# MICROALGAE DISINTEGRATION IN RAW WATER AS PRE-TREATMENT USING SONIC WAVE

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## DEDICATION

Special dedication to my lovely family Rosiah, Along, Angah dan Adik. Thank you for all your support, understanding, *Doa*, and patience during my critical time.

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May Allah reward both of you.

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**ABSTRACT**

Microalgae bloom significantly affects the quality and quantity of water produced at the Semberong Barat Drinking Water Treatment Plant (SBDWTP) at Semberong Barat Dam (SBD) Kluang, Johor, Malaysia. The water source is severely polluted by microalgae bloom due to the use of large quantities of fertilisers by farmers. Consequently, this has increased the presence of nutrients such as nitrate, phosphate, and potassium from the release of fertilisers to the lake nearby, resulting in the rapid growth of microalgae and aquatic plants. Therefore, reducing the microalgae count in raw water is crucial to ensure minimal impact on subsequent water treatment processes. Concurrently, the presence of excessive residual soluble aluminium coagulants in the treated water are also caused microalgal interference that can severely affect the water purification process. Hence, this study was undertaken to investigate the best coagulant that can enhance the reduction of microalgae for the water treatment processes at SBDWTP coupled with sonic treatment. The selected coagulants used include Polyaluminium Chloride (PAC) Type 1, 2, and 3 which differed from each other in terms of density of aluminium, basicity and concentration of sulphate ions. Different types of microalgae were identified in the raw water. These microalgae were treated using ultrasonic wave coupled with the coagulants. The coagulants work to enhance the efficiency of water treatment at SBDWTP. Identification study showed the presence of genera *Spirulina, Oscillatoria, Microcystis, Asterionella, Navicula, Peridinium, Ceratium, Coelastrum, Planktosphaeria, Actinastrum, Chlorella, Ankistrodesmus, Scenedesmus, Pediastrum, Staurastrum, Golenkinia, Rhodomonas* and *Euglena* in the microalgal bloom. Results showed that the use of sonic wave coupled with PAC successfully reduced the microalgae count by 79%, with PAC Type 3 as the best coagulant. The correlation coefficient ($R^2$) between the raw water intake and the residual aluminium was 0.9986. Meanwhile, the $R^2$ between the raw water intake and the dam level was 0.9984, and between raw water intake and the turbidity value was 0.9979. The turbidity of the raw water was probably due to the presence of high residual aluminium. The findings of this study showed that the coupling of the pre-treatment using ultrasonic wave with coagulant agent (PAC) enhanced the treatment of microalgal bloom, and improved the production of drinking water, making the production to be above the current level of 54 million litres/day (MLD).

# ABSTRAK

Ledakan mikroalga sangat mempengaruhi kualiti dan kuantiti air yang dihasilkan di Loji Rawatan Air Minuman Semberong Barat (SBDWTP) yang terletak di Tasik Semberong Barat (SBD) Kluang, Johor, Malaysia. Sumber air sangat tercemar oleh ledakan mikroalga berikutan penggunaan baja pada kuantiti yang banyak oleh petani. Keadaan ini telah meningkatkan kehadiran nutrien seperti nitrat, fosfat, dan kalium akibat pelepasan baja ke dalam tasik berdekatan sekaligus menyebabkan pertumbuhan pesat mikroalga dan tumbuhan akuatik. Oleh itu, pengurangan jumlah mikroalga dalam air mentah adalah sangat penting bagi memastikan kesan yang minimum terhadap proses rawatan air seterusnya. Pada masa yang sama, kehadiran sisa koagulan aluminium terlarut yang berlebihan di dalam air terawat juga disebabkan oleh gangguan mikroalga yang boleh menjejaskan dengan teruk proses penulenan air. Oleh itu, kajian ini dilakukan untuk mengkaji koagulan terbaik yang dapat mempertingkatkan pengurangan mikroalga untuk proses rawatan air di SBDWTP digandingkan dengan rawatan sonik. Koagulan terpilih yang digunakan termasuk Polialuminium Klorida (PAC) Jenis 1, 2, dan 3. Perbezaan antara koagulan adalah dari segi ketumpatan aluminium, kebesan, dan kepekatan ion sulfat. Pelbagai jenis mikroalga yang berbeza telah dikenal pasti di dalam air mentah. Mikroalga ini akan dirawat menggunakan gelombang ultrasonik yang digandingkan dengan koagulan. Koagulan berfungsi untuk meningkatkan kecekapan rawatan air di SBDWTP. Kajian pengenalpastian menunjukkan kehadiran mikroalga daripada genera *Spirulina*, *Oscillatoria*, *Microcystis*, *Asterionella*, *Navicula*, *Peridinium*, *Ceratium*, *Coelastrum*, *Planktosphaeria*, *Actinastrum*, *Chlorella*, *Ankistrodesmus*, *Scenedesmus*, *Pediastrum*, *Staurastrum*, *Golenkinia*, *Rhodomonas,* dan *Euglena* dalam ledakan mikroalga. Keputusan menunjukkan penggunaan gelombang sonik yang digandingkan dengan PAC berjaya mengurangkan jumlah mikroalga sebanyak 79%, dengan PAC Jenis 3 sebagai koagulan terbaik. Pekali korelasi ($R^2$) antara pengambilan air mentah dan sisa aluminium adalah $R^2 = 0.9986$. Sementara itu, $R^2$ di antara pengambilan air mentah dan paras empangan adalah 0.9984, dan nilai di antara pengambilan air mentah dan kekeruhan adalah 0.9979. Kekeruhan air mentah adalah mungkin disebabkan oleh kehadiran sisa aluminium yang tinggi. Dapatan kajian ini menunjukkan gabungan pra-rawatan menggunakan gelombang ultrasonik dengan agen koagulan (PAC) meningkatkan rawatan ledakan mikroalga dan menambah baik penghasilan air minuman, menjadikan penghasilannya berada di atas paras semasa iaitu 54 juta liter/hari (MLD).

