# COMPARISON OF PRODUCTION OF NUTRIENT IN THE ORGANIC DEGRADATION OF REFINERY THROUGH AEROBIC AND ANAEROBIC DIGESTION

by

Ny Vanneth

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

SEPTEMBER 2013

UniversitiTeknologi PETRONAS

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# CERTIFICATION OF APPROVAL

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BACHELOR OF ENGINEERING (Hons)
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Approved by,

_________________________________

(DR SHAMSUL RAHMAN B M KUTTY)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
SEPTEMBER 2013

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this report of the 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.

NY VANNETH

# ABSTRACT

The aim of this study is to investigate the different between the productions of nutrients within aerobic and anaerobic productions of nutrients within aerobic and anaerobic sludge digestion. Using biomass from clarifier of refinery wastewater, the analysis give a promising results. There are nitrification process in both reactors, and due to the experiments, anaerobic digester produce more nitrification than in aerobic digester. The retention time for both reactors is 362 hours. The characteristic of the sludge given from the refinery are as follows: nitrate = 1.5 mg/L of $NH_3$-N.

Ammonia = 15 mg/L $NO_3$-N and total alkalinity of 488 mg/L of $CaCo_3$. The comparison of the digestion in both reactors give the results as follow. Higher nitrification which expected to occurs by theory in aerobic digestion, but by the result, more nitrification occur in anaerobic digestion.

# ACKNOWLEDGEMENT

Foremost, I would like to extend my gratitude to my supervisor, DR Shamsul Rahman B M Kutty, for his acceptance as my supervisor, his continuous support, time patience, guidance, motivation, and immense knowledge.

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# CHAPTER 1: INTRODUCTION

## 1.1 Background of Study

Wastewater released by crude oil-processing and petrochemical industries are characterized by the presence of large quantities of oil products and chemicals (Gasim, Kutty, Isa, & Isa, 2012). Due to the incapability of total purification of the treatment systems within the refinery, this wastewater can become a serious threat to the receiving environment by its accumulation of toxic waste and other disinfection by-products to receiving streams (Hladik, Focazio, & Engle, 2014).

## 1.2 Problem Statement

### 1.2.1 Problem Identification

In Malaysia, Oil and Gas industry is considered to be more advance in term of its technology and devices especially in extracting crude oil from underground or beneath the ocean bed, and according to (Oil & Engineering, 2005). And according to (Sumi, 2005)the processing the crude oil from the rock and extracted into different type of oil, there are a lot of stages need to be undergo and all of these stages are producing the waste that contain a lot of harmful and toxic compound. In general, produced water are of high mineral content, containing total dissolved solids (TDS) concentrations in the range from 500-6,000 upwards to greater than 100, 000 mg/l for coal bed natural gas and conventional non-associated gas, respectively (Plaines, Hayes, Arthur, & Ok, 2004).

Its nutrient which is a by-products of refinery wastewater is very harmful to receiving environment such as nitrate and ammonia that cause severe damage to environment and living organism and also effect water quality (Francis-floyd, Watson, Petty, & Pouder, 2012; "Nitrates and Their Effect on Water Quality – A Quick Study : Wheatley River Improvement Group," n.d.). Studies have shown that refinery effluent that discharge into receiving environment results in the presence of high concentrations of pollution in the water and sediment. The toxicants have been shown to be toxic individually to different aquatic organisms. Pollution of the aquatic organisms and ultimately the entire ecosystem (Gasim, Kutty, & Isa, n.d.).

So that these sample of produced wastewater from the above oil production need to be treated properly so that it would not pose any harm to the people and environment after it is discharge into the natural water resource later. Terengganu refinery also have been working cautiously to ensure that the wastewater discharge into the river or sea is not harmful and safe in a local standard, yet it is believed that the treatment is not fully investigate as there is no record on the nutrients of the effluent of that discharge into the receiving environment and proper nutrient treatment has not been study.

A treatment and disposal of refinery wastewater becoming an undeniable problem, owning to it toxic nutrient contents that being disposed into receiving environment.

Aerobic and anaerobic digestion are considered a popular measures for treatment of refinery biomass, however there is no proper investigation on biodegradation of refinery biomass in aerobic and anaerobic digestion.

### 1.2.2 Significant of the Study

The result from the analysis of this experiment will be a key to help the decision maker for choosing the system of treatment whether in aerobic sludge digester, aerobically or anaerobically and the efficiency of the treatment. Besides that, investigation would provide lot of advantages that can be obtained such as:

#### *1.2.2.1 Reduced Capital Costs of Expansion/Upgrading*

There will be cost saving for the treatment or the expansion/upgrading

#### *1.2.2.2 Overall improvement of the plant performance*

Applying this best practice will result in improved plant performance, and reduce the risk of noncompliance with either effluent quality requirements or bio solids quality regulations.

#### *1.2.2.3 Reduced Operating Cost*

By reducing the amount of excessive chemical use, and also energy use through the treatment process optimization, the operating cost surely can be significantly reduced.

## 1.3 Objectives

The objectives of the research are the characterization of refinery biomass, the determination of alkalinity due to biodegradation of refinery wastewater in aerobic and anaerobic stage, the analyzing the biodegradability of removal efficiency of ammonia, nitrogen, and alkalinity and the investigation of the efficiency of both aerobic and anaerobic measures.

## 1.4 Scope of Study

The study will focus on aerobic and anaerobic wastewater treatment by using aerobic sludge digestion through aerobic and anaerobic processes. It involves the nutrient characterization of the refinery wastewater such as the Ammonia, Nitrate, Content and others organic characterization such as Chemical Oxygen Demand, MLVSS, MLSS.

## 1.5 Relevancy of the Project

This project can be a huge impact for industry implementation as it products are being constantly produced and this will lead to the production of wastewater that discharge into the environment. It is really unfortunate if the operator did not investigate in details the methods of treatment that operate most effectively. By comparison and investigation of the production of nutrient, it would help in decision making for modification or implementation new system. The research work will cover two semesters starting from May to December 2013 which is sufficient to collect data and analyze the result.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Introduction

In the refinery of crude oil, 240 to 340 *l* of water are used to process one barrel of crude oil, and this amount of water is equivalent between 0.4 to 1.6 times the volumes of oil processed. Within this wastewater, there are some contamination, and harmful substance such as carbon, nitrogen, phosphorus and other toxic microorganism (Lacerda et al., 2011).

Many of the processes in a petroleum refinery use water, however, not each process needs raw or treated water, and water can be cascaded or reused in many places (Practice, 2010). The same source also gives an overview of refinery water balance as shown in (Figure 1) below.

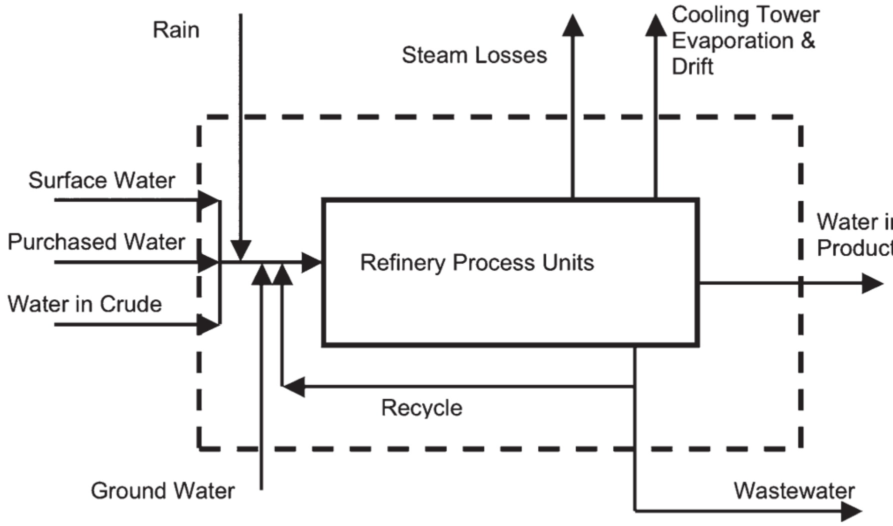


Figure 1. A schematic example of the typical water balance in a refinery

Wastewater in sewerage refers to wastewater that is generated in kitchens, locker rooms and washrooms in the refinery. At many locations the sewerage is combined with the wastewater generated in the refinery and sent to the wastewater treatment plant (Practice, 2010).

