COMPACT EXTENDED AERATION REACTOR (CEAR)

by

Muhammad Izzat Shafiq bin Sanusi

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

SEPTEMBER 2012

UniversitiTeknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzuan

CERTIFICATION OF APPROVAL

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Civil Engineering Programme
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Approved by,

____

(Assoc. Prof. Dr. Shamsul Rahman bin Mohamed Kutty)

UniversitiTeknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzuan

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible to 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 and person.

____

(Muhammad Izzat Shafiq bin Sanusi)

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ABSTRACT

This project was conducted to treat wastewater in a single reactor by using the integration of various treatment processes. In other words, the treatment process such denitrification, aeration and sedimentation are combined in a single reactor. The advantages of having this integration system are that the reactor requires less space compared to the conventional wastewater treatment plant. It is essential to have a new developed technology where the usage of space for wastewater treatment plant can be reduced. This study attempts to propose a new type of wastewater reactor which is Compact Extended Aeration Reactor (CEAR). The main objective of this study was to evaluate the performance of the reactor. The project was focusing on aerobic biological oxidation where the organic matter is oxidized in order to achieve a low BOD level in the reactor discharge. The design of the CEAR will focus on the existing extended aeration design and it is adapted and integrated into this project. This project was using a reactor model with overall volume of 0.5 m^3 and it is operated with actual biomass taken from UTPSTP. The reactor was feed with synthetic wastewater with inflow of 15 L/d and samples were collected at the input, output and also within of the reactor. The average COD reading for the raw wastewater is set to be 500 mg/L. The parameters that have been chosen are BOD, COD, TSS and MLSS the where percentage reduction for COD result was 82%, 73% of reduction for BOD result and finally 80% of TSS reduction. Most of the results have complied with the DOE standard discharge limit. Therefore, this report has successfully evaluated the performance of the reactor where the result for BOD, COD and TSS percentage of reduction were 73%, 82% and 80% respectively and most of the results have complied with DOE standard discharge limit.

CHAPTER 1: INTRODUCTION

1.1 Background of Study

A common sense that at any place that have a high population area, there must be a wastewater management system to control the water that have been used by the people before discharging into nearby river. Wastewater is defined as a "combination of liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and stormwater that may be present" [1]. A common plant which is activated sludge from biological wastewater treatment plant (WWTP) is used to regulate and control the discharge of wastewater and it is build around the populated area.

The aim of the wastewater treatment is to reduce the quantities of nitrogen, phosphorus, organic matter and solid matters in suspension [2]. A typical plant may consist of mechanical screening, aeration tank, clarifier tank and several other related tanks depending on the type of wastewater. The aeration tank may take up to 2000-2500 m^2 of area and the clarifier may have area of 1000-2000 m^2 for 20,000 m^3/d of average wastewater flow. These are not included in sludge handling and other processes that also require some space to have a complete wastewater treatment plant. In other words, a small WWTP has an area ranging from 3-10 acres and hence it requires some space to be constructed.

In recent times, some of the ongoing development may have WWTP to be constructed as a requirement from authority regulation. Therefore developers need to allocate some area of land to build a WWTP in order to abide to the regulations given. As a proposed development area is increased, the population equivalent is increased and so does the WWTP area to be made. The high usage of land for WWTP may be costly to developers where they can use the land for other purpose which brings them more revenue. As a result of these challenges, an idea to have an integrated wastewater treatment system where the processes of wastewater treatment are combined into a single reactor is derived. In this project, **anoxic tank, aeration tank** and **sedimentation tank** are combined together to form an integrated treatment system. However, based on a survey of 13 European countries, the integrated operation of WWTP is still not far being developed where a key issue in the integrated automation systems for the WWTP is the choice of system architecture and control strategy [3]. Therefore, this project will design the system carefully together with all considerations of external factor that may be involved in the design.

1.2 Problem Statement

The problem that has been identified in the current conventional WWTP is the conventional WWTP require massive area to be constructed due to its nature of the tanks that have huge size such as aeration tank and clarifier. Therefore, this project will attempt to solve the problem by creating an integrated and compact treatment system where it requires less space to be made.

1.3 Objective

From the problem statement, the objective was to evaluate the performance of a reactor that consists of anoxic tank, aeration tank and sedimentation tank integrated together in a single unit of reactor. This can be done by measuring certain parameters analyze it to evaluate the reactor.

1.4 Scope of Study

The scope of the study investigates the aerobic biological oxidation process in the reactor. Parameters that have been chosen to evaluate the performance of the reactor were Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) and Mixed Liquor Suspended Solid (MLSS). The first three parameters were measured to check the percentage reduction of BOD, COD and TSS between influent and effluent of the reactor. As for MLSS, it was measured to check the concentration of biomass within the aerobic reactor.

CHAPTER 2: LITERATURE REVIEW

Before proceed further into the reactor design, it would be best to understand the concept used in this project. There are several researches that explain the extended aeration concept. The typical extended aeration treatment plant has a long sludge age between 40-60 days [1]. The reaction process that occurred in the reactor is aerobic biological oxidation process. The process of aerobic oxidation will occur in aeration tank where some amount of oxygen will be supplied into the suspension of wastewater. There are three equations that illustrate the process of aerobic oxidation as shown below:

Oxidation:

$$\text{CHONS (organic matter)} + O_2 + \text{bacteria} \rightarrow CO_2 + H_2O + NH_3$$

Synthesis:

$$\text{CHONS} + O_2 + \text{bacteria} + \text{energy} \rightarrow C_5H_7NO_2 \text{ (new cell)}$$

Endogenous Respiration:

$$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + NH_3 + 2H_2O$$

From the equation, the process of oxidation, synthesis and endogenous respiration take place in aeration tank. From here, the amount of oxygen needed to be supplied in the aeration tank can be determined.

The other one is hybrid anoxic-aeration biological treatment plant where anoxic tank is integrated with aeration tank to treat the wastewater where the primary goal of the hybrid is to give operators and process engineers a guideline of optimum operational strategy in terms of fulfilling effluent standards while maintaining operational costs as low as possible [4]. This is similar to the proposed project where the anoxic tank, aeration tank and several other tanks are combined and operated in a single unit. Figure 2.1 (Anoxic-Aeration Tank) below shows the process of anoxic-aeration integration:

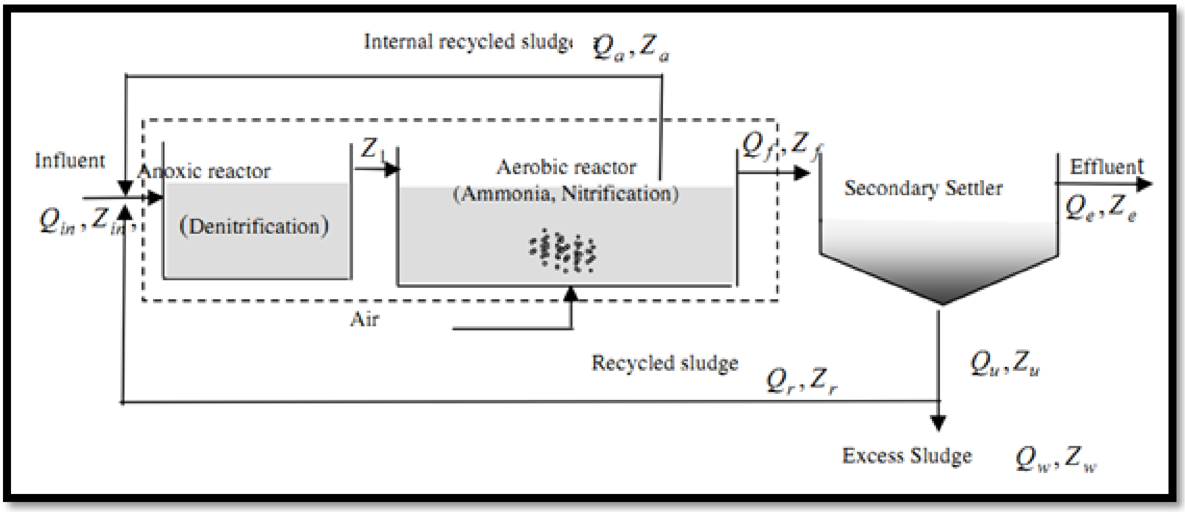
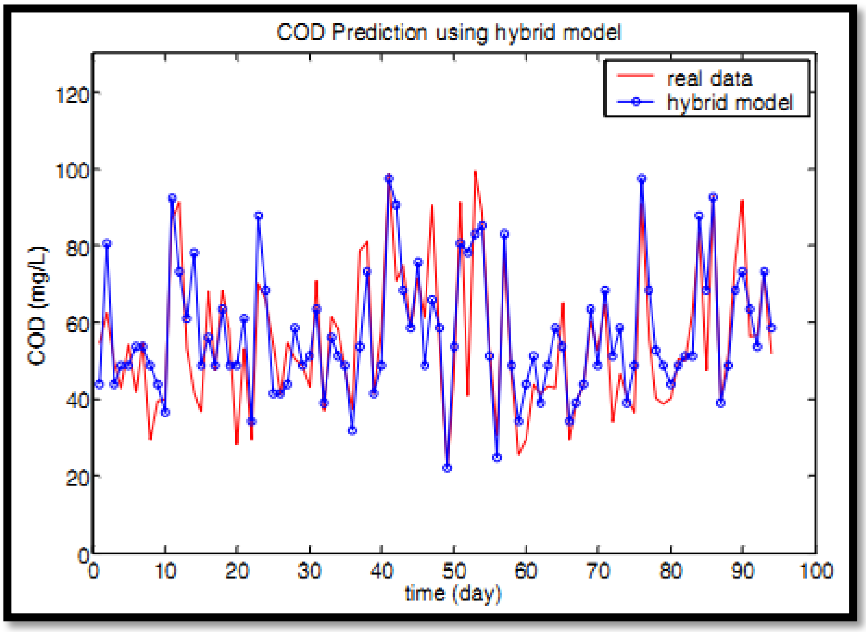


Figure 2.1: Anoxic-Aeration Tank

The study found out that the COD contain in the effluent is not more than 100 mg/L which is below than the limit allowed [4]. This is a good result from the system as seen in the graph 2.1 (the COD value in anoxic-aeration system) below:



Graph 2.1: The COD value in the hybrid anoxic-aeration system

Besides that, an article describes an Intermittently Decanted Extended Aeration (IDEA) process that was introduced by Ranhill Corporation Sdn Bhd where the process use dual-tank aeration tank [5]. The first tank acts as normal aeration tank while the second tank has a temporary aeration and then become clarifier as illustrate in the figure 2.2 (dual-tank IDEA process) below:

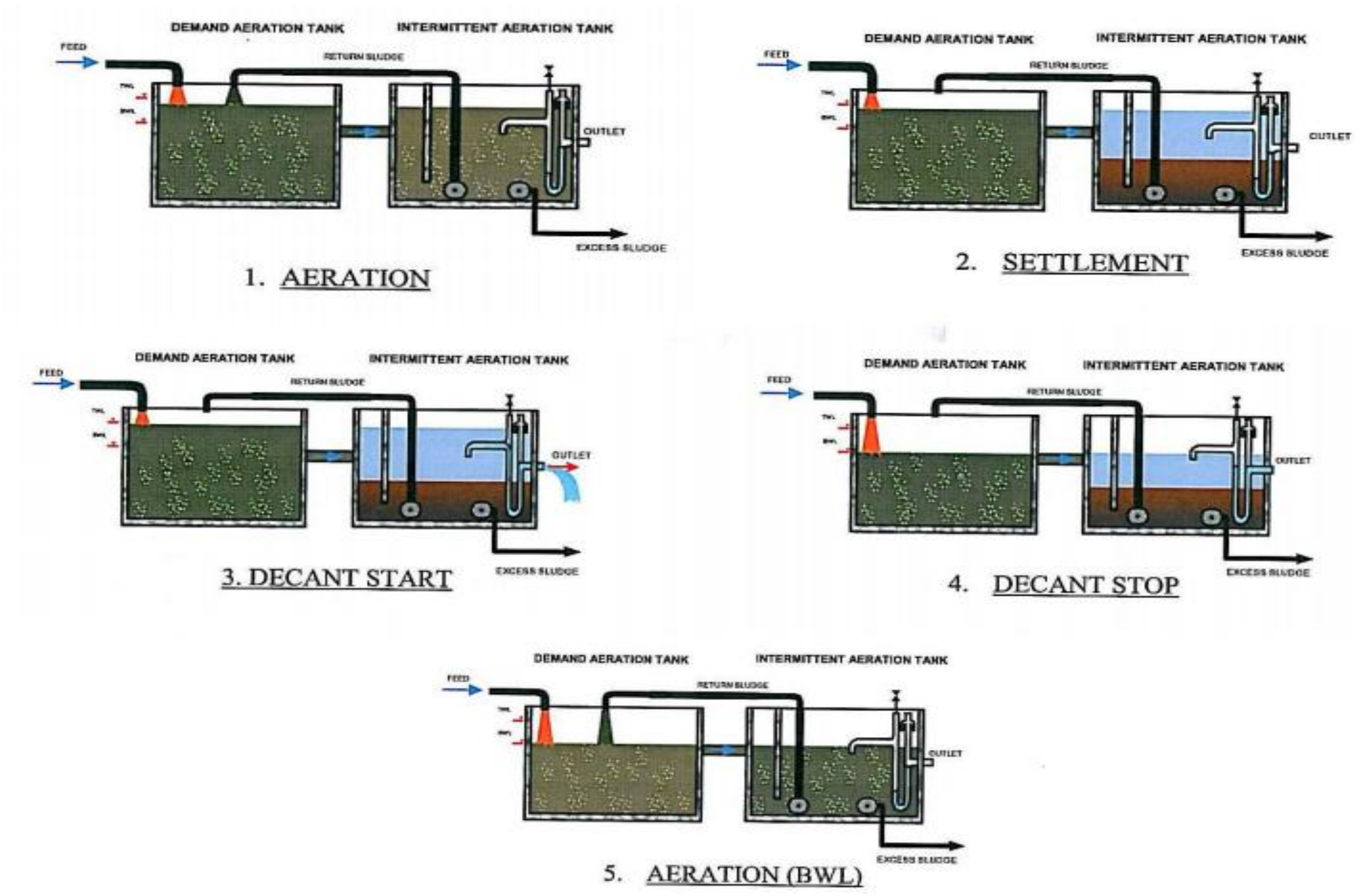


Figure 2.2: Dual Tank IDEA Process

This shows that the process contain some versatility of the second tank where it act as aeration, clarifier and as well as digester. Intermittently Decanted Extended Aeration (IDEA) is a continuously-feed and intermittently-decant system and it is a cyclic process. In contrast to the continuous flow system, metabolic reaction and effluent clarification are carried out in one tank and in a well-defined and continuously repeated time sequence. IDEA sewage treatment process has been developed and built based on the recognized advantages of sequencing Batch reactor (SBR) and Extended Aeration (EA) system. High flexibility in process design had enabled IDEA process to be successfully implemented and help to convert the old, ailing, or malfunctioning existing sewage treatment works. The IDEA process is capable of carrying out biological nitrogen removal and achieving low consistent total nitrogen where full nitrification and denitrification take place without the need for a separate anoxic tank.

