Nutrients Removal of Treated Wastewater of UTP Sewage Treatment Plant by Using Aquatic Macrophytes in Horizontal Baffle Flow Reactor

by

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Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil and Environmental Engineering Programme
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Approved by,

……………………….
(Assoc. Prof. Dr. Shamsul Rahman Kutty)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(ANTHEA TESSA ALVIN)

ABSTRACT

Wastewater originates from numerous activities from domestic, industrial, agricultural, surface run-off and also infiltration system. The discharge of the wastewater from the activities listed above is considered as a serious treats to the ecosystem if it not dealt properly. That is why the discharges or effluent from the wastewater needs to be treated properly before it can be safely release back to the ecosystem. Phytoremediation is a type of bioremediation process where it utilizes green plants as a removal body to biologically clean up the hazardous contaminants in soil and water. This study will assess on the efficiency, suitability of the aquatic macrophyte ie. water lettuce to treat the wastewater effluent. The study resulted in nitrate removal of 20 – 40%, 30 – 95% for removal of ammonia, 45% of phosphorus removal and COD removal is 20 – 50%. Reactor 1 containing Pistia Stratiotes or water lettuce had the most nutrient removal than Reactor 2 and this is confirmed by the water lettuce growth of more than 90% in all compartments of Reactor 1. Water lettuce is able to absorb the nutrients from the system and use it for its growth.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND OF STUDY

Wastewater originates from numerous activities from domestic, industrial, agricultural, surface run-off and also infiltration system. The discharge of the wastewater from the activities listed above is considered as a serious treats to the ecosystem if it not dealt properly (Valipour et al., 2015). That is why the discharges or effluent from the wastewater needs to be treated properly before it can be safely release back to the ecosystem (Mulling et al., 2014).

The Universiti Teknologi PETRONAS (UTP) has its own municipal sewage treatment plant that is meant to cater for the treatment of the wastewater for the whole university. As for the standard, it adheres to the Standard ‘A’ of Malaysia’s Environmental Quality Act 1974 limits. It is found that the effluent from the wastewater treatment plant contains the hazardous contaminant in the form of inorganic fertilizer-related chemical. The inorganic fertilizer-related chemical has an excessive amount of nutrient such as ammonia, nitrate and phosphorus. It has been outlined by the National Oceanic and Atmospheric Administration (NOAA) that an excessive amount of these chemicals can lead to a build up of nutrients and encourage the overgrowth of algae.

Phytoremediation is a type of bioremediation process where it utilizes green plants as a removal body to biologically clean up the hazardous contaminants in soil and water (Pandey et al., 2015). The phytoremediation itself has a unique advantage in which utilized capability of the plant root system that combines the process of translocation, bioaccumulation and contaminant storage and also degradation abilities to help cleaning up the hazardous nutrients. It is considered as a cheaper alternative in comparison to the excavation and disposal of contaminated site where it involve a very extensive and tedious process. The process is also accepted by the United States Environmental Protection Agency (2012) where it capable of removing heavy metals, nutrients, oil and other contaminant by using plants to absorb the contaminants.

1.2 PROBLEM STATEMENT

Release of organic and inorganic pollutants including Nitrogen and Phosphorus into water bodies causes eutrophication invariable, which may deplete dissolved oxygen content of water bodies posing a serious threat to both aquatic life and human health (Pramanik et. al., 2012). Thus, it also encouraged the overgrowth of algae in the streams. The effect of the release of the hazardous nutrients into the normal stream, irrigation and land without treating the wastewater would eventually contaminate the adjacent soil and groundwater system. Therefore, ample amount of study need to be implemented in the usage of aquatic plants for process of nutrients removal from the wastewater effluent that could contribute to the achievement of zero discharge to the environment.

1.3 OBJECTIVES

The objectives of this study are outlined as below:

i. To identify the effect of aquatic macrophyte (water lettuce or *Pistia stratiotes*) on nutrient uptake.
ii. To assess water lettuce growth based on fresh weight in relation to nutrients removal rate (nitrate, phosphorus, ammonia and C.O.D) in defined time.

1.4 SCOPE OF STUDY

The scope of this study will encompass the testing stages in which will establish the main objectives of the study. The proposed study will be focussing on the usage of a normal aquatic plant ie. the water lettuce which is used as a medium for purifying the wastewater effluent that is enriched with nutrients. Wastewater effluent from the

UTP sewage plant is used in this study and the phytoremediation method is conducted by utilizing a reactor to simulate the actual condition in order to achieve zero discharge from the wastewater effluent.

1.5 RELEVANCY OF STUDY

The study is considered relevant due to the needs of UTP to achieve zero discharge from the wastewater effluent. By implementing the phytoremediation, the contaminants in the wastewater could be removed at a lesser cost and in an easier manner. This is due to the usage of the water lettuce which is considered as natural water plants easily available for usage.