For typical refinery wastewater treatment plants consist of preliminary, primary and secondary oil/water separation, followed by biological treatment, and tertiary treatment (if necessary). A typical refinery wastewater treatment system is shown in (Figure 2). The main purpose of wastewater treatment is to remove all contaminated and harmful substance to reach an acceptable standard (Metcaf & Eddy, 2004) before discharge into receiving environment.

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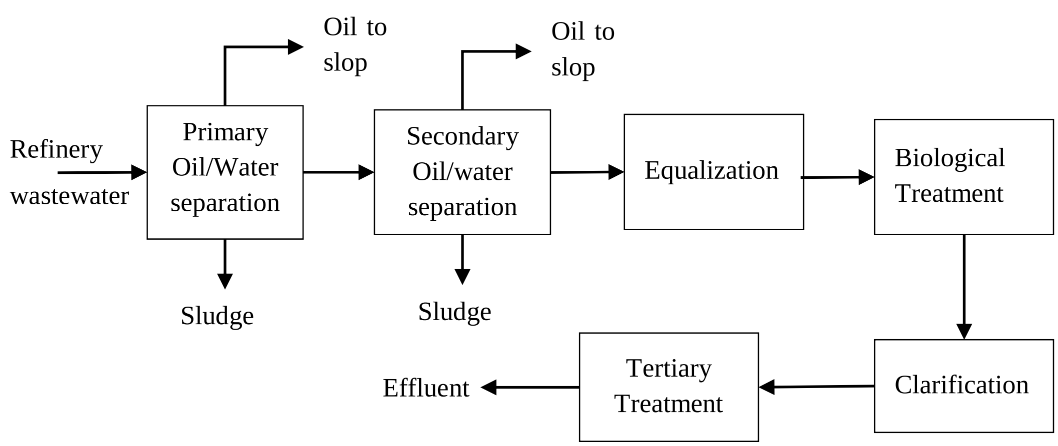


Figure 2: Typical refinery wastewater treatment

In the secondary treatment, there is a process of removal biodegradable organic matter (in solution or suspension) and suspended solids. For conventional secondary, disinfection is also included in its definition.

And in this research, the refinery biomass is collected from clarifier separation for the further analysis.

## 2.2 Aerobic & Anaerobic Digestion

Sludge need to be treated through variety of measures and techniques, the purpose of treating sludge is to remove biodegradable organics, suspended solids, and nutrients (nitrogen, phosphorus, or both nitrogen and phosphorus) (Metcaf & Eddy, 2004).

### 2.2.1 Aerobic Digestion

Before the discussion of various aerobic biological treatment process, it is important to briefly the terms aerobic and anaerobic. According to (Metcaf & Eddy, 2004), aerobic means in the presence of air (oxygen), therefore aerobic treatment processes take place in the presence of air and utilize those microorganisms (also called aerobes), which use molecular/free oxygen to assimilate organic impurities i.e. covert them in to carbon dioxide, water and biomass (Mittal, 2011) as shown in figure 3 below.

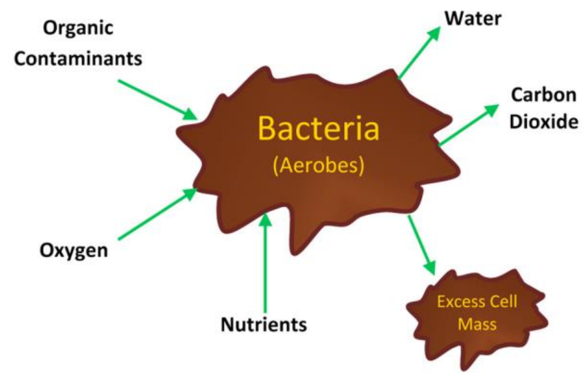


Figure 3: Aerobic Treatment Principle

This stage of the process is known as endogenous respiration (Shao, Wang, Li, Lü, & He, 2013). Solids reduction occurs in this phase as the bacteria need to eat each other to survive. According to (Metcaf & Eddy, 2004), considering the biomass wasted to a digester and the formula $C_5H_7NO_2$ is represent for cell mass of a microorganism, the biochemical changes in an aerobic digester can be described by the following equations:

Biomass destruction:

$$C_5O_7NO_2 + 5O_2 \rightarrow 4CO_4 + H_2O + NH_4HCO_3$$

Nitrification of released ammonia nitrogen:

$$NH_4^+ + 2O_2 \rightarrow NO_3 + 2H^+ + H_2O$$

Overall equation with complete nitrification:

$$C_5O_7NO_2 + 7O_2 \rightarrow 5CO_2 + 3H_2O + HNO_3$$

Using nitrate nitrogen as electron acceptor (denitrification):

$$C_5O_7NO_2 + 4NO_3^- + H_2O \rightarrow NH_4^+ + 5HCO_3^- + 2NO_2$$

With complete nitrification/denitrification

$$2C_5O_7NO_2 + 11.5O_2 \rightarrow 10CO_2 + 7H_2O + 2N_2$$

And for general case,

$$Biomass + O_2 \rightarrow Less\ Biomass + CO_2 + H_2O + NH_3$$

Theoretically, approximately 50 percent of the alkalinity consumed by nitrification can be recovered by denitrification.

Based on the research, aerobic digestion occurs much faster than the anaerobic digestion, hence it help to reduce the capital cost. Beside, high quality supernatant, also being produced and this process is much safer as there is no methane being produced and it is easy to operate. Nevertheless, the operating cost will be much higher because more energy is required to supply the aeration as oxygen is needed for the process and the digested sludge becomes more difficult to dewater.

The temperature of aerobic is similar to the room temperature, as it required oxygen, and the reactor tank is open. So in this research, the temperature of aerobic tank is same like the room temperature which is 24 ± 1 °C.

### 2.2.2 Anaerobic Digestion

The anaerobic treatment processes, on other hand take place in the absence of air (and thus molecular/free oxygen) by those microorganisms (also called aerobes), which use molecular/free oxygen to assimilate organic impurities i.e. The final products of organic assimilation in anaerobic treatment are methane and carbon dioxide gas and biomass (Metcaf& Eddy, 2004). Figure 4 depicts simplified principle of anaerobic process. The major applications of anaerobic digestion are in the stabilization of concentrated sludges produced from the treatment of wastewater.

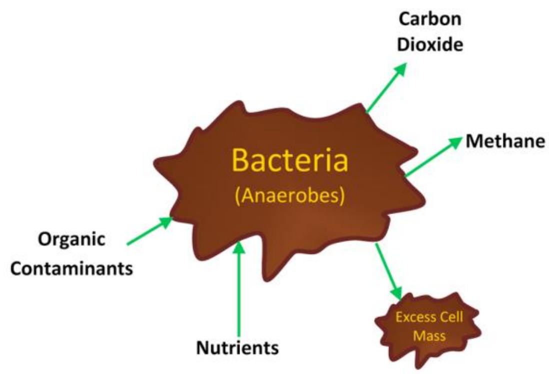


Figure 4: Principle of anaerobic process

High proportion of biogas is produced in the process and is being used to both heat the tank and run engines or micro-turbines for other on-site processes. In large treatment plants sufficient energy can be generated in this way to produce more electricity than the machines require. The methane took quite a long time and the capital cost also is high.

