# Water Treatment for GDC UTP Chilled Water System by Using Physical and Chemical Approach

by

Hazim Bin Abdul Halim

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Chemical Engineering)

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## CERTIFICATION OF APPROVAL

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Approved:

(Mr Azizul B. Buang)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 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 specified sources or persons.

HAZIM BIN ABDUL HALIM

# ABSTRACT

The use of Thermal Energy Storage (TES) tank that currently being practice by GDC UTP has become a widely accepted method for the production and storage of chilled water for air conditioning cooling. However in 2009, GDC UTP's TES has detected having high turbidity which is higher than 300 NTU and accumulation of sludge at bottom of the tank due to no clarification system for chilled water system for 10 years. This accumulation of sludge will be starting point of heat transfer failure and corrosion cell. This project will investigate a suitable clarification system that would help to achieve reducing the turbidity and total iron value in TES tank into desirable range. Coagulation & Flocculation and Dissolved Air Floatation (DAF) system only being take into our consideration because this project will focus toward turbidity as an indicator that we want to reduce. Based on the experiment carried out through this project, Coagulation – Flocculation is very good approach to be implemented for water treatment for GDC UTP Chilled Water System compared to Dissolved Air Floatation. Results of treated water by Coagulation – Flocculation shows around 20 NTU which is already below 30 NTU, allowable specification turbidity for chilled water in GDC UTP.

## ACKNOWLEDGEMENT

Alhamdulillah, thanks to the Almighty, Allah s.w.t, this project is finally completed and all results were successfully obtained. All process flows were run smoothly according to the work timeline.

With the exposure to the reality of researching, it is very good understood that researching process is not as easy as it looks. Researching through his study has provided me tools and skills to be successful researcher. Even though there are problems encountered along the way in completing this project, with the help of my supervisor Mr Azizul Bin Buang, such problems were managed to be handled wisely. With his assistance and guidance, much information and understanding of this project were successfully obtained and developed through experimental works and literature research. My utmost gratitude goes to her for spending lots of time monitoring all FYP students worked under her supervision.

Not to forget the coordinator of FYP II, Dr. Asna for her arrangement and assistance for making all of this possible.

Last but not least, my gratitude also goes for Chemical Department Lab Technicians, Mr. Fazli, Mr. Jailani and Mr. Shaharudin for working through hours to make all the FYP students are supplied accordingly to their needs and to assist us in using equipments available in Chemical Engineering Laboratory.

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# CHAPTER 1
# INTRODUCTION

## 1.1 Background Of Study

Cogeneration/ District Cooling Plant for Universiti Teknologi PETRONAS (UTP) are designed to produce electric power and steam from Cogeneration system, and supply chilled water from chilled water system. Electric power produced from Cogeneration system is used for UTP and Plant operation, and the steam is used mainly to produce chilled water in Steam Absorption Chiller (SAC).

Water chillers are used in a variety of air conditioning and process cooling applications. They cool water that is subsequently transported by pumps and pipes. The water passes through the tubes of coils to provide air conditioning comfort to the occupants of commercial buildings and industrial facilities and to support industrial processes. Systems that employ water chillers are commonly called chilled-water system.

The chilled water system in GDC UTP consists of mainly Steam Absorption Chiller (SAC) system and Thermal Energy Storage (TES) system with Air Cooled Chiller (ACC), and this chilled water supply and return system is connected with those systems. Primary pump system is provided in chilled water system, so that pumps in SAC and TES system supply directly chilled water to customer building. And chilled water is also used for air-conditioning system in plant, and supplied to AHU and FCU for electrical room, administrator area and CCR etc.

The thermal energy storage (TES) tank is a place where the charging of cooling energy happened during night time. TES tank is provided for purpose of reduction of total chiller's capacity by using stored chilled water in TES at peak time of customer's chilled water demand. And also electric consumption in plant at the peak time can be deducted, due to reduction of total chiller's capacity. The TES tank has a capacity for 10,000RTH, and it is able to store chilled water of 5,400 m3. There are 4 pump to discharge chilled water from TES tank to chilled water distribution pipeline (customer building), and these pumps are able to discharge chilled water for 1,500RT, and will cover 4,00RT.

## 1.2 Problem Statement

Thermal Energy System (TES) tank at Cogeneration/ District Cooling Plant UTP has been detected having high turbidity and accumulation of sludge since no cleaning conducted after years in operation. In 2009, the turbidity level is measured higher than 300NTU. The fine sedimentation or known as suspended solids which is soluble in the chilled water will precipitate and accumulating at the bottom of the TES tank.

This is because the system is designed to avoid turbulence as water re-enter the tank, sludge tends to form and is not dispersed by the flow of water. This sludge can accumulate and harbour microbiological organisms that can increase deposit and corrosion problems throughout the TES system.

The sludge also will be a starting point of heat transfer failure and also corrosion cell which known as under deposit corrosion. Under deposit corrosion will thinning the piping material and resulting a total shutdown of system.

## 1.3 Objective

To study suitable clarification system for Gas Distilled Cooling UTP Chilled Water System that would help to achieve reduce the turbidity and total iron values in TES tank and distribution line into desirable range. This project only takes Coagulation & Flocculation and Dissolved Air Floatation (DAF) system into consideration because turbidity is the main indicator in this project.

## 1.4 Scope of Study

The scope of study for this project is on analyzing the high turbidity level that has happened in GCD UTP chilled water system and propose a clarification system to control the problem. A few techniques have been identified as potential solutions to be implemented on the chilled water. Further discussion is made by comparing the result of turbidity level for the different techniques through the experimental method in the laboratory.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Definition of Turbidity

Turbidity is a measure of the cloudiness or murkiness of water due to suspended particle. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and other microscopic organisms. This measurement is relate to the optical property of a water that causes light to be scattered and absorbed rather than transmitted in straight lines through samples. For example, at high particle concentrations, scattered light itself be rescattered by the suspended solid before reaching the detector or observer's eye.

There are several methods may be used in the measurement of water turbidity, but only two of these, nephelometry and turbidimetry, form the basis for present standard method. A Jackson turbidity unit (JTU) is an empirical measure of turbidity based on the depth of a sample water column that is just sufficient to extinguish the image of a burning standard candle observed vertically through the sample. The current method of choice for turbidity measurement, in both Canada and United States is the nephelometric method. Nephelometric turbidimeters measure the intensity of light scattered at 90° to the path of the incident light. However, that as there is no direct relationship between the intensity of light scattered at 90° and JTU("UN Water Learning Center," 1995).

## 2.2 Important of Treatment for Thermal Energy Storage System

Chilled water system is used in a variety of air conditioning and process cooling application. This chilled water is subsequently transported by pump and pipes, passes through the tubes of coil to cool air in an air conditioning system, or it can provide cooling for a manufacturing or industrial process. Chilled water system control temperatures by transferring heat from ambient air into the chilled water, which carries the heat away.

