Factors Affecting Performance of Sewage Treatment Plant

by

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In partial fulfillment of the requirements for the

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(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

CHEMICAL ENGINEERING PROGRAMME
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In partial fulfillment of the requirement for the

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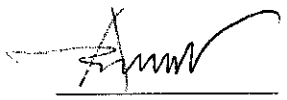

(Pn Asna Mohd Zain)

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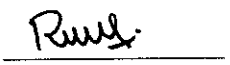
January 2004

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 reference and acknowledgements, and that the original work contained herein has not been undertaken or done by unspecified sources or persons.



ANG YI CHING

ABSTRACT

The objective of this project is to study and find the optimum factors such as pH, temperature and microbial nutrients that affect the performance of the sewage treatment plant.

The problem to the project is to minimize the value of Biological Oxygen Demand (BOD) of an activated sludge sewage treatment plant. The effluent of a treatment plant should meet the requirements of Environmental Quality (Sewage and Industrial Effluents) Regulations 1979.

The scope of this project would be limited to the aeration tank. Although there are many other factors that can affect the performance of the treatment plant, pH, temperature and microbial nutrients are identified for analysis.

In order to find the optimum conditions for a wastewater treatment plant, a multi-national company is identified as my case study. Then, literature reviews on the activated sludge and other related issues are conducted to obtain background information and previous study.

Experimental works was carried out to determine the value of Biochemical Oxygen Demand (BOD) using BODTrak and Chemical Oxygen Demand (COD) using digestion method. The analysis is conducted before and after the treatment at the aeration tank. The data gathered from the experiments is then further analyzed in terms of performance or percentage reduction of BOD value.

It is found out that the optimum conditions for the BOD removal is at temperature between 30°C to 31°C and pH of 7.5. The amount of Total Organic Carbon should be higher than 50mg/L with the ratio of Carbon:Nitrogen:Phosphorus of 100:10:1. All these are the nutrients for the synthesis of microorganisms in the treatment plant.

ACKNOWLEDGEMENT

This project would not have been possible without the help of a number people, and hereby the writer would like to express her deepest gratitude to all those who had directly and indirectly involved.

First of all, the writer would like to thank her family for their continuous support and encouragement. The writer also likes to extend her gratitude to her senior, Ho Siew Hone for giving advice and support throughout the project.

On top of that, the writer is greatly indebted to her project supervisor, Pn Asna Mohd Zain, who has continuously monitored her progress and advice her throughout the duration of the project. Her thoughtful advices and guidance were given serious consideration that leads to the final outcome of this project. The write also want to extend her gratitude to Mr Zaaba and Mr Shaharuddin for their cooperation and guidance during the experimental works.

A special thank to Miss Koay Hui Nee, Environmental Engineer of the case study company, for sharing her knowledge and experience on the project background. Her cooperation has enabled the writer to obtain samples for the project without any difficulty.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background of Study

Sewage treatment plant can employ various type of treatment process, chemically or biologically. The case study selected is using an activated sludge system to treat the sewage water from all the washrooms of the plant and cafeteria waste. Activated sludge system is a biological method of wastewater treatment that is performed by bacteria or microorganisms in aerobic environment and removes from the wastewater the substances that have a demand for oxygen from the system.

1.2 Problem Statement

1.2.1 Problem Identification

As the activated sludge system requires living components to break down the organic waste, the performance of the system is affected by few factors such as retention time, degree of mixing, temperature and pH of sewage water and amount of microbial nutrients present in the wastewater. Among the factors, pH, temperature and microbial nutrients are identified for analysis. Although microbial count could be equally important, the microbial nutrients are more or less related to the microbial count and hence will be taken into account during the project. The monitoring of the treatment plant is important to ensure that the BOD and COD values meet the requirements of local law such as Standard B of Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 as shown in Table 1.

Table 1 : Standard B value for parameters in EQ (Sewage And Industrial Effluents) Regulations 1979

Parameters	Value
Temperature	40°C
pH Value	5.5 – 9.0
BOD_5 at 20°C	50 mg/L
COD	100mg/L

1.2.2 Significant of the Project

The findings of this project would help the company in the case study to be aware of the optimum pH, temperature and microbial nutrients (Total Organic Carbon or TOC and Phosphorus) to ensure the performance of the sewage treatment plant is excellent and at its maximum capacity. Utilizing the knowledge, the effluent of the system can be controlled to discharge lower BOD and COD values.

The study on nitrification and denitrification can also help the case study company to decide whether they should add another anoxic tank for the optimum nitrification and denitrification to happen for further reduction of Biochemical Oxygen Demand value.

Personally, this project will also benefit me as I am majoring in Chemical Engineering (Environmental). It will prove to be a great asset for me when I come out to the working world in the same field. Since this project requires experimental work, it helps me to be able to plan experimental work appropriately and enhance my data analyzing skill.

1.3 Objective and Scope of Study

1.3.1 The Relevancy of the Project

The project basically required a mixture of new and learned knowledge either from University, self-learned knowledge or from Industrial Training Program. The courses that were being offered to me throughout my university life which are applicable are Water and Wastewater Engineering, Environmental Law, Health Safety and Environment, Industrial Internship and Chemistry. Also, the project will widen my knowledge as a Chemical Engineer as the study relates much to reactions of bacteria and the mechanisms that will be affected by the temperature, pH and microbial count.

1.3.2 Feasibility of the project within the Scope and Time Frame

Referring to the Gantt Chart in Appendix A, it is decided that the scope of the project is parallel to the time frame of 14 weeks. Literature review, experimental work and analysis have to be planned properly to meet the time frame.

By adhering closely to the Gantt Chart generated, the project proceeds smoothly and is able to complete on time.

CHAPTER 2

2.0 LITERATURE REVIEW AND THEORY

2.1 Biochemical Oxygen Demand and Chemical Oxygen demand

Firstly, the concept of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) need to be realized. COD results are obtained to support the BOD values. BOD is a measure of how much dissolved oxygen is being consumed as microbes break down organic matter. A high BOD value indicates that the levels of dissolved oxygen are falling, which can be caused by high levels of organic pollution or high nitrate levels. The BOD classifications or types are represented in Figure 1 (Gerardi, 2002).

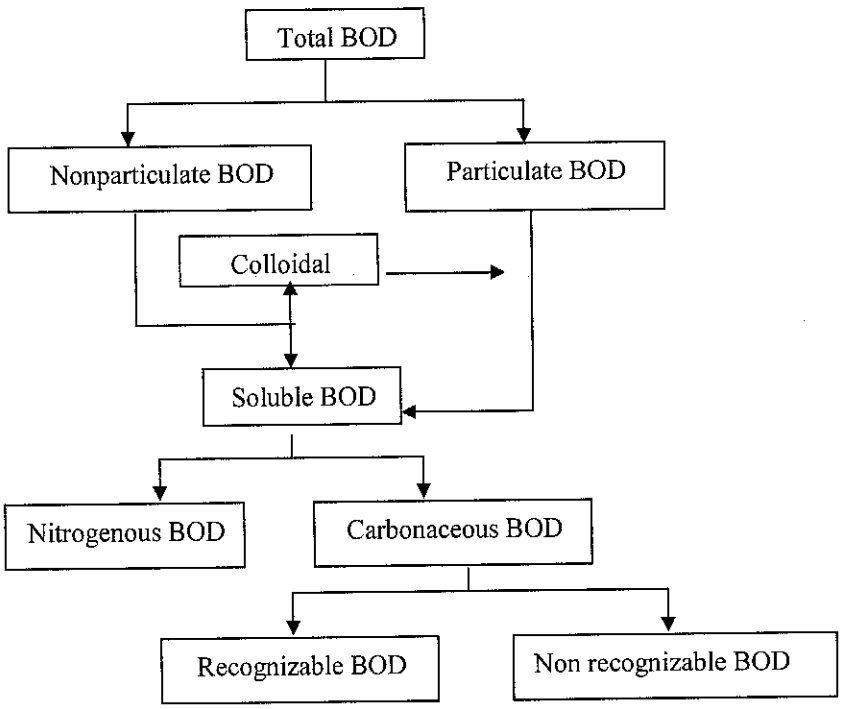


Figure 1 : Types of BOD

The important types of BOD that will be studied in this project are nitrogenous and carbonaceous BOD. The treatment plant studied is activated sludge in the aeration tank and the compounds that contribute to both measurements can pass through the homogenization tank to the aeration tank. Hence, they are very much related to the performance of the treatment plant.

BOD removal can be contributed by both the removal of nitrate from the wastewater and organic pollution. Hence, the BOD parameter in the wastewater is highly influenced by the effectiveness of the processes mentioned above. Those reactions or processes generally are influenced by the pH and temperature

COD is a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant.