The temperature of 55± 1 °C because the sludge is going through thermophilic digestion in which sludge is fermented in tanks. And it also can be in mesophilic at temperature of around 36 °C (Mittal, 2011). But because due to a short amount of retention time, thus smaller tanks, thermophilic digestion consume more energy for heating sludge.

# CHAPTER 3: METHODOLOGY

The important of this chapter is to list out all necessary procedures and analysis for this project to be successfully conducted. It includes the related procedures step by step in order to achieve the main objectives and goals of the research project. This involved the characterization of the biomass sample, the operation of the both reactors, data collection, and data analysis.

## 3.1 Characterization of the Biomass Sample

Initial tests for the raw biomass is being conducted in the laboratory before running the digestion. A separation of supernatant from the suspended biomass is being conducted to ensure the clearance of the oil solution.

Those tests give the value of the pH = 7.8 below 8.3 and content of nitrate of 1.5 mg/L, ammonia content of 15 mg/L, and total alkalinity of 488 mg/L. The methodology of the test are to be detailed in below session.

## 3.2 The Operation of the reactors

In the operation of both reactors which operate aerobically and anaerobically, both reactors are being check using distilled water. This checking is too ensure all components in both reactors are running properly before the real reaction started, the checking is also to ensure that there is no leakage occurs which will affect the results afterward. The reactors which shown in Figure 5 below, are aerobic (left) and anaerobic (right). The different between these two reactors is that one is operated under the room temperature (24 to 25 degree Celsius) with the air circulation to provide oxygen (aerobic) and another which operate anaerobically without the circulation of air or oxygen under the temperature of 55 degree Celsius.

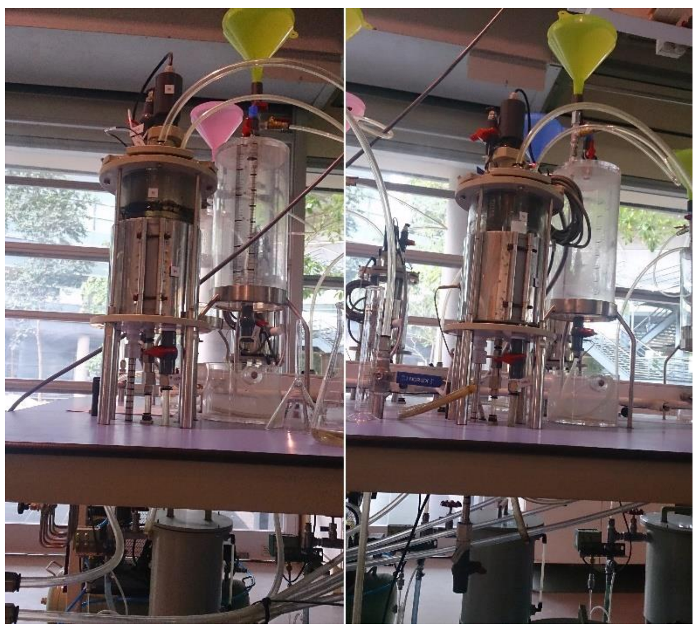

Figure 5: Aerobic (left) and Anaerobic (right) Sludge digesters

From the results collected, a graph for each nutrients that is being observed such as the $NH_3$-$NO_3$, and Alkalinity will be constructed respectively to see the pattern of the substance during the treatment of each sample. Charts, tables, and textual write-up of the data for each experiment will be included.

This methodology will include charts, tables, and textual write-ups of data. These methods are proposed to process and distill the data so that readers can assemble interesting information without needing to sort through all of the data on their own.

### 3.2.1 Sample Collection

100 mL of sample is collected every 1 (one) hour starting from the beginning of the reactions of both reactors until it reaches it first 24 hours period, than 100 mL of sample will be collected 24 hours continuously until there is all biomass are completely die off. The methodology of the reaction is brief in simply diagram as in Figure 6 below.

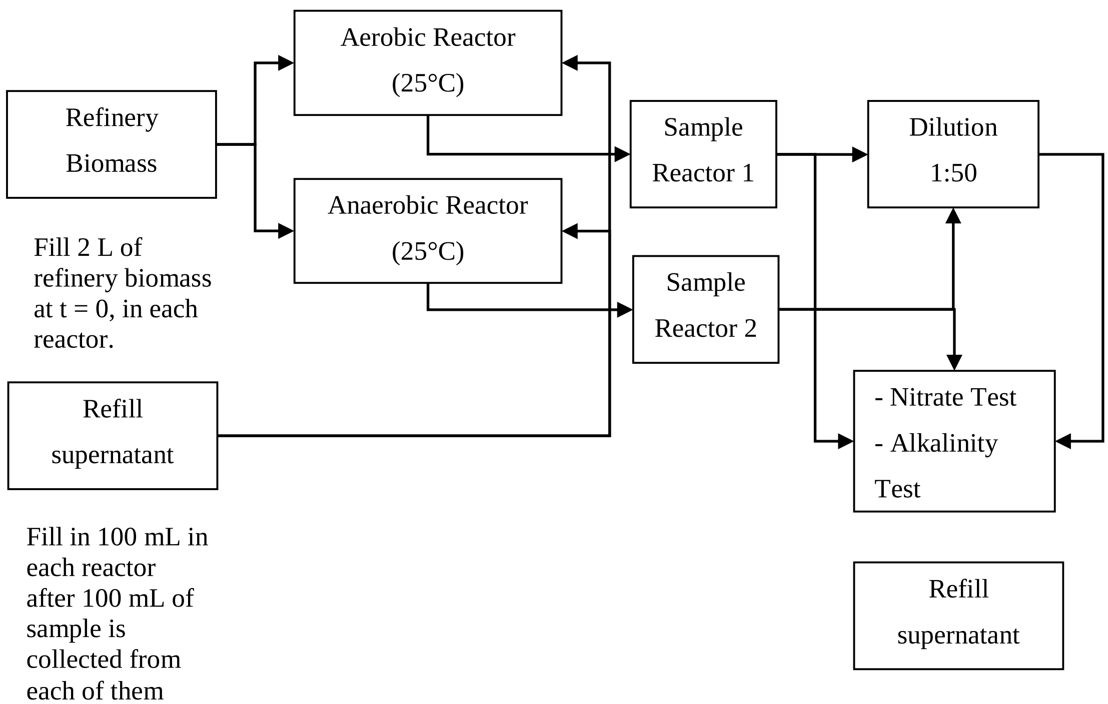


Figure 6: Complete reaction methods of the whole process

### 3.2.2 Nitrate Test

In this experiment, a nitrate test is being conducted right after the sample is collected. First of all, 30 mL is used from a 100 mL of each sample, and at the same time, start the Spectrometer (as shown in Figure 7.), and select the menu and choose program 355 N, Nitrate HR PP that range from 0.3 to 30 mg/L $NO_3$. For the sample, start preparing

3 (three) samples by filling 3 (three) square sample cells with 10 mL of sample each, follow by continue adding one package of Nitra-Ver-5 Nitrate Reagent Powder Pillow than the solution is shake for a about a minute for each sample. 10 mL of black sample is prepared by adding just the sample without any reagent powder.

After the preparation of the 3 (three) samples, and the blank, the cells are wiped clean before start the reading. The blank sample is used to zero the reading, follow by the three samples. To be clear, each sample is placed its face to the right of the reading.