In TES systems, scaling is rarely a problem because most the system has low temperature and low hardness system but fouling due to microbial and steel corrosion products are far the biggest problems in TES system. This problem is due to a variety of condition:(Meier, 1998)

1. Large volumes of water that can sit stagnant for extended periods of time. This will locally deplete the corrosion inhibitors leading to corrosion and the development of corrosion-based deposits. The lack of flow can affect the distribution of treatment program throughout the system.
2. Inadequate mechanical removal of solid due to the lack of filters and size of the system.
3. Economics of proper corrosion inhibitor treatment and microbiological control
4. Lack of designed blow down or replacement of water

As the result, there will be decomposition of pre-formed particles such as corrosion by-product and transport of corrosion dirt or microbial particles throughout the chilled water system. These problems can cause clog in small air handler tubing and lead to poor environment control in a building.

Meier also stated that, fouling due to corrosion product and microbial contamination can also lead to underdeposit corrosion. This underdeposit corrosion can bring to leaks in air handler affecting individual building officers as well as leaks in underground piping that may be difficult to located and repair. Solids and sludge will accumulate in the bottom of TES tank. The accumulation sludge has been known to harbour anaerobic corrosive organism that can affect a system and make microbial control difficult. Treatment water system that use physical and chemical approach is needed for removal of solids for optimal performance of chilled water system

Thus, chilled water system's turbidity has direct affect towards reliability, efficiency and cost of industry. Monitoring and maintaining control of corrosion, deposition, microbial growth and system operation is essential to provide the optimum Total Cost of Operation. When the chilled water system cannot remove the heat efficiently, the entire process suffers and costs increase. In addition, if the chilled water system operation is not optimized, excess water, wastewater and energy cost result.

## 2.3 Potential Treatment for Chilled Water System

### 2.3.1 Coagulation and Flocculation System

Most naturally occurring fine particle, such as those produced at an aggregate operation, have a negative surface charge. This charge sets up repulsive forces that reduce the tendency for the particle to agglomerate and settle. However, other factors such as particle size, particle density, and liquid density also exert considerable influence on the tendency of fine particle to settle. Stokes law, shown below, can be used to estimate the time it takes for a free falling particles in a liquid to settle.

$$V = \frac{2g\, r^2(d_1 - d_2)}{2\eta}$$

V = final velocity of particle

r = radius of particle

$d_1$ = density of particle

$d_2$ = density of liquid

$\eta$ = coefficient of viscosity

$g$ = gravitational constant

**Table 2.1**: Effect of particle size on settling rate

| Particle Diameter (mm) | Order of Size | Total Surface Area*, $cm^2$ | Time Required to Settle, 1 foot** |
|---|---|---|---|
| 10.0 | Gravel | 3.142 | 0.03 sec |
| 1.0 | Coarse Sand | $3.142 \times 10^1$ | 0.3 sec |
| 0.1 | Fine Sand | $3.142 \times 10^2$ | 33 sec |
| 0.01 | Silt | $3.142 \times 10^3$ | 55 min |
| 0.001 | Bacteria | $3.142 \times 10^4$ | 92 hr |
| 0.0001 | Colloidal | $3.142 \times 10^5$ | 384 days |
| 0.00001 | Colloidal | $3.142 \times 10^6$ | 105 hr |

* Area for particle of indicated size produced from a particle 10 mm in diameter

** Calculation based on a sphere with sg 2.0 at 25°C

Based on J. Pillai (1997) in his article '*Flocculants and Coagulants: The Key to water and Waste Management in Aggregate production*', by using Stokes Law, settling times for particle of different sizes can be estimated and are given in Table 1. These calculations are based on a spherical particle with a specific gravity of 2.0 at 25°C.

As expected, decreasing a particle's size reduces its settling rate. The main area of interest in the aggregate industry is particle in the size range of "silt". Settling times are on the order of 55 minutes per foot or 0.2 inches per minute.

Since Stokes law assumes that the particle is settling freely, it is reasonable to expect that in conditions such as those typical to aggregate production, some particle-to-particle interference, or hindered settling, will occur, further slowing down the settling rate. In order to handle the same volume of effluent in a small pond, settling rates

**Coagulation**

As mentioned earlier, fine aggregate particle have a negative surface charge. In order to bring these particles together, these surface charges need to be neutralized. The process of charge neutralization and bonding of particles to form microfloc particles is called coagulation. Charge neutralization is achieved by injection of a coagulant, which neutralize the negative surface charge by its positive charge. Coagulated particle are then aggregated to larger particle sizes and settle by the addition of a flocculants. The coagulation mechanism is shown in Figure 1.

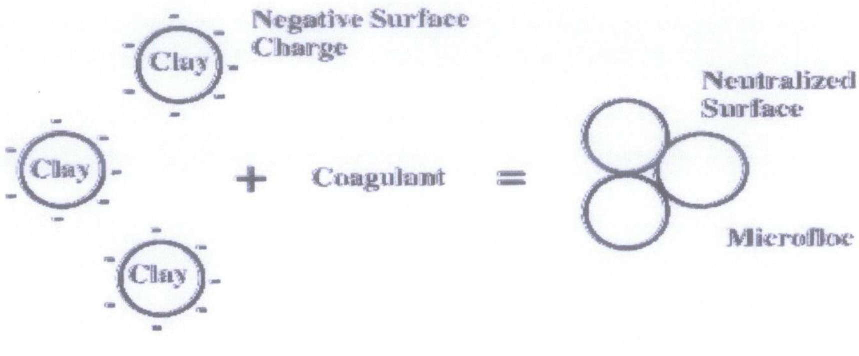



**Figure 2.1**: Coagulation of fine clay particles in a slurry

Use of natural coagulant has been documented for over 100 years. Natural coagulants such as starch, glue, guar gum, and sodium alginate were favoured on most industries application in early in this century. However, these natural coagulants eventually gave way to more cost effective, synthetic polymeric coagulants introduces on early 1950s.

After the surface charges of particles are neutralized and microflocs are formed, flocculants are often added to bring the microfloc particles together. Modern synthetic flocculants have gained widespread acceptance in a number of industrial application. These products can be, and often are, tailor-made to fit number of applications to provide a cost efficient method of improving plant productivity.

**Flocculation**

The function of a flocculants is to bring together coagulated particles into a large aggregate and settle them. Figure 2 shows the mechanism of flocculation on fine clay particles.

