AEROBIC DIGESTION OF MUNICIPAL WASTE ACTIVATED SLUDGE AND WASTEWATER USING SPRINKJET AND DIFFUSER

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by

Ashmil Fanaz b. Alla Ditta

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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

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Supervisor

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Tronoh, Perak

January 2008

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.

ASHMIL FANAZ BIN ALLA DITTA

ABSTRACT

Aerobic digestion is an endogenous respiration process whereby it will release energy to maintain vital cell function. Using municipal waste as the sample is quite common in this project as it does not create difficulties to maintain the bacteria inside the waste. The main objectives of this project are to reduce the solid content of biodegradable organic sludge and degrading the municipal wastewater. Various methods were used to achieve the objective. However, this project focus on the best method to reduce the organic sludge in shorter time and economical manner besides of the wastewater degradation research using two different types of aerators which are diffuser and SPRINKJET. Parameters used to indicate sludge digestion and wastewater are mass liquor volatile suspended solid (MLVSS), mass liquor suspended solid (MLSS), chemical oxygen demand (COD) and total suspended solid (TSS). SPRINKJET, which is an innovative creation of aerator show a good result. The decrement of MLSS was quite good (4700 mg/L to 6500 mg/L) within 3 days aeration period without neglecting the minimum level of dissolved oxygen. Average of dissolved oxygen recorded was around 7.3 mg/L. Looking at the overall result, there is still room for improvement in order to achieve best results.

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CHAPTER 1

INTRODUCTION

1.0 BACKGROUND OF STUDY

Sludge digestion is a biological process in which organic solids are decomposed into stable substances while biological Wastewater Treatment involves the use of microorganisms (bacteria) to naturally degrade organic waste resulting in BOD reduction, COD reduction and wastewater odour control [1]. Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge. Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Aerobic digestion may be used to treat waste sludge from extended aeration of municipal wastewater plants. Advantages claimed for aerobic digestion as compared to anaerobic digestion are as follows; (1) volatile solids reduction is approximately equal to that obtained anaerobically, (2) lower BOD concentrations in supernatant liquor, (3) production of an odourless, humus - like, biologically stable and product, (4) recovery of more of the basic fertilizer values in the sludge, (5) operation is relatively easy and (6) lower capital cost. The major disadvantages of the aerobic digestion process are that; (1) a high power cost is associated with supplying the required oxygen, (2) a digested sludge is produced with poor mechanical dewatering characteristics, (3) the process is affected significantly by temperature, location, and type of tank material and (4) a useful by - product such as methane is not recovered [2].

As the supply of available substrate is depleted, the microorganisms begin to consume their own protoplasm to obtain energy for cell maintenance reactions. When this occurs, the microorganisms are said to be in the endogenous phase. In actuality, only about 75 to 80 % of the cell tissue can be oxidized, the remaining is composed of inert components and organic compounds that are not biodegradable [3].

1.1 Problem Statement

Everyday as population keep increasing, the sludge also will be increased. In order to solve this problem, the responsible body should become manifest with some of the effective solution in disposing the biodegradable solids rather than just using the traditional method which buried inside the land.

Based on the survey done by the Malaysia Environmental Health Country Profile World Health Organization in 2001 [4], about 6.378 million tons of sludge was generated throughout the year. Besides that, there are 170 recycle centers throughout the country.

Therefore; the purpose of this study is to reduce the solid content of an aqueous biodegradable organic sludge by equipment which can deliver higher dissolved oxygen at the cheaper cost. By doing this, the total of sludge that needed to be dispose can be reduced and significantly reduced the disposing cost.

1.2 Objective of Project

The objectives of this study are to determine the feasibility study of (i) increasing the dissolved oxygen in wastewater and sludge using SPRINKJET (ii) reducing the solid content of the biodegradable organic sludge using diffuser (iii) degrade the municipal wastewater using SPRINKJET.

1.3 Scope of Work

1.3.1 Scope of Work for Phase 1

The scoped of work covered in this phase touch the aspect of sludge digestion which the sludge taken from the clarifier of University Technology PETRONAS Sewage Treatment Plant. Parameters measured were mass liquor volatile suspended solid (MLVSS), mass liquor suspended solid (MLSS) and dissolved oxygen.

1.3.2 Scope of Work for Phase 2

The scope of work covered in this phase including the process of fabricating a new model of aerator which can mix the sludge and wastewater well by providing sufficient dissolved oxygen in the reactor. Tests measured during this phase were mass liquor volatile suspended solid (MLVSS), mass liquor suspended solid (MLSS), total suspended solid (TSS), Chemical Oxygen Demand (COD) and dissolved oxygen.

CHAPTER 2
LITERATURE REVIEW

2.1 Aerobic Digestion and Sludge Reduction

Aerobic digestion of waste have been defined as the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste [Chris White, (2002)]. During oxidation process, pollutants are broken down into carbon dioxide (CO2), water (H2O), nitrates, sulphates and biomass (microorganisms). By operating the oxygen supply with aerators, the process can be significantly accelerated. Of all the biological treatment methods, aerobic digestion is the most widespread process that is used throughout the world [Mr. Ken Kerri (1988)].

Wastewater treatment plants produce organic sludge as wastewater is treated; this sludge must be further treated before ultimate disposal. Sludges are generated from primary settling tanks, which are used to remove settable, particulate solids, and from secondary clarifiers (settling basins), which are used to remove excess biomass production generated in secondary biological treatment units.

Disposal of sludges from wastewater treatment processes is a costly and difficult problem. The processes used in sludge disposal include: (1) reduction in sludge volume, primarily by removal of water, which constitutes 97–98% of the sludge; (2) reduction of the volatile (organic) content of the sludge, which eliminates nuisance conditions by reducing putrescibility and reduces threats to human health by reducing levels of microorganisms; and (3) ultimate disposal of the residues.

Aerobic sludge digestion is one process that may be used to reduce both the organic content and the volume of the sludge. Under aerobic conditions, a large portion of the organic matter in sludge may be oxidized biologically by microorganisms to carbon dioxide and water. The process results in approximately 50% reduction in solids content. Aerobic sludge digestion facilities may be designed for batch or continuous flow operations. In batch operations, sludge is added to a reaction tank while the contents are continuously aerated. Once the tank is filled, the sludges are aerated for two to three weeks, depending on the types of sludge. After aeration is discontinued, the solids and liquids are separated. Solids at concentrations of 2–45% are removed, and the clarified liquid supernatant is decanted and recycled to the wastewater treatment plant. In a continuous flow system, an aeration tank is utilized, followed by a settling tank [Corbitt, R. A. (1990)].

Aerobic sludge digestion is usually used only for biological sludges from secondary treatment units, in the absence of sludges from primary treatment units. The most commonly used application is for the treatment of sludges wasted from extended aeration systems (which is a modification of the activated sludge system). Since there is no addition of an external food source, the microorganisms must utilize their own cell contents for metabolic purposes in a process called endogenous respiration. The remaining sludge is a mineralized sludge, with remaining organic materials comprised of cell walls and other cell fragments that are not readily biodegradable.

The advantages of using aerobic digestion, as compared to the use of anaerobic digestion include: (1) simplicity of operation and maintenance; (2) lower capital costs; (3) lower levels of biochemical oxygen demand (BOD) and phosphorus in the supernatant; (4) fewer effects from upsets such as the presence of toxic interferences or changes in loading and pH; (5) less odor; (6) nonexplosive; (7) greater reduction in grease and hexane soluble; (8) greater sludge fertilizer value; (9) shorter retention periods; and (10) an effective alternative for small wastewater treatment plants [Corbitt, R. A.(1990)].

Disadvantages include: (1) higher operating costs, especially energy costs; (2) highly sensitive to ambient temperature (operation at temperatures below 59°F [15°C]) may require excessive retention times to achieve stabilization; if heating is required, aerobic digestion may not be cost-effective); (3) no useful byproduct such as methane gas that is produced in anaerobic digestion; (4) variability in the ability to dewater to reduce sludge volume; (5) less reduction in volatile solids; and (6) unfavorable economics for larger wastewater treatment plants [Corbitt, R. A.(1990)].

The aerobic digestion process is a treatment process that utilizes aerobic microbes to stabilize the solids. The microbes digest solids from primary sedimentation processes, and those from secondary treatment processes like those attached to the microbial flow from activated sludge and biofilters (trickling filters). Due to the length of time that the solids remain under aeration, the long solids retention time allows for the microbes to feed off of the cell contents of other dying/decaying microbes under digestion. This is referred to as "endogenous respiration" or "endogenous stabilization." There will be an "inert faction" between 20 and 25% by weight, in the resulting stabilized solids. This inert faction will consist of fine inorganic solids, organic solids, and cell components that will not be degradable by the process. It may be beneficial to think of an "aerobic digester" as an "activated sludge aeration basin with a much higher concentration of microbes [Manual of Practice (1985)].

Aerobic bacteria are very efficient in breaking down waste products [Mr. Ken Kerri(1988)]. The result of this is; aerobic treatment usually yields better effluent quality that that obtained in anaerobic processes. The aerobic pathway also releases a substantial amount of energy. A portion is used by the microorganisms for synthesis and growth of new microorganisms.

Aerobic decomposition; A biological process, in which, organisms use available organic matter to support biological activity. The process uses organic matter, nutrients, and dissolved oxygen, and produces stable solids, carbon dioxide, and more organisms. The microorganisms which can only survive in aerobic conditions are known as aerobic organisms. In sewer lines the sewage becomes anoxic if left for a few hours and becomes anaerobic if left for more than 11/2 days. Anoxic organisms work well with aerobic and anaerobic organisms. Facultative and anoxic are basically the same concept [Mr. Ken Kerri (1988)].