2.2 Sewage Treatment Plant System

The sewage treatment plant operated in the case study has few components that have their own functions in treating the wastewater. Please refer to the Appendix B for the treatment plant plan. The components of the plant and their functions are summarized in Figure 2 below.

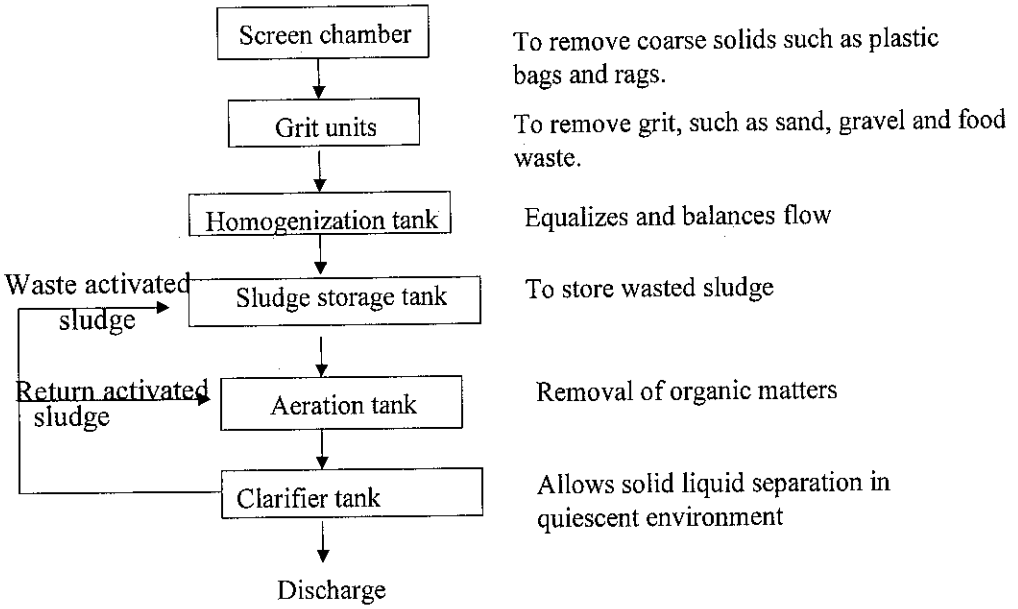


Figure 2 : Sewage treatment plant process

2.3 Sewage Water Content

Sewage water content varies from one industry to another as different industries would discharge different type of wastewater. For sewage treatment plant, the wastewater usually is the human waste. There are three types of organic matter in sewage water quality control:-

- Carbohydrates containing carbon, hydrogen and oxygen. Typical examples are sugars including glucose, starch and cellulose.
- Nitrogeneous compounds containing carbon, hydrogen, oxygen, nitrogen and occasionally sulphur (CHONS). The main compounds in this group are proteins which are complex molecules, amino acid which is the building

block of proteins and urea. This nitrogen content is liberated as ammonia during oxidation.

- Lipids or fats, containing carbon, hydrogen and smaller amount of oxygen (CHO). They are slightly soluble in water and soluble in organic solvents.

Due to the numerous compounds found in sewage water, it is rarely feasible to isolate them. Hence, it is normally sufficient to categorize the total amount of organic matter present as CHONS.

2.4 Activated Sludge

There are several types of microorganisms that are important to break down the wastewater such as bacteria, fungi and protozoa in activated sludge system.

According to the projects conducted by students of University of California, Los Angeles (UCLA), bacteria has the greatest number of importance in the activities of activated sludge. Bacteria can be heterotrophic or autotrophic, where the former predominate. Heterotrophic bacteria, for example *Achromobacter* and *Pseudomonas*, obtain energy from carbonaceous organic matter in influent wastewater for the synthesis of new cells. At the same time, they release energy via the conversion of organic matter into compounds such as carbon dioxide and water. Please refer to Figure 3 for the picture of *Pseudomonas*.

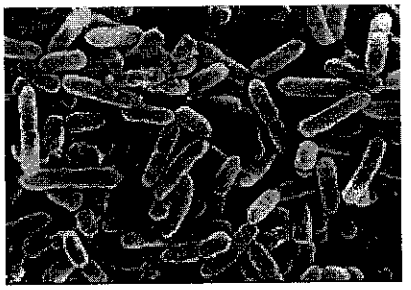


Figure 3 : *Pseudomnas* (UCLA)

Autotrophic bacteria reduce carbon compound such as carbon dioxide for cell growth and obtain energy by oxidizing ammonia nitrogen to nitrate nitrogen in nitrification process. Due to the fact that very little energy is derived from these oxidation reactions and more energy is required to convert carbon dioxide to cellular carbon, nitrifying bacteria represent a small percentage of the total population of microorganisms in activated sludge. In addition, autotrophic nitrifying bacteria have a slower rate of reproduction. Example of autotrophic bacteria are *Nitrobacter* and *Nitrosomonas*. Please refer to Figure 4 for the close up of *Nitrobacter*.

Figure 4 : *Nitrobacter* (UCLA)

According to Gerardi (2002)

> The population size of *Nitrosomonas* is larger than *Nitrobacter*. Because *Nitrosomonas* obtains more energy from the oxidation of ammonium ions than *Nitrobacter* obtains from the oxidation of nitrite ions, *Nitrosomonas* has a shorter generation time and is able to increase quickly in numbers as compared to *Nitrobacter*. A larger population size of *Nitrosomonas* than *Nitrobacter* in the activated sludge process provides for more ammonium ion oxidizing ability than nitrite ion oxidizing ability.

Fungi are generally filamentous and have a true cell wall. Most fungi are aerobic. Fungi can tolerate lower pH than bacteria and their nitrogen and phosphorus requirements are lower than requirements for bacteria. Fungi are capable of oxidizing ammonia to nitrite and nitrate.

Protozoa are single-celled organisms. Protozoa have a minor role in most wastewater treatment process but they play the dominant role in removing Escherichia Coli from wastewater. Example of protozoa are *Carchesium polypinum*, *Opercularia coarcta* and *Vorticella convallaria* as shown in Figure 5 , Figure 6 and Figure 7 respectively.

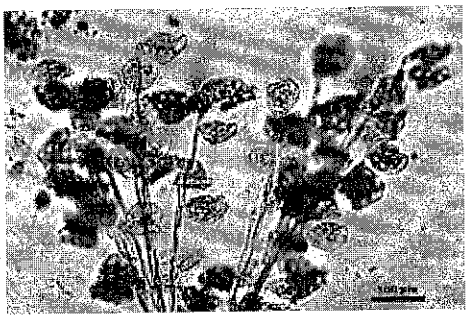


Figure 5 : *Carchesium sp* (UCLA)

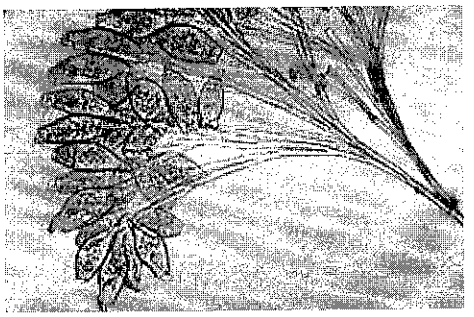


Figure 6 : *Opercularia sp* (UCLA)

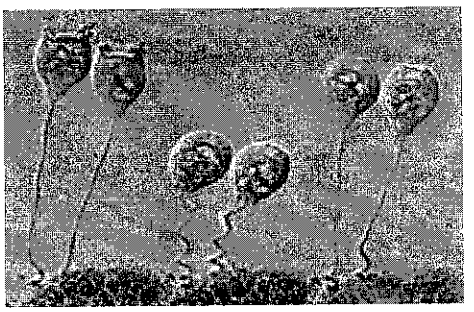


Figure 7 : *Vorticella Convallaria* (UCLA)

The activated-sludge process is a biological method of wastewater treatment that is performed by a variable and mixed community of microorganisms in an aerobic aquatic environment. These microorganisms derive energy from carbonaceous organic matter in aerated wastewater for the production of new cells in a process known as synthesis. Simultaneously, releasing energy through the conversion of this organic matter into compounds that contain lower energy, such as carbon dioxide and water in a process called respiration. A variable number of microorganisms in the system obtain energy by converting ammonia nitrogen to nitrate nitrogen in a process termed nitrification. This consortium of microorganisms, the biological component of the process and spent sludge is known collectively as activated sludge.