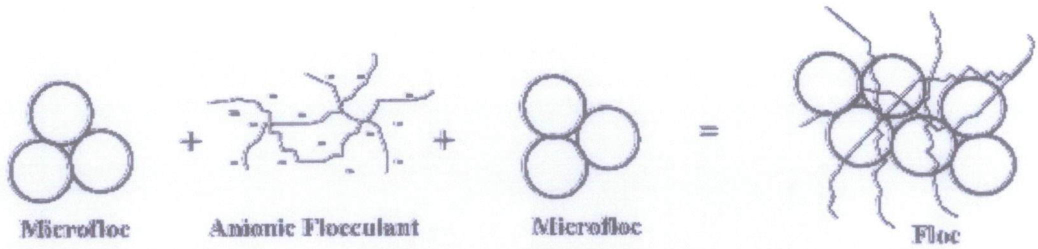



**Figure 2.2**: Flocculation of coagulated fine clay particles

A typical flocculant is a long chain hydrocarbon. These polymers consist of several (poly) repeating units (mer) and have molecular weights varying from 5 to 20 million. Molecular weights of flocculants are significantly higher than those of coagulants which range from 2,000 to 200,000.

The molecular weight of both coagulants and flocculants can be controlled and modified by changing process variable during manufacturing. Also, variety different functional groups can be attached to the backbone of a flocculants to give it different properties. Those products can be tailor-made for specific application, resulting in synthetic polymers that are much more active than natural polymers.

J. Pillai also stated that, depending on its chemistry, the charge of a flocculants can be neutral, anionic, or cationic. Most aggregate operations are neutral (nonionic) or anionic flocculants. Nonionic flocculants are long chain polymers of polyacrylamides made from acrylamide monomer. Most flocculants used in aggregate applications are copolymers of acrylamide and sodium acrylate. Acrylamide-acrylate copolymers are anionic due to present of negatively charge carboxylate groups in the polymer. The ratio of sodium acrylate to acryl amide in the polymers determine its anionicity. A higher proportaion of sodium acrylate will be result in a higher charged flocculants.

### 2.3.2 Dissolved Air Floatation (DAF) System

Dissolved air floatation (DAF) is a process for removing suspended particle liquid by bringing particle to the surface of the liquid. Raw water, wastewater or liquid sludge can be influent feed for the system. There are four major components for the floatation system which is air supply, pressuring pump, saturator and floatation chamber. By referring to Hendry's Law, the solubility of a gas in an aqueous solution increases with increasing pressure.

According to S. Srinivasan and T. Viraraghavan in his article '*Dissolve Air Flotation In Industrial Waste Water Treatment*', air is dissolved in the wastewater at high pressure in a saturator at high pressure. Then, micro bubbles are formed when water is released in the floatation cell at atmospheric pressure. The influent feed stream may be pressurized by mean of a pressurizing pump to 172-620 kPa with compressed air added at the pump suction before the pressurized stream is held in a retention tank at this high pressure for about 0.5 to 30 min to allow sufficient time for the air to dissolve into the feed stream.

It is then admitted through a pressure reducing valve to the floatation chamber. In the flotation chamber, sudden reduction in pressure makes the release of microbubbles. This microbubbles will attached to suspended or colloidal particles in the process water, then increasing their buoyancy and allowing them to rise to the surface to form a floted layer.

S. Srinivasan and T. Viraraghavan also stated that the vertical rise rate of air bubbles range from 0.152 to 0.061 m/min. Flight scrapers or other skimming device continuously remove the float material. The effluent from DAF is drawn from the bottom of the flotation chamber for reuse or discharge.

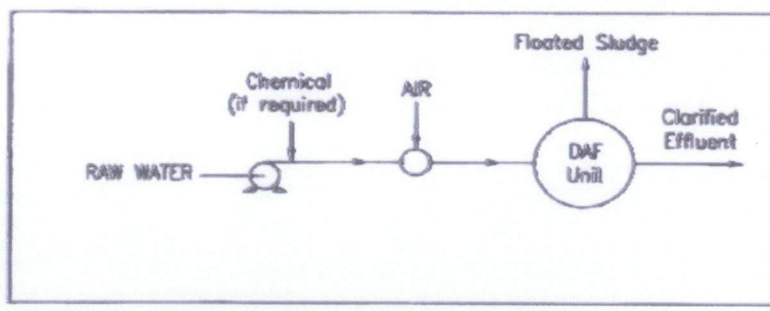



**Figure 2.3: Full flow dissolved air floatation**

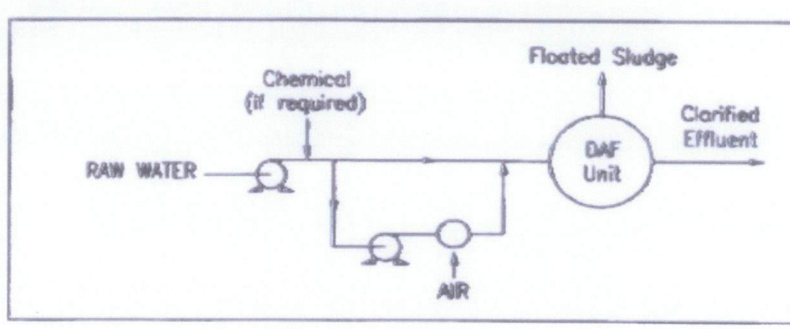



**Figure 2.4**: Partial flow dissolves air floatation without recycle

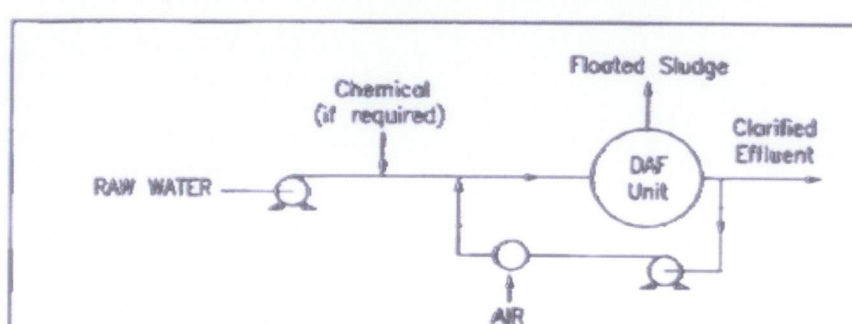


**Figure 2.5**: Recycle flow dissolved air floatation

The design of a specific dissolved air floatation (DAF) system depends upon the factors such as the volume of waste water to be treated, the degree and nature of contamination, the extent of treatment required, and any subsequent treatment that is required for the recovered product concentration. These factors later need to be considered to get the appropriate dissolution pressure, flow rate, retention time, recycle ratio, coagulant and flocculent pre treatment, floatation tank design and baffle setup for the desired treatment. (Oliveira, Gonzalez, & Oliveira, 1999)

R. Oliveira, G. Gonzalez and J. Oliveira also stated that the caption efficiency is defined as the ratio of the number of bubble-captured particle to the number of particle initially located in the volume that the bubble swept. As the bubbles concentration increase, the collision opportunity between bubble and particle also increase, thereby, leading to improved attachment efficient. The efficiency of a DAF, therefore is directly proportional to the bubble concentration which is generated by the dissolved gas in the saturator. The equilibrium concentration of a dissolved gas depends mainly upon the temperature of the water and partial pressure of the gas in the atmosphere in contact with the water.