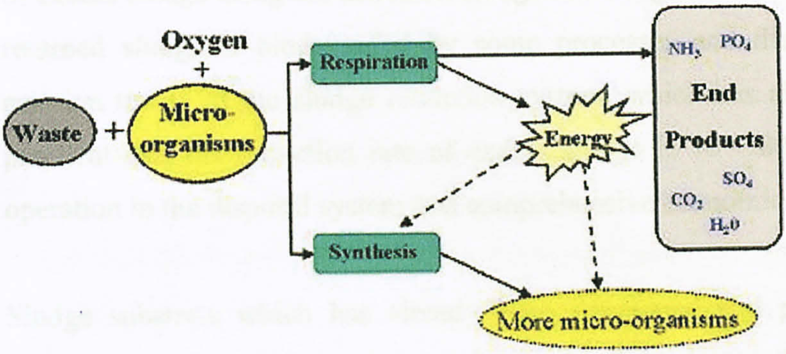

Figure 1: Path of Aerobic Digestion

[Corbitt, R. A. "Wastewater Disposal." Standard Handbook of Environmental Engineering (1990)]

2.1.1 Biodegradation process

As contrasted with the conventional activated sludge process, sludge reduction (or sludge substrate) activated sludge process was developed as a method to reduce sludge disposal costs by controlling the excess sludge volume. This is the process that reduces sludge by degradation and digestion of microorganisms after a portion of returned sludge was disposed into the substrate (to change sludge into biodegradable form) and this substrate sludge was returned to the aeration tank.

2.1.2 Principle and classification of sludge reduction process

The zero emission concept should be considered to reduce wastewater and then to reuse it as resource. Also, it should be disposed of properly. Controlling wastewater itself becomes the real zero emission. The process was developed as a biological wastewater treatment process with zero emission in order to dispose of excess sludge using the activated sludge microorganisms after a portion of the returned sludge is biodegraded by some processes and then returned to the aeration tank. In the sludge reduction system, which has already been put to practical use, the reduction rate of excess sludge is 70 - 80% allowing stable operation in the disposal system and comprehensive economic efficiency.

Sludge substrate which has already been developed and proposed from the viewpoint of the cell level of a microbe is divided into the following three classifications: 1) eliminated cells; 2) crushed cells; 3) cells with low molecular weight. There are also some substrate processes which fall on the borderline of the said classifications.

Dead cells and cell-wall materials are degraded and solubilized by enzyme action of microorganisms in the aeration tank. If the whole sludge substrate process including degradation and reduction of cells to a low molecular weight are considered, the sludge substrate process can be also called solubilization.

2.2 Aerobic Treatment of Wastewater

Naturally occurring microorganisms are the workhorses of wastewater treatment. Consisting of bacteria, fungi, protozoa, rotifers, and other microbes, these organisms thrive on many of the complex compounds contained in domestic wastewater. Secondary-treatment processes (found at municipal wastewater treatment plants) are highly engineered bioreactors. These bioreactors are designed to provide the microbes with the optimum conditions to assist in the renovation of domestic wastewater. With the mechanical addition of dissolved oxygen, aerobic and facultative microbes can rapidly oxidized soluble, bioavailable organic and nitrogenous compounds [Seabloom, R.W. and J.R Buchanan (2005)].

Onsite and decentralized wastewater management systems can also take advantage of this technology. Aerobic treatment units can be an option when insufficient soil is available for the proper installation of a traditional septic tank and soil absorption area. Increasingly, homes and small commercial establishments are being constructed in rural areas with no central sewer and on sites with marginal soils. In these situations, wastewater must receive a high-level of pretreatment before being discharged into the soil environment. Depending on local regulations, the use of an aerobic treatment unit may allow for reductions in the required infiltration area and/or reduction in depth to a limiting soil layer. This ability to produce a high-quality effluent may open sites for development that were previously unsuitable because of soil limitations [U.S. EPA (2000)].

The main application for an aerobic treatment system is to retrofit a failed septic system. Other applications include poor soil, high groundwater/bedrock, and little available land for a drain field, high proportion of organic matter or the need for high-quality effluent for environmentally sensitive sites. There are a variety of designs for aerobic systems, but they do have some common features. These include pretreatment to reduce the amount of clogging solids, an aeration process, settling for suspended growth systems, and final treatment/disinfection. The most common kind of aerobic system is "suspended growth." Air is forced into an aeration compartment in which sewage-digesting bacteria are freely suspended in the liquid/air mixture. The other method is "attached growth," in which a surface is provided for bacteria to attach themselves. The surface is alternately exposed to the liquid and air. Because of the possibility of disruption under a sudden heavy waste load, some systems do not allow continuous flow, but restrict it through various devices such as pretreatment tanks, surge chambers, and baffles [Mark C. M. Van Loosdrecht and Mogens Henze (1999)].

2.2.1 Process Control

To maintain high levels of treatment performance with the activated-sludge process under a wide range of operating conditions, special attention must be given to process control. The principal approaches to process control are (1) maintaining dissolved oxygen levels in the aeration tanks, (2) regulating the amount of return activated sludge (RAS), and (3) controlling the waste-activated sludge (WAS). The parameter used most commonly for controlling the activated-sludge process is SRT. The mixed-liquor suspended solids (MLSS) concentration may also be used as a control parameter. Return activated sludge is important in maintaining the MLSS concentration and controlling the sludge blanket level in the secondary clarifier. The waste activated-sludge flow from the recycle line is selected usually to maintain the desired SRT. Oxygen uptake rates (OURs) are also measured as a means of monitoring and controlling the activated-sludge process. Routine microscopic observations are important for monitoring the microbial characteristics and for early detection of changes that might negatively impact sludge settling and process performance [Metcalf and Eddy (2004)].

2.2.2 Dissolved Oxygen Control

Theoretically, the amount of" oxygen that must be transferred in the aeration tanks equals the amount of oxygen required by the microorganisms in the activated-sludge system to oxidize the organic material. In practice, the transfer efficiency of oxygen for gas to liquid is relatively low so that only a small amount of oxygen supplied is used by the microorganisms. When oxygen limits the growth of microorganisms, filamentous organisms may predominate and the settleabil-ity and quality of the activated sludge may be poor. In general, the dissolved oxygen concentration in the aeration tank should be maintained at about 1.5 to 2 mg/L in all areas of the aeration tank. Higher DO concentrations (>2.0 mg/L) may improve nitrification rates in reactors with high BOD loads. Values above 4 mg/L do not improve operations significantly, but increase the aeration costs considerably [Metcalf and Eddy (2004)].

Low dissolved oxygen (DO) concentrations occur commonly in aerobic digesters treating thickened sludge, with benefits of smaller digester size, much reduced aeration cost, and higher digestion temperature (especially important for plants in colder areas). The effects of low DO concentrations on digestion kinetics were studied using the sludge from municipal wastewater treatment plants in Akron, Ohio, and Los Lunas, New Mexico. The experiments were conducted in both batch digestion and a mixed mode of continuous, fed-batch, and batch operations. The low DO condition was clearly advantageous in eliminating the need for pH control because of the simultaneous occurrence of nitrification and denitrification. However, when compared with fully aerobic (high DO) systems under constant pH control (rare in full-scale plants), low DO concentrations and a higher solids loading had a negative effect on the specific volatile solids (VS) digestion kinetics. Nonetheless, the overall (volumetric) digestion performance depends not only on the specific digestion kinetics, but also the solids concentration, pH, and digester temperature. All of the latter factors favor the low DO digestion of thickened sludge. The significant effect of temperature on low DO digestion was confirmed in the mixed-mode study with the Akron sludge. When compared with the well-known empirical correlation between VS reduction and the product (temperature X solids retention time), the experimental data followed the same trend, but was lower than the correlation predictions. The latter was attributed to the lower digestible VS in the Akron sludge, the slower digestion at low DO concentrations, or both. Through model simulation, the first-order decay constant (kd) was estimated as 0.004 h-1 in the mixed-mode operations, much lower than those (0.011 to 0.029 h-1) obtained in batch digestion. The findings suggested that the interactions among sludges with different treatment ages may have a substantially negative effect on digestion kinetics. The use of multistage digesters, especially with small front-end reactors, may be advantageous in both process kinetics and biological reaction kinetics for sludge digestion [ToolBase Services (2001)].

2.3 Endogenous respiration

Under substrate-limited conditions, microbes will feed on each other at a higher rate than new cells can be produced. The aerobic degradation of cellular material is endogenous respiration (eq. 1, pg 13). Endogenous respiration is not 100% efficient and thus there is an accumulation of slowly-degradable cellular material and other residuals [Reynolds, T. D(1982)]. Aerobic treatment units employed in the decentralized wastewater management industry operate in the endogenous respiration phase. Referred to as "extended aeration," this process provides plenty of aeration to ensure that once the food is consumed, the microbes will start feeding on each other. This effect minimizes the mass of accumulated biomass that must be removed by the maintenance provider.