Figure 7: Spectrophotometer DR 2800

### 3.2.3 Ammonia Test

This following test is conduct for analyzing the amount of ammonia within the sample. Due to high range of ammonia, a dilution of 1:50 is made to ensure the sample is in range of measure for ammonia. 1.5 mL of sample is used for the dilution of 75 mL of diluted sample for the triplicated sample. 75 mL of diluted sample are used to be filled into 25 mL mixing graduated cylinder to thee 25 mL mark with deionized water. After that, 3 (three) drops of mineral stabilizer is added to each cylinder, and is being mixed several time, before three drops of polyvinyl alcohol dispersing agent is being added to each cylinder and being mixed again. After that, 1 mL of Nessler reagent is being added into each cylinder, and mixed. For the blank sample, 25 mL of distilled water is being used and same amount of mineral stabilizer, polyvinyl alcohol dispersing agent, and Nessler Reagent.

After all the solution are mixed in each cylinder of the sample, 10 mL of solution is pour into a 10 mL square sample cell for measurement. The Spectrometer is started and program 380 N, Ammonia Ness is selected for the reading. All sample cell, include the blank sample celled is being wiped clean and start the reading. The blank is used to zero the reading.

### 3.2.4 Total Alkalinity Test

Check the pH of the sample, and as the above sample having pH below 8.3, it can categorize as stage 1.

Fill in a 50 mL of sample into 100 mL of beaker, start to put 3 drop of methyl orange, and the solution will turn orange. Fill in slowly acid sulfuric with 0.02 Normality, stop it when the solution turn to red. The calculation of Total Alkalinity is shown as below:

$$Total\ Alkalinity = \frac{(Final\ Volume - Initial\ Volume) * 0.02N}{Volume\ of\ Solution} * 50\ 000$$

## 3.3 Key Milestones

The Key Milestones of the entire project will be demonstrated in the below Figure 8.

**Problem Statement and Objective**

Identifying the main purpose of this research project

**Literature Review**

Research on related information as much as possible from various sources included books, journal papers, and websites

**Operation of the Aerobic Sludge Digester**

Bio Treating Wastewater Sample using Aerobic Sludge Digester

**Data Analysis and Interpretation**

The findings obtained are analyzed and interpreted critically. Comparison with other literature readings will also be done.

**Documentation and Reporting**

The details of this research project will be documented and reported. Discussion and recommendation will be analyzed based on the existing work

Figure 8 : Key Milestones

## 3.4 Gantt chart

| | Details /Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Primary Research Work | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Extended Proposal Defense Submission | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | Mid-Semester Break | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | Proposal Defense | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Project Work Continues | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Interim Draft Report Submission | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Interim Report Submission | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | Examination and Semester Break | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | Experimentation in the Lab | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | Progress Report Submission | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Project Work Continues | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | Pre-SEDEX | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | Submission of Draft Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | Submission of Dissertation (Soft bound) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | Submission of Technical Paper | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | Oral Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | Submission of Project Dissertation (Hard Bound | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 9: Gantt Chart

# CHAPTER 4: RESULT AND DISCUSSION

## 4.1 Results

The result will be divided into two main parts, is the hourly results and daily results. The test results has been listing down in Appendix I. Moreover the below graphical results are the results of the nitrate, ammonia, and alkalinity of both aerobic and anaerobic digestion.

### 4.1.1 Hourly Nitrate Production (within the first 24 hours)

For the first 24 of Nitrate production, a graph comparison is generated through the obtained data from the analysis as shown in Figure 10 below.

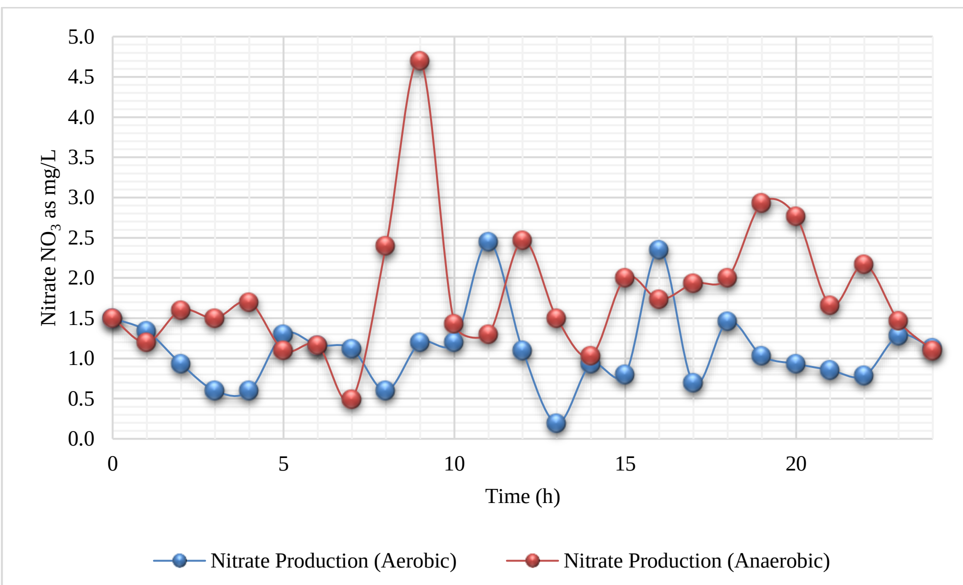


Figure 10: Hourly nitrate production (first 24 h) in aerobic and anaerobic digestion

In Figure above, the production of Nitrate in anaerobic is higher than the production of nitrate in aerobic digestion for the first 24 hours. The changing from original 1.5 mg of Nitrate within both reactors are significant low. For aerobic, there is some denitrification which reduce the amount of nitrate within the solution, while in anaerobic, nitrification occur during 10 -24 hours after reaction occurs.

### 4.1.2 Daily Nitrate Production

In the daily production of nitrate, a graph comparison is generated also through the obtained data in appendix I, and the generated graph is plotted in below Figure 11.

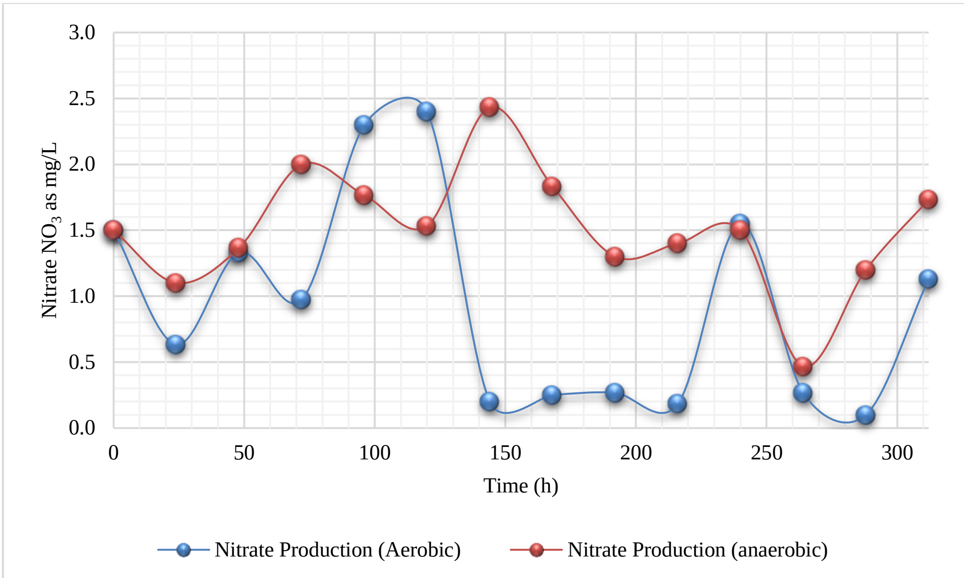


Figure 11: Daily nitrate production in aerobic and anaerobic digestion

In the above diagraph the nitrification still occurs in anaerobic and denitrification in aerobic. And at the end of the 392 hours, both reactors obtain a nitrate 0.1 mg/L and 0.1 mg/L for anaerobic and aerobic which mean there is reduction of nitrate.

### 4.1.3 Hourly Production of Alkalinity (within the first 24 hours)

For the first 24 of Total Alkalinity, a graph comparison is generated through the obtained data from the analysis as shown in Figure12 below.