Based on Reay and Ratcliff, the influence of droplet and bubble sizes in floatation can be briefly discussed by following probability of floatation ($P_f$) expression where, $P_c$ is the probability of collision, $P_a$ is the probability of adhesion and $P_s$ is the probability of a stable aggregate formation that depend on the contact angle value.

$$P_f = P_c.P_a.P_s \text{.................} (1)$$

Reay and Ratcliff also studied that the flotation of fine particle by dissolved gas floatation and propose hydrodynamic equations for the movement of the particle in relation to the bubbles. They defined the collision efficiency parameter

($E_c$) as a relation between the number of particle that effectively collide with a bubble and the number of particles that effectively collide with a bubble the number of particle laying along its cylindrical trajectory. They have found that the collision efficiency is related to the diameter of the particle ($d_p$) and that of the bubble ($d_b$) by the expression:

$$E_c = \alpha_{\circ}.(\frac{d_p}{d_b})^N \text{ ............... (2)}$$

The volume of each particle was disregarded and the limiting condition for collision is considerate to occur when the centre of the particle touches the surface of the bubbles. The Reay and Ratckiff hypothesis for the limiting condition, however, is that in which the particle surface touches the bubble surface. For particles smaller than 0.2 mm, Reay and Ratchiff deduced that following expression for the particle-bubble collision efficiency

$$E_c = \frac{R^2}{(1+G)}\left[1 + G - \left(\frac{1.5}{R}\right) + \left(\frac{0.5}{R^3}\right)\right] \text{..... (3)}$$

Where R and G is given by:

$$R = 1 + \frac{d_p}{d_b} \text{ .............(4)}$$

$$G = (R^2 - 1).\left[\left(\frac{\rho_p}{\rho_f}\right) - 1\right] \text{... (5)}$$

# CHAPTER 3
# METHODOLOGY

## 3.1 Research Methodology

The methodology used in performing the research can be divided into 5 parts:

a. **Selection of a few process**
   Student is given a problem statement that needs to be studied. The process will be used for real scenario study in case of the clarification system for chilled water system in GDC UTP. A few techniques of water treatment for the further investigation have to be selected. The selected treatment method would be coagulation & flocculation system and dissolve air floatation (DAF) system.

b. **Sample Preparation and Designing of Dissolved Air Floatation**
   Student has to design clarification system in order for the experiment of turbidity reduction to carry out. After selection of process, student needs to come up with the process modelling that represents the whole process. Student has to do research in the internet and books on the past modelling of the techniques that have been chosen previously for reference.

c. **Comparison Analysis**
   Based on specific initial characteristics of chilled water sample, the performance between the two selected treatment methods will be analysed.

**d. Manipulation Parameter of Clarification System**

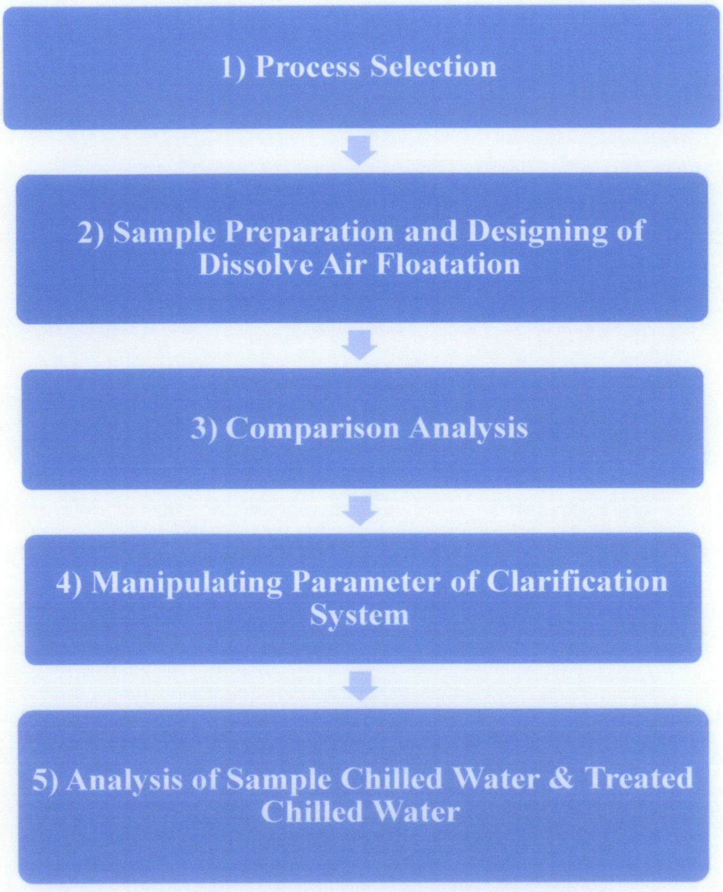
Analysis on the design of clarification system is carry out by manipulating the parameter of the system through the experiment in the laboratory. Thus, the student can determine the best parameter condition to achieve optimization in the system. By determining the best parameter condition, student is able to achieve high performance clarification system.

| Parameters | |
|---|---|
| **Coagulation-Flocculation** | **Dissolved Air Floatation** |
| ▪ Dosage<br>▪ Mixing Time<br>▪ Settling Time | ▪ Intensity of Bubbles |

**e. Analysis of Sample Chilled Water & Treated Chilled Water**

All the analysis of chilled water quality will be conducted on the HACH 2100P Portable Turbidimeter. The parameters that are concerned are turbidity only.

## 3.2 Project Activities




### 3.2.1 Sample Preparation

In order to prepare sample for this experiment, 6 bottles of 1.5 litre of chilled water was taken through drain valve at Thermal Energy Storage in Gas Distilled Cooling UTP. This sample basically represents the current chilled water quality at the bottom of TES tank.

**Figure 3.1**: TES Drain Valve

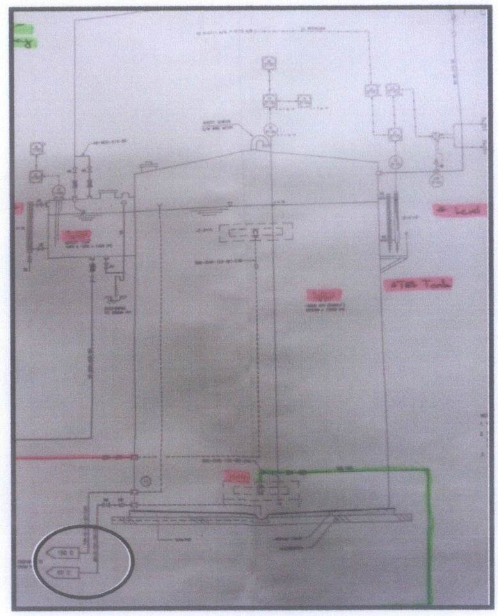


**Figure 3.2**: Position of Drain Valve

However chilled water system in GDC UTP Plant was already treated by Makhostia Sdn. Bhd by April 2013 and the turbidity is already reduce to 12 NTU. In order to make this chilled water feasible sample for this experiment, sludge have to add up to chilled water to increase the turbidity level. The sludge was taken from Universiti Teknologi PETRONAS Waste Water Treatment Plant.