This process is done by combining the advantage of two most common activated sludge systems known as Extended Aeration (EA) and Sequencing Batch Reactor (SBR). It combines the advantages of both systems i.e. SBR requires less space while EA produce less sludge and have good settling characteristics. Dual-tank IDEA address the limitation of single-tank IDEA process by providing a demand aeration tank (DAT) prior to the intermittent aeration tank (IAT), and incorporating a recycle activated sludge (RAS) stream. The performance of IAT as fill and draw clarifier is one of the most important and innovative aspects of intermittently decanted process. Figure 2.2 (dual-tank IDEA process) illustrate the process sequence.

Table 2.1: The result of IDEA system

Sample Data	BOD_5 (mg/l)		COD (mg/l)		NH_3 (mg/l)		NO_3^- (mg/l)		pH		SS (mg/l)	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Standards A*	-	**20**	-	**50**	-	**N/a**	-	**N/a**	-	**6-9**	-	**50**
Sample # 1	104	2	228	50	19	1	-	1	6.9	6.6	64	2
Sample # 2	160	2	335	28	22	3	-	1	6.9	6.7	112	9
Sample # 3	160	2	335	17	21	1	-	1	6.9	6.7	101	2
Sample # 4	164	2	340	22	14	2	-	1	6.9	7.0	106	3
Sample # 5	172	4	318	28	12	2	-	1	6.9	6.8	125	6
Sample # 6	327	5	488	21	18	1	-	1	7.4	6.7	140	16
Sample # 7	204	4	411	22	21	1	-	1	7.1	6.8	136	7
Mean	184	3	351	27	18	2	-	1	7.0	6.8	112	6
Removal Eff. %	**98.4**		**92.3**		**88.9**		-		-		**94.6**	
90 Percentile	280	4	430	40	23	2	-	1	7.1	6.9	130	12

* Environmental Quality Regulations, 1979, Malaysia

The following results in table 2.1 (IDEA system result) were obtained on the grab from a dual-tank IDEA sewage treatment plant designed and built under the Indah Water Konsortium (IWK) Refurbishment Program in Negeri Sembilan, Malaysia. The result shows the consistency of high quality effluent during its operation.

Next, other type of integration system is a reactor that combines coagulation, activated sludge and reverse osmosis to the treatment of the wastewater produced by the meat industry [6]. The wastewater from the meat industry was treated in the system linking the processes of: coagulation, biological treatment using the activated sludge method, simultaneous precipitation of phosphor and reverse osmosis. The carried out investigation studies showed that after the simultaneous precipitation of phosphor the sewage could be returned to the natural receiving water, since its pollution ratio did not exceed the permissible values for sewage waters which can be returned to natural receiving waters. By cleaning up the wastewater in the process of reverse osmosis, it was possible to use it again in the technological cycle. Reference figure 2.3 (the process diagram for coagulation, activated sludge and reverse osmosis) shows the process below:

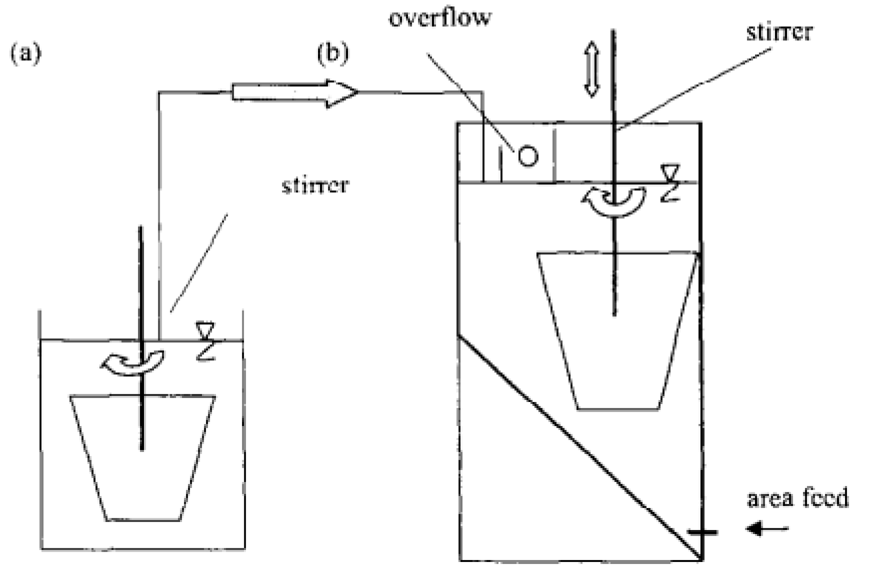


Diagram of apparatus system for the treatment of wastewater from the meat industry linking the coagulation method with the method of activated sludge: (a) coagulation tank, (b) bioreactor.

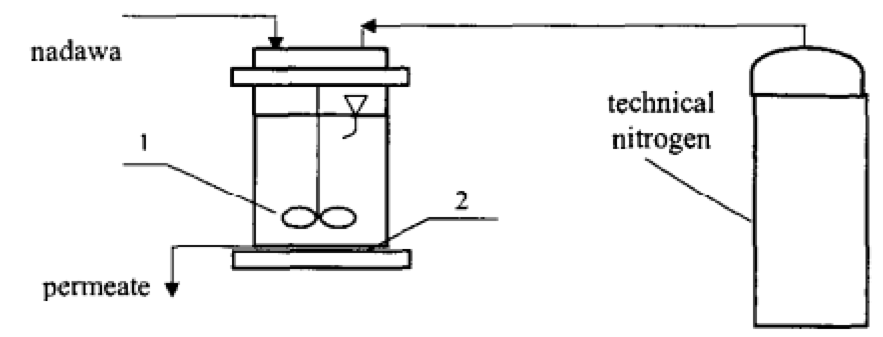


Diagram of the system for reversed osmosis: stirrer (1), membrane (2).

Figure 2.3: The process diagram for coagulation, activated sludge and reverse osmosis

The analysis of operating results of two bio- reactors, i.e. biological treatment using the method of activated sludge and simultaneous precipitation of phosphor shows that better efficiency of sewage treatment could be achieved by linking the biological system with the chemical one. The result can be obtained below:

Table 2.2: The result for the hybrid system of the coagulation, activated sludge and reverse osmosis

Treatment efficiency of sewage from the meat industry in the hybrid system linking the process of simultaneous precipitation of phosphor with reverse osmosis

Pollution indices	Concentration of pollution in raw wastewater, mg/dm^3	Wastewater after activated sludge bioreactor		Wastewater after RO process	
		Concentration, mg/dm^3	Retention R, %	Concentration, mg/dm^3	Retention R, %
COD	1940	146	92.5	4	99.8
BOD_5	1800	26	96.5	3	99.8
Total phosphate	26	3.5	86.5	0.0	100
Total nitrogen	350	14	96	3.5	99
Ammonium	35	>5	<85	1	97

After the understanding of the integration concept has been acquired, all the basics fundamental knowledge about the WWTP needs to be read further. As for the proposed project, the tank is a biological aerobic WWTP where biological treatment processes are used to remove the dissolved organic load from the water using [7]. As the proposed project is an aerobic type based, it may need to look in the aerobic system that currently been used. The aerobic reactor can be improved by using a direct adaptive recurrent neural control with Integral-Plus-State Action (IPS) for the aerobic continuous stirred tank reactors bioprocess [8]. The other one is regarding on the growth and ability of aerobic bacteria for WWTP where all of factors such as temperature, food and others will affect the performance of the aerobic reactor [9]. Both of the journals will be useful for understanding of the aerobic type of tank where its behavior can be studied.

Furthermore, as the proposed project contains several tanks which are anoxic, aeration and clarifier, reading about each tank is essential in order to understand the function of each tank and give some input in designing the project. For the first tank which is anoxic tank, it is important for denitrification where the process of reducing nitrate into nitrogen gas and also for supplying the alkalinity to aeration tank. The process of nitrification and denitrification can be designed by using Sharon Process [10]. The Sharon process, being one of the several novel nitrogen removal processes originated in the Netherlands is becoming widely-used nowadays which is ideally suited to remove nitrogen from wastewater streams with high ammonium concentration [10]. The process is important to minimize the ammonia contain in the wastewater to a certain amount before discharging to the river. Ammonium nitrogen wastewater is one of important pollution sources, which causing non-point pollution [11].

As the study of aeration tank went further, the variation of DO can affect the performance of the aeration tank where a slight reform or adjust the process, with a view to improving BOD and nitrogen removal efficiency [12]. Using a right DO level is the key to an efficient aeration. Therefore, it is essential to have a high-quality diffuser in the aeration tank.

Moving on to alkalinity consideration where some review for alkalinity is made in order to understand the importance of alkalinity in the integrated tank. The aeration tank needs certain amount of alkalinity in order for nitrification to work properly. Without them, the nitrification process will not occur in the aeration tank. The pH and alkalinity have important role to play in the aerobic biodegradation system [13]. Therefore, it is not wise to neglect the amount alkalinity that will be used in the integrated tank.

Finally, the constituent and quality of the effluent must be assessed to determine whether the effluent has reach into the discharge limit set by the local authority. Hence, some references are taken from the local authority to create a target for the effluent quality to be achieved. In this country, Department of Environment (DOE) has set a guideline and regulation regarding the discharge of wastewater treatment plant where there are two standards; Standard A and Standard B [14]. Standard A will be used as the target for the effluent discharge. Other reference is taken from the Environmental Protection Agency (EPA) of United States for further comparison for the discharge limit from foreign country [15]. This is necessary to see whether the effluent discharge of this tank has met the international standard from developed country or not. Both standard of effluent discharge limit are shown below: (DOE standard and EPA standard)

SECOND SCHEDULE

(Regulation 7)

ACCEPTABLE CONDITIONS OF SEWAGE DISCHARGE OF STANDARDS A AND B

New Sewage Treatment System

	Parameter	Unit	Standard	
			A	B
1	Temperature	°C	40	40
2	pH Value	-	6.0-9.0	5.5-9.0
3	BOD5 for 20°C	mg/L	20	50
4	COD	mg/L	120	200
5	Suspended Solid	mg/L	50	100
6	Oil and Grease	mg/L	5	10
7	Ammonia Nitrogen (enclosed water body)	mg/L	5	5
8	Ammonia Nitrogen (river)	mg/L	10	20
9	Nitrate (river)	mg/L	20	50
10	Nitrate (enclosed water body)	mg/L	10	10
11	Phosphorus (enclosed water body)	mg/L	5	10

Adapted from DOE of Malaysia 2010

Parameter	Unit	Maximum permissible limit
Total coliforms	MPN per 100 ml	<400
E. Coli	MPN per 100 ml	<200
Free Chlorine	mg/l	0.5
Total Suspended Solids (TSS)	mg/l	35
Reactive Phosphorus	mg/l	1
Colour	-	Not objectionable
Temperature	^0C	40
pH	-	5 – 9
Chemical Oxygen Demand (COD)	mg/l	120
Biochemical Oxygen Demand (BOD_5)	mg/l	40
Chloride	mg/l	1500
Sulphate	mg/l	1500
Sulphide	mg/l	0.002
Ammoniacal Nitrogen	mg/l	1
Nitrate as N	mg/l	10
Total Kjeldahl Nitrogen (TKN)	mg/l	25
Nitrite as N	mg/l	1
Aluminium	mg/l	5
Arsenic	mg/l	0.1
Beryllium	mg/l	0.1
Boron	mg/l	0.75
Cadmium	mg/l	0.01
Cobalt	mg/l	0.05
Copper	mg/l	0.5
Iron	mg/l	2
Lead	mg/l	0.05
Lithium	mg/l	2.5
Manganese	mg/l	0.2
Mercury	mg/l	0.005
Molybdenum	mg/l	0.01
Nickel	mg/l	0.1
Selenium	mg/l	0.02
Sodium	mg/l	200
Total Chromium	mg/l	0.05
Vanadium	mg/l	0.1
Zinc	mg/l	2
Oil & Grease	mg/l	10
Total Pesticides	mg/l	0.025
Total organic halides	mg/l	1
Cyanide (as CN^-)	mg/l	0.1
Phenols	mg/l	0.5
Detergents (as LAS*)	mg/l	15

***Adapted from Environmental Protection Agency of USA 2003**

CHAPTER 3: METHODOLOGY

3.1 Prototype Design

Before building a prototype tank, all design calculations needs to be made in order to determine the size of tank with a given of a suitable average flow of wastewater. The prototype tank will be designed in a smaller scale with a small amount flow rate, Q for demonstration and experiment purposes. All tests and experiment such as Biological Oxygen Demand (BOD), Total Suspended Solid (TSS) and other test will be conducted after completion of the prototype tank to determine the quality of effluent produced.

