Impact of Houseboats Wastewater Discharge on Performance of Small Sewage Treatment System (SSTS) in Removing Nutrient at Temenggor Lake

by

Amy Izzati binti Husain
20000021

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

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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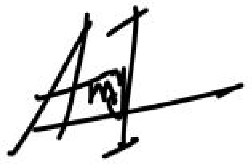
(Dr Lavania A/P Baloo)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2022

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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or person.



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(AMY IZZATI BT HUSAIN)

ABSTRACT

Temenggor Lake is an eco-tourism destination in Malaysia that supplies water to populations in Perak and Penang. A houseboat has been used to transport tourists to Banding Island from the jetty complex for them to enjoy the natural beauty. After completing the Banding Island trip, the houseboat will continue the journey back to the jetty complex and park their houseboat at the jetty complex to unload the wastewater discharged into the Small Sewage Treatment System (SSTS). Therefore, the amount of wastewater discharged from the forty houseboats into the SSTS caused spikes in ammonia, nitrate, and phosphorus. The objective of this study is to determine the influent characteristics of the wastewater discharge from houseboats for ammonia, nitrate, and phosphorus, evaluate the performance of SSTS to treat the additional wastewater discharge from the houseboats in removing nutrient, and propose the design of i-sewage treatment system (i-STS) for an anoxic tank to treat wastewater from houseboat and jetty complex. However, wastewater generated by jetty complexes and houseboats will be discharged into the existing SSTS, which was discovered to be inoperable. Due to this, a concern has been raised about the existing SSTS's ability to handle the extra load of wastewater discharged from houseboats since the SSTS was built just for the jetty complex's purposes. Thus, a nutrient assessment for wastewater discharge from houseboats and jetty complexes will be conducted in order to stimulate the SSTS capacity on the excessive load from the houseboats, resulting in a new design for an anoxic tank of the i-STS that is suitable in conjunction with the testing parameters conducted at Temenggor Lake. This study used laboratory tests to evaluate eight sampling points for the SSTS, namely influent 10 a.m. (IF10), influent 2 p.m. (IF2), effluent 10 a.m. (EF10), effluent 2 p.m. (EF2), and four houseboat wastewater samples, namely HB1, HB2, HB3, and HB4, to monitor ammonia, nitrate, and phosphorus concentrations. According to the experimental data, the influent ammonia concentration for SSTS and houseboats ranges between 35 mg/L and 175.33 mg/L, while the effluent ammonia concentration in SSTS ranges between 12 mg/L and 38.5 mg/L. The influent nitrate concentration varies from 36.5 mg/L to 171.67 mg/L, while the effluent ammonia concentration in SSTS varies from 35.17 mg/L to 77.67 mg/L. The influent phosphorus concentration varies from 16.83 mg/L to 264.33 mg/L, while the effluent ammonia concentration in SSTS varies from 16.67 mg/L to 31.83 mg/L. This study indicated that the design of a new i-STS is desirable to meet the effluent discharge criteria of the National Lake Water Quality Criteria and Standard.

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In the name of Allah, the Most Gracious and the Most Merciful.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Temenggor Lake is a lake in Malaysia's Hulu Perak District, about 45 kilometers from the district capital, Gerik. Kenyir Lake in Terengganu is the largest lake in Peninsular Malaysia while Temenggor Lake is the second largest. This artificial lake is situated south of the 1,533-meter-tall Ulu Titi Basah peak. Temenggor Lake is a synthetic lake that was formed after the construction of the Temenggor Dam for an electric power generation in Perak's north region. This dam began construction in 1970 and was completed in 1974. The dam has a total area of 152 square kilometers and holds 6,050 million cubic meters of water, which covers 117,500 hectares of the Belum Forest Reserve. As a result, water from this dam is used to supply drinking water to the people in Perak and Penang (Khalik et al., 2012).

A human-made island known as Banding Island or Banding Lake is situated in the central part of Temenggor Lake and is accessible through the Lake Temenggor Bridge, which crosses the lake. To ensure the safety of the Temenggor Dam, a military camp was built in this area. Banding Lake, as portrayed in Figure 1.1, is a tropical island in Gerik surrounded by a human-made lake.

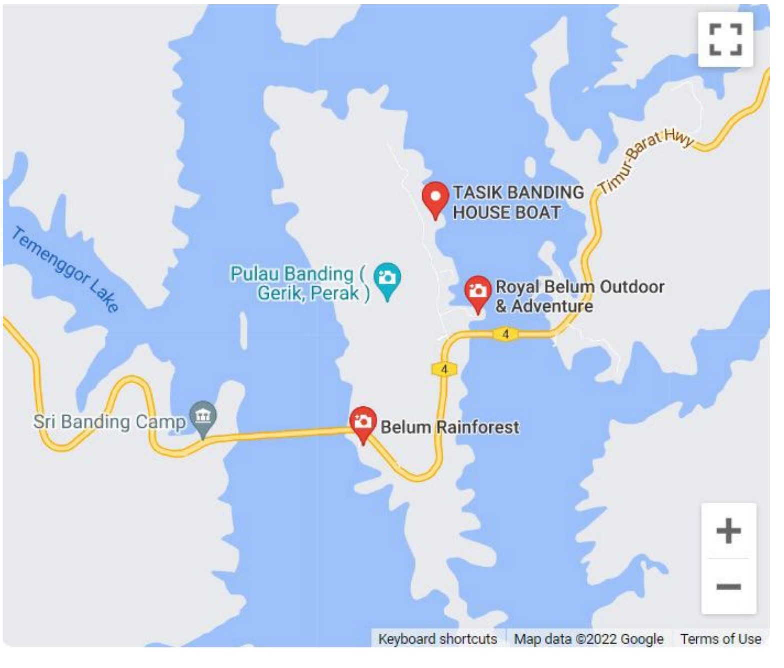

FIGURE 1.1: Banding Island surrounded by a human-made lake known as Temenggor Lake.

Banding Island became famous for its main asset, the Royal Belum State Park, which is still preserved for its greenery, uniqueness, and the original habitat for enormous flower species, specifically Rafflesia. Belum Rainforest Resort is a premier ecotourism vacation destination in Malaysia. Banding Island is the ideal destination for nature lovers and vacationers seeking complete relaxation and tranquilly, breath-taking views and surroundings, adventure, and the chance to get close to nature. With the Belum-Temenggor Rainforest at their doorstep, resort guests will have the rare opportunity to experience the tranquil beauty and mystique of the vast jungle, which has remained untouched for centuries. Nature lovers will delight at the opportunity to witness the majesty of plants and scenery found nowhere else. Meanwhile, thrill seekers seeking adrenaline-pumping experiences will find thrilling outdoor activities.

There are houseboat trips that go all the way around Banding Island, and tourists may use them to attend local gatherings, evening barbecues, and jungle tracking. According to the information, the total number of houseboats registered with the houseboat organisation is forty (40). Most of the houseboat is made up of three rooms, two dormitories, three bathrooms, culinary utensils, small boats, and a tourist raft. Each houseboat can accommodate between 6 and 40 people, including employees, per trip, depending on its size. As shown in Figure 1.2, each houseboat usually has a custom septic tank to collect waste from the on-board toilets under the houseboat.

FIGURE 1.2: Custom septic tank has been installed under the houseboats.

Furthermore, houseboat cruises on the lake are provided for tourists as shown in Figure 1.3, with activities such as jungle trekking during the day, wildlife observation at night, visiting natives, swimming in a waterfall and lake, fishing, barbecue under the stars, and even karaoke. There are forty (40) houseboats operating on the lake that can accommodate between ten (10) until forty (40) persons for a maximum of three (3) days and two (2) nights per trip. The houseboats are fully equipped with adequate facilities to accommodate families or groups. Some houseboats are fully equipped with septic tanks at the bottom of the houseboat to store the sanitary wastewater from the toilet facilities on the houseboats. When the boat moves across the middle of the Temenggor Lake, the houseboat septic tank used to store the sewage during the trip. However, the situation becomes more serious when some of the houseboats without a septic tank, the sewage will be dumped into the lake directly since not all houseboats are equipped properly.

FIGURE 1.3: Houseboat on the lake is provided for tourists.

As illustrated in Figure 1.4, the houseboats are parked around the jetty at the Temenggor lake after making trip for three (3) days and two (2) nights every weekend. The jetty complex consists of restaurants, toilet facilities and offices that connect the wastewater into the Small Sewage Treatment System (SSTS) before release the effluent to the Temenggor Lake. The wastewater generated from the complex and houseboats are discharged into the SSTS located at the end of the complex's building as shown in Figure 1.4.

FIGURE 1.4: Location of existing SSTS and the houseboat at Temenggor lake jetty.

Furthermore, the wastewater generated from the jetty complex includes toilets, restaurants, and offices, are discharged together into the existing SSTS. It was determined that the SSTS is unattended, lacks appropriate signage, and is overgrown with vegetation as shown in Figure 1.5 during the site visit. It was unknown if the SSTS was operational or not to remove the contaminants before releasing the effluent into the Temenggor Lake.

FIGURE 1.5: Condition of SSTS at the end of the complex building.

In this report, one way to improve water quality is to stop discharging sewage overboard and dispose of waste from portable toilets correctly. Discharges from small sewage treatment system are unsightly and contain disease-causing microorganisms that can contaminate shellfish beds and swimming, skiing, and fishing areas. Additionally, sewage decomposition can harm aquatic habitats by reducing oxygen levels. To maintain Temenggor Lake's water quality in the future as an ecotourism destination, an integrated lake management system based on the integrated water resource management concept should be implemented since clean water is essential for all of us.

1.2 Problem Statement

The houseboats are fully equipped and have enough space to accommodate families or groups. Some houseboats are outfitted with septic tanks at the bottom to collect the sewage from the toilet facilities on the houseboats. However, it was highlighted that some of the houseboats do not have any septic tanks for wastewater storage which eventually discharged into the lake. There is no proper method of treatment and disposal of sewage from houseboats and sometimes the sewage stored in the septic tanks will be drained into the lake as they move at locations in the middle of the lake. Unsanitary conditions caused by improper septic tank system maintenance can lead to health and environmental issues.

Moreover, the public jetty at the Banding Island consists of restaurants and offices. These premises also generate wastewater from the kitchen as well as from the toilets. The wastewater generated from the complex is discharged into SSTS located that initially design to treat the wastewater generated from the jetty only. In addition, houseboats with septic tanks discharges their sanitary wastewater into the SSTS as presently there is no proper treatment for houseboat’s sanitary waste. So, the SSTS is having an extra loading from the houseboats wastewater that affect the performance of the SSTS. However, the SSTS was found to be unattended, with no proper signage and overgrown with vegetation. It was unclear whether the SSTS was operational. The goal of this research is to determine the influent characteristics of the wastewater discharge from houseboats for Ammonia, Nitrate and Phosphorus, evaluate the performance of the SSTS to treat the additional wastewater discharge from the houseboats for Ammonia, Nitrate and Phosphorus and design a sewage treatment system for an anoxic tank to treat wastewater from houseboat and jetty in removing nutrient.

As indicated in Figure 1.6, the Temenggor Lake sewage system is currently not operating. The SSTS is overcapacity for standard treatment due to the combination of collected wastewater from jetty complexes and houseboats. The SSTS was not treating wastewater efficiently before it was released into the lake. The most concerning issue is that effluent from SSTS will be dumped into lakes. Lack of leadership is characterised as a circumstance in which the organization's leader does not fully motivates the owner of the houseboat to have an adequate system for handling sanitary waste. Due to the rapid increase in the number of registered houseboats in the lake, Temenggor Lake is concerned about the absence of a sufficient facility to treat the additional effluent from houseboats.

FIGURE 1.6: Current condition of the SSTS not functioning.

1.3 Objectives

This project is to investigate the impacts of houseboats wastewater discharge on performance of Small Sewage Treatment System (SSTS) in removing nutrient at Temenggor Lake. The objective of this project is detailed as below:

1. To determine the influent characteristics of the wastewater discharge from houseboats for Ammonia, Nitrate and Phosphorus.

2. To evaluate the performance of small sewage treatment system (SSTS) to treat the additional wastewater discharge from the houseboats for Ammonia, Nitrate and Phosphorus.

3. To propose and design a sewage treatment system for an anoxic tank to treat wastewater from houseboat and jetty in removing nutrient.

As mentioned above, this study has three main objectives related to the impacts of houseboats wastewater discharge on performance of the SSTS in removing nutrient at Temenggor Lake. These objectives can be fulfilled by the end of this study by conducting lab experiments on the samples collected to evaluate ammonia, nitrate, and phosphorus levels. The results of the lab experiment will be compared to the National Lake Water Quality Criteria and Standard.

1.4 Scope of Study

The main scope of study for this project is the contamination assessment of houseboats wastewater discharge on the ability of Small Sewage Treatment System (SSTS) to remove nutrients at Temenggor Lake. As depicted in Figure 1.7, the project will also focus on specific fields of research:

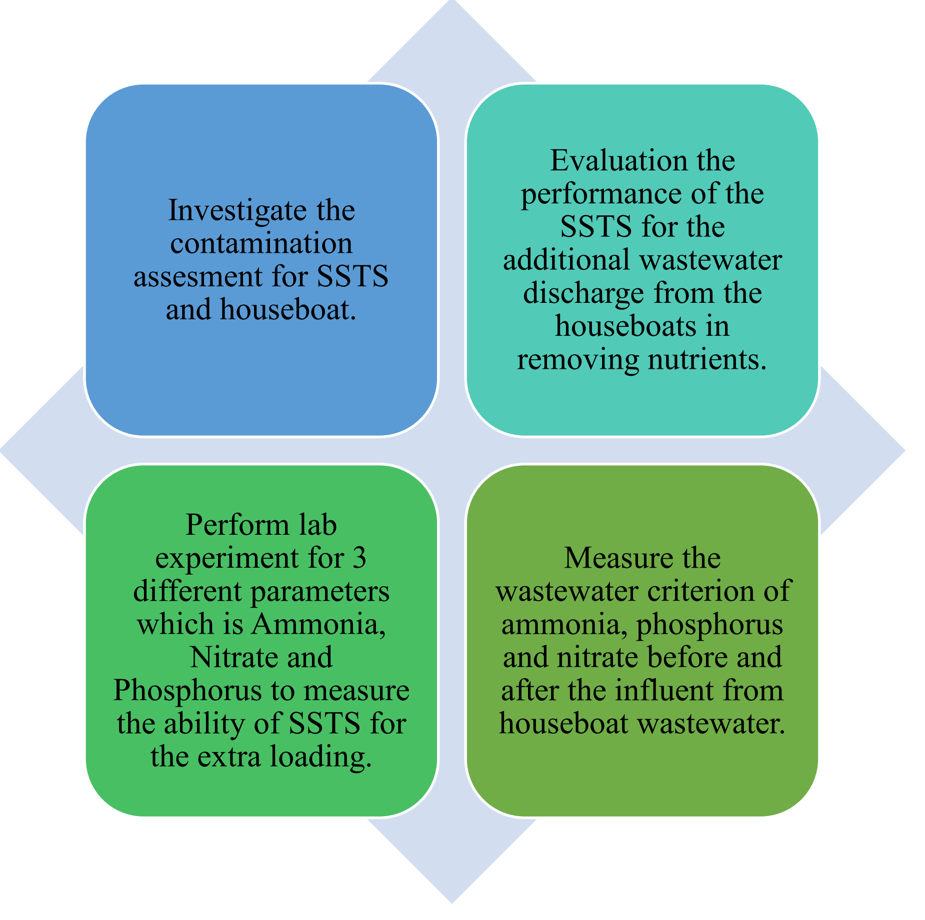

FIGURE 1.7: The scope of study for the research study for the impact of the additional loading into the SSTS.

CHAPTER 2
LITERATURE REVIEW

The literature review of this project report will discuss on the impacts of houseboats wastewater discharge on performance of Small Sewage Treatment System (SSTS) in removing nutrient at Temenggor Lake. The main topics that will be discussed in this literature review are Houseboats as Tourism Transportation, Sewage Treatment Plant (STP), Small Sewage Treatment System (SSTS), removal of nutrient and nutrient discharge standards.