The primary goal of the activated-sludge process is to remove substances that have a demand for oxygen from the system. This is accomplished by the metabolic reactions (synthesis-respiration and nitrification) of the microorganisms, followed by the separation and settling of activated-sludge solids to create an acceptable quality of secondary wastewater effluent.

2.5 Carbonaceous BOD removal

Carbonaceous biochemical oxygen demand (CBOD) is measurement of oxygen demand for the biochemical degradation of organic material. The CBOD value can be obtained during the five days BOD test.

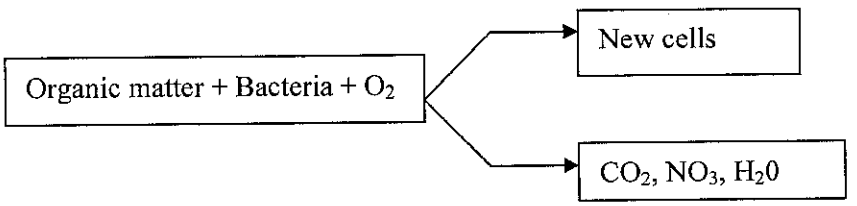


Figure 8 : Carbonaceous BOD removal process

Microorganisms in the activated sludge utilize oxygen during the consumption of food or organic material. The chemical structure of the food molecules is broken

down, some of the fragments are incorporated into the cellular structure of the microorganisms and others are oxidized to give energy. The net result is to utilize oxygen and food to produce carbon dioxides as shown in Figure 8 and new cell materials and to provide energy for other activities of the microorganism, for example motility.

The rate of removal of CBOD is influenced by few factors such as water temperature, pH and microbial nutrients, which in turn affect the microbial count. CBOD decay occurs at a rate, which increases with increasing temperature up to the point where protein denaturation begins.

2.6 Nitrification and Denitrification process

Nitrogen compounds may exist in wastewater in the form of organic nitrogen, ammonia, nitrite and nitrate. In sewage, normally only organic nitrogen and ammonia are present. During carbonaceous oxidation of wastewater, many forms of organic nitrogen are converted to ammonia (ammonification). In turn, further biological oxidation, mostly facilitated by proper autotrophic microorganisms such as *Nitrosomonas* and *Nitrobacter*, converts ammonia to nitrite and nitrate during nitrification process (McGhee. 1991).

The energy-yielding, two-step oxidation of ammonia to nitrate is generally accepted to be as follows :-

Nitrosomonas

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

Nitrobacter

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

Total reaction

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

According to Randall et.al (1992)

Dissimilating nitrate reduction or denitrification is coupled to the respirating electron chain and involves the reduction of nitrate to nitrite and further reduction of to nitric oxide to nitrous oxide and finally to nitrogen :

$$NO_{3-} \rightarrow NO_{2-} \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Heterotrophic reduction of nitrite and nitrate to molecular nitrogen (dissimilatory denitrification) leads to substantial elimination of nitrogen from wastewater. During this process, denitrifying bacteria remove significantly amounts of BOD during the reduction of nitrate. This mechanism of nitrogen elimination from wastewater also helps to prevent eutrophication of receiving water bodies. In another mechanism, assimilatory denitrification, nitrate is reduced to ammonia level and is utilized in cell synthesis.

CHAPTER 3

3.0 METHODOLOGY

3.1 Procedure Identification

Basically few steps are drawn out to achieve toward the completion of my project.

1. Understand microbiology and physical system of the sewage treatment plant.
2. Planning of sampling.
3. Sampling
   i) Wastewater sampling in determining BOD and COD.
      a) wastewater sample from aeration tank
      b) influent sample
      c) effluent sample
   ii) Wastewater sampling for factors of :
      a) pH using pH meter
      b) temperature using thermometer
      c) microbial nutrients by external lab

The sampling of the factors identified in this project will be done at the same time of wastewater sampling for BOD and COD to ensure that the parameters are correlated to each other in one sample.

4. Data analysis.
5. Correlation and conclusion.

3.2 Tools required

1. BODtrak and the provided accessories for conducting BOD testing.
2. COD Reactor Model for conducting COD testing
3. Thermometer
4. pH meter
5. TOC analyzer (Siever 820)

3.3 Experimental Procedure

3.3.1 Biochemical Oxygen Demand

Sample preparation procedure

1. Heat or cool the sample to within 2°C of its incubation temperature, which is normally 20°C.
2. Using a clean measuring cylinder, fill the correct sample volume into a BODTrak sample bottle. Please refer to the Table 2 below.

Table 2 : Required volume for BOD testing

BOD Range (mg/L)	Required Volume (mL)
0 – 35	420
0 – 70	355
0 – 350	160
0 - 700	95

3. Place the magnetic stirrer in each sample bottle.
4. Add one BOD Nutrient Buffer Pillow to each bottle for optimum bacteria growth (Step 4 can be excluded if sample characteristics is required).
5. Apply Stopcock Grease to the seal lip of each bottle and to the top of each seal cup.
6. Place a seal cup in each bottle.

7. Add one Lithium Hydroxide pack into each seal cup using the funnel. Do not let the chemical fall into the sample and if this occurs, dispose the sample and prepare a new one.
8. Place the bottles on the chasis of the BODTrak and connect the correct tube to the sample bottle and firmly tighten the cap.
9. Place the BODtrack in the incubator.

BODTrak Setup

1. Start the instrument.
2. Make sure all stirrers are rotating. Do not start the channel until the stirrer is rotating properly.
3. To select test duration, simultaneously press and hold the left (<) and right (>) button until the time menu appears. Press the 1 – 6 buttons to select the correct month, date, year, time and duration of the testing.
4. Press the ON key and a menu for selecting BOD range will be displayed. Use the left (<) and right (>) key to scroll.
5. Press and hold the ON key to start a test A graph will be shown.
6. Read the BOD results directly from the BOD Trak display by pressing the key corresponding to each sample.

Principles behind the methodology

The method consists of filling with sample, to an airtight bottle and incubating it at 20°C for five or seven days (according to experiment). The experiment to determine the nitrogenous BOD removal requires seven days as nitrifiers, which induce nitrification process to occur, will start to develop only after five days and within seven days. The bottle has to be dark bottles because algae, which may present in the sample, will produce oxygen when exposed to light. Dissolved oxygen (DO) is measured continuously until the preset period of days. Hence, a graph can be seen on the display. The BOD is commuted from the difference between initial and final DO.

Pressure changes within the closed BODTrak system are being measured, which indicated the DO being used up.

As carbon dioxide is produced when microorganisms oxidize organic matter within the sample, the carbon dioxide must be removed from the system so the measure pressure difference is proportional only to the amount of O_2 consumed. Lithium hydroxide, as mentioned earlier, is placed on the seal cup of each sample bottle prior to testing to remove the carbon dioxide.

3.3.2 Chemical Oxygen Demand

Digestion

1. Turn on the COD Reactor and preheat to 150°C.
2. Remove the cap of a COD Digestion Reagent Vial.
3. Hold the vial at a 45° angle and pipet 2.00 mL of sample into the vial.
4. Replace the vial cap tightly. Rinse the outside of the COD vial with deionized water and wipe the vial clean.
5. Hold the vial by the cap over the sink and invert gently several times to mix the contents.
6. Place the vial in the preheated COD Reactor.
7. Prepare a blank by repeating steps 2 – 6, substituting 2.00 mL of deionized water for the sample.
8. Heat the vials for 2 hours
9. Turn off the reactor [power and wait for about 10 minutes. Invert each vial several times while still warm. Place the vials into a rack and wait till the vials have cooled to room temperature.

COD measurement

1. Enter the stored program number for COD depending on whether it is low range or high range. If it is low range, key in 430 and press ENTER. If it is high range, key in 435 and press Enter. The display will show **Dial nm to 420** for low range and **620** for high range.

2. Rotate the wavelength dial until the small display shows the correct value. The display with quickly show : **Zero Sample** then **mg/L COD LR** or **HR**
3. Place the COD Vial Adapter into the cell holder with the marker to the right.
4. Clean the outside of the blank with a towel.
5. Place the blank vial into the adapter with the Hach logo facing the front of the instrument. Place the cover on the adapter.
6. Press ZERO and the display will show **Zeroing**.. then **0. mg/L COD LR** or **HR**.
7. Clean the outside of the sample vial with a towel.
8. Place the sample vial into the adapter with the same position as blank and then place the cover on the adapter.
9. Press READ and the display will show **Reading**... then the result in mg/L COD will be displayed.

Principles behind the methodology

Samples for COD testing are collected in glass bottle because there might be organic contaminants on plastic containers. The vials contain strong oxidizing agent of potassium dichromate. Oxidizable organic compounds react, reducing the dichromate ion to green chromic ion. The COD reagent vials also contain silver and mercury ions where the silver is catalyst and mercury is used to hinder chloride interferences.