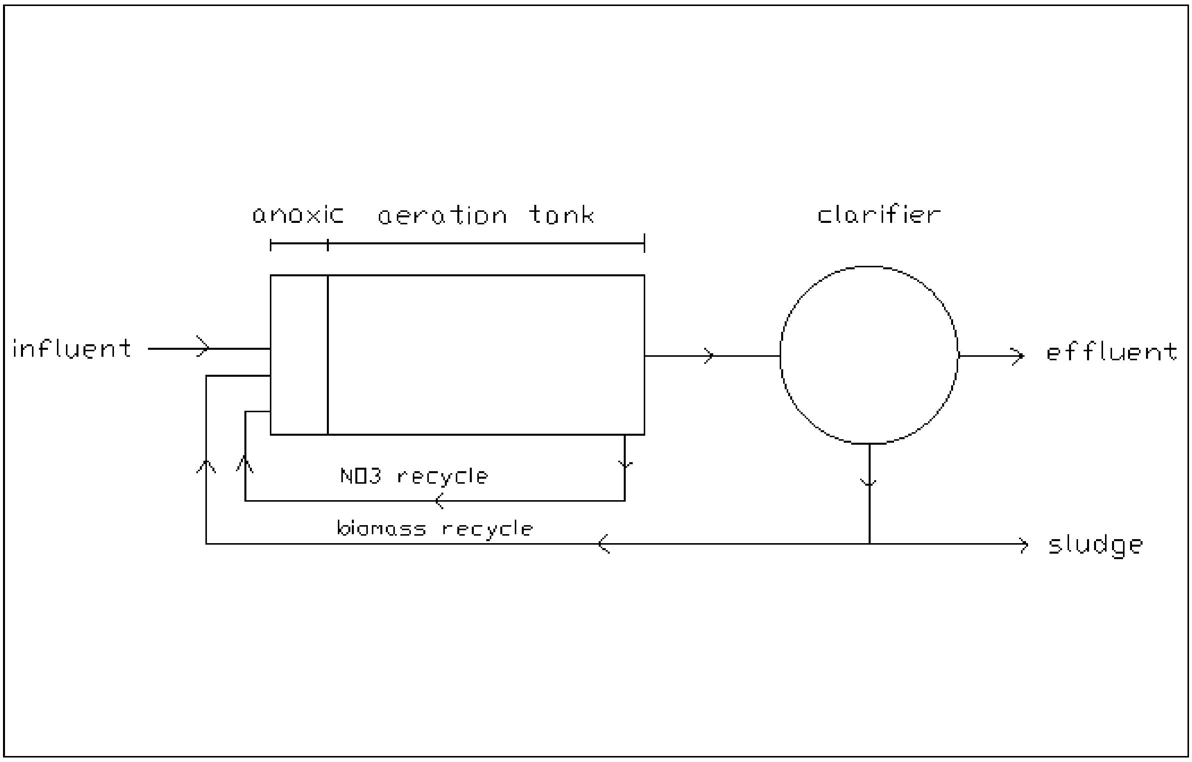


Figure 3.1: Typical WWTP using anoxic and aeration tank

The concept of this project can be simplified by examining the current WWTP used today. The WWTP as shown as in Figure 3.1 (Typical WWTP using anoxic and aeration tank) above is the typical system used in a treatment plant. The plant consists of anoxic tank, aeration tank and also clarifier. The process start as the influent enters the anoxic tank for denitrification, then followed by aeration for oxidation and endogenous respiration process. The nitrification also occurs in the aeration tank where it needs to be recycled back to the anoxic tank at the end of the aeration tank. This is because the treatment plant has a long sludge age which stimulates the growth of nitrogenous bacteria. Later the water is transferred to the clarifier where it produces the effluent and the sludge. The sludge will be settle down and some of them will be recycled back to maintain the concentration of biomass inside the tank. The excess sludge is removed to dewatering process for further treatment.

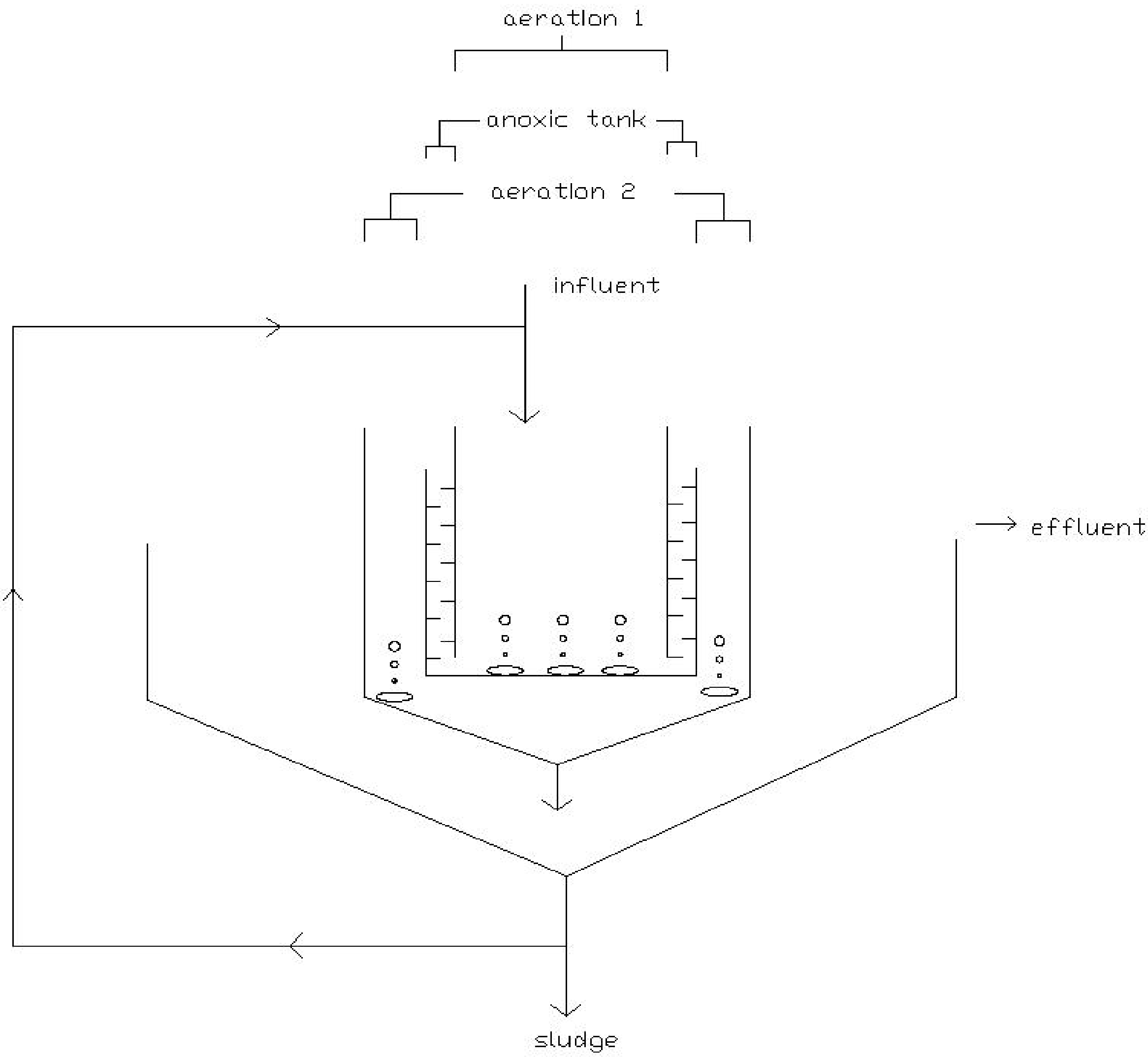


Figure 3.2: The Compact Extended Aeration Reactor (CEAR)

As understanding of the system of the current treatment plant process have been obtained, now the process can be derived into this integrated system. Figure 3.2 (the integrated wastewater treatment system) above shows the cross section of the proposed integrated reactor where it is also consists of anoxic, aeration and also the clarifier. The process is similar to the previous system except that all part of the system have been combined together to form a single unit of reactor.

The proposed integrated reactor consists of anoxic tank, aeration tank, and also clarifier as shown in the Figure 3.2 (sketch of CEAR) above. The reactor has a series of aerobic-anoxic-aerobic of flow where the anoxic tank is located between the two aeration tanks. The influent of the wastewater will enter into the first aeration at the centre of the reactor. Then, it will enter the anoxic tank from the bottom of the first aeration. Later, the water will overflow into the second aeration tank for further oxidation process. Then, the water will go through the clarifier. The sludge will settle down to clarifier and will be recycled back into the tank to maintain the concentration of biomass in the aeration tank. At the same time the water in clarifier will overflow and become the effluent of the tank. The effluent of the tank will the end product of the tank and will be tested to observe the quality of the effluent.

The reason to have two aeration tanks was to promote the growth of bacteria for nitrification. The bacteria for nitrification process are a slow grower and it is found out the retention time for the first aeration was not enough for the growth of the bacteria. Therefore, the first aeration tank was for BOD removal and the second aeration tank was for nitrification.

3.2 Parameter Measurement

Parameters that will be measured in this project are the BOD removal parameters which involve Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) and Mixed Liquor Suspended Solid (MLSS).

a) BOD test

Biochemical oxygen demand or BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at temperature of 20^0C and 5 days of incubation. 19 L of aerated water was prepared one day before the experiment conducted by using diffuser that was put into the water container. After the aerated water was prepared, BOD buffer was poured into the 19 L of aerated water and wait for 30 minutes. Blank sample was prepared by pouring aerated water into a BOD bottle until it reach to its neck. 5 mL of sample was taken and it was put into BOD glass and it was filled with aerated water until it reaches its neck. The blank sample was measured with DO meter and the reading was recorded. The BOD glass was closed with cap and aluminum foil. The BOD glass was kept inside the BOD incubator where temperature is set to be 20^0C and it is stored for 5 days. After 5 days, all the BOD glass were measured by using DO meter and record the reading. The difference of blank sample before and after reading should not exceed 2 mg/L.

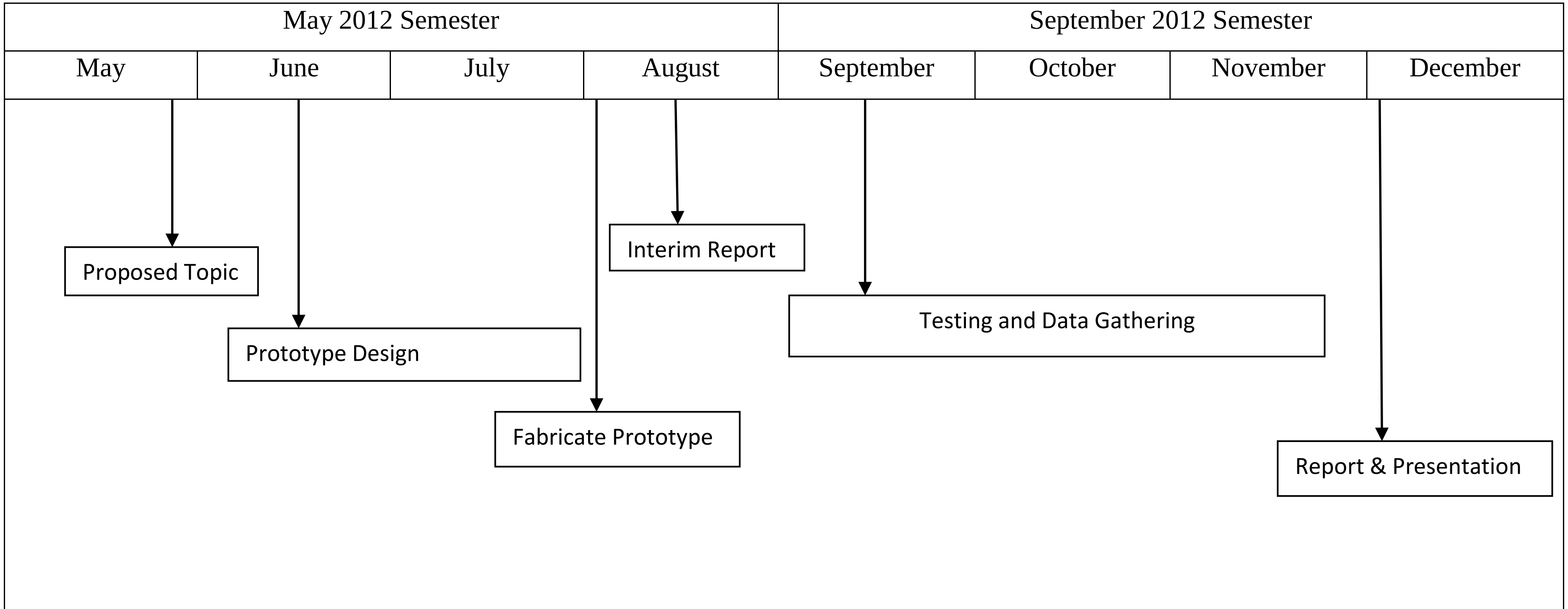
b) COD test

Chemical oxygen demand (COD) is a measure of oxygen requirement of a sample that is susceptible to oxidation by strong chemical oxidant. The procedure starts with a 100 mL of sample was homogenized for 30 seconds in a blender. The DRB200 Reactor need to be turned on and preheat was set to 150^0C. The caps were removed from two COD Digestion Reagent Vials. A clean volumetric pipet was used to add 2 mL of sample to the vial. Another clean volumetric pipet was used to add 2 mL of distilled water to the vial for blank sample. Cap the vials were closed tightly and the vials were shook vigorously. The sample vials become very hot during mixing. The vials were heated for two hour using the DRB200 reactor. The vials were place into a rack and cool to room temperature. The vials were wiped with a damp towel followed by a dry one. The blank vial sample was put into the spectrophotometer in order to set it to zero. Then the sample vial was put into spectrophotometer to record the COD reading in mg/L. Finally, all COD readings were recorded.

c) TSS and MLSS test

Total Suspended Solid TSS is measured for influent and effluent of a tank while Mixed Liquor Suspended Solid MLSS is measured for the biomass contained in the aeration tank. The procedure for both tests is same. A filter paper was prepared by letting water run through the filter paper to open the pores by using TSS pump equipment. It was dried in a oven for 24 hours. Then the filter paper was moved into desiccator for 30 minutes. The filter paper was weight with weighing machine and the reading was recored. The filter paper was put on the TSS equipment and it was poured with 50 mL of sample into it. The pump was turned on until the water in the TSS equipment has been passed through the filter paper. The filter paper was dried into the oven for one hour. The filter paper was moved into the disiccator for 30 minutes. The filter paper was wieght with weighing machine and the final reading was recoded.

