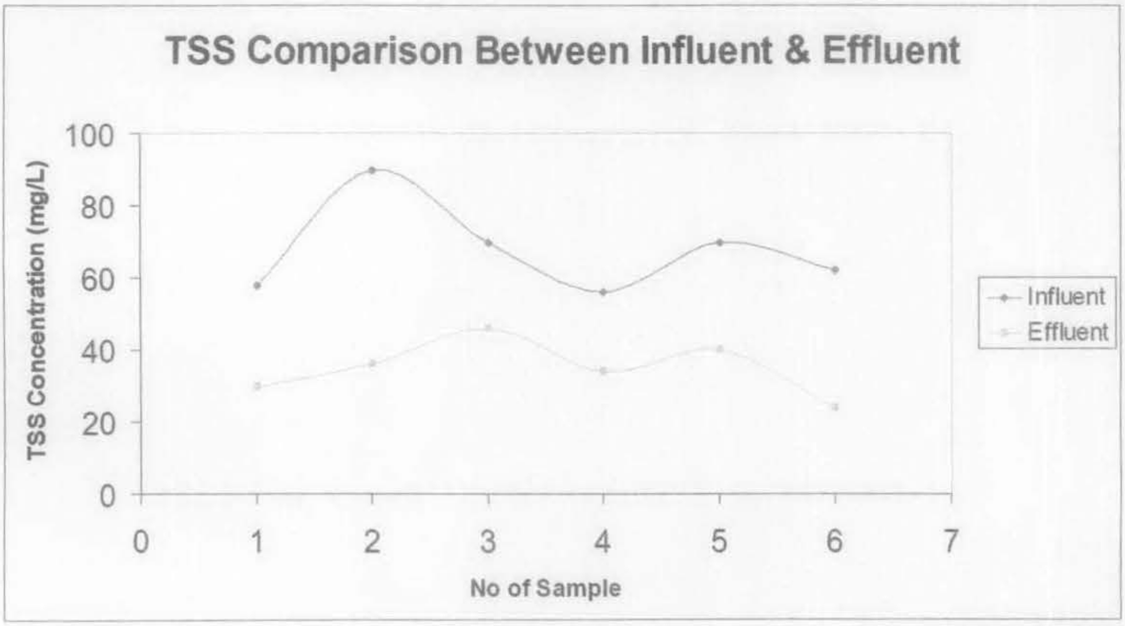


Figure 4.10: TSS Comparison Diagram

4.2 Discussion

4.2.1 MLVSS Analysis

Applying a dilution factor of 1:500 of MLVSS,

Table 4.22: Average value of MLVSS measured

No	Trial of Experiment	Sample Size (ml)	Dilution Factor	Average MLVSS (mg/L)
1	First	50	1:500	2827
2	Second	50	1:500	3076
3	Third	50	1:500	2957
4	Fourth	50	1:500	**3097**

The fourth result was selected as the benchmark of MLVSS value in order to run the reactor process and used in calculation in order to evaluate the food to mass ratio of the lab scale experiment.

4.2.2 Soluble COD (sCOD) Analysis

As for soluble sCOD, the measurement was made for raw wastewater effluent to calculate the sCOD loading into the reactor. After conducting few testing for sCOD measurement, the average sCOD selected was 100 mg/L.

Before running the biological process, the mix liquor suspended solid (MLVSS) and the soluble Chemical Oxygen Demand (sCOD) was evaluated in order to calculate the food to mass ratio (F/M Ratio). The food to mass ratio was the parameter used for determining whether the microorganism had enough supply of nutrient in order to degrade the organic matter presence in the effluent and produce a high-quality discharged standard. The flowrate and the MLVSS for the filling state were set to be 0.008 m^3/day and 2 liters. The total volume of the reactor was about 12.21 liters and the effective volume of the reactor was measured to be 10 liters.

4.2.3 Calculation and Conversion Factor

Obtained data:

Table 4.23: Data Require for Calculation

Flowrate, Q	0.008 m^3/day
MLVSS (mg/L)	3097 mg/L
sCOD (mg/L)	100 mg/L
Radius of reactor	0.12 m
Height of Sludge, h_2	0.442 m
Height of Influent (sCOD), h_1	0.177 m

Conversion Factor and Formula

1000 liters = 1 m3

100 cm = 1 m

3.142 = π, h = height and j = radius

Q = flowrate (m^3/d)

Volume of cylinder = $\pi j^2 h$

Loading (kg/d) = [Q (m^3/d) x concentration (mg/L)] / 1000

F/M ratio = Concentration Loading (kg/d) / MLVSS Loading (kg)

Calculation

sCOD Loading (kg/d) = [Q (m^3/d) x sCOD (mg/L)] /1000

= [0.008 (m^3/d) x 100 (mg/L)] /1000

= 0.0008 kg/day

Total volume reactor (liters) = $\pi j^2 h$

= [π x (0.12 m)^2 x 0.27 m] x 1000

= 12.21 liters

Volume of influent (sCOD) = $\pi j^2 h_1$

= [π x (0.12 m)^2 x 0.177 m] x 1000

= 8 liters

Volume of sludge (MLVSS) = $\pi j^2 h_2$

$= [\pi \times (0.12 \text{ m})^2 \times 0.442 \text{ m}] \times 1000$

$= 2$ liters

Effective volume (liters) $= \pi r^2 h$

$= [\pi \times (0.12 \text{ m})^2 \times (0.221 \text{ m}] \times 1000$

$= 10$ liters

MLVSS Loading (kg) $= \dfrac{\text{MLVSS concentration (mg/L)} \times \text{Volume of Sludge (m}^3\text{)}}{1000 \times 1000}$

= (3097 mg/L x 2 L) / 1000000

= 0.0062 kg

F/M Ratio = sCOD Loading (kg/d) / MLVSS Loading (kg)

= 0.0008 (kg/d) / 0.0062 (kg)

= **0.13**

Hence, the F/M ratio for the reactor in running the cycle was 1:4, which in true lab scale volume; the selected ratio representing the volume of sludge, 2 liters and the volume of influent (sCOD), 8 liters.

4.2.4 Comparison Analysis Between Different Hydraulic Retention Time (HRT)

From observation and data analysis between the two different Hydraulic Retention Time (HRT), it was determined that the larger the HRT gives better result compared to the lower HRT which in this experiment, 17.22 hours of HRT acquired better percentage reduction compare to 12.22 hours of HRT. The efficiency in COD and ammonia-nitrogen removal was 69.40% and 86.07% respectively. The COD concentration was reduced from 169 mg/l to 60 mg/l and the nitrogen content reduced from 5.45 mg/l to 0.76 mg/l.

4.2.5 Overall Performance of SBR

The overall performance of SBR is capable in removing nutrient and COD. The result also indicates the removal percentage of nitrate and total suspended solids (TSS) about

59.16% and 47.67% respectively. The concentration of nitrate was reduced from 12.1 mg/l to 4.8 mg/l and for total suspended solids (TSS) the reduction was from 68 mg/l to 35 mg/l.

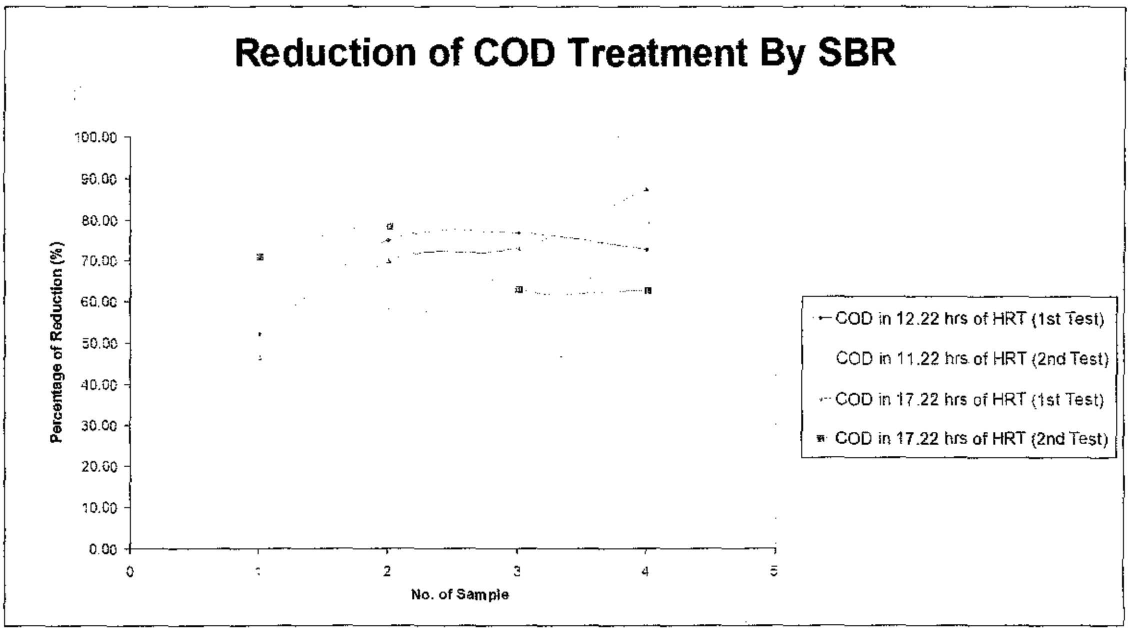


Figure 4.11: Reduction of COD in different HRT

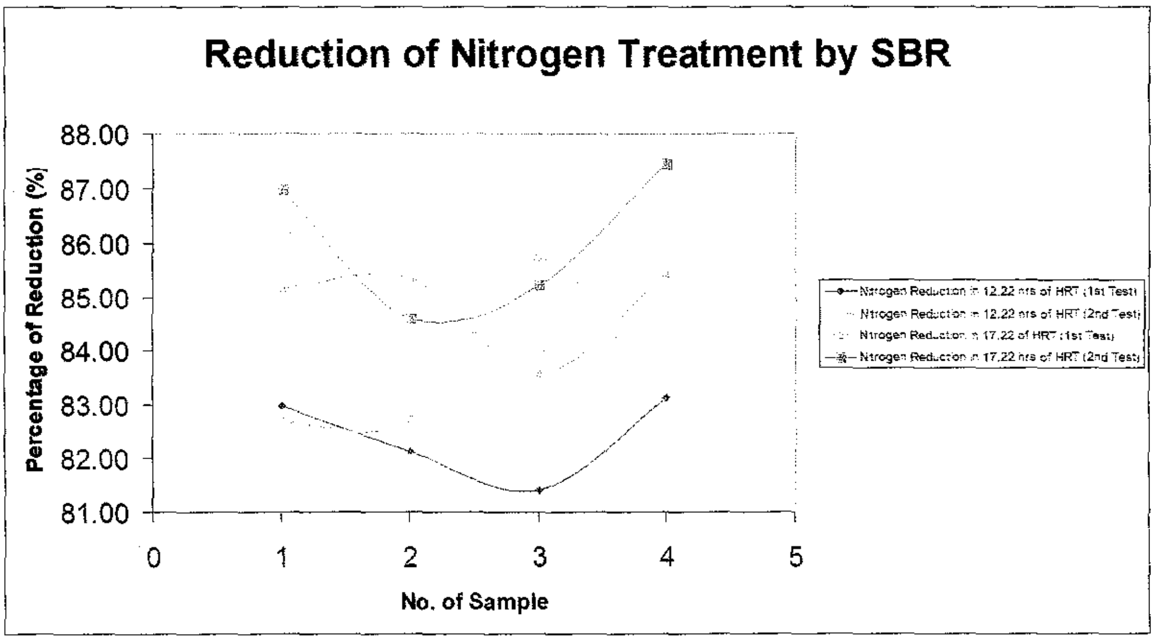


Figure 4.12: Reduction of Nitrogen in different HRT

5.0 CONCLUSION AND RECOMMENDATION

The study was made to investigate the efficiency of SBR in removing of organic matters and nutrient in domestic wastewater. The treatment efficiency is measured by the reduction in each parameter of effluent (COD and Nitrogen) throughout the system. Optimal condition was required during a 17.22-hour cycle. Since all biological reaction was dependent on the biomass concentration, MLVSS concentration above 3000 mg/l was maintained.