2.1 Houseboats as Tourism Transportation

According to Camilleri (2018), there are numerous other modes of water transportation available, such as ocean cruises, ferries, hovercrafts, passenger cargo ships, river cruises, houseboats, and yacht charters. In contrast to the traditional houseboats used in Kerala's backwater canals to transport rice and other grains, a new houseboat invention has been positioned as a distinct tourist attraction in the state's already thriving tourism sector as portrayed in Figure 2.1 (Jeevan, 2006).

FIGURE 2.1: Houseboat at Banding Lake jetty as tourism attraction.

According to Jeevan, luxurious bedrooms are outfitted with up-to-date technology such as home theatre systems, DVD players, music systems, and more. Septic tanks are critical because houseboats are equipped with toilets and kitchen as shown in Figure 2.2. Septic tanks are low-rate anaerobic digesters that serve as a passive treatment system (Mahon et al., 2022). According to Mahon et al., regular desludging of accumulated solids from faeces, toilet paper, and other solid items disposed through toilets and sinks is required for the effective operation of septic tanks, and knowledge of expected sludge filling rates is essential not only for homeowners but also for local municipalities or private businesses that must accept this sludge into licenced premises.

FIGURE 2.2: Houseboat equipped with toilets and kitchen.

According to the houseboat owner, his houseboat has a proper septic tank that measures 2.4 m (L) x 11.2 m (W) x 0.8 m (H), has a capacity of 22.4 m^3, and is located beneath the houseboat's deck. The septic tank is made of steel and requires approximately 4-5 trips to ensure it is full. Yachts generate black and grey water while sailing, which is stored in the septic tank. Every houseboat was required to have a sewage tank, and the houseboats were required to stop at a local sewage plant before disembarking the guests, but few boats followed this rule (Gupta et al., 2019).

2.2 Sewage Treatment Plant (STP)

Sewage treatment, also known as domestic wastewater treatment, aims to remove contaminants from sewage to produce effluent suitable for discharge to the surrounding environment. A sewage treatment plant (STP) is a facility that receives and treats waste from domestic, commercial, agricultural, and industrial sources (Schaefer K., 2013). Water is treated using a variety of physical, biological, and chemical processes. Sewage has always been occupied of wastewater from homes and businesses, as well as pre-treated industrial wastewater. In addition, sewage treatment falls under the category of sanitation includes the management of human waste, solid waste, and stormwater (drainage). When discharged into aquatic systems, the STP aims to remove contaminants that degrade water quality and endanger public health and safety. At the conclusion of the STP process, environmentally safe fluid waste (the treated effluent) and solid waste (the treated sludge) are produced (Schaefer K., 2013). Some methods of sewage treatment generate sewage sludge, which can be treated prior to disposal or reuse. Depending on its chemical makeup, treated sewage sludge can sometimes be used as fertiliser (Schaefer K., 2013). Overall, the objective of sewage treatment is to produce effluent that can be discharged to the environment with minimal water pollution or that can be reused for beneficial purposes.

Typical sewage treatment consists of two stages: primary and secondary treatment, with advanced treatment including a tertiary treatment stage consisting of polishing and nutrient removal. The primary treatment of sewage is the removal of a portion of the suspended solids and organic matter. It involves slowly passing sewage through a basin in which heavy solids settle to the bottom and oil, grease, and lighter solids float to the surface, where they are skimmed off. Using aerobic or anaerobic biological processes, the secondary treatment can then reduce the amount of organic matter as measured by the biological oxygen demand in sewage. The purpose of the tertiary treatment process is to improve the effluent quality generated by the primary and secondary treatment processes. When wastewater reaches the tertiary treatment stage, residual suspended matter and fine particles are still present (Chokhavatia Associates, 2021). In addition, it is rich in nutrients such as nitrogen and phosphorus and contains microbes and odour (Chokhavatia Associates, 2021). During the tertiary treatment process, numerous techniques are applied to remove all these contaminants and properties from wastewater (Byrossman, 2022). After tertiary treatment, the water can be safely released into rivers, lakes, etc (Chokhavatia Associates, 2021).

2.3 Small Sewage Treatment System (SSTS)

Small sewage treatment plants treat domestic wastewater and produce clean water that can be used directly in the environment for a variety of purposes, the most common of which are agriculture and farming. Small sewage treatment plants utilise microbe culture in the form of small floccules (activated sludge method) or bacterial film, which is attached to the biofilter plenum (Krzanowski et al., 2007). Proper sewage treatment requires enough organic matter, preferably in the form of short-chained organic acids, prolonged contact of sewage with microorganisms, as well as separation and drainage of the excessive bacteria biomass (Krzanowski et al., 2007). This is a secondary treatment that is specifically designed to remove biological contaminants from water. Food waste, human waste, detergent, and soap are common sources of these contaminants. As illustrated in Figure 2.3, this is the current condition of SSTS in removing nutrients at Temenggor Lake.

FIGURE 2.3: The current condition of SSTS in removing nutrients.

Small sewage treatment plants can be designed to meet the needs of a particular region, which are primarily influenced by the climate, the lifestyle of the local population, and geographical location. A small sewage treatment plant is used to remove salts such as sodium, nitrates, phosphate, and nitrogen that are commonly found in household waste, particularly kitchen waste. This procedure also separates microorganisms. As a result, small-scale sewage treatment plants are critical for residential or small-scale water treatment processes. Small sewage treatment plants are mostly biological aerobic treatment plants with activated sludge or biofilters, although these two systems combined into one are more and more frequently observed as hybrid systems (Krzanowski et al., 2007). In small sewage treatment plants, biological part of the process is usually combined with secondary settlement tanks in which sedimentation of produced bacterial mass occurs (Krzanowski et al., 2007).

2.4 Removal of Nutrient

Insufficiently treated wastewater discharges contribute to the build-up of nutrients in the bed sediments of rivers and lakes. These stored nutrients contribute to internal loading as they are recycled throughout the water column, especially during stratified summer periods when oxygen deprivation in isolated bottom waters leads to the release of phosphate and ammonium from sediments (White et al., 1978; Burger et al., 2007). According to Ashraf et al. (2010), human activities are the primary cause of water contamination at Varsity Lake, University of Malaya, Kuala Lumpur, Malaysia. Humans generate body wastes that are discharged into lakes and reservoirs (Ashraf et al., 2010). Industries release several pollutants, including heavy metals, organic toxins, nutrient-rich oils, and sediments, in their effluent (Ashraf et al., 2010).

Micropollutants (MPs) as single chemicals or in complex mixes have an impact on water quality and can cause undesirable ecological impacts (Eggen et al., 2014). The effluents from conventional wastewater treatment plants (WWTPs) that do not or cannot remove all MPs are a key source (Eggen et al., 2014). It is vital from an environmental perspective to assess the potential implications of discharging nutrients into the lake, as nutrient additions can result in unwanted ecological effects such as excessive algal development. Increase in nutrient load may result in eutrophication; organic wastes increase the oxygen demand in water, resulting in a depletion of oxygen in water, which may have catastrophic consequences for entire ecosystems as shown in Figure 2.4 (Ashraf et al., 2010).

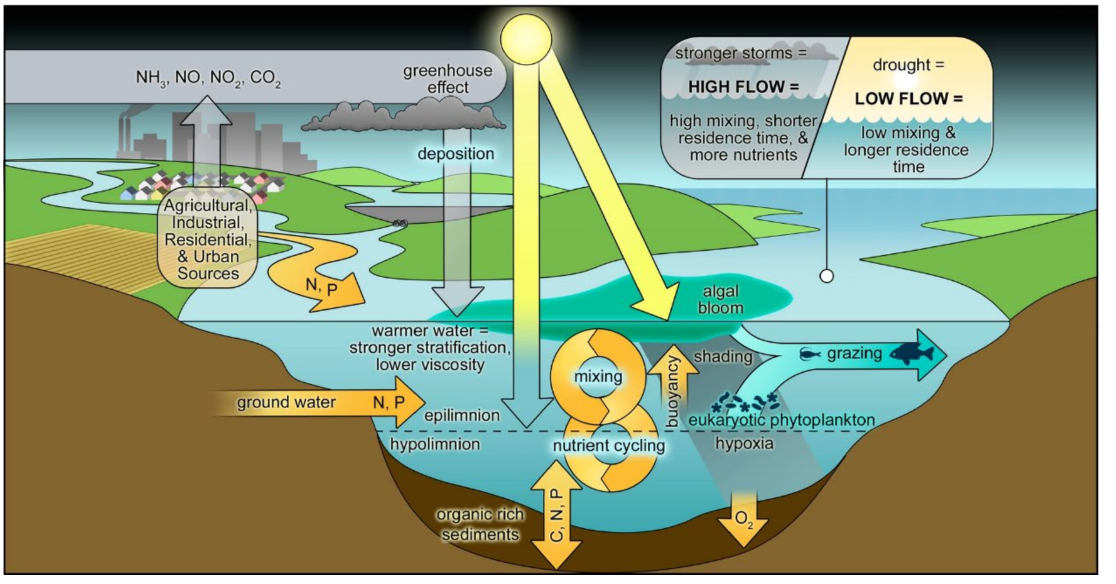

FIGURE 2.4: The process for expansion of harmful algal blooms in lake.

Sewage may contain prominent levels of the nutrient's nitrogen and phosphorus. Nitrogen and phosphorus can be found in wastewater in various forms. Nitrogen can be converted into four different forms which are ammonia (in equilibrium with ammonium), organic nitrogen, nitrite, and nitrate. In developing nations, the following typical values for nutrient loads per person and nutrient concentrations in raw sewage have been published: 6 to 10 g/person/day of total nitrogen (35 to 60 mg/L), 3.5 to 6 g/person/day of ammonia-N (20 to 35 mg/L), and 0.7 to 2.5 g/person/day of total phosphorus (4 to 15 mg/L) (Maurer et al., 2006). Multiple proposals for nutrient recovery from source-separated urine have been presented, as urine contributes about 80% of nitrogen and 50% of phosphorus to domestic wastewater (Maurer et al., 2006).

Such conditions have raised concerns on deterioration in water quality of the lake. According to the study conducted by Ainon, Ratuah, Mimi, and Affendi (2006) have found that the Chini Lake water was threaten by excessive growth of bacteria (total coliform and faecal coliform), which are not safe for drinking. In recent years, Chini Lake experienced major development in agriculture activities (Shuhaimi et al., 2007). Agriculture activities were believed to release pollutant such as nitrate and phosphate into the lake (Shuhaimi et al., 2007). Soil erosion generated by the conversion of forest to agriculture land and logging activities in this area was believed as one of the main contributions to the increase of suspended solid concentration in the river and lake water body (Barzani Gasim, Sahibin, Shuhiami Othman, & Ang, 2005).

The construction of National Service Centre for National Service Training programme in Chini Lake since 2004 also contributed to the increase in nutrient and organic loading into the lake (Shuhaimi et al., 2007).

Several treatment processes exist to remove nitrogen and phosphorus, but biological nutrient removal (BNR) as portrayed in Figure 2.5 is preferred due to its lower cost, energy, and chemical requirements than physical-chemical treatment (Ergas & Aponte-Morales, 2013). Phosphorus can also be removed through chemical precipitation, typically with iron salts (ferric chloride) or alum or lime. Chemical phosphorus removal has a significantly smaller equipment footprint than biological phosphorus removal, is easier to operate, and is often more reliable. Some systems utilise both chemical and biological phosphorus removal. Chemical phosphorus removal can be used as a backup system in these systems, or it can be used continuously if biological phosphorus removal is insufficient. Combining biological and chemical phosphorus removal has the advantage of not increasing sludge production as much as chemical phosphorus removal alone but has a higher initial cost due to the installation of two separate systems.

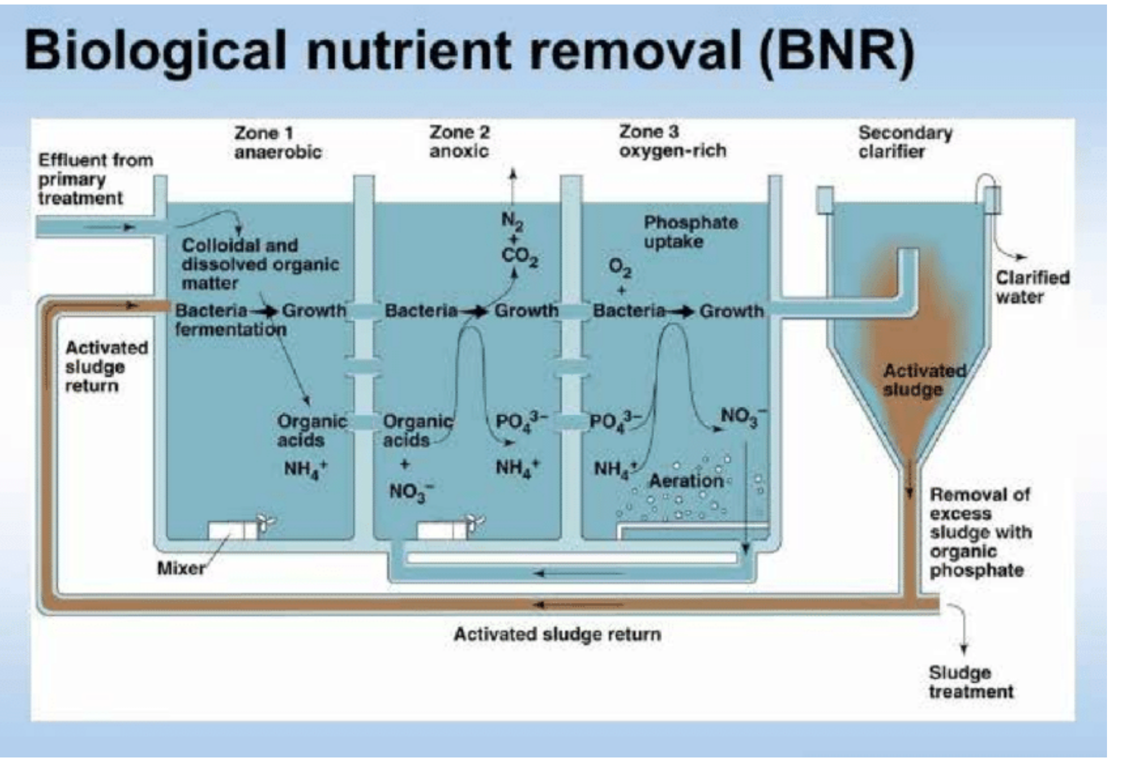

FIGURE 2.5: The treatment processes of biological nutrient removal.

Generally, ammonia is the main nitrogen compound found in wastewater (Abbas et al., 2014). Ammonia removal has become a global issue because it causes eutrophication, causes oxygen levels to drop, and kills aquatic life. During the nitrification process in a body of water, dissolved oxygen is used to change nitrogen from ammonia to nitrite and then to nitrate as shown in Figure 2.6 (Abbas et al., 2014). The traditional biological process for getting rid of ammonia, called nitrification followed by denitrification, needs a lot of energy for aeration to turn nitrite into nitrate and an outside source of carbon for denitrification (Abbas et al., 2014). Nitrogen is removed through nitrification, the biological oxidation of nitrogen from ammonia to nitrate, and denitrification, the reduction of nitrate to nitrogen gas. Nitrogen is removed from the water by releasing it into the atmosphere. The standard biological nitrogen removal method is used to clean up wastewater with low levels of nitrogen.