1.6 FEASIBILITY OF STUDY

The methodology of this study is closely associated with the scope of work. Thus, the time frame of the study will also be taken into account to enable it to be feasible and completed within the planed period. The selection of the water lettuce is due to its ability to grow easily in the reactor as well as in the real wastewater environment. With a well design and composed methodology and scope of work, the study will be able to be completed within the acquired time frame.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Annual growth of population in the world has triggered the needs of demand in food, facilities and other amenities. The usage of water resources has increased tremendously, through our daily routine and activity. The natural forces itself also gradually decreases the availability of water resources through the daily environmental cycle without us knowing it. In order to counter the problem, a constant public awareness on the needs of proper management of water has increased in the last decade but the in this era, the way forward is to ensure the balance of ecosystem via an environmentally natural process.

The heavily usage of water resources due to the human activity such as urbanization process, industrial revolution booming, population growth, increased in the standards of living has amicably not just had an effect on the needs of water resources but also adversely contribute to the pollution of water. In addition, the effect of climate change and variations in natural conditions had also affected the water system that eventually creates the hazardous contaminants in the water system. Through the years, efforts has been done by the scientific and engineering community to ensure proper measures is being done to treat the water system before it can be safely returned to the ecosystem.

2.2 CONSTRUCTED WETLANDS

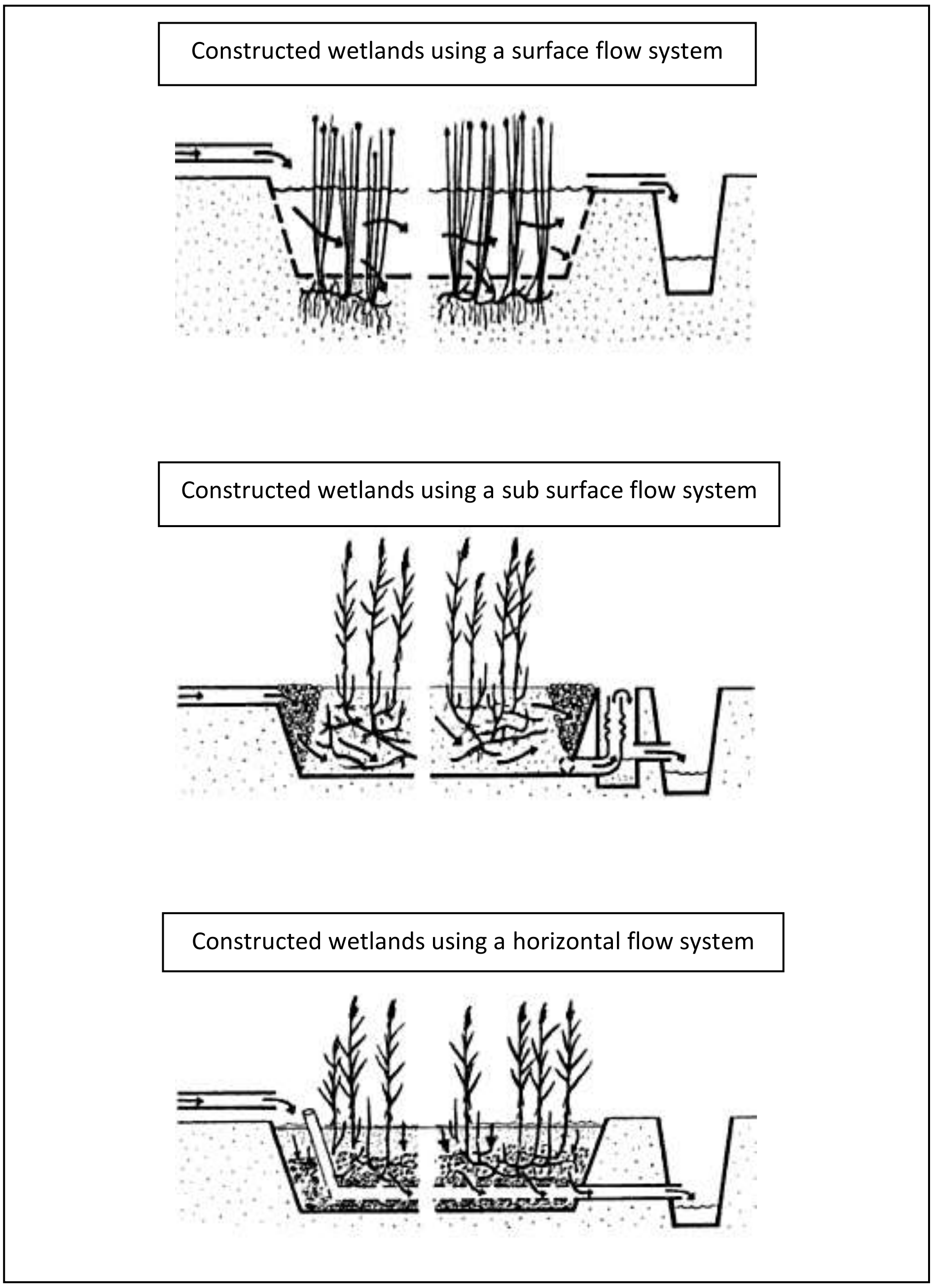
A wetland is an area in which it is by nature covered by water and each wetland has its own niche of flora and fauna. Adversely, the constructed wetland is man-made or an engineered structure that is designed to mimic the natural wetland for wastewater treatment that acts as ecological sanitary system which is able to act as filtration system that filters the contaminants and pollutants from the domestic or industrial sewage and also from the storm water run-off (Farooqi et al., 2008).