From this project, we can conclude that;

- The SBR lab scale model was functioning properly according to its cycle and reduction in nutrient was achieved;
- The SBR model can remove nutrient namely nitrogen and nitrate; and
- The optimum operating parameters of the SBR for MLVSS, soluble COD (sCOD) and Food to Mass ratio;
- The higher of HRT gives better result in nutrient reduction.
- At 17.22 hours of HRT can reduce COD to levels below the standard of 100 mg/l and nitrate below 10 mg/l as specified by discharge Standard B for the SBR model.

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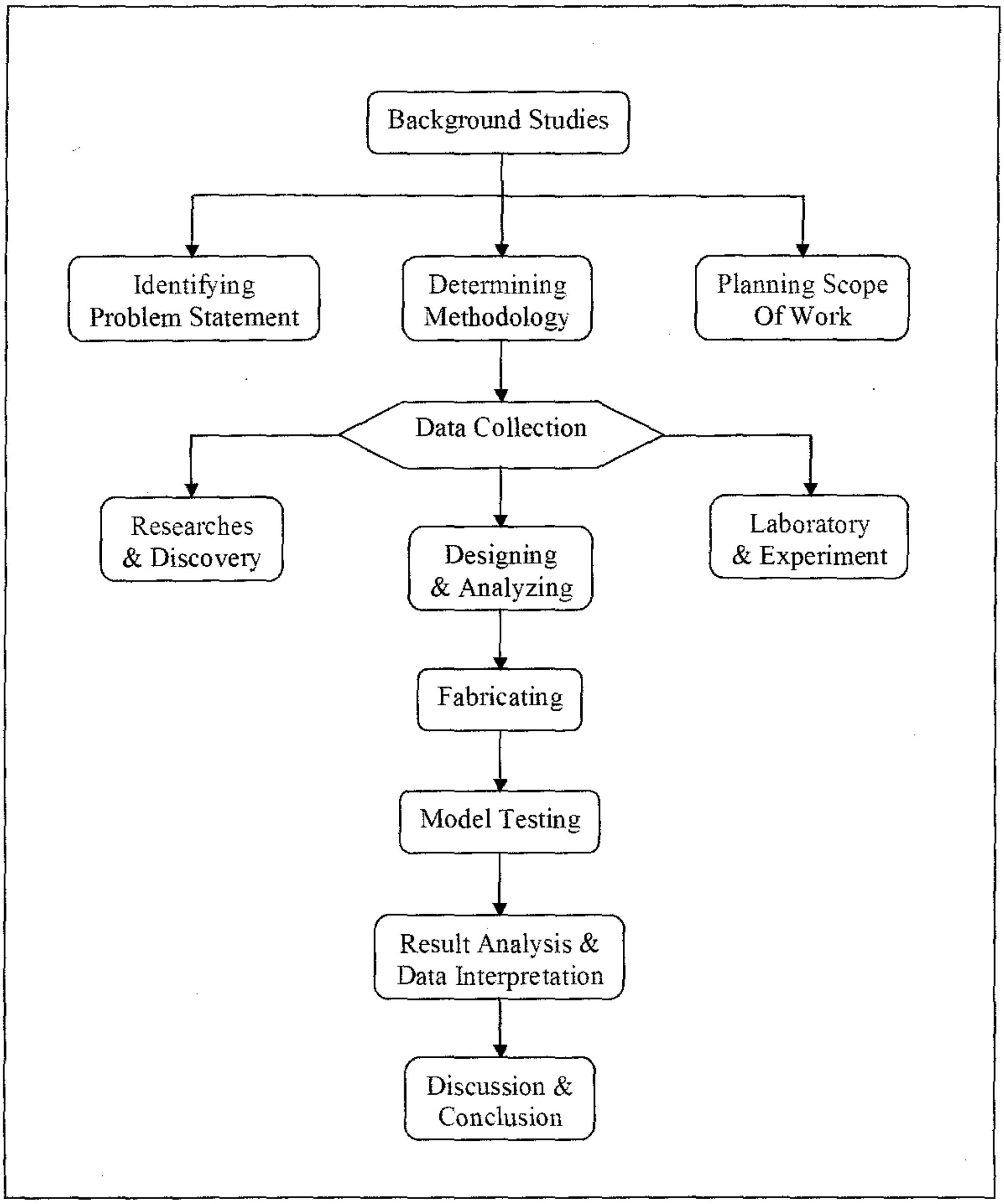
APPENDIX

Final Year Project Milestone

NO	Activity/ Week	FYP I																	FYP II															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	EW	SB	SB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	EW	SB
	Selection of Topics																																	
1	Proposed Topic																																	
2	Topic assign to student																																	
3	Literature Review																																	
4	Determining Works/ Framework																																	
5	Planning																																	
**	Submission of Preliminary Report				SV																													
	Gathering Data																																	
6	Research & Discovery																																	
7	Laboratory & Experiment																																	
8	Design & Analysis																																	
9	Fabrication																																	
10	Model Testing																																	
11	Result Analysis & Data Interpretation																																	
12	Finishing & Final Touch																																	
**	Submission of Progress Report								SV																	SV								
**	Submission of Interim Report													SV																	SV			
**	Oral Presentation																																	
**	Submission of Final Report																															SV		

Note:
EW = Examination Week
SB = Semester Break
** = Urgent Task/ Event
SV = Submitting Report to SV (First Draft)

Flow Programme for Works Procedure



Results for Mix Liquor Volatile Suspended Solids (MLVSS) Determination

Result for MLVSS Analysis (1st Experiement)

		Mass in Gram (g)				Mass in Gram (mg/L)		
No	Sample Size (ml)	Pan	Pan + Filter	Pan + Filter at 105°C	Pan + Filter + Residue at 505°C	MLFSS	MLSS	MLVSS
1	50	1,1203	1,2870	1,2660	1,1206	0,30	210000	2908
2	50	1,3681	1,5260	1,5070	1,3687	0,60	190000	2766
3	50	1,2511	1,4230	1,3920	1,2516	0,50	310000	2808
	Average	1,2465	1,4120	1,3883	1,2470	0,47	236667	**2827**

Result for MLVSS Analysis (2nd Experiment)

		Mass in Gram (g)				Mass in Gram (mg/L)		
No of Sample	Sample Size (ml)	Pan	Pan + Filter	Pan + Filter at 105°C	Pan + Filter + Residue at 505°C	MLFSS	MLSS	MLVSS
1	50	1,1633	1,3168	1,3151	1,1641	0,80	17000	3020
2	50	1,1831	1,3408	1,3383	1,1835	0,40	25000	3096
3	50	1,1330	1,2866	1,2848	1,1318	-1,20	18000	3060
Blank	50	1,1244	1,2815	1,2788	1,1224	-2,00	27000	3128
	Average	1,1510	1,3064	1,3043	1,1505	-0,50	21750	**3076**

Result for MLVSS Analysis (3rd Experiment)

		Mass in Gram (g)				Mass in Gram (mg/L)		
No of Sample	Sample Size (ml)	Pan	Pan + Filter	Pan + Filter at 105°C	Pan + Filter + Residue at 505°C	MLFSS	MLSS	MLVSS
1	50	1,1325	1,2845	1,2767	1,1318	-0,70	78000	2898
2	50	1,1813	1,3375	1,3300	1,1815	0,20	75000	2970
3	50	1,1834	1,3362	1,3292	1,1841	0,70	70000	2902
4	50	1,1883	1,3451	1,3393	1,1896	1,30	58000	2994
5	50	1,0550	1,2066	1,2011	1,0545	-0,50	55000	2932
Blank	50	1,1810	1,3383	1,3332	1,1809	-0,10	51000	3046
	Average	1,1536	1,3080	1,3016	1,1537	0,15	64500	**2957**

Result for MLVSS Analysis (4rd Experiment)

		Mass in Gram (g)				Mass in Gram (mg/L)		
No of Sample	Sample Size (ml)	Pan	Pan + Filter	Pan + Filter at 105°C	Pan + Filter + Residue at 550°C (g)	MLFSS	MLSS	MLVSS
1	50	1,1504	1,3155	1,3090	1,1508	0,40	65000	3164
2	50	1,1258	1,2832	1,2759	1,1244	-1,40	73000	3030
3	50	1,1196	1,2738	1,2696	1,1201	0,50	42000	2990
4	50	1,1235	1,2876	1,2834	1,1239	0,40	42000	3190
5	50	1,1730	1,3312	1,3273	1,1729	-0,10	39000	3088
6	50	1,1830	1,3415	1,3386	1,1832	0,20	29000	3108
7	50	1,1546	1,3117	1,3097	1,1541	-0,50	20000	3112
	Average	1,1471	1,3064	1,3019	1,1471	-0,07	**44286**	**3097**

Soluble COD (sCOD) Result for Raw Wastewater Effluent (Municipal)

sCOD Test (1st Test)

No	Type of Influent	Sample Size (ml)	COD (mg/L)
1	Raw Wastewater	50	74
2	Raw Wastewater	50	141
3	Raw Wastewater	50	84
4	Blank Sample	50	0

sCOD Test (2nd Test)

No	Type of Influent	Sample Size (ml)	COD (mg/L)
1	Raw Wastewater	50	63
2	Raw Wastewater	50	76
3	Raw Wastewater	50	103
4	Raw Wastewater	50	94
5	Raw Wastewater	50	85
6	Blank Sample	50	0

sCOD Test (3nd Test)

No	Type of Influent	Sample Size (ml)	COD (mg/L)
1	Raw Wastewater	50	35
2	Raw Wastewater	50	68
3	Raw Wastewater	50	65
4	Raw Wastewater	50	70
5	Raw Wastewater	50	56
6	Blank Sample	50	0

sCOD Test (4rd Test)

No	Type of Influent	Sample Size (ml)	COD (mg/L)
1	Raw Wastewater	50	90
2	Raw Wastewater	50	86
3	Raw Wastewater	50	92
4	Raw Wastewater	50	100
5	Raw Wastewater	50	75
6	Raw Wastewater	50	100
7	Raw Wastewater	50	99
8	Blank	50	0

** Assume taking **100 mg/L** sCOD to be measured and calcluated in the design

RESULT ON COD TESTING BY SEQUENCIAL BATCH REACTOR

COD (First Experiment) - (1222 hours of HRT)

No	COD (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	195	93	52,31
2	173	43	75,14
3	204	47	76,96
4	188	51	72,87

COD (Second Experiment) - (12.22 hours of HRT)