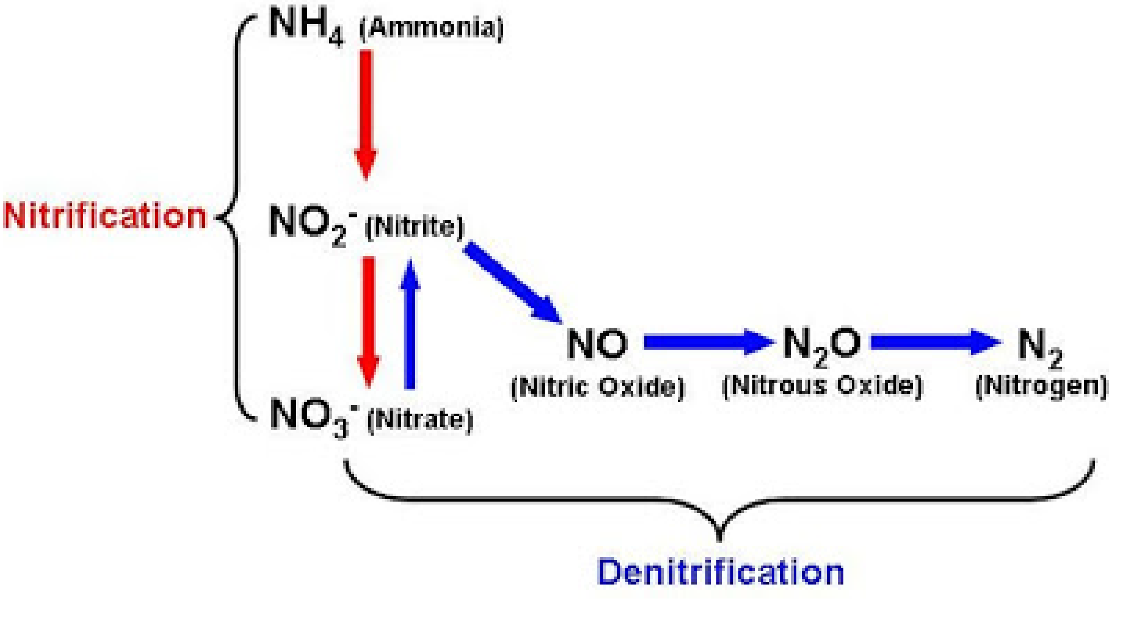

FIGURE 2.6: The nitrification and denitrification reaction sequence.

Nitrification is a two-step aerobic process that is aided at each stage by a distinct type of bacteria. According to Figure 2.7, Nitrosomonas spp. bacteria are frequently involved in the oxidation of ammonia (NH^{4+}) to nitrite (NO^{2}) and Nitrobacter spp. bacteria previously believed to be facilitated the nitrite oxidation to nitrate (NO^{3}) in the environment. Denitrification necessitates anoxic conditions for the formation of the proper biological communities. The term "anoxic conditions" refers to the absence of oxygen and the presence of nitrate. Denitrification is the conversion of nitrate to dinitrogen (molecular nitrogen) gas by Bacillus Pseudomonas Clostridium bacteria, which requires an electron donor. Using submersible mixers, the sludge in the anoxic tanks (denitrification tanks) must be thoroughly mixed with the mixture of recirculated mixed liquor, return activated sludge, and raw influent to achieve the desired denitrification.

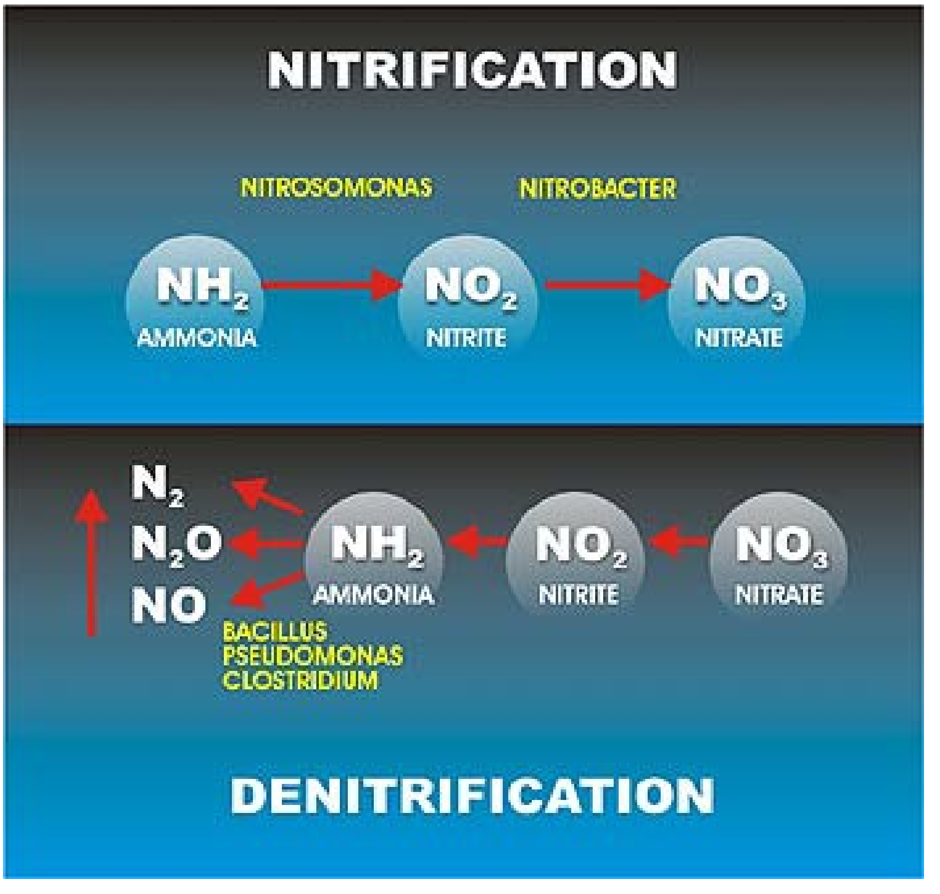

FIGURE 2.7: The biological nitrification and denitrification bacteria in SSTS.

The plants and animals that make up the aquatic food web need phosphorus to function properly. Since phosphorus is the nutrient that is in short supply in most fresh waters, even a small increase in phosphorus can, under the right conditions, cause a whole chain of bad things to happen in a stream, such as faster plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals (Bhateria, R., & Jain, D., 2016). Phosphorus is most often found in nature as part of a phosphate molecule (Bhateria, R., & Jain, D., 2016). Phosphorus can be found in water as both organic and inorganic phosphate as shown in Figure 2.8. Organic phosphate is made up of a phosphate molecule and a carbon-based molecule, like those found in plant or animal tissue. Phosphate that is not connected to living things is called inorganic. Both organic and inorganic phosphorus can be dissolved in water or suspended in the water column by attaching themselves to other particles (Spellman, 2017).

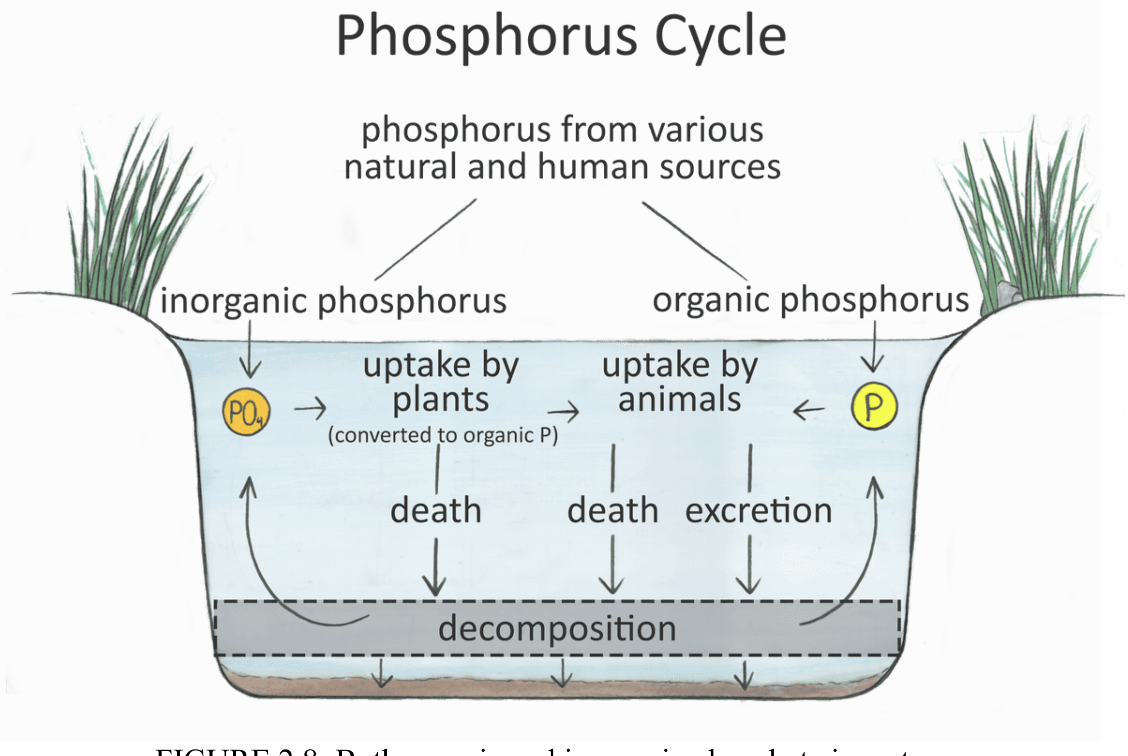

FIGURE 2.8: Both organic and inorganic phosphate in water.

2.5 Nutrient discharge standards for Temenggor Lake

Temenggor Lake is one of the tourist spots so it is very important to preserve the environment thus the effluent must fulfill the requirement before being discharged into the lake or SSTS. The nutrient removal from wastewater is crucial to meet the strict nutrient discharge standards to protect aquatic ecosystems. The preliminary stages for determining the project's title, problem description, and aim, as well as conducting a site visit, have been completed. Currently, wastewater samples have been collected before and after houseboat discharge into SSTS and houseboat wastewater has been collected for data collection by conducting a lab experiment on the wastewater obtained in removing nutrient for Ammonia, Nitrate, and Phosphorus. Then, the data obtained needs to be analyzed with the results with the global regulations where the effluent discharge must not exceed the National Lake Water Quality Criteria and Standard as displayed in Figure 2.9. The outcomes will be compared to existing global regulations.

PARAMETER	UNIT	CATEGORY B
Colour	TCU	150 - 300
Conductivity	µS/cm	1000
Salinity	ppt	nvd
Floatables	-	NV
Dissolved oxygen	mg/L	5.5 - 8.7
DO percentage saturation	%	70 -110
Odour	-	NOO
pH	-	6.5 - 8.5
Taste	-	NOT
Temperature	°C	28
Total Suspended Solid	mg/L	100 - 500
Turbidity	NTU	40 - 170
Transparency (Secchi)	m	0.6
Oil & Grease	mg/L	1.5
BIOLOGICAL/MICROBIOLOGICAL		
Chlorophyll-a	µg/L	15 [b]
CHEMICALS		
Ammoniacal Nitrogen (NH_3-N)	mg/L	0.3 [a]
Nitrate (NO_3-N)	mg/L	7 [h]
Total Phosphorus	mg/L	0.035 [d]

FIGURE 2.9: The National Lake Water Quality Criteria and Standard, which shall not be exceeded by effluent discharge.

CHAPTER 3
METHODOLOGY

The methodology part of this project discussed the methods and procedures in achieving the goal of this project which is to investigate the impacts of houseboats wastewater discharge on the performance of the Small Sewage Treatment System (SSTS) in removing nutrient at Temenggor Lake. This methodology part explained in detail the lab experiment procedures for ammonia, nitrate, and phosphorus. Other than that, the flow chart of this project will be explained.

3.1 Collection of wastewater sample from houseboat and Small Sewage Treatment System (SSTS)

Every weekend, the houseboats used to accommodate tourists spending at least three days and two nights on the lake. The houseboats' wastewater output will be collected in the septic tanks installed under the houseboats. At the conclusion of the houseboats, approximately 1.5 litres of influent with labelled will be collected and analysed. The water samples were collected monthly for six months from the septic tanks of four (4) houseboats as shown in Figure 3.1, 3.2, 3.3 and 3.4, as well as the influent and effluent of the Small Sewage Treatment System (SSTS). Additionally, the number of tourists utilising each houseboat will be tracked. All houseboats equipped with septic tanks will have their septic tank sizes analysed to establish the maximum capacity that can be stored.

FIGURE 3.1: Houseboat 1 (HB1) for wastewater collection.

FIGURE 3.2: Houseboat 2 (HB2) for wastewater collection.

FIGURE 3.3: Houseboat 3 (HB3) for wastewater collection.

FIGURE 3.4: Houseboat 4 (HB4) for wastewater collection.

Water samples were collected once per month at two distinct times, 10 a.m. and 2 p.m. on the same day for the influent as illustrated in Figure 3.5 and effluent for SSTS in Figure 3.6, while houseboat wastewater samples were collected from the septic tanks of four (4) units' houseboats at 2 p.m. only for the influent. The objective of taking water samples at two different times was to compare the performance of the SSTS operation before and after including loads from houseboat septic tanks. The following day, the collected samples will be analysed for ammonia, nitrate, and phosphorus. The properties of houseboat wastewater discharge were also investigated. Thus, the optimal design value will be established and incorporated into the design of the treatment facility.

FIGURE 3.5: Influent wastewater collection from SSTS at 10 a.m. and 2 p.m.

FIGURE 3.6: Effluent wastewater collection from SSTS at 10 a.m. and 2 p.m.

3.2 Research Procedure

In this research, water samples had been collected on-site in the quantities specified in the Table 1 depending on the tests conducted throughout this study. To ensure that the findings are as accurate as possible, three samples were collected from each spot. The water samples were calculated based on the need for 3 parameters, including Ammonia, Nitrate, and Phosphorus, all of which are in line with the objective. Since all houseboats would return to the jetty after being leased out by tourists for the whole weekend, the suitable day for collecting wastewater sample was chosen on Sunday while the lab testing will be on Monday which is the next day.

TABLE 1: Water sample had been collected from SSTS and Houseboats per month.

Month	SSTS				Each Houseboat
	10 a.m.		2 p.m.		
	Influent	Effluent	Influent	Effluent	
July	3	3	3	3	3
August	3	3	3	3	3
September	3	3	3	3	3
October	3	3	3	3	3

3.3 Lab-based analysis of the wastewater characteristics of sanitary discharge from houseboats and SSTS.

The removal of nutrients from the SSTS at Temenggor Lake in the treatment of houseboat wastewater will be analyzed using lab experiment methods in this project by monitoring samples near the discharge. The test will be carried out at the Civil and Environmental Engineering Laboratory of the Universiti Teknologi PETRONAS (UTP) to determine the presence of nutrients in Temenggor Lake. The procedures for determining the amount of ammonia, nitrate, and phosphorus will be described. The impact of the current SSTS discharge on lake water quality will be assessed by monitoring samples near the discharge for several months. The outcomes will be compared to current global regulations.

3.3.1 Ammonical nitrogen analysis

The wastewater sample for ammonia (NH^3) was diluted in a volumetric flask with a dilution factor of 1:50 for the influent and effluent in SSTS by adding 1 mL of wastewater sample with 49 mL of distilled water. The dilution factor used for houseboat wastewater was 1:100 by mixing 1ml of wastewater and 99 ml of distilled water. 25 mL of the diluted sample was measured in a measuring cylinder and poured into the conical flask (Jagaba et al., 2021). Three drops of mineral stabiliser and three drops of polyvinyl alcohol dispersing agent were added to the sample and mixed thoroughly. The chemicals used in ammonia measurement are Nessler reagents, which are corrosive and yellowish in colour. The sample was mixed for 1 minute after 1 mL of Nessler reagent was added (Jagaba et al., 2021). A 10 mL diluted sample was inserted into the cuvette to be examined.

A blank sample was created by measuring 25 mL of distilled water with a measuring cylinder. With the sample, three drops of mineral stabiliser and three drops of polyvinyl alcohol dispersing agent were added and thoroughly combined (Jagaba et al., 2021). Next, 1 mL of Nessler reagent was added and thoroughly mixed for one minute before adding 10 mL of sample to the cuvette cell. For zero calibration, a cuvette containing distilled water was placed into the spectrophotometer along with the code 380 for Nitrogen Ammonia (Jagaba et al., 2021). The sample-filled cuvette was inserted into the spectrophotometer, and the "READ" button was pressed. The sample was examined three times to get an average for influent, effluent in SSTS and houseboat wastewater. The reading from the spectrophotometer was recorded for the blank sample and wastewater sample as the result.

