“Enhancement of Nitrogen Removal in the Compact Extended Aeration Reactor (CEAR) by using Attached Growth System”

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CERTIFICATION OF APPROVAL

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Siti Nazira Binti Mohd Som

A project dissertation submitted to the:

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In partial fulfilment of the requirement for the:

Bachelor of Engineering (Hons.)

Civil Engineering

Approved by,

____

(Associate Professor Dr Shamsul Rahman Mohamed Kutty)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2013

CERTIFICATION OF ORIGINALITY

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

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(Siti Nazira Binti Mohd Som)

ABSTRACT

As the Nitrogen limit in water body becomes more stringent, the treatment system also needs to be upgraded. Plus, due to human population that kept increasing by days, the area for the system was limited. Adopting the CEAR (Compacted Extended Aeration System) as the system to be used, this system will be modified to increase the efficiency in removing Nitrogen. CEAR is an integrated reactor that use activated sludge system for the wastewater treatment, where it consist of aeration, anoxic and clarifier compartments. Previously it has been tested and produced significant effluent of Ammonia and Nitrate of 0.5 mg/L and 0.3 mg/L respectively (Sani F. A., 2012). The modification done in this project was the insertion of attached growth media in both aeration and anoxic compartments after the role of the compartments in the reactor had been changed. The Aero-packer was installed in the aeration compartment, while the Bio-balls were inserted into the anoxic compartment. Experimental works were done to justify the effects of the installation of the attached growth media in the CEAR. For that, the wastewaters from the aeration tank of UTP STP together with the formulated synthetic wastewater were used as experimental materials. The reactor was operated in two phases, first for 35 days with 10 L/d and 15 L/d of influent flowrate to monitor the performance of CEAR without the attached growth media. Continuing that, the reactor was run for another 18 days with the attached growth media by using 15 L/d flowrate in the second phase. From the experiment done, the average final effluent during the first phase gave an average effluent 17.4 mg/L of Ammonia concentration and 0.4 mg/L Nitrate concentration. These provide an overall percentage removal of 34.3% and 80.9% for Ammonia and Nitrate respectively. During the second phase, the average final effluent gave 18.6 mg/L and 1.1 mg/L of Ammonia and Nitrate concentration respectively. These provide 24.8% and 47.6% of overall removal rate respectively. Therefore, the objective of the attached growth media to enhance the Nitrogen removal was not achieved because the percentage of removal is higher in the first phase. However, the conclusion was made irrespective to the control towards alkalinity and Carbon source since they cannot be determined due to technical problems. Thus, the recommendation proposed was to make further study on how to accurately add the additional alkalinity and Carbon source so that the performance of the CEAR can be optimized.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nitrogen content in the surface waters can be both beneficial and harmful. This is because, for most aquatic plants, Nitrogen act as one of their nutrients requirement, but for aquatic animals the excessive contents of Nitrogen can cause Oxygen depletion to their living system. Apart from that, other effects of Nitrogen pollution will include underground water pollution, blue-baby syndrome in infants and the emission of gasses contributing to the greenhouse effect (Takaya, Catalan-Sakairi, Sakaguchi, Kato, Zhou, & Shoun, 2003).

As a result, regulations were designed and implemented in order to control the negative impact of Nitrogen contents to the environment. One of them would be the provision of discharged standard for sewerage provided by the Malaysian Department of Environmental in **Figure 3**. Accordingly, there are many types of Nitrogen form that should be control by which the principal Nitrogen types of concern to wastewater treatment are total Nitrogen, Total Kjehdal Nitrogen (TKN), Ammonia (NH_3), Organic Nitrogen, Nitrate (NO_3) and Nitrite (NO_2). The contents of these Nitrogen forms shall be controlled either through biological or chemical treatment.

Biological treatment is more favourable compared to chemical treatment because it is more economical and safe. However, the conventional biological treatment done in the wastewater treatment plant (WTP) usually required huge land area depending on the number of population. This requirement somehow is not practical since the population of the world kept increasing by days. Thus, provision of an integrated biological treatment plant is deemed necessary in order to solve the problem. The practice use in this research paper is the Compact Extended Aeration Reactor (CEAR) by which the aeration tank, anoxic tank and primary clarifier were combined as a single system.

Previously, the CEAR had been tested with a 40 days of SRT and produced effluent discharge of Ammonia-Nitrogen and Nitrate as 0.5 mg/L and 0.3 mg/L respectively (Sani F. A., 2012). The practice use before this was enhancing on the extended aeration by using suspended growth system and leave behind the potential of attached growth system in enhancing the Nitrogen removal. Thus, the opportunity is used by providing more area of treatment in the tank. The area shall be used for bacteria growth, with the objective to promote more treatment area. For that, the Aero-packer was installed into the aeration compartment while the Bio-balls were inserted into the anoxic compartment. Early hypothesis was made that these attached growth media can enhance the Nitrogen removal in the CEAR tank. Therefore, the focus of this paper is to enhance the Nitrogen removal rate through the installation of the attached growth media in aeration and anoxic compartments of CEAR. Experimental works were done to justify the stated hypothesis.

1.2 Problem Statement

The conventional WTP usually requires a big land area depending on the population of the residence using the system. This is not a practical approach since the land area had been limited by the increase in population growth. Therefore, an innovation to provide CEAR to reduce the area for the treatment facilities was indeed a great approach to solve the problem. The application of CEAR in removing the Nitrogen content had been demonstrated previously and produced a significant result. However, enhancement still can be done through providing more area in the tank itself. The approach is to provide attachment area through the insertion of the Aero-packer in the aeration compartment and Bio-balls in the anoxic compartment by which the main processes to remove Nitrogen happen here; nitrification and denitrification. The attached growth media should somehow increase the area of attachment for the bacteria to grow and helps in boosting the rate of nitrification and denitrification. Eventually, the effects of the installation will be justified through the experimental work and estimated to give a better effluent quality compared to the original CEAR.

1.3 Objectives

To demonstrate the impact of the attached growth media installation, a special Aero-packer was designed to fit the aeration compartment and specific size of Bio-ball

was chosen to be inserted in the anoxic tank of the CEAR. Thus, the objectives of the research are outlined as follows:

1. To evaluate the performance of CEAR in removing Nitrogen without the attached growth system.
2. To evaluate the performance of CEAR in removing Nitrogen with the attached growth system.
3. To compare the performance of both cases above.

1.4 Scope of Study

The scope of study will be focusing on the:

1. Phase 1 : Experimental work to study the Nitrogen removal rate without the installation of attached growth media in the CEAR
2. Phase 2: Experimental work to study the Nitrogen removal rate with the installation of attached growth media in the CEAR

1.5 Relevancy of the project

The project is the integration of the theory learned in the class and the practical application in real life. Thus, it provide a good platform for the student to understand more about the theory and in the same time might spark some ideas to improve the current practical application. Apart from that, there has been extensive study done to the same area of this project. Therefore, student can make a comparative study to the proposed project carried out so that if it is proven to provide better practical application it can benefit the society. Besides, due to the rapid growth in population where large facilities is needed to treat the wastewater, this finding might give a solution in minimizing the area for the treatment site.

1.6 Feasibility of Project within Time Frame

This project will be carried out in two (2) semesters of study, from January to September 2013. In the first semester, the scope of study will be mainly on the testing for the materials involved for the experimental job. Besides, numerous studies will also be done to make sure that the experiment will be carried out in most optimum way. To the completion of this project, the experimental work for both the objectives had been carried out and produced significant results even it does not achieve some of the objectives. The objective that was not achieved was to prove that the system with attached growth media provide better effluent. However, there are still extensive works

need to be done because the scope of work is actually cover bigger area. Thus, the conclusion was made based on the early assumption that the system will work well without the extra control towards the external factors; alkalinity and Carbon source. Even so, the objective to evaluate the performance for both CEAR with and without the attached growth media had been achieved. Therefore, the time frame is just nice to fit the range of time needed to obtain the desirable results. Apart from that, the scope of study had been narrowed down to only Nitrogen removal instead of nutrients removal. Thus, the project is feasible to be carried out as a final year project whereby for nutrients removal, a lot more jobs need to be done and a lot more time will be needed.

CHAPTER 2

LITERATURE REVIEW

2.1 Concept of Extended Aeration System

The system is adopting the role of microorganism or bacteria to carry out the natural biological treatment by which the role of these bacteria usually referred as activated-sludge process. "The activated-sludge process was so named because it involved the production of an activated mass of microorganisms capable of stabilizing a waste under aerobic conditions" (Metcalf & Eddy, 2004, p.76). As it suggest from the name given, aeration is important parameters to promote the process where sufficient Oxygen gas need to be supplied to the system. Plus, the extended aeration process happen when the activated sludge operates at a sufficiently long sludge age and low food to microorganism (F/M) ratio. Also, the activated sludge is kept in the system for a long period of time (long sludge retention time, SRT) with sufficient Oxygen gas supplied. **Table 1** shows the design parameters for major activated sludge process.

Table 1: Design Parameters for Major Activated Sludge Process.

(Wang, Pereira, & Hung, 2009)

Process modification	Parameter					
	F/M ratio, kg BOD/kg MLVSS/d	Volumetric loading			Sludge retention time, d	Hydraulic retention time, h
		lb BOD/10^3 ft^3/d	kg BOD/m^3/d	MLSS mg/L		
Conventional	0.2-0.4	20-40	0.32-0.64	1500-3000	5-15	4-8
Step aeration	0.2-0.4	50-60	0.64-0.96	2000-3500	5-15	3-5
Complete mix	0.2-0.6	50-120	0.80-1.90	3000-6000	5-15	3-5
Extended aeration	0.05-0.15	10-25	0.16-0.40	3000-6000	20-30	18-36
Contact stabilization	0.2-0.6	60-75	0.96-1.20	1000-3000	5-15	0.5-1.0
Kraus process	0.3-0.8	40-100	0.64-1.60	2000-3000	5-15	4-8
Pure Oxygen system	0.25-1.0	100-250	1.60-4.0	6000-8000	8-20	1-3

With this system, the excess sludge production can be greatly reduced as a result from the lower observed biomass yield which depends by SRT (Foladori, Andreottola, & Ziglio, 2010). This lower biomass yield is a product from the overall process involved in the extended aeration system, which are oxidation, synthesis and endogenous respiration. A conventional system of extended aeration usually involved the combination of distinguishes aeration tank and clarifier. In aeration tank, extensive Oxygen gas is supplied to allow aerobic process. By maintaining the good environment, this aerobic process will help to boost the growth of bacteria that will eventually help in treating the wastewater (Lenntech, 2013). While the growth of bacteria had been promoted, their function is to degrade the substrate before the bacteria itself create flocks and gases and finally being removed to the clarifier. Allowing some periods for settling, the activated sludge from the clarifier will be recycle back to aeration tank to increase the rate of treatment by increasing the total number of bacteria. **Figure 1** shows the schematic diagram of the extended aeration by activated sludge.

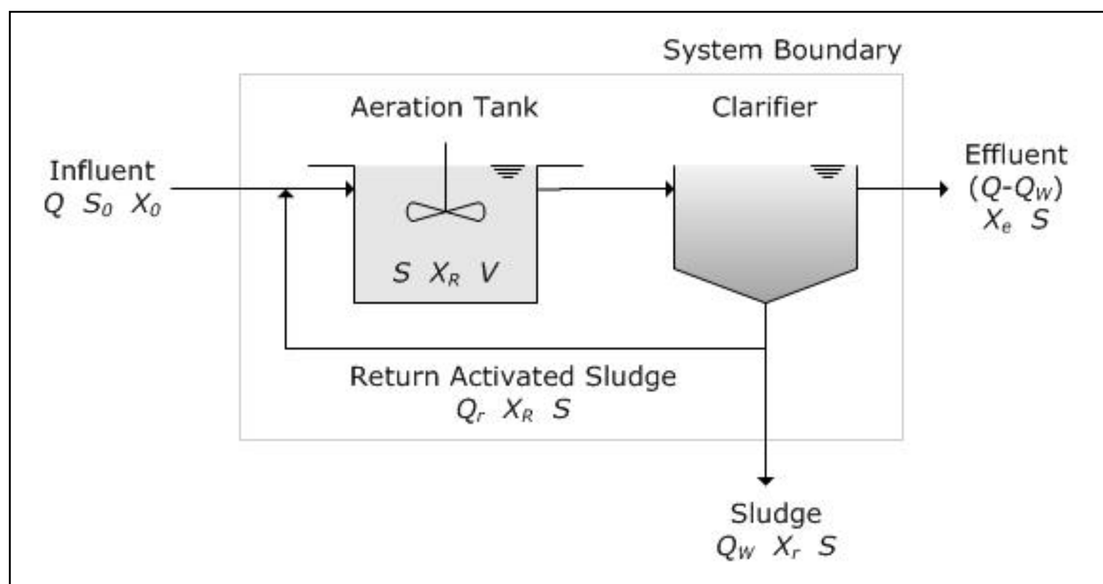


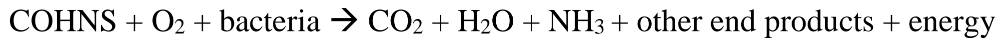
Figure 1: Activated Sludge Process Schematic Diagram
(Lenntech, 2013)

The operational system of this extended aeration process usually can be classified based on three sub- process namely oxidation, synthesis and endogenous respiration.

Equation 1 to 3 shows the balance equation of the stated process adopted from Metcalf and Eddy, 2004:

Oxidation:

Equation 1:



$$COHNS + O_2 + bacteria \rightarrow CO_2 + H_2O + NH_3 + other\ end\ products + energy$$

Synthesis:

Equation 2:

$$COHNS + O_2 + bacteria + energy \rightarrow C_5H_7NO_2$$

Endogenous respiration:

Equation 3:

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

From the equations, COHNS is taken as the general building block of the substrate in the wastewater. The oxidation, synthesis and endogenous process had reduced them into various final products which mainly consist of gases. As such, for oxidation and endogenous respiration process the end products are Carbon Dioxide gas (CO_2), water molecules (H_2O) and Ammonia (NH_3). These products usually are desirable compared to the product from synthesis process as they can be released into the atmosphere or collected to be used in other beneficial process. Except for Ammonia, it should be treated further as Ammonia can cause detrimental to public health and environment. Nevertheless, the extended aeration usually operates in the endogenous phase of microbial growth (Karia & Christian, 2006).

2.2 Compact Extended Aeration Reactor (CEAR)

Conventional extended aeration system usually comprise of different compartment of tank as illustrated in **Figure 1** previously. This had somehow requires a big area for the plant to be build. In order to cater the problem, a Compact Extended Aeration Reactor (CEAR) was designed to meet the demand. CEAR consist of all basic tanks needed in extended aeration system, except that it is a system which operates as integrated single sludge system. All the tanks were combined as a compacted system as illustrated in **Figure 2.**

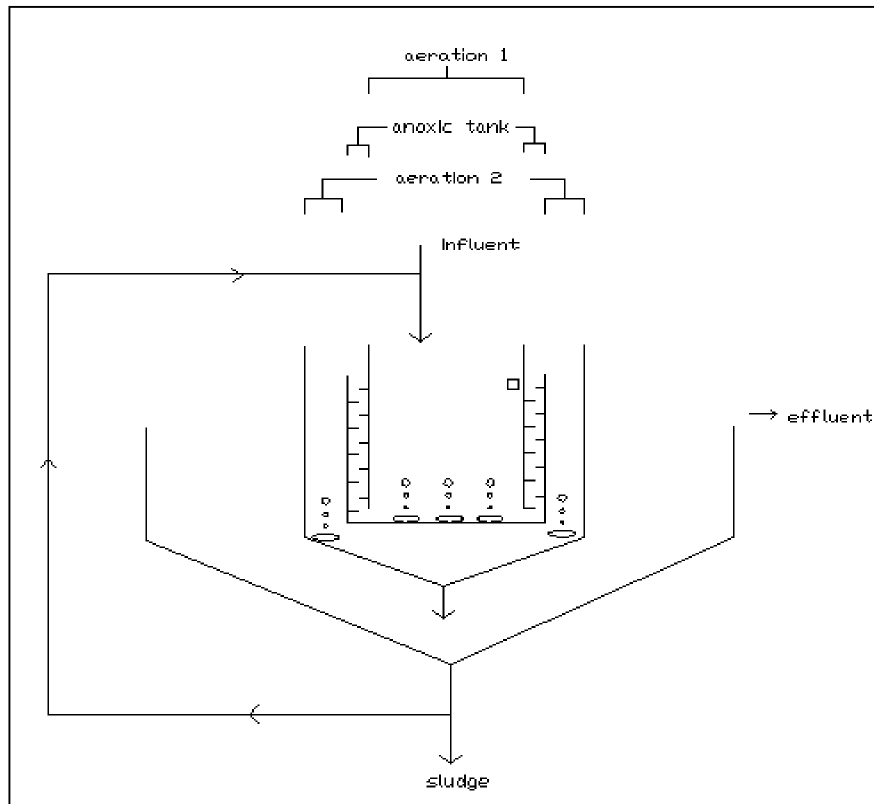


Figure 2: Conceptual drawing of CEAR
(Sani F. A., 2012)

From the conceptual diagram, it can be seen that the in fluent wastewater will be transferred first to the aeration compartment, next to anoxic compartment, then to the second aeration compartment and lastly to clarifier. Besides, at several times, the thickened sludge from the clarifier will be recycled back to aeration and anoxic compartment or wasted from the system in order to balance the biomass content. The system had been tested previously with a 40 days of SRT and produced effluent discharge of Ammonia-Nitrogen and Nitrate as 0.5 mg/L and 0.3 mg/L respectively (Sani F. A., 2012).