3.3 Key Milestone



Project Key Milestone (May-December 2012)

3.4 Gantt Chart

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Extended Proposal					■	■	■																					
Prototype Design				■	■	■	■	■	■	■																		
Fabricate Prototype											■	■	■	■														
Interim Report												■	■	■														
Data Gathering															■	■	■	■	■	■	■	■	■	■	■			
Final Report																										■	■	■

3.5 Raw Wastewater Preparation

To ease the monitoring performance of each tank, **synthetic wastewater** is used in this project. The synthetic wastewater was prepared by using dog's food that is mixed together with water in approximately 3600 mg/L. First, the dog's food was weighed to 200 grams then it is mixed with tap water in 55 L container. After the mixing process has complete, it was used as the raw or influent of the tank. The synthetic wastewater will resemble a medium strength wastewater which is commonly come from residential area. The constituent of the influent is shown in the table below:

Table 3.1: The Typical Medium Strength of Wastewater Composition

Parameter	**Synthetic Wastewater (mg/L)**	**Typical Medium Strength Wastewater Composition (mg/L)**
COD	500	430
BOD_5	150	190
TSS	150	210

Figure 3.3: Dog's food and influent

3.5 Experimental Procedure

The overall tank will have a series of aeration-anoxic-aeration system. The first aeration is for BOD removal and second aeration is nitrification. Below is the flow of CEAR:

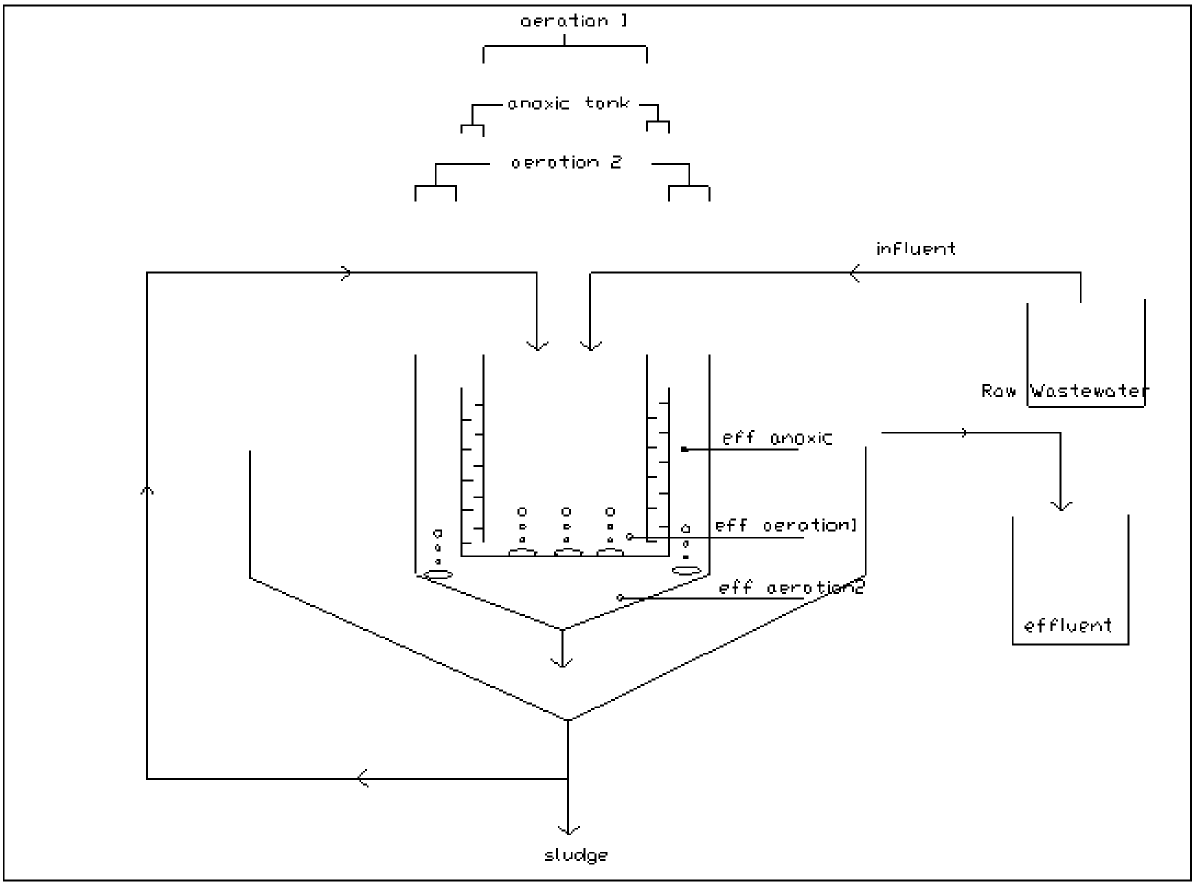


Figure 3.4: Experimental Procedure of CEAR

The volume of each tank is determined:

Table 3.2: The Volume of Each Tank

Tank	Volume (L)	Retention Time (day)
Aeration 1	17	1.13
Anoxic	1	0.07
Aeration 2	40	2.67
Clarifier	273	18.20
Total	**331**	**22**

15 Liter/day is used as inflow rate, Q and from there it is calculated that retention time for the water to completely flow through the tank is 22 days. Therefore, the reactor needs to be acclimatized within the time period. Below is the picture of the reactor setup:

Figure 3.5: Setup of the Reactor

3.7 Performance Monitoring

The samples were taken from five points of the tank which are influent, effluent aeration1, effluent anoxic, effluent aeration 2 and final effluent as shown as Figure 3.6 (sample collection point) below:

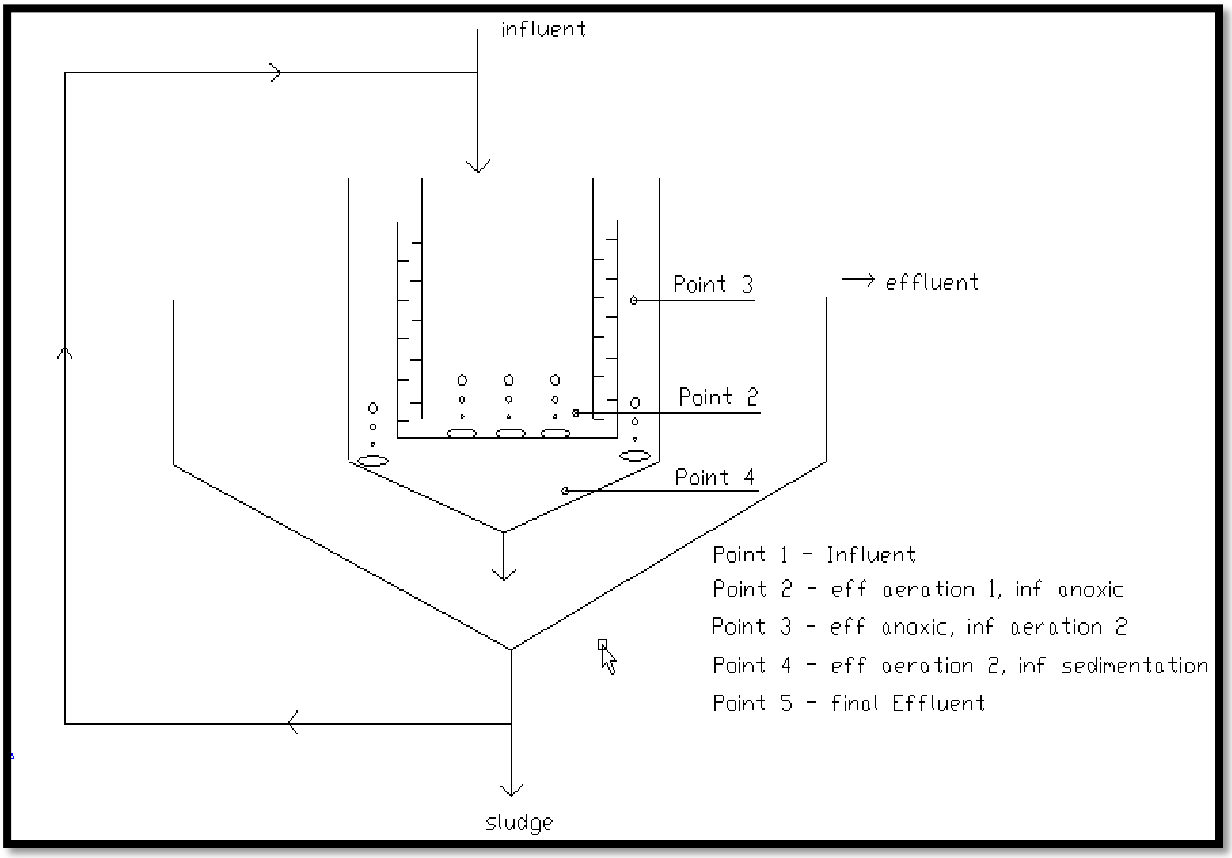


Figure 3.6: Sample Collection Points

The samples were obtained by using pipette with bulb and it is taken at the designated point. 1000 mL was collected at each point for several tests. The sample taken from specific point is important to measure the performance of each tank. For example, to monitor the performance of aeration tank, the sample was taken from between anoxic and aeration tank as the influent and between aeration and clarifier as the effluent of the aeration tank. In other word, the input and output of each tank is measured to see the whether the tank is working or not in order to achieve overall result of the integration process.

Each sample was taken regularly and it was taken three times a week to monitor the performance of the tank. The sample collected was tested with several experimental tests. These are the tests will be conducted for each sample which are BOD, COD, TSS, and MLSS. After all data have been collected, the data will be analyzed and several graphs will be plotted to see the pattern of the tank's performances. From the result of the obtained data, it can be used as evaluation to the reactor.

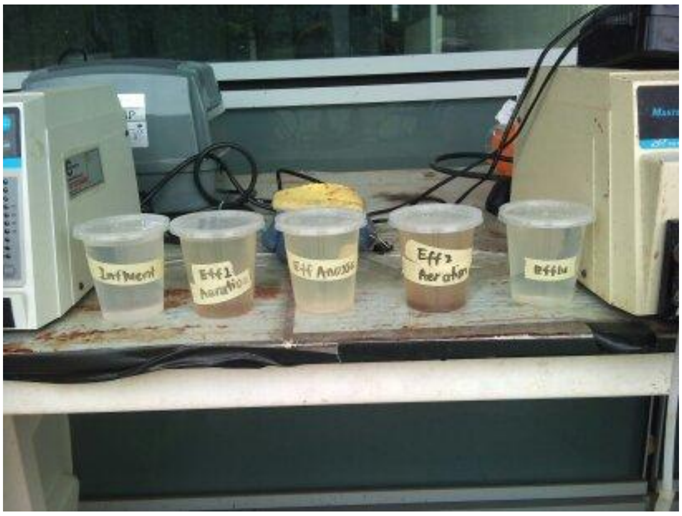


Figure 3.7: Samples Taken

CHAPTER 4: RESULTS & DISCUSSION

As for part in BOD Removal of the reactor, the author will focus on results in BOD, COD, TSS and MLSS. Each sample was tested 3 times and average was taken for each test. All the raw data can be seen in the appendix. There are 5 samples that have been taken in different point which are influent, effluent aeration 1, effluent anoxic, effluent aeration 2 and final effluent.

The results will be divided in two phases, one is before modification and the other is after modification. The details of the modification made will be discussed later in second phase.

4.1 BOD Results (First Phase)

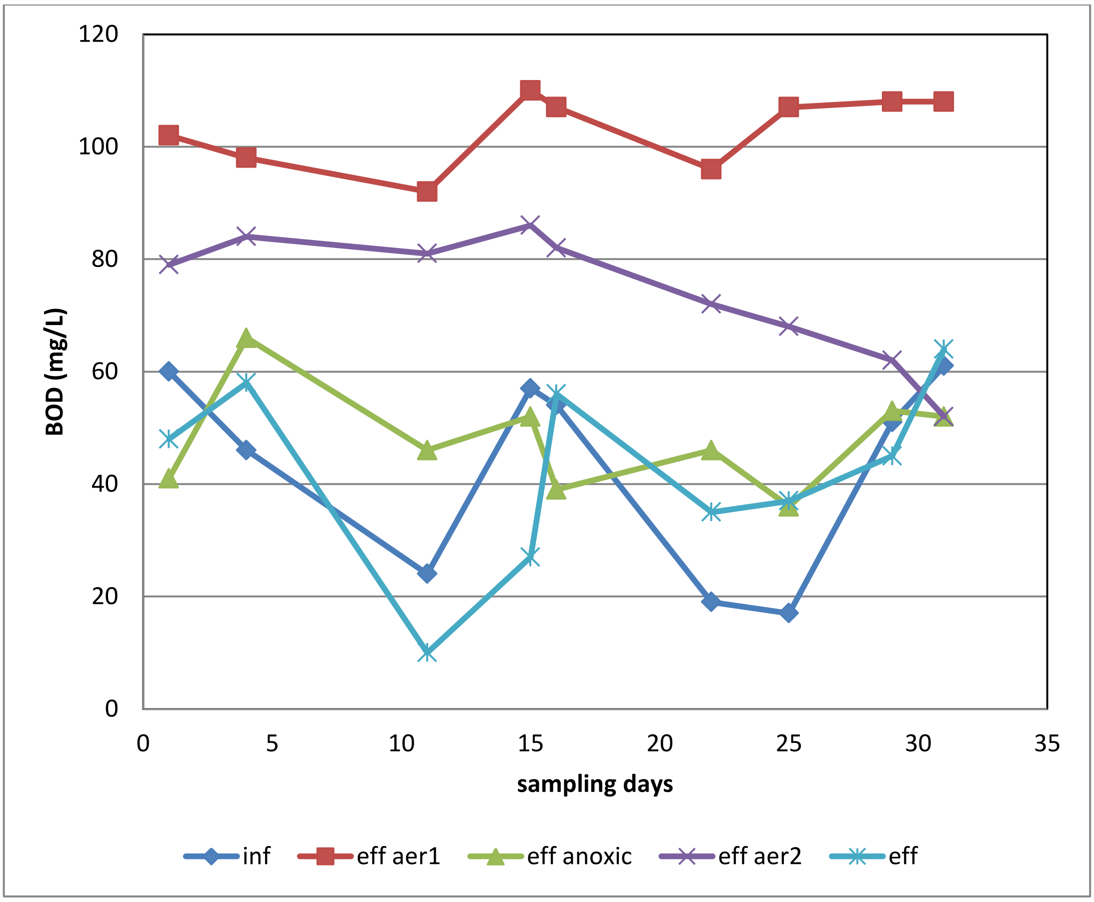


Figure 4.1: BOD (mg/L) vs sampling days

Based on the Figure 4.1 (BOD vs sampling days), the duration of the sampling day wass 31 days. As for the influent, the BOD reading was relatively low where the value was ranging from 20-60 mg/L. This is similar to the BOD reading of the effluent where the range was 10-60 mg/L. There was no significant reduction of BOD in the effluent by comparing the

BOD influent. Therefore, the reactor did not work properly and need to be adjusted. As for the sample within the reactor, the graph shows that the BOD reading for effluent aeration 1 was high where the average value was 100 mg/L while for the effluent aeration 2 was 80 mg/L from day 1 until day 15, and gradually decreased to 55 mg/L on the 31 day. The high value of BOD from these two aeration tanks were mostly due to the high amount of biomass contain inside the sample. The author might not filter the sample first before testing it for BOD. Hence, some corrections have been made in the phase two results where the sample was filtered first before doing the BOD test.