In activated sludge processes an increased sludge age is associated with a decreased sludge production. This phenomenon is generally interpreted as a result of endogenous respiration processes. In the activated sludge models cell lysis (or decay) is incorporated. The lysis is modelled such that it leads to generation of particulate substrate, which by a hydrolysis process is converted into soluble substrate. The substrate is then converted to biomass again by growth processes. In this manner a good description of activated sludge processes is obtained, however this does not mean that the proposed mechanism is microbiologically correct. The lysis/decay model mechanism is a strongly simplified representation of reality. This paper tries to review the processes grouped under endogenous respiration in activated sludge models. Mechanisms and processes such as maintenance, lysis, internal and external decay, predation and death-regeneration are discussed. From recent microbial research it has become evident that cells do not die by themselves. Bacteria are however subject to predation by protozoa. Bacteria store reserve polymers that in absence of external substrate are used for growth and maintenance processes [Mark C. M. Van Loosdrecht and Mogens Henze (1999)].

$$\underset{\text{Cellular material}}{C_{60}H_{87}N_{12}O_{23}P} + O_2 \xrightarrow[\text{Microbes}]{\text{aerobic}} CO_2 + H_2O + PO_4 + NH_3 + \text{residuals} \quad \text{- Eqn 1}$$

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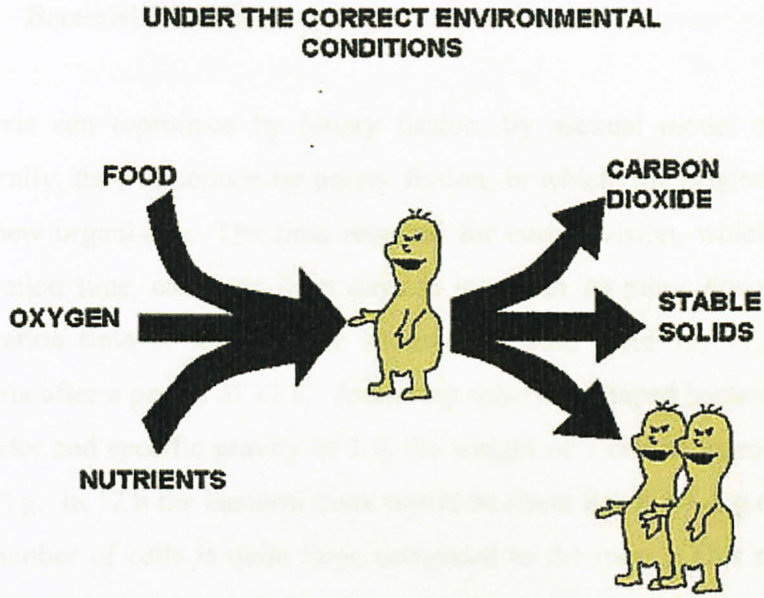


Figure 2: Path of the correct environmental conditions

2.3.1 Bacterial Growth and Energetic

In the description of microbial metabolism it was noted that as microorganisms consume substrate and carry out oxidation-reduction reactions, growth occurs by the production of additional cells. Thus, in wastewater treatment applications biomass is produced continuously as the substrate in the wastewater is consumed and biodegraded. Topics considered in this section include (1) bacterial reproduction, (2) bacterial growth patterns in a batch reactor, (3) bacterial growth and biomass yield, (4) methods used to measure biomass growth, (5) estimating cell yield and oxygen requirements from stoi-chiometry, (6) estimating cell yield from bioenergetics, and (7) observed versus synthesis yield [Metcalf and Eddy (2004)].

2.3.2 Bacterial Reproduction

Bacteria can reproduce by binary fission, by asexual mode, or by budding. Generally, they reproduce by binary fission, in which, the original cell becomes two new organisms. The time required for each division, which is termed the generation time, can vary from days to less than 20 min. For example, if the generation time is 30 min, one bacterium would yield 16,777,216 (i.e., 224) bacteria after a period of 12 h. Assuming spherical-shaped bacteria with a 1 /urn diameter and specific gravity of 1.0, the weight of 1 cell is approximately 5.0 X 10~13 g. In 12 h the bacteria mass would be about 8.4 X 10~6 g or 8.4 /Ag; thus the number of cells is quite large compared to the mass. This rapid change in biomass with time is a hypothetical example, for in biological treatment systems bacteria would not continue to divide indefinitely because of environmental limitations, such as substrate and nutrient availability [Metcalf and Eddy, (2004)].

2.3.3 Bacterial Growth Patterns in a Batch Reactor

Bacterial growth in a batch reactor is characterized by identifiable phases as illustrated on Fig. 3. The curves shown on Fig. 3 represent what occurs in a batch reactor in which, at time zero, substrate and nutrients are present in excess and only a very small population of biomass exists. As substrate is consumed, four distinct growth phases develop sequentially [Metcalf and Eddy (2004)]:

(1) The lag phase. Upon addition of the biomass, the lag phase represents the time required for the organisms to acclimate to their new environment before significant cell division and biomass production occur. During the lag phase enzyme induction may be occurring and/or the cells may be acclimating to changes in salinity, pH, or temperature. The apparent extent of the lag phase

may also be affected by the ability to measure the low biomass concentration during the initial batch phase.

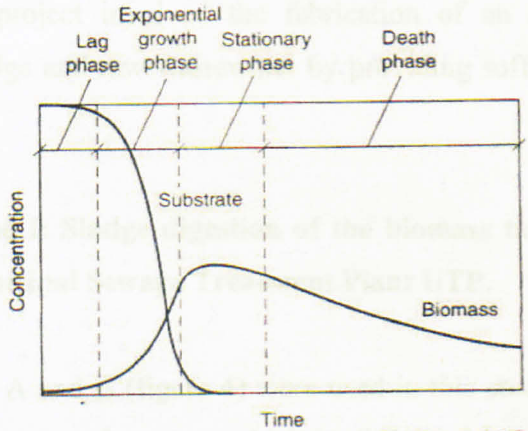


Figure 3: Batch process biomass growth phases with changes in substrate and biomass versus time.

(2) The exponential-growth phase. During the exponential-growth phase, bacterial cells are multiplying at their maximum rate, as there is no limitation due to substrate or nutrients. The biomass growth curve increases exponentially during this period. With unlimited substrate and nutrients the only factor that affects the rate of exponential growth is temperature.

CHAPTER 3

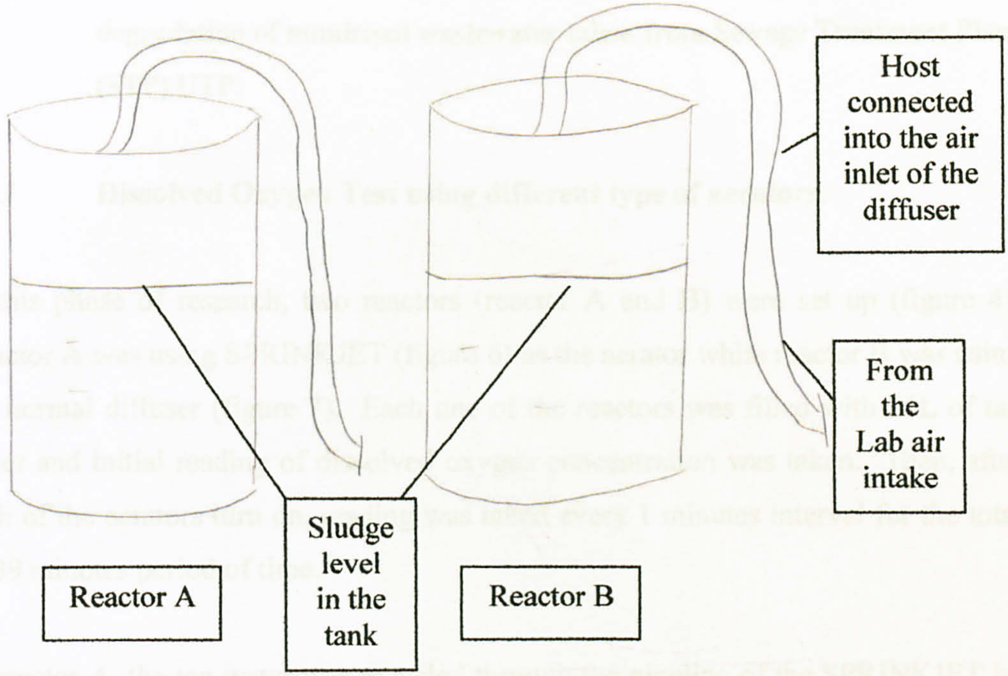
METHODOLOGY

The projects were conducted in two phases. The first phase involved aerobic sludge digestion of sludge taken from the clarifier of University Technology PETRONAS Sewage Treatment Plant. In this phase, diffuser was used as the aerators. The second phase of this project involved the fabrication of an aerator which can digest wastewater sludge and raw wastewater by providing sufficient dissolved oxygen in the reactor.

3.1 Phase 1: Sludge digestion of the biomass taken from the clarifier of Municipal Sewage Treatment Plant UTP.

Two reactors, A and B (figure 4) were used in this study with both of the reactor using the same types of aerators which is diffuser. Meanwhile both of the reactors are using the same types of biomass taken from the clarifier at Sludge Treatment Plant in UTP. The diffuser gets the constant air supply from the Solid Laboratory Air Pipe intake which directed into the diffuser using the normal hose. This study was done for the total of 15 days sampling period. The steps took in the process shown in figure 5.

The parameters monitored for both influent and effluent were mass liquor suspended solid (MLSS) and mixed liquor volatile suspended solid (MLVSS). Sampling was conducted every 24 hours of aeration period.