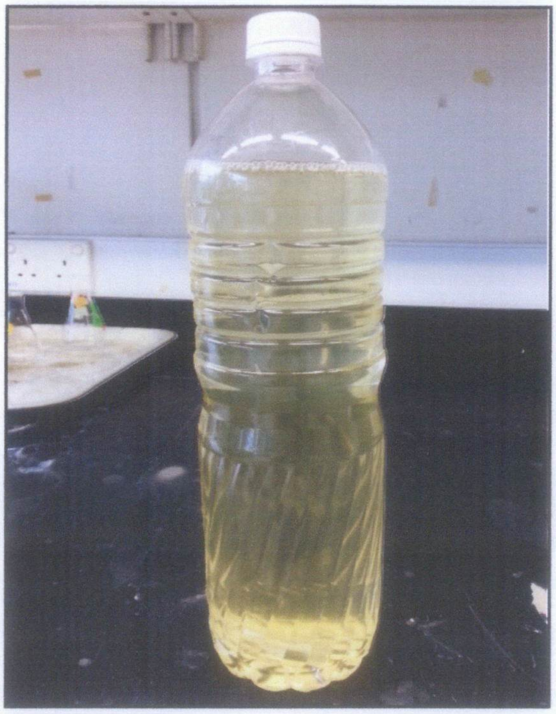


**Figure 3.3:** 1.5 litre bottle of Chilled Water

**Figure 3.4**: Sample of Sludge

In order to produce chilled water with 300 NTU, a few trial of mixing ratio between chilled water and sludge have been made as below:

**Table 3.1**: Dosage ratio between chilled water and sludge

| Chilled Water Dosage (mL) | Sludge Dosage (mL) | Ratio | Turbidity (NTU) |
|---|---|---|---|
| 200 | 20 | 0.1 | Out of range |
| 200 | 20 | 0.05 | 592 |
| 200 | 5 | 0.025 | 320 |
| 200 | 1 | 0.005 | 78 |

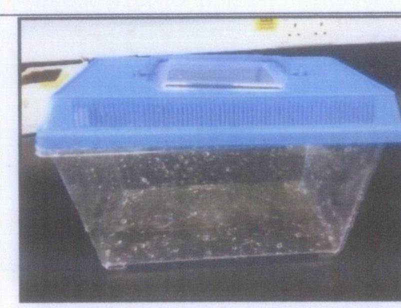
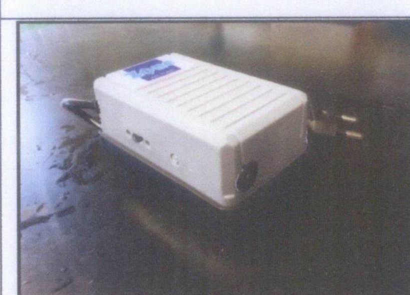
Thus, dosage ratio between chilled water and sludge 0.025 is chosen in order to get turbidity level which is 320 NTU.

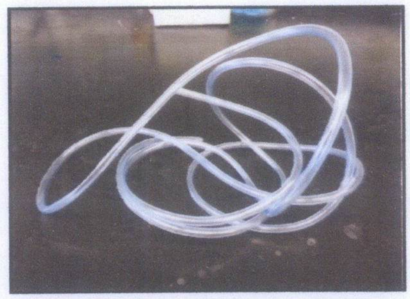
**Figure 3.5**: Chilled water sample with turbidity 320NTU

### 3.2.2 Designing of Dissolved Air Floatation

By referring to conventional concept of conventional Dissolved Air Floatation, a laboratory size model of DAF can be build by using:

**Table 3.2:** Dissolved Air Floatation Model's components

| Items | Unit | Picture |
|---|---|---|
| 1) Aquarium Tank | 1 |  |
| 2) Air Pump | 1 |  |

| | | |
|---|---|---|
| 3) Plastic Tube | 1 |  |
| 3) Air Stone | 1 |  |

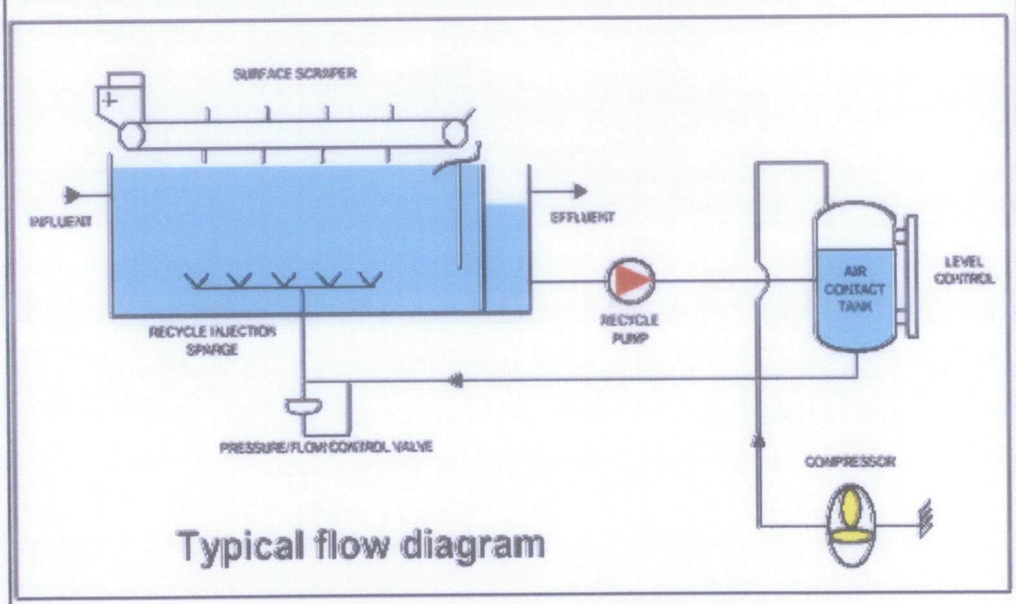



**Figure 3.6:** Conventional Dissolve Air Floatation System

**Figure 3.7:** Model of Dissolve Air Floatation (DAF) in laboratory

### 3.2.3 Comparison Analysis

Experiment A: Induced Air Floatation System

1. Dissolved Air Floatation is prepared according to the model.
2. The model is filled up with 1.5 litre of sample.
3. The air pump of DAF model is run for 20 minutes. Turbidity of the sample is taken for every 5 minutes interval which 3 times measurement of turbidity is considered n order to reduce random errors.
4. Step 1 to 3 is repeated for both high and low intensity of air bubble.
5. Gathered data is analysed.