Thus, it can be said the system had successfully operated as it achieved the desired objectives to increase the quality of the effluent. The quality of the effluent can be measured according to the standard discharged limit setup the authorities. **Figure 3** shows the Acceptable Conditions of Sewage Discharge of Standards A and B extracted from Environmental Quality (Sewage) Regulations 2009.

	Parameter	Unit	Standard	
			A	B
	(1)	(2)	(3)	(4)
(a)	Temperature	°C	40	40
(b)	pH Value	-	6.0-9.0	5.5-9.0
(c)	BOD5 at 20°C	mg/L	20	50
(d)	COD	mg/L	120	200
(e)	Suspended Solids	mg/L	50	100
(f)	Oil and Grease	mg/L	5.0	10.0
(g)	Ammonical Nitrogen (enclosed water body)	mg/L	5.0	5.0
(h)	Ammonical Nitrogen (river)	mg/L	10.0	20.0
(i)	Nitrate – Nitrogen (river)	mg/L	20.0	50.0
(j)	Nitrate – Nitrogen (enclosed water body)	mg/L	10.0	10.0
(k)	Phosphorous (enclosed water body)	mg/L	5.0	10.0

Figure 3: Sewage Discharge of Standards A and B
(Environmental Quality Sewage Regulation, 2009)

Adopting the same reactor, slight changes to the role of each compartment in the tank were done. However, it still espousing the concept of Compact Extended Aeration System, where all tanks was combined together. **Figure 4** shows the schematic drawing of the CEAR, while **Figure 5** shows the conceptual drawing of the CEAR used in this research. This time around, the influent wastewater will first flow into the aeration compartment, then to the anoxic compartment, and lastly to the clarifier. In addition, the thickened sludge in the clarifier will be recycle back to the aeration and anoxic compartment at certain times allocated or wasted from the system.

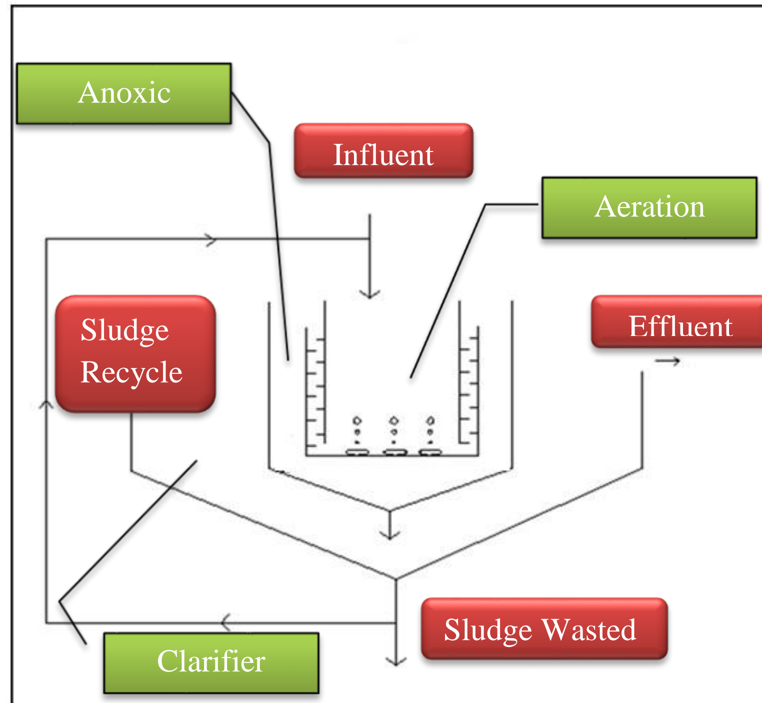


Figure 4: Schematic drawing for the CEAR adopted in this research

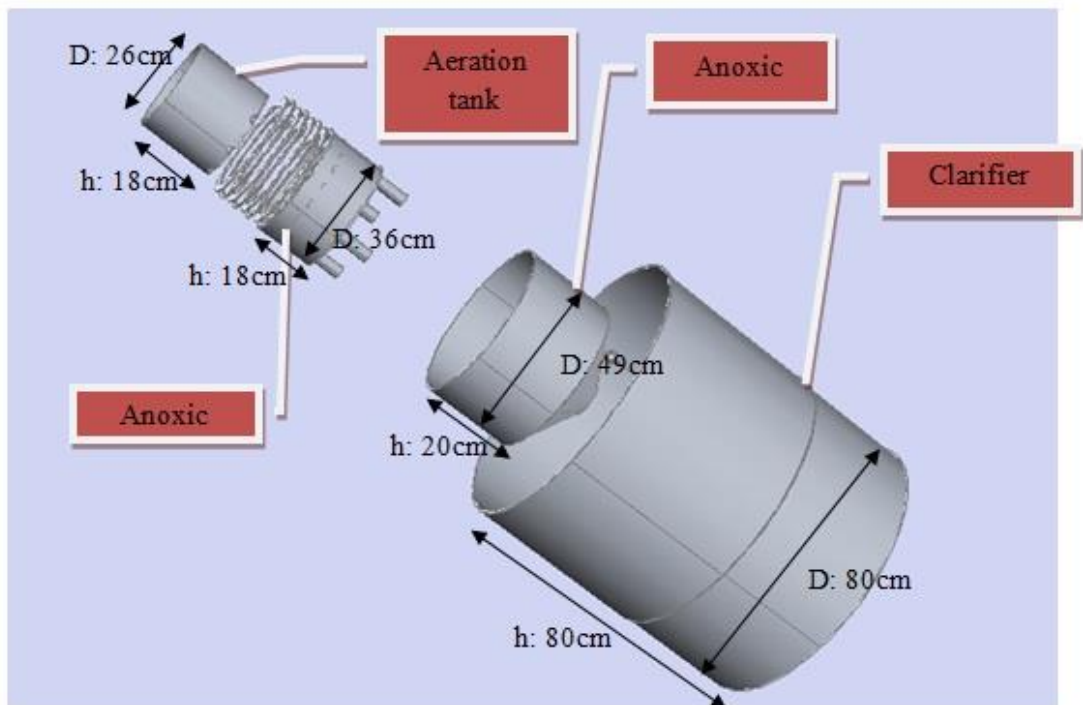


Figure 5: Conceptual drawing of the CEAR adopted in this research

2.3 Nitrogen Removal in CEAR

The presence of Nitrogenous or Nitrogen-containing wastes in the final effluent of an activated sludge process can adversely impact or pollute the quality of receiving water (Gerardi, 2003). The impact can cause detrimental to public health and environment (Babu, 2011) such as underground water pollution, blue-baby syndrome in infants and the emission of gasses contributing to the greenhouse effect (Takaya, Catalan-Sakairi, Sakaguchi, Kato, Zhou, & Shoun, 2003).

Thus, the biological treatment through the use of extended aeration system can be adopted to control this Nitrogen content. The aim of the treatment is to achieve effluent Nitrogen reading not more than the limit. Accordingly, the focus is the process that happens in the anoxic tank since the final process of Nitrogen removal takes place here. Two main processes are highlighted for the Nitrogen removal in the CEAR, which is nitrification and denitrification by which most of the denitrification happen in the anoxic tank, which is followed from the nitrification in the aeration tank. The final product of the treatment is to produce Nitrogen gas because the most stable form of Nitrogen is Nitrogen gas (N_2) and it is needed in the atmosphere (Kedlec & Wallace, 2008).

2.3.1 Nitrification

Nitrification is the two-step biological oxidation of Ammonia and ammonium ions which is performed by aerobic autotrophic bacteria frequently called nitrifiers. Aerobic autotrophic bacteria is classified as the bacteria that accept Carbon Dioxide (CO_2) or raw organic compound as Carbon source, ammonium ions (NH_3^-) and Nitrate (NO_2^-) as electron donor, and Oxygen (O_2) as electron acceptor (Metcalf & Eddy, 2004, p.563). The predominant bacteria species responsible are nitrobacter and nitrosomonas (Edward (Ned) C. Fiss, 2000). Metcalf and Eddy (2004) present the chemical oxidation of Ammonia during nitrification as in **equation 4 and 5,** while overall conversion is in **equation 6**:

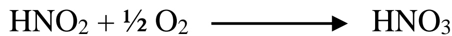
Conversion of Ammonia to nitrite (as typified by Nitrosomonas):

Equation 4:

$$NH_3 + 3/2\ O_2 \longrightarrow HNO_2 + H_2O$$

Conversion of nitrite to Nitrate (as typified by Nitrobacter):

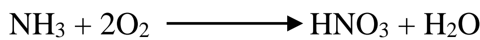
Equation 5:



$$HNO_2 + \frac{1}{2} O_2 \longrightarrow HNO_3$$

Overall conversion of Ammonia to Nitrate:

Equation 6:

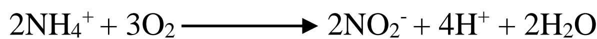


$$NH_3 + 2O_2 \longrightarrow HNO_3 + H_2O$$

Besides, due to the presence of ammonium ions, (Babu, 2011) comes out with the two-steps reactions as:

Conversion of ammonium ions to nitrite ions (as typified by Nitrosomonas):

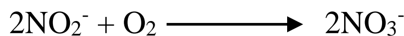
Equation 7:



$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 4H^+ + 2H_2O$$

Conversion of nitrite ions to Nitrate ions (as typified by Nitrobacter):

Equation 8:



$$2NO_2^- + O_2 \longrightarrow 2NO_3^-$$

From all the equation above, sufficient Oxygen must be present to allow the process. Moreover, the bacteria involved also sensitive to small changes in pH, alkalinity and temperature. Thus, Metcalf and Eddy (2004) reported 4.57 g O_2 and 7.07 g of alkalinity (as calcium Carbonate) is required for complete oxidation of 1g of NH_4^+ - N. For pure bacterial cultures, temperature range from 25° to 35° C has been found to be optimum for nitrification (Kedlec & Wallace, 2008) while the optimum pH values required in suspended growth range from 7.2 to 9.0 (Metcalf & Eddy, 1991). As a conclusion, the role of bacteria is very important in nitrification by which a stringent range of pH, temperature, Oxygen supply, alkalinity, source of Carbon and source of energy should be followed.

2.3.2 Denitrification

Denitrification is the process to convert Nitrate to Nitric Oxide, Nitrous Oxide and Nitrogen gas by microorganism, which should be initiated first by nitrification. Without nitrification, denitrification cannot happen and thus biological N removal is

not possible (Mogens, Loosdrecht, & Ekama, 2008). Approximately 80% of the bacteria are facultative anaerobes (Gerardi, 2003) which have the ability to use Oxygen as well as Nitrate or nitrite as electron acceptor. In the presence of Oxygen and Nitrate at the same time, these bacteria choose Oxygen instead of Nitrate as electron acceptor due to the low energy yields (Babu, 2011). Thus, it is essential to minimize or completely remove the Oxygen during the treatment process so that the rate of denitrification is optimized. Even in some recent studies exist the denitrifiers such as *Paracoccus Denitrificans* that can reduce Nitrates even at Oxygen saturation (Takaya, Catalan-Sakairi, Sakaguchi, Kato, Zhou, & Shoun, 2003), the focus of this paper will be denitrification in the absence of Oxygen.

"In denitrification process, the electron donor is typically one of three sources: (1) the bsCOD in the influent wastewater, (2) the bsCOD produced during endogenous decay, and (3) an exogenous source such as methanol or acetate" (Metcalf & Eddy, 2004). These three sources are considered as the Carbon source for the bacteria. The biodegradable organic matter in wastewater usually is represents as $C_{10}H_{19}O_3N$ (U.S EPA, 1993).

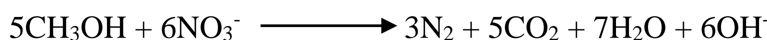
Wastewater:

Equation 9:

$$C_{10}H_{19}O_3N + 10NO_3^- \longrightarrow 5N_2 + 10CO_2 + 3H_2O + NH_3 + 10OH^-$$

Methanol:

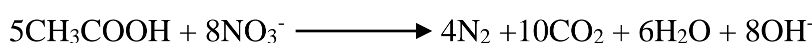
Equation 10:



$$5CH_3OH + 6NO_3^- \longrightarrow 3N_2 + 5CO_2 + 7H_2O + 6OH^-$$

Acetate:

Equation 11:



$$5CH_3COOH + 8NO_3^- \longrightarrow 4N_2 + 10CO_2 + 6H_2O + 8OH^-$$

From all the three equations, the concern of the final product is the Nitrogen gas as it will be removed to the atmosphere. We also can notify the presence of Nitrate ions (NO_3) as the electron acceptor while the sources become the electron

donour. Hence, the optimization in providing the sources is important to create the demand for the oxidation-reduction to occur. Alkalinity is not the main concern in the process as compared to nitrification process above, since 3.57g of alkalinity (as $CaCO_3$) is produced per g of Nitrate reduced (Metcalf & Eddy, 2004). This alkalinity recovered the alkalinity that has been used up in nitrification. For range of optimum pH, in pure cultures of *Pseudomonas* species based on denitrification activities, it was found to be from 7 to 7.5 (Laka *et al*,.2009). While for range of temperature, the best will be between 20°C to 30°C since there is no significant increase in the bacteria growth for temperature outside the range (Laka *et al*,.2009).

2.3.3 Alkalinity

As discussed earlier, alkalinity is one of the parameters needed in nitrification and denitrification. In brief, alkalinity is the measurement of alkaline compounds in water such as Bicarbonates, Carbonate and Hydroxide. Often, alkalinity is misunderstand as pH measurement with the typical believe that pH higher than 7 is alkalinity. Indeed, pH is actually the measurement of Hydrogen ions and express as logarithm with measurement of scale from 0 to 14. Thus, alkalinity is not simply the pH, but the measurement of pH can define alkaline condition.

Alkalinity can be measured in different ways depending on its end point. The Standard Methods for the Examination of Water and Wastewater by American Public Health Association (1999) had listed Total Alkalinity and Phenolpthalein Alkalinity as the main methods to measure the Alkalinity. The end point of both test will define the measurement of the three principle forms of alkalinity; Bicarbonate Alkalinity, Carbonate Alkalinity, and Hydroxide Alkalinity.

2.4 Attached Growth for Nitrogen Removal

In a biological treatment system, bacteria will grow either in suspension (suspended growth) or attached on a medium (attached growth). The medium growth of the bacteria is an important parameter to be taken care aside from the parameters highlighted in Nitrification and Denitrification process. The attached growth mechanism has long ago being used in the biological treatment system. One of the most popular system is the trickling filter and rotating algal disk, but it mainly focus on the organic matter removal, not the nutrients removal; specifically Nitrogen.