It is highlighted among the researchers that the constructed wetland has been highly utilized for wastewater treatment from the municipal and industrial activities (Fields, 2004 and Maine et al. 2007). The constructed wetlands are also preferred due to its cost effectiveness in operational and maintenance wise (Brix, 1987).

The main characteristics of a constructed wetland are its flora distribution where the vascular and non-vascular plants together with the invertebrates and the microorganisms will create a mechanism that could "clean-up" the wastewater. Ii is described by EPA (1993) that a constructed wetland will generate the activities of:

- Creating a suspension in the liquid
- Making usage of the vegetation to filtrates the chemical nutrients from the pollutants
- Enable of chemical transformation of the wastewater
- Enabling the activities such as adsorption and ion exchange on the surfaces of plants, substrate and sediment
- Through the uptake process it creates the breaking down and transformation of the nutrients from the pollutants by the vegetation and plants
- Predation and natural die-off of pathogens.

There are several categories of constructed wetlands. Figure 2.1 shows the three major types of constructed wetlands that reflected on the types of the in-flow system of the effluent as categorized by Brix (1993). However, Vymazal (2001) has combined the aspect of macrophytic or plants and the water flow system into its classification of constructed wetlands (Figure 2.2).



Constructed wetlands using a surface flow system

Constructed wetlands using a sub surface flow system

Constructed wetlands using a horizontal flow system

Figure 2.1 : Schematic diagram of the types of constructed wetlands (Brix, 1993).

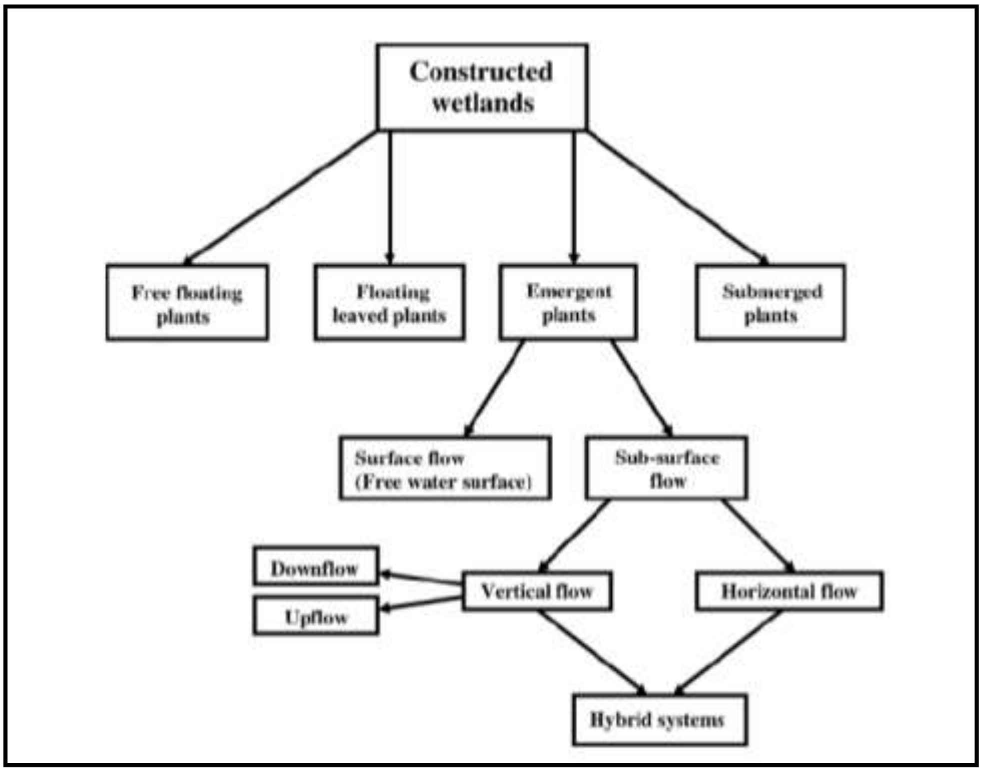


Figure 2.2 : Classification of constructed wetlands (Vymazal, 2001).