3.3.3 Total Organic Carbon

As there is no facility to conduct Total Organic Carbon analysis, the assistance of external lab through case study company is obtained. The external lab utilizes equipment

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Experimental data

The experiments conducted for this project is the BOD and COD testing. The results of microbial nutrients and microbial count are obtained from analysis at the treatment plant. Microbial count data is obtained as supporting data to relate microbial nutrients effects to the performance of the sewage treatment plant.

Four experiments are conducted to analyze the water sample from the activated sludge treatment plant. The results of the parameters are tabulated in Table 3, Table 4, Table 5 and Table 6. Where as the BOD trend for each experiment is shown in Figure 9, Figure 10, Figure 11 and Figure 12. Please note that the performance indicated is the percentage of removal of either BOD_5 or BOD_7 and COD by comparing the influent and effluent data.

4.1.1 Testing Results

Table 3 : Experiment 1 results for 20th August 2003

	Influent	Aeration tank	Effluent	Performance
Temperature	29.5°C	30°C	30°C	N/A^
pH	7.14	7.2	7.22	N/A
Microbial count (CFU*)	4.10E+14	2.36E+12	8.50E+11	N/A
TOC	42 mg/L	52mg/L	N/A	N/A
Ammonia	8.5 mg/L	9.00 mg/L	N/A	N/A
Phosphorus	1.25 mg/L	0.63 mg/L	N/A	N/A
BOD_5	164 mg/L	225 mg/L	40.4 mg/L	75.37%
COD	325 mg/L	300 mg/L	90 mg/L	72.31%

* CFU : Colony forming unit
^ Not applicable

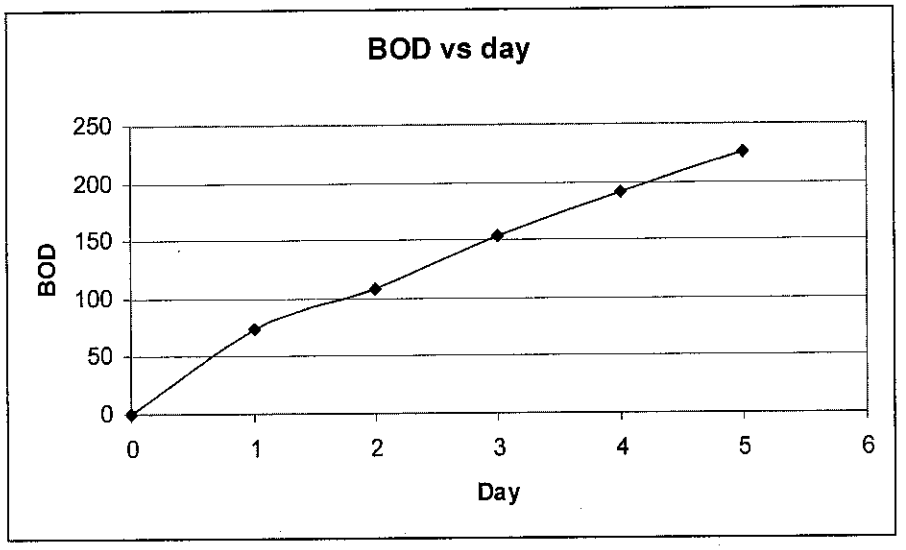


Figure 9 : BOD trend for Aeration Tank in Experiment 1

Table 4 : Experiment 2 results for 26th August 2003

	Influent	Aeration tank	Effluent	Performance
Temperature	30.5°C	31°C	31°C	-
pH	7.3	7.5	7.55	-
Microbial count (CFU*)	4.70E+11	2.50E+12	9.50E+12	-
TOC	59 mg/L	37 mg/L		-
Ammonia	13 mg/L	13 mg/L	-	-
Phosphorus	1.8 mg/L	1.7 mgL	-	-
BOD_5	330 mg/L	317mg/L	29.2 mg/L	91.15%
BOD_7	425 mg/L	388mg/L	44.6 mg/L	89.50%
COD	320 mg/L	311 mg/L	85 mg/:	73.44%

* CFU : Colony forming unit

^ Not applicable

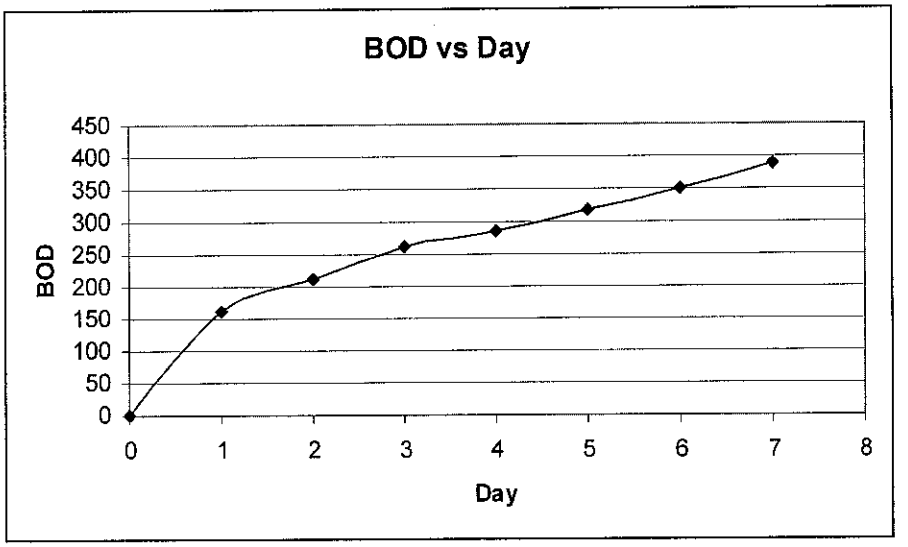


Figure 10 : BOD trend for Aeration Tank in Experiment 2

Table 5 : Experiment 3 results on 3rd September 2003

	Influent	Aeration tank	Effluent	Performance
Temperature	30°C	30.5°C	30.5°C	N/A
pH	7.12	7.33	7.38	N/A
Microbial count (CFU)	5.60E+12	6.00E+13	9.30E+12	N/A
TOC	19 mg/L	18 mg/L	18 mg/L	N/A
Ammonia	6.5	7	8.25	N/A
Phosphorus	0.32	0.34	0.95	N/A
BOD5	280 mg/L	265 mg/L	28 mg/L	90.00%
BOD7	375 mg/L	320 mg/L	41.2 mg/L	89.01%
COD	323 mg/L	295 mg/L	87 mg/L	73.06%

* CFU : Colony forming unit

^ Not applicable

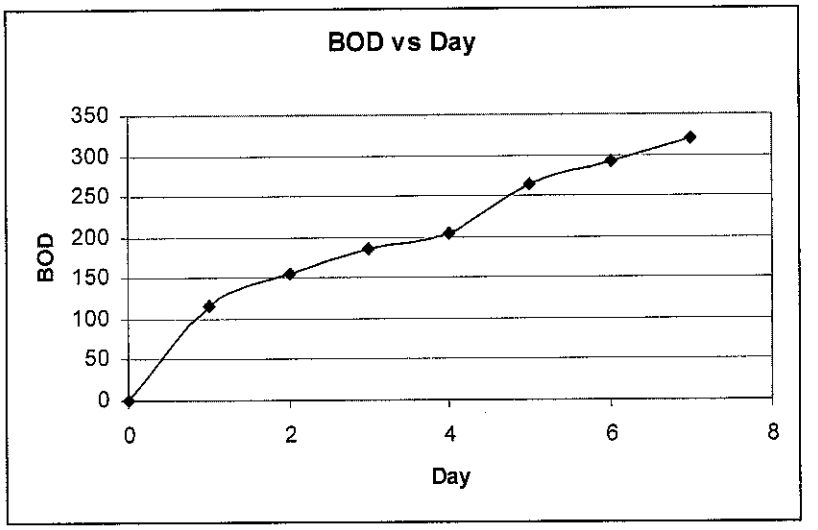


Figure 11 : BOD trend for Aeration Tank in Experiment 3

Table 6 : Experiment 4 results for 16th September 2003

	Influent	Aeration tank	Effluent	Performance
Temperature	30°C	31°C	31°C	N/A
pH	7.4	7.52	7.56	N/A
Microbial count (CFU)	7.60E+12	7.89E+13	9.13E+12	N/A
TOC	40	20	36	N/A
Ammonia	11.5	10.25	13	N/A
Phosphorus	1.35	1.15	1.7	N/A
BOD5	300 mg/L	285 mg/L	26.8 mg/L	91.07%
BOD7	428 mg/L	373 mg/L	45.4 mg/L	89.39%
COD	320 mg/L	308 mg/L	87 mg/L	72.81%