2.4.1 Attached Growth in Hybrid Membrane Biological Reactor (MBR)

Nevertheless, the increase in awareness to remove nutrients from wastewater brings a number of researches that also focusing on removing the nutrient traces. For example, Polyurethane sponge with density of 30 kg/m^3 was used in a research done by Khan, Ilyas, Javid, C. Visvanathan, & V. Jegatheesan (2011) to become the media in hybrid Membrane Biological Reactor (MBR). The study was done to compare between the suspended growth MBR and the attached growth MBR, by which the sponge was inserted into the compartment of the reactor. Evaluation done to the Nitrogen removal in the attached growth MBR had shown higher efficiencies of removal compared to the suspended growth MBR. 89% removal efficiency of Total Nitrogen is achieved in the attached growth MBR, while 73.9% removal efficiency in the suspended growth MBR.

2.4.2 Nitrification and Hydrogenotrophic Denitrification in Simple Attached Growth Reactors

Another study regarding the attached media was done by Khanitchaidecha, Shakya, Tatsuru, & Kazama (2012) in treating the groundwater. Here, two different system were constructed as one is used to treat the on-site wastewater, and another is used to treat the synthetic wastewater with additional Inorganic Carbon. Both systems were made up of two different compartments, specially designed to allow nitrification and denitrification. The nitrification reactor was design as a 2.5 x 100 cm of acrylic column with a 2.5 x 100 cm fiber carrier (from NET CO., Ltd Japan) along the column **(Figure 6 a)**, with the outlet become in influent point for denitrification reactor. The denitrification reactor however, was designed as 11.5 x 16 x 26 cm of acrylic container with 3-L working volume and contained 1100 cm^2 of the carrier area **(Figure 6 c and d)**. From the experiment done, it was found that the effluent treated water contained low Ammonia and Nitrate concentration (less than 1.5 mg/L and less than 11 mg/L respectively). The carrier inserted in the reactor had somehow helps in the treatment by providing growth media.

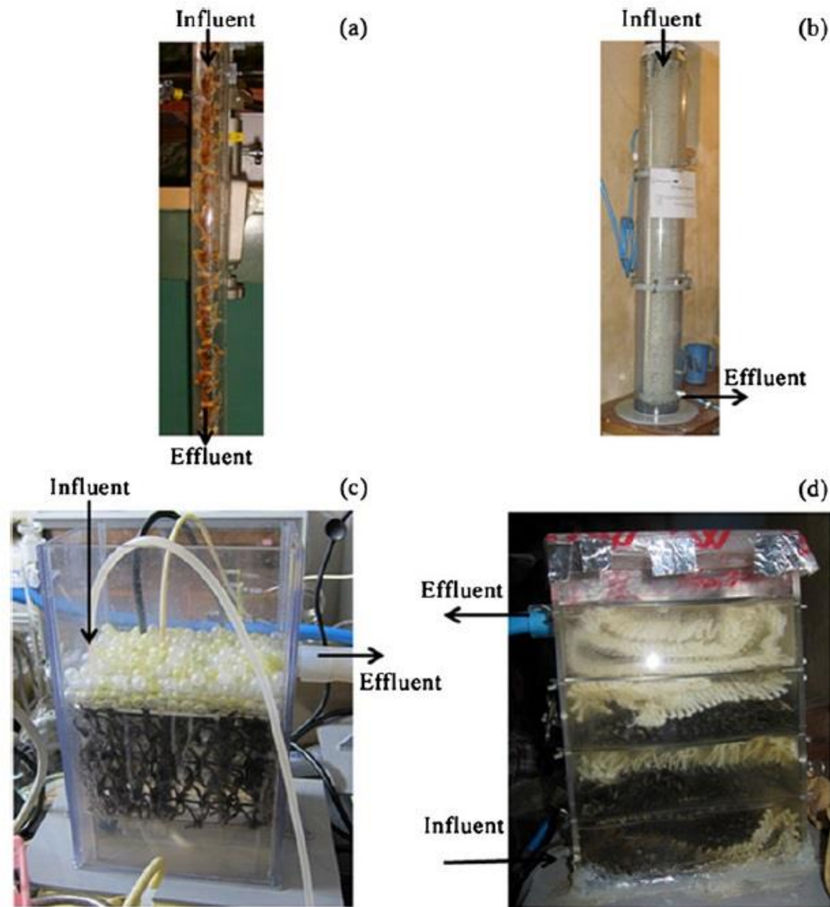


Figure 6: (a) and (c) the laboratory reactor, **(b) and (d)** the on-site reactor. (Khanitchaidecha, Shakya, Tatsuru, & Kazama, 2012)

2.4.3 Compact Fibre-based Bioconversion/Bio-filtration System

Research done by Kim, Yang, Scarano, Lewis, & Laolache (2007) focus on the experimentation to test the fibre-based material to become the material baseline to judge the overall biofilter performance. The Bio Balls® and Bio Fill® from Aquatic Eco-System, Inc. **(Figure 7)** had been used in carrying out the experiment. The objective of the research was to enhance the bioconversion effects of flocked surface, which is why both materials were used in promoting the flocks growth of bacteria. The operational procedure was to run the Recirculating Trickling Biofilter with the Bio Balls® and Bio Fill inserted and without the media, that will act as the standard. **Figure 8** shows the Recirculating Trickling Biofilter and its operational diagram. Results had shown a significant reduction in Ammonia concentration, with a rate of depletion about 0.11 ppm per day.

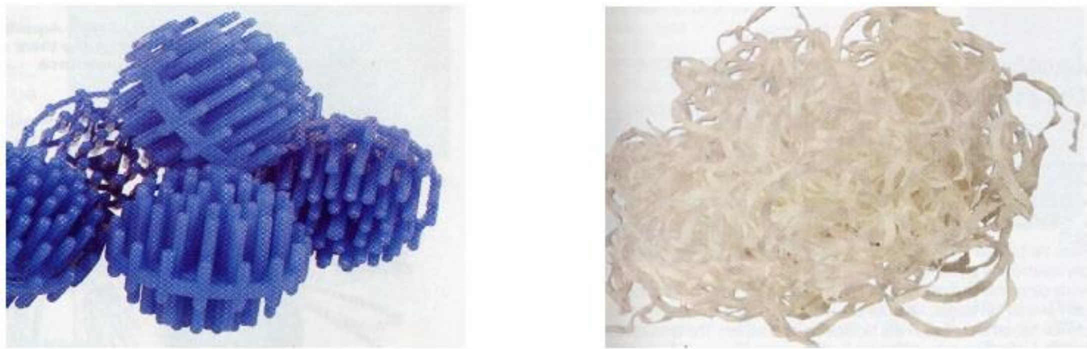


Figure 7: Left; Bio Balls®, right; Bio Fill® inserted into the Trickling Biofilter

(Kim, Yang, Scarano, Lewis, & Laolache, 2007)

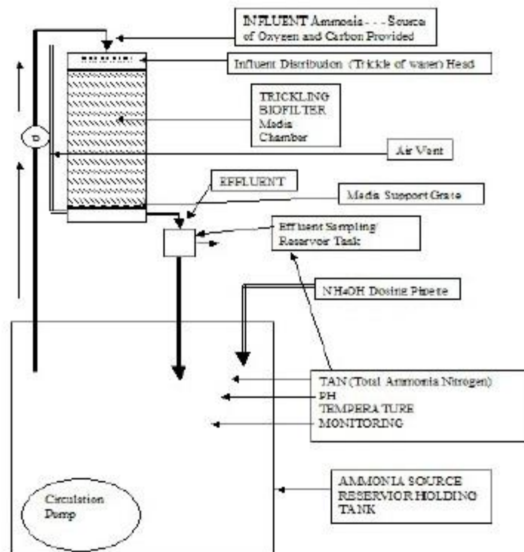


Figure 8: The Trickling Biofilter system

(Kim, Yang, Scarano, Lewis, & Laolache, 2007)

As a conclusion, the provisions of attached media in the compartment for biological treatment were proved to have significant impacts to the rate of removal. The only matter is that, in providing the medium certain parameters should be control such as the maximum head of the fluid, the backwash and the suitable size of attached medium so that the fluid can flow fluently

CHAPTER 3
METHODOLOGY

The methodology carried out in this study had been divided into two sections which are:

1. Research, data collection and analysis
2. Experimental Methodology

3.1 Research, Data Collection and Analysis

This is the primary work done to justify the problem statement, objectives and scope of works of the study. Most of the work will focus on the literature review, data to be used and analysis to be carried out. Besides, in this stage student define which data is included, factors involved and implication to the chosen decision. The data collected in this stage is used throughout the study as it provides the basis theory for the practical application.

Accordingly, all the data collected from various resources such as UTP Information Resource Centre, and UTP Wordpress website had been documented in this report. As such, the information collected from thesis, journal and books were included as part of the literature review. While the selected procedure for experimental work is to be described further in this methodology section

3.2 Experimental Methodology

3.2.1 Formulation of Synthetic Wastewater

The synthetic wastewater was prepared by using tap water and dog's food brand Purino Alpo High Protein Puppy Dog Meal as the main ingredients. This synthetic wastewater was formulated based on the typical medium strength of domestic wastewater as the main reference (**Table 2**). The dog's food was first grinded for 5 minutes before being sieved for finer result. In the experimental stage, three different weight of the dog's food were prepared and mix with 1 litre of tap water respectively. The weight of the respective dog's food is 3.6 g, 1.5 g and 0.5 g. Then, the COD reading of the samples were taken in order to pick the synthetic wastewater that have COD reading close enough to typical medium strength of wastewater as in **Table 2**.

Table 2: Typical composition of untreated domestic wastewater (medium strength)

Contaminants	Unit	Concentration
BOD_5	mg/L	190
COD	mg/L	430
Nitrates	mg/L	0
TKN	mg/L	40
Ammonia	mg/L	25
Total Phosphorus	mg/L	7
C:N:P ratio	-	100:6:2

(Source: Metcalf and Eddy, 2004, p.186)

From the experiment to check the COD value, the nearest value is obtained from 1.5 g of dog's food to 1 litre of tap water. By using the same sample (1.5 g dog food), other parameters were also tested so that it complies with the objective to produce typical medium strength of wastewater. The other parameters tested for this stage include BOD, Nitrate and Ammonia-Nitrogen. The only problem came from the Ammonia-Nitrogen reading from the sample where it does not give desired value or at least a close enough to the value. Thus, the approach taken was to add chemical namely, Ammonium Chloride to increase the Ammonia content. Different weight of Ammonium Chloride was mix with the synthetic wastewater respectively. The results showing that the optimum weight is 150 mg for 1 litre of tap water. All the associated results for carrying this part of feasibilities study will be presented in results and discussion section.

3.2.2 Setting up the Reactor

3.2.2.1 Measuring the Volume of the aeration tank

Volume of the aeration compartment of the reactor needs to be measured to become the input data in the calculation to obtain optimum flowrate based on **Equation 12** and **Equation 13**. Due to the fix volume of the existing reactor, the measurement of the volume was conventionally done by using tap water. The tap water was poured into respective tank and the volume inside the tank was taken out to be measured by using measuring cylinder. **Figure 9** shows the tap water inserted into the aeration tank to measure the volume.

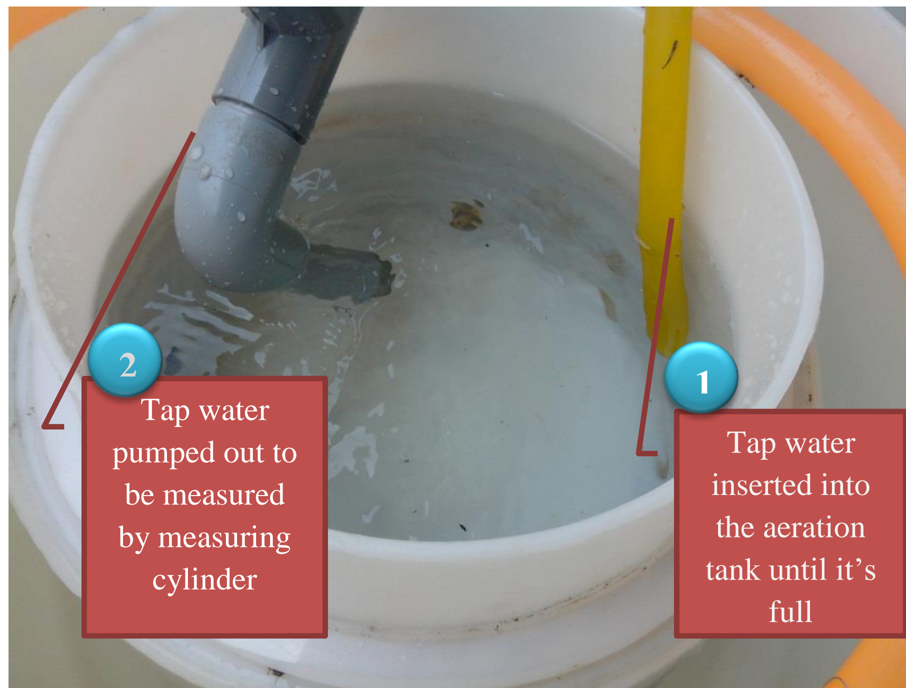


Figure 9: Tap water is used to measure the volume of aeration tank

3.2.2.2 Setting up the Flowrate, Solid Retention Time (SRT) and sludge to be wasted.

Metcalf and Eddy(2004) had provided guideline on the calculation in designing tank for BOD removal and nitrification. Firstly, the formula used to estimate the biomass production is:

Equation 12:

$$P_{X,bio} = \frac{QY(S_o - S)}{1 + (k_d)SRT} + \frac{(f_d)(k_d)Q(Y)(S_o - S)SRT}{1 + (k_d)SRT} + \frac{QY_n(NO_x)}{1 + (k_{dn})SRT}$$

Where;

$P_{X,bio}$ =Biomass production (g VSS/d)

Q = Influent Flowrate (L/d)

$P_{X,bio}$ = Biomass growth (Kg/day)

SRT = Solid Retention Time (day)

$Y, Y_n, S_o, S, f_d, k_d, k_{dn}$ = kinetic coefficient for heterotrophic bacteria at 20°C

NO_X = Nitrogen oxidised to Nitrate (mg/L)

Assumption of $NO_X \approx 80\% TKN$ was made as Nitrogen balance cannot be done yet. This formula will be used as the basis for the fix flow rate and SRT due to lack of data. Once the experiment had commenced, following equation will be used as a comparison to the values calculated early:

Equation 13:

$$(X_{VSS})(V) = (P_{X,Bio})\ SRT$$

Where:

X_{VSS} = Volatile Suspended Solids (mg/L)

V= Volume of aeration tank (L)

It can be seen that the value for the volume of aeration tank measured previously is used in this calculation. Thus, an excel spread sheet was formed to calculate the value of $P_{X,Bio}$ by using design SRT set by student. The value of $P_{X,Bio}$ is important to be used in the determination of alkalinity and is used as reference for sludge to be wasted daily. Also, the typical values for the kinetic coefficient were taken based on Metcalf and Eddy (2004). The steps, results and discussion regarding this section will be explained further in results and discussion section.