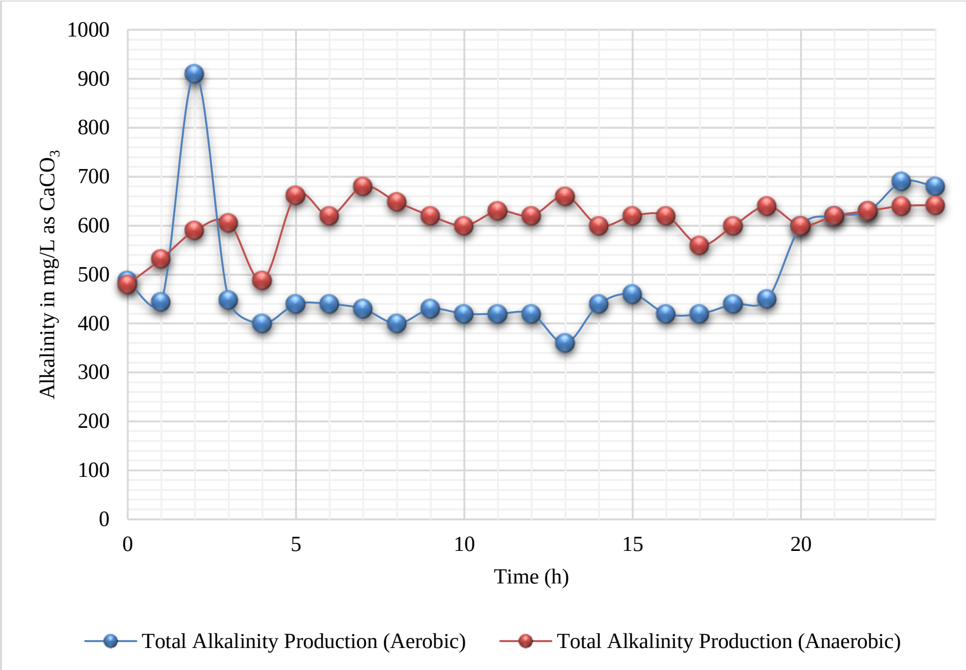


Figure 12: Hourly Total Alkalinity Production (first 24 h) in Aerobic and Anaerobic Digestion

The above graph suggest that there are production of alkalinity in anaerobic process more than aerobic process. But after 24 hours, the amount of alkalinity are increasing in both reactors, from 488 mg/L to 630 mg/L and 642 mg/L for aerobic and anaerobic process.

### 4.1.4 Daily Alkalinity Production

In the daily alkalinity production, a graph comparison for both reactions, aerobic and anaerobic are generated through the obtained data in appendix I, and the generated graph is plotted below in Figure 13.

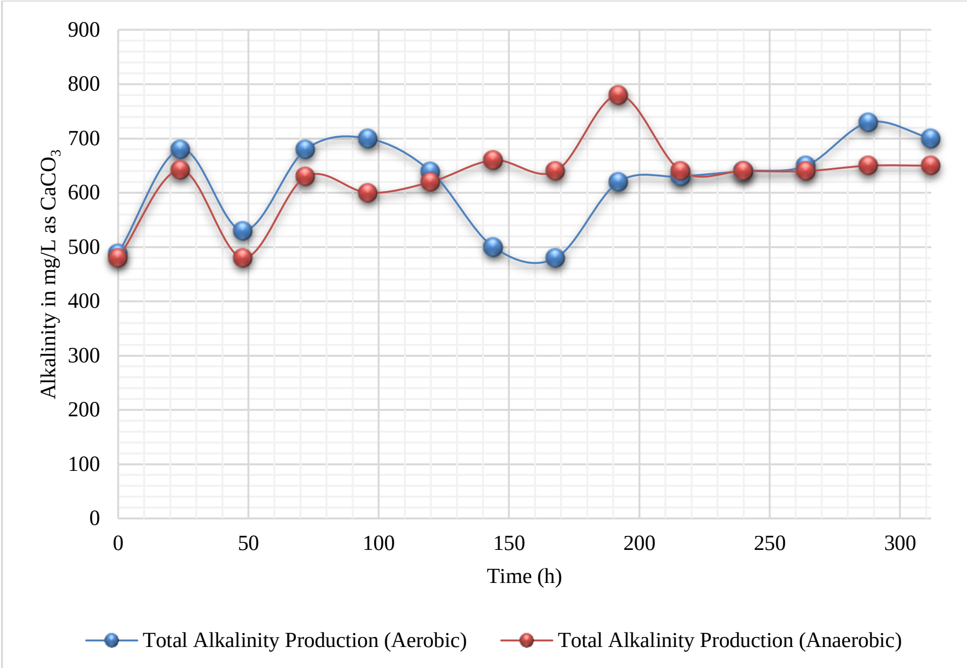


Figure 13: Daily total alkalinity production in aerobic and anaerobic digestion

Continue from the first 24 hours, the production of alkalinity are increasing continuously to 700 mg/L and 650 mg/L for aerobic and anaerobic reactors. The graph start to stabilize and reach a horizontal curve within 362 hours which mean there is no more active biomass within the reactors.

### 4.1.5 Hourly Ammonia Production (within the first 24 hours)

For the first 24 of Ammonia production, a graph comparison for aerobic and anaerobic are generated through the obtained data from the analysis as shown in Figure 14 below.

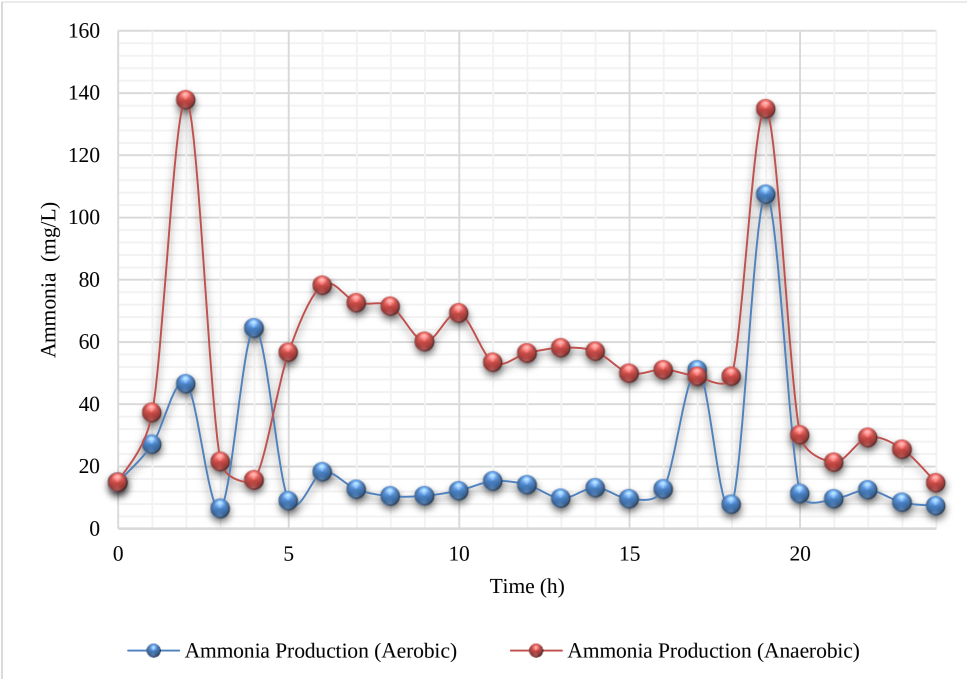


Figure 14: Hourly ammonia production (first 24 h) in aerobic and anaerobic digestion

Ammonia production are associated closely with the nitrate production, so in this graph, anaerobically produce more ammonia content within the first 24 hours and the amount of ammonia reduce at the end of the 24 hours from original 15 mg/L to 7.33 mg/L and 14 mg/L for aerobic and anaerobic process.