* CFU : Colony forming unit
^ Not applicable

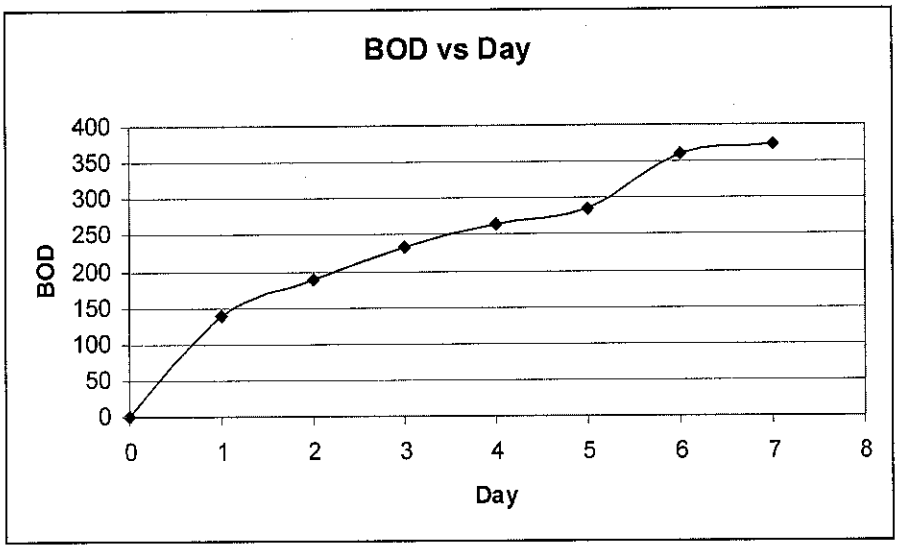


Figure 12 : BOD trend for Aeration Tank in Experiment 4.

4.2 Significance of results

After conducting the experiment, it is found out that nitrification process does occur during the incubation period of seven days. This can be confirmed by comparing to the graph in Figure 13 below (University of Nottingham, 2002).

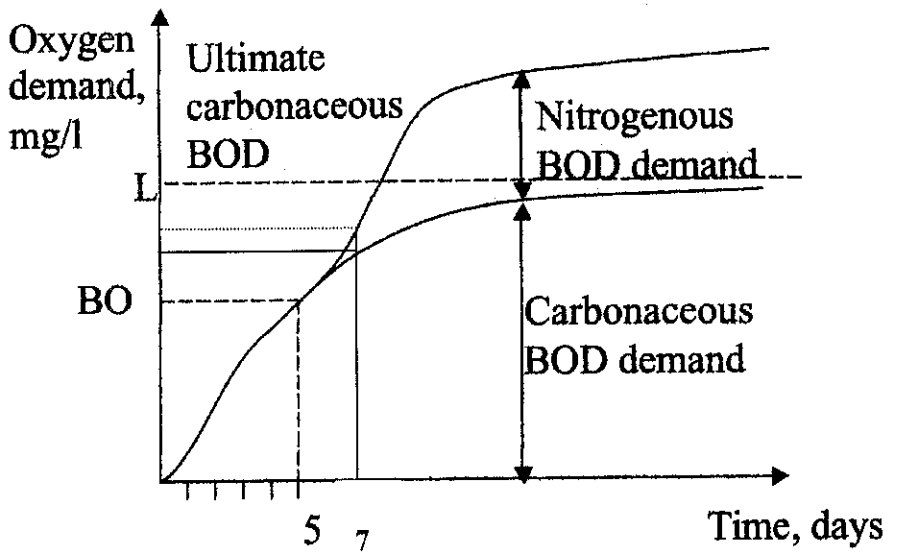


Figure 13 : Example of BOD Curves

The initial rapid BOD removal occurs when contacts between the wastewater with the microorganism of activated sludge occurs in the presence of dissolved oxygen, the suspended solid, colloidal solids and to some extent the soluble organics substances in the wastewater. The nutrients and oxygen are absorbed on the surface of activated sludge flocs. It is also caused by intensive biological activity converts part of the wastewater organics into a reserve food inside the microbial cells of the sludge.

Biological oxidation of organic nitrogen usually occurs after five days with sewage water because it takes that long for the nitrifying bacteria to develop. However, an abnormally high uptake of oxygen is evidence of nitrifying bacteria adding appreciably to the oxygen demand.

The results from four experiments of BOD_5 and temperature were tabulated in the Figure 14 below. The BOD_5 is expressed in term of percentage of reduction by comparing the BOD_5 at the influent to the effluent to show the performance of the sewage treatment plant.

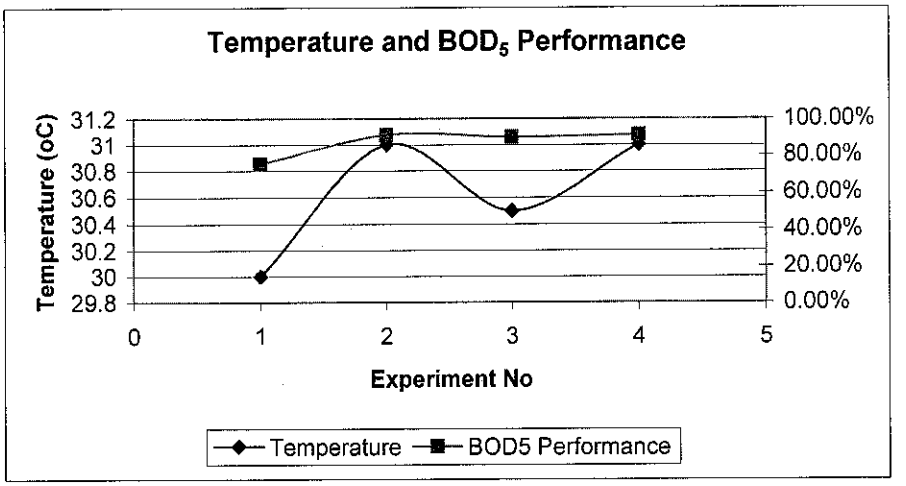


Figure 14 : Relationship between temperature and BOD_5 performance

From the experiment conducted, it can be seen that at higher temperature of 31°C (second and fourth experiment) and lower than 40°C, the performance of the treatment plant is higher comparing to the other two experiments. In the third experiment, where the temperature is around 30.5°C, the performance dropped by 1.26%. Although the difference is not very significant, it shows that at lower temperature, the removal of BOD_5 is less.

The findings can be explained by referring to the Equation 1. It can be seen that the higher the temperature, the bigger the reaction rate coefficient, K is. However, the limit lies around 31°C to 39°C where the value of K is approximately constant and declines at higher temperature. The decline in the rate coefficient at temperature higher than 40°C is frequently associated with deterioration and dispersion of the biological floc, poor sludge settleability and high effluent suspended solids concentration.

pH

The effect of pH on the carbonaceous BOD removal is not much studied in literature review as the effect is not very significant. As long as the pH lies in the range of 6.5 to 8.5, the breaking down of the organic waste can take place. However, in other source (Michael H Gerardi, 2002), it is stated although higher pH would appear to be more desirable for nitrification, it would adversely affect many organotrophs that are required to degrade CBOD. Hence, it can be said that the optimum pH for carbonaceous BOD removal should be more or less between 7.2 to 8.

As the bacteria is helped by enzymes to break down nutrients and in rebuilding broken down nutrients into the new compounds they require for growth and reproduction, the optimum condition for the enzyme to survive is also important. It is found out that the optimum pH should be between 7.0 and 7.5.