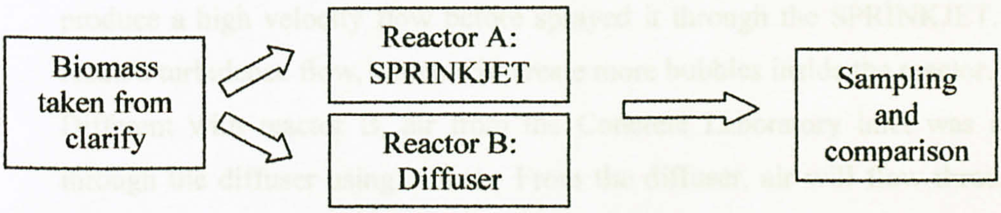


Figure 4: Sludge Digestion Process of reactors A and B.

Table 1: Condition in the Continuous Flow Reactors (Phase 1)

Reactors	A	B
Volume/L	25	
Biomass	STP UTP	
Sampling days	15 days	

3.2 Phase 2: Dissolved Oxygen Test using different type of aerators and degradation of municipal wastewater taken from Sewage Treatment Plant (STP) UTP.

3.2.1 Dissolved Oxygen Test using different type of aerators.

In this phase of research, two reactors (reactor A and B) were set up (figure 4). Reactor A was using SPRINKJET (figure 6) as the aerator while reactor B was using the normal diffuser (figure 7). Each one of the reactors was filled with 25L of tap water and initial reading of dissolved oxygen concentration was taken. Then, after both of the aerators turn on, reading was taken every 1 minutes interval for the total of 39 minutes period of time.

In reactor A, the tap water was recycled through the pipeline of the SPRINKJET by using a water pump located at the bottom of reactor A. Basically the pump will produce a high velocity flow before sprayed it through the SPRINKJET. This will result a turbulence flow, which will create more bubbles inside the reactor.
Different with reactor B, air from the Concrete Laboratory inlet was connecting through the diffuser using a host. From the diffuser, air will flow through the air outlet moving into the water.

Dissolved oxygen concentration was measured using the dissolved oxygen metered (figure 5). The sensor was put into the reactor and reading was taken.The parameters monitored were dissolved oxygen itself.

Figure 5: Dissolved oxygen meter

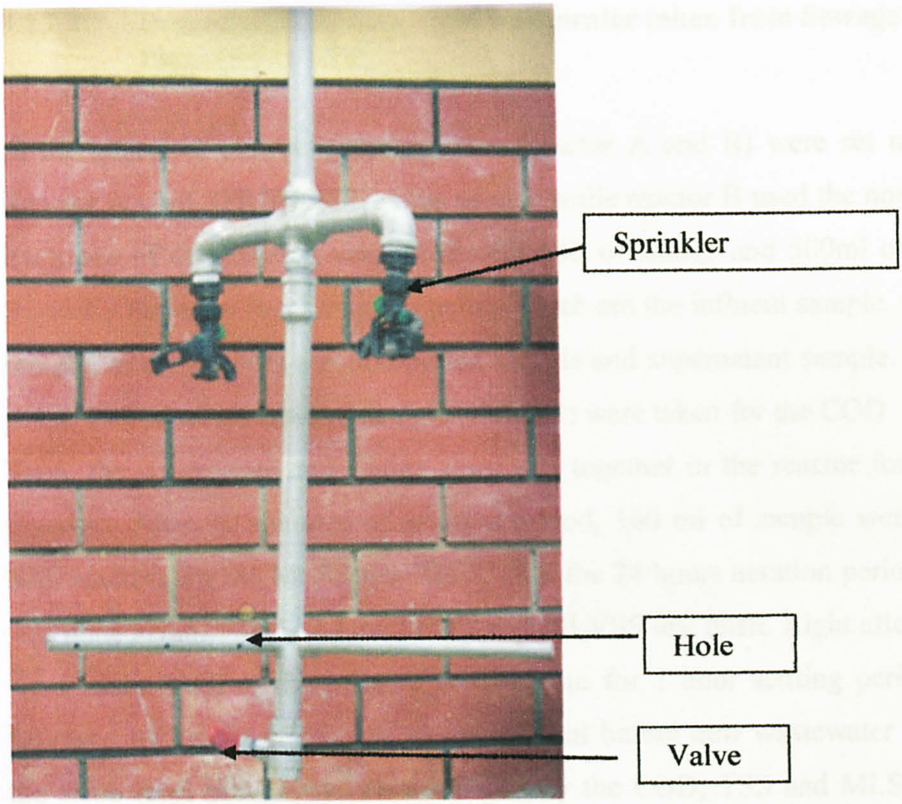


Figure 6: SPRINKJET

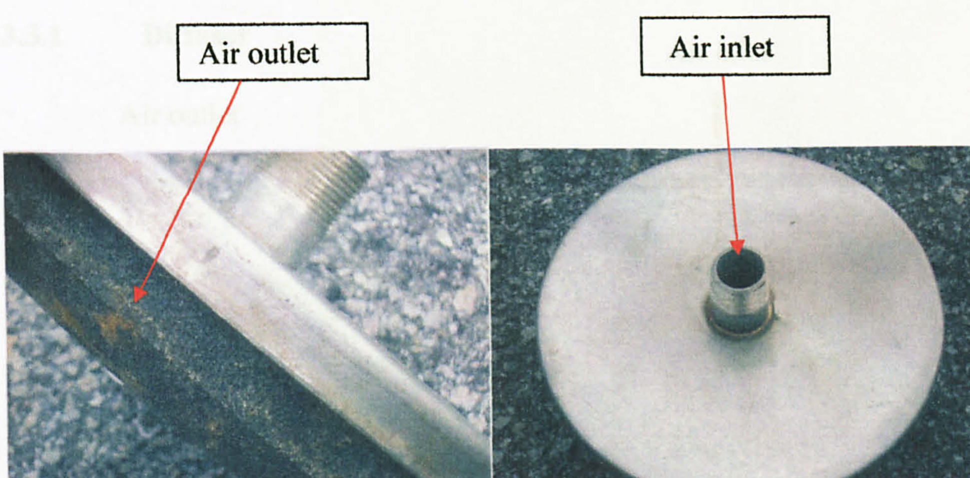


Figure 7: Diffuser

3.2.2 Degradation of municipal wastewater taken from Sewage Treatment Plant (STP) UTP.

In this phase of research, two reactors (reactor A and B) were set up (figure 4). Reactor A used SPRINKJET as the aerator while reactor B used the normal diffuser. Each one of the reactors was filled with 24L of sludge and 500ml of wastewater. Basically there are four sampling points which are the influent sample, while mixing sample, after 24 hours aeration period sample and supernatant sample. At the initial point, 100 ml of wastewater sample (influent) were taken for the COD and TSS test. Then, the wastewater and sludge were mix together in the reactor for the aeration process. After 30 minutes of aeration period, 100 ml of sample were taken from both reactors for the MLSS test. Next, after the 24 hours aeration period, sampling was done again. This is for the MLSS and MLVSS test itself. Right after the samples were taken, both of the mixture was left out for 1 hour settling period. This was followed by decant of 18L of the supernatant before new wastewater was added to the same level previously. This will end by the COD, TSS and MLSS test for the supernatant sample. Same steps were repeated continuously for 3 days time.

3.3 Tools and Equipments

3.3.1 Diffuser

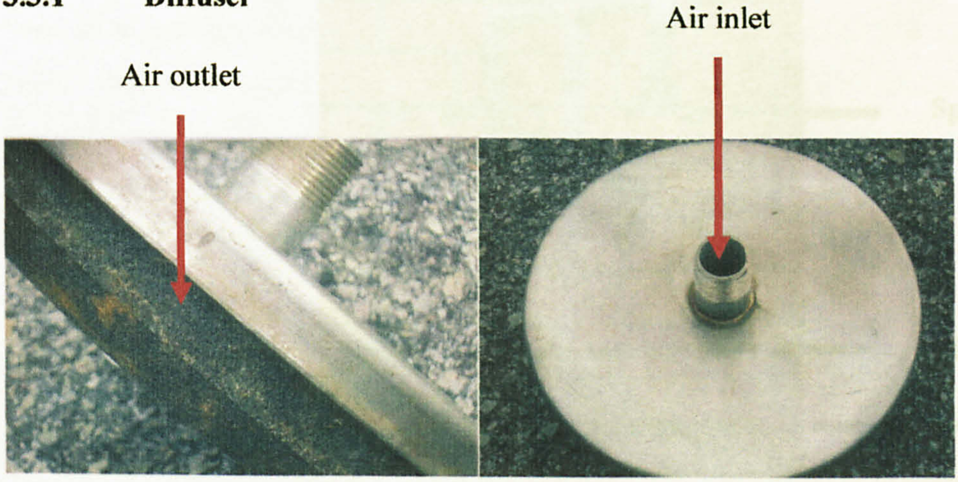


Figure 8: Diffuser

Figure 8 shows pictures of a diffuser used in this project. Air will flow inside the diffuser through the top hole as shown above. Air will move out from the diffuser through the air outlet before flow into the reactor.