4.2 COD Results (First Phase)

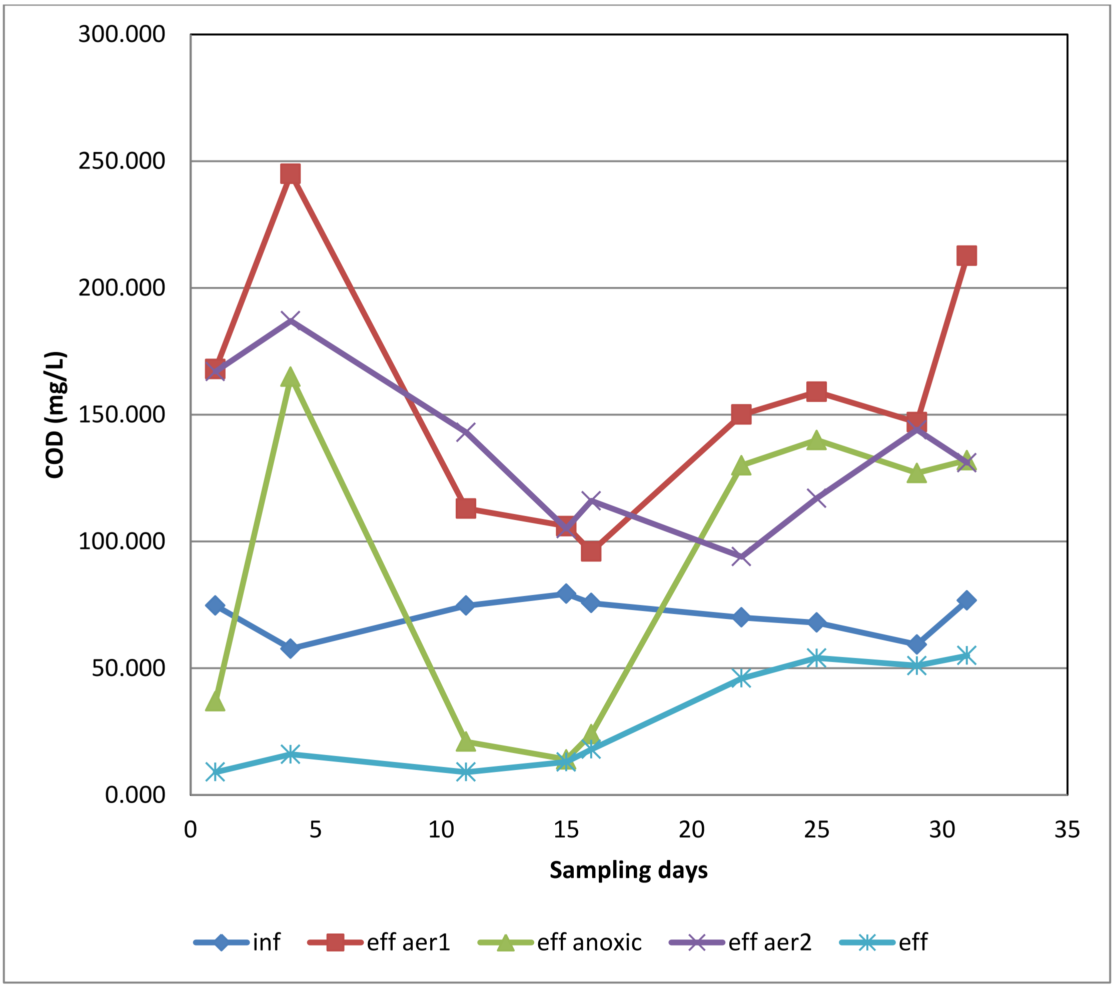


Figure 4.2: COD (mg/L) vs sampling days

Based on the Figure 4.2 (COD vs sampling days), the COD reading of the influent showed average value of 75 mg/L. This is considered to be very low because the ideal value for the COD reading of influent is 500 mg/L. As for the effluent, the COD reading was also relatively low where value is 20 mg/L from day 1 until day 15 and gradually increased to 50 mg/L on the day 31. However, the samples within the reactor showed a very high COD reading especially in the aeration 1 tank. The reading for aeration 1 was 170 mg/L on the day 1, and it was increase to 250 mg/L on the day 5. Then it was gradually decreasing to 100 mg/L on the day 17 day but it was increasing up to 225 mg/L on the day 31. This reading showed inconsistency in of the COD reading in the aeration 1 tank where the tank might not be working properly. This pattern is similar to the effluent aeration 2 and effluent anoxic where the COD reading is not stable and very high. This was probably due to the sample that was not filtered before testing which is similar to BOD cases. Therefore, correction must be done in order to get an accurate of COD reading.

4.3 TSS Results (First Phase)

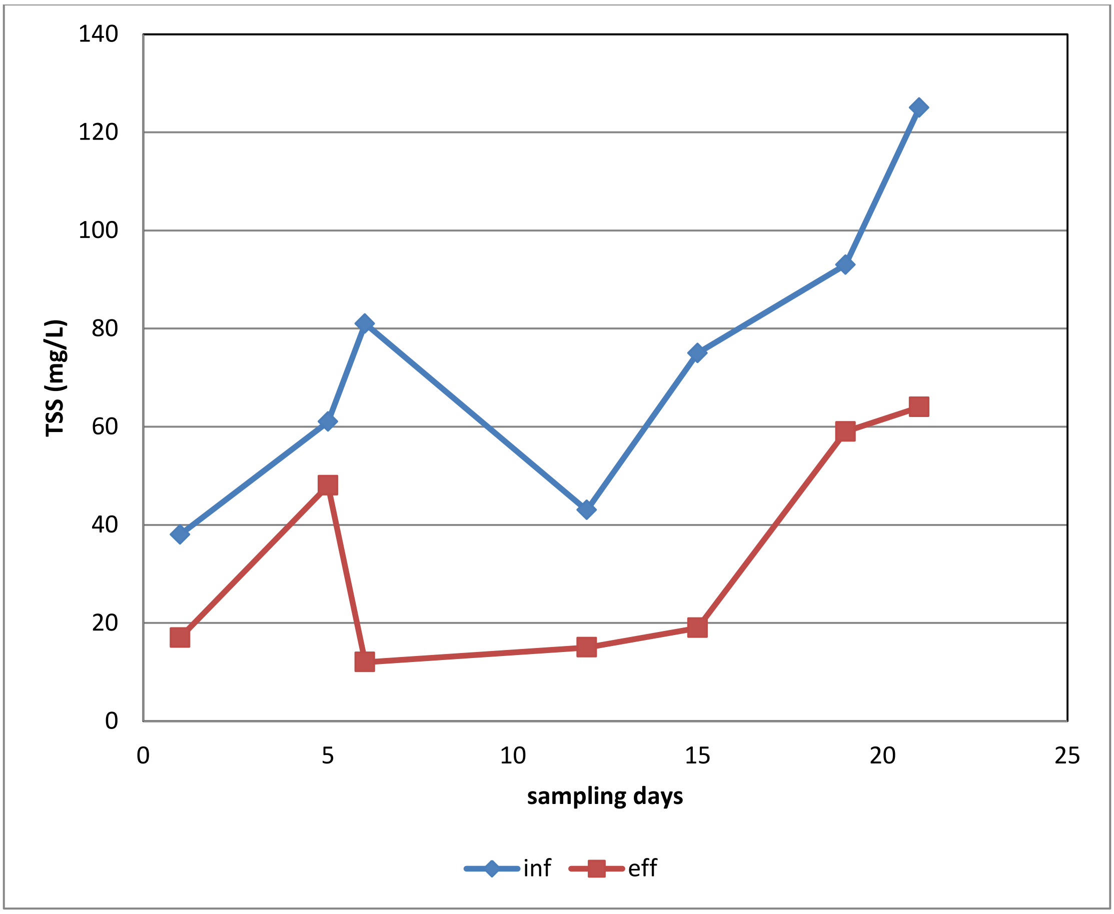


Figure 4.3: TSS (mg/L) vs sampling days

Based on the Figure 4.3 (TSS for influent and effluent), the graph shows that TSS reading for influent was 40 mg/L on the day 1, later it was increasing to 80 mg/L on the day 6. Then it was decreasing to 45 mg/L on the day 13. Lastly, it was gradually increased to 125 mg/L on the day 22. As for the effluent, the TSS reading start from 20 mg/L and it was increased to 50 mg/L on the day 5. Later it was dropped to 15 mg/L on the next day and it was increased slightly to 20 mg/L on the day 15. Finally, the reading increased up to 65 mg/L which is exceeding the limit of Standard A which 50 mg/L. However, the overall TSS reading of the effluent was still within the Standard B limit which is 100 mg/L.

4.4 MLSS Results (First Phase)

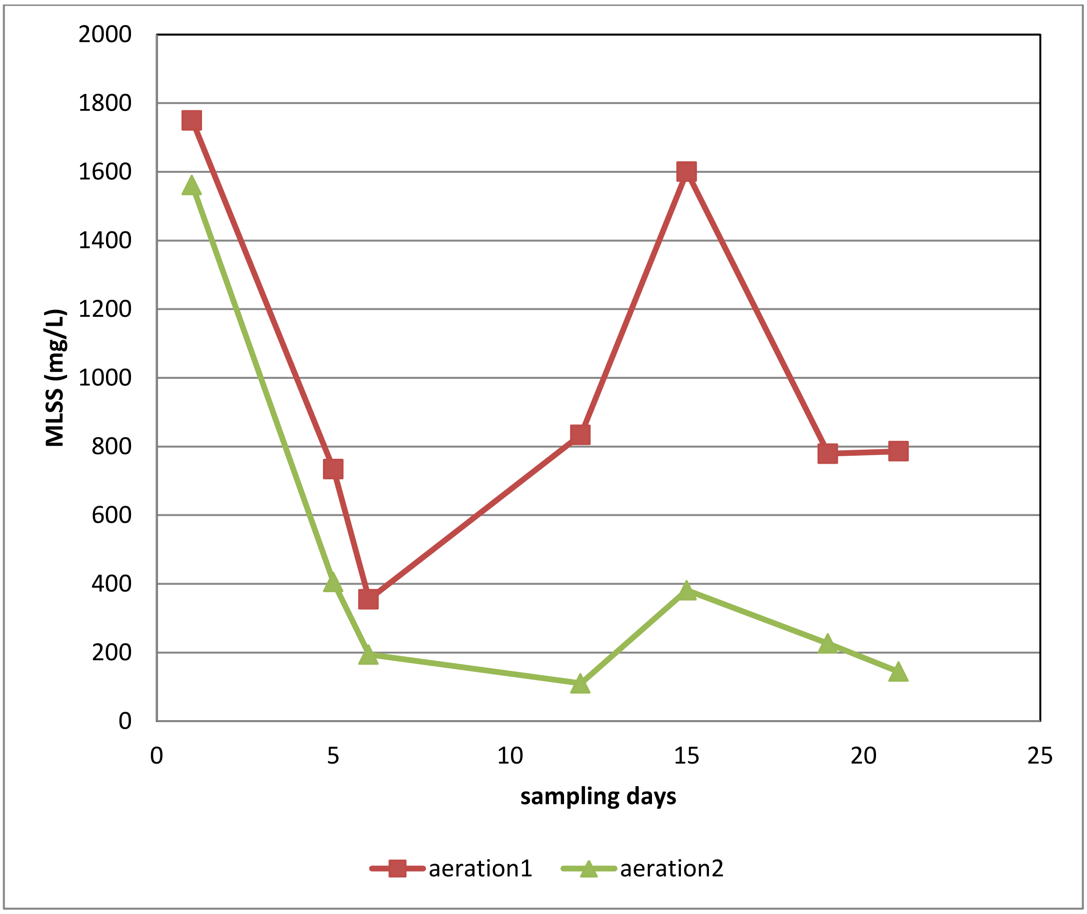


Figure 4.4: MLSS (mg/L) vs sampling days

As for MLSS, two points were taken to test the MLSS value which are point 2 and point 4. Point 2 was the aeration tank 1 while point 4 was aeration tank 2. From the Figure 4.6 (MLSS for aeration 1 & 2) showed that the aeration tank 1 has the higher value of MLSS compare to the aeration tank 2. The MLSS reading for the aeration 1 was 1750 mg/L on day 1 and it was dropped to 350 mg/L on day 6. The reason the biomass was low in the aeration tank is the biomass might undergone endogenous respiration process where the biomass oxidized itself to CO_2 gas, water and ammonia. In other word, the biomass consumed itself and caused the biomass to be reduced. Hence it was the reason why the concentration of biomass was low in the aeration tank. Later the MLSS reading was increased to 1600 mg/L and lastly it was decreased to 800 mg/L on day 23. This was most probably because the sample was taken out right after the sludge has been recycled. Similar pattern applied to the aeration 2 where the MLSS reading start from 1550 mg/L and end at 150 mg/L.