Experiment B: Coagulation – Flocculation

1. Coagulant which is Aluminium Chloride is prepared.
2. 250mL of sample is measured and filled up into each jar test reactor. The portions of aluminium chloride that will give dose of 100, 200 and 300 mg for every 250mL of sample is prepared.
3. The mixture is rapid mix for 10 minutes at 300 rpm. This can programmed into the jar test. Formation of flocs is observed. Then turn off the mixers.
4. Particle is allowed to settle for 10 minutes (removes the paddles during quiescent settling)
5. Take note on the turbidity of the sample and data is analyzed.

6. Step 1 -5 is repeated by manipulating mixing time to 10 min, 20 min and 30 min, 100 mg are chosen as the constant dosage of Aluminium Chloride and 10 minutes as the constant settling time.
7. Step 1-5 is repeated by manipulating settling time to 10 min, 20 min and 30 min, 100 mg are chosen as the constant dosage of Aluminium Chloride and 10 minutes as the constant mixing time.

## 3.3 Gantt Chart

Gantt Chart

| No | Project Activities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Selection of Project Topic | ■ | ■ | | | | | | Mid-semester break | | | | | | | |
| 2 | Preliminary Research Work | | | ■ | ■ | ■ | ■ | | | | | | | | | |
| 3 | Submission of Extended Proposal Defense | | | | | | | ● | | | | | | | | |
| 4 | Proposal Defense | | | | | | | | | ■ | ■ | | | | | |
| 5 | Clarification System Designing | | | | | | | | | | | ■ | ■ | ■ | | |
| 6 | Submission of Interim Draft Report | | | | | | | | | | | | | | ● | |
| 7 | Submission of Interim Report | | | | | | | | | | | | | | | ● |

● Suggested Milestone

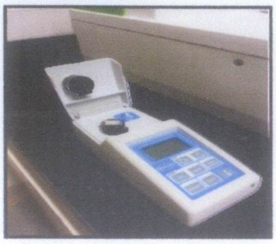
| Key Milestones | Completion Date |
|---|---|
| Confirmation of project supervisor | At week 3 |
| Confirmation of research title | At week 5 |
| Completion of first stage literature study<br>- Concept of Turbidity<br>- Important of Water Treatment for Chilled Water System | At week 5 |
| Completion of extended research proposal submission | At week 8 |
| Completion of second stage literature study<br>- Coagulation-Flocculation System<br>- Dissolve Air Floatation (DAF) System | At week 8 |
| Outlining experimental methods and procedures | At week 8 |
| Completion of proposal defense presentation | At week 9 |
| Completion of clarification system modeling | At week 12 |
| Submission of interim report | At week 14 |

### 3.4 Material & Equipment

The material required to develop this project:

| Chemical | Purpose |
|---|---|
| **Polyaluminium Chloride (PAC)** | To employ as coagulant in the coagulation flocculation process. |

The tool required to develop this project:

| Tool | Purpose | Picture |
|---|---|---|
| **HACH DR5000** | To measure level of turbidity and iron contain in the sample. |  |

# CHAPTER 4
# RESULTS AND DISCUSSION

Turbidity was measured according to standard methods using HACH DR5000, a turbiditymeter (Hach Company, Loveland CO). For every 5 minutes interval, turbidity level of the sample is taken by measuring three different reading to avoid random errors. The point of measurement for turbidity level is also being consistent along the experiment.

## 4.1 Dissolved Air Floatation

Shown below in Table 4.1 and Table 4.2 is the turbidity level of the sample on the respective time for both high and low intensity of bubbles. Intensity of bubbles can be controlled on the air pump.

**Table 4.1:** Turbidity Level with High Intensity of Bubbles

| Time (min) | Turbidity (NTU) | | | Average Turbidity (NTU) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 0 | - | - | - | 306.0 |
| 5 | 187.0 | 196.0 | 192.0 | 191.6 |
| 10 | 207.0 | 216.0 | 213.0 | 212.3 |
| 15 | 222.0 | 217.0 | 223.0 | 220.6 |
| 20 | 197.0 | 225.0 | 214.0 | 212.0 |
| 25 | 199.0 | 193.0 | 200.0 | 197.3 |
| 30 | 216.0 | 213.0 | 216.0 | 215.0 |

**Table 4.2:** Turbidity Level with Low Intensity of Bubbles

| Time (min) | Turbidity (NTU) | | | Average Turbidity (NTU) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 0 | - | - | - | 306.0 |
| 5 | 266.0 | 275.0 | 274.0 | 271.6 |
| 10 | 265.0 | 284.0 | 277.0 | 275.3 |
| 15 | 277.0 | 273.0 | 277.0 | 275.6 |
| 20 | 275.0 | 277.0 | 276.0 | 276.0 |
| 25 | 274.0 | 276.0 | 290.0 | 280.0 |
| 30 | 273.0 | 274.0 | 284.0 | 277.0 |

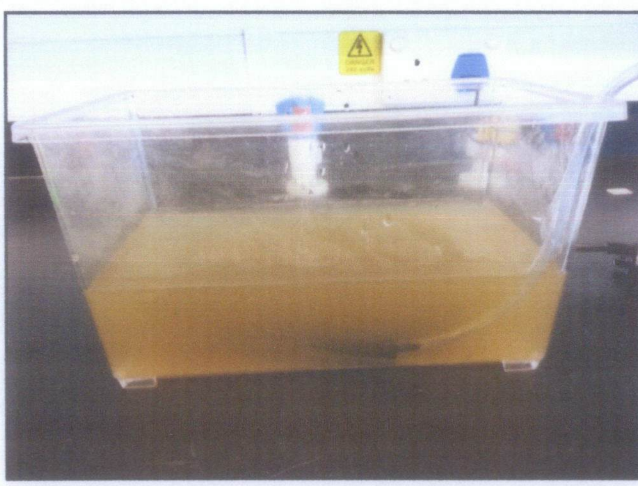


**Figure 4.3:** Dissolved Air Floatation on $0^{th}$ minutes (high intensity of bubbles)

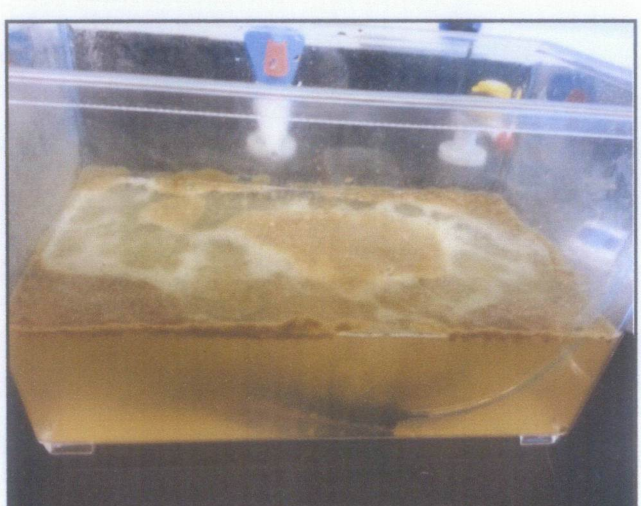


**Figure 4.4:** Dissolved Air Floatation on $10^{th}$ minutes (high intensity of bubbles)

From observation, we can notice that on the 10th minute of interval, microbubbles already lift solid particles to the surface. There are sudden drop of turbidity level on 5$^{th}$ minutes of interval from 306 NTU to 271.6 NTU. By repeating this procedures to low intensity of bubbles, there are no significant observation different can be noticed except the efficiency of turbidity reduction is reduced. Dissolve Air Floatation with low intensity of bubbles only can reduce turbidity from 306 NTU to 277 NTU.