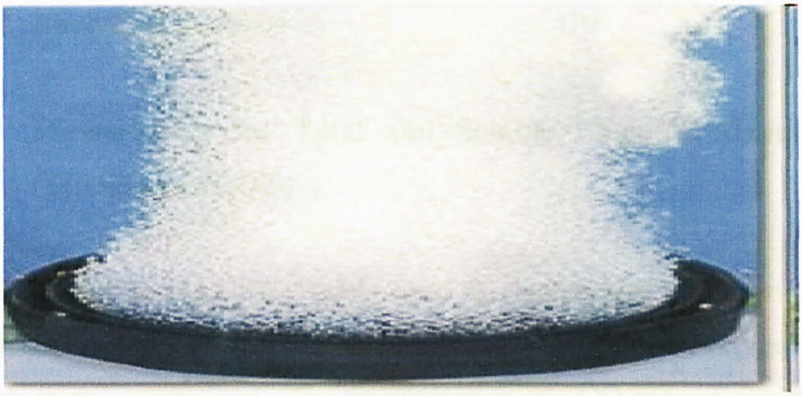


Figure 9: Diffuser in the water

3.3.2 SPRINKJET

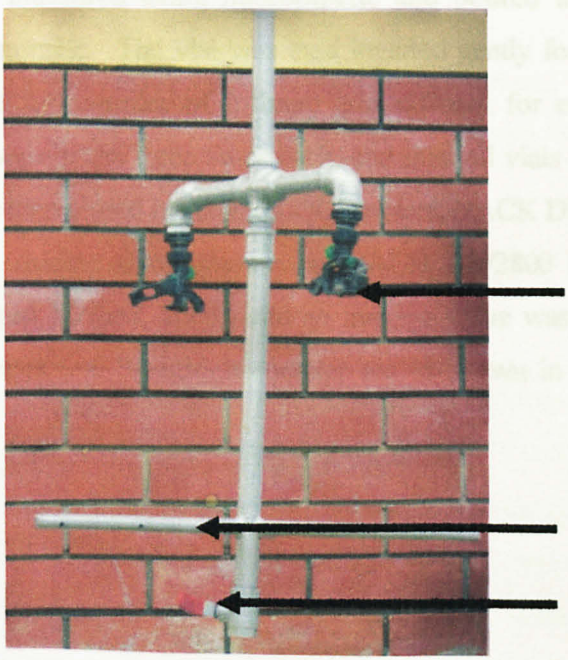


Figure 10: SPRINKJET

SPRINKJET is a combination of sprinkler and normal diffuser. The sprinkler is used to mix the solution equally in the reactor by rotating at 180°. The hole at the bottom elbow used to avoid any suspended solid settled at the bottom of reactor. The valve used to control the pressure of the liquid.

3.4 Analytical methods

3.4.1 Measurement for Total and Soluble Chemical Oxygen Demand (TCOD and SCOD)

Chemical oxygen demand was widely used to characterize the organic strength of wastewater and pollution of natural water. It was amount of oxygen required to oxidize an organic compound. The determination of COD content was performed by using HACK Method 8000 (Standard Method).

For determine the parameter of Total Chemical Oxygen Demand (TCOD), 2ml of wastewater sample was measured using micropipette and poured into a vial that containing potassium dichromate. The vial was then inverted gently for several times. The steps were repeated for samples of influent and effluent for each reactor of treatments. All samples were taken three times each, and then all vials together with a blank as an indicator were then placed inside the COD reactors, HACK DRB 200 for two hours. After two hours, reading were taken using HACH DR/2800 Direct Reading Spectrophotometer (Standard Method, 2005), and an average value was calculated and recorded. The COD reactors and Spectrophotometer are as shown in Figure 12 and Figure 13.

Figure 11: COD Reactor (HACH DRB)

Figure 12: Spectrophotometer

The above steps were repeated for the Soluble Chemical Oxygen Demand (SCOD), but all the wastewater samples were filtered first, before being poured into a vial that containing potassium dichromate.

3.4.2 Total Suspended Solid (TSS)

The gravimetric method was used to determine TSS where samples were filtered with a 47 mm diameter glass-fiber filter disk (Whatman grade 934AH). The filter disk was placed in the filter holder with the wrinkled surface upwards. Tweezers was used to handle filter disc in order to avoid adding moisture content from fingers that will caused weighing error. Certain amount of well mixed wastewater sample was filtered by applying vacuum to flask, and followed by washings with distilled water to ensure that all the solids have been filtered. The vacuum was released from the filtering system and the filter disc was gently removed. The disc then was placed on the watch glass. The filtrate was inspected to ensure that proper trapping of solids was accomplished on the disc. The steps were repeated for influent and effluent sample, and both of the samples were done three times for both of the reactors (Standard Method).

The filter disc and watch glass were placed in drying oven 103 °C for half an hour. The filter disc and watch glass were removed from the oven and placed in incubator (BOEKEL Scientific Dricycler). The discs were carefully removed from the incubator and weighted using an analytical balance.

For the MLSS procedure, same step of TSS were applied but the different is the sample being diluted at 1:500 scale before filtration were done. For the MLVSS, it is just adding one more procedure in which the disc inserted into furnace and burned out at 550°C for 1 hour 30 minutes time before it been weighted using an analytical balance.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Phase 1: Sludge digestion of the biomass taken from the clarifier of Municipal Sewage Treatment Plant UTP. This process is using the diffuser as the aerator.

Two continuous flow reactors were used in this phase of treatment system where both reactors used the same aerators and biomass for the aerobic digestion.

Table 2: Condition in the Continuous Flow Reactors (Phase 1)

Reactors	A	B
Volume/L	25	
Biomass	STP UTP	
Sampling days	15 days	

4.1.1 MLSS and MLVSS Results

Those data that have been collected (MLSS and MLVSS) were shown in the graph below. Graphs of MLSS and MLVSS versus days in Figure 13 show the percentage reduction for the total of 15 days.

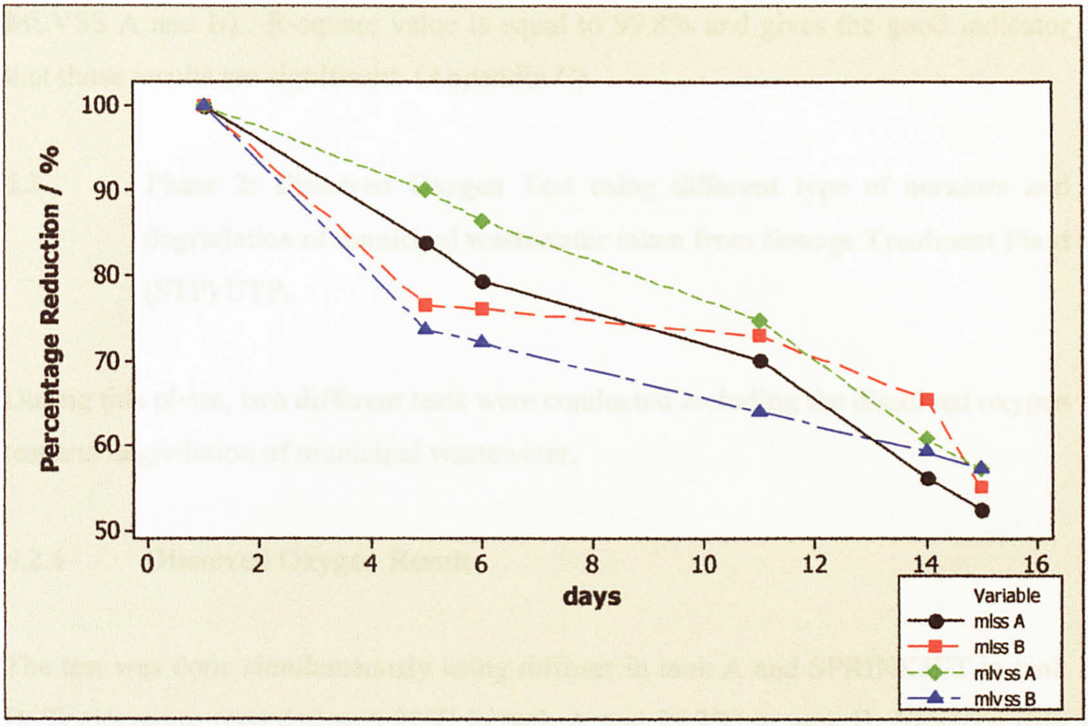


Figure 13: Graph showed the percentage reduction of MLSS and MLVSS in tank A and tank B

From Figure 13, MLSS of tank A showed the total of 47.4 percent reduction while tank B experienced about 44.8 percent reduction from day 1 to day 15.This showed that total reduction in tank A is rapidly faster than in tank B.

From Figure 13 again, MLVSS of tank A and B showed the same percentage of reduction which is about 42.7 percent from day 1 to day 15. This showed that total reduction in tank A and B are same.

The overall result meets the expectation of this project's objective that is to reduce the solid content of an aqueous biodegradable organic sludge.

Regression analysis has been made for those parameters (MLSS A and B and MLVSS A and B). R-square value is equal to 99.8% and gives the good indicator that those results are significant. (Appendix C)

4.2 Phase 2: Dissolved Oxygen Test using different type of aerators and degradation of municipal wastewater taken from Sewage Treatment Plant (STP) UTP.

During this phase, two different tests were conducted including the dissolved oxygen test and degradation of municipal wastewater.

4.2.1 Dissolved Oxygen Result

The test was done simultaneously using diffuser in tank A and SPRINKJET in tank B. Temperature recorded was 28°C in tank A and 25.2°C in tank B. Nineteen data recorded in the total of 36 minutes test using interval of 2 minutes. Initial dissolved oxygen recorded both in tank A and tank B filled with 55 L of tab water was 4.3 mg/L and 4.2 mg/L.