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| Al | Aluminium |
| ALF | Alert level framework |
| ANN | Artificial neural network |
| AOM | Microalgae organic matter |
| BHT | Butylated hydroxytoluene |
| Cell/mL | Cell per millilitre |
| Chl-a | Chlorophyll-a |
| Cl | Chlorine |
| COD | Chemical oxygen demand |
| DAF | Dissolve air flotation |
| DBP | Disinfection by product |
| DNA | Deoxyribonucleic acid |
| DOC | Dissolved organic carbon |
| E | Energy |
| ECF | Electrocoagulation-flotation |
| EOM | Extracellular organic matter |
| Fe | Ferum |
| FESEM | Field emission scanning electron microscope |
| GAC | Granular activated carbon |
| GA-SVR | Genetic algorithm-support vector regression |
| GPRS | General packet radio service |
| H | Hydrogen |
| Hz | Hertz |
| IOM | Intracellular organic matter |
| J | Joule |
| kHz | Kilohertz |
| LPUV | Low pressure ultraviolet |
| m | Metre |
| MAAs | Mycosporine-like amino acids |
| mg | Milligram |

| | |
|---|---|
| mg/L | Milligram per litre |
| MHz | Megahertz |
| min | Minute |
| MLD | Million Litre per Day |
| MLR | Multilinear regression |
| mm | Millimetre |
| Mn | Manganese |
| MoH | Ministry of Health |
| MPUV | Medium pressure ultraviolet |
| mV | Millivolt |
| NOM | Naturally occurring organic matter |
| NTU | Nephelometric Turbidity Unit |
| PAC | Poly aluminium chloride |
| PFS | Poly ferric sulphate |
| ppmv | Part per million volt |
| ROS | Reactive oxygen species |
| SBD | Semberong Barat Dam |
| SBDWTP | Sembrong Barat Dam Water Treatment Plant |
| SCM | Stream current monitor |
| SEM | Scanning electron microscope |
| SEM-EDX | Scanning Electron Microscope – energy dispersive X-ray |
| Sq. km | Square kilometre |
| TCU | True Colour Unit |
| TEM | Transmission electron microscopy |
| THM | Trihalomethane |
| TOC | Total organic carbon |
| UV | Ultraviolet |
| UVR | Ultraviolet radiation |
| $V$ | Volume |
| VOC | Volatile organic compound |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| $B$ | - | Potential sonic wave |
| $Cl_2$ | - | Dichlorine |
| $ClO_2$ | - | Chlorine dioxide |
| $CO_2$ | - | Carbon dioxide |
| $Co$ | - | Initial cell density |
| $Ct$ | - | Final cell density |
| $D_\gamma$ | - | Complete breaking of microalgae cell |
| $D_\alpha$ | - | Osmosis process |
| $D_\beta$ | - | Microalgae cell wall disintegration |
| $FeO_4^{2-}$ | - | Ferum oxide |
| $HCO_3^-$ | - | Bicarbonate |
| HOCL | - | Hypochlorous acid |
| $H_2O_2$ | - | Hydrogen peroxide |
| $KMnO_4$ | - | Potassium permanganate |
| $K_2FeO_4$ | - | Potassium ferric oxide |
| $K_L$ | - | Mass transfer coefficient |
| $NH_3$ | - | Ammonia |
| $NH_2Cl$ | - | Dichloroamine |
| NaOCL | - | Sodium hypochlorite |
| $O_3$ | - | Ozone |
| $OCL^-$ | - | Hypochlorite |
| $OH^-$ | - | Hydroxide |
| $Q$ | - | Main frequency |
| $T$ | - | Transmission coefficient |
| $U$ | - | Potential energy |
| $W$ | - | Work done |
| $b_n$ | - | Fourier coefficient values |
| $d_t$ | - | Integration process in regards to time |
| $f$ | - | Frequency |
| $f(x)$ | - | Regression graph function |

| | | |
|---|---|---|
| $g$ | - | Gram |
| g $cm^{-3}$ | - | Gram per centimetre cube |
| $h^{-1}$ | - | Per hour |
| $h$ | - | Planck constant |
| $kg/m^3$ | - | Fluid density |
| $km^{-3}$ | - | Per kilometre cub |
| $k$ | - | Wave number |
| $m/s^{-2}$ | - | Standard gravity |
| $m^2kg/s$ | - | Metre square kilogram per second |
| $m^3$ | - | Meter cube |
| $mg^{-1}$ | - | Per milligram |
| $\dot{m}$ | - | Flowrate |
| $t$ | - | Time |
| $x$ | - | Quality parameter |
| $y$ | - | Relationship of the unknown parameter |
| α | - | Alpha |
| $\beta$ | - | Sonic wave |
| $\mu mVs^{-1}cm^{-1}$ | - | Micrometre volt per second per centimetre |
| °C | - | Degree Celsius |
| µm | - | Micrometre |
| $\delta$ | - | Affinity of wave solvent |
| Δ | - | Accumulation of $x$ |
| $a_0$ | - | Fourier coefficient values |
| $a_n$ | - | Fourier coefficient values |
| Ψ | - | Wave equation |
| µg/L | - | Microgram per litre |
| $\rho$ | - | Density (rho) |
| $\rho f$ | - | Buoyant force formula |
| % w/w | - | Percentage weight/weight |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Microalgae are photosynthetic organisms that exploit inorganic nutrients such as phosphorus and nitrogen (Manahan, 2000). Cyanobacteria are characteristically denoted as blue-green microalgae since they accomplish photosynthesis and are comparable in colour and size albeit they are bacteria (WHO, 2004). Microalgae are omnipresent on surface water but are not a problem to water treatment processes with the condition where the total population is considered as moderately small (< 20,000 cells/mL) (WHO, 2004). However, seasonal algal blooms can spike the communities fairly quickly. Consequently, it lessened the competence of the water treatment process. The existence of microalgae in treated water can cause closure to a particular site. For instance, in the Anglian Region of UK, Microcystis bloom reaching up to 400,000 cells/mL cause the closure of water treatment plant for eight weeks (WHO, 2004).