3.2.2.3 Assembling the Compartment of Reactor

This section of work is actually assembling all the components of the tanks such as the air diffuser, recycle pump, feeder pump, and piping connection. This step is essential to make sure all the equipment to be used in the real experiment are in good condition. First, the reactor was run with tap water after all the setting had been setup in order to make sure that no leaking is observed. Next, the reactor was run for the first phase of the project with the sludge obtained from aeration tank of UTP STP with average MLVSS strength of 4000 mg/L together with the influent synthetic wastewater prepared. The value of MLVSS was obtained from laboratory experiment to the sample inserted into the reactor. The arrangement of the reactor is as follows (**Figure 10 and Figure 11**):

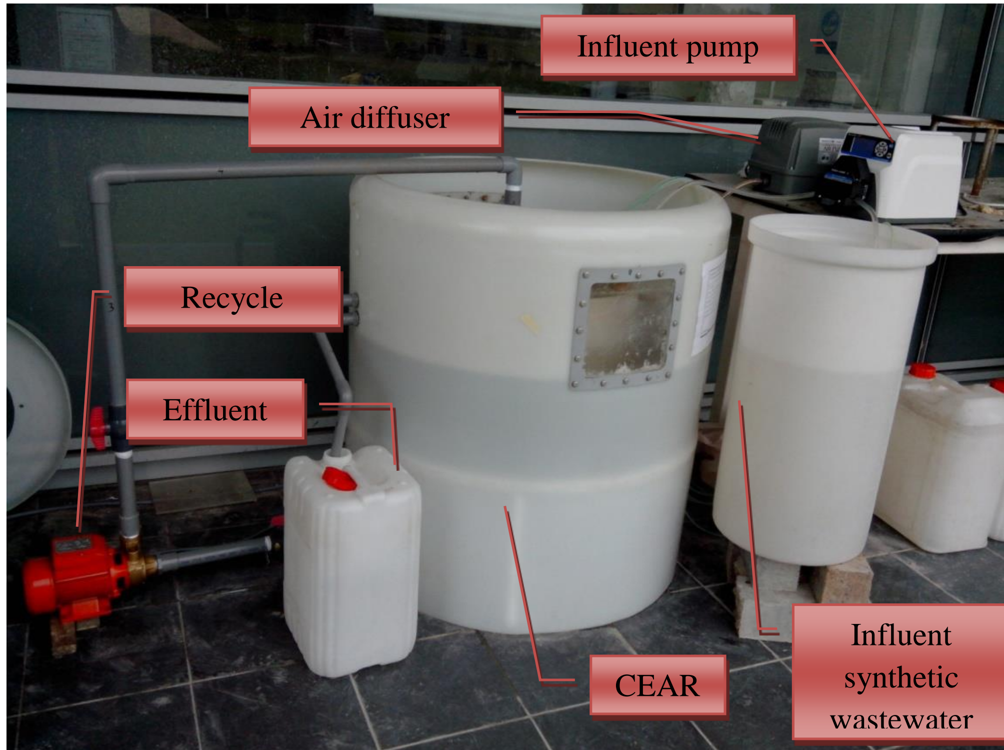


Figure 10: Arrangement of the experiment reactor

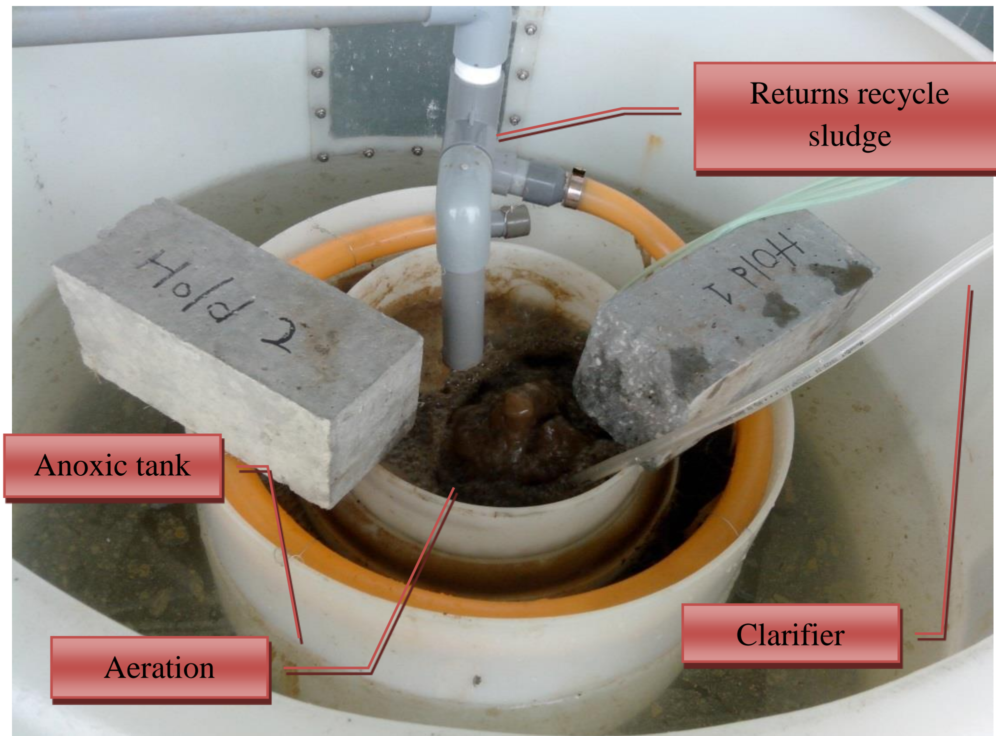


Figure 11: Top view of the Reactor

3.2.3 Installing the Aero-packer and the Bio-balls

The first phase of the experiment is to evaluate the performance of CEAR without the installation of attached growth media. Thus, after it had commenced, the attached growth media were installed into the anoxic tank. For that, a specially designed Aero-packer of specific dimensions and Bio-balls with diameter 3.5 cm are selected. The Aero-packer was fabricated by using Perspex materials and assembled by the technician at RIO laboratory at UTP academic Block 16. **Figure 12** shows the Aero- packer installed in the aeration tank. Apart from that, because the anoxic tank is directly connected to the clarifier, a net was used to hold the Bio-balls so that they did not interrupt the process in the clarifier. A number of 130 Bio-balls were inserted into the tank. For the sake of testing purpose, only half of the height of the anoxic tank is filled with the Bio-balls. **Figure 13** shows the Bio-balls used in this experiment, while **Figure 14** shows the net used to hold the Bio-balls. **Figure 15** shows where the attach growth media were located while **Figure 16** shows both structure installed in respective tanks.

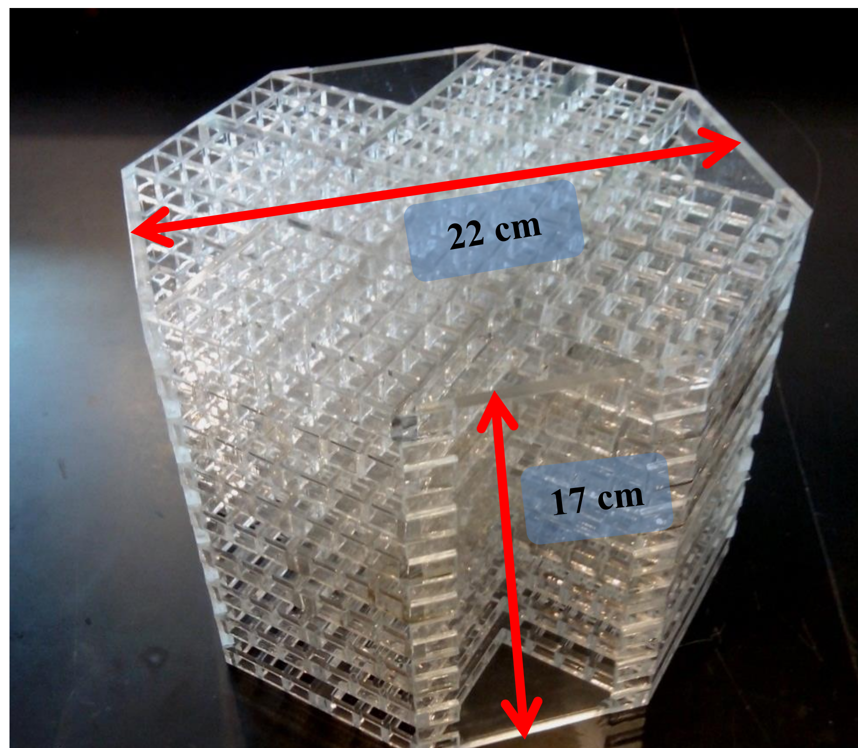


Figure 12: The Aero-packer installed in the aeration compartment

Figure 13: The Bio-balls used in this experiment

Figure 14: Net is used to hold the Bio-balls together

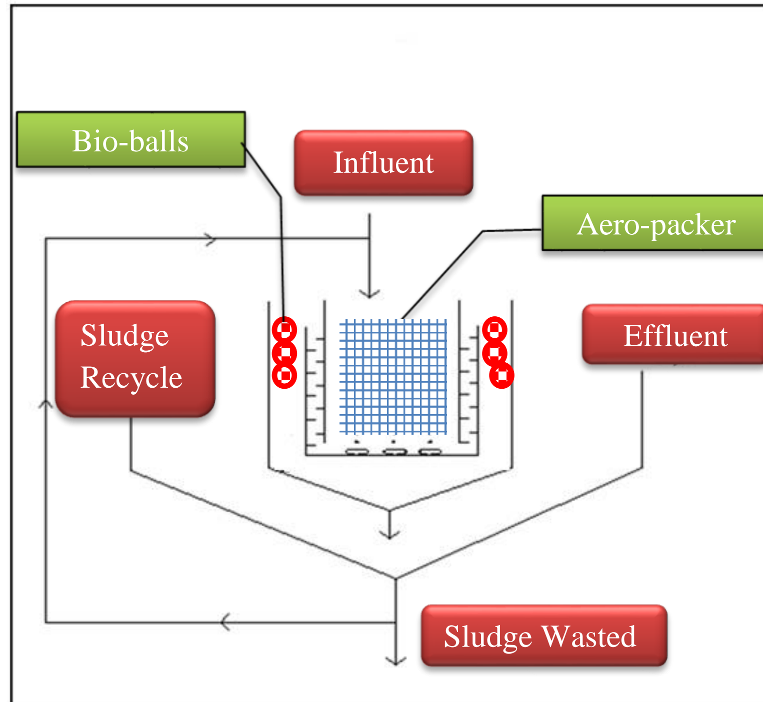


Figure 15: Schematic diagram on the location of the attached growth media in the CEAR

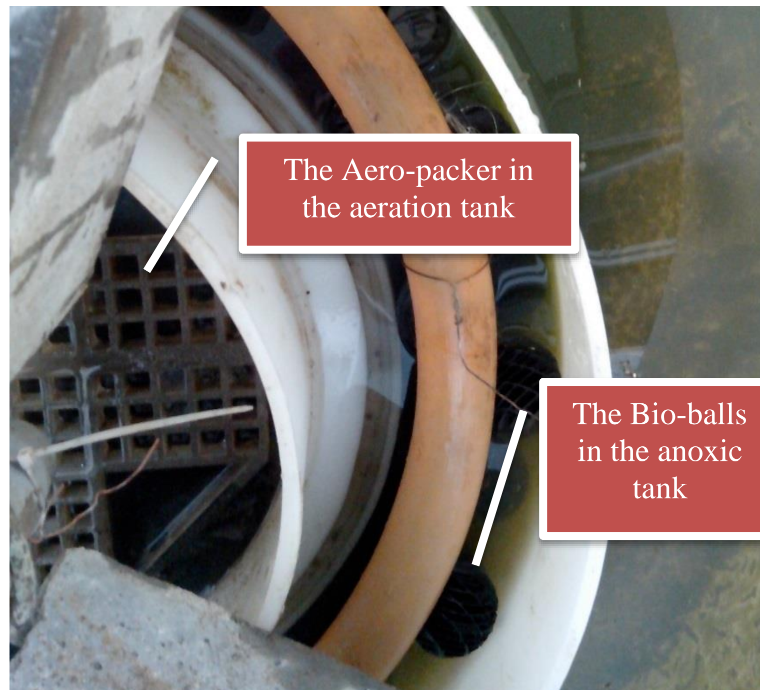


Figure 16: The Bio-balls and the Aero-packer in respective tanks

3.2.4 Sample Collection for Performance Monitoring

The samples will be taken from four points of the tank which are (1) influent, (2) aeration, (3) effluent anoxic, and (4) final effluent as shown as Figure 17 (sample collection point) below:

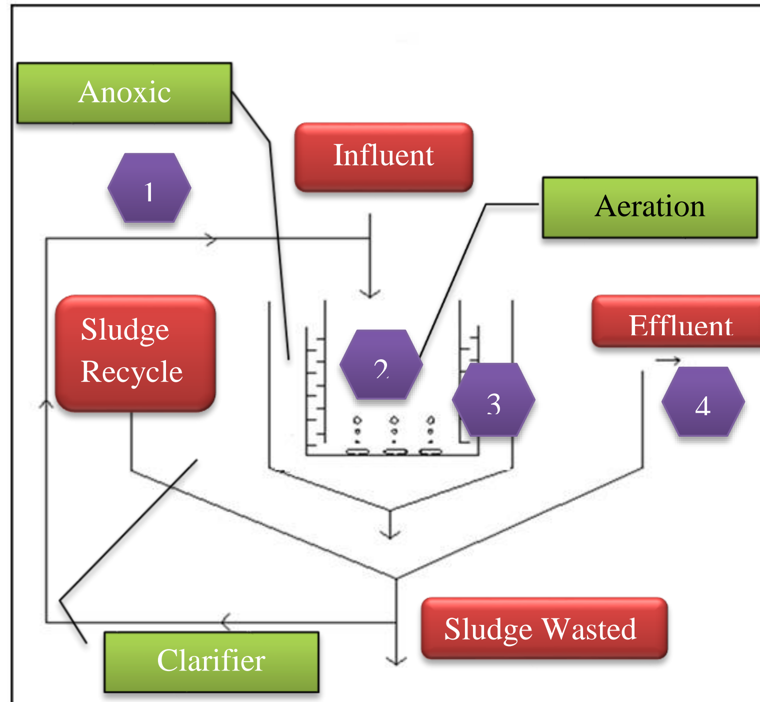


Figure 17:Sample collection points

The samples will be collected by using pipette with big bulb and it is taken at the designated point. 1000 mL is to be collected at each point to be used in laboratory test. The sample taken from the chosen point is important to measure the performance of each tank. **Figure 18** shows how the sample was collected using pipette.

Figure 18: Sample collection using pipette

Each sample will be taken regularly and it will be taken at least three times a week to monitor the performance of the tank. The tests that will be conducted for each sample are Ammonia-Nitrogen, Nitrate and MLVSS. For the Total Phosphorus, the test will only be done regularly as it is needed only to check the presence of nutrients in the influent. The test for the Total Phosphorus will be done at least once per week. Also for the alkalinity test and TKN, it is done at least once to check the alkalinity needed, if any. Evaluation of the tank performance will be done based on the results obtain.

3.2.5 Ammonia-Nitrogen Laboratory Experiment Procedure

To test for Ammonia-Nitrogen, USAPA Nessler Method (Method 8038) was used. For the first step, sample and blank were prepared by filling 25 mL of sample and deionized water into separate mixing cylinder. Three drops of Mineral Stabilizer was then added to both mixing cylinders before they were inverted for mixing. The Mineral Stabilizer will break the complex hardness in the sample. After that, three drops of Polyvinyl Alcohol Dispersing Agent (to aids in colour formation in the reaction) were added to each cylinder, followed by 1.0 mL of Nessler Reagent. Following these processes, the cylinders were inverted several times for better mixing. The mixture was then left for one-minute reaction period and once the timer goes off, 10 mL of the mixture of each solution were poured into sample cell. The content of Ammonia-Nitrogen was then measured using Spectrophotometer after the instrument is zero by using the blank. For the sample taken, all need to be filtered first so that no further Ammonia reduction is done by the bacteria presents.

3.2.6 Nitrate Laboratory Experiment Procedure

To test for Nitrate, Cadmium Reduction Method (Method 8039) was used. Preparation of sample was done by filling the sample cell with 10mL of sample. After that, the content of one NitraVer 5 Nitrate Reagent was added, shake for one-minute, and left for five-minute reaction period. An amber colour will develop if Nitrate was present. Content of Nitrate can then be measure after the instrument was zero using the blank. Blank was prepared by filling the sample cell with 10 mL of similar sample. For the sample taken, all need to be filtered first so that no further Nitrate reduction is done by the bacteria presents.