3.3.2 Nitrate analysis

The wastewater sample for nitrate (NO^3) was diluted in a volumetric flask with a dilution factor of 1:50 for the influent and effluent in SSTS by adding 1 mL of wastewater sample with 49 mL of distilled water. The dilution factor used for houseboat wastewater was 1:100 by mixing 1ml of wastewater with 99 ml of distilled water. A 10 mL sample of the wastewater was collected into a cuvette cell. Without adding NitraVer5 Nitrate reagent powder pillow, the cuvette was inserted into the spectrophotometer for zero calibration along with the code 355 for Nitrate. Then, the cuvette was removed from the spectrophotometer and a packet of NitraVer5 Nitrate reagent powder pillow was added to the cuvette. The cuvette was shaken for 1 minute to dissolve before being placed into the spectrophotometer. The spectrophotometer “READ’’ button was pressed, and the reading was recorded. A spectrophotometer is used to measure the colour of the sample when measuring nitrate. The sample was examined three times to get an average for influent, effluent in SSTS and houseboat wastewater.

3.3.3 Phosphorus analysis

The wastewater sample for phosphorus (P) was diluted in a volumetric flask with a dilution factor of 1:50 for the influent and effluent in SSTS by adding 1 mL of wastewater sample with 49 mL of distilled water. The dilution factor used for houseboat wastewater was 1:100 by mixing 1ml of wastewater with 99 ml of distilled water. A 5 mL of wastewater sample was added to the Total Acid Hydrolyzable Test vial with a packet of potassium persulfate powder pillow. A vibrator was used to mix the sample inside the vial. For digestion, the sample was placed in a HACC 200 DRB reactor at 150°C for 30 minutes. After completing digestion for 30 minutes, it was cooled by leaving the sample at room temperature. Then, 2 mL of 1.54 NaOH was pipetted into the sample, and the sample was thoroughly mixed before being placed in a spectrophotometer for zero calibration. The vial was inserted into the spectrophotometer for zero calibration along with the code 536 for Phosphorus. The sample was removed and a pack of PhoVer3 powder pillow was added to it. The sample was mixed for 30 seconds until dissolved. After mixing, the sample-filled cuvette was inserted into the spectrophotometer, and the "READ" button was pressed. The sample was examined three times to get an average for influent, effluent in SSTS and houseboat wastewater. The reading from the spectrophotometer was recorded for the wastewater sample as the result.

3.4 Project flow chart

This study began with wastewater sampling, was followed by laboratory testing and an analysis of the results performance of SSTS and concluded with the proposal of a new SSTS design for anoxic tanks. The project flow chart will show the exact procedure and method of completing this project according to the objective and scope of work for this project. Figure 3.7 below shows the project flow chart for research activities which the impacts of houseboats wastewater discharge on performance of SSTS in removing nutrient at Temenggor Lake.

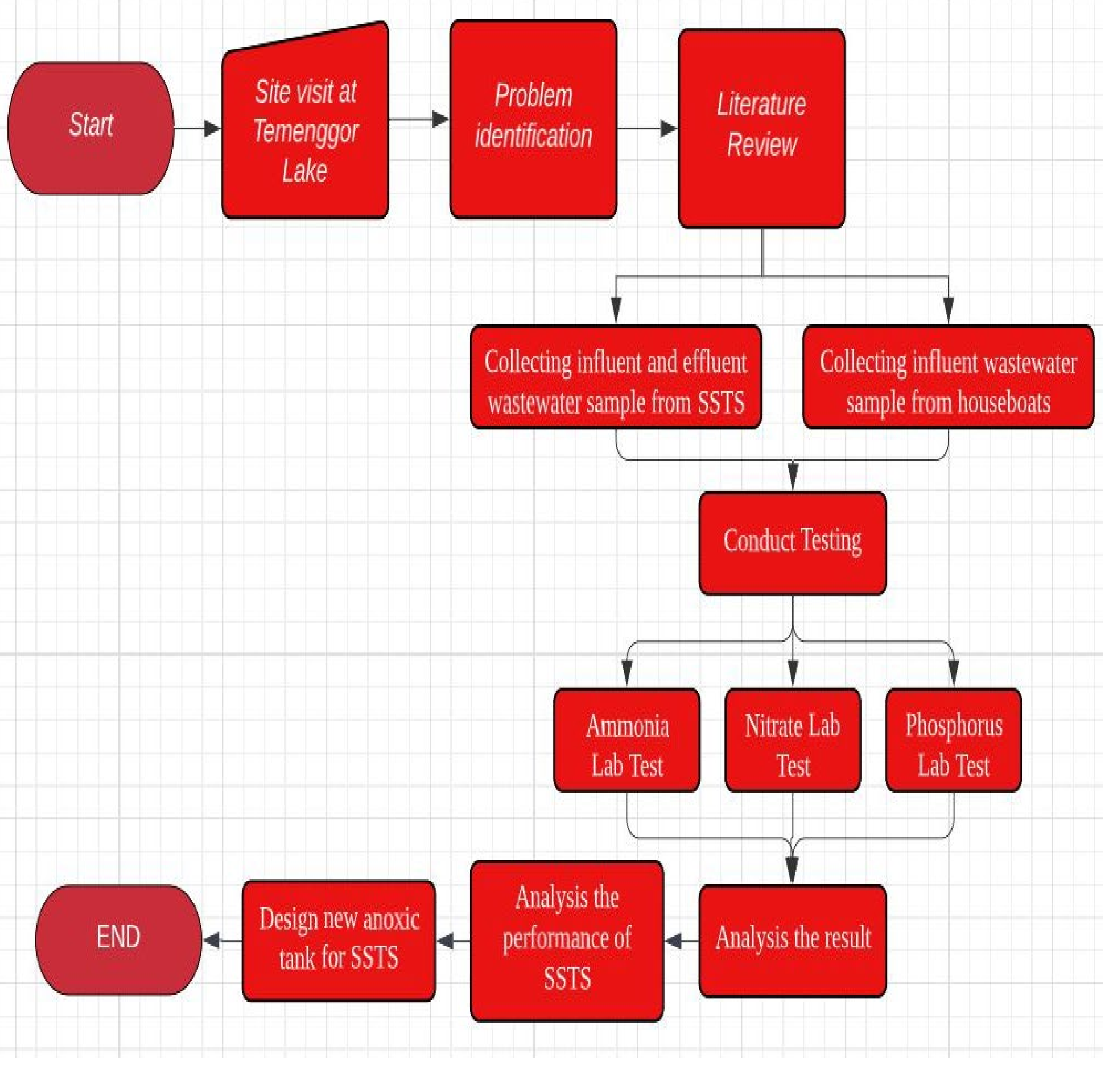

FIGURE 3.7: The project flow chart for research activities.

CHAPTER 4
RESULTS AND DISCUSSION

The results of the study on the impacts of houseboats wastewater discharge on performance of Small Sewage Treatment System (SSTS) in removing nutrient which are Ammonia, Nitrate and Phosphorus at Teenager Lake are presented in this section.

4.1 Results for Ammonia Concentration throughout the Study

Experiment for ammonia was conducted for four sampling as mentioned in methods were collected and experiments are conducted for every month. The first sampling date of the experiment was carried out on 24th July 2022 and for the Sampling 2, Sampling 3, and Sampling 4 was on 28th August 2022, 19th September 2022, 30th October 2022 respectively. The Ammonia were monitored for the influent of houseboats and SSTS including the effluent of SSTS for two different time at 10 a.m. and 2 p.m. which is during peak hours for both influent and effluent.

4.1.1 Influent of SSTS for Ammonia Results throughout the Study

Influent ammonia throughout the study was plotted as in Figure 4.1 below shows the ammonia concentration against sampling. The variations in ammonia influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m.

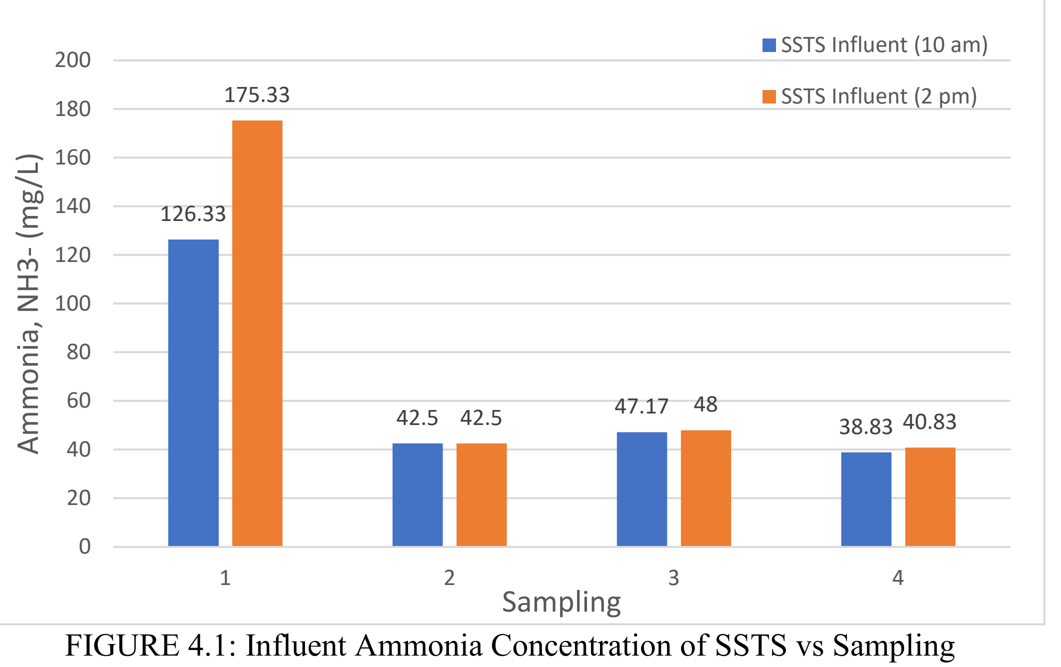

FIGURE 4.1: Influent Ammonia Concentration of SSTS vs Sampling

Based on Figure 4.1, it can be observed that during Sampling 1, when the influent was diluted at 1:50, influent ammonia was averaged about 126.33 mg/L. It can be observed that influent ammonia increased to an averaged value of 175.33 mg/L for influent ammonia during peak hours which is at 2 pm. The concentration of ammonia in the influent (orange colour) is quite high on the first sampling because the SSTS is not functioning. When the SSTS failed to operate, the sludge into the aeration tank will appeared to float on top of the clarifier. Those floating sludges are the organic matter that has been degraded to ammonia but not yet undergo nitrification, this explains why high ammonia concentration was tested (SRM Kutty, K., 2018). For Sampling 2, both influent ammonia for 10 a.m. and 2 p.m. was averaged about 42.5 mg/L which can be conclude that day not many people use the facilities at jetty complex during peak hour. The influent ammonia for Sampling 3 was averaged 47.17 mg/L at 10 am while increasing to 48 mg/L at 2pm. Then, the influent ammonia for Sampling 4 was averaged 38.83 mg/L at 10 am while increasing to 40.83 mg/L at 2pm. Throughout the study, it can be observed from Figure 13 that even when the Ammonia in the influent at 2pm was increased for Sampling 3 and Sampling 4, the ammonia concentration did not increase very much.

Table 2 shows the averaged ammonia concentration values throughout the study period. Throughout the study, influent ammonia concentration varies between 38.83 mg/L to 175.33 mg/L. Hence, this correlates to the ammonia obtained where there is higher in ammonia concentration in the influent especially during peak hour (2 p.m.).

TABLE 2: Averaged Influent Ammonia Concentration vs Sampling

Number of Sampling	Average Influent of Ammonia (mg/L)	
	Influent 10 a.m.	Influent 2 p.m.
Sampling 1	126.33	175.33
Sampling 2	42.5	42.5
Sampling 3	47.17	48
Sampling 4	38.83	40.83

4.1.2 Effluent of SSTS for Ammonia Results throughout the Study

Effluent ammonia from all four-sampling taken for each different time was measured throughout the study and plotted in Figure 4.2 shows the ammonia concentration against sampling. The variations in ammonia influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m. from Sampling 1 until Sampling 4.

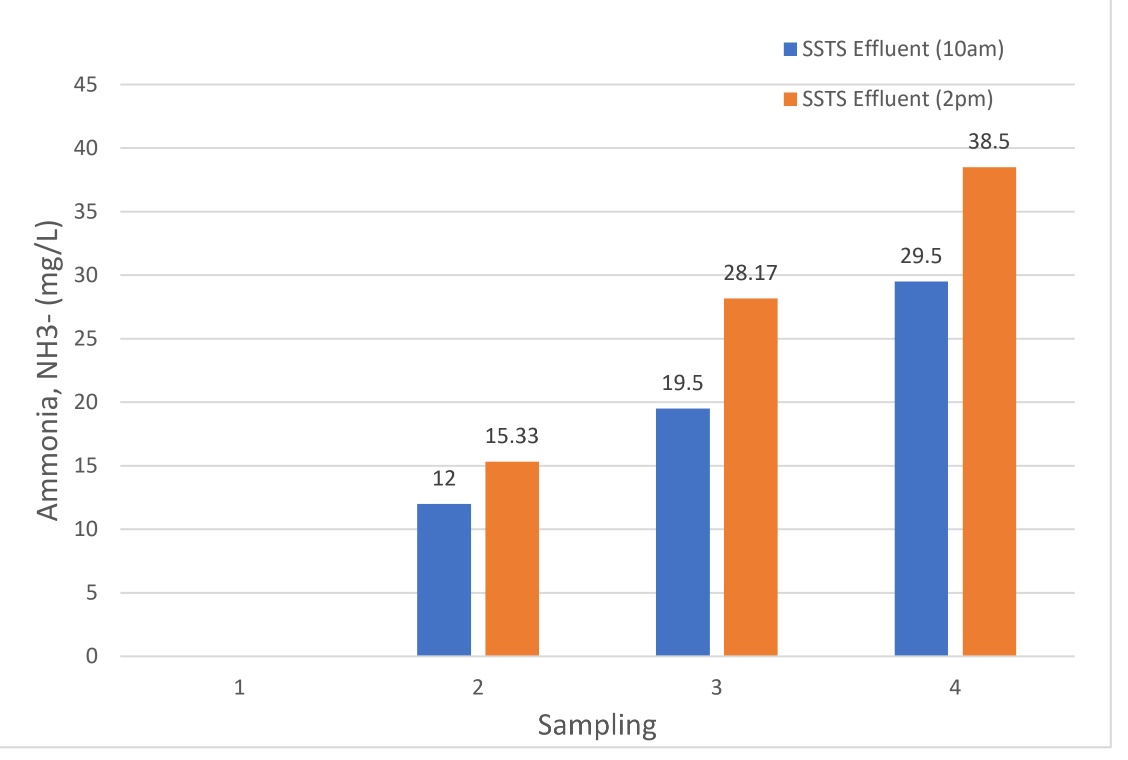

FIGURE 4.2: Effluent Ammonia Concentration of SSTS vs Sampling

During Sampling 1 as shown in Figure 4.2, effluent ammonia concentration at both different time values cannot be measured since there is no effluent discharge at the drain outlet from the SSTS to the lake. This is because the SSTS is not functioning or operate to treat the wastewater collected in the SSTS in removing nutrients. However, during collection of effluent for Sampling 2, Sampling 3, and Sampling 4, the effluent has been taken at the drain outlet. The effluent ammonia concentrations at Sampling 2, Sampling 3, and Sampling 4 for 10 am were found to average at 12 mg/L, 19.5mg/L, and 29.5 mg/L, respectively. There was not much nitrification occurring in this time since the people consumes the facilities at the jetty was not much as peak hours or lunch hour. During peak hours at 2 p.m., the effluent ammonia concentration increased that achieve an averaged ammonia concentration of 15.33 mg/L, 28.17 mg/L, 38.5 mg/L for effluents at Sampling 2, Sampling 3, and Sampling 4, respectively. The increased ammonia concentration may be due to the time when taking sample was around 2 pm, where most of the people will use the toilet before going back home after completing their nature discovery in Banding Island. Throughout the period, effluent ammonia concentrations from all sampling still does not meet the Standard B of ammonia discharge limit of 0.3 mg/L according to National Lake Water Quality Criteria and Standard. Throughout the study, it can be observed from Figure 15 that the Ammonia for Sampling 2, Sampling 3, and Sampling 4 for the effluent at 2 p.m. was increased than the ammonia concentration at 10 a.m.