Microalgae can cause detrimental effects to the water treatment processes because algogenic material can react with chlorine that is used in water treatment to form a carcinogenic agent such as trihalomethane (Roslan, 2007). Due to the existence of microalgae contamination in raw water, the use of chlorine has to be controlled. Furthermore, microalgae such as *Microcystis* can form a toxin, *Microcystin*-LR (MCLR) (WHO, 1998), that can cause toxic contamination to the water system. Decomposed microalgae biomass can also release offensive odour compounds such as 2-methylisoborneol (2-MIB) and geosmin that can contaminate drinking water supply (Palmer, 2003).

Microalgae can be referred to as microscopic, unicellular organisms where several species can create colonies and reach sizes that are visible to the naked eye as minute green particles. These organisms are often evenly spread all over the water and may cause substantial turbidity if they achieve high density. Cyanobacteria are organisms that contain several characteristics of microalgae although they are bacteria. They are comparable to microalgae in size. In contrast to other bacteria, they comprise blue-green and green pigment thus they can photosynthesise. Consequently, they are also labeled as blue-green microalgae even though they typically look greener than blue (Bridgeman *et al.,* 2013).

Microalgae are usually categorised based on the variances in cell complexity and pigmentation as a result of evolution (Barsanti, 2008). The existence of cyanobacteria occurred before all algal phyla and identified as prokaryotic cells. Microalgae progressed as a result of primary endosymbiosis where a prokaryotic cell engulfed a bacterium on two occasions to yield eukaryotic green and red algal phyla which are distinguished by the cellular pigmentation and quantity of chlorophyll. The present belief is that secondary endosymbiosis whereby eukaryotic cells engulfed other eukaryotic cells, produce phyla including diatoms, brown microalgae, chrysophytes, cryptomonads, and dinoflagellates (Palmer, 2003). Although this categorisation method is acceptable from a biologist's viewpoint, it is not useful in water treatment setting since microalgae are not grouped by the characteristics that impact the treatment processes. Within a particular phylum, the species can contrast significantly in terms of their morphology and other vital functionalities including the composition and quantity of the excreted extracellular organic matter (EOM). This advocates that a water treatment process may be able to eliminate some species effectively from particular phyla while finding it difficult with others due to the resistance of microalgal cells. Hence, this has reinforced the importance of microalgae being eradicated from the drinking water, if possible, during the preliminary phases to certify nominal effect on the following processes.

This study investigated the characteristics of freshwater microalgal populations from a water treatment perspective and assessed the effect of their changing functionality, especially their pre-oxidation, physiological, and morphological on their treatability concerning procedures including flotation, direct filtration, and sedimentation. This study also focused to examine the green microalgae which are currently accountable for the occurrence of microalgae blooms in Semberong Barat Dam (SBD). This study sought to create a foundation for the usage of a coagulant aid or coagulant agent to support the Semberong Barat Drinking Water Treatment Plant (SBDWTP) coupled with sonic treatment. The quantity and quality of water production in this treatment plant are severely impacted by the existence of microalgae.

## 1.2 Background of the Study

This study was conducted at Semberong Barat Dam (SBD), located about 10 km from the town of Air Hitam in Johor, at Jalan Air Hitam – Kluang. Semberong Barat Dam was built in 1981 and completed in 1984 at the cost of RM24, 000,000. It forms part of the Johor Barat Integrated Agriculture Development Project Area. SBD serves as flood mitigation, agricultural and domestic water supply (Figure 1.1 and Figure 1.2).

Raw water of Semberong Barat Drinking Water Treatment Plant (SBDWTP) is supplied directly from the Semberong Barat Dam (SBD). This water treatment plant is the largest water treatment in Kluang District. The treated water distribution area covers most of the Kluang City up to the Renggam area, approaching the border of the Johor Bahru area. The raw water from SBD is supplied to the water treatment plant through 800 mm pipelines, with a flow rate of 35 cubic meter/ second (Figure 1.2).