3.2.7 Total Kjehdal Nitrogen (TKN) Laboratory Experiment Procedure

The TKN value is needed to verify the alkalinity needed in the system. To measure the TKN of the sample, the BUCHI Kjeldahl Line is used. It consist of Distillation Units B-316, B-324 and B-339. According to the standard provided by the BUCHI Labortechnik, the volume needed to do the test for wastewater is 15 ml. Thus, to obtain an accurate result, 5 samples of the influent is prepared with 3 blanks which is made up distilled water. The samples were inserted into the test tube specially designed for TKN test. After that, in the fume chamber, 10 tablets of catalyst and 20 ml of Sulphuric Acid (98% pure) is added into each test tube respectively. Next, all the samples were placed into the digestion chamber and digested for 40 minutes. Cooling is needed for about 30 minutes before next process take place. The next process is distillation which will be done sample per sample and takes about 5 to 7 minutes for each sample. The main chemicals used for the distillation is 30% pure Sodium Hydroxide (NaOH) and 2% pure Boric Acid. The machine will give the reading of acid used to titrate the sample. Following is the formula used to calculate the TKN value:

$$TKN = (V_1 – V_2 \text{ x } C \text{ x } 14.01 \text{ x } 1000)/V_0$$

Where:

TKN= TKN in mg/L

V_1 = Volume in mL of the acid used for titration of the sample

V_2 = Volume in mL of the acid used for titration of the blank

V_0 = Volume in mL of the sample

C = molarity of the acid (0.5 for Sulphuric Acid)

(Note:14.01 is the relative atomic mass of Nitrogen)

3.2.8 Total alkalinity Laboratory Experiment Procedure

The test for Total Alkalinity is done following the guidance provided in the Standard Methods for the Examination of Water and Wastewater by American Public Health Association (1999). Accordingly, there are two end points of the titration, which is phenolphthalein end point and methyl orange end point. To determine which end point is suitable for the specific sample, the pH of the sample should be taken first. The sample must be freshly taken and immediately measured in order to maintain the originality of the pH in the system. Following that, after the pH is determined, the type of titration or end point will be chosen. If the pH is more than 8.3, both end point test will be carried out. First titration is carried out until pH is lowered to 8.3 (phenolphthalein end point) and followed by titration of the sample to pH equivalent or almost equivalent to 4.5(methyl orange end point). If the sample pH is less than 8.3, only single titration using methyl orange end point is needed.

Therefore, after the measurement of pH had been made, 50 mL of the sample is transferred into a conical flask. Next, about three drops of the indicator is inserted into the conical flask (phenolphthalein or methyl orange). For phenolphthalein end point, it will be titrated using 0.02N Sulphuric Acid by using a burette. The colour of the sample will change from pink to colourless, and gives phenolphthalein alkalinity. For methyl orange end point, the same acid is also used by which the colour will change from yellow-orange to red. This will gives total alkalinity, and the following are the calculation used to calculate both alkalinity:

Phenolphthalein alkalinity (P), as mg $CaCO_3$/L

=(mL H_2SO_4 titrant used) x (Normality of H_2SO_4 x 50000)/mL sample

Total alkalinity (T), as mg $CaCO_3$/L

=(Total H_2SO_4 titrant used) x (Normality of H_2SO_4 x 50000)/mL sample

3.2.9 Total Phosphorus Laboratory Experiment Procedure

To measure the Total Phosphorus, PhosVer® 3 Acid Persulphate Digestion Method (Method 8190) by USEPA. First of all, the DRB200 Reactor has to be turned on and preheated to 150°. Then, the sample was prepared by inserting 5 mL of sample to a

Total Phosphorus Vial. The sample was inserted into the vial by using a TenSette® Pipet after it has been filtered using filter paper. Next, by using a funnel the contents of one Potassium Persulfate Powder Pillow is inserted for Phosphonate to the vial. The vial was then capped tightly and shaken to dissolve. After that, it is inserted into the DRB200 that has been preheated to 150°, for a 30 minutes heating period. After the timer had expired, the vial was removed from the reactor and cooled to room temperature in the test tube rack. Following that, 2 mL of 1.54 N Sodium Hydroxide Standard Solution is added into the vial by using TenSette Pipet. After mixing the solution through shaking, a tissue was used to wipe the outside of the vial. Next, it is inserted into the Spectrophotometer to Zero the instrument. Afterward, a funnel was used to add the content of PhosVer 3 Powder Pillow to the vial. The vial is then immediately capped tightly and shaken to mix for 20-30 seconds. The powder will not dissolved completely. Subsequently, a timer was started for 2 minutes to allow the reaction in the vial. Lastly, after the time expires, the reading was taken by using the Spectrophotometer. For each sample, a triplicate was used in order to give accurate result. Also, all samples need to be filtered first so that no further reaction is done by the bacteria presents.

3.2.10 Chemical Oxygen Demand (COD) Laboratory Experiment Procedure

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 ^{0}C. 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. The vials caps were closed tightly and then were shook vigorously. Next, the vials were heated for two hour using the DRB200 reactor. When finished, the vials were place into a rack and cool to room temperature. After they have cooled down, 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.

3.2.11 Biochemical Oxygen Demand (BOD) Laboratory Experiment Procedure

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. On the day of experiment, Blank sample was prepared by pouring aerated water into a BOD bottle until it reached its neck. Next, 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. After that, the blank sample was measured with DO meter and the reading was recorded. The initial reading of DO for the bottles filled with sample was also taken as well. Subsequently, the BOD glass was closed with cap and aluminum foil before being kept inside the BOD incubator where temperature is set to be 20^0C and is stored for 5 days. After 5 days, all the final DO were measured by using DO meter and reading was recorded. The difference of the DO reading for blank sample before and after reading should not exceed 2 mg/L.

3.2.12 Mix Liquor Volatile Suspended Solids (MLVSS) Laboratory Experiment Procedure

Before the test can be conducted, preparation of microfiber filter paper need to be done at least 24 hours early. Firstly, the filter paper was placed on the flask set and rinse thoroughly using distilled water before the vacuum is turned on until all the water had been sucked out. Then, the filter paper was carefully taken using forceps and placed in the aluminium disc with the wrinkled surface upward. Next, the filter paper together with the aluminium disc is inserted into the furnace of 550°C for 24 hours.

The next day when the experiment is to be commenced, the filter paper set was taken out and cooled down before being weigh. This is considered as the initial weight of the filter paper set. Next, the filter paper was placed onto the flask set, and 20 mL of sample is poured into the flask. Before it is poured, the sample need to be shaken or stirred so that it is homogenous. After that, the vacuum is turned on to sucked all the liquid. A forceps is used to take the filter paper and to put it back at the aluminium disk. Thereafter, the filter paper, together with its aluminium disk is inserted into 550°C furnace for one hour. Later after one hour, it is taken out and cooled down in

the desiccator before being weigh. The difference between the initial weight and the final weight is calculated.

Table 3: The Key-Milestone of the project

3.3 Key Milestone

Event or Deliverable	Target Date	Responsibility
Project works continues.	Week 1-7	Student carry out relevant experimental activities and research
Submission of Progress Report to Supervisor and Course Coordinator. Project works continues.	Week 8	Student submit the report on the stipulated date.
Preparation for pre-SEDEX and continuation of project works.	Week 9-10	Student carry out relevant activities for the preparation
Pre-SEDEX	Week 11	Student present the finding through poster presentation to the examiners. Course coordinator will arrange the slot and the examiners.
Submission of draft final report and technical paper.	Week 12	Students must submit the draft and technical paper to the supervisor.
Submission of final report.	Week 13	Students must submit the final report to the supervisor and internal examiner.
VIVA (Final Presentation)	Week 14	Student verbally present the finding of the projects to supervisor, internal and external examiners. All details will be arranged by course coordinator.

3.4 Overall Gann-chart:

	FYP 1 Semester January 2013																		FYP 2 Semester May 2013														
Detail/Week	1	2	3	4	5	6	7	mid semester break	8	9	10	11	12	13	14	study week	exam week	semester break	1	2	3	4	5	6	7	mid semester break	8	9	10	11	12	13	14
Preliminary research and study	■	■	■	■	■	■	■																										
Selection of Medium							■		■	■	■	■	■	■	■																		
Design and Fabrication of Aero-packer							■		■	■	■	■	■	■	■																		
Laboratory Experiment											■	■	■	■	■				■	■	■	■	■	■	■		■	■					
Submission and Presentation:																																	
Proposal Title		●																															
Extended Proposal						●																											
Viva/Project Defence										●																							
Interim Draft Report														●																			
Interim Report															●																		
Progress Report																											●						
Pre-SEDEX																														●			
Draft Report																																●	
Technical Paper																																	●
Viva 2																																	●
Project Dissertation																																	●

3.5 Tools

Table 4: Software used

No.	Software	Description
1.	Microsoft Office • Microsoft Word • Microsoft Excel	This software will be used for the documentation of paperwork and any calculations
2.	AutoCAD	This software will be used for designing the baffle in anoxic tank

Table 5: Hardware used

No.	Hardware	Description
1.	Existing Integrated biological reactor	The reactor will be used to carry out the experiment in lab scale
2	Bio-balls	To be used as the attached growth media in the anoxic tank of CEAR

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Formulation of Synthetic Wastewater

The steps to formulate the synthetic wastewater had been discussed in the methodology section. **Table 6** shows the parameters reading taken from the synthetic wastewater made. Comparison was made to the typical medium strength of wastewater as a reference. Besides, the raw materials to make the synthetic wastewater is presented in **Table 7** for 1 Litre of tap water.

Table 6: The average reading of the parameters in the synthetic wastewater

Parameters	Average Reading for Synthetic Wastewater (mg/L)	Typical Medium Strength Wastewater Composition (mg/L)
COD	500	430
BOD_5	170	190
NH_3-N	27	25
NO_3	2.5	0
Total p	13	7
C:N:P ratio	100:5:3	100:6:2

Table 7: Raw materials that make up the synthetic wastewater

Constituent	Gram Per Litre Tap Water
Purino Alpo High Protein Puppy Dog Meal	1.5
Ammonium Chloride powder	0.15

The final ingredients to make the synthetic wastewater are 1.5 g of dogs' foods and 0.15 g of Ammonium Chloride in 1 Litre of tap water. The synthetic wastewater will be prepared by batch of 50 L tap water in order to make sure that a constant loading is provided throughout the experiment. Thus 75 g of dog's food and 7.5 g of Ammonium Chloride is homogenously mixed in 50 L of tap water for each batch prepared.

4.2 Setting up the Reactor

4.2.1 Measuring the Volume of the Aeration Tank

The volume of the aeration tank of the reactor had been measured by using tap water and measuring cylinder. Following are the results obtained (**Table 8**):

Table 8: Volume of aeration Tank of the Reactor

Section of Reactor	Volume in Litre, L
Aeration tank	10

Based on the value recorded, now the calculation regarding the flowrate, and sludge to be wasted to be used for the experiment can be done. The details were presented in following section.

4.2.2 Setting up the Flowrate, Solid Retention Time (SRT) and Sludge to be wasted

In this calculation, the variable to be control is the influent flowrate with fix design SRT. Following the typical values for extended aeration in **Table 1** the SRT was set to be 35 days. The other parameters in the calculation were taken from the typical value provided in Metcalf and Eddy (2004). **Table 9** shows the value adopted to do the calculation according to the **Equation 12** in **section 3.2.2.2** While **Table 10** shows the calculated $P_{x,bio}$ based on different flowrate assumed.

Table 9: Value adopted for the coefficient used

Coefficient	Value
Y	0.4 g VSS/g bCOD
Y_n	0.12 g VSS/ g NO_X
K_d	0.088 g/g.d
K_{dn}	0.06 g VSS/ g VSS.d
f_d	0.15
S_o	224 g bCOD/m³
S	0.7 g bCOD/m³

Table 10: Value of Px,bio based on different flowrate for SRT of 35 days

Flowrate (L/day)	**$P_{x,bio}$ (g VSS/ day)**
50	1.655
25	0.827
15	0.496
10	0.331

From the calculated value, the tank was run for 7 days with constant feeding of synthetic wastewater prepared by using 50 L/day of influent flowrate. Virtual observation was made, and the production of biomass is too much that it needs to be removed from the system very regularly. This is supported by the calculation made above. Besides, the objective of the extended aeration process is to provide less sludge from low F/M ratio. Thus, the flowrate was reduced to 25 L/day and run for another 10 days. This was done at the first semester (January 2013 semester) of the Final Year Project, where not all laboratory analysis is yet done to monitor the tank performance. The value for the influent flowrate 15 L/day and recycle rate of consecutive 1 and 1/2 hours were adopted for the future work in the second semester (May 2013 semester). Besides, a 10 L/day flowrate was also used in order to see the variation in the final value of the effluent.

4.3 Performance Monitoring

4.3.1 Evaluation of CEAR without the Attached Growth System (First Phase)

In the second semester of the project, the tank was run by using the input that had been discussed previously. Besides, laboratory experiments were done to assess the performance of the tank in removing the Nitrogen. Two main constituent of the sample become the focus which is Ammonia and Nitrate. This is because, the value of Ammonia and Nitrate will determine how much Nitrogen had been removed through nitrification and denitrification activities. The final product of Nitrogen cycle is the Nitrogen gas. But because it is untraceable and released to the atmosphere, the Ammonia and Nitrate values will become the indicator of how much Nitrogen gas had been released.

The first phase of the experiment was done without the installation of attached growth media in the CEAR for 35 days. **Figure 19** shows the graph of Ammonia VS Sampling Days while **Figure 20** shows the graph of Nitrate VS Sampling days. Both of the graphs were plotted based on the experiment done with respective to the days the tank was run.

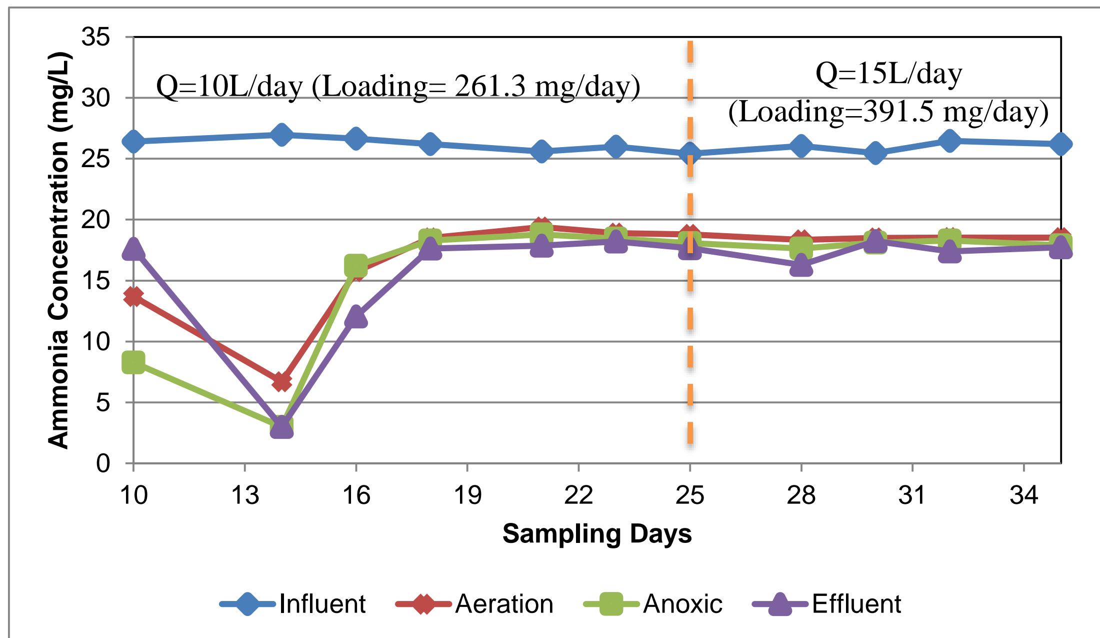


Figure 19: Graph of Ammonia Concentration VS Sampling Days (First Phase)