Table 3 shows the averaged effluent ammonia concentration values throughout the study period. Throughout the study, effluent ammonia concentration varies between 12 mg/L to 38.5 mg/L. Hence, this correlates to the ammonia obtained where there is higher in ammonia concentration in the effluent especially during peak hour (2 p.m.).

TABLE 3: Averaged Effluent Ammonia Concentration vs Sampling

Number of Sampling	Average Effluent of Ammonia (mg/L)	
	Effluent 10 a.m.	Effluent 2 p.m.
Sampling 1	0	0
Sampling 2	12	15.33
Sampling 3	19.5	28.17
Sampling 4	29.5	38.5

The source of ammonia was from the degradation of the organics as well as endogenous respiration in the SSTS as were operated at extended aeration. In aerobic oxidation, the conversion of organic matter is carried out by mixed bacterial cultures in general accordance with the stoichiometry shown below:

Equation 1:

Organic compounds + O_2 + nutrients bacteria CO_2 + NH_3 + $C_5H_7NO_2$ + Other end products.

Equation 2: Endogenous respiration of biomass:

$C_5H_7NO_2$ + O_2 bacteria $5CO_2$ + $2H_2O$ + NH_3+ energy

According to Metcalf and Eddy (2014), the organic matter in wastewater which serves as the electron donor while the oxygen serves as electron acceptor. In the aeration tank, degradation of organic matter will produce ammonia. The product from oxidation, mainly ammonia will be oxidized again into nitrite and nitrate during nitrification.

4.1.3 Influent of Houseboat for Ammonia Results throughout the Study

Influent ammonia from all four-sampling taken from four houseboats was measured throughout the study and plotted in Figure 4.3 shows the ammonia concentration against sampling. The variations in ammonia influent can be explained by the method of sampling taken at different capacity of people occupied at each houseboat.

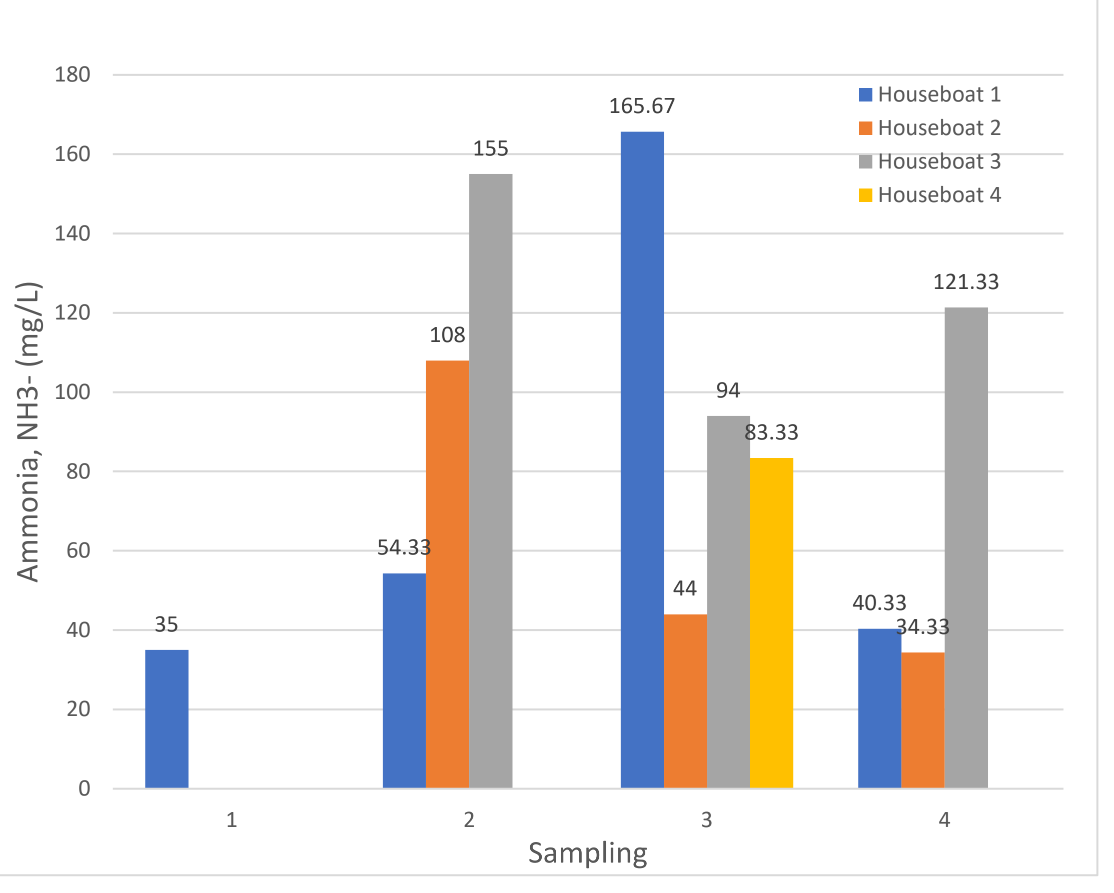

FIGURE 4.3: Influent Ammonia Concentration of Houseboat vs Sampling

Based on Figure 4.3, the influent ammonia concentration for Sampling 1 was averaged about 35 mg/L for Houseboat 1 (HB1) while for Houseboat 2 (HB2), Houseboat 3 (HB3) and Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats. As shown in Figure 4.3, the influent for HB1 during Sampling 1 has the lowest concentration of ammonia since the wastewater has been diluted. This is happened because the wastewater solids were released from the houseboat tank to the lake along the journey before arriving to the jetty complex. Thus, the solid wastewater was cleared from the septic tank and the wastewater collection taken was the diluted wastewater. For Sampling 2, the influent ammonia concentration for HB1, HB2, and HB3 was averaged of 54.33 mg/L, 108 mg/L, and 155 mg/L respectively while HB4 has not been taken due to the houseboat did not make any trip for this month. As illustrated in Figure 4.3, Houseboat 3 was averaged 155 mg/L which is the highest value during Sampling 2 because the houseboat has the highest capacity of people during the trip than other houseboats. For Sampling 3, the influent ammonia concentration for HB1, HB2, HB3 and HB4 was averaged of 165.67 mg/L, 44 mg/L, 94 mg/L and 83.33 mg/L respectively. The highest ammonia concentration was 165.67 mg/L for HB1 since the capacity of houseboat can occupied 40 people and 5 workers during the trip. For Sampling 4, the influent ammonia concentration for HB1, HB2, and HB3 was averaged of 40.33 mg/L, 34.33 mg/L, and 121.33 mg/L respectively while for Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats.

Table 4 shows the averaged ammonia concentration values throughout the study period. Throughout the study, influent ammonia concentration varies between 35 mg/L to 165.67 mg/L. Hence, this correlates to the ammonia obtained where there is higher in ammonia concentration in the influent varied with the capacity of the houseboat.

TABLE 4: Averaged influent Ammonia Concentration vs Sampling

Number of Sampling	Average Influent of Ammonia (mg/L)			
	Houseboat 1	Houseboat 2	Houseboat 3	Houseboat 4
Sampling 1	35	-	-	-
Sampling 2	54.33	108	155	-
Sampling 3	165.67	44	94	83.33
Sampling 4	40.33	34.33	121.33	-

4.2 Results for Nitrate Concentration throughout the Study

Experiment for ammonia was conducted for four sampling as mentioned in methods were collected and experiments are conducted for every month. The first sampling date of the experiment was carried out on 24th July 2022 and for the Sampling

2, Sampling 3, and Sampling 4 was on 28th August 2022, 19th September 2022, 30th October 2022 respectively. The concentration of nitrate was monitored for the influent of houseboats and SSTS including the effluent of SSTS for two different time. Influent and effluent of SSTS for nitrate were measured throughout the study at 10 a.m. and 2 p.m. which is during peak hours for both influent and effluent.

4.2.1 Influent of SSTS for Nitrate Results throughout the Study

Influent nitrate throughout the study was plotted as in Figure 4.4 below shows the nitrate concentration against sampling. The variations in nitrate influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m.

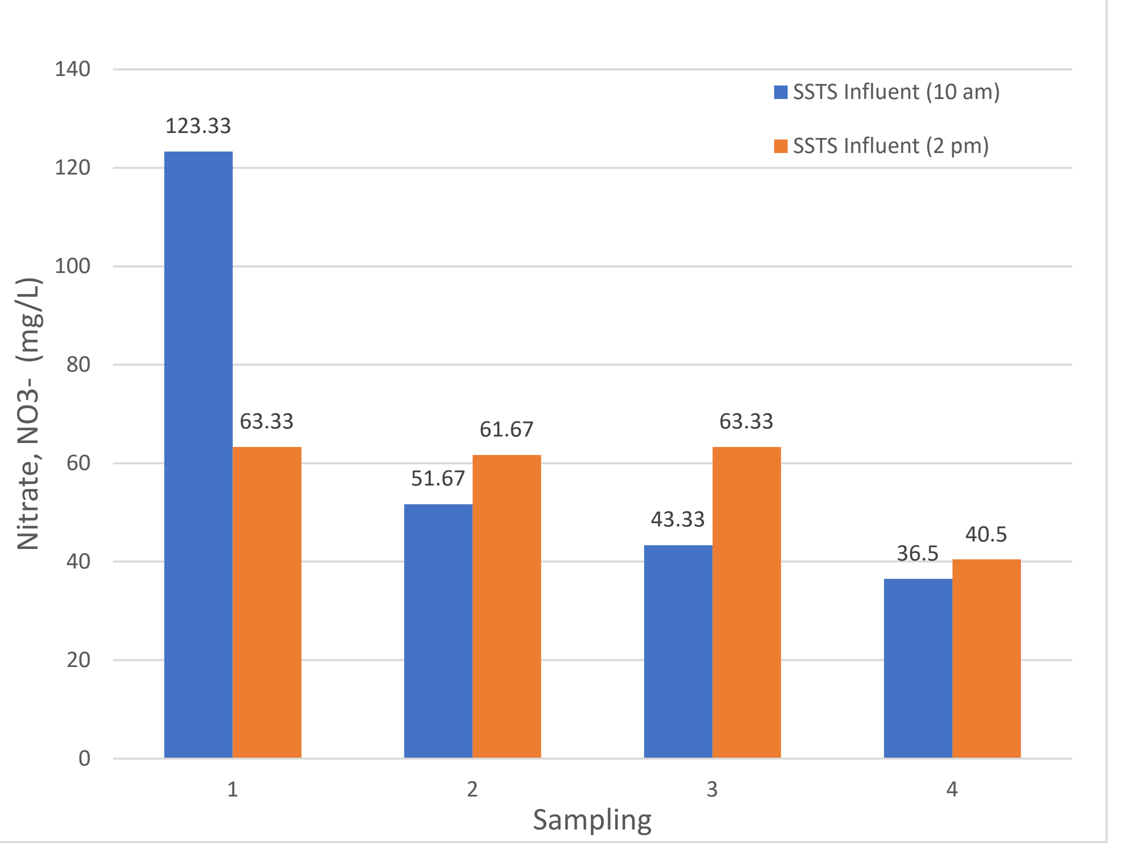

FIGURE 4.4: Influent Nitrate Concentration of SSTS vs Sampling

Based on Figure 4.4, it can be observed that during Sampling 1, when the SSTS influent was diluted at 1:50, influent of nitrate at 10 a.m. and 2 p.m. was averaged about 123.33 mg/L and 63.33 mg/L respectively. The concentration of nitrate in the influent (blue) is quite high on the first sampling because the SSTS is not functioning. As shown in Figure 4.4, the nitrate concentration for Sampling 1 decreased at 2 p.m. since the samples were taken probably in the late afternoon where tourist or people no longer use the toilet at the jetty complex hence less nitrate concentration in the influent. For Sampling 2, the influent of nitrate for 10 a.m. and 2 p.m. was averaged about 51.67 mg/L and 61.67 mg/L which can be conclude that day not many people use the facilities at jetty complex during peak hour. The influent nitrate for Sampling 3 was averaged 43.33 mg/L at 10 a.m. and it can be observed that influent increased to an averaged value of 63.33 mg/L for influent of nitrate during peak hours which is at 2 p.m. Then, the influent nitrate for Sampling 4 was averaged 36.5 mg/L at 10 a.m. while increasing to 40.5 mg/L at 2 p.m. Throughout the study, it can be observed from Figure 4.4 that even when the nitrate in the influent at 2 p.m. was increased for Sampling 2, Sampling 3, and Sampling 4, the nitrate concentration did not increase very much.

Table 5 shows the averaged nitrate concentration values throughout the study period. Throughout the study, influent nitrate concentration varies between 36.5 mg/L to 123.33 mg/L. Hence, this correlates to the nitrate obtained where there is higher in nitrate concentration in the influent especially during peak hour (2 p.m.).

TABLE 5: Averaged Influent Nitrate Concentration vs Sampling

Number of Sampling	Average Influent of Nitrate (mg/L)	
	Influent 10 a.m.	Influent 2 p.m.
Sampling 1	123.33	63.33
Sampling 2	51.67	61.67
Sampling 3	43.33	63.33
Sampling 4	36.5	40.5

4.2.2 Effluent of SSTS for Nitrate Results throughout the Study

Effluent nitrate from all four-sampling taken for each different time was measured throughout the study and plotted in Figure 4.5 shows the nitrate concentration against sampling. The variations in nitrate influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m. from Sampling 1 until Sampling 4.

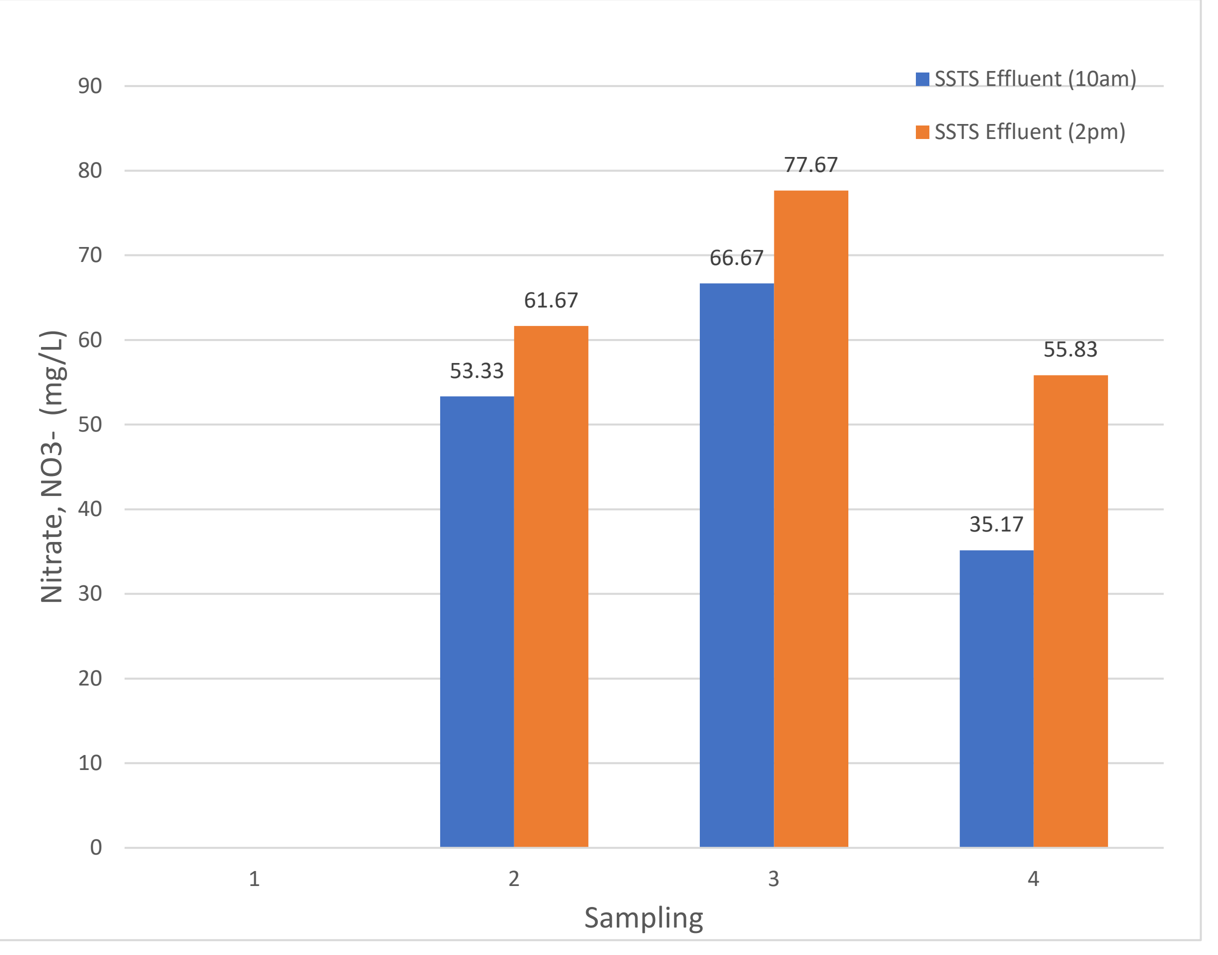

FIGURE 4.5: Effluent Nitrate Concentration of SSTS vs Sampling

During Sampling 1 as shown in Figure 4.5, effluent nitrate concentration at both different time values cannot be measured since there is no effluent discharge at the drain outlet from the SSTS to the lake. This is because the SSTS is not functioning or operate to treat the wastewater collected in the SSTS in removing nitrate. However, during collection of effluent for Sampling 2, Sampling 3, and Sampling 4, the effluent has been taken at the drain outlet. The effluent nitrate concentrations at Sampling 2, Sampling 3, and Sampling 4 for 10 a.m. (blue colour) were found to average at 53.33 mg/L, 66.67 mg/L, and 35.17 mg/L, respectively. During peak hours at 2 p.m., the effluent nitrate concentration increased that achieve an averaged nitrate concentration of 61.67 mg/L, 77.67 mg/L, 55.83 mg/L for effluents at Sampling 2, Sampling 3, and Sampling 4, respectively. Throughout the study, it can be observed from Figure 4.5 that the nitrate concentration for Sampling 2, Sampling 3, and Sampling 4 for the effluent at 2 p.m.