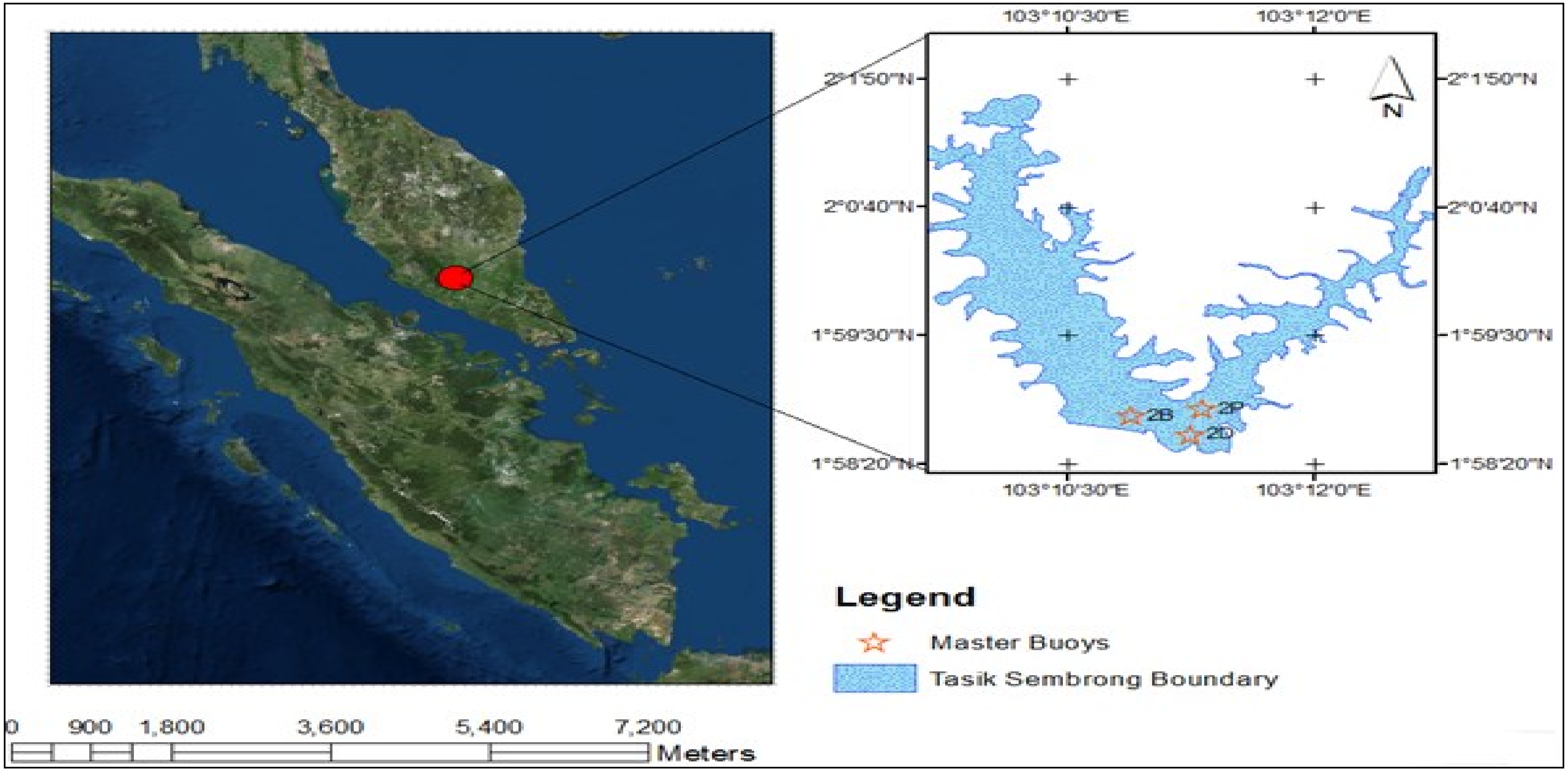


Figure 1.1 Location of Semberong Barat Dam. (Average reading for the year 2015–2016: Rain (daily average) 50 mm, Minimum level 7.20 M, Level (at sea level) 9.8 m, active reserve 19 Million $m^3$, reserve percentage 45%, and total release/Day 66 Million Litre/Day (Source: SAJ Ranhill, 2010).