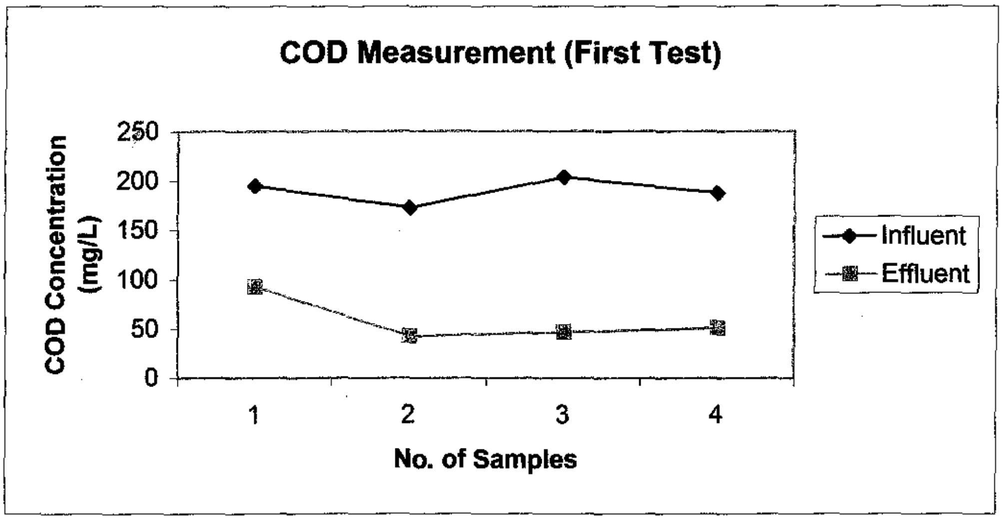
No	COD (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	176	68	61,36
2	205	87	57,56
3	179	70	60,89
4	198	41	79,29

COD (Third Experiment) - (17.22 hours of HRT)

No	COD (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	200	107	46,50
2	204	61	70,10
3	184	49	73,37
4	194	24	87,63

COD (Fourth Experiment) - (17.22 hours of HRT)

No	COD (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	190	55	71,05
2	190	41	78,42
3	187	69	63,10
4	202	75	62,87


COD Measurement (First Test)
COD Concentration (mg/L)
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150
100
50
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1
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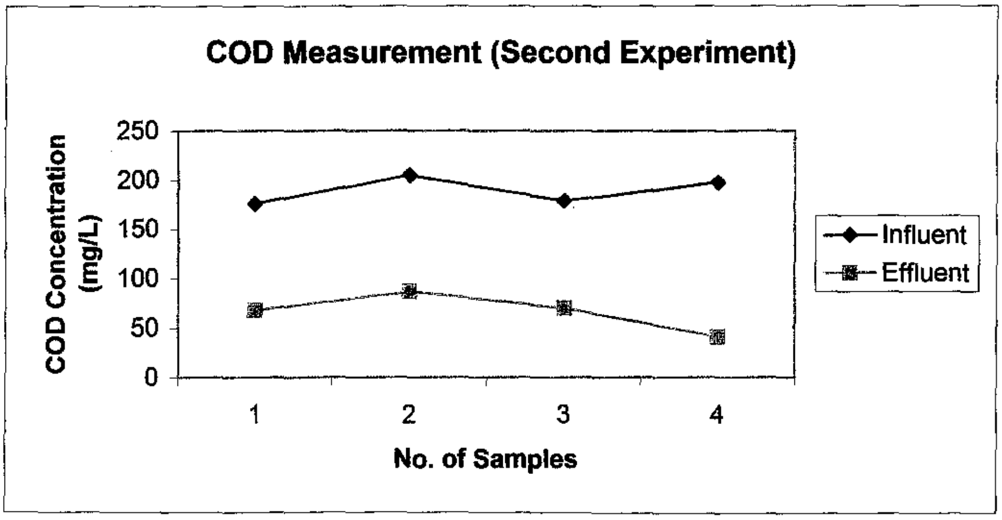
No. of Samples
Influent
Effluent


COD Measurement (Second Experiment)
COD Concentration (mg/L)
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150
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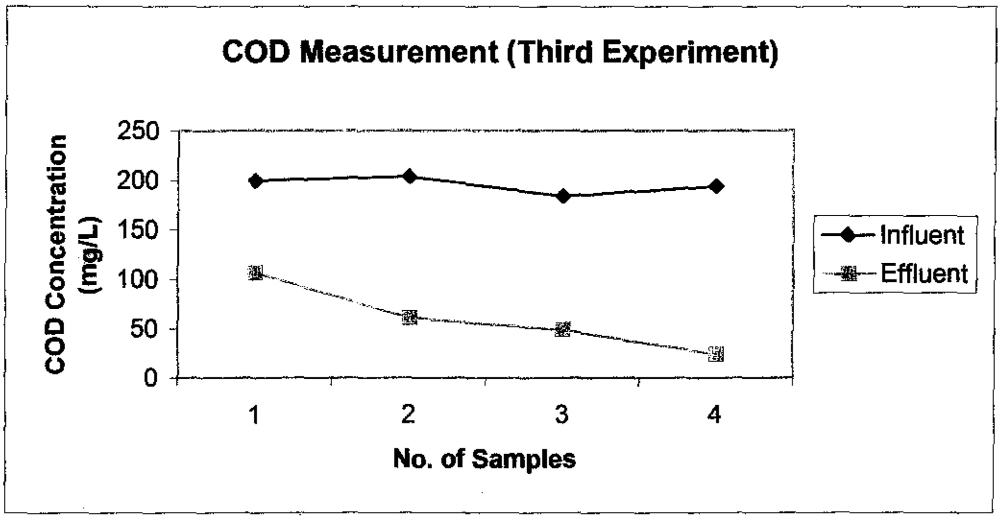
0
1
2
3
4
No. of Samples
Influent
Effluent


COD Measurement (Third Experiment)
COD Concentration (mg/L)
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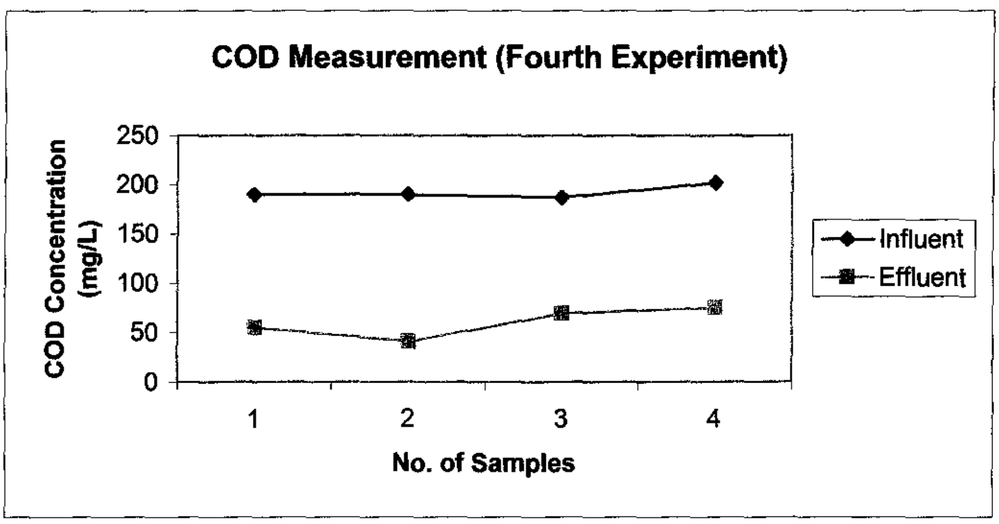
1
2
3
4
No. of Samples
Influent
Effluent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COD Concentration (mg/L)
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200
150
100
50
0
1
2
3
4
No. of Samples
Influent
Effluent

RESULT ON NITROGEN TESTING BY SEQUENCIAL BATCH REACTOR

Nitrogen (First Experiment) - 12.22 hours of HRT

No	Nitrogen (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	5,76	0,98	82,99
2	4,98	0,89	82,13
3	5,06	0,94	81,42
4	5,04	0,85	83,13

Nitrogen (First Experiment) - 12.22 hours of HRT

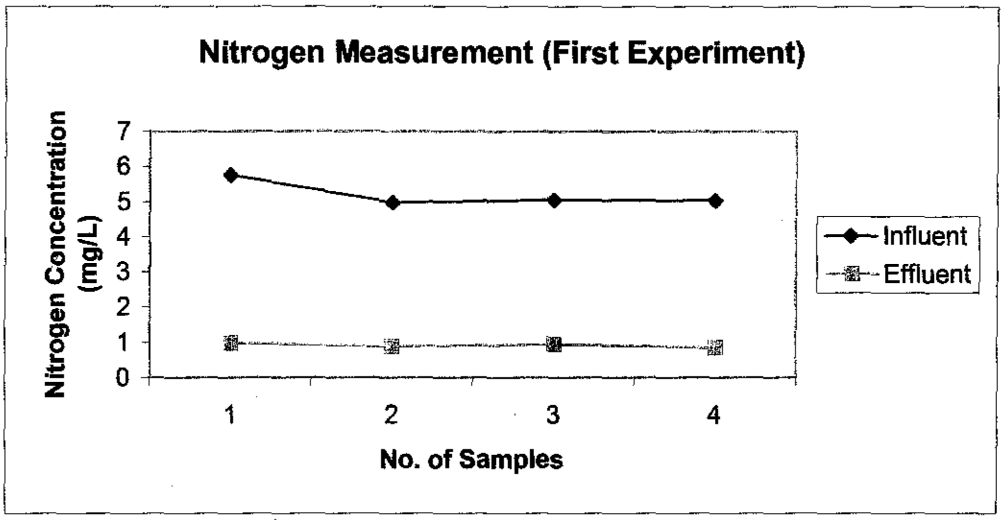
No	Nitrogen (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	5,25	0,91	82,67
2	5,44	0,94	82,72
3	5,88	0,84	85,71
4	5,72	0,98	82,87

Nitrogen (Third Experiment) - 17.22 hours of HRT

No	Nitrogen (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	5,06	0,75	85,18
2	5,54	0,81	85,38
3	5,12	0,84	83,59
4	5,43	0,79	85,45

Nitrogen (Fourth Experiment) - 17.22 hours of HRT

No	Nitrogen (mg/L)		Percentage Reduction (%)
	Raw Influent	Effluent	
1	5,61	0,73	86,99
2	5,78	0,89	84,60
3	5,22	0,77	85,25
4	5,18	0,65	87,45