Both of them have very low MLSS value. The ideal MLSS value for both tanks is 6000 mg/L. The low MLSS reading indicates a low amount of biomass inside the aeration tank. With low biomass, it will not cause any COD and BOD reduction occurred in the aeration. This is because the biomass will consume the organic matter and caused the BOD to be reduced. Therefore, the amount of the biomass needs to be increase in both tanks. This also might due to poor recycle of sludge into the aeration tank. The sludge recycle will maintain the concentration of biomass inside the aeration tank and if it is not properly worked, it will cause low biomass content inside the aeration.

4.6 Adjustment and Modifications

Several adjustment and modifications have been made in order to improve the reactor. From the first phase results, it was found out that the COD loading was too low which is average value of 75 mg/L. The COD loading in the influent should be around 500 mg/L. Besides that, the MLSS reading in the aeration tank was also too low which has 1800 mg/L where it should be 6000 mg/L as an ideal value of MLSS in the aeration. Therefore, the first adjustment was to increase the COD loading to 500 mg/L and the second adjustment was increase the biomass or MLSS value to 6000 mg/L.

The first adjustment or modification that has been made in order to increase the COD loading was the mixture of the dog's food has been revised. Before this, the mixture of the dog's food and water was set to be 600 mg/L as the influent in the first phase results. However, the COD loading from the influent in the first phase prove to be too low. Therefore, the mixture of the dog's food has been revised to be 3600 mg/L. The details of preparation on the influent have been discussed before in methodology of preparing raw wastewater.

The second adjustment was to increase the MLSS value in the aeration tank by addition of sludge into the reactor. The sludge was collected at the nearest STP and it was added into the reactor to increase the biomass inside the aeration tank. Then the recycle rate of sludge has been monitored in order to maintain the concentration of biomass within the range of MLSS value of 6000 mg/L. All results with modification made will be presented in the second phase results.

4.7 BOD Results (Second Phase)

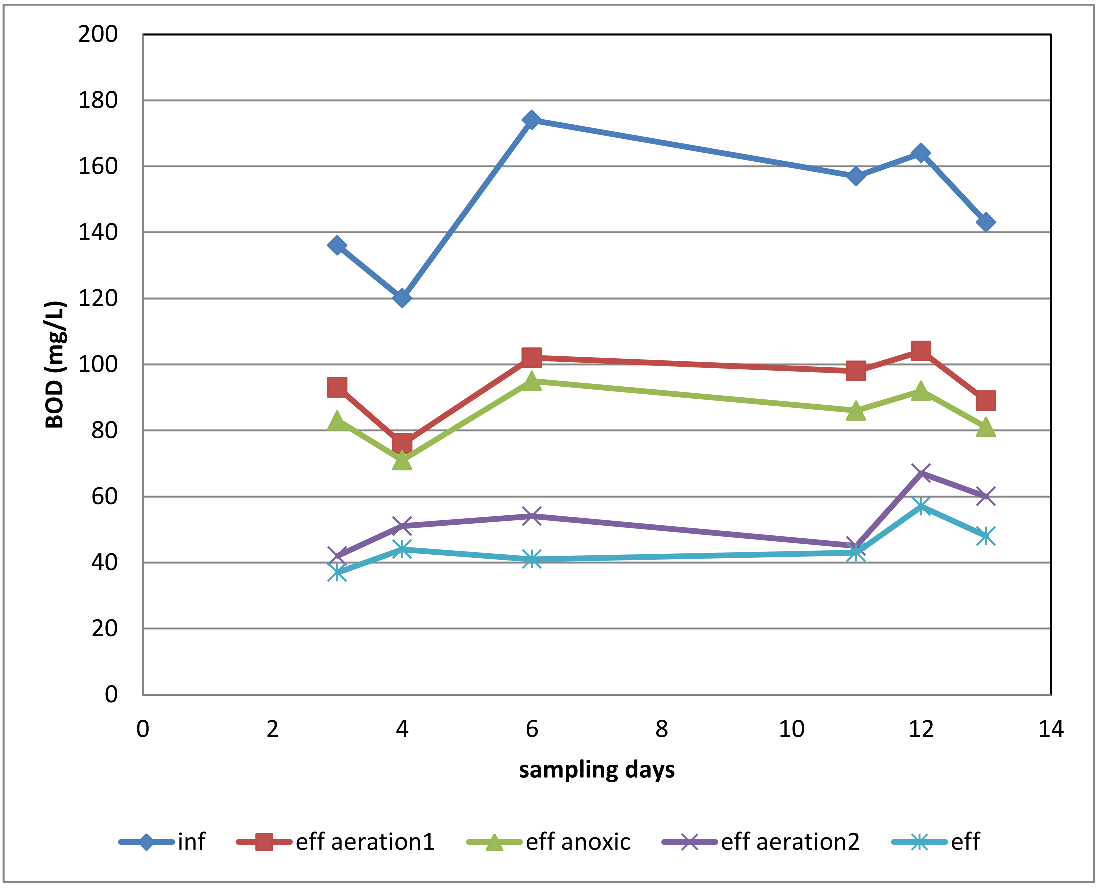


Figure 4.5: BOD (mg/L) vs sampling days

Based on the Figure 4.5 (BOD vs sampling days), the duration of the sampling days was 13 days in total. The BOD reading of the influent starts at day 3 which was 135 mg/L and then it was dropped slightly to 120 mg/L on the next day and later it was increased to 175 mg/L on day 6. Then it was gradually decreased to 140 mg/L on day 13. As for the effluent aeration 1, the BOD reading was similar to effluent anoxic which has the range of 80-100 mg/L. Lastly, the final effluent and effluent aeration 2 showed a similar pattern where the BOD reading for both of them ranging from 40-60 mg/L. By comparing BOD reading of influent and effluent, there is a significant reduction of BOD level. The BOD level was dropped first after went through the aeration 1 tank. Later, the BOD level was further dropped after went through the aeration 2. Therefore, it can be concluded that the aerobic treatment is working properly.

4.8 COD Results (Second Phase)

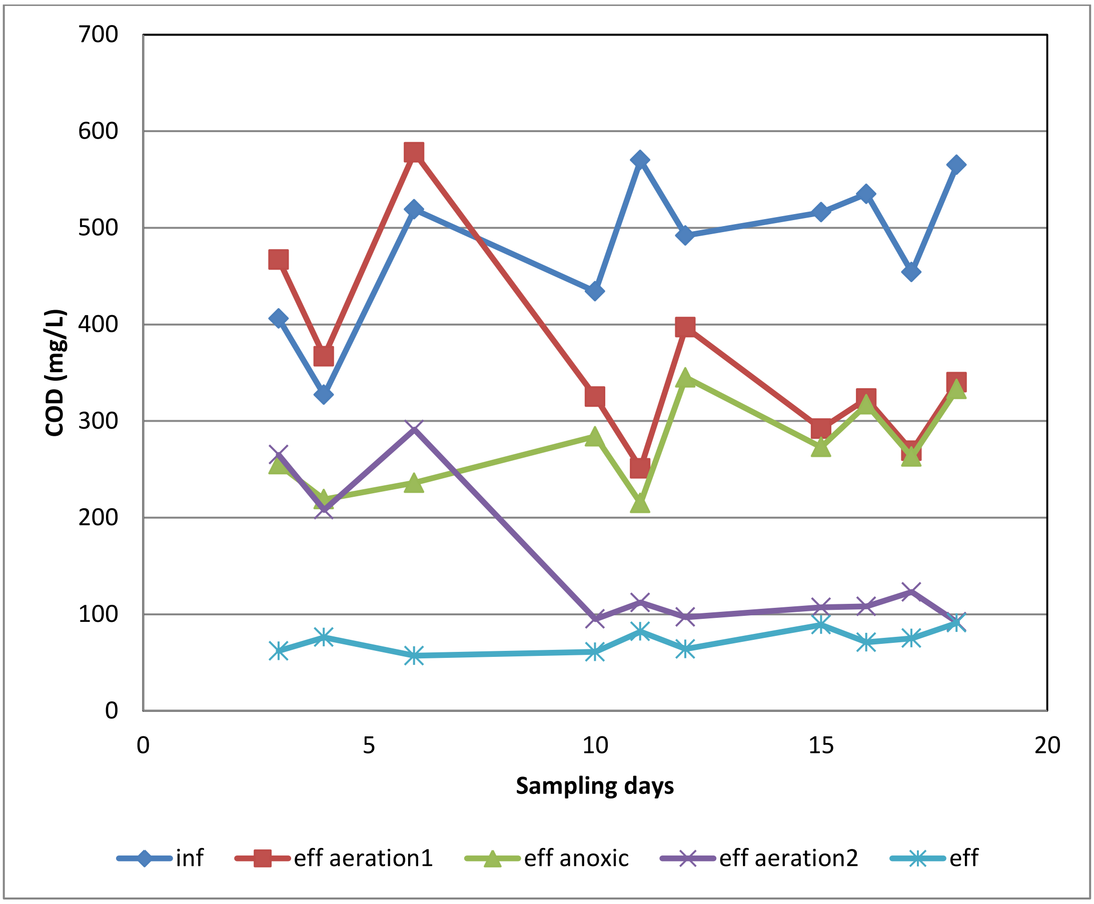


Figure 4.6: COD (mg/L) vs sampling days

Based on the Figure 4.6 (COD vs sampling days), the COD reading for the influent was 400 mg/L on day 3 and steadily increased to 550 mg/L on day 11. Later the COD reading was constant at 500 mg/L. As for effluent aeration 1, the COD reading for the first 3 points were higher than the influent. After some investigation, it was found out that the sample was not filtered before doing the COD test. When the sample was not filtered, the biomass contained in the sample will cause the COD reading to be high. Hence, correction has been made and the COD reading become reduce and lower than the influent. The COD reading of effluent aeration 1 gave an average of 300 mg/L after day 10. Similar to the effluent aeration 1, the effluent aeration 2 also has a higher COD reading for the first 3 points. After rectification done, the COD reading for effluent aeration 2 has dropped to a constant value of 100 mg/L COD. As for the final effluent, the COD reading showed range of value from 50-100 mg/L. This is considered a good result where the limit of Standard A is 120 mg/L. By comparing COD reading of the influent and effluent, there is also significant reduction occurred in the reactor. The COD level as high as 500 mg/L in the influent can be reduced to below

100 mg/L in the effluent. This indicates that the reactor has worked as planned. The COD level has dropped to 300 mg/L in the aeration 1 tank and it is dropped further down to 100 mg/L in the aeration 2 tank. Therefore, the COD level has reached to below 100 mg/L in the effluent.

4.9 TSS Results (Second Phase)

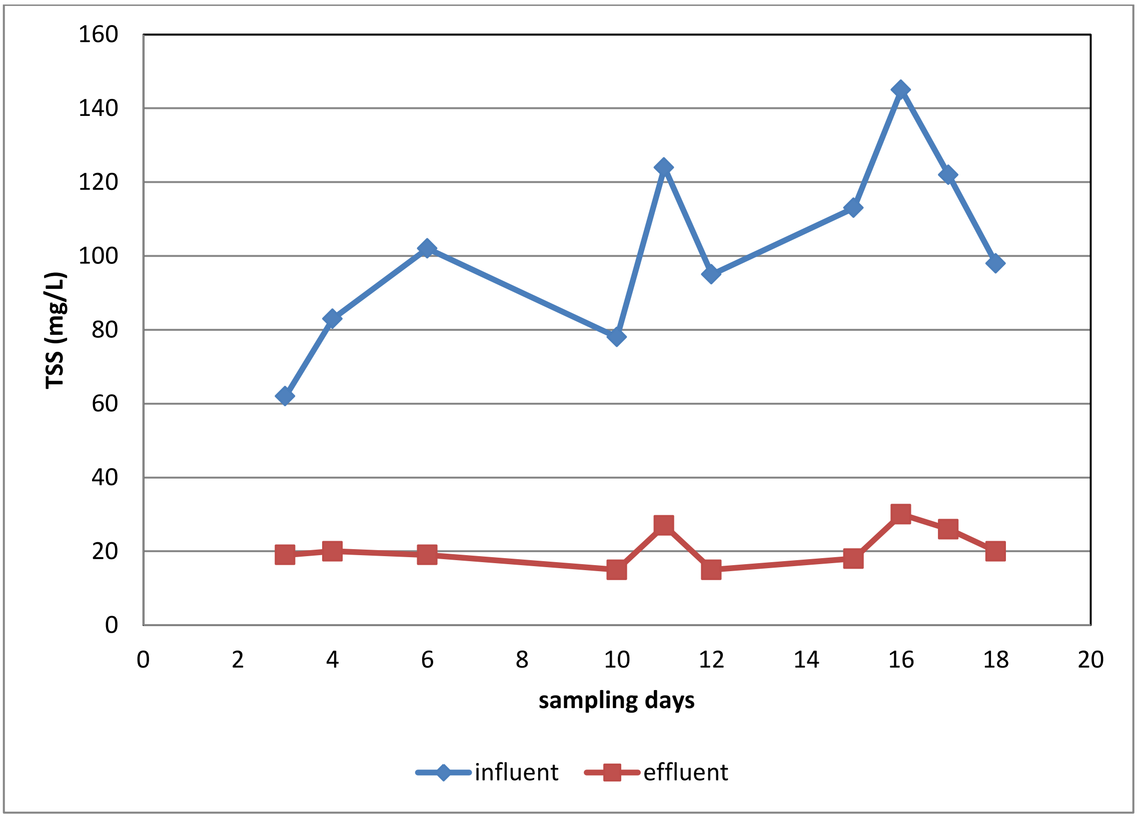


Figure 4.7: TSS (mg/L) vs sampling days

Based on the Figure 4.7 (TSS vs sampling days), the TSS reading for the influent was 60 mg/L on day 3. Then it was increased to 100 mg/L on day 6 and later it was increased to 125 mg/L. The influent has the highest TSS reading on day 16 which was 150 mg/L. Then it was decreased to 100 mg/L on day 18. As for the effluent, the TSS reading gave a range of 20-25 mg/L which is within the standard A limit of 50 mg/L.