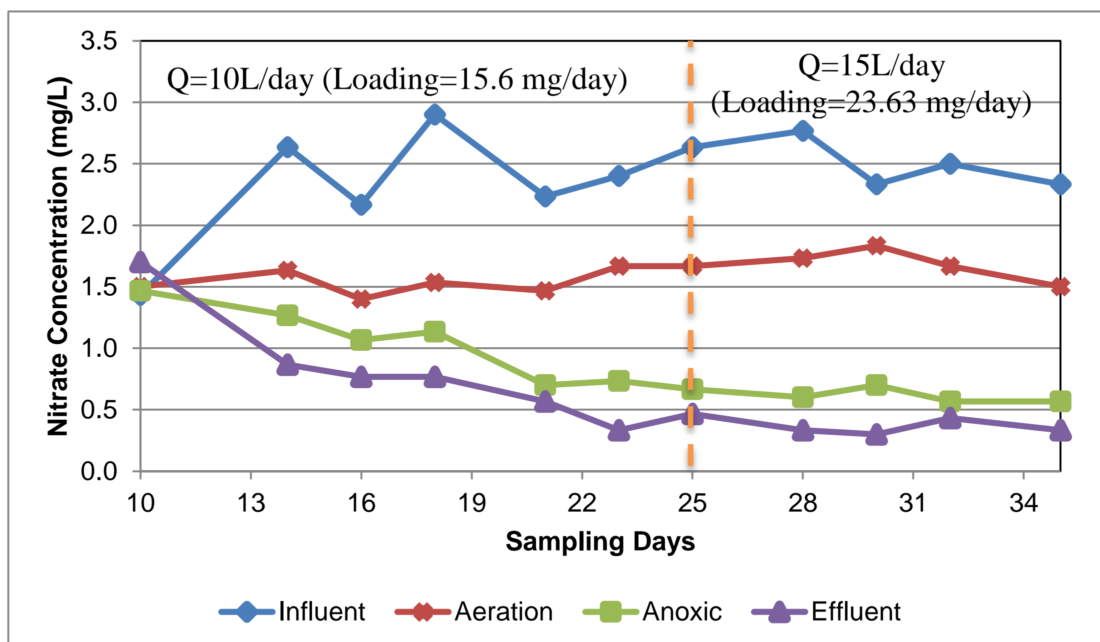


Figure 20: Graph of Nitrate Concentration VS Sampling Days (First Phase)

Based on both graph, it can be seen that the value of both Ammonia and Nitrate in different sampling points still fluctuates at the early days of the experiment. This is due to the bacteria activity that still adapting the new environment. Thus, allowing some acclimatized period, the results gave almost a stable value after day 18. From this day onwards, for respective flowrate, the value from each sampling point were added and averaged to be used for the analysis. Besides, on day 25, the flowrate had been increased to 15 L/day to increase the loading rate. This was done to compute the value of nitrification kinetics, k of the system. From the graph also, it can be seen that the value of both Ammonia and Nitrate were reduced from the first sampling point to the last sampling point. However, the reduction of Ammonia from aeration tank to anoxic tank and to effluent does not give a good figure. This is because, Nitrification only takes place at aeration tank and it requires extensive aeration.

Apart from that, there are few misleading results observed in both graphs by which the concentration kept reducing from anoxic point to effluent point. There should be no more reduction since the sludge is settling in the clarifier and clear water is brought outside as the effluent. Thus, the reduction observed might be due to bacteria activity in the clarifier which is cause by longer detention time of sludge. The sludge held in the clarifier need to be more frequently recycled into the aeration tank. Next, for both flowrate and loading applied, the rate of reduction also does not give a clear reduction pattern. This might be due to only small changes applied to the system; which is difference of 5 L/day. Nonetheless, all the conclusions made above do not include the control towards Carbon source and alkalinity due to the technical problems that will be discussed later.

As a conclusion for this part, the first phase of the project which is to evaluate the performance of the tank without the attached growth media had been achieved. From the series of experiment done, it can be concluded that the system is successful in reducing the Nitrogen content from the wastewater. The overall average reduction and average reduction from compartment to next compartment of Ammonia is presented in **Table 11** while for Nitrate is in **Table 12.** For 10 L/day flowrate, the average effluent Ammonia is 17.8 mg/L while for Nitrate is 0.5 mg/L. For the 15 L/day flowrate, the average effluent for Ammonia is 17.4 mg/L and for Nitrate is

0.4 mg/L. This gives an overall percentage of reduction of 32.8% and 76.2% for Ammonia and Nitrate respectively (10 L/day flowrate). Also, the overall percentage of reduction is 34.3% and 80.9% for Ammonia and Nitrate respectively (15 L/day). However, the average reading of Ammonia in the effluent still does not meet the regulations set by DOE as stated in **Figure 3.** Thus, the system still need to be upgraded or at least corrected since the control towards alkalinity and Carbon source still cannot be done at this phase.

Table 11: Average reduction of Ammonia during first phase

Influent	**10 L/day**			**15 L/day**		
Compartment	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**
Influent	26.5	-	32.8	26.5	-	34.3
Aeration	18.9	28.7		18.5	30.18	
Anoxic	18.4	2.7		18.0	2.7	
Effluent	17.8	3.3		17.4	3.3	

Table 12: Average reduction of Nitrate during first phase

Influent	**10 L/day**			**15 L/day**		
Compartment	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**
Influent	2.1	-	76.2	2.1	-	80.9
Aeration	1.6	23.8		1.7	19.0	
Anoxic	0.8	50.0		0.6	64.7	
Effluent	0.5	37.5		0.4	33.3	

4.3.2 Evaluation of CEAR with Attached Growth System

The second phase of the project was carried out with the installation of attached growth media in the aeration and anoxic compartment of the CEAR. However, for this time around, only one flowrate is adapted in the experiment which is 15 L/day due to time limitation. **Figure 21** shows the graph of Ammonia Concentration VS Sampling Days while **Figure 22** shows the graph of Nitrate Concentration VS Sampling Days for the second phase of the project, with the attached growth system.

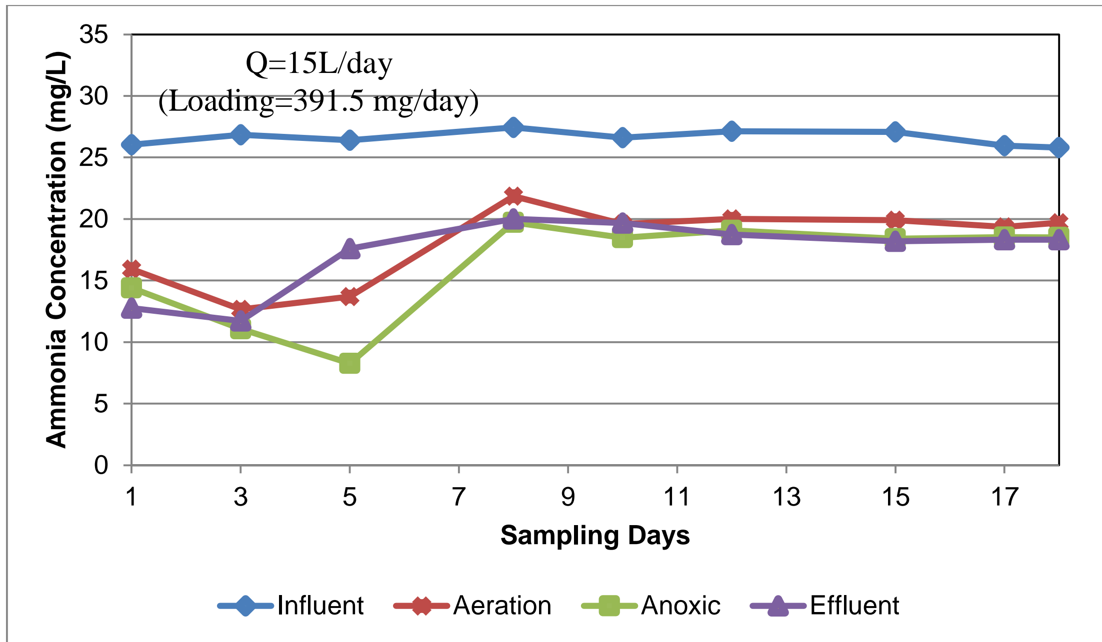


Figure 21: Graph of Ammonia Concentration VS Sampling Day (Second Phase)

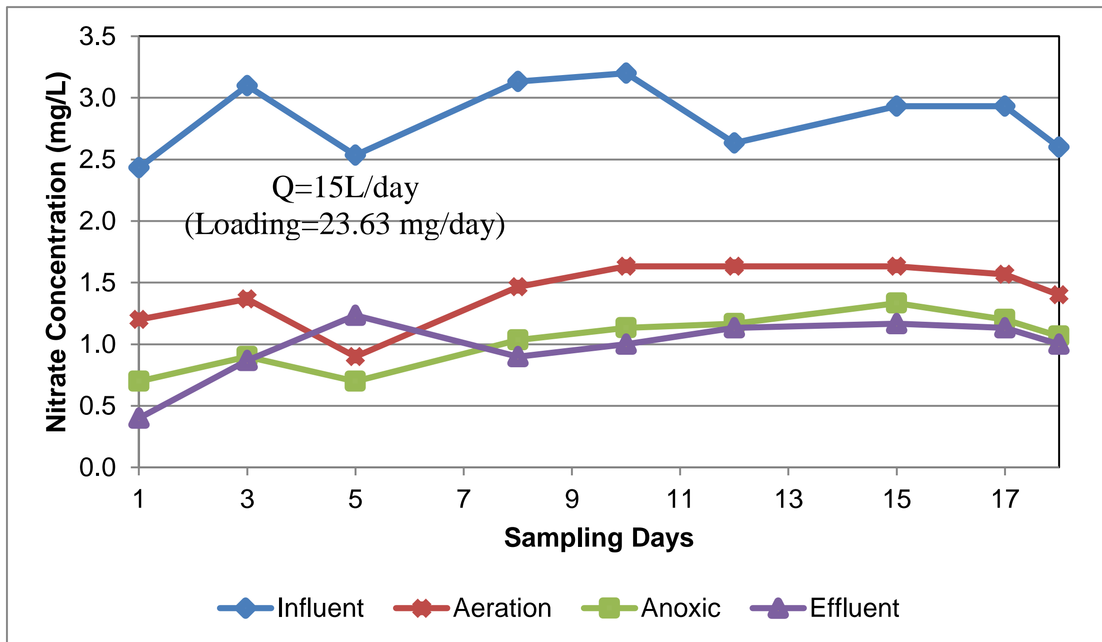


Figure 22: Graph of Nitrate Concentration VS Sampling Days (Second Phase)

Based on both graphs, fluctuation occurs from day 1 to day 8 due to bacteria activity that is adapting to the new environment. After day 8, the average value at each point seems to be stable and thus can be averaged. Roughly, the pattern of reduction of the Nitrogen in the system is almost the same like previously (without attached growth system). However, there is slight difference in term of numbers of the value recorded.

Table 13 shows the overall average reduction and average reduction from compartment to next compartment of both Ammonia and Nitrate for this system; reactor with attached growth system. From the results shown, the system is able to reduce the Nitrogen content, and all the explanation towards the bacteria activity is actually almost the same with the previous system. Also, because no control towards the Carbon source and alkalinity, the reduction of the Nitrogen still not accurate. This might be the only reason why the effluent of Ammonia does not meet the limit, other than due to lack of Oxygen. Nevertheless, the comparison for the reduction value will be discussed further in next section.

Table 13: Average reduction of Ammonia and Nitrate during second phase

Influent	**15 L/day**					
Reduction of	**Ammonia**			**Nitrate**		
Compartment	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**	**Average reading (mg/L)**	**Reduction (%)**	**Overall reduction (%)**
Influent	26.5	-	29.8	2.1	-	47.6
Aeration	19.7	25.7		1.6	23.8	
Anoxic	18.7	5.1		1.2	25	
Effluent	18.6	0.5		1.1	8.3	

4.3.3 Comparison for both system

Based on the plotted graph and analysis done to both systems in the previous section, now the comparison towards the performance can be done. **Table 14** shows the comparison of the percentage reduction by each compartment in both reactors while **Table 15** shows the summary of the overall reduction of Nitrogen.

Table 14: Percentage of reduction by compartment in both reactors (15 L/day)

Reduction of	**Compartment**	**Reduction (%)**		**Difference (%)**
		1st-phase	**2nd-phase**	
Ammonia	**Aeration to Anoxic**	30.18	25.7	-4.5
	Anoxic to Clarifier	2.7	5.1	+2.4
Nitrate	**Aeration to Anoxic**	19.0	23.8	+4.8
	Anoxic to Clarifier	64.7	25	-39.7

Table 15: Overall reduction during first and second phase

Influent Constituent	15 L/day			
	1st-phase		2nd-phase	
	Average Final effluent (mg/L)	**Overall removal (%)**	**Average Final effluent (mg/L)**	**Overall removal (%)**
Ammonia	17.4	34.3	18.6	29.8
Nitrate	0.4	80.9	1.1	47.6

From both tables, the comparison can only be done to one flowrate; 15 L/day due to time limitation to change the flowrate back to 10 L/day. It can be seen from **Table 14** that the difference in the reduction had been tabulated in the most right column. The difference were calculated based on the value obtained in the first phase reactor in order to assess either they are performing better than the second phase reactor or not. Generally, the pattern shows that for every positive increment towards the Ammonia reduction there will be negative increment towards the Nitrate reduction and vice versa. Also it can be concluded, that the Aero-packer provides less efficiency in Nitrate removal rather than Ammonia removal. While the Bio-balls on the order hand, provide better environment for Ammonia removal compared to Nitrate removal.

Next, from **Table 15** it can be observed that the average Ammonia and Nitrate effluent for the first phase is more than during the second phase where difference in the percentage reduction from both reactors is 4.5% and 33.3% for Ammonia and Nitrate respectively. This suggests that the reactor with attached growth system does not contribute to the enhancement of the Nitrogen removal as a whole. One main reason could be the lack of alkalinity and Carbon source since they are the special driving force needed in the system. The other requirement such as nutrient and COD had been tested to be sufficient for the bacteria growth as presented in **Table 6**. However, for the introduction of Aero-packer in the aeration compartment, the supply of oxygen might be affected and reduced. This had caused less ammonia removal observed.

Besides, the average effluent of the first phase reactor is already exceeding the limit stated in **Figure 3.** Therefore, the original condition of the system itself already sparks

some idea that it has to be fixed first. Nevertheless, the calculation towards the alkalinity and Carbon source needed cannot be done for the time being due to technical problems faced. Additional finding shows that the source and quantity should be fairly determined first, because wrongly added materials will cause other problems especially towards the organics removal. As such, the additional of Calcium Carbonate in the system will increase the Carbonate ion which is one of the constituent for alkalinity, but can elevated turbidity due to precipitation (Hart, 2008). Besides, the other type of alkalinity induced materials also sometimes quite expensive such as soda ash.

For Carbon source, the original plan of the experiment is to get the additional supply from the return activated sludge from the clarifier as illustrated in Error! Reference source not found.. Apart from adding more biomass in the system, it was also aimed to add more Carbon source for the denitrification to take place as suggested in Equation 9 and through promoting endogenous decay as in **Equation 3**. However, the assumption is considered insufficient considering the influent loading is too high for the system. Plus, the mitigation applied is actually works only for pre-denitrification system. A suggestion proposed is to add some part of the influent wastewater directly to the anoxic tank rather than from the clarifier. However, this addition could increase the Ammonia flux in the anoxic part and complication could happen to further treating the water. Besides, the addition of external Carbon source such as methanol needs further investigation towards the capital cost and safety issue in handling the chemicals. Thus, the determination towards the best option should be done before any change is done towards the system.

Previously, author has stated a few things regarding the determination of alkalinity for the system. In order to determine the additional alkalinity needed, the influent alkalinity and TKN had been measured for several times. However, the results obtain is not consistent and misleading. Due to time limitation, cost, and complexness of the experiment, only 3 TKN test managed to be done. **Table 16** shows the alkalinity used up and alkalinity to be added in the system, calculated based on the measured influent TKN and alkalinity.