Nitrogen Measurement (First Experiment)
Nitrogen Concentration (mg/L)
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Influent
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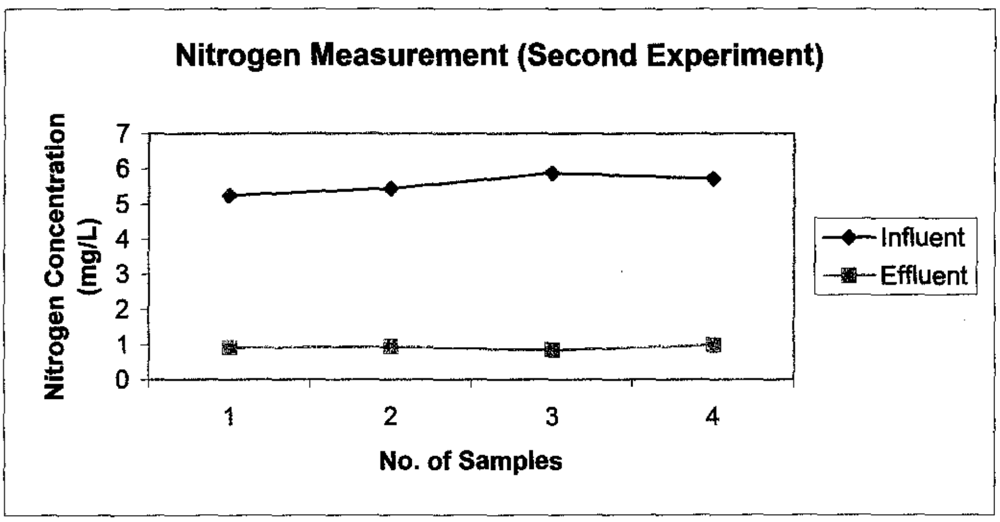
Nitrogen Measurement (Second Experiment)
Nitrogen Concentration (mg/L)
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Effluent
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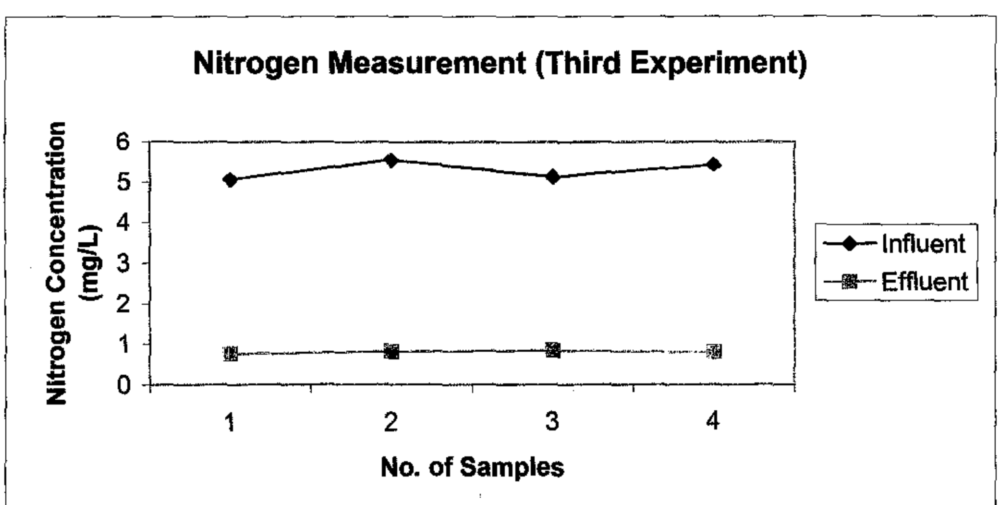
Nitrogen Measurement (Third Experiment)
Nitrogen Concentration (mg/L)
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Influent
Effluent
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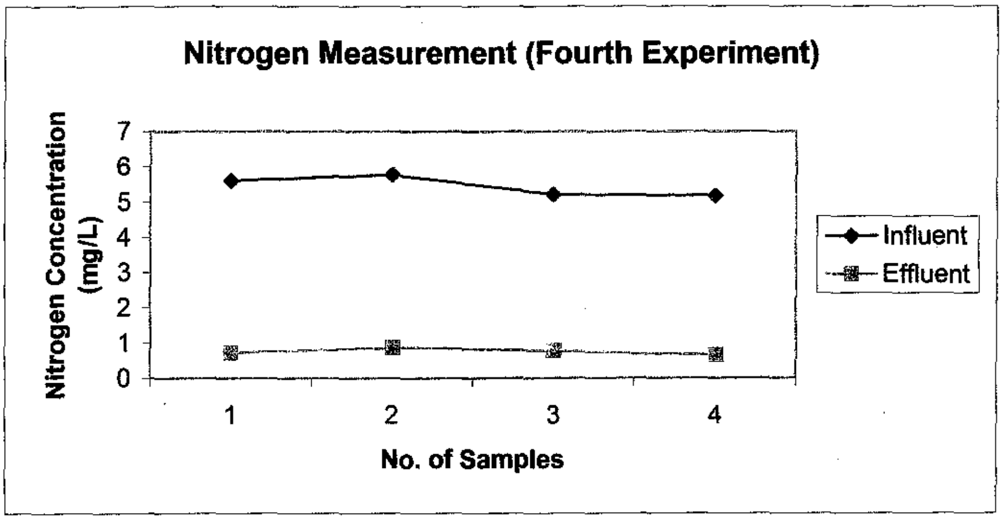
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Nitrogen Concentration (mg/L)
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5
4
3
2
1
0
1
2
3
4
No. of Samples
Influent
Effluent

RESULT ON TSS TESTING BY SEQUENCIAL BATCH REACTOR

TSS (Effluent)

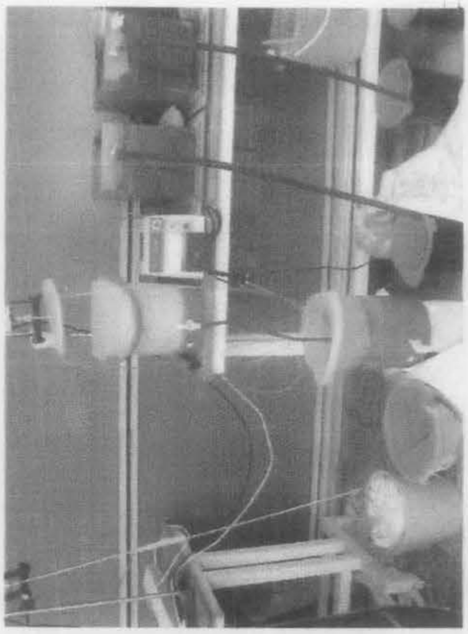
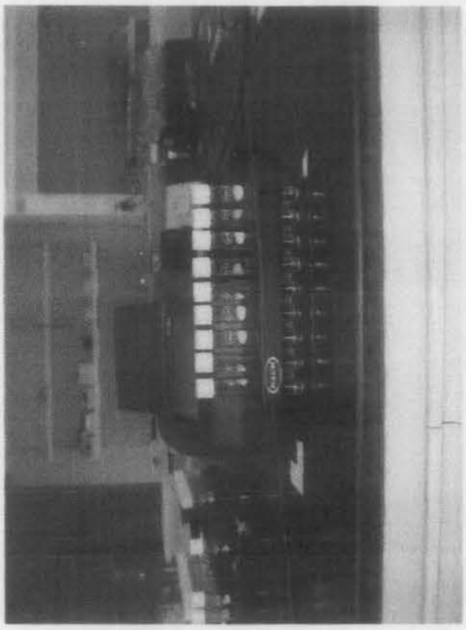
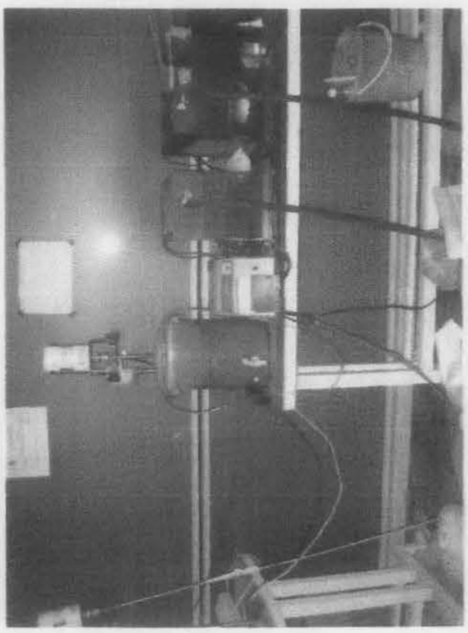
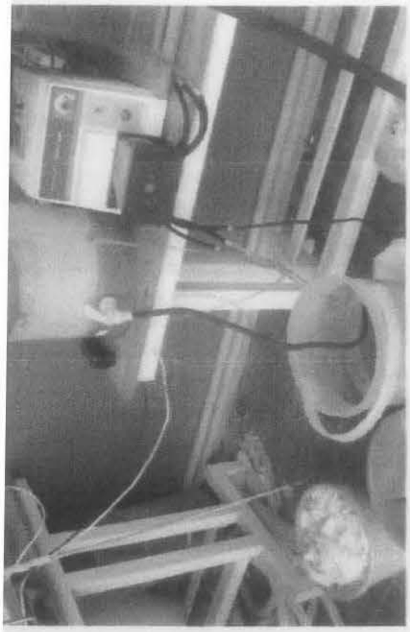
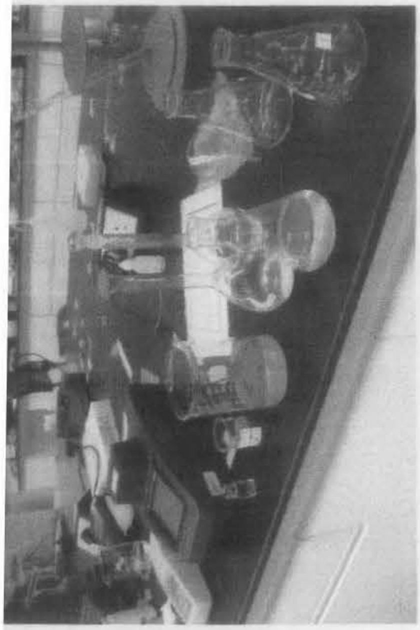
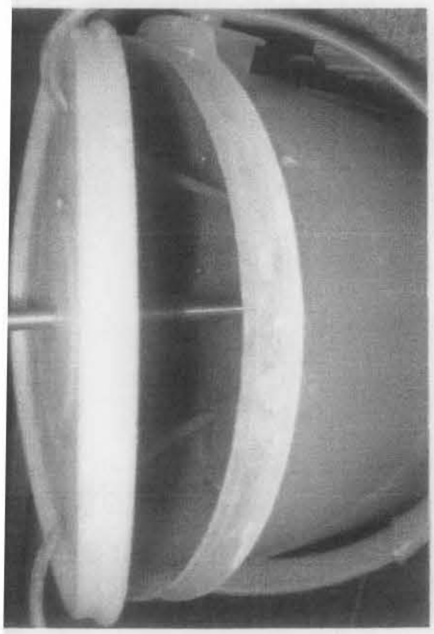
	Mass (g)				Mass (mg/L)
No	**Foil**	**Foil + Filter Paper**	**Foil + Filter Paper at 105oC**	**Foil +Filter Paper + Residue at 105oC**	**TSS**
1	1,183	1,3471	1,3402	1,3387	30
2	1,1794	1,3408	1,335	1,3332	36
3	1,1842	1,34	1,3355	1,3332	46
4	1,1904	1,3471	1,3424	1,3407	34
5	1,2391	1,394	1,3896	1,3876	40
6	1,124	1,2779	1,2739	1,2727	24

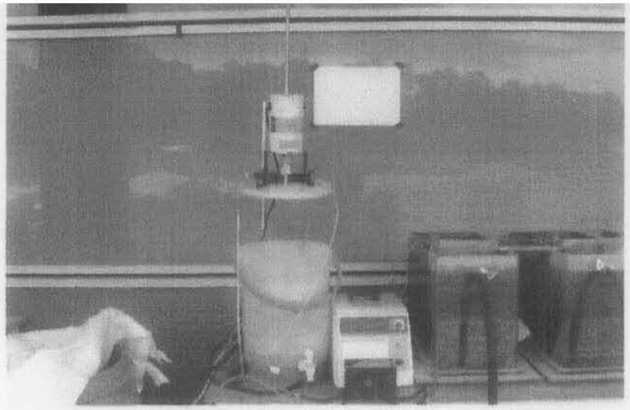
TSS (Influent)