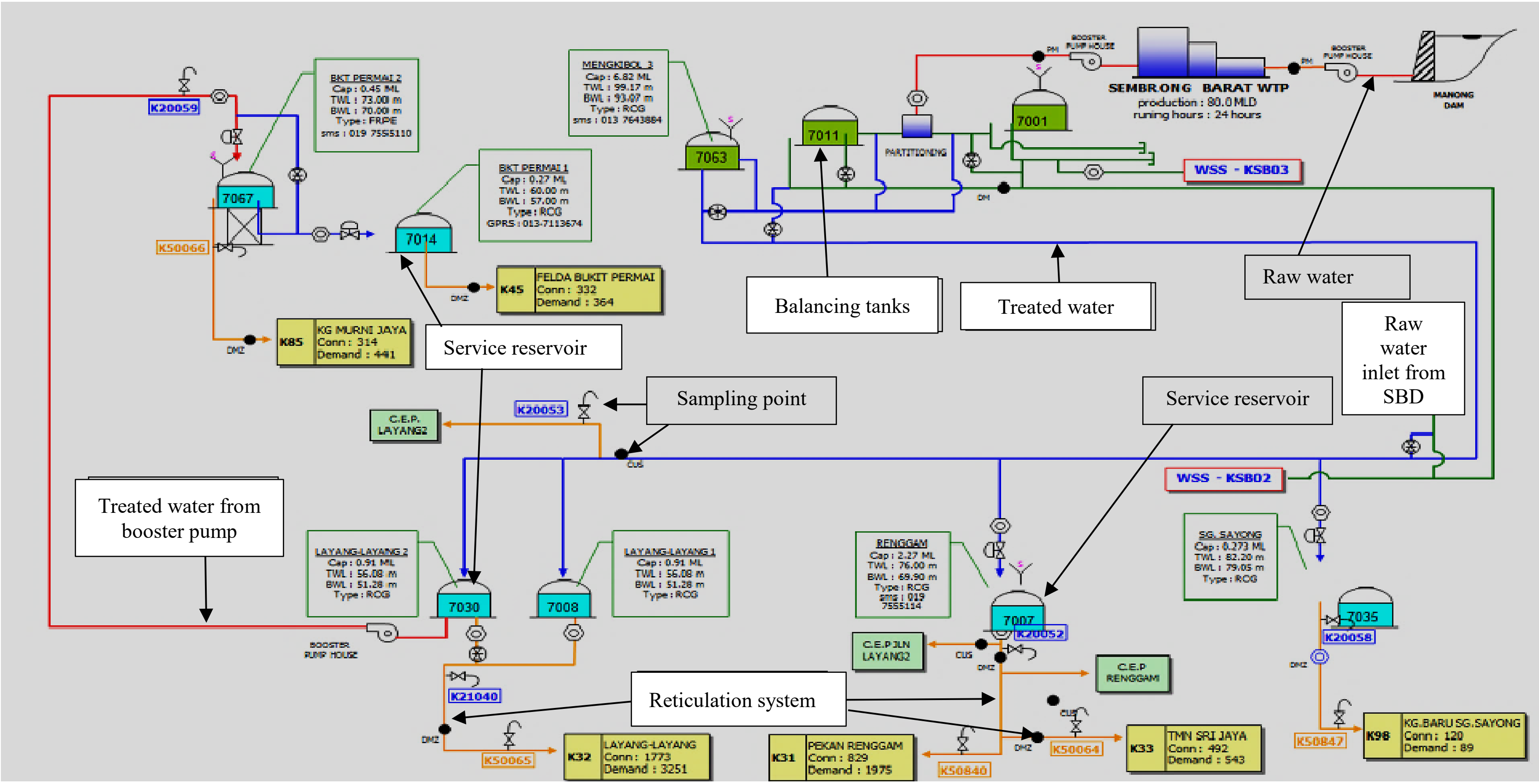


Figure 1.2 Semberong Barat Water Supply System. The treated water distribution area covers most of the Kluang City up to the Renggam area, which is approaching the border of the Johor Bahru area at the south (Source: SAJ Ranhill, 2010)

## 1.3 Problem Statement

Microalgae are omnipresent in surface water but usually they do not give difficulties to the water treatment processes. However, seasonal algal blooms can surge populations on a comparatively swift timespan. In a particular case, the existence of microalgae in treated water can cause a specific site to be shut-down. High frequency, incessant growth of microalgae bloom, severe eutrophication can be used to categorise water pollution of SBD. Various studies have revealed the solids (human feces, swine feces and logs) dependence of the SBD eutrophication, and microalgae bloom on meteorological factors and human activities (Attachment A).

In tropical and semi-tropical zones, microalgae can grow at an excessive rate because these regions possess high level of nutrients in surface water, particularly in water reservoirs and lakes. Normally, the high level of nutrients is caused by the nutrient run-off during rain from the nearby farm. The presence of microalgae in water is a global issue because they negatively impact the quality of drinking water and the water treatment procedure (Elke *et al.,* 2006). In SBD, the presence of microalgae bloom impact negatively on SAJ water treatment system; it affects the water quality for human consumption. The quantity of the treated water supplied to consumer is also affected due to the interference in water treatment.

Figure 1.3 and 1.4 show the failure of the coagulation process at SBWTP in laboratory scale. In the real situation, all floating materials were carried to the filter system, causing its lifetime to become shorter and the flow rate of the water treatment plant to be reduced. Post chlorination that is expected to eliminate the bacteria will fail because part of the chlorine was used to oxidise the remaining microalgae. The consumption of chlorine will increase significantly. Then, the microalgae will interfere the processing system by forming floating flocs as shown in Figure 1.3 and 1.4 (by jar testing). Figure 1.5 shows the failure of the coagulation process to remove the floc and result in the floc to be carried to the filtration system. High cost has been allocated to overcome this problem. The allocation includes the water used for sand filter backwash and filter replacement. Furthermore, the failure of coagulation treatment has resulted in the non-conformance of residual aluminium in the treated water. As stated in the

Malaysia Ministry of Health Quality Assurance Parameter (QAP), the maximum allowable percentage for non-conformance aluminium is 10.2%.

Figure 1.6 shows the raw water from SBD that was contaminated or polluted by dissolve microalgae bloom that entered SBDWTP system. Thus, it is important to strengthen the conventional technology used to enhance microalgae removal by selecting a necessary coagulant to improve the process, eliminates microalgae and reduce the number of residual microalgae in the water treatment process using sonification as a pre-treatment method. Tabulation of the Semberong Barat profile structure is shown in Attachment B.

Several issues can occur in the traditional water treatment process due to the presence of algal blooms in the raw water reservoir such as clogging, formation of disinfection by-products, and bad taste and odours (Hung *et al.,* 2005). Eutrophication which is usually instigated by microalgae bloom is a severe problem that impacts the purification of water and water work process which increases the risk of jeopardising human and marine live (Henriksen *et al.,* 2005). Due to this problem, the zeta potential values during water treatment in SBDWTP has become a major concern. Zeta potential is a measure of the electrical potential between particles, and it indicates the repulsive interaction between particles. A zero zeta potential means that the conditions for aggregation of contaminants are exploited. Zeta potential, also known as electrokinetic potential, is measured in millivolts (mV) (Helmenstine, Anne Marie, 2018).