### 4.1.6 Daily Ammonia Production

In the daily production of ammonia, a graph comparison is generated also through the obtained data in appendix I, and the generated graph is plotted below in Figure 15.

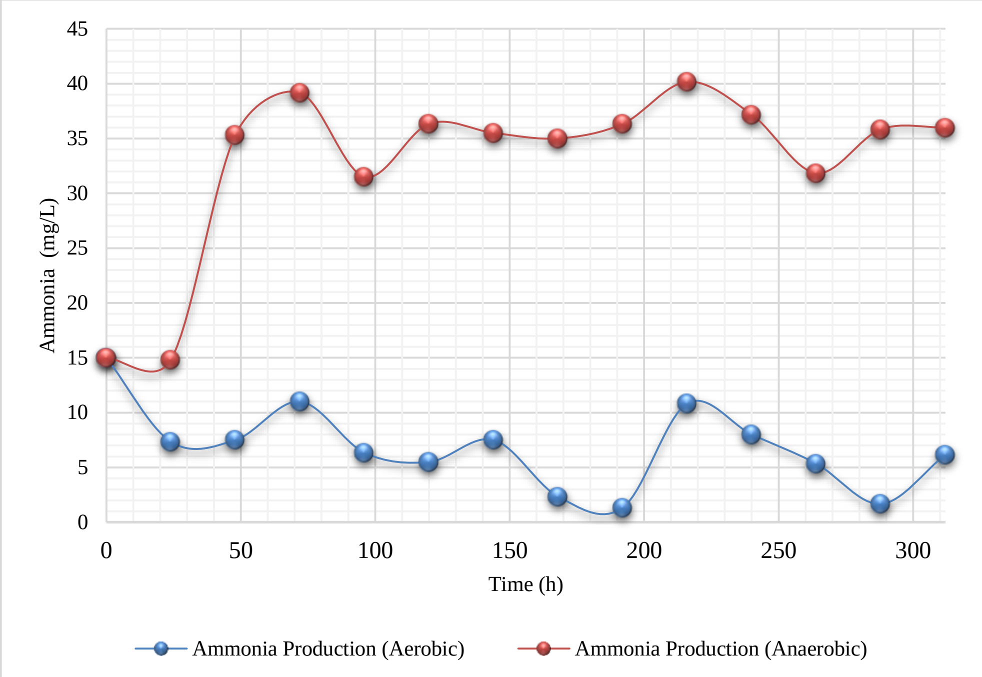


Figure 15: Daily ammonia production in aerobic and anaerobic digestion

In ammonia, huge different of ammonia production is created within the 392 hours that there is increasingly of ammonia production within anaerobic production and low production of ammonia production, which is 6.17 mg/L and 36 mg/L.

## 4.2 Discussions

The discussion of the research will be divided into 2 main parts. First of all, the hourly production of nitrate, ammonia, and alkalinity which shown in the above figure 9, 11, and 13. The characteristic of the sludge given from the refinery are as follows: nitrate = 1.5 mg/L of $NH_3$-N, ammonia = 15 mg/L $NO_3$-N and total alkalinity of 488 mg/L of $CaCo_3$.

In the first day of the reaction, there is some nitrification process occurring in anaerobic digestion reactor while there is some denitrification process occurring in aerobic digestion. There is also production of ammonia within anaerobic digestion better than in aerobic digestion. Together with the alkalinity.

While after the first day, or after 362 hours, when the biomass already eat themselves completely, the reaction within both reactors seem to be constant. There is no much change within the coming days or weeks, which lead to suggestion that the biomass already totally die within the first 362 hours.

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

As the experiment is being conduct within timeframe of 4 weeks, the results are to be consider very successfully as the objective of investigation of the sludge digestion in both method are fully compare.

However base on the research that have been conducted worldwide, it is believe that the objective of this research can be achieved successfully in the amount of longer time frame.

## 5.2 Recommendation

To achieve the objective of this project, there are some significant future works to be conducted such as site visit to refinery to collect the sample for the experiments, study how to be conducted the experiments with aerobic sludge digesters.

# CHAPTER 6: REFERENCES


Blika, P. S., Stamatelatou, K., Kornaros, M., & Lyberatos, G. (2009). Anaerobic digestion of olive mill wastewater, *11*(3), 364–372.

Francis-floyd, R., Watson, C., Petty, D., & Pouder, D. B. (2012). Ammonia in Aquatic Systems 1, 1–4.

Gasim, H. A., Kutty, S. R. M., & Isa, M. H. (n.d.). Biodegradability of Petroleum Refinery Wastewater in Batch Reactor, 1–4.

Gasim, H. A., Kutty, S. R. M., Isa, M. H., & Isa, M. P. M. (2012). Treatment of Petroleum Refinery Wastewater by using UASB Reactors, 174–177.

Hladik, M. L., Focazio, M. J., & Engle, M. (2014). Discharges of produced waters from oil and gas extraction via wastewater treatment plants are sources of disinfection by-products to receiving streams. *The Science of the total environment*, *466-467*, 1085–93. doi:10.1016/j.scitotenv.2013.08.008

Lacerda, L. M. C. F., Queiroz, M. I., Furlan, L. T., Lauro, M. J., Modenesi, K., Jacob-Lopes, E., & Franco, T. T. (2011). Improving refinery wastewater for microalgal biomass production and CO2 biofixation: Predictive modeling and simulation. *Journal of Petroleum Science and Engineering*, *78*(3-4), 679–686. doi:10.1016/j.petrol.2011.07.003

Metcaf & Eddy, I. (2004). *Wastewater Engineering, Treatment and Reuse*. (T. George, L. B. Franklin, & S. H. David, Eds.) (4th ed., pp. 1533–1545). Singapore: McGraw-Hill. Retrieved from www.mhhe.com

Mittal, B. A. (2011). Biological Wastewater Treatment, 2–9.

Nitrates and Their Effect on Water Quality – A Quick Study : Wheatley River Improvement Group. (n.d.). Retrieved from http://www.wheatleyriver.ca/currentprojects/wrig-pilot-nitrate-study/nitrates-and-their-effect-on-water-quality-a-quick-study/

Oil, M., & Engineering, G. (2005). Oil and Gas Industry in Malaysia – An Overview Malaysian Oil and Gas Engineering Consultants – Moving Forward, (January).

Plaines, D., Hayes, T., Arthur, D., & Ok, T. (2004). OVERVIEW OF EMERGING PRODUCED WATER TREATMENT TECHNOLOGIES.

Practice, B. (2010). Petroleum refining water / wastewater.

Shao, L., Wang, T., Li, T., Lü, F., & He, P. (2013). Comparison of sludge digestion under aerobic and anaerobic conditions with a focus on the degradation of proteins at mesophilic temperature. *Bioresource technology*, *140*, 131–7. doi:10.1016/j.biortech.2013.04.081

Sumi, L. (2005). Produced water from oil and gas production.