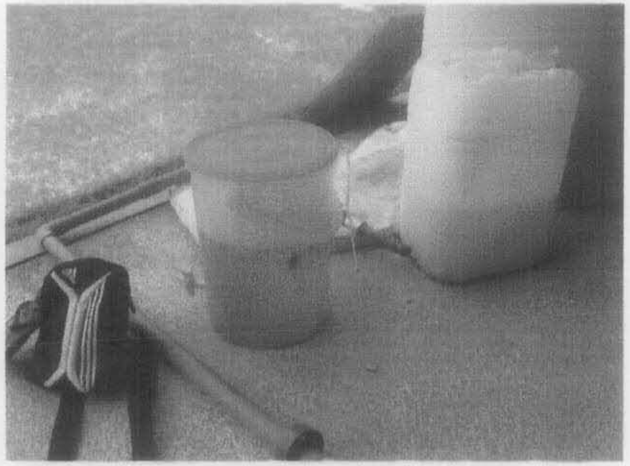
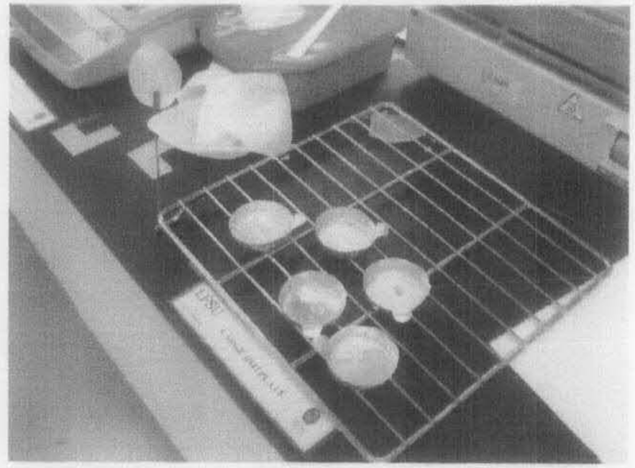
	Mass (g)				Mass (mg/L)
No	**Foil**	**Foil + Filter Paper**	**Foil + Filter Paper at 105oC**	**Foil +Filter Paper + Residue at 105oC**	**TSS**
1	1,2003	1,3515	1,342	1,3449	58
2	1,1229	1,2741	1,2655	1,27	90
3	1,1214	1,2724	1,2645	1,268	70
4	1,131	1,2827	1,2759	1,2787	56
5	1,1791	1,3323	1,3263	1,3298	70
6	1,1756	1,3252	1,3199	1,323	62

No	**Initial TSS (mg/L)**	**Final TSS (mg/L)**	**Percentage Reduction (%)**
1	58	30	48,28
2	90	36	60,00
3	70	46	34,29
4	56	34	39,29
5	70	40	42,86
6	62	24	61,29
Average	67,67	35,00	47,67




LFSU FURNACE
LFSU FOR LABORATORIES USE ONLY
Nabertherm


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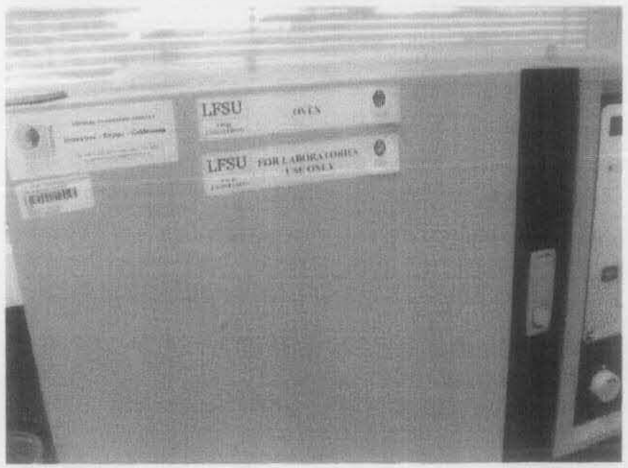
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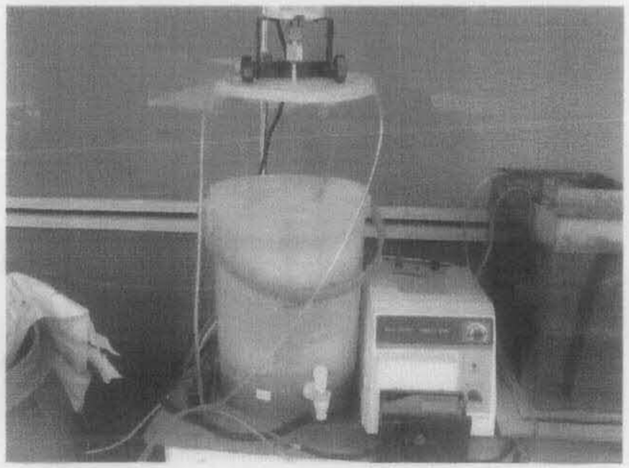
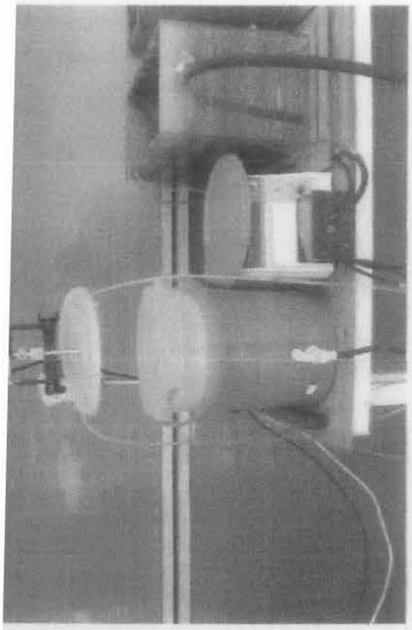
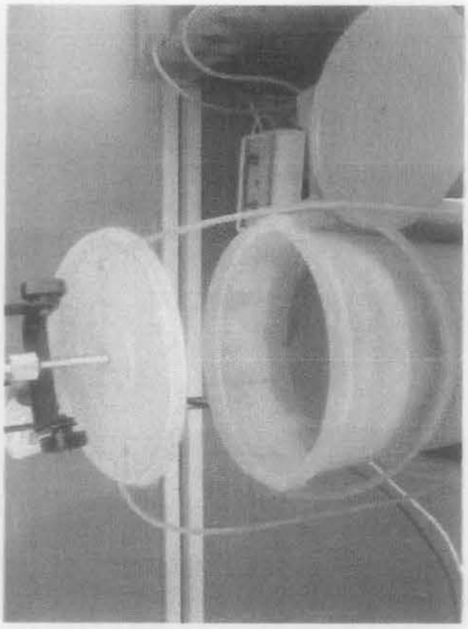
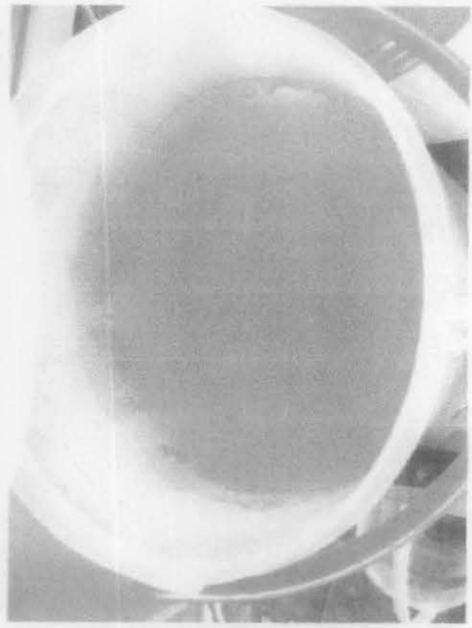
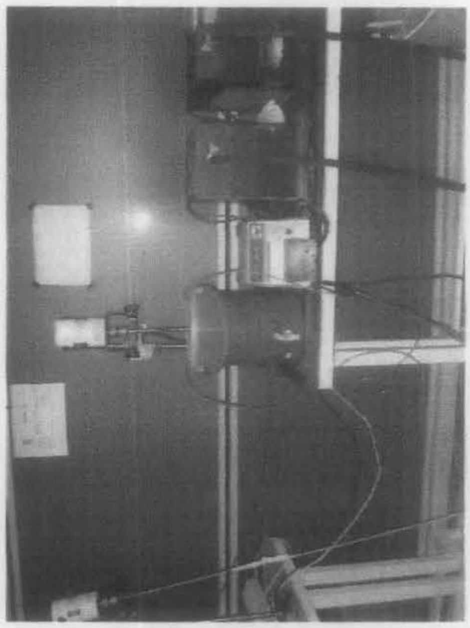
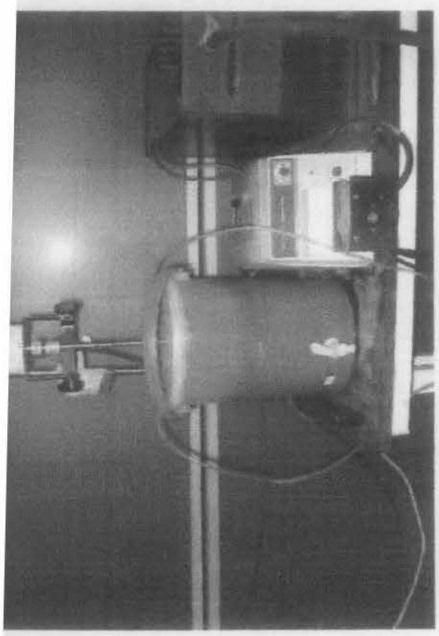
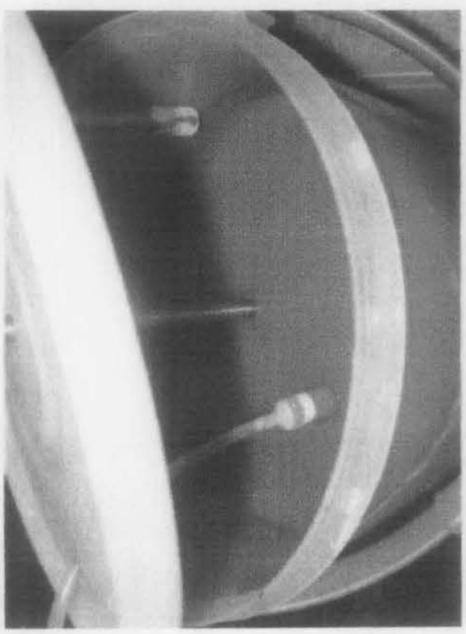
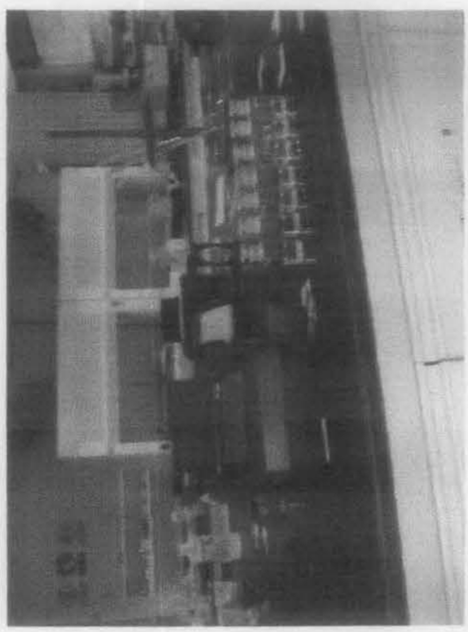
LFSU FOR LABORATORIES USE ONLY


Wastewater, Industrial Discharge Standards 'TCVN 5945, 1995)

'ack to : Index : Environmental Law (ASEAN-10) : Vietnam : implementing Regulations
)isclaimer

INDUSTRIAL WASTE WATER DISCHARGE STANDARDS TCVN 5945-1995

.. Scope

..1 **This standard specifies limit values of parameters and concentration of substances in ndustrial waste water.**

n this standard **industrial waste water** means: liquid water or waste water produced by 'eason of working or production processes taking place at any industrial, servicing and rading premises, etc.

l.2 This standard is applied to control of quality of industrial waste waters before being lischarged into a water body.

Water body means: inland water, include any reservoir, pond, lake, river, stream, canal, lrain, spring or well, any part of the sea abutting on the foreshore, and any other body of natural or artificial surface or subsurface water.

2. Limitation Values

2.1 Values of parameters and maximum allowable concentrations of substances in industrial waste waters before being discharged into water bodies are shown in the table 1.

2.2 Discharge standards applying for waste waters produced by specific industry such as **paper, textile or oil industries are specified in a separate standard, respectively.**

2.3 Industrial waste waters containing the values of parameters and concentrations of substances which are equal to or lower than the values specified in the column A (table 1) may be discharged into the water bodies using for sources of domestic water supply.