(orange colour) was increased than the nitrate concentration at 10 a.m. (blue colour) due to the tourists will arrived at the jetty complex at 2 p.m. from the Banding Island. Thus, mostly of the tourist will use the toilet or eat at the jetty complex restaurant for their lunch. Based on the effluent nitrate concentration graph, the nitrate concentration increased at 2 p.m. for Sampling 2, Sampling 3, and Sampling 4 because clarifier is noticed to appear some floating biomass in it. The floating biomass was resulted from the malfunctioning pump that is not able to recycle back the biomass into the aeration tank. In the aeration tank, the nitrate in the biomass which is not being recirculated will remain in the floating sludge. Hence, this cause the nitrate is not being remove from the system. In conclusion, the effluent nitrate concentrations from all sampling still does not meet the Standard B of nitrate discharge limit of 7 mg/L according to National Lake Water Quality Criteria and Standard.

Table 6 shows the averaged effluent nitrate concentration values throughout the study period. Throughout the study, effluent nitrate concentration varies between 35.17 mg/L to 77.67 mg/L. Hence, this correlates to the nitrate obtained where there is higher in nitrate concentration in the effluent especially during peak hour (2 p.m.).

TABLE 6: Averaged Effluent Nitrate Concentration vs Sampling

Number of Sampling	Average Effluent of Nitrate (mg/L)	
	Effluent 10 a.m.	Effluent 2 p.m.
Sampling 1	-	-
Sampling 2	53.33	61.67
Sampling 3	66.67	77.67
Sampling 4	35.17	55.83

4.2.3 Influent of Houseboat for Nitrate Results throughout the Study

Influent nitrate from all four-sampling taken from four houseboats was measured throughout the study and plotted in Figure 4.6 shows the nitrate concentration against sampling. The variations in nitrate influent can be explained by the method of sampling taken at different capacity of people occupied at each houseboat.

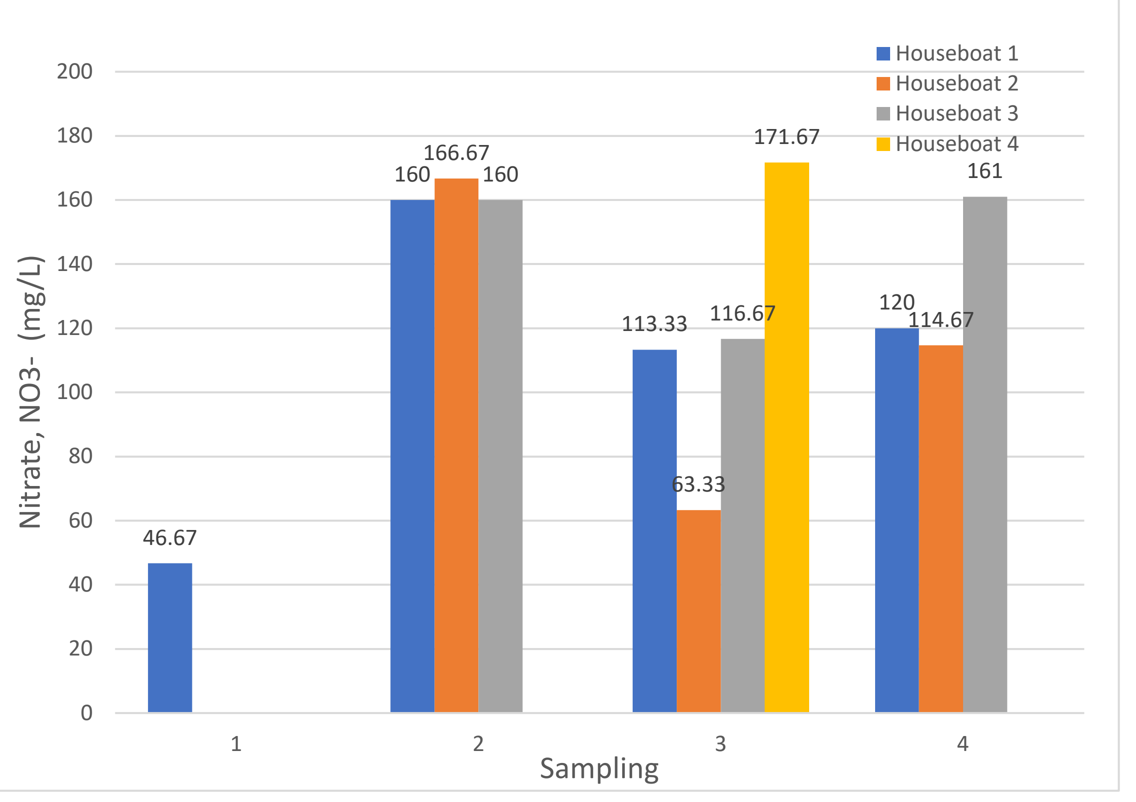

FIGURE 4.6: Influent Nitrate Concentration vs Sampling

Based on Figure 4.6, the influent nitrate concentration for Sampling 1 was averaged about 46.67 mg/L for Houseboat 1 (HB1) while for Houseboat 2 (HB2), Houseboat 3 (HB3) and Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats. As shown in Figure 4.6, the influent for HB1 during Sampling 1 has the lowest concentration of nitrate since the wastewater has been diluted. This is happened because the wastewater solids were released from the houseboat tank to the lake along the journey before arriving to the jetty complex. Thus, the solid wastewater was cleared from the septic tank and the wastewater collection taken was the diluted wastewater. For Sampling 2, the influent nitrate concentration for HB1, HB2, and HB3 was averaged of 160 mg/L, 166.67 mg/L, and 160 mg/L respectively while HB4 has not been taken due to the houseboat did not make any trip for this month. As illustrated in Figure 4.6, all houseboat during Sampling 2 was contain higher nitrate concentration because the houseboat has the highest capacity of people during the trip than other houseboats. For Sampling 3, the influent nitrate concentration for HB1, HB2, HB3 and HB4 was averaged of 113.33 mg/L, 63.33 mg/L, 116.67 mg/L and 171.67 mg/L respectively. The highest nitrate concentration was 171.67 mg/L for

HB4 since the capacity of houseboat can occupied 42 people and 5 workers during the trip. For Sampling 4, the influent nitrate concentration for HB1, HB2, and HB3 was averaged of 120 mg/L, 114.67 mg/L, and 161 mg/L respectively while for Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats.

Table 7 shows the averaged nitrate concentration values throughout the study period. Throughout the study, influent nitrate concentration varies between 46.67 mg/L to 171.67 mg/L. Hence, this correlates to the nitrate obtained where there is higher in nitrate concentration in the influent varied with the capacity of the houseboat.

TABLE 7: Averaged influent Nitrate Concentration vs Sampling

Number of Sampling	Average Influent of Nitrate (mg/L)			
	Houseboat 1	Houseboat 2	Houseboat 3	Houseboat 4
Sampling 1	46.67	-	-	-
Sampling 2	160	166.67	160	-
Sampling 3	113.33	63.33	116.67	171.67
Sampling 4	120	114.67	161	-

4.3 Results for Phosphorus Concentration throughout the Study

Experiment for phosphorus was conducted for four sampling as mentioned in methods were collected and experiments are conducted for every month. The first sampling date of the experiment was carried out on 24^{th} July 2022 and for the Sampling 2, Sampling 3, and Sampling 4 was on 28^{th} August 2022, 19^{th} September 2022, 30^{th} October 2022 respectively. The concentration of phosphorus was monitored for the influent of houseboats and SSTS including the effluent of SSTS for two different time. Influent and effluent of SSTS for phosphorus were measured throughout the study at 10 a.m. and 2 p.m. which is during peak hours for both influent and effluent.

4.3.1 Influent of SSTS for Phosphorus Results throughout the Study

Influent phosphorus throughout the study was plotted as in Figure 4.7 below shows the phosphorus concentration against sampling. The variations in phosphorus influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m.

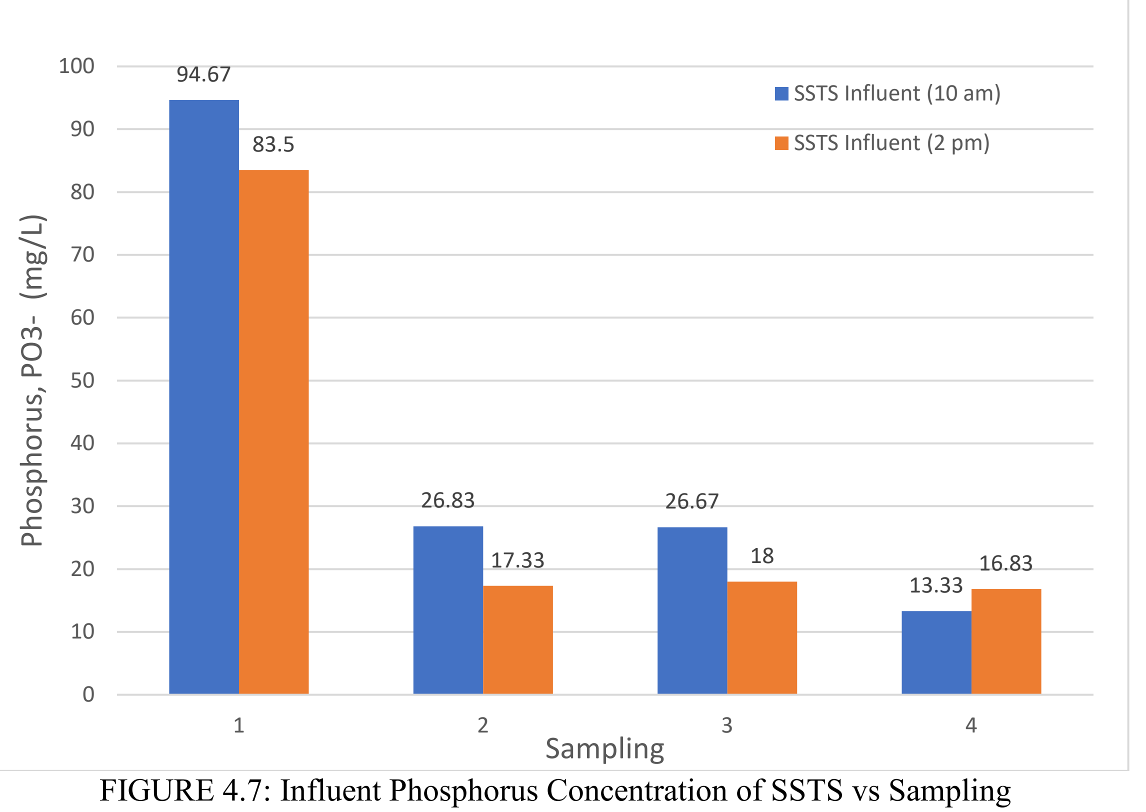

FIGURE 4.7: Influent Phosphorus Concentration of SSTS vs Sampling

Based on Figure 4.7, it can be observed that during Sampling 1, when the SSTS influent was diluted at 1:50, influent of phosphorus at 10 a.m. and 2 p.m. was averaged about 94.67 mg/L and 83.5 mg/L respectively. The concentration of phosphorus in the influent (blue) is quite high on the first sampling because the SSTS is not functioning. For Sampling 2, the influent of phosphorus for 10 a.m. and 2 p.m. was averaged about 26.83 mg/L and 17.33 mg/L which can be conclude that day not many people use the facilities at jetty complex during peak hour. The influent phosphorus concentration for Sampling 3 was averaged 26.67 mg/L at 10 a.m. while decreasing to 18 mg/L at 2 p.m. The concentration of the influent collected has been decreasing at 2 p.m. for Sampling 1, Sampling 2, and Sampling 3 due to the tourist going to toilet to wash their hand or take a shower after the trip that make a lot of water channel to the SSTS and make the wastewater inside the SSTS diluted. Then, the influent phosphorus for Sampling 4 was averaged 13.33 mg/L at 10 a.m. and it can be observed that influent increased to an averaged value of 16.83 mg/L for influent of phosphorus during peak hours which is at 2 p.m.

Table 8 shows the averaged phosphorus concentration values throughout the study period. Throughout the study, influent phosphorus concentration varies between 16.83 mg/L to 94.67 mg/L. Hence, this correlates to the phosphorus obtained where there is higher in phosphorus concentration in the influent especially during peak hour (2 p.m.).

TABLE 8: Averaged Influent Phosphorus Concentration vs Sampling

Number of Sampling	Average Influent of Phosphorus (mg/L)	
	Influent 10 a.m.	Influent 2 p.m.
Sampling 1	94.67	83.5
Sampling 2	26.83	17.33
Sampling 3	26.67	18
Sampling 4	13.33	16.83

4.3.2 Effluent of SSTS for Phosphorus Results throughout the Study

Effluent Phosphorus from all four-sampling taken for each different time was measured throughout the study and plotted in Figure 4.8 shows the phosphorus concentration against sampling. The variations in phosphorus influent can be explained by the method of sampling taken at different time which at 10 a.m. and 2 p.m. from Sampling 1 until Sampling 4.