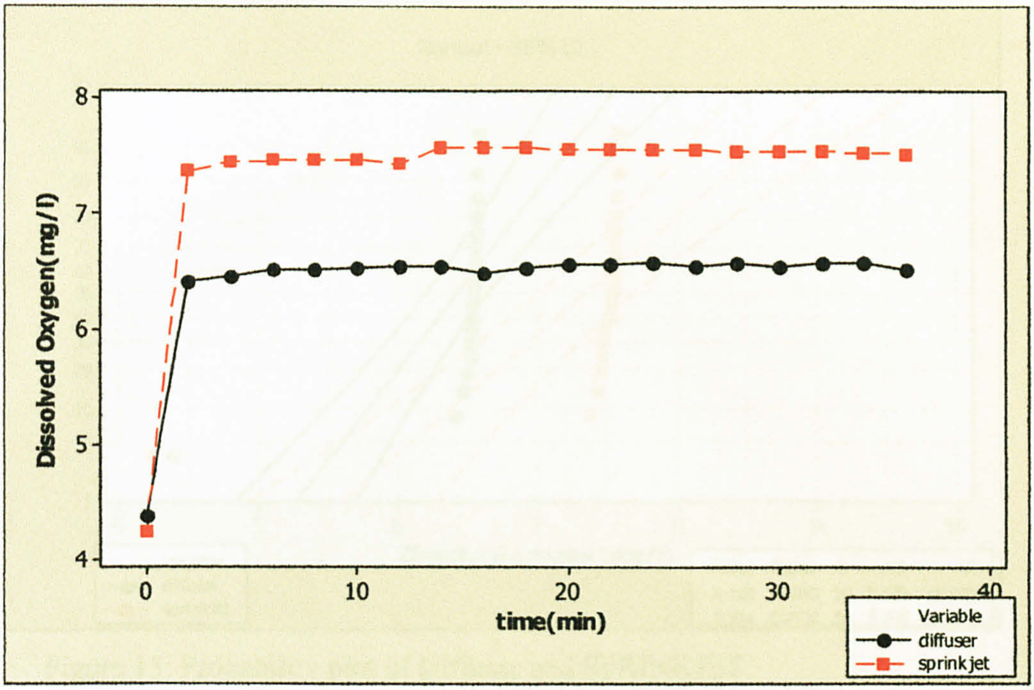


Figure 14: Dissolved Oxygen comparison between diffuser and SPRINKJET

Based on the graph above, tap water has reached the saturated point in the reactor as early as the experiment was started. In order to get more accurate result, interval time of 1 minutes that been used before shall be changed into shorter time maybe every 30 second per sampling.

From the Probability Plot in figure 15 below, average dissolved oxygen recorded in tank A (diffuser) is 6.418 mg/L and 7.344 mg/L in tank B (SPRINKJET). By that, SPRINKJET is more efficient compare to diffuser as it reflects higher dissolved oxygen reading of tap water. The probability of both result are less than 0.05 ($p<0.05$). This may validate the results.

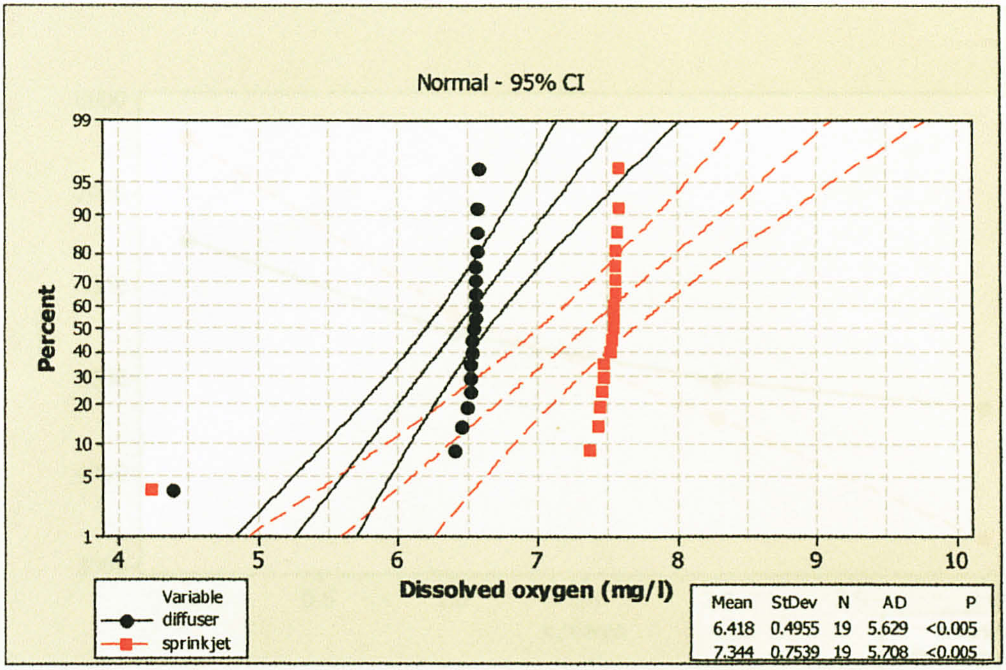


Figure 15: Probability plot of Diffuser and SPRINKJET

4.2.2 Degradation of municipal wastewater.

Analysis of the influent and effluent chemical oxygen demand (COD) and total suspended solid (TSS) in tank A (SPRINKJET) compare to tank B (diffuser) showed an average performance of the SPRINKJET. The reduction of COD in tank A is not so good compare to Tank B. Although it recorded higher dissolved oxygen in tap water, but it seems that there was something wrong to the equipments while running the process.

Besides that, mass liquor volatile suspended solid (MLVSS) and mass liquor suspended solid (MLSS) reduction after 24 hours aeration in both tank are not good enough. One of the possible causes identified are the settling time factor. One hour may not enough for the sludge to settle down effectively. Adding more, sludge in tank A is slower to settle compared to sludge in tank B. This happened because of the sized difference between tank A and tank B. Tank A more wider and bigger compare to tank B and may need more settleability time.

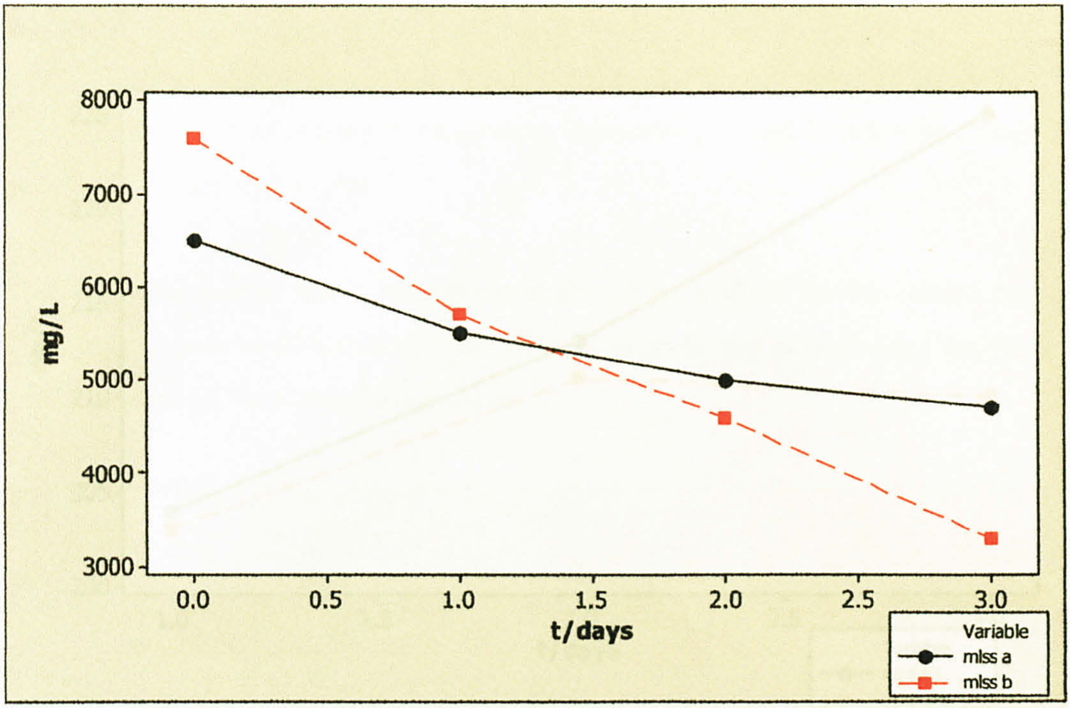


Figure 16: Graph of MLSS in Tank A and Tank B

From Figure 16, the difference of MLSS reduction can be seen clearly. Tank B which using diffuser reduce larger amount of MLSS compare to the SPRINKJET in Tank A.

Figure 17 below show the COD record in Tank A (influent and effluent). It can be seen clearly that each effluent show the reduction. But then the amount of reduction is not so much if compared with figure 18.