2.4 Industrial waste waters containing the values of parameters and concentration of substances which are lower than or equal to those specified in the column B (table 1) are discharged only into the water bodies using for navigation, irrigation purposes or for bathing, aquatic breeding and cultivation, etc.

2.5 **Industrial waste waters containing the values of parameters and concentrations of substances which are greater than those specified in the column B but not exceeding those**

›ecified in the column C (table 1) are discharged only into specific water bodies permitted
y authority agencies.

6 Industrial waste water containing the values of parameters and concentrations of ıbstances which are greater than those specified in the column C (table 1) shall not be ischarged into surroundings.

.7 Standard methods of analysis of parameters and concentration of substances in ıdustrial waste waters are specified in available current TCVNs.

Table 1
Industrial Waste Water: Limit Values of Parameters and Maximum Allowable Concentration of Pollutants

N°	Parameters and Substances	Unit	Limitation Values		
			A	B	C
1	Temperature	°C	40	40	45
2	pH value		6 - 9	5,5 - 9	5 - 9
3	BOD5 (20°C)	mg/l	20	50	100
4	COD	mg/l	50	100	400
5	Suspended solids	mg/l	50	100	200
6	Arsenic	mg/l	0,05	0,1	0,5
7	Cadmium	mg/l	0,01	0,02	0,5
8	Lead	mg/l	0,1	0,5	1
9	Residual Chlorine	mg/l	1	2	2
10	Chromium (VI)	mg/l	0,05	0,1	0,5
11	Chromium (III)	mg/l	0,2	1	2
12	Mineral oil and fat	mg/l	Not detectable	1	5
13	Animal-vegetable fat and oil	mg/l	5	10	30
14	Copper	mg/l	0,2	1	5
15	Zinc	mg/l	1	2	5
16	Manganese	mg/l	0,2	1	5
17	Nickel	mg/l	0,2	1	2
18	Organic phosphorous	mg/l	0,2	0,5	1
19	Total phosphorous	mg/l	4	6	8
20	Iron	mg/l	1	5	10
21	Tetrachlorethylene	mg/l	0,02	0,1	0,1
22	Tin	mg/l	0,2	1	5
23	Mercury	mg/l	0,005	0,005	0,01
24	Total nitrogen	mg/l	30	60	60
25	Trichlorethylene	mg/l	0,05	0,3	0,3

26	Ammonia (as N)	mg/l	0,1	1	10
27	Fluoride	mg/l	1	2	5
28	Phenol	mg/l	0,001	0,05	1
29	Sulfide	mg/l	0,2	0,5	1
30	Cyanide	mg/l	0,05	0,1	0,2
31	Coliform	MPN/100 ml	5000	10000	--
32	Gross alpha activity	Bq/l	0,1	0,1	--
33	Gross beta activity	Bq/l	1,0	1,0	--

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Acknowledgement: Text courtesy of NEA Policy Division, MOSTE.

Last updated 1st August 1998
Asia-Pacific Centre for Environmental Law
Faculty of Law
National University of Singapore

For non point sources, control measures should be implemented to reduce loadings of suspended solids to streams, rivers and lakes. Farming practices such as no-till minimize soil erosion and help protect water quality. For construction sites, controls such as silt fences and sedimentation basins are designed to prevent eroding soils from reaching surface waters. In urban areas, storm water retention ponds or a regular schedule of street sweeping may be effective in reducing the quantity of suspended solids in storm water run-off.

Water Quality Standards for Total Suspended Solids

Rule 50 of the Michigan Water Quality Standards (Part 4 of Act 451) states that waters of the state shall not have any of the following unnatural physical properties in quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foam, settles able solids, suspended solids, and deposits. This kind of rule, which does not establish a numeric level, is known as a "narrative standard." Most people consider water with a TSS concentration less than 20 mg/l to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/l usually appears dirty. The nature of the particles that comprise the suspended solids may cause these numbers to vary.

Typical values of untreated TSS of domestic wastewater are as follows:

	CONCENTRATION (mg/L)		
	Strong	**Medium**	**Week**
Solids, total	1200	720	350
Suspended, total	350	220	100
Fixed	75	55	20
Volatile	275	165	80

Table 4.1: Concentration values of untreated TSS of domestic wastewater

CALCULATION & CONVERSION FACTOR

1000 ml = 0.001 cubic m

sCOD Loading (kg/day) = [Q (m3/d) x COD (mg/L)] / 1000

sCOD determined from the exp, **100 mg/L**

F/M Ratio = sCOD Loading (kg/d) / MLVSS (kg)

Flow rate determine, 8 L/d = 0.008 m3/d

sCOD Loading (kg/d) = Q x COD = (0.008 m3/d x 100.00 mg/L) / 1000 = **0.0008 kg/d**

Reactor Diameter = 24cm = 0.24 m

Selected Volume of Sludge = 2 L = 0.002 m3

Total Reactor Height = 31.5 cm = 0.315 m

Total Volume of Reactor = PI x $(0.12)^2$ x 0.315 = 0.0143 cu m = **14.3 L**

MLVSS Loading (kg) = MLVSS (mg/L) x Volume of Sludge

MLVSS Loading (kg) = 3097 (mg/L) x 2 L = 6194 mg = **0.0062 kg**

F/ M ratio = sCOD Loading (kg/d) / MLVSS Loading (kg)

F/ M ratio = 0.0008 (kg/d) / 0.0062 kg = **0.13**

Food to Mass Ratio = 2 : 8, hence, **1 : 4**

Nitrification and Denitrification in the Activated Sludge Process. Michael H. Gerardi
Copyright © 2002 John Wiley & Sons, Inc.
ISBN: 0-471-06508-0

Appendix II

F/M, HRT, MCRT

FOOD/MICROORGANISM RATIO (F/M) CALCULATION

The food/microorganism ratio, or F/M, is a measurement of the food entering the activated sludge process and the microorganisms in the aeration tank(s). Each activated sludge process has an F/M at which it operates best. This F/M may fluctuate throughout the year according to changes in operational conditions, such as industrial discharges, permit requirements, and temperature.

The food value or food supply entering the activated sludge process consists of the BOD loading or pounds discharged to the aeration tank(s). The BOD loading is calculated by multiplying the concentration (mg/l) of BOD entering the aeration tank by the influent aeration tank flow in millions of gallons per day (MGD) by the weight constant of 8.34 pounds per gallon of wastewater (Equation II.1).

$$\text{BOD mg/l} \times \text{Flow (MGD)} \times 8.34 \text{ pounds/gal wastewater} = \text{BOD loading} \qquad \text{(II.1)}$$

The microorganism value or amount of microorganisms in the activated sludge process consists of the pounds of mixed liquor volatile suspended solids (MLVSS) in the on-line aeration tank(s). The pounds of MLVSS is calculated by multiplying the concentration (mg/l) of MLVSS by the aeration tank(s) volume in million gallons

(MG) by the weight constant of 8.34 pounds per gallon of wastewater (Equation II.2).

$$\text{MLVSS (mg/l)} \times \text{Aeration tank volume (MG)} \times 8.34\ \text{pounds/gal wastewater} = \text{pounds MLVSS} \quad \text{(II.2)}$$

The F/M of an activated sludge process can be calculated by dividing the pounds of food as BOD applied to the microorganisms or MLVSS present in on-line aeration tanks (Equation II.3)

$$F/M = \text{Pounds BOD to aeration tank/Pounds MLVSS in aeration tank} \quad \text{(II.3)}$$

HYDRAULIC RETENTION TIME (HRT) CALCULATION

The hydraulic retention time or HRT is the amount of time in hours for wastewater to pass through a tank, such as an aeration tank. Changes in the HRT of an activated sludge process can affect biological activity. For example, decreasing HRT adversely affects nitrification, while increasing HRT favors nitrification and the solublization of colloidal BOD and particulate BOD.

The HRT of an aeration tank is determined by dividing the volume of the aeration tank in million gallons by the flow rate through the aeration tank (Equation II.4). The flow rate through the aeration tank must be expressed as gallons per hour (gph).

$$\text{HRT (hours)} = \text{(Volume of aeration tank, gal)/(Flow rate, gph)} \quad \text{(II.4)}$$

MEAN CELL RESIDENCE TIME (MCRT) CALCULATION

The mean cell residence time or MCRT is the amount of time, in days, that solids or bacteria are maintained in the activated sludge system. The MCRT is known also as the solids retention time (SRT). To calculate the MCRT of an activated sludge process, it is necessary to know the amount or pounds of solids or suspended solids in the activated sludge system and the amount or pounds of suspended solids leaving the activated sludge system.

To determine the pounds of suspended solids in the activated sludge system, the pounds of mixed liquor suspended solids (MLSS) must be calculated. The MLSS consists of all solids in the aeration tank(s) and secondary clarifier(s). Therefore the pounds of MLSS in an activated sludge systems consists of the concentration (mg/l) of MLSS times the volume (MG) of the aeration tank(s) and clarifier(s) times the weight constant of 8.34 pounds per gallon of wastewater (Equation II.5).

$$\begin{aligned}\text{Pounds of MLSS}\\ &= \text{MLSS mg/l} \times (\text{Volume of aeration tanks} + \text{Clarifiers, MG})\\ &\quad \times 8.34\,\text{pounds/gal wastewater} \qquad \text{(II.5)}\end{aligned}$$

To determine the pounds of suspended solids leaving the activated sludge process, the amount or pounds of suspended solids loss through wasting and discharge in the secondary effluent must be calculated. Therefore the pounds of suspended solids leaving the activated sludge process consists of pounds of activated sludge wasted per day and the pounds of activated sludge or secondary effluent suspended solids discharged per day (Equation II.6).

$$\begin{aligned}\text{Pounds of suspended solids leaving activated sludge process}\\ &= \text{Wasted sludge (mg/l)} \times \text{Wasted sludge flow (MGD)}\\ &\quad \times 8.34\,\text{pounds/gal wastewater}\\ &\quad + \text{Secondary effluent suspended solids (mg/l)}\\ &\quad \times \text{Effluent flow (MGD)} \times 8.34\,\text{pounds/gal wastewater} \qquad \text{(II.6)}\end{aligned}$$

The mean cell residence time of an activated sludge process can be calculated by dividing the pounds of suspended solids or MLSS in the activated sludge system by the pounds per day of suspended solids leaving the activated sludge system (Equation II.7).

$$\text{MCRT} = \frac{\text{Suspended solids in system, pounds}}{\text{Suspended solids leaving system per day}} \qquad \text{(II.7)}$$

CONVERSIONS AND CALCULATIONS

The figures in the central columns can be read as either the metric or the Canadian measure. Thus 1 inch = 25.4 millimetres; or 1 millimetre = 0.039 inches.