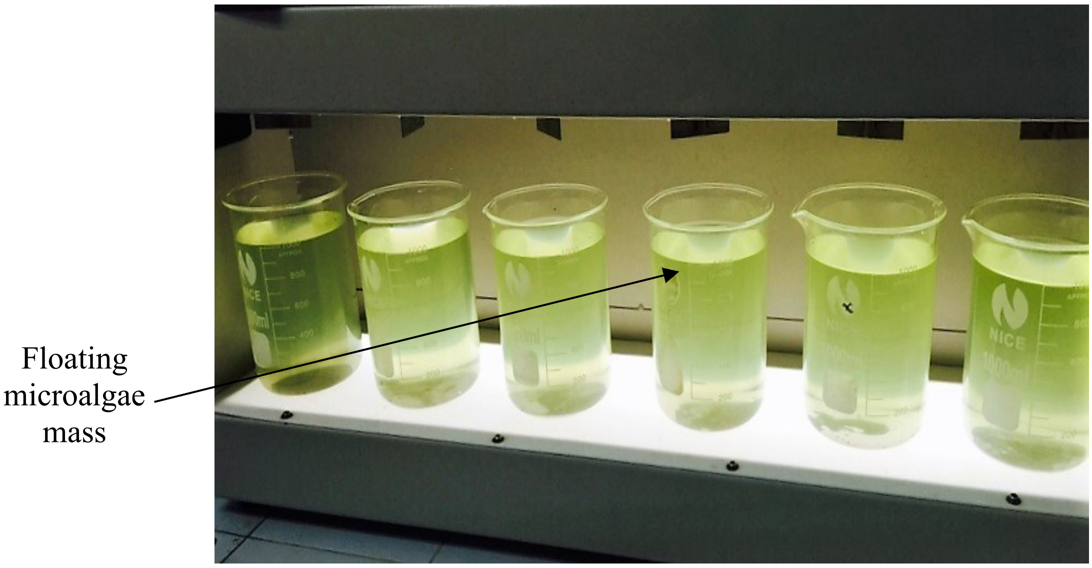


Figure 1.3 Floating microalgae after jar tested. The microalgae mass is floating and fail to settle down

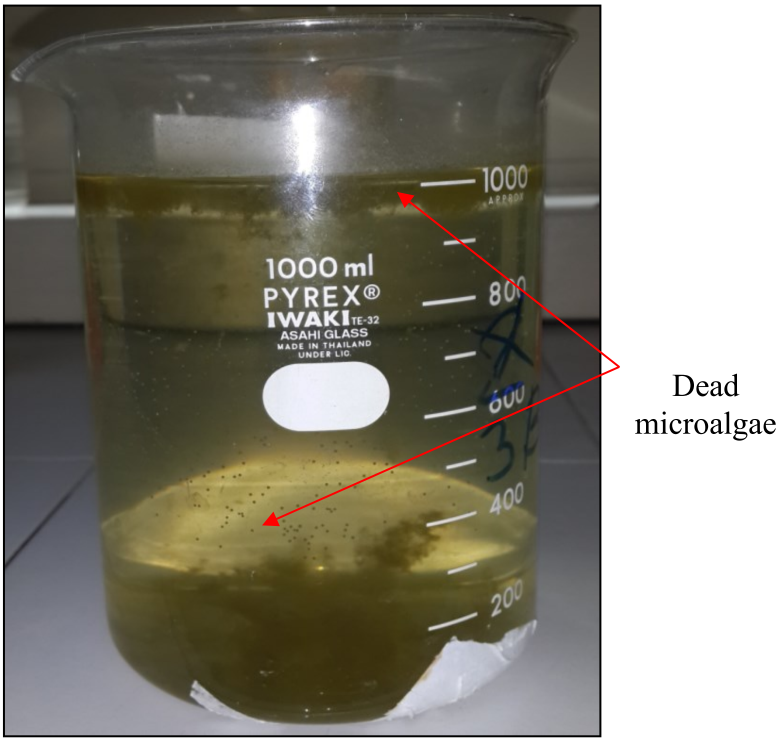


Figure 1.4 Failure of the coagulation process; occurs when prechlorination was applied at the intake point (lab scale jar tested analysis). The flocs were observed to be still floating at the surface.

Figure 1.5 Failure of the coagulation process. Scum from microalgae (white patches on the water surface) contributed to the failure of the treatment system and thus interfere during the coagulation process

Figure 1.6 Polluted raw water from SBD. The dark green colour of the raw water shows a high content of microalgae which is difficult to be treated

SBDWTP was set up to produce 80 million litres per day (MLD) of treated water. The raw water pump can feed the plant at 85 MLD. Due to the interference of microalgae, the plant can only produce the treated water at 45 to 50 MLD. The shortage of treated water quantity generated by the plant (Figure 1.7) affect the domestic and industrial consumer. Although many bench-scale analyses have examined the feasibility of the enhanced microalgae removal by chlorination coupled with coagulation, a pilot-scale study has not been reported.


Figure 1.7 Floc carry over during the water treatment process at a sedimentation tank (brownish colour) – the main cause for clogged filter. The production output will decrease, and the in-plant losses will increase.