Table 16: Alkalinity used up and Alkalinity to be added

Sampling day	Sample	Influent TKN (mg/L)	Average TKN (mg/L)	Alkalinity used up (mg/L)	Alkalinity to be added (mg/L)
3	1	441	441	3023	3043
	2	Nil			
9	1	2458	2797	19845	19865
	2	3135			
22	1	1555	1840	13012	13032
	2	3007			
	3	2125			
	4	7089			
	5	7691			

From the table, it can be seen the reading of TKN is not consistent, even towards the same test, same sample itself. For example, at 9th day of sampling the value of TKN gave a difference to 677 mg/L which is unacceptable to be included in the calculation. Nonetheless, both values still be included and averaged since it is not easy to obtain the results and to prove that there is something wrong with the experimental equipment. Also, when comparing the average value between the TKN of different days, the lowest value give 441 mg/l while the highest is 1840 mg/L which give difference of 1399 mg/L. As a conclusion, the value of the alkalinity cannot be determined yet due to this problem.

4.3.4 Formulation of Nitrification Kinetics, K

The nitrification kinetics was calculated based on the value of substrate consumed by the biomass and effluent Ammonia observed in the system. For the value in y-axis, they were calculated based on the difference of influent and effluent Ammonia divided by the volume of MLVSS produced in the aeration tank. The points were then plotted with respective value of effluent Ammonia. Next, the slope of the graph was calculated in order to obtain the nitrification kinetics by which only reactor without attached growth system can be used in defining the nitrification kinetics since there were two different loading used in the system. The nitrification kinetics in the second phase reactor cannot be calculated because the slope cannot be obtained if there is no difference in value plotted. **Figure 23** shows the specific substrate removal rate versus

effluent Ammonia in the first phase reactor. The slope of the graph indicates k which is the nitrification kinetics.

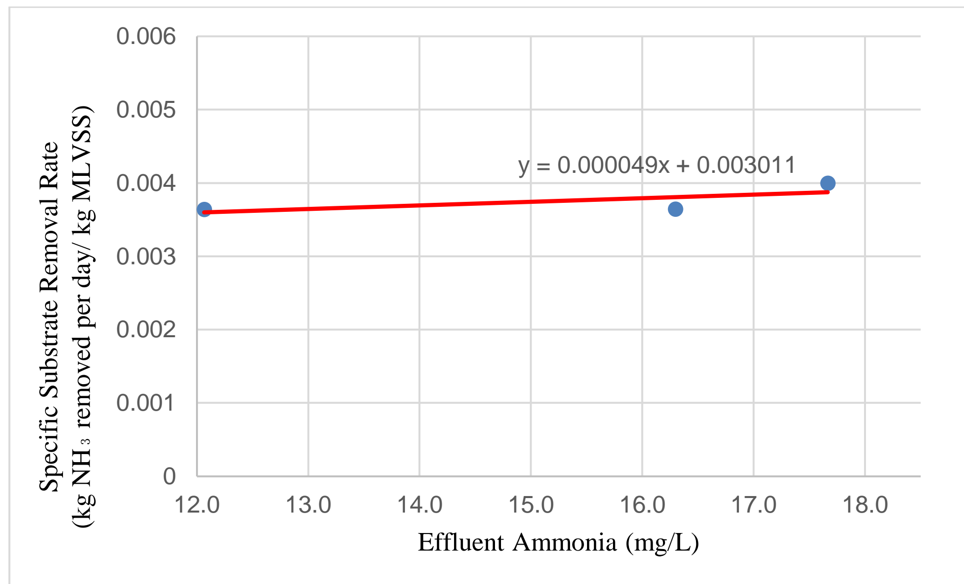


Figure 23:Specific subtrate removal rate vs effluent Ammonia

From the graph, the slope observed is 0.000049, which is close to 0. This shows that there are lack of nitrifiers in the system and strengthen by the fact that not much difference observed in effluent Ammonia produced between two different loadings as tabulated in **Table 11**. Even so, the value still shows that nitrification still happen in the system.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The first part of the Final Year Project (FYP1) had been ceased with some findings to be used in the second part of the FYP (FYP2). Student manages to formulate the synthetic wastewater and set up the reactor. The ingredients to make the synthetic wastewater are 1.5 g of grinded dogs' food and 150 g of Ammonium Chloride powder in 1 L of tap water. The recycle rate for the return recycle sludge was set to be done every one and half an hour consecutively with flowrate of 35 L per day, for one minute each time the pump is turned on, that will make 0.0243 L/min.

In the second part of the project which commenced on May 2013 Semester, the works were divided into two phases. The first phase was monitoring the performance of the reactor without the installation of attached growth media, while the second phase was with the attached growth media. For the first 35 days the reactor was run as the first case scenario, with two different influent flowrate of 10 L/day and 15 L/day. The average final effluent for 15 L/day flowrate were 17.4 mg/L of Ammonia concentration and 0.4 mg/L Nitrate concentration. This gave 34.3% and 80.9% for Ammonia and Nitrate reduction respectively. For 10 L/day of flowrate, it gave average effluent of 17.8 mg/L and 0.5 mg/L of Ammonia and Nitrate respectively, with percentage of reduction of 32.8% and 76.2%.

The next 18 days, the reactor was run with the installation of the attached growth media with an influent flowrate of 15 L/day. The results show average effluent concentration of 18.6 mg/L and 1.1 mg/L of Ammonia and Nitrate concentration respectively. These gave 24.8% and 47.6% of removal rate respectively. Therefore, by comparing the percentage of reduction for both reactors of the same flowrate of 15 L/day, the objective to enhance the Nitrogen removal by using attached growth system was not achieved. The percentage of reduction in the reactor of the first phase is higher than the later one.

However, the conclusion was made irrespective to the control towards alkalinity and Carbon source since they cannot be determined yet due to technical problems. Thus, the recommendation proposed is to make further study on how to accurately add the additional alkalinity and Carbon source so that the performance of the CEAR can be optimized.

For the formulation of nitrification kinetics, the plotted graph gave a **k** value of 0.00049 which is almost a negligible value. Nonetheless, the results show that there are nitrification happen but the amount of nitrifiers is low.

5.2 Recommendation

Due to the uncertainties in the value of TKN and eventually the value of alkalinity to be added, the first recommendation would be focusing on the method to obtain such values. The TKN values should first be determined in order to calculate the alkalinity needed. Because the equipment in the environmental laboratory seems to be inaccurate, the test should be done in order laboratory. Other than that, the test also can be done by using different set of equipment bought from the market, but then a lot of money will be needed. Thus, the best option is to search for other available equipment in laboratory of other department first. The most probable laboratory is at UTP chemical engineering department. Next, if the equipment also does not give significant results, then the test needs to be done outside, as such in other university.

Following that, the assessment towards the type of chemicals to be added also needs to be done. Some of the criteria need to be assessed is the economic wise, safety in handling, and availability in the market. Also, the effect towards other parameters in the wastewater need to be added since the reactor is an integrated reactor that aimed to treat a lot of constituents. The example of the chemicals that can be added will include quick lime, hydrated lime and caustic soda. The same procedure goes for the Carbon source need to be added in the system by which the normal practice is either to add methanol, ethanol or acetate. A research done showing the denitrification rates with the addition of ethanol, acetate, and methanol reached up to 9.6, 12, and 3.2 mg N/(g VSS_h), respectively (Zhen, MA, & Wang, 2007). The other recommendation would be to monitor on the oxygen supply in the aeration

compartment of CEAR. This is because, the Aero-packer might have blocked the oxygen to some part in the compartment, and inhibit the nitrification.

References

1.Takaya, N., Catalan-Sakairi, M., Sakaguchi, Y., Kato, I., Zhou, Z., & Shoun, H. (2003). Aerobic Denirifying Bacteria that Produce Low Levels of Nitrous Oxide. *Applied and Environmental Microbiology*, 3152-3157.

2. *Standard Methods for the Examination of Water and Wastewater.* (1998). New York: American Public Health Association.

3.(1999). Alkalinity. In *Standard Methods for the Examination of Water and Wastewater* (pp. 108-114). New York: American Public Health Association.

4.(2009). *Environmental Quality Sewage Regulation.* Malaysia: Department of Environmental.

5. *Environmental Quality Sewage Regulation.* (2009). Malaysia: Department of Environmental.

6. Babu, M. (2011). *Effect of Algal Biofilm and Operation Conditions on Nitrogen Removal in Wastewater Stabilization Pond.* Netherlands : Wageningen University.

7.Chae, S., Kang, S., Watanabe, Y., & Shin, H. (2006). Development of an innovative vertical submerged membrane bioreactor (VSMBR) for simultaneous removal of organic matter and nutrients. *Water Research*, 2161-2167.

8. Edward (Ned) C. Fiss, J. P. (2000). *Nitrogen Removal Alternatives for Industrial Wastewater.* AWARE Environmental Inc.

9. Foladori, P., Andreottola, G., & Ziglio, G. (2010). *Sludge Reduction Technologies in Wastewater Treatment Plants.* Italy: IWA Publishing.

10. Gerardi, M. H. (2003). *Nitrification and Denitrification in the Activated Sludge Process.* Wiley Publishers.

11. Godbole, A., & Chakrabarti, T. (1991). Biodegradation in upflow anoxic fixed film-fixed bed reactors of resorcinol, catechol and phenol in mono and binary substrates matrices. *Water Research*, 1113-1120.

12. Hart, V. (2008). Alkalinity Addition Utilizing Carbon DiOxide & Lime: Inexpensive Solution to a Historically Expensive Problem. *Florida Water Resources Journal*.

13. Karia , G., & Christian, R. (2006). *Wastewater Treatment: Concept and Design Approach.* PHI Learning. Ptd.Ltd.

14. Kedlec, R., & Wallace, S. (2008). *Treatment Wetlands, Second Edition.* Taylor & Francis.

15. Khan, S., Ilyas, S., Javid, S., C. Visvanathan, & V. Jegatheesan. (2011). Performance of suspended and attacheded growth MBR systems in treating high strength synthetic wastewater. *Bioresource Technology*, 5331-5336.

16. Khanitchaidecha, W., Shakya, M., Tatsuru, K., & Kazama, F. (2012). NH4-N Removal Through Nitrification and Hydrogenotrophic Denitrification in Simple Attacheded Growth Reactors. *Water Air Soil Pollution*, 3939-3953.

17. Kim, Y., Yang, C.-L., Scarano, F., Lewis, A., & Laolache, R. (2007). *Compact Fibre-Based Bioconversion/Bio-filtration System.* National Textile Center.

18. Kimura, K., Rie, N., Taro , M., Ryusuke, S., & Yoshimasa, W. (2008). Baffled membrane bioreactor (BMBR) for efficient nutrient. *Water Research 42*, 625-632.

19. Lenntech, B. (7 February, 2013). *Diagram of Activated Sludge Process*. Retrieved from Water Treatment Solutions - Lenntech: http://www.lenntech.com/wwtp/wwtp-activated-sludge-process.htm

20. Metcalf, & Eddy. (1991). *Wastewater Engineering; Treatment Disposal and Reuse.* New York: McGraw-Hill Education.

21. Metcalf, & Eddy. (2004). *Wastewater Engineering; Treatment and Reuse.* Mc Graw Hill.

22. Mogens, H., Loosdrecht, M., & Ekama, G. (2008). *Biological Wastewater Treatment - Principles, Modelling and Design.* IWA Publishing.

23. Przytocka-Jusiak, M., Baszczyk, M., Kosińska, E., & Bisz-Konarzewska, A. (1984). Removal of Nitrogen from Industrial Wastewater with the Use of Algal Rotating Disks and Denitrification Packed Bed Reactor. *Water Research 18*, 1077-1082.

24. Sani, F. A. (2012). Compact Extended Aeration Reactor - Study on Nitrogen Removal. Perak, Malaysia: Universiti Teknologi PETRONAS.

25. Wang, L., Pereira, N., & Hung, Y.-T. (2009). *Biological Treatment Processes.* Springer: Humana Press.

26. Wu, H., Kong, H., Liu, T., & Xia, M. (2006). Performance of Combined Process of Anoxic Baffled Reactor - Biological Contact Oxidation Treating Printing and Dyeing Wastewater. *Bioresource Technology*, 1501-1504.

27. Zhen, P. Y., MA, Y., & Wang, S. (2007). Denitrification Potential Enhancement by Addition of External Carbon Sources in a Pre-Denitrification Process. *Journal of Environmental Sciences 19*, 284-289.

APPENDIX I

APPENDIX II

Excel spreadsheets to calculate Synthetic Wastewater

1.Determine the theoretical and design SRT

a.Find theoretical SRT using equation (7-37)

SRT = 1/μn

μn = 0.12 g/g.d (assume T = 12˚C) (1)

SRT = 35.00 d

b.Determine the design SRT using eq (7-71)

FS = TKN peak/ TKN average

= 1.5 (where to get this value) (2)

Design SRT= (FS)(theoretical SRT)

= 52.5 day

2. Calculate Px,bio based on:

Xvss . V = Px,bio . SRT *Px,bio = Px,vss

Xvss = assume to be 4000 g/m3 or mg/L

V = 0.01 m3

Thus, Px,bio = 1.143 g/d *for theoretical SRT

= 0.762 g/d *for design SRT

3.Determine Q using equation (8-15), Parts A,B and C

a. Determine using theoretical SRT

$P_{x,bio} = ((QY(S_o - S))/((1+(K_d)SRT)) + ((f_d)(K_d)Q(Y)(S_o - S)SRT)/((1+(K_d)SRT)) + ((QY_n(NO_x))/(1+(K_{dn})SRT))$

b.Define input data for the above equation

			Ks =	20	g/m^3				
Y =	0.4	VSS/gbCOD	SRT =	52.5	day	and	35.00	day
So =	224	g $bCOD/m^3$(step 1)	Yn =	0.12	g VSS/ g Nox				
kd =	0.088	g/g.d (step 2a)	Kdn =	0.06	g VSS/ g VSS.d				
μm =	3.5	g/g.d (step 2a)	TKN =	35	g/m^3				
			fd =	0.15					

c. Determine S from Eq (7-40) in Table 8-5

S = Ks [1 + (kd) SRT]/ SRT (μm - Kd) - 1

S = 0.7

Assume Nox ~ 80% (TKN)

Nox = 28 g/m^3

Y(So-S)/1+(Kd)SRT = 21.89323 (1)

(fd)(kd)(Y)(So-S)SRT/1+(Kd)SRT = 10.11467 (2)

Yn(Nox)/1+(Kdn)SRT = 1.083871 (3)

Total = 33.09177

Px,bio = 1.1 g VSS/d

Q (m3/d)	
0.01	0.330918
0.015	0.496377
0.025	0.827294

Q = 0.034536 m3/d

34.53599	L/d		0.05	1.654589

d. Determine using design SRT

$P_{x,bio}$ = $((QY(S_o - S))/ ((1+ (K_d)SRT)) + ((f_d)(K_d)Q(Y)(S_o - S)SRT/((1+(K_d)SRT)) + ((QY_n(NO_x))/(1+ (K_{dn})SRT))$

Y(So-S)/1+(Kd)SRT = (1)
15.89402

(fd)(kd)(Y)(So-S)SRT/1+(Kd)SRT = (2)
11.01455

Yn(Nox)/1+(Kdn)SRT = (3)
0.809639

Total = 27.71821

Px,bio = 0.8 g VSS/d

Q =	0.027488	m3/d
	27.48752	L/d

4. Determine the amount of Nitrogen oxidized to Nitrate.

Ne= effluent NH4-N concentration = 0.5 g/m3

Nox = TKN -Ne -0.12 Px,bio
/Q
= 30.52899 g/m3

*will be based on experiment

5.Determine F/M and BOD volumetric loading

F/M = g BOD/ g MLVSS

=	0.0475	TRUE	*will be based on experiment

COD TEST

TEST 1			
Material Weight:			
3.5g/L			
3.6g/L			
3.7g/L			
sample:	10	ml	
dilution:	1:100		
Sample Weight (g)	**COD(mg/L)**	**real COD(mg/L)**	**Note**
3.5g/L	195	19500	
3.6g/L	73	7300	shaked
3.6g/L	15	1500	not shaked
3.7g/L	18	1800	
TEST 2(3/4/2013)			
Material Weight:			
0.5g/L			
2.0g/L			
sample:	10	ml	
dilution:	1:100		
Sample Weight (g)	**COD(mg/L)**	**real COD(mg/L)**	**Note**
0.5g/L	10	1000	
2.0g/L	27	2700	