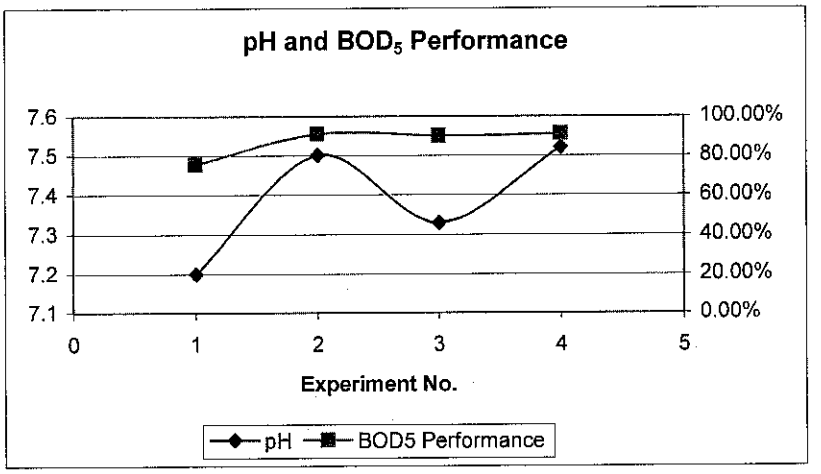


Figure 15 : Relationship between pH and BOD_5 Performance

The results of the experiments are tabulated in Figure 15. It can be seen that at 91.15% removal of CBOD in second experiment, the pH is 7.5. When the pH drops to 7.33, the percentage removal also decreases to 90.00%. Then, in the last experiment where the pH is 7.52, the percentage of removal is 91.07%. After analyzing the results, it can be concluded that the optimum pH for the treatment plant is around 7.5, assuming that other factors are constant.

Microbial Nutrient

Basic nutrients of abundance in raw sewage are carbon, nitrogen and phosphorus with the ratio of C:N:P is 100:10:1. The trace amounts of sodium, potassium, magnesium, iron and others are also required. Domestic wastewater contains organic nitrogen compounds and ammonium compounds. Nitrogen in domestic wastewater originates from protein metabolism in the human body. In the case study, the treatment plant also treats wastewater from the cafeteria, hence, dairy waste has to be considered. Dairy waste contains nitrogen-containing proteins, including casein.

The biomass in the activated sludge requires nitrogen and phosphorus in order to effect synthesis and removal of organics during the treatment process. Deficiency will also cause metabolism fails and slime begin to accumulate around cell. The cells activity will slow down because cannot produce enough enzymes and the needed nutrients would not be able to penetrate the slime layer as they should. All this will cause the BOD removal to slow down.

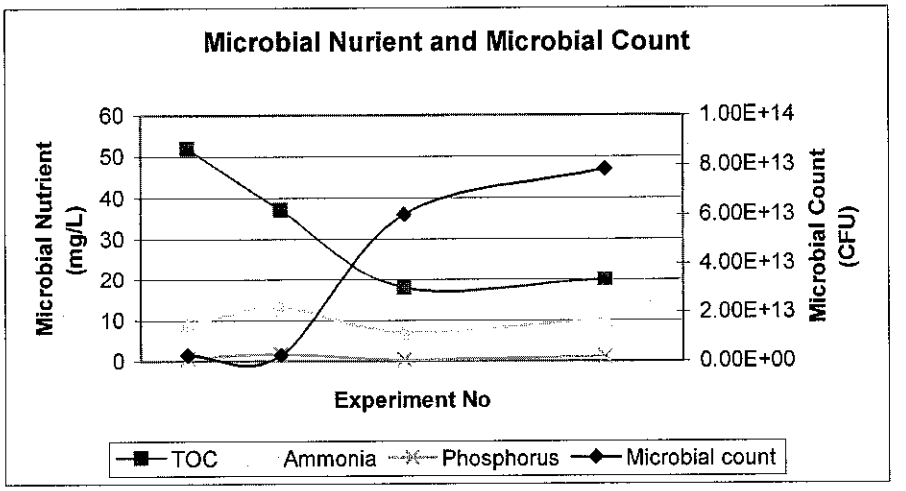


Figure 16 : Relationship between Microbial Nutrient and Microbial Count

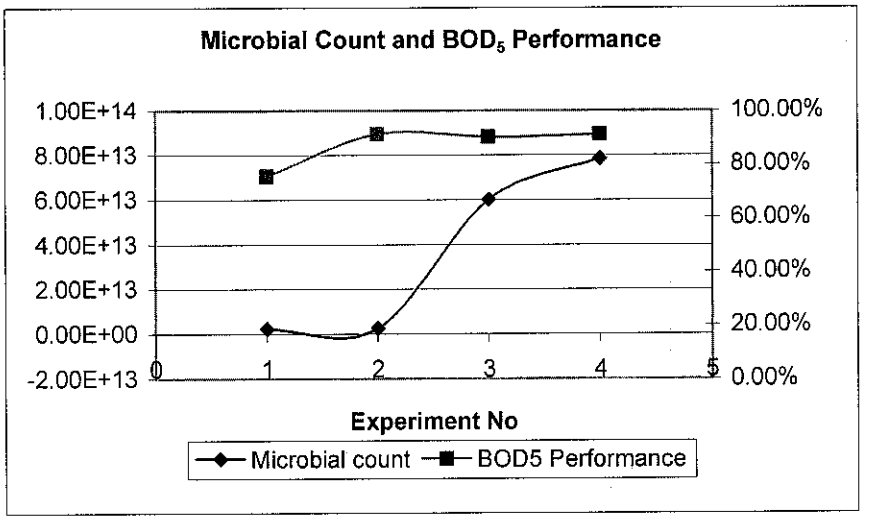


Figure 17 : Relationship between Microbial Count and BOD_5 Performance

It is shown in Figure 16 that when the amount of TOC is high, it will induce the growth of microbial in later part. In the third and fourth experiment, when the microbial count rise to higher value, the TOC value is less because the microbes in the tank have utilized it. When the microbial count increased, the BOD_5 performance of the tank also increases due the more organic breakdown is done, according to Figure 17.

However, in the second experiment it is encountered that the performance of the tank in terms of BOD_5 still very high although relatively the amount of microbes is less. This may be caused by the sample storage that more than one day. Due to some technical problems, the second experiment could not be carried out within 24 hours after the sampling was done. Hence, it might cause some deviation from the expected results.

As the microbial count relates most to the amount of TOC in the wastewater, the important parameter is the TOC value. It is hard to obtain a value for the optimum TOC required but it can be said that the amount should be more than 50mg/L to enhance the microbial growth in the later part.

4.3.2 Nitrification and Denitrification Process

Aerobic autotrophic bacteria are responsible for nitrification in activated sludge process. Although normally these two processes happen in low DO concentrations, they can also happen in aerated activated sludge tank. This is due to both aerobic and anaerobic zones exist depending on mixing conditions and distance from the aeration point, so that nitrification and denitrification can happen in the same tank. Another argument is that when oxygen is present, the bacteria will oxidize the ammonia with oxygen as the electron acceptor. Hence, the nitrification and denitrification process should be studied in this project as well.

Temperature

Higher temperature induces other dissolved oxygen levels in water. Nitrification is strongly inhibited at low temperature than is carbonaceous BOD removal although it is affected by the same way hence Equation 1 applies. Nitrification rates at 10°C are only about one fourth those at 30°C. The nitrification process can occurs over a range of approximately 4 to 45°C (Environmental Protection Agency, 2000). However, they also quote from Borchardt, stating that the nitrification rate is inhibited by the high temperature, around 30°C that beyond this temperature the rate rapidly decrease. In short, Michael H. Gerardi (2002) summarizes the effects of temperature in Table 7 below. Also, please refer to the chart attached in Appendix C : Effect of temperature on nitrification as reported by Environmental Protection Agency, 2000) .

Table 7 : Temperature and Nitrification

Temperature	Effect upon Nitrification
> 45°C	Nitrification ceases
28°C to 32°C	Optimal temperature range
16°C	Approximately 50% of nitrification rate that occurs at 30°C
10°C	Significant reduction in rate, approximately 20% of rate that occurs at 30°C
< 5°C	Nitrification ceases

It is anticipated that the effects does not differ much as on nitrification process as the denitrification is also influenced by dissolved oxygen. Because denitrification is biologically mediated, it occurs more rapidly with increasing temperature and conversely, occurs more slowly with decreasing temperature.

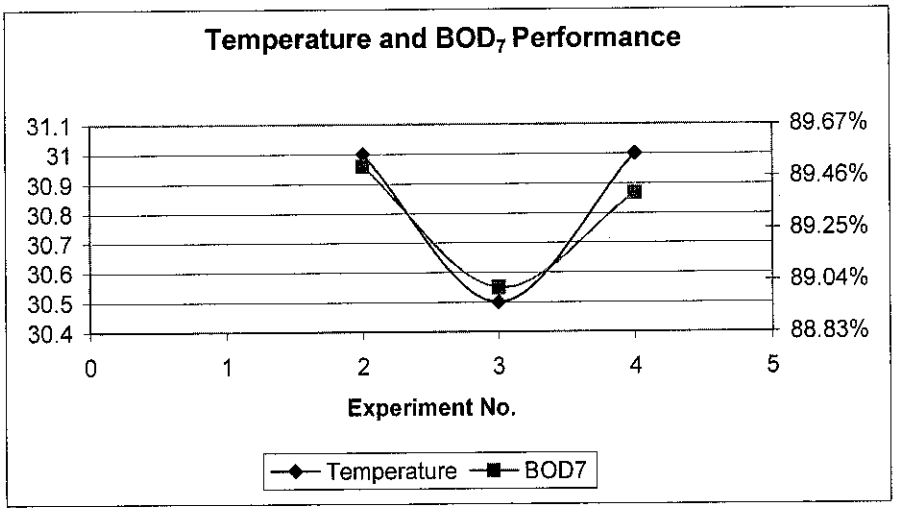


Figure 18 : Relationship between temperature and BOD_7 performance

The results of the experiments was studied and represented in Figure 18. It is seen that at higher temperature, which is 31°C but less than 35°C, the BOD reduction is the best comparing to others. Hence, this verified the theory that at higher temperature of 28°C to 35°C or 32°C, the nitrification and denitrification rate can be elevated.