# CHAPTER 7: APPENDIX

Table 1: Test Analysis Results of Samples Collected from Aerobic Sludge Digestion

| Day | Hour | Nitrate($NO_3$) | | | | Alkalinity | | | | Ammonia*50 ($NH_3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Av. | Initial | Final | Final-Initial | Alkalinity | 1 | 2 | 3 | Av. | $NH_3$ |
| 1 | 0 | 1.21 | 1.71 | 1.58 | 1.50 | 1.00 | 25.40 | 24.40 | 488.00 | 0.20 | 0.20 | 0.50 | 0.30 | 15.00 |
| | 1 | 1.40 | 1.12 | 1.50 | 1.34 | 49.20 | 71.40 | 22.20 | 444.00 | 0.65 | 0.40 | 0.58 | 0.54 | 27.17 |
| | 2 | 0.93 | 0.92 | 0.95 | 0.93 | 2.00 | 47.50 | 45.50 | 910.00 | 0.93 | 0.92 | 0.95 | 0.93 | 46.67 |
| | 3 | 0.70 | 0.50 | 0.60 | 0.60 | 18.00 | 40.40 | 22.40 | 448.00 | 0.20 | 0.08 | 0.11 | 0.13 | 6.50 |
| | 4 | 0.80 | 0.50 | 0.50 | 0.60 | 20.00 | 40.00 | 20.00 | 400.00 | 0.63 | 1.63 | 1.61 | 1.29 | 64.50 |
| | 5 | 1.20 | 1.40 | 1.30 | 1.30 | 37.00 | 59.00 | 22.00 | 440.00 | 0.21 | 0.21 | 0.12 | 0.18 | 9.00 |
| | 6 | 1.21 | 1.13 | 1.15 | 1.16 | 59.00 | 81.00 | 22.00 | 440.00 | 0.30 | 0.50 | 0.30 | 0.37 | 18.33 |
| | 7 | 1.20 | 1.11 | 1.05 | 1.12 | 31.00 | 52.50 | 21.50 | 430.00 | 0.29 | 0.22 | 0.25 | 0.25 | 12.67 |
| | 8 | 0.40 | 0.60 | 0.80 | 0.60 | 1.00 | 21.00 | 20.00 | 400.00 | 0.24 | 0.27 | 0.12 | 0.21 | 10.50 |
| | 9 | 1.10 | 1.20 | 1.30 | 1.20 | 53.50 | 75.00 | 21.50 | 430.00 | 0.27 | 0.27 | 0.10 | 0.21 | 10.67 |
| | 10 | | 1.10 | 1.30 | 1.20 | 7.00 | 28.00 | 21.00 | 420.00 | 0.24 | 0.27 | 0.23 | 0.25 | 12.33 |
| | 11 | 2.70 | 2.20 | | 2.45 | 60.00 | 81.00 | 21.00 | 420.00 | 0.32 | 0.29 | 0.31 | 0.31 | 15.33 |
| | 12 | | 1.10 | 1.10 | 1.10 | 35.50 | 56.50 | 21.00 | 420.00 | 0.25 | 0.29 | 0.31 | 0.28 | 14.17 |
| | 13 | 0.20 | 0.20 | 0.19 | 0.20 | 2.00 | 20.00 | 18.00 | 360.00 | 0.20 | 0.20 | 0.19 | 0.20 | 9.83 |
| | 14 | 1.00 | 0.90 | 0.90 | 0.93 | 53.00 | 75.00 | 22.00 | 440.00 | 0.24 | 0.29 | | 0.27 | 13.25 |
| | 15 | 0.80 | 0.80 | | 0.80 | 30.00 | 53.00 | 23.00 | 460.00 | 0.17 | 0.17 | 0.24 | 0.19 | 9.67 |
| | 16 | 2.80 | | 1.90 | 2.35 | 0.00 | 21.00 | 21.00 | 420.00 | 0.25 | 0.26 | 0.26 | 0.26 | 12.83 |
| | 17 | | 0.80 | 0.59 | 0.70 | 51.00 | 72.00 | 21.00 | 420.00 | 1.05 | 0.97 | 1.05 | 1.02 | 51.17 |
| | 18 | 1.51 | 1.41 | | 1.46 | 59.50 | 81.50 | 22.00 | 440.00 | 0.17 | 0.15 | 0.15 | 0.16 | 7.83 |
| | 19 | 1.00 | 1.20 | 0.90 | 1.03 | 0.00 | 22.50 | 22.50 | 450.00 | | 2.00 | 2.30 | 2.15 | 107.50 |
| | 20 | 0.70 | 1.10 | 1.00 | 0.93 | 0.00 | 30.00 | 30.00 | 600.00 | 0.25 | 0.21 | 0.22 | 0.23 | 11.33 |
| | 21 | 0.87 | 0.80 | 0.90 | 0.86 | 0.00 | 31.00 | 31.00 | 620.00 | 0.24 | 0.18 | 0.16 | 0.19 | 9.70 |
| | 22 | 0.98 | 0.68 | 0.70 | 0.79 | 0.00 | 31.50 | 31.50 | 630.00 | 0.24 | 0.26 | 0.25 | 0.25 | 12.50 |
| | 23 | 1.30 | 1.32 | 1.23 | 1.28 | 20.50 | 55.00 | 34.50 | 690.00 | 0.16 | 0.20 | 0.15 | 0.17 | 8.50 |
| | 24 | 1.24 | 1.10 | 1.05 | 1.13 | 2.00 | 36.00 | 34.00 | 680.00 | 0.17 | 0.14 | 0.13 | 0.15 | 7.33 |
| 2 | 48 | 0.60 | 0.60 | 0.70 | 0.63 | 0.00 | 26.50 | 26.50 | 530.00 | 0.19 | 0.19 | 0.07 | 0.15 | 7.50 |
| 3 | 72 | 1.30 | 1.35 | 1.34 | 1.33 | 28.00 | 62.00 | 34.00 | 680.00 | 0.24 | 0.22 | 0.20 | 0.22 | 11.00 |
| 4 | 96 | 1.00 | 0.94 | 0.98 | 0.97 | 2.00 | 37.00 | 35.00 | 700.00 | 0.15 | 0.12 | 0.11 | 0.13 | 6.33 |
| 5 | 120 | 2.10 | 2.30 | 2.50 | 2.30 | 1.55 | 33.50 | 31.95 | 639.00 | 0.11 | 0.13 | 0.09 | 0.11 | 5.50 |
| 6 | 144 | 2.40 | 2.30 | 2.50 | 2.40 | 2.00 | 27.00 | 25.00 | 500.00 | 0.11 | 0.25 | 0.09 | 0.15 | 7.50 |
| 7 | 168 | 0.20 | 0.00 | 0.20 | 0.20 | 0.00 | 24.00 | 24.00 | 480.00 | 0.04 | 0.04 | 0.06 | 0.05 | 2.33 |
| 8 | 192 | 0.20 | 0.30 | | 0.25 | 32.00 | 63.00 | 31.00 | 620.00 | 0.03 | 0.04 | 0.01 | 0.03 | 1.33 |
| 9 | 216 | 0.20 | 0.20 | 0.40 | 0.27 | 0.00 | 31.50 | 31.50 | 630.00 | 0.15 | 0.17 | 0.33 | 0.22 | 10.83 |
| 10 | 240 | 0.15 | 0.20 | 0.20 | 0.18 | 0.00 | 32.00 | 32.00 | 640.00 | 0.15 | 0.17 | 0.16 | 0.16 | 8.00 |
| 11 | 264 | 1.50 | 1.60 | | 1.55 | 31.50 | 64.00 | 32.50 | 650.00 | 0.08 | 0.15 | 0.09 | 0.11 | 5.33 |
| 12 | 288 | 0.30 | 0.30 | 0.20 | 0.27 | 0.00 | 36.50 | 36.50 | 730.00 | 0.02 | 0.07 | 0.01 | 0.03 | 1.67 |
| 13 | 312 | 0.10 | 0.10 | | 0.10 | 0.00 | 35.00 | 35.00 | 700.00 | 0.09 | 0.12 | 0.16 | 0.12 | 6.17 |