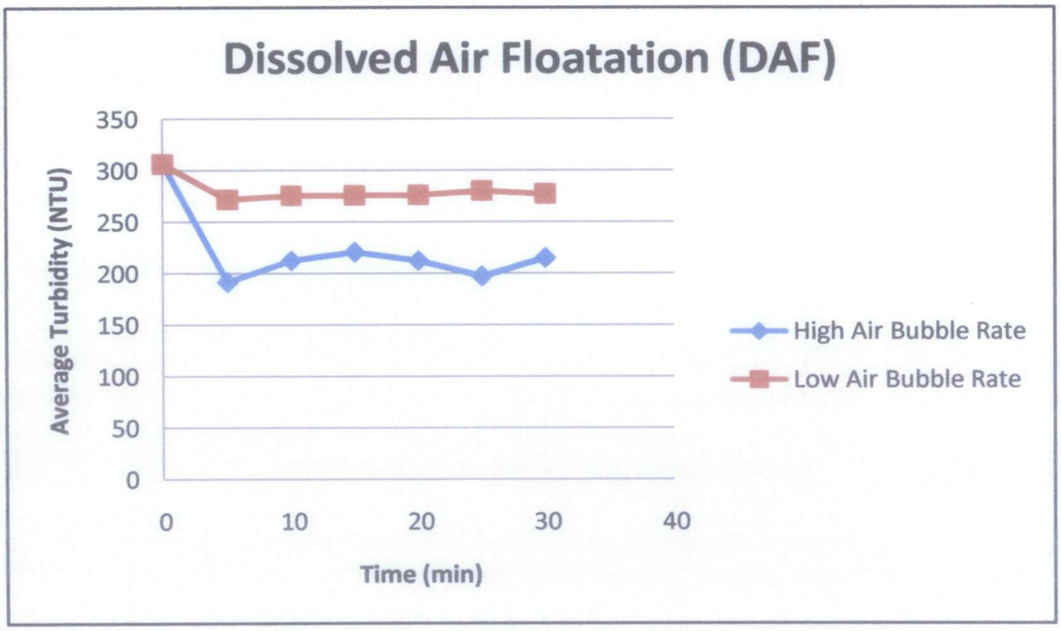



**Figure 4.5:** Turbidity Reduction by Dissolved Air Floatation Model

By referring to graph above, different intensity of air bubbles will effects the performance of a Dissolve Air Floatation. High intensity of air bubbles clearly will give better reduction towards turbidity of the chilled water sample. This is due to more microbubbles available to lift solid particle to surface. Thus, chances for the solid particle to float on the surface are higher and separation process will gives off better result.

## 4.2 Coagulation - Flocculation

Coagulation – Flocculation test were performed in 800 mL jar test with 250 mL of samples. There are three parameters being tested in this experiment which is dosage, rapid mixing time and setting time. The value for those parameters is as below:

**Table 4.3:** Turbidity Level with Different Dosage of Aluminium Chloride

| Dosage (mg) | Turbidity | | | Average Turbidity (NTU) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 100 | 19.6 | 24.4 | 25.9 | 23.33 |
| 200 | 96.10 | 105.00 | 96.20 | 99.10 |
| 300 | 99.90 | 93.70 | 83.70 | 92.43 |

**Figure 4.6:** Coagulant – Flocculants for the 100 mg, 200 mg and 300 mg

Based on Figure 4.9, we can observe that 100 mg give better separation. Chilled water sample for 100 mg shows clearer result and this observation support the turbidity reading on table 4.3.

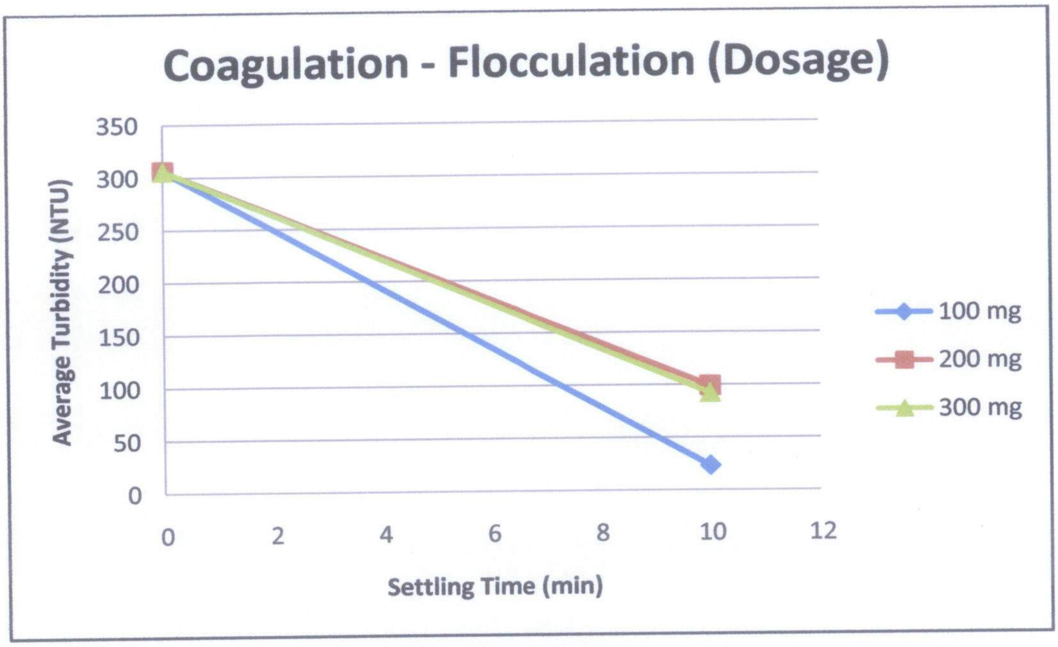



**Figure 4.7:** Turbidity Reduction by Coagulant – Flocculants (Dosage)

Dosage for 100 mg gives the best reduction compared to 200 mg and 300 mg of aluminium chloride. Over-dosing was observed for 99.10 NTU and 92.43 NTU when for 200 mg and 300 mg was used. This reduction may be attributed to charge reversal and destabilization of colloidal particle due to overdosing. Generally, aluminium salts are rapidly hydrolyzed in water to give a range of products including cationic species, which can be absorbed by negatively charged particles and neutralized their charge. This is one mechanism whereby particles can be destabilized, so that flocculation can occur. Overdosing can disrupt this phenomenon.