2.3 PHYTOREMEDIATION AND WASTEWATER TREATMENT

The term “Phytoremediation” is referring to the type of technologies that use plants for the process remediating soils, sludge, sediments and water contaminated with organic and inorganic contaminants (Pandey et al. 2015). The process enables the activity of removal, detoxification or even immobilise the environmental contaminants in its medium of growth either it is in soil or water via the plants inner activities which include biological, chemical or physical. It is stated that the term itself was created by United States Environmental Protection Agency (USEPA) in 1991 (Raskin, 1996). It is also indicated that such technology of utilizing plants for removal of contaminants was introduced since 1983 but researchers also stated that it has been used for the past 300 years (Rao and Babu, 2014).

Plant has the ability of selectively absorbing nutrients and contaminants from the growth matrix as well as acting as a transportation medium. In the phythoremediation process the plant itself will be placed in the soil or water in which contains the hazardous nutrients. Within the plant itself, it has the genetic adaptation in order handle the accumulated contaminants in the vicinity of the growth area.

Throughout the growth period of the plant, it will either remove the contaminants, facilitate in binding the contaminants or degrading and detoxifying of the pollutants. The method is considered as environmentally safe as eventually after the “treatment” process to the soil or water, the plants can be harvested and disposed. That is why the phytoremediation can be utilized for the cleaning up of the contaminated soil or water from elements such as pesticides, metals, solvents, explosives, crude oil, polyaromatic hydrocarbons, and also landfill leachates.

It is stated by researchers such as Krishna and Polprasert (2015) that these process are becoming popular and accepted worldwide due to the fact that it is cheaper and easily maintained and operated.

There are several ways in which plants are used to clean up, or remediate, contaminated area. That is why the phytoremediation itself has several categories as explained in Table 2.1 (Vamerali et al. 2010 and Favas et al. 2014).

To explain the process of phytoremediation in detail, it involves the “uptake” of contaminants in plants occurs primarily through the root system. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth, as well as other non-essential contaminants (Figure 2.3). According to McCutcheon and Schnoor (2003), rhizofiltration method is widely used in treating nitrate, ammonia and phosphate.

Table 2.1 : Phytoremediation categories.

Categories of Phytoremediation	
Phytoextraction	Plants will uptake the pollutants from growth source and translocate to and store it in the harvestable biomass of the plants. This process is focussing on the removal of pollutants from the contaminated area.
Phytostabilation	Plants will reduce the mobility and phytoavailibility of contaminants in the environment. Pollutants will not be removed but the mobility of contaminants will be restricted. It dexcludes metals nutrients from plant uptake.
Phytovolatilization	The hyperaccumulating plants will uptake pollutants from the growth source and translocate it to the aerial parts of the plants. It will then volatilize the pollutants in the air.
Phytotransformation	The hyperaccumulating plants will modify, inactivate, degrade (phytodegradation), or immobilize (phytostabilization) the pollutants through the plants' metabolisme process.
Phytofiltration	Plants will absorbed the contaminants, ie. heavy metal or radioactive nutrients. The contaminants are absorbed within the plant system whereby the plant is tolerant to the contaminants.
Rhizofiltration	This process usually refers to aquatic plants. The hyperaccumulating aquatic plants adsorb and absorb pollutants from aquatic environments (water and wastewater).

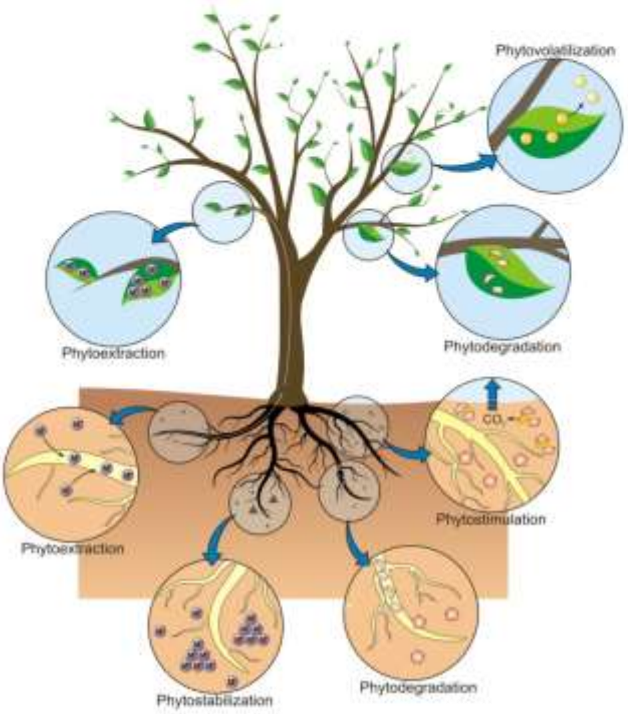


Figure 2.3 : Schematic diagram of phytoremediation process (Favas et al., 2014).