4.10 MLSS Results (Second Phase)

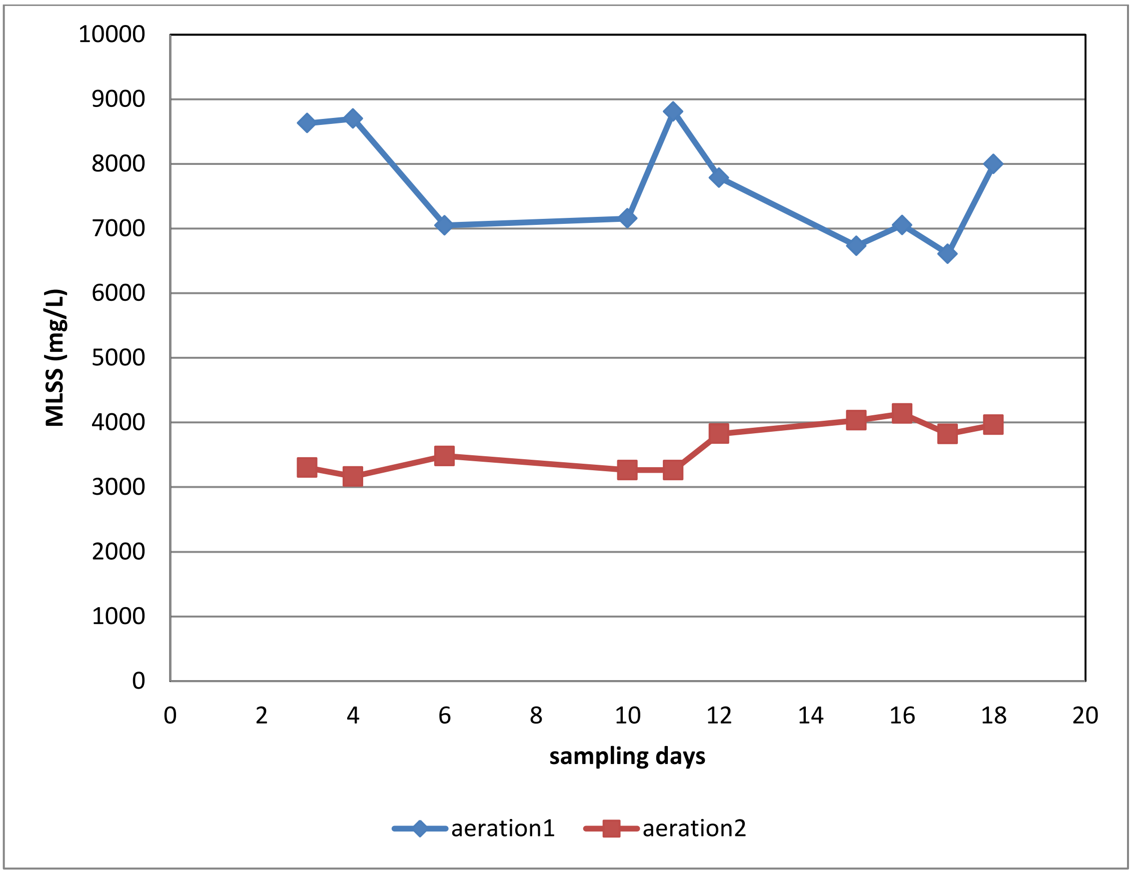


Figure 4.8: MLSS (mg/L) vs sampling days

Based on the Figure 4.8 (MLSS vs sampling day), the MLSS loading in the aeration 1 had a range of 7000-9000 mg/L throughout the sampling days. The MLSS reading was well above from the ideal value which is 6000 mg/L. This is the result of addition of sludge into the reactor and it was proved to be working properly. However, the MLSS reading for aeration 2 tank was slight below 6000 mg/L where it gave a range of 3000-4000 mg/L. Even after some rectifications have been done, it was hard to retain the biomass inside the aeration 2 tank because the biomass was blown out from the aeration 2 by the diffuser. Hence, by having 4000 mg/L of MLSS, it was sufficient for the aeration 2 tank to carry out aerobic treatment.

4.11 Summary of Results

Table 4.1: Reduction Percentage

Parameter	Unit	Influent (average)	Effluent (average)	Reduction %
BOD_5	mg/L	150	40	73
COD	mg/L	450	80	82
TSS	mg/L	100	20	80

The Table 4.1(Reduction Percentage) shows the reduction percentage for all parameters. As for the first the parameter which is BOD, the percent reduction from influent to effluent is 73%. For COD reduction is 82% and last the TSS reduction is 80%. All of parameters show a significant amount of reduction which ranging from 70-80%. Further improvement need to done in order to achieve a higher percent of reduction.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

As for the conclusion, the objective of this project is to evaluate the performance of the reactor has successfully been achieved where the first aspect of evaluation in BOD removal has a percentage of BOD reduction of 73%. The result is considered to be satisfactory. The second aspect of evaluation of the reactor is the COD removal where the percentage reduction of COD was 82%. This result and performance of the reactor is considered very good in term of COD removal. The last aspect is the TSS removal where the percentage reduction of TSS was 80%. This is also considered as a good result and performance shown by the reactor.

Another conclusion that can be found from this project is the concentration of biomass will greatly affect the performance of the reactor in term of BOD and COD removal. As the biomass become lower the removal of organic content by the reactor is also become poor. Therefore, it is essential to monitor the concentration of biomass within the reactor in order to has a better performance of the reactor.

As for the recommendations, as soon as the reactor has stabilize, there are various study can be conducted to monitor the performance of the reactor. The first aspect of study is the flow rate of the influent. The flow rate can be increased gradually until the point that the reactor will not work properly. From there the optimum flow rate for the reactor can be determined. The next aspect of study is the organic loading. The organic loading also can be increase gradually in order to see the limit of the reactor can take. The objective is also to find the optimum value of organic loading that can be supplied into the reactor. Other studies that can improve the reactor are also recommended.

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APPENDICES

First Phase

COD Result

	inf	eff2	eff3	eff4	eff5
22nd Oct 2012 (HR)	90.000	155.000	51.000	164.000	13.000
	56.000	172.000	38.000	174.000	8.000
	78.000	177.000	22.000	164.000	5.000
	74.667	**168.000**	**37.000**	**167.333**	**8.667**
25th Oct 2012 (LR) Dilution 10mL in 100mL	45.000	544.000	504.000	527.000	496.000
	72.000	535.000	482.000	547.000	494.000
	56.000	528.000	491.000	510.000	496.000
	57.667	**535.667**	**492.333**	**528.000**	**495.333**
1st Nov 2012 (LR) Dilution 10mL in 250 mL	67.000	21.000	40.000	58.000	2.000
	89.000	22.000	14.000	51.000	15.000
	68.000	46.000	8.000	40.000	9.000
	74.667	**29.667**	**20.667**	**49.667**	**8.500**
5th Nov 2012 (LR)	79.000	17.000	14.000	20.000	7.000
	76.000	13.000	9.000	8.000	19.000
	83.000	16.000	19.000	11.000	14.000
	79.333	**15.333**	**14.000**	**13.000**	**13.333**
6th Nov 2012 (LR)	74.000	4.000	23.000	16.000	17.000
	85.000	15.000	25.000	14.000	16.000
	68.000	16.000	23.000	20.000	21.000
	75.667	**11.667**	**23.667**	**16.667**	**18.000**
12-Nov	63.000	145.000	122.000	110.000	19.000
	69.000	149.000	143.000	104.000	45.000
	78.000	156.000	126.000	117.000	76.000
	70.000	**150.000**	**130.333**	**110.333**	**46.667**
15-Nov	76.000	134.000	132.000	103.000	73.000
	56.000	178.000	143.000	107.000	48.000
	72.000	165.000	144.000	128.000	41.000
	68.000	**159.000**	**139.667**	**112.667**	**54.000**
19-Nov	45.000	147.000	121.000	113.000	67.000
	72.000	138.000	125.000	118.000	63.000
	61.000	156.000	134.000	111.000	57.000
	59.333	**147.000**	**126.667**	**114.000**	**62.333**
21-Nov	72.000	193.000	134.000	127.000	45.000
	81.000	261.000	130.000	124.000	87.000
	77.000	184.000	133.000	104.000	39.000
	76.667	**212.667**	**132.333**	**118.333**	**57.000**

BOD result	inf			Effluent 2			Effluent 3			Effluent 4			eff5		
	Before	After	BOD5	Before	After	BOD5	Before	After	BOD5	Before	After	BOD5	Before	After	BOD5
22nd Oct 2012 (Blank = 8.86 - 8.93)	8.510	4.540	59.550	8.780	7.300	22.200	8.710	6.180	37.950	8.540	3.440	76.500	8.510	5.480	45.450
	8.530	4.550	59.700	8.720	6.930	26.850	8.640	5.510	46.950	8.540	3.530	75.150	8.530	5.290	48.600
	8.580	4.470	61.650	8.740	6.840	28.500	8.690	6.090	39.000	8.520	2.870	84.750	8.580	5.300	49.200
			60.300			**25.850**			**41.300**			**78.800**			**47.750**
25th Oct 2012 (Blank = 8.86 - 8.93)	8.440	5.480	44.400	8.190	1.650	98.100	8.410	4.480	58.950	8.320	2.120	93.000	8.440	4.540	58.500
	8.390	5.290	46.500	8.260	2.020	93.600	8.450	3.930	67.800	8.330	3.410	73.800	8.390	4.550	57.600
	8.360	5.300	45.900	8.210	1.460	101.250	8.370	3.720	69.750	8.390	2.700	85.350	8.360	4.470	58.350
			45.600			**97.650**			**65.500**			**84.050**			**58.150**
1st Nov 2012 (Blank = 8.86 - 8.93)	8.810	7.131	25.185	8.090	2.830	78.900	8.280	5.000	49.200	8.080	4.700	50.700	8.300	7.710	8.850
	8.800	7.367	21.495	8.060	1.610	96.750	8.260	5.160	46.500	8.190	1.970	93.300	8.330	7.850	7.200
	8.790	7.145	24.675	8.140	1.550	98.850	8.250	5.450	42.000	8.120	1.530	98.850	8.340	7.370	14.550
			23.785			**91.500**			**45.900**			**80.950**			**10.200**
5th Nov 2012 (Blank = 8.97 - 8.52)	8.300	4.540	56.400	8.930	1.678	108.780	8.960	5.100	57.900	8.990	3.560	81.450	8.980	7.131	27.735
	8.330	4.550	56.700	8.930	1.657	109.095	8.990	5.680	49.650	8.990	3.780	78.150	8.990	7.367	24.345
	8.340	4.470	58.050	8.950	1.564	110.790	9.030	5.890	47.100	8.990	2.450	98.100	8.980	7.145	27.525
			57.050			**109.555**			**51.550**			**85.900**			**26.535**
6th Nov 2012 (Blank = 8.97 - 8.52)	8.980	5.480	52.500	8.780	1.698	106.230	8.820	5.450	50.550	8.740	3.440	79.500	8.810	5.012	56.970
	8.990	5.290	55.500	8.790	1.569	108.315	8.880	6.780	31.500	8.760	3.530	78.450	8.800	5.940	42.900
	8.980	5.300	55.200	8.800	1.751	105.735	8.860	6.470	35.850	8.770	2.870	88.500	8.790	4.230	68.400
			54.400			**106.760**			**39.300**			**82.150**			**56.090**
12-Nov	8.280	6.710	23.550	8.080	1.650	96.450	8.410	5.556	42.810	8.930	3.140	86.850	8.930	6.740	32.850
	8.260	6.850	21.150	8.190	2.020	92.550	8.450	5.340	46.650	8.930	4.450	67.200	8.930	6.230	40.500
	8.250	7.370	13.200	8.120	1.460	99.900	8.370	5.210	47.400	8.950	4.780	62.550	8.950	6.790	32.400
			19.300			**96.300**			**45.620**			**72.200**			**35.250**
15-Nov	8.080	7.300	11.700	8.780	1.678	106.530	8.090	5.270	42.300	8.300	4.130	62.550	8.820	6.120	40.500
	8.190	6.930	18.900	8.720	1.657	105.945	8.060	5.340	40.800	8.330	3.740	68.850	8.880	6.970	28.650

	8.120	6.840	19.200	8.740	1.564	107.640	8.140	6.470	25.050	8.340	3.560	71.700	8.860	6.15	40.650
			16.600			**106.705**			**36.050**			**67.700**			**36.600**
19-Nov	8.71	5.480	48.450	8.630	1.475	107.325	8.910	5.970	44.100	8.700	4.689	60.165	8.580	5.58	45.000
	8.78	5.290	52.350	8.730	1.487	108.645	9.040	5.360	55.200	8.800	4.630	62.550	8.620	5.9	40.800
	8.82	5.300	52.800	8.780	1.498	109.230	9.100	5.120	59.700	8.870	4.680	62.850	8.670	5.36	49.650
			51.200			**108.400**			**53.000**			**61.855**			**45.150**
21-Nov	8.59	4.540	60.750	8.610	1.355	108.825	8.600	5.250	50.250	8.650	4.980	55.050	8.670	4.19	67.200
	8.6	4.550	60.750	8.520	1.346	107.610	8.610	5.160	51.750	8.650	5.170	52.200	8.650	4.32	64.950
	8.61	4.470	62.100	8.580	1.368	108.180	8.630	4.950	55.200	8.660	5.450	48.150	8.680	4.69	59.850
			61.200			**108.205**			**52.400**			**51.800**			**64.000**