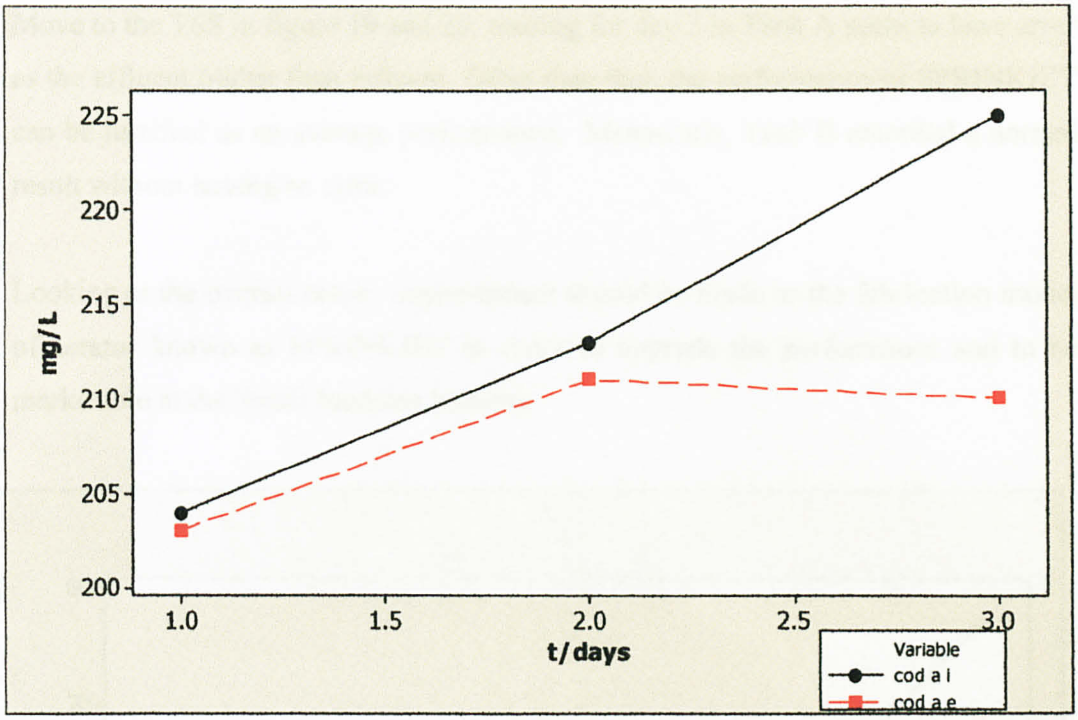


Figure 17: Graph of COD in Tank A (influent and effluent) vs. time

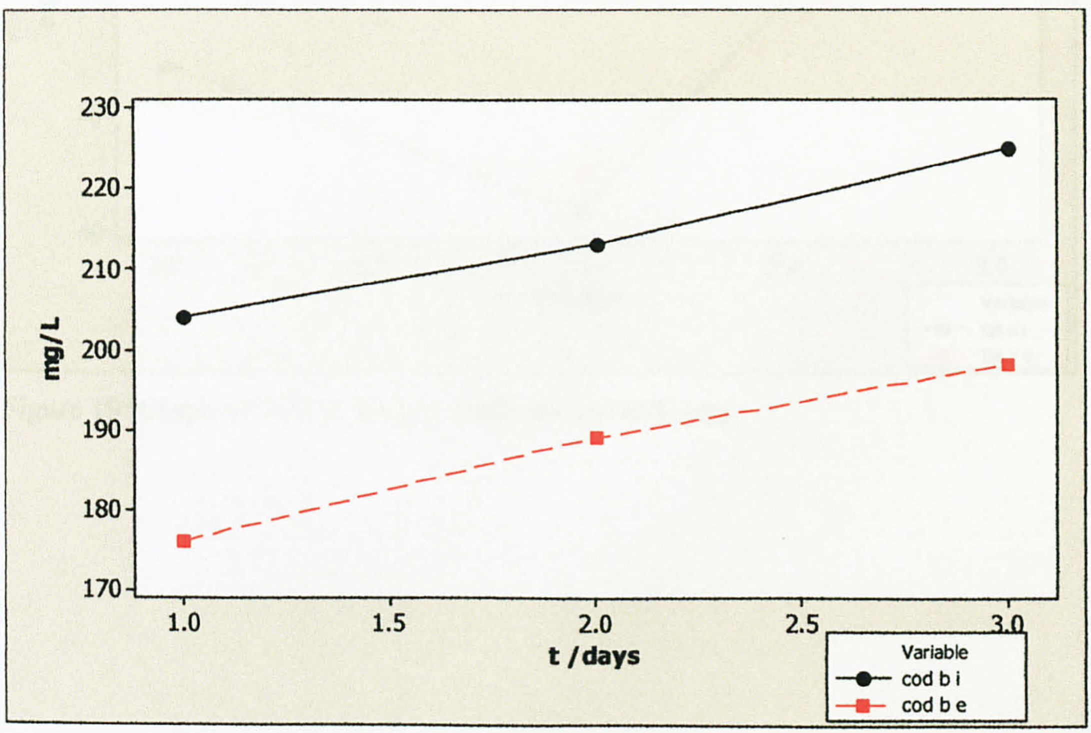


Figure 18: Graph of COD in tank B (influent and effluent) vs. time

Move to the TSS in figure 19 and 20, reading for day 2 in Tank A seem to have error as the effluent higher than influent. Other than that, the performance of SPRINKJET can be justified as an average performance. Meanwhile, Tank B recorded a normal result without having an error.

Looking at the overall result, improvement should be made to the fabrication model of aerator known as SPRINKJET in order to upgrade the performance and to be marketable at the Small Medium Industry.

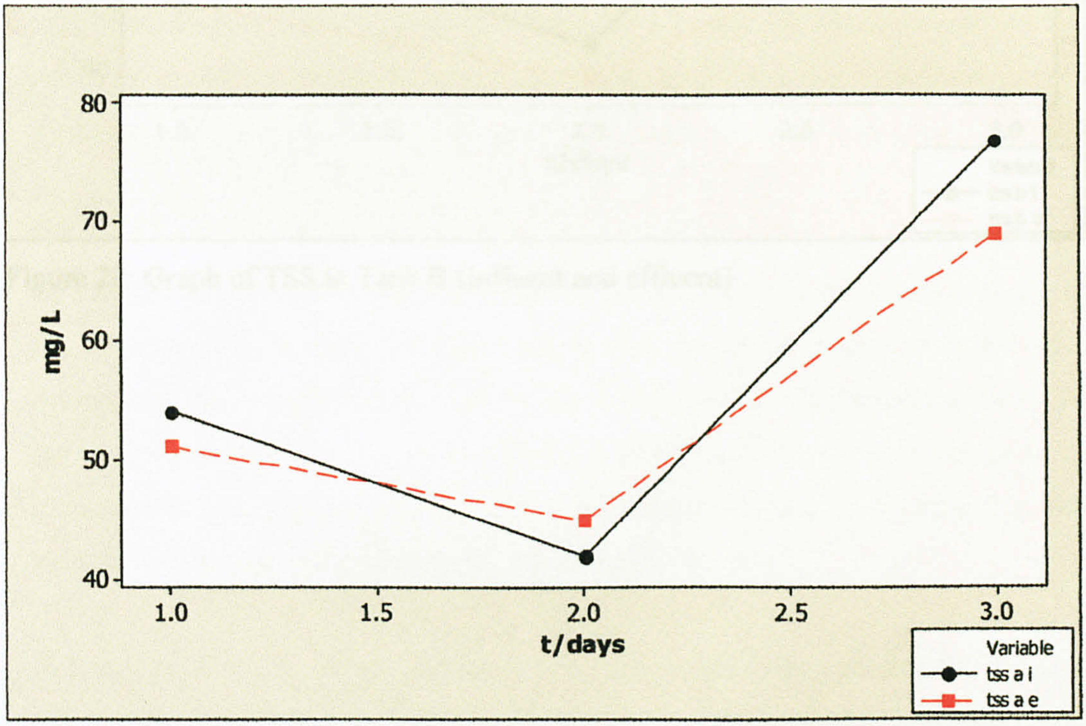


Figure 19: Graph of TSS in Tank A (influent and effluent)

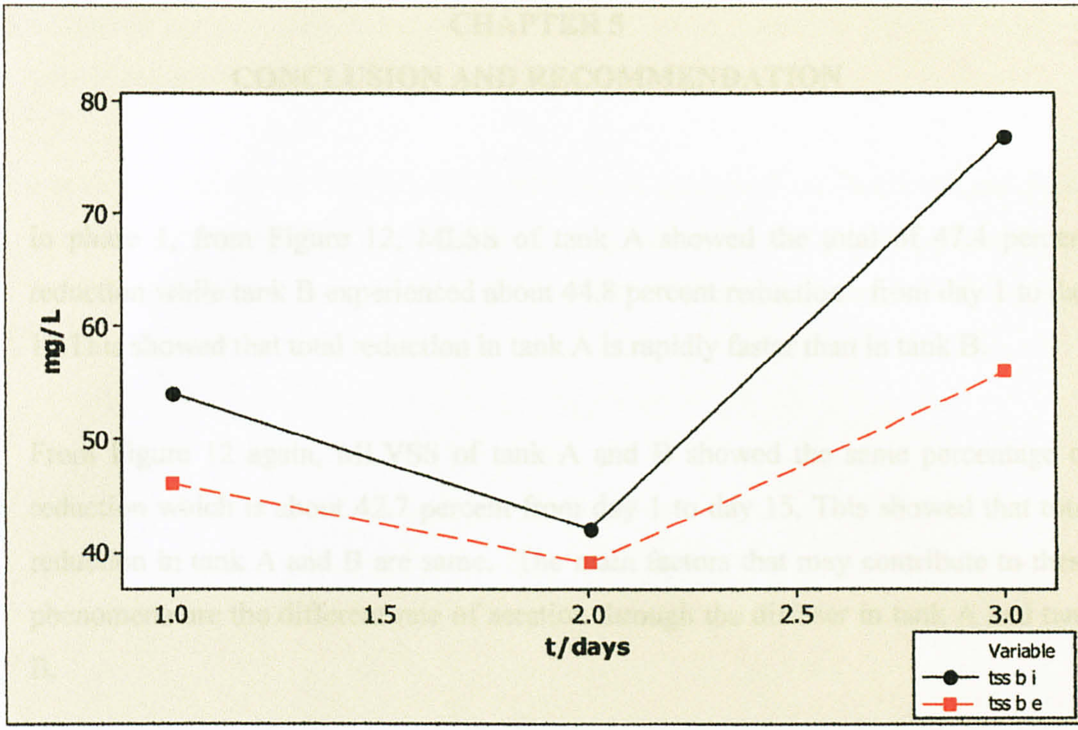


Figure 20: Graph of TSS in Tank B (influent and effluent)

CHAPTER 5
CONCLUSION AND RECOMMENDATION

In phase 1, from Figure 12, MLSS of tank A showed the total of 47.4 percent reduction while tank B experienced about 44.8 percent reduction from day 1 to day 15.This showed that total reduction in tank A is rapidly faster than in tank B.