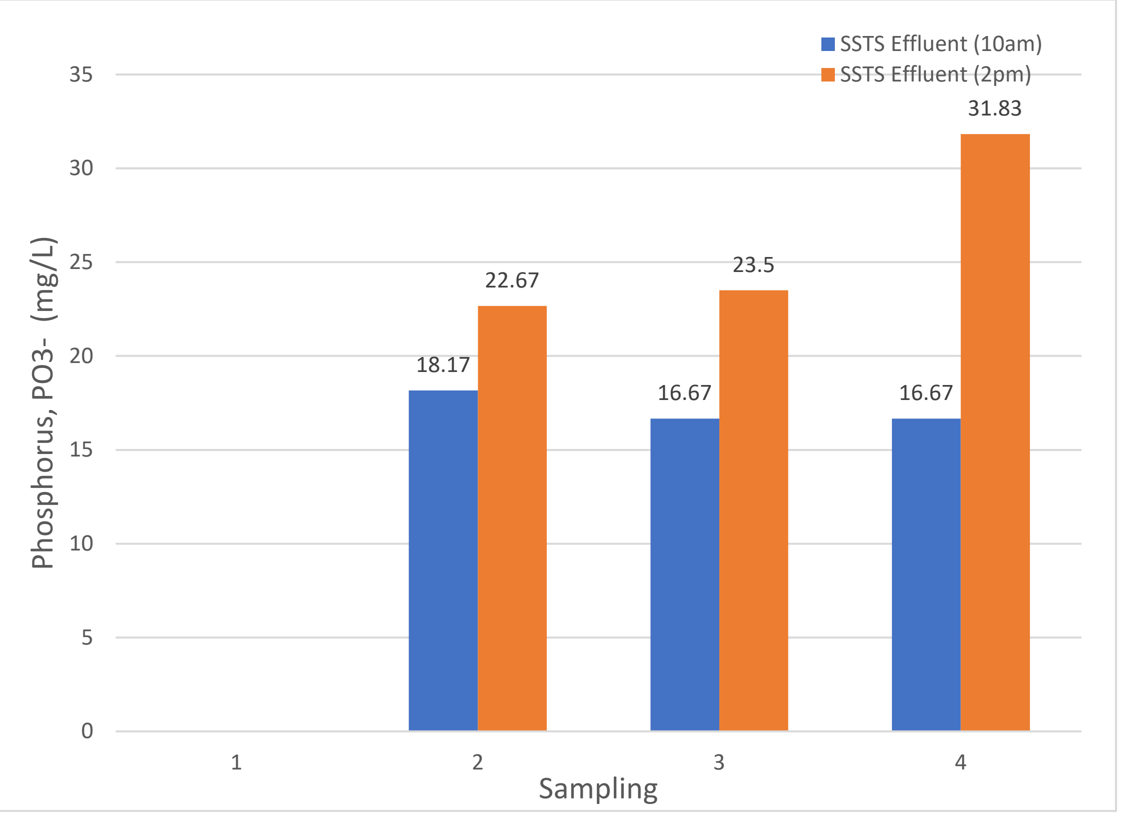

FIGURE 4.8: Effluent Phosphorus Concentration of SSTS vs Sampling

During Sampling 1 as shown in Figure 4.8, effluent phosphorus concentration at both different time values cannot be measured since there is no effluent discharge at the drain outlet from the SSTS to the lake. This is because the SSTS is not functioning or operate to treat the wastewater collected in the SSTS in removing phosphorus. However, during collection of effluent for Sampling 2, Sampling 3, and Sampling 4, the effluent has been taken at the drain outlet. The effluent phosphorus concentrations at Sampling 2, Sampling 3, and Sampling 4 for 10 a.m. (blue colour) were found to average at 18.17 mg/L, 16.67 mg/L, and 16.67 mg/L, respectively. During peak hours at 2 p.m., the effluent phosphorus concentration increased that achieve an averaged phosphorus concentration of 22.67 mg/L, 23.5 mg/L, 31.83 mg/L for effluents at Sampling 2, Sampling 3, and Sampling 4, respectively. According to Ruiz et. al. (2014), the lower the phosphate removal rate, the higher the internal biomass P content. Throughout the study, it can be observed from Figure 4.8 that the phosphorus concentration for Sampling 2, Sampling 3, and Sampling 4 for the effluent at 2 p.m. (orange colour) was increased than the phosphorus concentration at 10 a.m. (blue colour) due to the tourists arrived at the jetty complex at 2 p.m. from the Banding Island. Thus, mostly of the tourist will use the toilet or eat at the jetty complex restaurant for their lunch. Based on the effluent phosphorus concentration graph, the phosphorus concentration increased at 2 p.m. for Sampling 2, Sampling 3, and Sampling 4 because the degradation of organic matter heavily influences the removal of nitrogen and phosphorous in the wastewater treatment process (Xiaoling et. al. 2017). Hence, this cause the phosphorus is not being remove from the system. In conclusion, the effluent phosphorus concentrations from all sampling still does not meet the Standard B of discharge limit of 0.035 mg/L respectively according to National Lake Water Quality Criteria and Standard.

Table 9 shows the averaged effluent phosphorus concentration values throughout the study period. Throughout the study, effluent phosphorus concentration varies between 16.67 mg/L to 31.83 mg/L. Hence, this correlates to the phosphorus obtained where there is higher in phosphorus concentration in the effluent especially during peak hour (2 p.m.).

TABLE 9: Averaged Effluent Phosphorus Concentration vs Sampling

Number of Sampling	Average Effluent of Phosphorus (mg/L)	
	Effluent 10 a.m.	Effluent 2 p.m.
Sampling 1	-	-
Sampling 2	18.17	22.67
Sampling 3	16.67	23.5
Sampling 4	16.67	31.83

4.3.3 Influent of Houseboat for Phosphorus Results throughout the Study

Influent phosphorus from all four-sampling taken from four houseboats was measured throughout the study and plotted in Figure 4.9 shows the phosphorus concentration against sampling. The variations in phosphorus influent can be explained by the method of sampling taken at different capacity of people occupied at each houseboat.

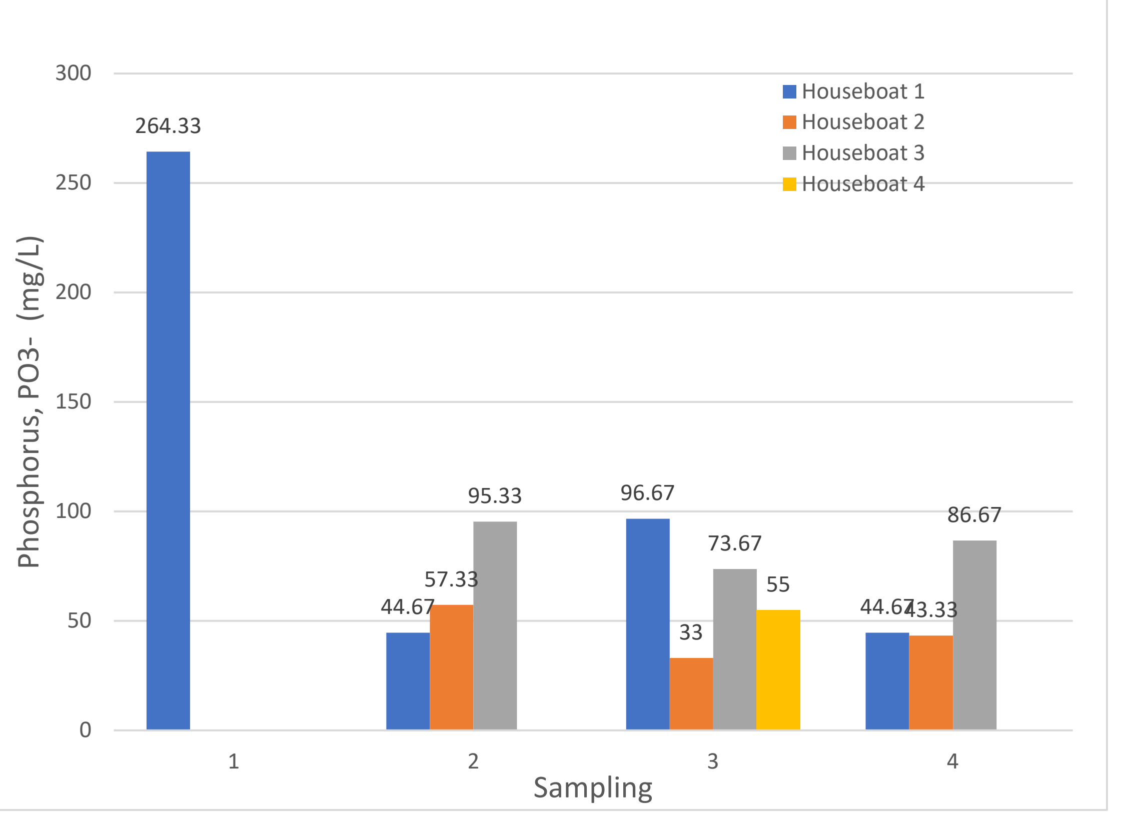

FIGURE 4.9: Influent Phosphorus Concentration of Houseboat vs Sampling

Based on Figure 4.9, the influent phosphorus concentration for Sampling 1 was averaged about 264.33 mg/L for Houseboat 1 (HB1) while for Houseboat 2 (HB2), Houseboat 3 (HB3) and Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats. As shown in Figure 4.9, the influent for HB1 during Sampling 1 has the highest concentration of phosphorus since the wastewater consist of solid sludge from wastewater collected. This is happened because the wastewater solids were not released from the houseboat tank to the lake along the journey before arriving to the jetty complex. Thus, the solid wastewater was accumulated in the septic tank and the wastewater collection taken was the high concentration of wastewater. For Sampling 2, the influent phosphorus concentration for HB1, HB2, and HB3 was averaged of 44.67 mg/L, 57.33 mg/L, and 95.33 mg/L respectively while HB4 has not been taken due to the houseboat did not make any trip for this month. For Sampling 3, the influent phosphorus concentration for HB1, HB2, HB3 and HB4 was averaged of 96.67 mg/L, 33 mg/L, 73.67 mg/L and 55 mg/L respectively. As illustrated in Figure 15, HB1 during Sampling 3 was contain higher phosphorus concentration because the houseboat has the highest capacity of people during the trip than other houseboats. The highest phosphorus concentration was 96.67 mg/L for HB1 since the capacity of houseboat can occupied 35 people and 5 workers during the trip. For Sampling 4, the influent phosphorus concentration for HB1, HB2, and HB3 was averaged of 44.67 mg/L, 43.33 mg/L, and 86.67 mg/L respectively while for Houseboat 4 (HB4) cannot be measured since there is no wastewater was taken from these houseboats.

Table 10 shows the averaged phosphorus concentration values throughout the study period. Throughout the study, influent phosphorus concentration varies between 33 mg/L to 264.33 mg/L. Hence, this correlates to the phosphorus obtained where there is higher in phosphorus concentration in the influent varied with the capacity of the houseboat.

TABLE 10: Averaged influent phosphorus Concentration vs Sampling

Number of Sampling	Average Influent of Phosphorus (mg/L)			
	Houseboat 1	Houseboat 2	Houseboat 3	Houseboat 4
Sampling 1	264.33	-	-	-
Sampling 2	44.67	57.33	95.33	-
Sampling 3	96.67	33	73.67	55
Sampling 4	44.67	43.33	86.67	-

4.4 Propose Design of Anoxic Tank in SSTS

According to the findings of this study, the SSTS did not perform any treatment on the wastewater collected from the jetty. Monitoring the characteristics of ammonia, nitrate, and phosphorus using experimental methods has revealed that the wastewater is only collected for storage and pumped out by the Indah Water Consortium Company after the storage tank has been filled with wastewater. On the other hand, suggestions for an appropriate treatment to handle the collected wastewater from the jetty and houseboat have been made. It is measured in litres per day, depending on the consumption of the jetty and houseboat. The capacity of the anoxic tank has been calculated to be 110 m^3 using the formula in Appendix 1. The i-STS sketch has been detailed in rectangular shapes rather than circles, as shown in Figure 4.10.

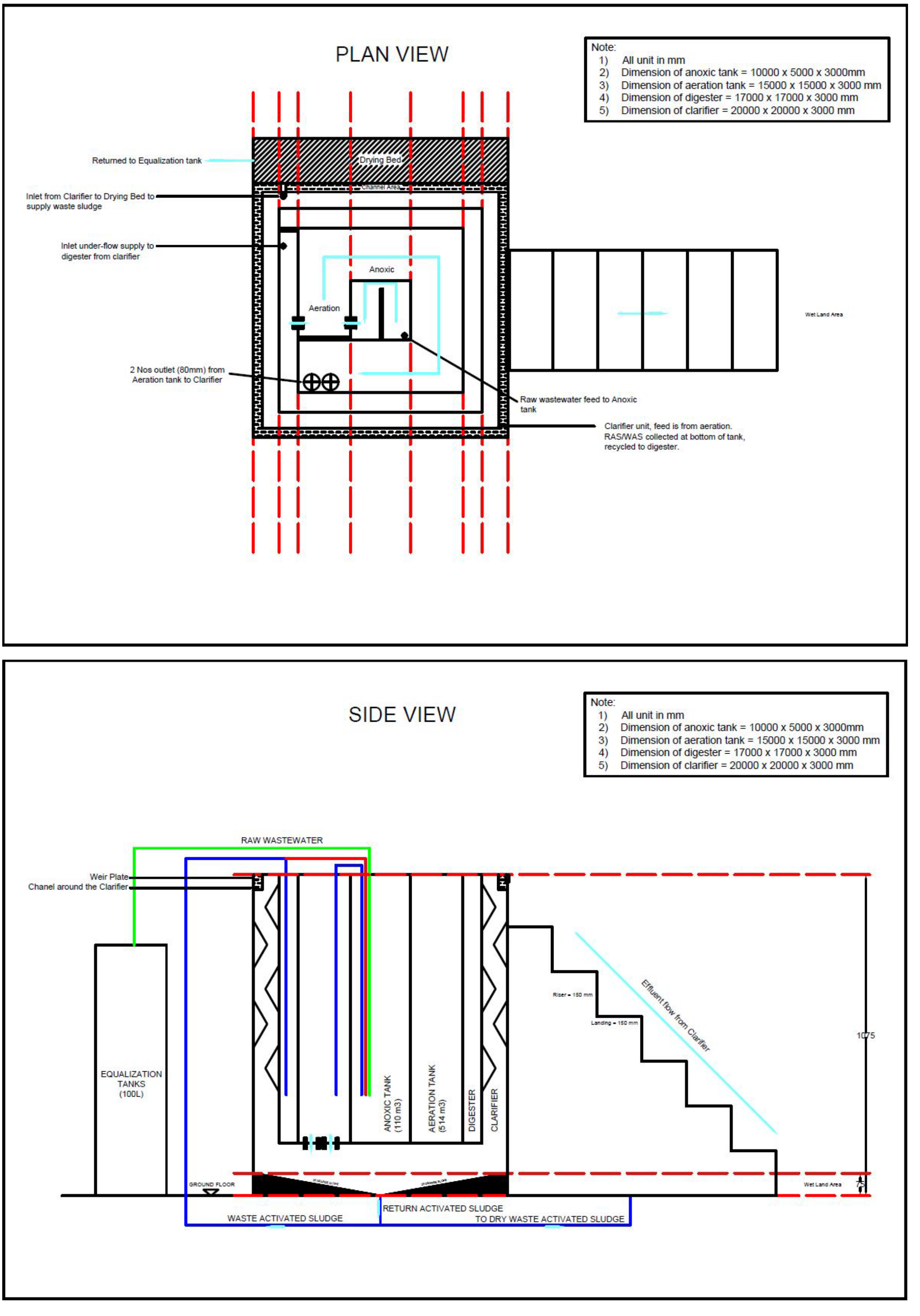

FIGURE 4.10: Sketch of plan view and side view for Anoxic tank i-STS.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

The quality of the water in Temenggor Lake was analysed for six months, from July 2022 to December 2022. Nutrient pollution has been a problem for many streams, rivers, lakes, bays, and coastal waters for several decades. This has caused serious problems for the environment, human health, and the economy. If there is too much nitrogen and phosphorus in the water, algae grow faster than ecosystems can handle. To meet the strict standards for nutrient discharge, it is important to remove nutrients from wastewater.

The parameters for removing nutrients such as ammonia, nitrate, and phosphorus from water were figured out. The results were compared with the National Lake Water Quality Criteria and Standard to determine how well the SSTS worked with the extra load of houseboat wastewater. For the first sample taken in July 2022, the results showed that none of the parameters met the standards set by the National Lake Water Quality Criteria and Standard. Results showed that removal of nutrient into lake were higher than maximum allowed by Malaysian and international standards in protecting aquatic life. Based on the result obtained, it can be observed that the additional loading of houseboat wastewater into the SSTS can decreased the performance of SSTS in removing nutrients.

In conclusion, an appropriate treatment system for the houseboat's wastewater discharge will be proposed for the enhancement of the lake and the surrounding environment. Houseboats that are not equipped with septic tanks will be evaluated for potential installation suitable septic tanks. From the results obtained, a sewage treatment system using integrated suspended growth bioreactor to treat wastewater from the houseboats will be proposed and designed. Considering the future development of Temenggor Lake as an ecotourism destination, the lake's water quality must be preserved, and an integrated lake management system model based on the concept of integrated water resource management must be adopted.