### 1.3.1 Semberong Barat Catchment

The Semberong Barat water catchment area is 128 sqkm in size. Impounding water storage area is approximately 8.5 sq. Km and about 98% of the water were channelled for agricultural uses. The raw water is severely affected by algae bloom from the use of fertilizers by the farmers. A significant contribution of phosphorus (P) and nitrogen (N) in the SBD came from the animal farm, located nearby the SBD area. This increases the nutrient contents such as nitrate, phosphate, and potassium (K) in the lake thus resulted in high algae and aquatic plant growth. All the concerning parameters were regarded as a feeding nutrient for algae and microalgae evolution. As shown in Figure 1.8 and 1.9, the effluent is flowing to the surrounding canal and then enter SBD. The situation became worst during the drought season because the agriculture activities were in high volume and the unnecessary effluent spillage occurred due to improper maintenance of the animal farm.

In conclusion, the 20% plant loss issue arises in SBDWTP is high compared to the standard condition where plant losses are usually under 5%. In normal circumstance, running raw water at 70 MLD will yield 67 MLD. However, only 50 MLD was produced from 70 MLD input due to the present raw water conditions. The deficit of 20 MLD caused by the high composition of algae is comparable to the supply to 50,000 populations, causing the treatment of drinking water to be futile. Massive floc transfers occurred at clarifiers, choked filters and the linking through filter media had caused quality non-conformance. Figure 1.8 and 1.9 show the current issue relating to the catchment development.

These findings stressed the importance of P and N in regulating toxic cyanobacteria blooms. Additionally, it provides support to the claim where the management act to diminish P without concurrent restriction on N loading might not effectively regulate the development and toxicity of non-diazotrophic toxic cyanobacteria including cosmopolitan toxin-producing genus, *Microcystis* (Gobler *et al.,* 2016).

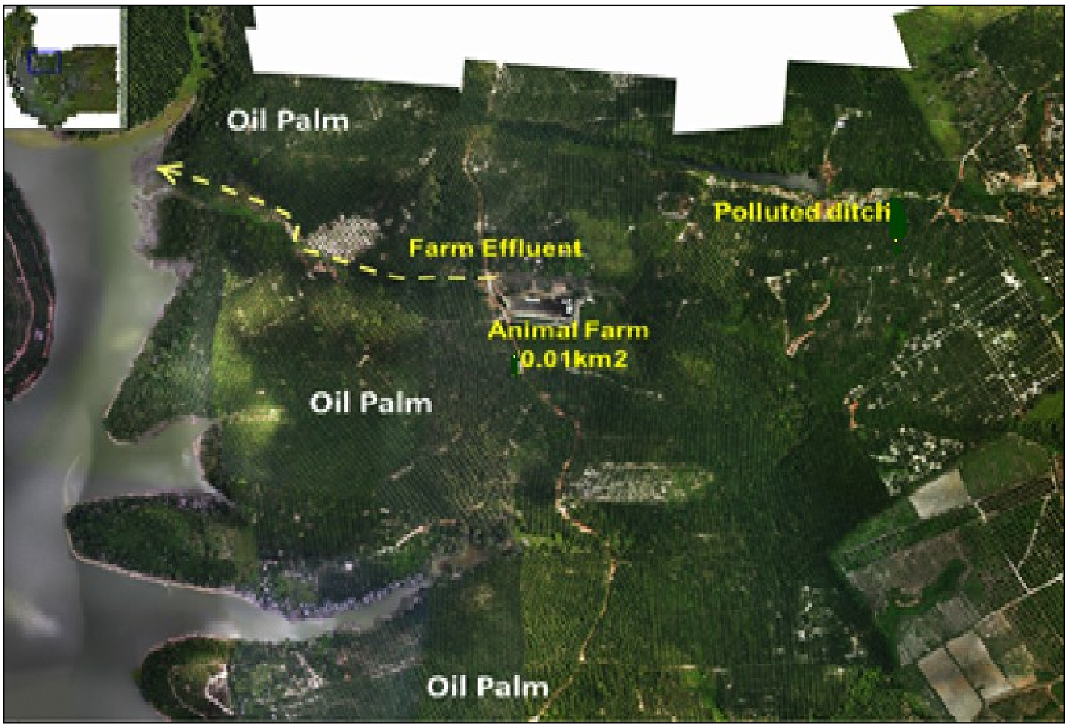


Figure 1.8 Point source pollution at Semberong Barat. The main origin where pollution comes from. The pollution then flows through the ditches and enter the SBD water catchment.