Table 2: Test Analysis Results of Samples Collected from Anaerobic Sludge Digestion

| Day | Hour | Nitrate($NO_3$) | | | | Alkalinity | | | | Ammonia*50 ($NH_3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Av. | Initial | Final | Final-Initial | Alkalinity | 1 | 2 | 3 | Av. | $NH_3$ |
| 1 | 0 | 1.21 | 1.71 | 1.58 | 1.50 | 1.00 | 25.00 | 24.00 | 480.00 | 0.20 | 0.20 | 0.50 | 0.30 | 15.00 |
| | 1 | 1.20 | 1.40 | 1.00 | 1.20 | 71.40 | 98.00 | 26.60 | 532.00 | 0.78 | 0.77 | 0.69 | 0.75 | 37.33 |
| | 2 | 1.70 | 1.60 | 1.50 | 1.60 | 48.00 | 77.50 | 29.50 | 590.00 | 2.80 | 2.75 | 2.72 | 2.76 | 137.83 |
| | 3 | 1.30 | 1.70 | 1.50 | 1.50 | 41.20 | 71.50 | 30.30 | 606.00 | 0.20 | 0.50 | 0.60 | 0.43 | 21.67 |
| | 4 | 1.80 | 1.70 | 1.60 | 1.70 | 40.00 | 64.40 | 24.40 | 488.00 | 0.42 | 0.43 | 0.09 | 0.31 | 15.67 |
| | 5 | 1.63 | 1.62 | 0.06 | 1.10 | 64.40 | 97.50 | 33.10 | 662.00 | 1.19 | 1.08 | 1.13 | 1.13 | 56.67 |
| | 6 | 1.21 | 1.13 | 1.15 | 1.16 | 0.00 | 31.00 | 31.00 | 620.00 | 1.30 | 1.70 | 1.70 | 1.57 | 78.33 |
| | 7 | 0.18 | 0.70 | 0.60 | 0.49 | 52.50 | 86.50 | 34.00 | 680.00 | 1.55 | 1.39 | 1.42 | 1.45 | 72.67 |
| | 8 | 2.40 | 2.40 | 2.40 | 2.40 | 21.10 | 53.50 | 32.40 | 648.00 | 1.33 | 1.49 | 1.47 | 1.43 | 71.50 |
| | 9 | 4.70 | 4.70 | 4.70 | 4.70 | 75.00 | 106.00 | 31.00 | 620.00 | 1.19 | 1.17 | 1.25 | 1.20 | 60.17 |
| | 10 | 1.40 | 1.50 | 1.40 | 1.43 | 28.00 | 58.00 | 30.00 | 600.00 | 1.20 | 1.49 | 1.47 | 1.39 | 69.33 |
| | 11 | 1.20 | 1.30 | 1.40 | 1.30 | 4.00 | 35.50 | 31.50 | 630.00 | 1.15 | 1.03 | 1.03 | 1.07 | 53.50 |
| | 12 | 0.60 | 2.40 | 4.40 | 2.47 | 56.50 | 87.50 | 31.00 | 620.00 | 1.14 | 1.12 | 1.13 | 1.13 | 56.50 |
| | 13 | 2.00 | 1.20 | 1.30 | 1.50 | 20.00 | 53.00 | 33.00 | 660.00 | 1.15 | 1.15 | 1.19 | 1.16 | 58.17 |
| | 14 | 1.30 | 1.20 | 0.60 | 1.03 | 0.00 | 30.00 | 30.00 | 600.00 | 1.14 | 1.15 | 1.13 | 1.14 | 57.00 |
| | 15 | 1.90 | 2.10 | 2.00 | 2.00 | 53.00 | 84.00 | 31.00 | 620.00 | 0.94 | 1.03 | 1.03 | 1.00 | 50.00 |
| | 16 | 2.30 | 1.20 | 1.70 | 1.73 | 21.00 | 52.00 | 31.00 | 620.00 | 1.05 | 0.97 | 1.05 | 1.02 | 51.17 |
| | 17 | 1.70 | 2.00 | 2.10 | 1.93 | 0.00 | 28.00 | 28.00 | 560.00 | 0.80 | 1.11 | 1.03 | 0.98 | 49.00 |
| | 18 | 1.90 | 2.00 | 2.10 | 2.00 | 28.00 | 58.00 | 30.00 | 600.00 | 0.95 | 1.00 | 0.99 | 0.98 | 49.00 |
| | 19 | 0.60 | 1.60 | 6.60 | 2.93 | 0.00 | 32.00 | 32.00 | 640.00 | 2.30 | 2.80 | 3.00 | 2.70 | 135.00 |
| | 20 | 2.10 | 2.00 | 4.20 | 2.77 | 0.00 | 30.00 | 30.00 | 600.00 | 0.48 | 0.78 | 0.55 | 0.60 | 30.17 |
| | 21 | 1.80 | 1.70 | 1.49 | 1.66 | 0.00 | 31.00 | 31.00 | 620.00 | 0.46 | 0.40 | 0.42 | 0.43 | 21.33 |
| | 22 | 1.90 | 2.40 | 2.20 | 2.17 | 0.00 | 31.50 | 31.50 | 630.00 | 0.50 | 0.61 | 0.65 | 0.59 | 29.33 |
| | 23 | 1.00 | 1.70 | 1.70 | 1.47 | 0.00 | 32.00 | 32.00 | 640.00 | 0.58 | 0.70 | 0.26 | 0.51 | 25.58 |
| | 24 | 1.00 | 1.00 | 1.30 | 1.10 | 0.00 | 32.10 | 32.10 | 642.00 | 0.32 | 0.25 | 0.32 | 0.30 | 14.83 |
| 2 | 48 | 1.40 | 1.40 | 1.30 | 1.37 | 26.50 | 50.50 | 24.00 | 480.00 | 0.64 | 0.73 | 0.75 | 0.71 | 35.33 |
| 3 | 72 | 2.10 | 1.90 | 2.00 | 2.00 | 0.00 | 31.50 | 31.50 | 630.00 | 0.60 | 0.90 | 0.85 | 0.78 | 39.17 |
| 4 | 96 | 2.00 | 1.70 | 1.60 | 1.77 | 0.00 | 30.00 | 30.00 | 600.00 | 0.65 | 0.60 | 0.64 | 0.63 | 31.50 |
| 5 | 120 | 1.70 | 1.50 | 1.40 | 1.53 | 0.00 | 31.00 | 31.00 | 620.00 | 0.80 | 0.68 | 0.70 | 0.73 | 36.33 |
| 6 | 144 | 2.40 | 2.50 | 2.40 | 2.43 | 27.00 | 60.00 | 33.00 | 660.00 | 0.42 | 0.82 | 0.89 | 0.71 | 35.50 |
| 7 | 168 | 1.50 | 2.00 | 2.00 | 1.83 | 56.50 | 88.50 | 32.00 | 640.00 | 0.78 | 0.77 | 0.55 | 0.70 | 35.00 |
| 8 | 192 | 1.20 | 1.30 | 1.40 | 1.30 | 63.00 | 102.00 | 39.00 | 780.00 | 0.88 | 0.86 | 0.44 | 0.73 | 36.33 |
| 9 | 216 | 1.30 | 1.40 | 1.50 | 1.40 | 59.50 | 91 .50 | 32.00 | 640.00 | 0.72 | 0.78 | 0.91 | 0.80 | 40.17 |
| 10 | 240 | 1.40 | 1.50 | 1.60 | 1.50 | 32.00 | 64.00 | 32.00 | 640.00 | 0.72 | 0.74 | 0.77 | 0.74 | 37.17 |
| 11 | 264 | 0.50 | 0.40 | 0.50 | 0.47 | 62.00 | 94.00 | 32.00 | 640.00 | 0.62 | 0.64 | 0.65 | 0.64 | 31.83 |
| 12 | 288 | 1.10 | 1.20 | 1.30 | 1.20 | 36.50 | 69.00 | 32.50 | 650.00 | 0.77 | 0.78 | 0.60 | 0.72 | 35.83 |
| 13 | 312 | 1.70 | 1.70 | 1.80 | 1.73 | 50.00 | 82.50 | 32.50 | 650.00 | 0.78 | 0.89 | 0.49 | 0.72 | 36.00 |