2.4 AQUATIC MACROPHYTES

If we look into explanation regarding the constructed wetlands, the reactor design and the phytoremediation, all of it are inter related with each other. Each component contributes in order to achieve a successful output which is to treat the wastewater effluent and eventually safely return the water into the ecosystem. The role of the macrophytes is very important where without it, the whole process will not be feasible (Stottmeister et al., 2003 and Kadlec & Wallace, 2008).

Vymazal (2002) stated that the macrophytes, have numerous ability of enabling the process of transportation between medium, providing ample area of growth of micro bacteria via the root system, many important functions, controlling the flow of water, controlling its own growth and also stabilising the sediment bed. In addition, Vymazal (2001) also categorized the macrophytes into four groups which are the free floating plants, floating leaved plants, submerged plants and the emergent plants.

There are also researchers that are looking specifically into the aquatic macrophytes for the wastewater treatment, where Pflugmacher et al. (2015) are only focussing on the floating plants and the submerged plants. Apart from it, researchers had narrowed down the area of study only into the usage of free floating plants (Zimmels et al., 2009 and Rahman & Hasegawa, 2011). At a glance, we could also see that through the years, there is a huge intensity of studies that solely focussing on a single species of the aquatic macrophytes which is the water hyacinth (Sooknah & Wilkie, 2004;. Jayaweera et al., 2008; Chunkao et al., 2012 and Valipour et al. 2015). All previous studies had focussed into the usage of the macrophytes toward the efficiency of removal of contaminated nutrients.

2.5 NUTRIENTS IN THE WASTEWATER

As it has been elaborated previously the constructed wetland are used to remove the contaminants from the wastewater. The wastewater initially generated from the municipal waste in which it is then channelled to the constructed wetland where the combined mechanism processes of physical, chemical and biological processes remove the contaminants ecologically from the wastewater.

It is stated by Nichols (1983) that although the wastewater had been transferred to the constructed wetland in order for the clean up process to take placed ecologically, the risk of a situation which is called ‘Eutrophication’. The eutrophication occurs where high amount of nutrients especially of nitrogen and phosphorus are accumulated and considered as the major cause of the process (Lau et al., 1997). This condition induced the growth of algae and thus once the algae died and decomposed, it will also reduce the availability of oxygen thus in effect the death of fish in the area (Art, 1993). Although the process itself is considered as a slow natural process, but the human activities could further speed up the process. The eutrophication process is schematically summarized in Figure 2.4.

The two major nutrients that spark the concern of researchers are the nitrogen and phosphorus (Nichols, 1983; Tam et al., 1992; and Abissi & Mandy, 1999). Both nutrients are accumulated from various activities such as municipal waste, industrial waste, manure from livestock and fertilizer usage. All of these activities contributed to the eutrophication process.

The researchers also focusing the efficiency of the usage of the constructed wetlands combined with the flora used in the system to achieve percentages of efficiency in reducing the amount of nitrogen and phosphorus (Jing et al., 2007). Apart from nitrogen and phosphorus, the other nutrients that would also be the subject of interest among researchers are suspended solids, biological oxygen demand and the chemical oxygen demand (Verhoeven & Meuleman, 1999 and Cheubarn & Peerapornpisal , 2010).