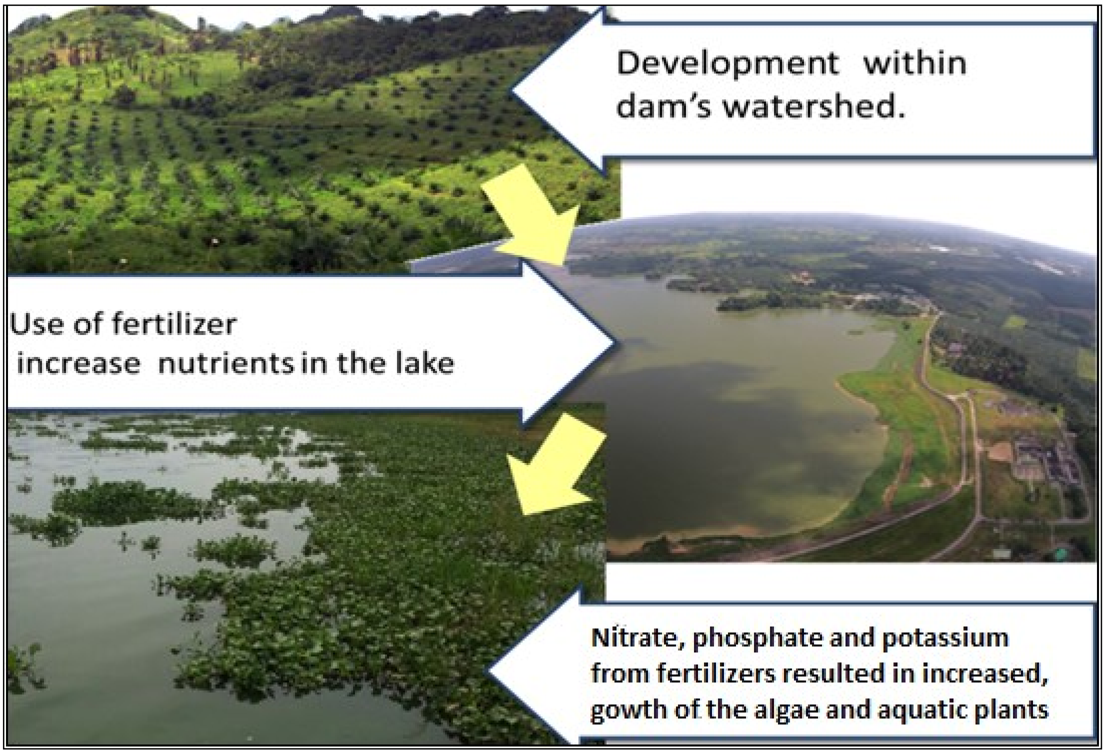


Figure 1.9 Activities that contribute the distribution of algae in SBD

## 1.4 Objective of the Study

In this research the objectives are:

1. To identify the genera of microalgae in Semberong Barat Dam using FlowCAM, a Fluid Imaging Technologies instrument.
2. To remove microalgae in raw water during the treatment process using sonic wave method coupled with Polyaluminium Chloride and analysed the count and percentage of microalgae removal using statistical tools.
3. To study the correlation coefficient at an earlier stage of the treatment process to improve the presence of dissolved aluminium in the treated water due to microalgae interference.

## 1.5 Scope of the Study

The research or study covered the raw water from the lake, intake, coagulation system, flocculation system, and filtration system at SBDWTP. Prior to the implementation of the actual proposed method, a preliminary study was conducted using jar test. This study was performed to observe the effectiveness of the chosen pre-treatment approach, in which the ultrasonic wave was represented by sonication. The actual trial using the selected coagulant was conducted after the success of the jar test. It is essential to reinforce the utilisation of joint traditional treatment process or technology since utilising a single traditional process to remove microalgae is very challenging in fulfilling the stipulated objective due to the inconsistency of the quality of water.

The application of dissolved air flotation (DAF) is seen as a good alternative way to overcome the problem. DAF is a water treatment process that clarifies wastewater by removing suspended solids. The removal was achieved by dissolving air in the water or wastewater under pressure followed by releasing the air at atmospheric pressure in a flotation tank. The released air formed tiny bubbles which adhere to the suspended matter causing the suspended matter to float on the surface of the water before a skimming device removes it. Chemicals were added to the feed water to improve solids removal. However, the substances that dissolve effectively were not completely removed by this system. The additional cost of chemical support aids (coagulants and flocculants) is relatively high, particularly if high yields are required.

## 1.6 Significance of the Study

The eutrophication and algal growth at SBD were examined based on the information obtained from the water quality monitoring by the SAJH Water Quality Department and Production Department. By defining the problem differently, new solutions to an old problem can be generated. Additionally, the research will be useful in the current and future planning as a reference for the water treatment plant operator. The research also significant in expanding the decision-making tools available to planners and policy-makers. There is no reason to say that the method applied in this research is the best in analysing the effectiveness of microalgae removal. Nevertheless, it provides additional options by which a problem can be observed.

However, the effectiveness of the finding during or after this research is unpredictable because microalgae are very sensitive to changes in their environment (Durrieu *et al.,* 2011). Algal pollution or algal bloom can occur at any time depending on the unpredictable temperature, level of the dam, enforcement of the local authorities, adaptability of the microalgae cells itself to absorb the surrounding environment and the surrounding geographical landform at SBD. Table 1.1 shows the drinking water quality performance (QAP) which was set up by Malaysia Ministry of Health (MMOH).

Table 1.1 Drinking Water Quality Performance (Source: MMOH, 2008)

| Parameter(s) | % of non-conformance Max / Units |
|---|---|
| Residual Chlorine | 2.8 |
| *E-Coli* | 0.4 |
| *E-Coli* & Residual Chlorine | 0.3 |
| Turbidity | 2.0 |
| Aluminium | 10.2 |

## 1.7 Outline of the Thesis

This thesis is started with Chapter 1, introducing about the thesis, from the background to problem statement, objectives, scopes and significance of the study.

Then, detailed information of the study is presented in Chapter 2. Relevant literatures and studies are presented in this chapter. It begins with review on the characteristics and identification of microalgae. Treatment processes involve in the removal of microalgae follow suit before more elaboration is made on the Semberong Barat Drinking Water Treatment Plant. Finally, summary of the literature is presented at the end of the chapter.

Chapter 3 presents the methodology used in this study. Instruments and how data were collected including the sampling location and analyses involved are detailed out in this chapter.

Chapter 4 presents on the findings of identification study. The genera obtained and the captured image of each genera are presented in this chapter.

Chapter 5 discusses on removal of microalgae during the treatment processes. This chapter then followed by Chapter 6 that presents more in the findings from the analysis of correlation coefficient and process optimisation. Finally, Chapter 7 conclude the thesis based on chapters on findings and give few recommendations.

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