8.2 Recommendation

1. Future studies should look at the biological mechanism of nutrient removal under varying retention periods, organic loading rates, and sludge retention time to determine the suitable SSTS in treating the industrial wastewater in removing nutrient.

2. Other types of biological treatment systems can be investigated such as anaerobic-aerobic combined system and anoxic environment of the denitrification reactor to remove nutrient in treating the industrial wastewater.

3. Conduct research to add more information regarding removing nutrients for wastewater such as using different types of bacteria or method to treat wastewater effectively, upgrading on-site removal systems, and other chemicals can be done.

REFERENCES

1. Journal

Abbas, G., Zheng, P., Wang, L., Li, W., Shahzad, K., Zhang, H., ... & Zhang, M. (2014). *Ammonia Nitrogen Removal by Single-stage Process: A Review. Journal of the Chemical Society of Pakistan,* 36(4).

Ainon, H., Ratuah, M., Mimi, N. M., & Affendi, M. T. (2006). *Water quality of Chini Lake from the bacteria aspect.* Paper presented at the Chini Lake Expedition 2004, UKM, Bangi, Malaysia.

Ashraf, M. A., Maah, M. J., & Yusoff, I. (2010). *Water quality characterization of varsity lake, University of Malaya, Kuala Lumpur, Malaysia*. E-Journal of Chemistry, 7(S1), S245-S254.

Barzani Gasim, M., Sahibin Abd. R., Shuhiami Othman, M., & Ang, L. K. (2005, April). *Degradation of holistic value of the Chini Lake watershed due to erosional process.* Paper presented at the Second Regional Symposium on Environment and Natural Resources, Kuala Lumpur, Malaysia.

Bhateria, R., & Jain, D. (2016). *Water quality assessment of lake water: a review.* Sustainable Water Resources Management, 2(2), 161-173.

Burger, D. F., Hamilton, D. P., Hall, J. A., Ryan, E. F. 2007. *Phytoplankton nutrient limitation in a polymictic eutrophic lake: community versus species–specific responses.* Fundamental and Applied Limnology 169: 57–68.

Byrossman, W. (2022, April 2). *Tertiary sewage treatment is designed to remove*. clarkashtonsmithpaintings.

Camilleri, M. A. (2018). Chapter 1 The Planning and development of the tourism product. *Tourism Planning and Destination Marketing*, 1–23.

Chokhavatia Associates. *Tertiary wastewater treatment*. (2021, September 20).

Eggen, R. I., Hollender, J., Joss, A., Schärer, M., & Stamm, C. (2014). *Reducing the discharge of micropollutants in the aquatic environment: the benefits of upgrading wastewater treatment plants*.

Ergas, S. J., & Aponte-Morales, V. (2013, October 21). *Biological nitrogen removal*. Comprehensive Water Quality and Purification.

Gupta, R., Narayan, K. S., Sharma, S., & Sunny, R. (2019). Wudstay and the houseboat sector in India. *Asian Case Research Journal*, *23*(01), 91–117.

Jagaba, A. H., Kutty, S. R. M., Noor, A., Birniwa, A. H., Affam, A. C., Lawal, I. M., Kankia, M. U., & Kilaco, A. U. (2021, June 19). *A systematic literature review of biocarriers: Central elements for biofilm formation, organic and nutrients removal in sequencing batch biofilm reactor*. Journal of Water Process Engineering.

Jeevan, S. (2006). Composite houseboat helps tourists explore India. *Reinforced Plastics*, *50*(4), 46–48.

J.Ruiz, Z. Arbib, P.D.A. Díaza, C.G. Pérez, J. Barragán, J.A. Peralesa (2014), "*Influence of Light Presence and Biomass Concentration on Nutrient Kinetic Removal from Urban Wastewater by Scenedesmus Obliquus",* Journal of Biotechnology, 178, 32-37

Khalik, W. M. A. W. A., & Abdullah, M. P. (2012). *Seasonal influence on water quality status of Temenggor Lake, Perak. Malaysian Journal Analytical Sciences,* 16, 163-171.

Krzanowski, S., & Walega, A. (2007). New technologies of small domestic sewage volume treatment applied in Poland. *Infrastruktura i Ekologia Terenów Wiejskich*, (3).

Mahon, J. M., Knappe, J., & Gill, L. W. (2022). Sludge accumulation rates in septic tanks used as part of the on-site treatment of domestic wastewater in a northern maritime temperate climate. *Journal of Environmental Management*, *304*, 114199.

Maurer, M., Pronk, W., & Larsen, T. A. (2006, September 1). *Treatment processes for source-separated urine*. Water Research.

Metcalf & Eddy Inc., Tchobanoglous, G., Burton, F. L., Tsuchihashi, R., & Stensel, H. D. (2014), "Wastewater engineering: Treatment and resource recovery (5th ed.)". *McGraw-Hill Professional,* pp 1-2018

Schaefer K. (2013) *Science-Policy Linkages in Ecotoxicology.* In: Férard JF., Blaise C. (eds) Encyclopedia of Aquatic Ecotoxicology. Springer, Dordrecht.

Shuhaimi-Othman, M., Lim, E. C., & Mushrifah, I. (2007). Water quality changes in Chini lake, Pahang, west Malaysia. *Environmental monitoring and assessment*, *131*(1), 279-292.

Spellman, F. R. (2017). *The drinking water handbook*. CRC Press.

SRM Kutty, K. (2018). Degradation of ammonia in an integrated anoxic aerobic clarifier system. *Degradation of ammonia in an integrated anoxic-aerobic clarifier system*, *9*, 1060-1070.

White, E., Don, B. J., Downes, M. T., Kemp, L. J., Mackenzie, A. L., Payne, G. W. 1978. Sediments of Lake Rotorua as sources and sinks for plant nutrients. *New Zealand Journal of Marine and Freshwater Research* 12: 121–130.

APPENDICES


WIDE
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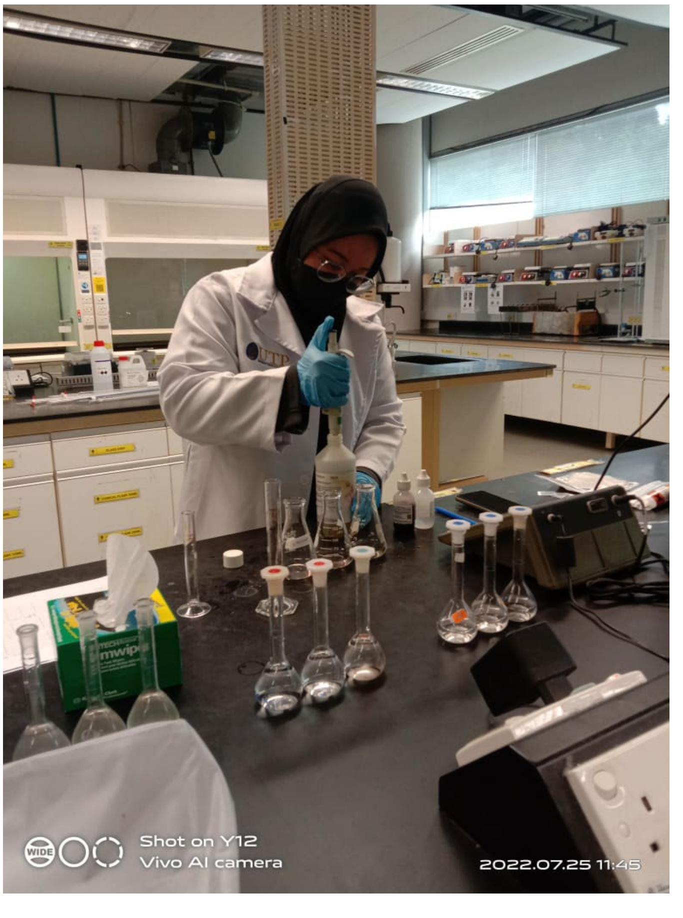
WIDE
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APPENDIX 1

PREANOXIC DENITRIFICATION PROCESS DESIGN

Categories	Source	Unit	Flowrate, L/unit.d
Jetty	Office	employee	38
	Public Lavatory	User	12
	Restaurant Conventional	Customer	24
Houseboat	Boarding House	Person	225
	Public Lavatory	User	12

Categories	Source	Unit	Flowrate, L/unit.d	Quantity	Total Flowrate	Unit
Jetty	Office	employee	38	10	380	
	Public Lavatory	User	12	50	600	
	Restaurant Conventional	Customer	24	100	2400	
Houseboat	Boarding House	Person	225	880	198000	
	Public Lavatory	User	12	880	10560	
Total =					211940	L/unit.d
					211.94	m^3/d

Wastewater Characteristics	Concentration mg/L	Remarks
BOD	400	
bCOD	640	From another researcher
rbCOD	80	Assume
NOx	21.9	From another researcher
TP	6	Assume
Alkalinity	140	As $CaCO^3$

Note: g/m^3 = mg/L

Design for Denitrification

Capacity: Flow Rate, Q **212000.00** L/day

S No	Description of Parameter	Value	Unit	Reference
	Quantity of Sewage Generated	**212000.00**	**Lpd**	
		212.00	**m^3/d**	
1	**Wastewater Characteristics Data**			
	Average Sewage flow entering the	212000.00	lpd	
	Assume Peak Factor	1.50		
	Peak Sewage flow entering the treatment plant, Q	318	m^3/d	
		318000.00	lpd	
	BOD	400	g/m^3	
	bCOD	640	g/m^3	
	rbCOD	80	g/m^3	Note:
	NOx	21.9	g/m^3	mg/L = g/m^3
	Ne (Assumed NO_3-N concentration in RAS)	4	g/m^3	
	TP	6	g/m^3	
	Alkalinity	140	as $CaCO_3$	
	Residual Alkalinity	80.00	as $CaCO_4$	
2	**Design conditions:**			
	Paramenter			**Assumptions:**
	Influent flowrate	318	m^3/day	1. Nitrate concentration in RAS = 6 g/m^3
	Temperature	28	^oC	2. Use the same coefficients as the nitrification process design
	MLSS	5000	g/m^3	3. Mixing energy for anoxic reactor = 10 $kW/10^3\ m^3$.
	MLVSS	3171	g/m^3	
	Aerobic SRT	30.00	d	
	Aeration basin volume	513.12	m^3	
	Mixing energy	10	$kW/10^3\ m^3$	
	RAS ratio	0.60	Unitless	
	R_o	11.1641	kg/h	
3	**Determine the active biomass concentration**			
	Note: Subtitude V/Q for τ			(Eq 7-43), substitute for v/Q

	Q (SRT) Y (So - S)			
	Xb = [-----------] [-----------------]	Equation 11		
	V 1 + (kd) SRT			
	where So - S can be assume as So			
	Y =	0.4	VSS/g bCOD	
	So =	640	g bCOD/m^3	
	S =	0.39	g bCOD/m^3	
	k_d =	0.16	g/g.d	
	X_b =	803.05	g/m^3	
4	**Determine the amount of nitrate produced in Digester**			
	Overall equation with complete nitrification			pg. 1534 Aerobic digestion
	$C_5H_7NO_2 + 7O_2$ -----> $5CO_2 + 3H_2O$ + HNO_3			
	HNO_3 -----> $H^+ + NO_3^-$			
	113mg of biomass produces 62 mg nitrate			
	Daily RAS flow to digester is 10000 Liter	**10000**	**lpd**	
	Therefore, 113mg/L biomass produces 62 mg/L nitrate			
	1 mg/L biomass produces 0.5486 mg/L nitrate in digester		**lpd**	
	Flow to the digester =	**10**	**m^3/d**	
	Assume 10,000 mg/L MLSS in RAS	**10000**	g/m^3	
	MLVSS concencentration = 10000 * 0.85 mg/L	8500	g/m^3	
	Nitrate produced in the digester = (X_{VSS} mg/L) * (62 mg / 113 mg)) =	4,663.72	g/m^3	*62m is atomic weight of Nitrate (16*3 * 14) = 62 mg
				*113 mg is atomic weight of biomass
	Mass of Nitrate in Aeration tank from Digester	9.09	mg	
	Concentration of nitrate from Digester into Aeration tank , Digester flow = 10000 lpd	0.0009	mg/L	

5	**Determine the IR ratio due to Aerobic tank + Digester**			
				(Eq 8-48).
	Aerobic tank NO_3-N effluent concentration = Ne =	4.00	g/m^3	
	NO_X			
	IR = --------- - 1.0 - R	Equation 12		
	Ne			
	= (C18 + C70 g/m^3) / (4 g/m^3) -1.0 - C32	**4**	**unitless**	
6	**Determine the amount of NO_3-N fed to the anoxic tank from Aeration tank**			
	Flow rate to anoxic tank = IR Q + R Q=	**1422.47**	**m^3/d**	
		1422470.57	**lpd**	
	NO_X feed = (1.42 m^3/d) (4.0 g/m^3) =	**5689.88**	**g/d**	
7	**Determine the anoxic volume due to Aerobic + Digester**			
	As a first approximation, use a detention time = 8 h	**8.0**	h	
	Vnox = τ * Q	Equation 13		
	Detention time = 8 h / (24 h/d) =	**0.33**	day	
	Vnox =	**109.33**	m^3	
		109333.33	liters	
8	**Determine Food to microorganisms ratio (F/M_b)**			
				Using Equation (8-43)
	F QSo			
	----------- = ------------	Equation 14		Terms previously
	M_b Vnox (X_b)			
	Hence F/M_b =	**1.45**	g/g.d	
9	**Determine the SNDR using the curve with an F/M_b range of 0 to 4**			
				Figure 8-23, page 755
	Fraction rbCOD = rbCOD/bCOD = (80 g/m^3) / (640 g/m^3)	**0.13**	%	

	From Figure 8-23, $SDNR_b$ = 0.35 g/g.d at 28°C	0.35	g/g.d	
	$SNDR_{28} = 0.35\ (1.026)^{28-20}$ =	**0.43**	g/g.d	
10	**Determine the amount of NO_3-N that can be reduced**			
				Equation (8-41)
	a. Check NOr based on detention time = 8 h	**8.00**	h	
	NOr = (Vnox) (SDNR) (MLVSS, biomass)	**37734.82**	g/d	
	Comparing NOr = 3.77 and NOx = 5.69 g/d			
	If it exceeds then the lower detention time may be used and vice versa			
11	**Determine the Oxygen saving and net oxygen for Nitrif.**			
	R_o (without denitrification) =	**11.1641**	**kg/h**	
	Oxygen credit =	16.2722	kg/d	
		0.678009862	kg/h	
	Net Oxygen required =	10.4861	kg/h	
				6.07
	Note the required aeration rate will decrease to a lower Ro. The oxygen required can be			
12	**Check alkalinity**			
	(a) Prepare an alkalinity balance			
	Alkalinity to maintain pH - 7 = Influent Alk - Alk used + Alk to be added			
	i. Influent alkalinity	140.00	g/m^3	
	ii. Alkalinity used	156.31	g/m^3	
	iii. Alkalinity produced	63.87	g/m^3	
	iv. Alkalinity needed to maintain neutral pH	80.00	g/m^3	as $CaCO_3$
	(b) Solve the above equation for alkalinity			
	Alk to be added = (iv - i+ ii- iii) above =	**32.43**	g/m^3	as CaCO3
	Mass of alkalinity needed =	10.3139	kg/d	
		10313.9279	g/d	

	(c) Compare to alkalinity needed for nitrification			
	For the nitrification only design, the	**36.0936**	kg/d	
	Alkalinity savings =	**25.7797**	kg/d	71.4
13	**Determine anoxic zone mixing energy**			
	Mixing energy = 10 kW/10^3 m^3 (given)	0.0100		
	Anoxic volume due to Aeration =	***109.3333***	***m^3***	***10 x 5 x 3***
	Power = (Anoxic volume,m^3) * (10 kW/10^3 m^3) =	1.093333	kW	= 150 m3
		1093.3333	*W*	
	Use 0.5 W submersible pump with speed rpm (speed) controller	0.5000	*W*	