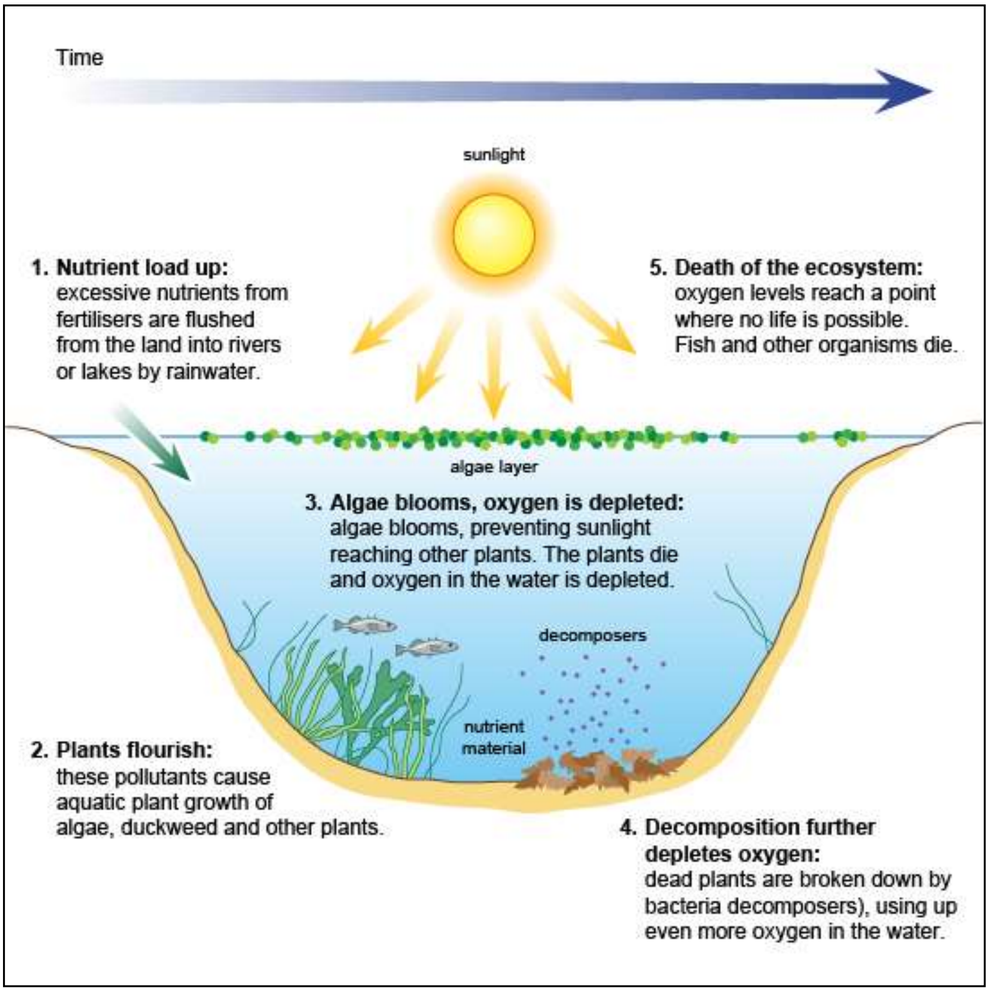


Figure 2.4 : Schematic diagram of eutrophication process (BBC, 2014).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this study, the steps taken in the whole research process is summarized in Figure 3.1. Firstly, the study started with the identification of problem. The study is a wastewater engineering related topic and it is narrowed down to the aspects of treatment process the effluent of the wastewater.

Next will be the literature review where an intensive literature review was conducted in order to obtain the overall view of the topic and thus identifying the research gap. Eventually the specific area of study is identified. The mainly relates into the engineering process of wastewater effluent in order for it to be safely discharged safely into the ecosystem. Reference has also been conducted on the primary and secondary resources as it has been summarized in the Literature Review.

The laboratory work is the main part of this study. Firstly the sourced of the wastewater effluent is identified. Then, selecting and obtaining the aquatic plant that is going to be used for the study. Also, the reactor used for the research is then being prepared in order to get ready for the laboratory process. Eventually, when the entire initial laboratory set up has been done, the laboratory can be started. The laboratory tests involve collection of samples that will be analyzed through a series of the designated parameters. Figure 3.1 shows the flow chart

After all the laboratory tests, observation and all the data that are taken from laboratory tests were analysed. Lastly, some conclusions from the analysis could be drawn out. In this section, the values from the analyzed parameters of the treated effluent will be discussed. The results obtained from nutrients removal from the wastewater effluent will lead to the final conclusions based on the objectives made earlier.