BOD TEST **TEST 1**						
influent	3.5 g/l					
	3.6 g/l					
	3.7g/l					
no dilution						
Sample	**sample added(ml)**	**DO Reading(mg/l)**		**Diff.(mg/l)**	**Average (mg/l)**	
		Initial	**Final**			
Blank	only aerated water	8.73	8.34	0.39	0.31	
		8.82	8.44	0.38		
		8.79	8.64	0.15		
3.5g/l	10	8.78	0.14	8.64	8.70	
		8.85	0.12	8.73		
		8.85	0.11	8.74		
3.6g/l		8.83	0.13	8.70	8.67	
		8.72	0.11	8.61		
		8.82	0.11	8.71		
3.7g/l		8.85	0.10	8.75	8.74	
		8.84	0.11	8.73		
		8.83	0.10	8.73		
TEST 2						

influent	0.5g/l					
	2.0g/l					
Sample	**Dilution**	**Sample Added(ml)**	**DO Reading(mg/l)**		**Diff.(mg/l)**	**Average (mg/l)**
			Initial	**Final**		
Blank(0.5g/l)	none	only aerated water	8.96	13.16	-4.20	-4.26
			9.03	13.25	-4.22	
			9.03	13.40	-4.37	
0.5g/l	1:10	2	9.04	12.62	-3.58	-3.66
			9.06	12.92	-3.86	
			9.10	12.65	-3.55	
		5	9.08	11.91	-2.83	-3.42
			9.07	12.60	-3.53	
			9.07	12.96	-3.89	
		10	9.07	11.57	-2.50	-3.18
			9.03	12.31	-3.28	
			9.00	12.77	-3.77	
	1:100	2	9.06	13.68	-4.62	-4.52
			9.03	13.55	-4.52	
			9.08	13.51	-4.43	
		5	9.08	13.17	-4.09	-4.13
			9.08	13.27	-4.19	
			9.09	13.21	-4.12	
		10	9.02	12.80	-3.78	-4.16
			9.00	13.43	-4.43	
			9.01	13.27	-4.26	
Blank(2.0g/l)	none		8.79	9.35	-0.56	-0.41

		only aerated water	8.88	9.33	-0.45	
			8.89	9.11	-0.22	
2.0g/l	1:10	2	8.84	9.51	-0.67	-0.21
			8.91	8.76	0.15	
			8.83	8.93	-0.10	
		5	8.82	4.33	4.49	2.42
			8.92	7.46	1.46	
			8.93	7.63	1.30	
		10	8.91	8.34	0.57	1.21
			8.80	8.12	0.68	
			8.90	6.52	2.38	
	1:100	2	8.84	9.01	-0.17	0.15
			8.85	8.45	0.40	
			8.82	8.60	0.22	
		5	8.84	9.78	-0.94	-0.91
			8.81	9.67	-0.86	
			8.81	9.74	-0.93	
		10	8.78	9.56	-0.78	-0.72
			8.81	9.52	-0.71	
			8.77	9.44	-0.67	

AMMONIA AND NITRSTE NITROGEN TEST

Material Weight: 0.5 g dogs' foods 150 mg Ammonium Chloride sample: dilution:	 25 1:20	 ml	
Sample Weight (g)	**(mg/L)**	**real Ammonia(mg/L)**	**Average (mg/L)**
0.5 g	1.35	27	
0.5 g	1.36	27.2	
0.5 g	1.34	26.8	27

Material Weight: 0.5 g dogs' foods 150 mg Ammonium Chloride sample: dilution:	 25 1:10	 ml	
Sample Weight (g)	**(mg/L)**	**real Nitrate(mg/L)**	**Average (mg/L)**
0.5 g	0.05	0.5	
0.5 g	0.04	0.4	
0.5 g	0.06	0.6	0.5

AMMONIA TEST (WITHOUT ATTCH GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
1	5/21/2013	1	30.4	27.9	11.8	11.1	9.6	8.9	8.4	8.1
		2	27.2		10.4		8.8		8.2	
		3	26.2		11.0		8.2		7.8	
2		1								
		2								
		3								
3	5/23/2013	1	26.2	26.0	12.0	11.9	8.0	8.2	8.4	8.3
		2	25.8		11.6		8.2		8.5	
		3	26.0		12.0		8.4		8.1	
4		1								
		2								
		3								
5		1								
		2								
		3								
6		1								
		2								
		3								
7		1								
		2								
		3								
8	28-May	1	29.4	29.0	13.6	12.7	11.0	11.1	12.0	11.7
		2	28.6		12.5		11.0		11.4	
		3	29.0		12.8		11.2		11.8	
9		1								
		2								
		3								

10	5/30/2013	1	26.8	26.4	13.0	13.7	8.2	8.3	17.4	17.6
		2	26.0		13.8		8.2		17.8	
		3	26.4		13.6		8.4		17.6	
11		1								
		2								
		3								
12		1								
		2								
		3								
13		1								
		2								
		3								
14	6/3/2013	1	27.0	27.0	5.4	6.7	2.8	3.0	4.6	3.0
		2	26.8		7.0		3.2		3.2	
		3	27.1		6.4		3.0		2.8	
15		1								
		2								
		3								
16	6/5/2013	1	26.8	26.6	13.2	13.8	11.2	11.9	12.0	12.1
		2	26.5		14.0		11.6		12.2	
		3	26.6		13.6		12.2		12.0	
17		1								
		2								
		3								
18	6/7/2013	1	34.0	26.2	16.0	16.2	14.8	14.9	13.0	13.1
		2	26.0		16.4		15.0		13.2	
		3	26.4		16.2		15.0		13.0	
19		1								
		2								
		3								

20		1								
		2								
		3								
21	6/10/2013	1	25.4	25.6	15.6	16.4	14.6	14.7	13.0	13.0
		2	25.6		16.8		14.8		12.8	
		3	25.8		16.8		14.8		13.1	
22		1								
		2								
		3								
23	6/12/2013	1	26.0	26.0	15.0	15.3	14.8	14.3	13.2	13.2
		2	26.2		15.4		14.0		13.4	
		3	25.8		15.6		14.1		13.0	
24		1								
		2								
		3								
25	6/14/2013	1	25.0	25.4	15.6	15.7	14.8	14.6	13.4	13.1
		2	25.8		16.0		14.5		13.0	
		3	25.4		15.6		14.4		13.0	
26		1								
		2								
		3								
27		1								
		2								
		3								
28	6/17/2013	1	25.8	26.0	16.4	15.9	14.4	14.4	13.0	12.8
		2	25.9		16.0		14.8		12.8	
		3	26.4		15.4		14.0		12.5	
29		1								
		2								
		3								

30	6/19/2013	1	25.2	25.5	16.2	16.4	14.5	14.5	13.0	13.2
		2	25.8		16.4		14.2		13.5	
		3	25.4		16.5		14.8		13.2	
31		1								
		2								
		3								
32	6/21/2013	1	26.4	26.5	16.2	16.0	14.8	14.8	12.5	12.8
		2	26.2		16.0		14.7		12.8	
		3	26.8		15.8		15.0		13.0	
33		1								
		2								
		3								
34		1								
		2								
		3								
35	6/24/2013	1	26.2	26.2	16.4	16.4	14.4	14.1	13.4	13.3
		2	26.0		16.2		14.0		13.6	
		3	26.4		16.6		14.0		13.0	

NITRATE TEST (WITHOUT ATTACHED GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
1	5/21/2013	1	0.8	0.7	-1.4	0.0	-1.7	0.0	0.3	0.5
		2	0.5		-1.3		-1.8		0.7	
		3	0.8		-1.4		-1.7		0.5	
2		1								
		2								
		3								
3	5/23/2013	1	0.7	0.7	3.3	3.3	3.4	3.3	2.0	2.1
		2	0.8		3.2		3.2		2.2	
		3	0.7		3.5		3.3		2.1	
4		1								
		2								
		3								
5		1								
		2								
		3								
6		1								
		2								
		3								
7		1								
		2								
		3								
8	5/28/2013	1	1.2	1.0	0.2	0.2	1.7	1.7	1.8	1.8
		2	0.8		0.1		1.6		1.8	
		3	1.0		0.2		1.7		1.8	
9		1								
		2								
		3								

10	5/30/2013	1	1.5	1.4	1.2	1.5	1.5	1.5	1.6	1.7
		2	1.4		1.8		1.4		1.8	
		3	1.4		1.5		1.5		1.7	
11		1								
		2								
		3								
12		1								
		2								
		3								
13		1								
		2								
		3								
14	6/3/2013	1	1.3	1.6	1.2	1.4	0.8	0.9	0.7	0.9
		2	1.7		1.4		1.0		1.0	
		3	1.8		1.5		0.9		0.9	
15		1								
		2								
		3								
16	6/5/2013	1	1.5	1.5	1.1	1.0	0.8	0.9	0.5	0.4
		2	1.4		1.0		0.9		0.4	
		3	1.6		1.0		0.9		0.2	
17		1								
		2								
		3								
18	6/7/2013	1	1.7	1.5	1.2	1.2	0.8	0.7	0.3	0.3
		2	1.4		1.2		0.7		0.2	
		3	1.4		1.1		0.7		0.4	
19		1								-
		2								
		3								

20		1								-
		2								
		3								
21	6/10/2013	1	1.5	1.6	1.3	1.2	0.8	0.7	0.2	0.2
		2	1.6		1.2		0.7		0.3	
		3	1.6		1.1		0.6		0.1	
22		1								
		2								
		3								
23	6/12/2013	1	1.7	1.6	1.1	1.1	0.8	0.7	0.4	0.3
		2	1.7		1.0		0.8		0.3	
		3	1.5		1.1		0.6		0.3	
24		1								
		2								
		3								
25	6/14/2013	1	1.9	1.6	0.9	1.2	0.8	0.7	0.1	0.2
		2	1.5		1.3		0.6		0.2	
		3	1.3		1.4		0.6		0.3	
26		1								
		2								
		3								
27		1								
		2								
		3								
28	6/17/2013	1	1.1	1.5	1.1	1.1	0.4	0.6	0.2	0.3
		2	1.6		1.2		0.6		0.4	
		3	1.8		0.9		0.8		0.2	
29		1								
		2								
		3								

30	6/19/2013	1	1.3	1.7	1.3	1.2	0.6	0.7	0.4	0.4
		2	1.8		1.1		0.8		0.3	
		3	1.9		1.2		0.7		0.5	
31		1								
		2								
		3								
32	6/21/2013	1	1.5	1.5	1.0	1.0	0.6	0.5	0.0	0.1
		2	1.2		1.0		0.5		0.1	
		3	1.7		1.0		0.4		0.3	
33		1								
		2								
		3								
34		1								
		2								
		3								
35	6/24/2013	1	1.4	1.6	1.1	1.2	0.6	0.6	0.2	0.3
		2	1.6		1.2		0.6		0.5	
		3	1.8		1.4		0.5		0.3	

TOTAL PHOSPHORUS TEST (WITHOUT ATTACHED GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
3	5/23/2013	1	17.0	15.9	16.6	17.3	7.8	8.1	3.2	3.3
		2	16.0		17.2		8.4		3.3	
		3	14.6		18.0		8.2		3.5	
17	6/6/2013	1	11.6	12.0	7.4	7.6	7.0	7.2	6.6	6.3
		2	12.4		7.8		7.2		6.0	
		3	12.0		7.6		7.3		6.4	

AMMONIA TEST (WITH ATTACHED GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
1	08-07-13	1	25.8	26.0	16.4	15.9	14.4	14.4	13.0	12.8
		2	25.9		16.0		14.8		12.8	
		3	26.4		15.4		14.0		12.5	
2		1								
		2								
		3								
3	10-07-13	1	27.0	26.8	13.6	12.7	11.0	11.1	12.0	11.7
		2	26.5		12.5		11.0		11.4	
		3	27.0		12.8		11.2		11.8	
4		1								
		2								
		3								
5	12-07-13	1	26.8	26.4	13.0	13.7	8.2	8.3	17.4	17.6
		2	26.0		13.8		8.2		17.8	
		3	26.4		13.6		8.4		17.6	
6		1								
		2								
		3								
7		1								
		2								
		3								
8	15-07-13	1	28.5	27.4	22.0	21.9	21.0	19.7	19.6	20.0
		2	27.3		22.4		19.6		19.8	
		3	26.5		21.2		18.6		20.6	
9		1								
		2								
		3								

10	17-07-13	1	27.5	26.6	19.4	19.6	18.4	18.5	19.2	19.7
		2	26.8		20.0		18.0		19.8	
		3	25.5		19.2		19.0		20.0	
11		1								
		2								
		3								
12	19/7/13	1	27.2	27.1	19.0	20.0	19.2	19.1	19.8	18.7
		2	27.4		20.0		18.8		18.8	
		3	26.8		20.0		19.2		17.6	
13		1								
		2								
		3								
14		1								
		2								
		3								
15	22/7/13	1	27.5	27.1	20.0	19.9	18.2	18.4	18.2	18.2
		2	26.7		19.0		18.4		18.0	
		3	27.0		20.8		18.6		18.4	
16		1								
		2								
		3								
17	24/7/13	1	27.2	26.0	20.0	19.4	18.8	18.5	18.2	18.3
		2	25.7		19.0		18.6		18.4	
		3	25.0		19.7		18.2		18.4	
18	25/7/13	1	26.9	25.8	20.0	19.7	18.7	18.5	18.5	18.3
		2	25.0		19.9		18.6		18.2	
		3	25.5		19.5		18.2		18.3	

NITRATE TEST (WITH ATTACHED GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
1	08-07-13	1	2.5	2.4	1.3	1.2	0.6	0.7	0.4	0.4
		2	2.6		1.1		0.8		0.3	
		3	2.2		1.2		0.7		0.5	
2		1								
		2								
		3								
3	10-07-13	1	3.0	3.1	1.2	1.4	0.8	0.9	0.7	0.9
		2	3.2		1.4		1.0		1.0	
		3	3.1		1.5		0.9		0.9	
4		1								
		2								
		3								
5	12-07-13	1	2.8	2.5	1.0	0.9	0.6	0.7	1.2	1.2
		2	2.5		0.9		0.7		1.1	
		3	2.3		0.8		0.8		1.4	
6		1								
		2								
		3								
7		1								
		2								
		3								
8	15-07-13	1	3.2	3.1	1.5	1.5	1.0	1.0	0.9	0.9
		2	3.2		1.7		1.1		0.8	
		3	3.0		1.2		1.0		1.0	
9		1								
		2								
		3								

10	17-07-13	1	3.1	3.2	1.6	1.6	1.0	1.1	1.1	1.0
		2	3.3		1.6		1.2		1.0	
		3	3.2		1.7		1.2		0.9	
11		1								
		2								
		3								
12	19/7/13	1	2.6	2.6	1.8	1.6	1.2	1.2	1.1	1.1
		2	2.8		1.6		1.2		1.1	
		3	2.5		1.5		1.1		1.2	
13		1								
		2								
		3								
14		1								
		2								
		3								
15	22/7/13	1	3.1	2.9	1.4	1.6	1.4	1.3	1.0	1.2
		2	2.5		1.6		1.3		1.2	
		3	3.2		1.9		1.3		1.3	
16		1								
		2								
		3								
17	24/7/13	1	2.9	2.9	1.6	1.6	1.2	1.2	1.2	1.1
		2	2.3		1.8		1.2		1.0	
		3	3.6		1.3		1.2		1.2	
18	25/7/13	1	2.9	2.6	1.2	1.4	0.9	1.1	1.0	1.0
		2	2.9		1.4		1.1		1.0	
		3	2.0		1.6		1.2		1.0	

TOTAL PHOSPHORUS TEST (WITH ATTACHED GROWTH MEDIA)

Day	Date	Sample	**Influent**	Average(mg/L)	**Aeration**	Average(mg/L)	**Anoxic**	Average (mg/L)	**Effluent**	Average(mg/L)
11	18/7/13	1	17.4	17.4	29.4	29.2	24.4	24.7	25.8	24.8
		2	17.4		29.0		25.0		23.8	
		3								
18	25/7/13	1	8.0	9.0	2.0	5.0	6.0	7.0	4.0	4.0
		2	10.0		8.0		8.0		4.0	
		3								