Nitrification occurs optimally at that temperature because the optimal growth rate for *Nitrosomonas* is at 30°C. Please refer to Appendix D for the chart of growth rate of nitrifiers and temperature. As denitrification also occurs rapidly with higher temperature, the nitrogeneous BOD removal is optimum at about 30°C to 31°C for the treatment plant.

pH

The optimum range for nitrification has been identified as 7.2 to 8.0. The effect of pH is more important comparing to CBOD removal. Since nitrification results in production of free acid which will tend to lower the pH.

Almost 30% decrease in nitrifiers biomass, activity and nitrification efficiency was obtained at pH level below 7. Therefore, to achieve nitrification stability, the process pH should be maintained above 7. pH levels in the more acidic range have been reported to decrease the rate of ammonium oxidation (Environmental Protection Agency, 2000). As a result, nitrification rates may drop significantly as pH is lowered below neutral range.

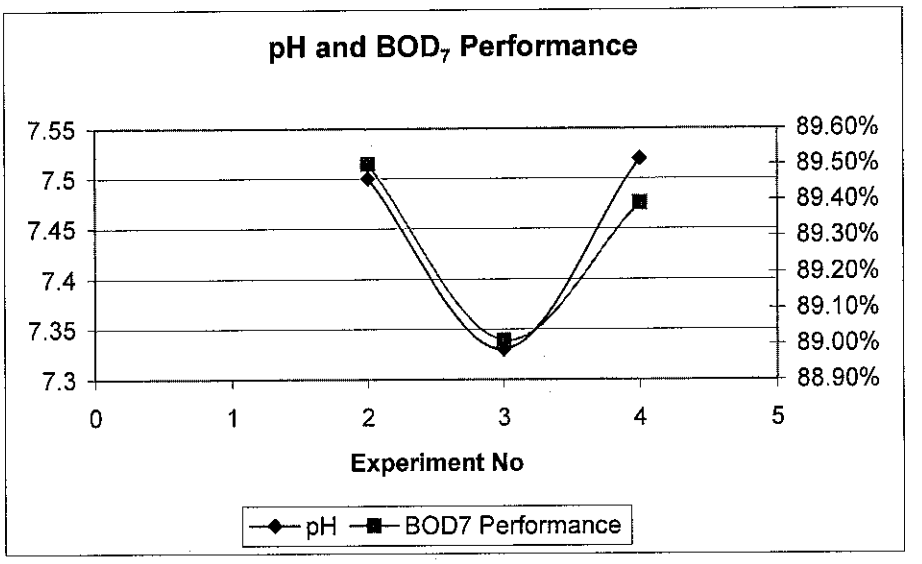


Figure 19 : Relationship of pH and BOD_7 Performance

In the denitrification process, alkalinity is produced during reactions and pH is generally elevated instead of depressed in nitrification. There is less concern about pH influences on the denitrification rates. However, it is discovered that an optimal denitrification rate at a pH of 7.0 is half the rate observed at pH values of 6.0 and 8.0

(Randall et.al, 1992). Another stated that the optimal pH range for denitrification is 7.0 to 7.5 (Gerardi, 2002).

The experiments conducted up to 7 days for BOD are only the second, third and fourth experiment. The procedure for both BOD_5 and BOD_7 testing is similar, only that for BOD_7, the incubator is left for seven days before results can be collected.

As nitrification process occurs mostly at pH 7.2 to 8.0 and denitrification occurs at 7.0 to 7.5, it can be said that the optimum range of pH for the removal of nitrates that will increase BOD reading is 7.2 to 7.5. Referring to Figure 19, the best percentage removal for seven days is at 89.850% with pH of 7.5 in Experiment 2. This followed by percentage removal of 89.39% at pH of 7.52 in Experiment 4. When the pH decreases to 7.33, the percentage removal is less at 89.01%. The results show that at pH 7.5, the nitrification and denitrification process occurs optimally for the removal of BOD_7.

Microbial Nutrient

The microbial nutrient in nitrification is nitrogen, which is usually in the form of ammonium or ammonia (Gerardi, 2002). Although ammonium ions and ammonia are reduced forms of nitrogen, that is not bonded to oxygen, it is the ammonium ion that is oxidized during nitrification. The quantities of ammonium ions and ammonia in an aeration tank are dependent on the pH of the activated sludge. At pH range of 7 to 8.5, about 95% of the reduced form of nitrogen is present as ammonium ions. The range of optimum pH for nitrification to occur is discussed in previous section is within this ammonium pH range. Figure 20 shows the effect of pH on amount of ammonia and ammnonium ions.

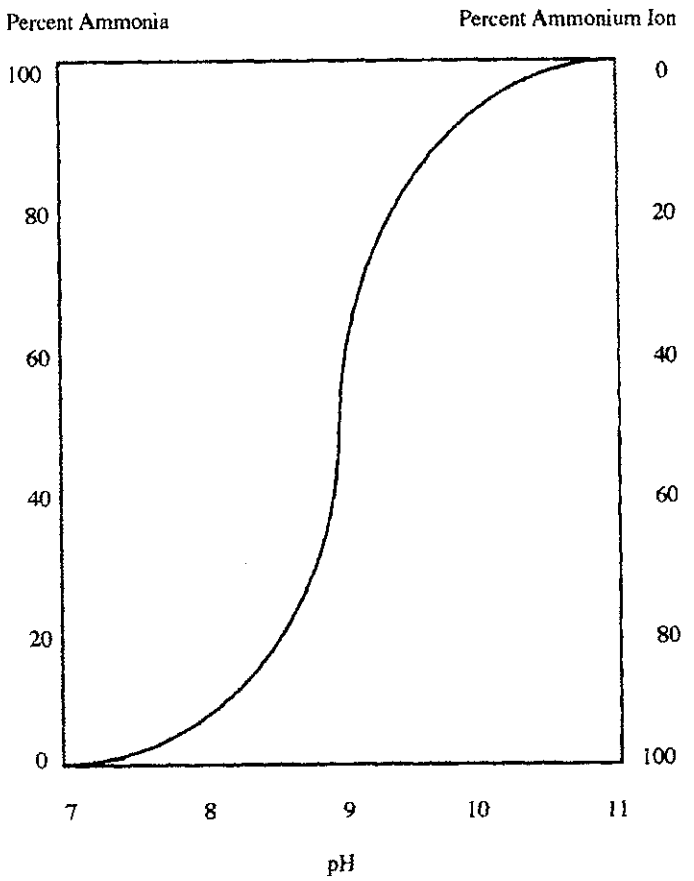


Figure 20 : pH and the conversion of ammonia and ammonium ions (from Michael H. Gerardi 2002)

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion the factors that affect the performance of the sewage treatment plant are studied and the optimum range of values are obtained.. Overall, the optimum conditions for the carbonaceous BOD removal and nitrogenous BOD removal is at 30°C to 31°C and pH of 7.5. As for the microbial nutrient, the amount of TOC should be more than 50mg/L and for better results, the ratio of C:N:P should be at 100:10:1.

5.2 Recommendations

After completing this project, there are few recommendations to further improve this project in the future. It may be a good approach to confirm the suggestion that modification to the aeration tank should be done. This can be done by testing the amount of ammonium, nitrogen and nitrate that actually are present in the wastewater to identify whether nitrification and denitrification do actually occur in the aeration tank. If the result is negative, the treatment plant in case study may consider to remodel the tank to have anoxic-oxic (A/O) system.

More detailed study into the Chemical Oxygen Demand (COD) is also possible to ensure that the effluent would not cause oxygen deficiency in the river or receiving stream. The study on effect of temperature on gas transfer rates and settling characteristics should also be carried out.