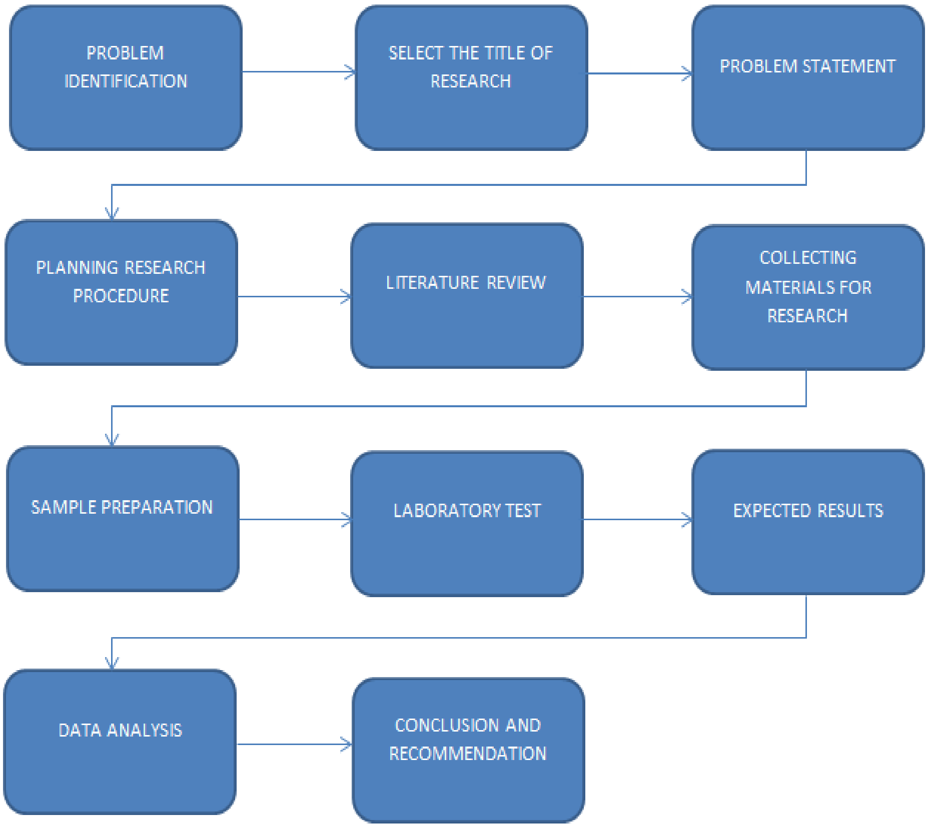


Figure 3.1 Flow Chart of Research Methodology

3.2 FABRICATION OF REACTOR

The study utilized two of the existing reactors available at the UTP Civil Engineering Laboratory. The reactor is made from concrete and as shown in Figure 3.2, whilst the detail dimension of the reactor is given in Figure 3.3. Baffles made of Perspex are included in the reactors so as to prevent short circuit flow from occurring.

Figure 3.2 : The reactor used in the study.

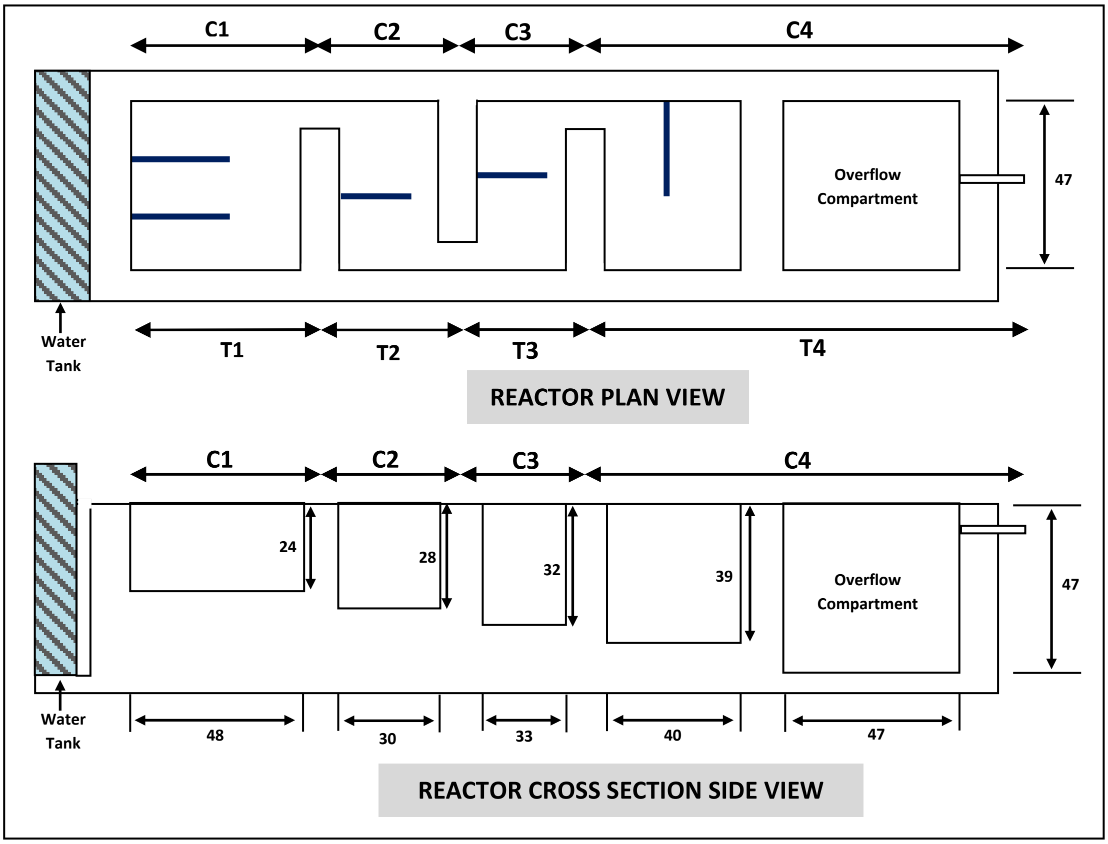


Figure 3.3 : Detail dimension of the reactor.