TSS/MLSS Result

	inf			Effluent 2			Effluent 4			Effluent 5		
	Initial	After	TSS	Initial	After	MLSS	Initial	After	MLSS	Initial	After	TSS
1st Nov 2012	1.3328	1.3345	34.0000	1.0860	1.1655	1590.0000	1.3368	1.4094	1452.0000	1.0964	1.0978	28.0000
	1.0786	1.0789	6.0000	1.2923	1.3370	894.0000	1.0846	1.1619	1546.0000	1.2808	1.2811	6.0000
	1.2695	1.2732	74.0000	1.3065	1.3537	944.0000	1.0843	1.1686	1686.0000	1.2987	1.2996	18.0000
			38.0000			**1142.6667**			**1561.3333**			**17.3333**
5th Nov 2012	1.3276	1.3289	26.0000	1.0810	1.1144	668.0000	1.0852	1.1063	422.0000	1.3269	1.3293	48.0000
	1.0967	1.1013	92.0000	1.3433	1.3807	748.0000	1.1006	1.1188	364.0000	1.0997	1.1013	32.0000
	1.0795	1.0828	66.0000	1.3394	1.3791	794.0000	1.0834	1.1049	430.0000	1.0795	1.0828	66.0000
			61.3333			**736.6667**			**405.3333**			**48.6667**
6th Nov 2012	1.0837	1.0899	124.0000	1.0906	1.1092	372.0000	1.2882	1.3001	238.0000	1.3328	1.3336	16.0000
	1.3419	1.3456	74.0000	1.0782	1.0962	360.0000	1.0859	1.0958	198.0000	1.0786	1.0789	6.0000
	1.0772	1.0794	44.0000	1.1031	1.1198	334.0000	1.0836	1.0909	146.0000	1.2695	1.2702	14.0000
			80.6667			**355.3333**			**194.0000**			**12.0000**
12-Nov	1.0964	1.0979	30.0000	1.3095	1.3565	940.0000	1.0886	1.0942	112.0000	1.3328	1.3330	4.0000

	1.2808	1.2846	76.0000	1.0803	1.1258	910.0000	1.0852	1.0935	166.0000	1.0786	1.0788	4.0000
	1.2987	1.2998	22.0000	1.3368	1.3694	652.0000	1.3288	1.3314	52.0000	1.2695	1.2714	38.0000
			42.6667			**834.0000**			**110.0000**			**15.3333**
15-Nov	1.2601	1.2665	128.0000	1.3368	1.4094	1452.0000	1.0906	1.1101	390.0000	1.3269	1.3297	56.0000
	1.0831	1.0849	36.0000	1.0846	1.1667	1642.0000	1.0782	1.0977	390.0000	1.0997	1.1088	182.0000
	1.1007	1.1038	62.0000	1.0843	1.1696	1706.0000	1.1031	1.1213	364.0000	1.0795	1.0865	140.0000
			75.3333			**1600.0000**			**381.3333**			**126.0000**
19-Nov	1.3269	1.3299	60.0000	1.0810	1.1189	758.0000	1.2882	1.3024	284.0000	1.3328	1.3376	96.0000
	1.0997	1.1026	58.0000	1.3433	1.3826	786.0000	1.0859	1.0978	238.0000	1.0786	1.0798	24.0000
	1.0795	1.0876	162.0000	1.3394	1.3791	794.0000	1.0836	1.0915	158.0000	1.2695	1.2773	156.0000
			93.3333			**779.3333**			**226.6667**			**92.0000**
21-Nov	1.2601	1.2681	160.0000	1.3095	1.3533	876.0000	1.0886	1.0899	26.0000	1.0837	1.0843	12.0000
	1.0831	1.0877	92.0000	1.0803	1.1239	872.0000	1.0852	1.0901	98.0000	1.3419	1.3421	4.0000
	1.1007	1.1069	124.0000	1.3368	1.3673	610.0000	1.3288	1.3292	8.0000	1.0772	1.0787	30.0000
			125.3333			**786.0000**			**44.0000**			**15.3333**

Second Phase

COD

	inf	eff aeration1	eff anoxic	eff aeration2	eff
3-Dec	403	415	142	144	61
	413	471	146	156	63
	401	432	152	148	61
	405.6667	**439.3333333**	**146.66667**	**149.3333333**	**61.66667**
4-Dec	327	346	295	259	78
	316	375	281	254	74
	338	359	288	261	75
	327	**360**	**288**	**258**	**75.66667**
6-Dec	523	576	191	190	60
	514	583	197	185	53
	519	577	182	189	57
	518.6667	**578.6666667**	**190**	**188**	**56.66667**
10-Dec	439	533	195	174	60
	437	548	184	178	61
	426	521	198	175	61
	434	**534**	**192.33333**	**175.6666667**	**60.66667**
11-Dec	568	589	243	216	81
	576	586	244	219	84
	567	586	248	222	83
	570.3333	**587**	**245**	**219**	**82.66667**
12-Dec	491	513	267	245	68
	488	511	278	249	64
	497	523	266	245	61
	492	**515.6666667**	**270.33333**	**246.3333333**	**64.33333**
15-Dec	514	298	277	107	89

	519	291	274	102	90
	516	289	269	112	89
	516.3333	**292.6666667**	**273.33333**	**107**	**89.33333**
16-Dec	535	319	310	99	71
	541	323	318	105	74
	529	327	322	119	69
	535	**323**	**316.66667**	**107.6666667**	**71.33333**
17-Dec	489	267	264	121	75
	493	278	261	125	79
	381	264	266	124	71
	454.3333	**269.6666667**	**263.66667**	**123.3333333**	**75**
18-Dec	566	336	321	94	89
	569	345	346	92	90
	562	341	333	91	94
	565.6667	**340.6666667**	**333.33333**	**92.33333333**	**91**

BOD			influent			eff aeration1			eff anoxic			eff aeration2			effluent
	before	after		before	after		before	after		before	after		before	after	
3-Dec	8.510	-0.49	135	8.780	2.34	96.6	8.710	3.31	81	8.540	5.720	42.3	8.510	6.030	37.2
blank	8.530	-0.51	135.6	8.720	2.57	92.25	8.640	3.15	82.35	8.540	5.83	40.65	8.530	6.16	35.55
8.93-8.84	8.580	-0.54	136.8	8.740	2.81	88.95	8.690	2.94	86.25	8.520	5.46	45.9	8.580	6.45	31.95
			135.8			**92.6**			**83.2**			**42.95**			**34.9**
4-Dec	8.440	0.41	120.45	8.190	3.42	71.55	8.410	3.56	72.75	8.320	4.91	51.15	8.440	5.49	44.25
blank	8.390	0.63	116.4	8.260	2.84	81.3	8.450	3.78	70.05	8.330	5.01	49.8	8.390	5.54	42.75
8.93-8.84	8.360	0.75	114.15	8.210	3.58	69.45	8.370	3.63	71.1	8.390	4.87	52.8	8.360	5.38	44.7
			117			**74.1**			**71.3**			**51.25**			**43.9**
6-Dec	8.810	-2.84	174.75	8.090	1.23	102.9	8.280	1.91	95.55	8.080	4.46	54.3	8.300	5.54	41.4
blank	8.800	-2.96	176.4	8.060	1.12	104.1	8.260	2.05	93.15	8.190	4.68	52.65	8.330	5.34	44.85

8.93-8.84	8.790	-2.54	169.95	8.140	1.19	104.25	8.250	1.99	93.9	8.120	4.55	53.55	8.340	5.47	43.05
			173.7			**103.75**			**94.2**			**53.5**			**43.1**
11-Dec	8.300	-2.21	157.65	8.930	1.35	113.7	8.960	3.8	77.4	8.990	5.94	45.75	8.980	6.09	43.35
blank	8.330	-2.19	157.8	8.930	1.67	108.9	8.990	2.91	91.2	8.990	6.04	44.25	8.990	6.23	41.4
8.97-8.89	8.340	-2.45	161.85	8.950	1.46	112.35	9.030	2.56	97.05	8.990	6.13	42.9	8.980	6.12	42.9
			159.1			**111.65**			**88.55**			**44.3**			**42.55**
12-Dec	8.280	-2.71	164.85	8.080	-0.36	126.6	8.410	0.43	119.7	8.930	4.44	67.35	8.930	4.64	64.35
blank	8.260	-2.86	166.8	8.190	-0.46	129.75	8.450	0.57	118.2	8.930	4.36	68.55	8.930	4.77	62.4
8.97-8.89	8.250	-2.54	161.85	8.120	-0.29	126.15	8.370	0.78	113.85	8.950	4.56	65.85	8.950	4.85	61.5
			164.5			**127.5**			**117.25**			**67.25**			**62.75**
13-Dec	8.080	-1.51	143.85	8.780	3.18	84	8.090	2.89	78	8.300	4.34	59.4	8.820	5.13	55.35
blank	8.190	-1.67	147.9	8.720	3.21	82.65	8.060	2.56	82.5	8.330	4.22	61.65	8.880	5.32	53.4
8.97-8.89	8.120	-1.74	147.9	8.740	2.12	99.3	8.140	2.54	84	8.340	4.39	59.25	8.860	5.26	54
			146.55			**88.65**			**81.5**			**60.1**			**54.25**

TSS			influent			effluent
	initial	final		initial	final	
3-Dec	1.3328	1.336	64	1.0860	1.0868	16
	1.0786	1.0825	78	1.2923	1.2925	4
	1.2695	1.2717	44	1.3065	1.3075	20
			62			**13**
4-Dec	1.3368	1.3415	94	1.0964	1.0977	26
	1.0846	1.0896	100	1.2808	1.2817	18
	1.0843	1.0871	56	1.2987	1.2994	14
			83			**19**
6-Dec	1.3276	1.334	128	1.0810	1.0816	12
	1.0967	1.1019	104	1.3433	1.3443	20
	1.0795	1.08385	87	1.3394	1.3407	26

			106			**19**
10-Dec	1.0852	1.0892	80	1.3269	1.3276	14
	1.1006	1.1051	90	1.0997	1.1002	10
	1.0834	1.0867	66	1.0795	1.0804	18
			79			**14**
11-Dec	1.0837	1.0901	128	1.0906	1.0919	26
	1.3419	1.3484	130	1.0782	1.0792	20
	1.0772	1.0829	114	1.1031	1.1048	34
			124			**27**
12-Dec	1.2882	1.2929	94	1.3328	1.3334	12
	1.0859	1.0908	98	1.0786	1.0791	10
	1.0836	1.0882	92	1.2695	1.2705	20
			95			**14**
15-Dec	1.0964	1.1022	116	1.0979	1.0988	18
	1.2808	1.2864	112	1.2846	1.2856	20
	1.2987	1.3042	110	1.2998	1.3001	6
			113			**15**
16-Dec	1.3095	1.3168	146	1.3565	1.3581	32
	1.0803	1.0875	144	1.1258	1.1275	34
	1.3368	1.3437	138	1.3694	1.3711	34
			143			**33**
17-Dec	1.0886	1.0947	122	1.0942	1.0952	20
	1.0852	1.0915	126	1.0935	1.0949	28
	1.3288	1.3352	128	1.3314	1.3327	26
			125			**25**
18-Dec	1.3328	1.3377	98	1.3330	1.3338	16
	1.0786	1.0831	90	1.0788	1.0797	18
	1.2695	1.2739	88	1.2714	1.2726	24
			92			**19**

MLSS			aeration1			aeration2
	initial	final		initial	final	
3-Dec	1.0964	1.5284	8640	1.0977	1.2901	3848
	1.2808	1.7125	8634	1.2817	1.4736	3838
	1.2987	1.7292	8610	1.2994	1.4101	2214
			8628			**3300**
4-Dec	1.0810	1.4737	7854	1.0816	1.3024	4416
	1.3433	1.8535	10204	1.3443	1.4461	2036
	1.3394	1.7411	8034	1.3407	1.4928	3042
			8697			**3165**
6-Dec	1.3269	1.6719	6900	1.3276	1.5161	3770
	1.0997	1.4968	7942	1.1002	1.2443	2882
	1.0795	1.3946	6302	1.0804	1.2701	3794
			7048			**3482**
10-Dec	1.0906	1.4574	7336	1.0919	1.2689	3540
	1.0782	1.4647	7730	1.0792	1.2224	2864
	1.1031	1.4227	6392	1.1048	1.2741	3386
			7153			**3263**
11-Dec	1.3328	1.7537	8418	1.3334	1.5078	3488
	1.0786	1.5252	8932	1.0791	1.2487	3392
	1.2695	1.7231	9072	1.2705	1.4161	2912
			8807			**3264**
12-Dec	1.0979	1.4272	6586	1.0988	1.3289	4602
	1.2846	1.7311	8930	1.2856	1.4816	3920
	1.2998	1.6917	7838	1.3001	1.4477	2952
			7785			**3825**
15-Dec	1.3565	1.6931	6732	1.3581	1.5597	4032

	1.1258	1.4662	6808	1.1275	1.3336	4122
	1.3694	1.7075	6762	1.3711	1.5771	4120
			6767			**4091**
16-Dec	1.0942	1.4468	7052	1.0952	1.3021	4138
	1.0935	1.4507	7144	1.0949	1.3086	4274
	1.3314	1.6912	7196	1.3327	1.5424	4194
			7131			**4202**
17-Dec	1.3330	1.6627	6594	1.3338	1.5265	3854
	1.0788	1.4135	6694	1.0797	1.2694	3794
	1.2714	1.5981	6534	1.2726	1.4636	3820
			6607			**3823**
18-Dec	1.0964	1.4982	8036	1.1022	1.2975	3906
	1.2808	1.675	7884	1.2864	1.4842	3956
	1.2987	1.7021	8068	1.3042	1.5057	4030
			7996			**3964**