REFERENCES

1. Eckenfelder , W. Wesley and Grau, Petr. 1998. Activated Sludge Process Design & Control : Theory And Practice, 2nd Edition. Technomic Publishing Co., Inc, USA.

2. Ganczarczyk, Jerzy J.. 1983. Activated Sludge Process. Marcel Dekker, Inc. New York, USA.

3. Tebbutt, THY. 1998. Principles of Water Quality Control, 5th Edition. Butterworth Heinemann, UK.

4. Randall et.al. 1992. Water Quality Management Library Volume 5 : Design and retrofit of wastewater treatment plants for biological nutrient removal. Technomic Publishing Co., Inc. USA

5. Orhon et.al. 1994. Modelling of Activated Sludge Systems. Technomic Publishing Co., Inc. USA

6. Metcalf and Eddy. 2003. Wastewater Engineering Treatment and Reuse. McGraw Hill, USA.

7. McGhee. 1991. Water Supply And Sewerage, 6th Edition. McGraw-Hill. USA.

8. Gerardi. 2002. Nitrification and Denitrification in the Activated Sludge Process. John Wiley & Sons, Inc. USA.

9. BODTrak Instrument Manual. 1998. HACH Company.

10. COD Reactor Instrument Manual. 2000. HACH Company.

11. www.abe.msstate.edu/csd/references/surface.html (Environmental Protection Agency)

12. http://www.dnr.state.wi.us/org/water/wm/ww/tech/biol.htm

13. http://www.eng.fsu.edu/~dommelen

14. www.college.ucla.edu/webproject/micro7/studentprojects7/Rader/asludge2.htm

15. www.nottingham.ac.uk/~evzngw/teaching/H23HWQ (University of Nottingham)

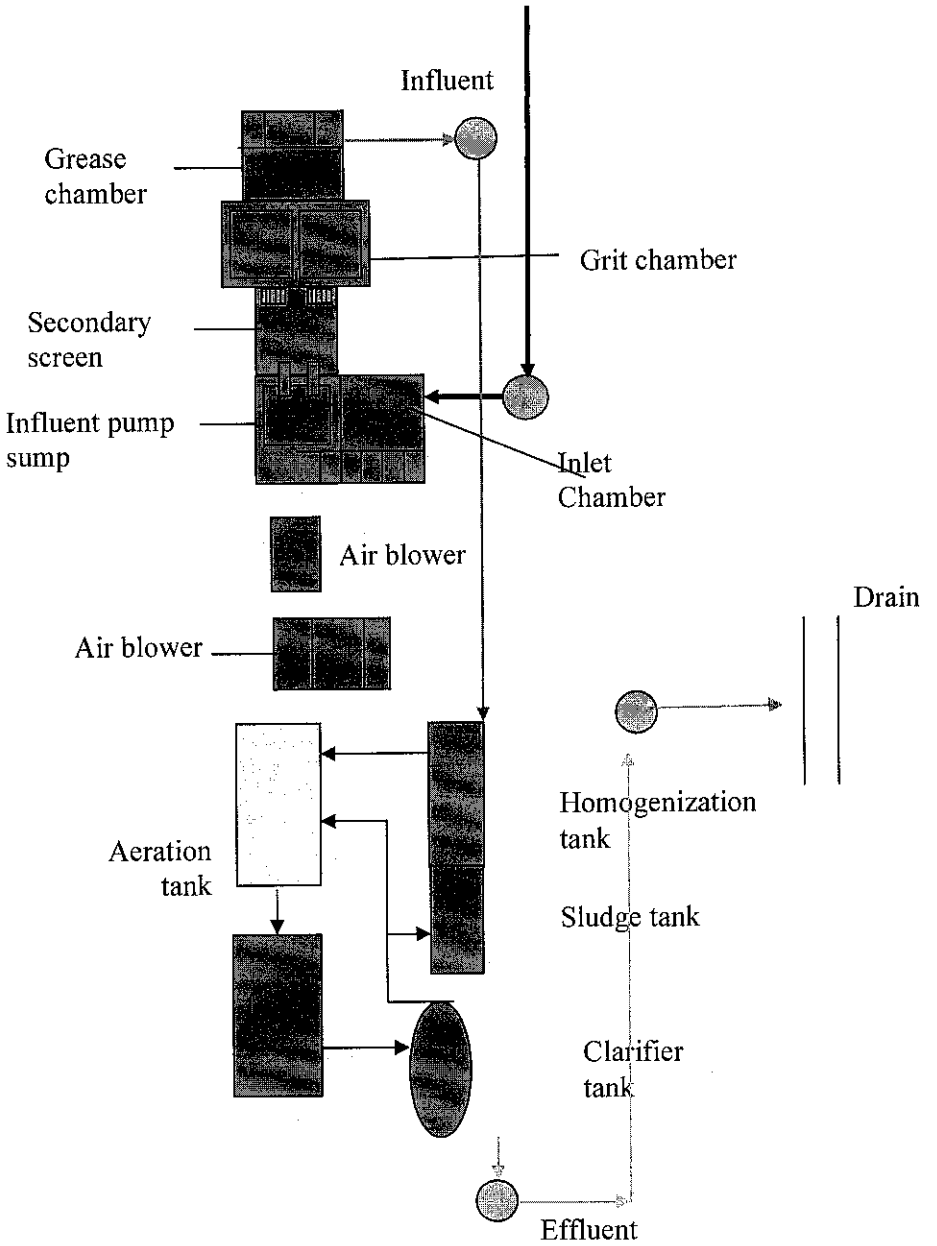
16. www.mrwa.com/wwfactsheets.htm

APPENDICES

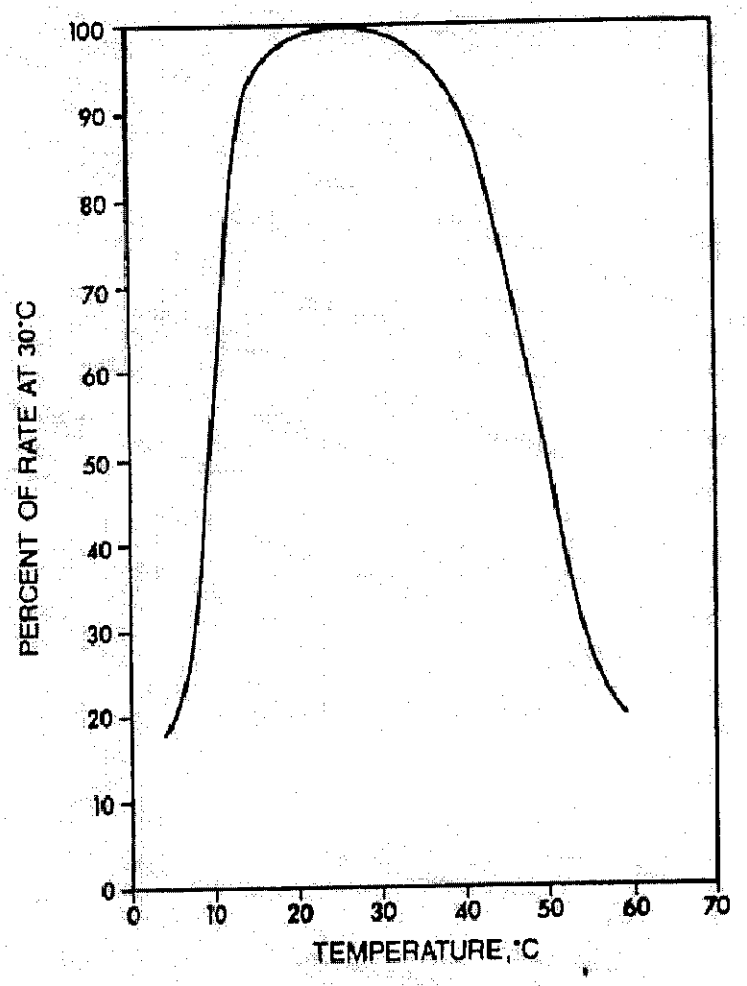
Appendix A : Project Milestone

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
	Propose topic														
2	Preliminary Reasearch Work														
	Introduction														
	Objectives														
	List of references/literature														
	Project planning														
3	Submission of Preliminary Report			•											
4	Project Work														
	Reference/Literature														
	Practical - BOD & COD testing														
5	Submission of Progress Report								•						
6	Project work continues														
	Practical - Data analysis														
7	Submission of Interim Report Final Draft												•		
8	Oral Presentation													•	
9	Submission of Interim Report														•

Appendix B : Sewage Treatment Plant Plan



Appendix C : Effect of temperature on nitrification as reported by Borchardt (1966).



Appendix D : Growth Rate of Nitrifiers and Temperature