From Figure 12 again, MLVSS of tank A and B showed the same percentage of reduction which is about 42.7 percent from day 1 to day 15. This showed that total reduction in tank A and B are same. The main factors that may contribute to these phenomena are the different rate of aeration through the diffuser in tank A and tank B.

One of the improvements that can be done in this project is the process to get the MLVSS result. Normally after the sample been taken out from the furnace and desiccators, the sample will be carried out to the weight. The process to bring the sample to the weight need a very careful and slow movement in order to avoid the burn sample been taken out from the foil by the surrounding air because it is very light. If it is happened then the result will be inaccurate at all.

In phase 2a, figure 4 shows the mean value for dissolved oxygen and SPRINKJET using tap water (6.418 mg/L and 7.344 mg/L), it can be concluded that SPRINKJET is more efficient and better than the diffuser.

But then, SPRINKJET seems having problems and not perform well in phase 2b process. Mass liquor volatile suspended solid (MLVSS) and mass liquor suspended solid (MLSS) reduction after 24 hours aeration in both tank are not good enough. One of the possible causes identified are the settling time factor. One hour may not enough for the sludge to settle down effectively. Adding more, sludge in tank A is slower to settle compared to sludge in tank B. This happened because of the sized difference between tank A and tank B. Tank A more wider and bigger compare to tank B and may need more time to settle.

Looking at the whole, SPRINKJET performance was good but then there are plenty rooms for improvement. As been discussing before, the design and equipment use can be modified and upgraded in order to fulfill the demand of Small Medium Scale Industry.

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APPENDIX A

Tank A:
SPRINJET

influent					effluent		
COD	TSS	MLSS	MLVSS	MLSS	COD	TSS	SCOD
			24	**24**			
204	**54**	**6500**	**3098**	**5500**	**203**	**51**	**190**
213	**42**		**3200**	**5000**	**211**	**45**	**189**
225	**77**		**3150**	**4700**	**210**	**69**	**208**

Tank B:
Diffuser

influent					effluent		
COD	TSS	MLSS	MLVSS	MLSS	COD	TSS	SCOD
		0	**24**	**24**			
204	**54**	**7600**	**4500**	**5700**	**176**	**46**	**172**
213	**42**		**3100**	**4600**	**189**	**39**	**181**
225	**77**		**3021**	**3300**	**198**	**56**	**183**

APPENDIX B

Condition in the Continuous Flow Reactors (Phase 1)

Reactors	A	B
Volume/L	25	
Biomass	STP UTP	
Air flow rate	36 cm^3/s	
Sampling days	15 days	

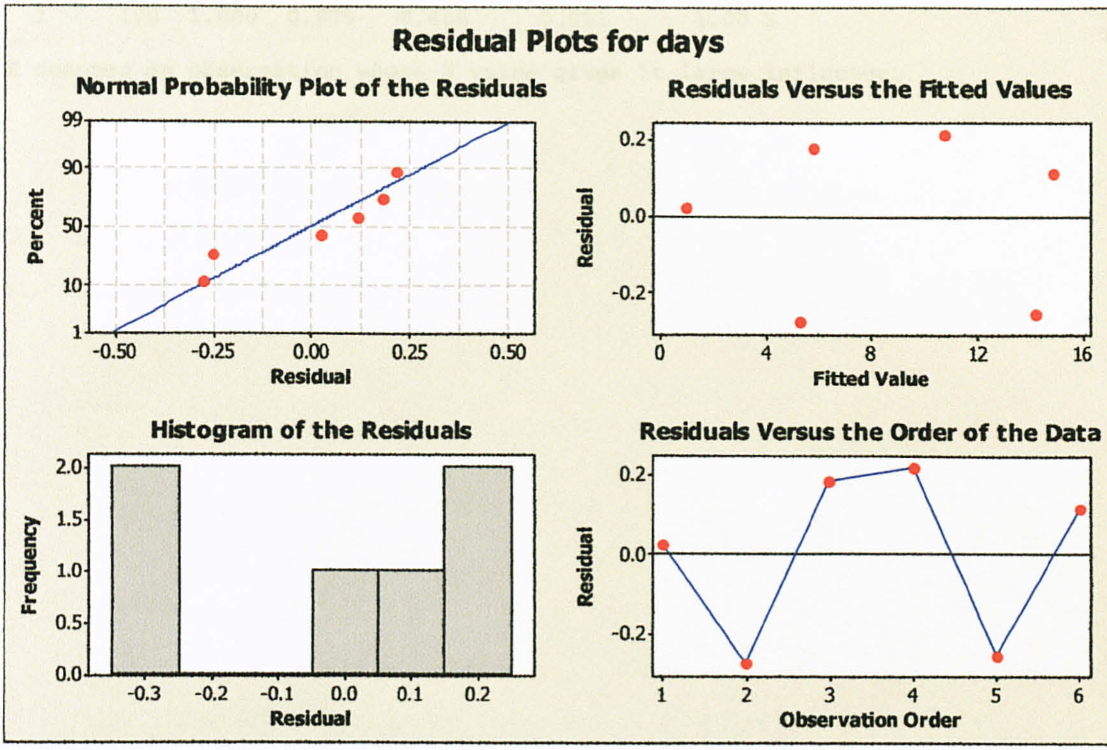
Condition in the Continuous Flow Reactors (Phase 2a)

Reactor	**A**	**B**
Aerator	SPRINKJET	Diffuser
Content	Tap water	Tap water
Volume	25L	25L
Flow rate	36 cm^3/s	
Sampling periods	39 minutes	

Condition in the Continuous Flow Reactors (Phase 2b)

Reactor	**A**	**B**
Aerator	SPRINKJET	Diffuser
Content	Sludge and wastewater	Sludge and wastewater
Volume	500ml of sludge and 24L wastewater	500ml of sludge and 24L wastewater
Flow rate	36 cm^3/s	
Sampling periods	3 days	

APPENDIX C




```
The regression equation is
days = 38.7 + 0.451 mlss A + 0.0370 mlss B - 0.635 mlvss A - 0.231 mlvss B


Predictor       Coef   SE Coef      T      P
Constant      38.694     3.784  10.22  0.062
mlss A        0.4511    0.3333   1.35  0.405
mlss B       0.03704   0.07694   0.48  0.714
mlvss A      -0.6347    0.2538  -2.50  0.242
mlvss B     -0.23065   0.09125  -2.53  0.240


S = 0.486363   R-Sq = 99.8%   R-Sq(adj) = 99.2%


Analysis of Variance

Source          DF       SS      MS       F      P
Regression       4  153.097  38.274  161.80  0.059
Residual Error   1    0.237   0.237
Total            5  153.333


Source    DF   Seq SS
mlss A     1  150.455
mlss B     1    0.969
mlvss A    1    0.162
mlvss B    1    1.511
```

```
Unusual Observations

Obs  mlss A   days    Fit  SE Fit  Residual  St Resid
  1     100  1.000  0.979   0.486     0.021      1.00 X

X denotes an observation whose X value gives it large influence.
```

CALCULATION

A = weight of filter + dried residue, mg,

B = weight of filter, mg.

C = weight from the oven,

D = weight from the furnace

E = D -A

1. MLSS(mg/L) = (C - A/50)*1000*1000

2. MLFSS(mg) = D – A

3. MLVSS(mg/L) = (MLSS- e)/50 x1000 x dilution factor (1000)

MLSS and MLVSS results

DATE	days	MLSS 1 mg/l	MLSS 2 mg/l	MLVSS 1 mg/l	MLVSS 2 mg/l
21/09/2007	1	116000	96000	103000	86000
25/09/2007	5	97300	73333	92667	63333
26/09/2007	6	92000	73000	89000	62000
01/10/2007	11	81300	70000	77000	55000
04/10/2007	14	65300	63000	62700	51000
05/10/2007	15	61000	58000	59000	49300

Degrading the municipal wastewater.

Tank A:
SPRINJET

influent					effluent		
COD	TSS	MLSS	MLVSS	MLSS	COD	TSS	SCOD
			24	**24**			
204	**54**	**6500**	**3098**	**5500**	**203**	**51**	**190**
213	**42**		**3200**	**5000**	**211**	**45**	**189**
225	**77**		**3150**	**4700**	**210**	**69**	**208**

Tank B:
Diffuser

influent					effluent		
COD	TSS	MLSS	MLVSS	MLSS	COD	TSS	SCOD
		0	**24**	**24**			
204	**54**	**7600**	**4500**	**5700**	**176**	**46**	**172**
213	**42**		**3100**	**4600**	**189**	**39**	**181**
225	**77**		**3021**	**3300**	**198**	**56**	**183**