Inches		**Milli-metres**	**Miles**		**Kilo-metres**	**Cu Feet**		**Cu Metres**
0.039	1	25.4	0.621	1	1.609	35.315	1	0.028
Cu Yards		**Cu Metres**	**Feet**		**Metres**	**Sq Feet**		**Sq Metres**
1.308	1	0.765	3.281	1	0.305	10.764	1	0.093
Pints		**Litres**	**Gallons**		**Litres**	**Yards**		**Metres**
1.760	1	0.568	0.220	1	4.546	1.094	1	0.914
Sq Yards		**Sq Metres**	**Ounces**		**Grams**	**Pounds**		**Kilo grams**
1.196	1	0.836	0.035	1	28.350	2.205	1	0.454

Area:

Rectangle = L x W

Triangle = 1/2 B x H

Circle $= \pi r^2$ or $\frac{\pi d^2}{4}$ or $.785(d^2)$

Sphere $= \pi d^2$ or $4\pi r^2$ or $4 \times .785(d^2)$

Volume:

Rectangle = L x W x D

Prism = 1/2 B x H x D

Cylinder $= \pi r^2 \times D$ or $\frac{\pi d^2}{4} \times D$ or

Cylinder $= (0.785)(d^2)(h)$

Cone $= \frac{\pi r^2}{3} \times D$ or $1/3\,(0.785)(d^2)(D)$

Sphere $= \frac{\pi}{6}(d)^3$ or $2/3\,(0.785)(d^3)$

1 U.S. Gallon = 8.33 lb

1 U.S. Gallon = .833 ig

1 U.S. Gallon = 3.785L

1 L = 0.264 U.S. Gallon

7.48 U.S. gallon/ft^3

1 ig = 1.2 U.S. Gallon

Velocity = flow rate divided by cross sectional area

1 ig = 10 lb

1 m^3 = 1000 kg

Detention time = volume/flow

1 psi pressure = 2.31 ft head (water)

1 ft (water) = 0.433 psi

1.122 ft water/in. of mercury

1 metre head = 9.8 kPa

1 ft^3 = 6.24 ig

1440 min/day

5280 ft/mile

1760 yd/mile

43,560 sq. ft/acre

10,000 sqm/hectare

Iorsepower

1 hp = 0.746 kW
= 33,000 ft lb/min

Water hp = $\frac{\text{lb of } H_2O \text{ raised per min. x head in ft}}{33{,}000}$

Brake hp = Whp divided by efficiency

1 Bhp = 746 watts

Power (kW) = $\frac{\text{Flow (L/sec) x Head (m) x 9.8}}{1000}$

Density (Water)
8.34 lb/U.S. gallon
10 lb/ig
62.4 lb/ft^3

MISC CONVERSIONS

emperature: °C = 5/9 (°F - 32°F)
nass: 1 grain = 0.0648 gram
l grain/gallon = 17.1 mg/L
ɔower: 1 Newton metre (N·m) = 0.734 ft lb
ɔressure: 1 kilopascal (Kpa) = 0.145 psi
force: 45 Newtons = 1 lb force
flow: 1 igpd x 0.004546 = m^3/day
electricity: Watts = I (amps) x V (volts)
V (volts) = I (current) x R (ohms resistance)

°F = 9/5 (°C) + 32°F
mass: 1 gram = 15.43 grains
L = 1 kg at + 4NC
Volume: 1m^3 = 219.97 ig
area: 1 hectare (ha) = 2.47 acres
energy: 1 kilojoule (kJ) = 0.948 BTU

WATER TREATMENT CALCULATIONS

Backwash rate

normally 24 in rise per minute
requires 12.5 IGPM/sq. ft
or 15 U.S.GPM/sq ft

Water Softening Equations

Carbonate hardness

1. $Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3\downarrow + 2H_2O$
(Lime)
2. $Mg(HCO_3)_2 + Ca(OH)_2 = CaCO_3\downarrow + MgCO_3 + 2H_2O$
(Lime)

Non Carbonate hardness

3. $CaSO_4 + Na_2CO_3 = CaCO_3\downarrow + Na_2SO_4$
(soda ash)
4. $MgSO_4 + Ca(OH)_2 + Na_2CO_3 = CaCO_3\downarrow + Mg(OH)_2\downarrow + Na_2SO_4$
(Lime)

CO_2 reaction

5. $CO_2 + Ca(OH)_2 = CaCO_3\downarrow + H_2O$

Wastewater Calculations

Loading = $\frac{\text{Flow (m}^3\text{/day) x conc. (mg/L)}}{1000}$ = kg/day

$BOD_5 = DO_1 - DO_2 \times \frac{300\text{ mL}}{\text{ml of sample}}$

Sludge Volume index = $\frac{\text{ml settled sludge x 1000}}{\text{mg/L MLSS}}$

Wastewater Treatment Calculations

F:M ratio = kg/day BOD: kg/day MLVSS in aeration tank

Sludge Age Aeration tank plus Clarifier (days) = MCRT (mean cell residence time)

Sludge Age = $\frac{\text{Suspended Solids in Aerator, lbs}}{\text{Suspended Solids in Primary Effluent, lb/day}}$

$\frac{\text{MLSS mg/L x Aerator Vol., M.G. x 8.34 lb/U.S. gal}}{\text{Prim.Eff. SS,. mg/L x Flow MGD x 8.34 lb/U.S. gal}}$

or $\frac{\text{MLSS mg/L x Aerator Vol, m}^3}{\text{Prim.Eff, SS, mg/L x Flow m}^3\text{/day}}$ = Days Sludge Age

MCRT = $\frac{(Va)(x)+(Vc)(x)}{(Qw)(Xu)+(Qe)(xe)}$

Va = Volume of aeration tanks (gal)

x = average solids conc. in aeration tanks (mg/L)

Vc = volume of final settling tank (gal)

Qw = flow rate per day of sludge wasted (gpd)

x_u = average activated sludge conc. in final settling tank (mg/L)

Qe = final effluent flow rate (gpd)

xe = final effluent average solids conc.(mg/L)

SS Wasting Rate (lb/day):

= $\frac{\text{solids conc. of aeration (lb)}}{\text{MCRT (days)}}$ - Solids conc. in effluent (lb/day)

SS Wasting Rate (gal/day):

= $\frac{\text{SS wasted (lb.day) x 1,000,000 mg/L}}{\text{RAS SS (mg/L) x 10 lb/gal}}$

SOLVING WASTEWATER TREATMENT PLANT PROBLEMS

Activated Sludge

1. MLSS, lbs = (Aer Vol, MG)(MLSS, mg/L)(8.34 lbs/U.S. gal)

2a. Settleable Solids % = $\frac{\text{(Settleable Solids, mL)(100\%)}}{\text{Sample Volume, mL}}$

2b. Return Sludge Rate, MGD = $\frac{\text{(Total Flow, MGD)(Settling volume ml/L, x 100\%)}}{\text{1000 ml/L – (settling volume, ml/L)}}$

3a. Solids in Aerator, lbs = (Aerator Vol, MG)(MLSS, mg/L)(8.34 lbs/U.S. gal)

3b. Solids Added, lbs/day = (Flow, MGD)(PE SS, mg/L)(8.34 lbs/U.S. gal)

3c. Sludge Age, days = $\frac{\text{Suspended Solids in Aerators, lbs}}{\text{Solids added by PE, lbs/day}}$

a. Desired MLSS, lbs = (Sludge Age, days)(Solids Added, lbs/day)

lb. Desired MLSS, mg/L = $\frac{\text{Desired MLSS, lbs}}{\text{(Aerator Vol, MG)(8.34 lb/U.S. gal)}}$

5a. Change in WAS Pumping, MGD = $\frac{\text{(Actual MLSS, lbs - Desired MLSS, lbs)/day}}{\text{(Waste Sludge Conc, mg/L)(8.34 lbs/U.S. gal)}}$

5b New WAS Pumping GPM = Current WAS Pumping, GPM + Change in WAS Pumping, GPM

5a. Aerator Loading, lbs COD/day = (Flow, MGD) (PE COD, mg/L) (8.34 lbs/U.S. gal)

5b. MLVSS, lbs = $\frac{\text{Aerator Loading, lbs COD/day}}{\text{Loading Factor, lbs COD/day/lb MLVSS}}$

6c. MLVSS, mg/L = $\frac{\text{MLVSS, lbs}}{\text{(Aerator Vol, MG)(8.34 lbs/U.S. gal)}}$

6d. Food/Microorganisms = $\frac{\text{Aerator Loading, lbs COD/day}}{\text{(Aerator Vol, MG) (MLVSS, mg/L) (8.34 lbs/U.S. gal)}}$

7. MCRT, days = $\frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs/day, + SS Lost, lbs/day}}$

8a. WAS, lbs/day = $\frac{\text{SS in Aeration System, lbs}}{\text{MCRT, days}}$ - SS Lost, lbs/day

8b. WAS Pumping, MGD = $\frac{\text{WAS, lbs/day}}{\text{(WAS SS, mg/L)(8.34 lbs/U.S. gal)}}$

SLUDGE DIGESTION

9. Seed Sludge, gal = $\frac{\text{Digester Volume, gal) (Seed Sludge, \%)}}{\text{100\%}}$

10a .Volatile Solids Pumped lbs/day =

$$\frac{\text{(Raw Sludge, GPD) (Raw Sl Sol, \%) (Volatile, \%) (8.34 UG gal)}}{\text{(100\%)} \quad \text{(100\%)}}$$

10b. Seed Sludge, lbs Volatile Solids =

$$\frac{\text{Volatile Solids Pumped, lbs VS/day}}{\text{Loading Factor, lbs VS/day/lb VS in Digester}}$$

10c. Seed Sludge, gallons = $\frac{\text{Volatile Solids Pumped, lbs VS/day}}{\text{(Seed Sludge, lbs/gal)}\left(\frac{\text{Solids, \%}}{100\%}\right)\left(\frac{\text{VS, \%}}{100\%}\right)}$

11. Lime Req'd lbs = (Sludge volume MG)(Volatile Acids, mg/L)(8.34 lbs/U.S. gal)

12. Piston Pump Vol., gal/stroke =

$$(0.785)(\text{Diameter, ft})^2(\text{Distance, ft/stroke})(7.5 \text{ U.S. gal/cu ft})$$

13a. Dry Solids, lbs = $\frac{\text{(Raw Sludge, gal) (Raw Sludge \%) (8.34 lbs/U.S. gal)}}{\text{100\%}}$

13b. Volatile Solids, lbs = (Dry Solids, lbs) (Raw Sludge, % VS)

100%

14. Reduction of Volatile Solids, % = $\frac{\text{(In - Out)(100\%)}}{\text{In - (In x Out)}}$

15. Digester Loading, lbs VS/day/cu ft = $\frac{\text{Volatile Solids Added, lbs/day}}{\text{Digester Volume, cu ft}}$

16. Digested Sludge in Storage, lbs = (VS Added, lbs/day) x $\frac{\text{(Loading, lbs Dig. Sl)}}{\text{lbs VS/day}}$

17. VS Destroyed, lbs/day/cu ft = $\frac{\text{(VS Added, lbs/day) (VS Reduction, \%)}}{\text{(Digester Volume, cu ft) (100\%)}}$

18. Gas Production, cu ft/lb VS = $\frac{\text{Gas Produced, cu ft/day}}{\text{VS Destroyed, lbs/day}}$

19. Solids Balance Water Change, lbs =

(Water In, lbs) - (Water Out, lbs) - (Supernatant Out, lbs)

EFFLUENT DISPOSAL

20. BOD Load, lbs BOD/day = (Flow, MGD)(BOD, mg/L)(8.34 lbs/U.S. gal)

21. Average BOD, mg/L = $\frac{\text{Sum of Measurements, mg/L}}{\text{Number of Measurements}}$

MAINTENANCE

22. Pump Capacity, GPM = $\frac{\text{Volume Pumped}}{\text{Pumping Time, minutes}}$

23a. Velocity, ft/sec = $\frac{\text{Distance, ft}}{\text{Time, sec.}}$

23b. Flow, cu ft/sec = (Area, sq ft)(Velocity, ft/sec)

LABORATORY

24. Temperature, °F = (Temperature, °C)(1.8) + 32°

25. Sludge pumped, GPD = (Sludge Removed, mL/L)(1000 mg/ml)(Flow, MGD)

26a. Total Susp. Sol, mg/L = $\frac{\text{(Dry Weight, mg)(1000 mL/L)}}{\text{Sample Volume, mL}}$

26b. Volatile Susp. Sol, mg/L = $\frac{\text{(Volatile Weight, mg)(1000 mg/L)}}{\text{Sample Volume, mL}}$