**Table 4.4:** Turbidity Level with Different Rapid Mixing Time

| Rapid Mixing Time (min) | Turbidity | | | Average Turbidity (NTU) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 10 | 32.7 | 33.0 | 28.7 | 31.5 |
| 20 | 38.2 | 36.9 | 36.5 | 37.2 |
| 30 | 36.5 | 43.7 | 38.0 | 39.4 |

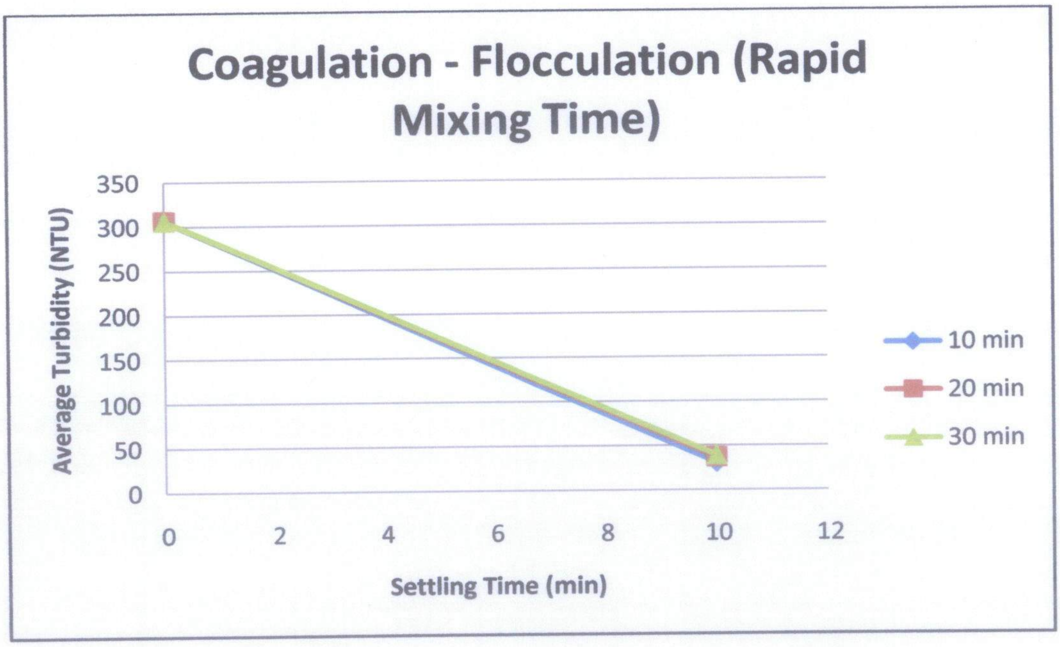



**Figure 4.8:** Turbidity Reduction by Coagulant – Flocculants (Rapid Mixing Time)

By referring to data above, basically there is no significant different in turbidity reduction if the experiment varies in rapid mixing time, 10 min, 20 min and 30 min. The turbidity level measured is around 30 NTU – 40 NTU. Thus, we can conclude that rapid mixing times do not affect the efficiency of turbidity reduction for chilled water samples.

**Table 4.5:** Turbidity Level with Different Settling Time

| Settling Time (min) | Turbidity | | | Average Turbidity (NTU) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 10 | 32.70 | 33.00 | 28.70 | 31.4 |
| 20 | 39.90 | 42.30 | 40.90 | 41.0 |
| 30 | 37.60 | 10.30 | 10.20 | 19.3 |

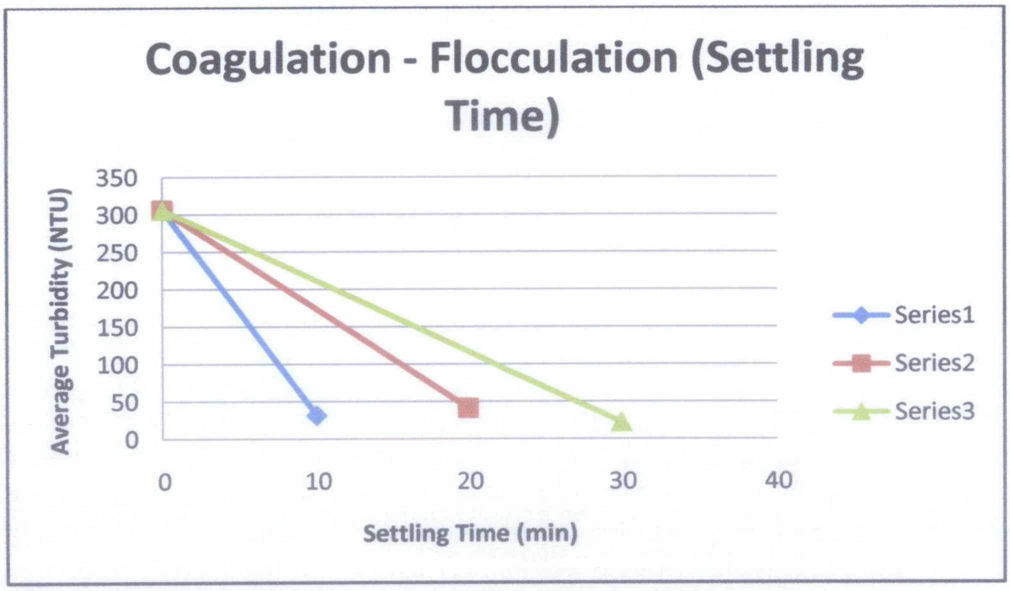



**Figure 4.9:** Turbidity Reduction by Coagulant – Flocculants (Settling Time)

Same goes to settling time based on data above, different settling time 10 min, 20 min and 30 min do not gives significant different in turbidity measured. This is may be due to range of settling time tested is too small, thus it is recommended to further study on this parameter by using larger range of settling time to observe the effects this parameter toward turbidity reduction's efficiency.

# CHAPTER 5
# CONCLUSION AND RECOMMENDATION

This project has made a lot of relevant research in order to understand the mechanism of Thermal Energy Storage and related treatment system, Coagulation & Flocculation and Dissolved Air Floatation (DAF) system very well. This is including studying the past studies in the literature review, analysing trending from past chilled water reading and understanding detailed methodology need to be done for this project. The project is also moving parallel with the proposed Gantt chart. Therefore, it can be concluded that this project will achieve its main objectives within the given time frame.

Based on the experiment carried out through this project, Coagulation – Flocculation is very good approach to be implemented for water treatment for GDC UTP Chilled Water System compared to Dissolved Air Floatation. Results of treated water by Coagulation – Flocculation shows around 20 NTU which is already below 30 NTU, allowable specification turbidity for chilled water in GDC UTP. Even though Dissolve Air Floatation shows some reduction of turbidity level for treated chilled water, but the reduction is only until 190 NTU which is still far from the allowable specification.

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