26c. Volatile SS, % = $\frac{\text{(Volatile SS, mg/L)(100\%)}}{\text{Total SS, mg/L}}$

26d. Fixed Susp Solids, mg/L = $\frac{\text{(Ash Weight, mg)(1000 mL/L)}}{\text{Sample Volume, mL}}$

26e. Fixed SS, % = $\frac{\text{(Fixed SS, mg/L)(100\%)}}{\text{Total SS, mg/L}}$

7. Removal, % = $\frac{(\text{In - Out})(100\%)}{\text{In}}$

3. Suspended Solids Removed, lbs/day =

(Flow MGD)(SS Removed, mg/L)(8.34 lbs/U.S. gal)

9. SVI = $\frac{(\text{Set Sol, \%})(10{,}000)}{\text{MLSS, mg/L}}$

0. CO_2,% = $\frac{(\text{Total Volume, mL - Gas Remaining, mL})(100\%)}{\text{Total Volume mL}}$

1. DO Saturation, % = $\frac{(\text{DO of Sample, mg/L})(100\%)}{\text{DO at Saturation, mg/L}}$

2. BOD Sample Size, mL = $\frac{1200}{\text{Estimated BOD, mg/L}}$

3. BOD5, mg/L = [Initial DO of Diluted Sample, mg/L - DO of Sample After 5 days, mg/L] $\frac{[\text{BOD Bottle Vol, mL}}{\text{Sample Vol, mL}}$

DATA ANALYSIS

34a. Mean = $\frac{\text{Sum of All Measurements}}{\text{Number of Measurements}}$

34b. Median = Middle measurement

34c. Mode = Measurement that occurs most frequently

34d. Range = Largest Measurement - Smallest Measurement

Biochemical Oxygen Demand (BOD)

The objective of the experiment was to determine the biochemical oxygen demand (BOD) in the wastewater sample.

Biochemical oxygen demand, BOD is commonly used as an indirect indicator to evaluate the amount of organic matter present in wastewater. BOD is the amount of oxygen used by bacteria to degrade the organic matter present in wastewater. When bacteria is placed in wastewater which contact with organic matter, it will utilize the organic matter as its source of food. The organic matter will be oxidized to produce an end product of carbon dioxide and water.

BOD has been widely used as a parameter in determining organic pollution applied to both wastewater and surface water in the 5 days measurement (BOD_5). The determination of pollution is measured by taking the value of BOD (the dissolved oxygen contain in the body of water) by measuring the initial value and the final value of BOD after 5 days.

Oxidation Reaction in Wastewater

$COHNS + O_2 + bacteria \rightarrow CO_2 + H_2O + NH_3 + Energy + other\ end\ product$

Synthesis

$COHNS + O_2 + bacteria + energy \rightarrow C_5HNO_2$

Apparatus

- BOD bottle, volume of 300ml
- Measuring cylinder
- Pipette
- DO probe equipped with a stirring mechanism

Sample/ Reagent

- Wastewater samples

- Tap water
- Distilled water
- Aerated distilled water

Procedure

1. Samples were prepared and poured into the BOD bottles according to the volume needed. Blank samples were also prepared.
2. After all the samples were prepared, the initial dissolve oxygen (DO) for each sample was measured by the DO probe that was equipped with a stirring mechanism.
3. The BOD bottles were then placed in the refrigerator at 20°C temperature and left for 5 days.
4. After 5 days incubation, the final DO is measured by using the DO probe.

Chemical Oxygen Demand (COD)

The objective of the experiment is to measure the chemical oxygen demand equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution.

Chemical oxygen demand is widely used to characterize the organic strength of wastewater and pollution of natural waters. It is the amount of oxygen that is required to oxidize an organic compound (biodegradable and non-biodegradable) to CO_2 and water under the influence of strong oxidizing agent or oxidant ($K_2Cr_2O_7$) in an acid environment (silver nitrate is used as catalyst). Compared to the BOD test, the major advantage of this test is that it requires a shorter time which is approximately 3 hours. The relationship between COD and BOD can be established so that the BOD value can be estimated quickly. The common relationship between these two parameters can be obtained by BOD_5 / COD for municipal wastewater = 0.5

Apparatus

- Reluxing unit – comprising the following
- Blender
- Oven – set to be in 150°C
- Dispensers – to deliver accurate volume of chemicals

Reagents

- Cleaning solutions:
- Mercuric sulfate
- Ferroin indicator
- Potassium dichromate solution, $K_2Cr_2O_7$

Procedure

1. 2ml of wastewater sample was measured and poured into a test tube containing potassium dichromate.

2. The test tube is then shaken properly. Heat was produced, indicating an exothermic process.
3. This procedure is repeated for other samples also.
4. All the test tubes together with a blank as an indicator were then put into the rotator and left for 2 hours.
5. Three readings are taken down and the average of those readings is calculated.

Total Suspended Solids (TSS)

The objective of this experiment is to calculate the non-filterable residue in water or wastewater using the gravimetric method.

Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter. Suspended solids are present in sanitary wastewater and many types of industrial wastewater. There are also non-point sources of suspended solids, such as soil erosion from agricultural and construction sites.

As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Some cold water species, such as trout and stoneflies, are especially sensitive to changes in dissolved oxygen. Photosynthesis also decreases, since less light penetrates the water. As less oxygen is produced by plants and algae, there is a further drop in dissolved oxygen levels.

TSS can also destroy fish habitat because suspended solids settle to the bottom and can eventually blanket the river bed. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in a diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may be disrupted.

For point sources, adequate treatment is necessary to insure that suspended solids are not present at levels of concern in waters of the state. Treatment typically consists of settling prior to discharge of the wastewater. Settling allows solids to sink to the bottom, where they can be removed. Some types of wastewaters, such as non contact cooling water, are naturally low in suspended solids and do not require treatment.

Apparatus

- Different sample of water / wastewater
- 47mm filter paper
- Filter holder
- Filtering flask
- Watch glass
- Drying oven
- Desiccators
- Tweezers
- Measurement cylinder

Procedures

1. A 47 mm filter disc is placed in the filter holder with wrinkle surface upward. Note: Always use tweezers to handle filter discs. Finger and moisture, will subsequently will cause a weighing error.
2. 100 ml (or more if solid content is low) of well mix is filtered, representative water sample by applying a vacuum to the flask. Follow by three separated 10 ml washing deionised water. Note: For greatest accuracy as much as possible should be filtered. However, using a sample more than 15 ml of solids will result in premature plugging of the water sample may have to be adjusted (increased or decreased) to achieved to optimum condition. Several completed test will show whether any adjustment is necessary.
3. The vacuum from the filtering system is slowly released and the filter is gently removed from the holder. The disc is placed on a watch glass. The filtrate is inspected (filtered water in flask) to ensure that proper trapping of solids was accomplished on the disc. Note: be sure to remove any residue adhering to the sides or bottom lip of the filter holder. A rubber policeman on the end of a stirring rod is very helpful in scrapping this residue loose, and small amounts of deionised water will help wash the residue down the filter disc.

4. Again the watch glass is placed and filtered in a drying oven at 103°C for 1 hour.
5. The watch glass is removed and filtered from the oven, and carefully placed in a desiccator. It was allowed to cool to room temperature.
6. Carefully, the disc is removed from the desiccator and weighted to the nearest 0.lmg using an analytical balance. Note: take extreme care when removing the lid of the desiccator to not disturb the dried suspended matter on the disc. Remove the watch glass and disc from the desiccator as a unit and place beside the analytical balance. Use plastic tweezers to transfer the disc to and from the weighing pan of the balance.
7. The disc is returned to the watch glass if the mg/L Volatile Non-Filterable Residue (VNR) is to be determined. If not, discard the disc. Note: If Volatile Non-Filterable Residue (VNR) also is to be determined, take care not to lose any portion of the suspended matter on the disc.

Nitrogen-Ammonia (Nessler Method)

The objective of this experiment is to determine the nitrogen-ammonia in the effluent of wastewater using the Nessler method in the wastewater according to the specific time.

Nitrogen is essential in for cell growth of bacteria used to treat wastes in an activated sludge system. Ammonia can be determine in two ways namely; the nesslerization procedure and the phenate methods. In Nessler method, potassium/mercury/iodine used to react with ammonia forming yellow to browned colored compound. The phenate method react phenol and hypochlorite with ammonia to create blue colored compound, where in both method, the color intensity is proportional to the ammonia concentration.

Apparatus / Reagent

- Ammonia Nitrogen reagent set
- Deionised water
- Graduated mixing cylinders
- Sample cells, 1 inch-square, 10 ml
- Serological pipette, 1 ml

Procedure

1. The sample is prepared by diluting it.
2. The sample prepared is filled into the Erlenmeyer.
3. Three drops of mineral stabilizer is added into each Erlenmeyer and mixed well.
4. Three drops of Polyvinyl Alcohol Dispersing agent is added to each and mixed well.
5. 1mL of Nessler Reagent is pipette into each and mixed well.
6. Wait for 1 minute for the reaction to begin.
7. 10ml of each sample is poured into vial.
8. The reading in spectrometer is read and noted.

Nitrate (Cadmium Reduction Method)

The objective of this experiment is to determine the value of nitrate which contain in each sample of wastewater using the Cadmium Reduction Method.

Nitrate is the most completely oxidized form of nitrogen. It is formed during the final stages of biological decomposition, either in wastewater treatment facilities or in natural water supplies. Low-level nitrate concentrations may be present in natural waters. However, a Maximum Contaminant Level of 10ppm nitrate-nitrogen has been established for drinking water by the USEPA. Process of ammonia become nitrate is called nitrification where ammonia changes into nitrite and then change onto nitrate.

Nitrogen-containing compounds released into environment can create serious problems, such as eutrophication of rivers, deterioration of water quality and potential hazard to human health, because nitrate in the gastrointestinal tract can be reduced to nitrite ions. In addition, nitrate and nitrite have the potential to form N-nitrous compounds, which are potent carcinogens. Biological removal of nitrate is widely used in the treatment of domestic and complex industrial wastewaters. Biological denitrification enables transformation of oxidized nitrogen compounds by a wide spectrum of heterotrophic bacteria into harmless nitrogen gas with the accompanying carbon removal.

The active sludge of this plant comprises microorganisms acclimated to nitrates, and variety of other substances. Therefore, biomass prepared from the active sludge of this wastewater treatment plant was used for investigations of the kinetics of the biological denitrification process. Attempts were made to optimize the temperature, pH values and methanol to nitrate ratio to achieve as rapid nitrate removal as possible, without nitrite accumulation, and to improve economical effectiveness of the process.

The denitrification of synthetic wastewater was investigated in a batch and in the continuous-flow stirred reacts.

Apparatus

- Beaker
- Spectrometer

Reagent

- Sample of wastewater
- NitraVer 5 Nitrate Reagent Powder

Procedure

1. The "store programme" at the spectrometer is pressed.
2. The appropriate test is selected which is "355 N, Nitrate HR PP".
3. A square sample cell with 10ml of sample is filled in the 10ml beaker.
4. The contents of NitraVer 5 Nitrate Reagent Powder Pillow are added into the beaker.
5. The beaker and its content is leave for one-minute reaction.
6. The cell is shaking vigorously until the timer expires.
7. When the timer expires, the beaker and its contents is leave for five-minute reaction. An amber color will develop if nitrate is present.
8. When the timer expires, a second square sample cell is filled with 10ml of sample.
9. The blank is wiped and it is inserted into the cell holder with the fill line facing right.
10. The "ZERO" button is pressed. The display will show: 0.0 mg/L NO_3 – N.
11. Within one minute after the timer expires, the prepared sample is wiped and it is being inserted into the cell holder with the fill line facing right.
12. The "READ" button is pressed. Results are in mg/L NO_3 – N.