3.3 EXPERIMENTAL PROCEDURE

In this study, two reactors are used in which Reactor 1 is designated for the main testing whilst Reactor 2 is used for control purposes. Both reactors are filled up with treated effluent coming from the clarifier. Since that Reactor 2 is solely used as control, only Reactor 1 is planted with the aquatic plant. The aquatic plant that is used in this study is *Pistia Stratiotes*, also known as water lettuce. 30g of fresh water lettuce is placed in each and every compartment of Reactor 1. The schematic diagram showing the placement of the aquatic plants in the reactor is given in Figure 3.4.

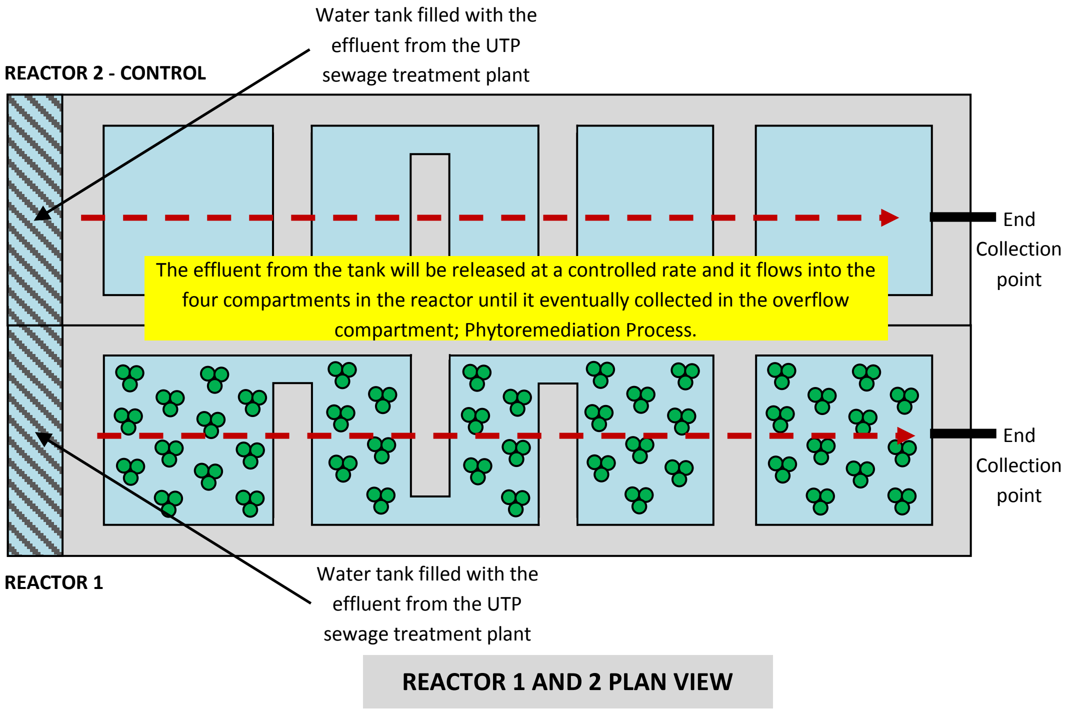


Figure 3.4 : Schematic diagram of the experimental set up.

Figure 3.5 : Initial condition of water lettuce in Reactor 1 (day 1).

Figure 3.6 : Final condition of water lettuce in Reactor 1 (day 14).

The water tank in the reactor will be filled up with the effluent from the UTP sewage treatment plant. The effluent will then be released into the reactor compartments at a steady flow rate, Q of 225L/day. Samplings of the water for both reactors will be conducted daily for 14 consecutive days based on 1 day Hydraulic Retention Time.

$$HRT\ (1\ day) = \frac{Volume\ of\ every\ compartment, V}{Flow\ rate, Q} \qquad \text{……. Equation 1}$$

Based on equation above, the retention time in every compartment (C1, C2, C3, and C4) is calculated. Taking 9 am as the starting time, therefore the retention time in every compartment are as follows :

i. $T1 = t1 = 3\ hours$
ii. $T2 = t1 + t2 = 6\ hours$
iii. $T3 = t1 + t2 + t3 = 10\ hours$
iv. $T4 = t1 + t2 + t3 + t4 = 14\ hours$

Consequently, the sampling time is determined to be at :

i. $T1 = 12\ pm$
ii. $T2 = 3\ pm$
iii. $T3 = 7\ pm$
iv. $T4 = 9\ am\ (the\ next\ day)$

For each sampling, the parameters as in concentration of Nitrate (NO_3), Ammonia (NH_3), Phosphorus (P) and Chemical Oxygen Demand (COD) are analysed in the laboratory. In addition, the overall growth development of the water hyacinth in each of the reactor compartments will also be observed throughout the study period.

3.4 PARAMETERS OBSERVED AT SAMPLING POINTS

This study will be focusing on the effect of using *Pistia Stratiote*s, known as *water lettuce* as a medium in the phytoremediation process. The phytoremediation process should be able to treat the already treated effluent from UTP Sewage Treatment Plant further resulting in much lower concentration of nutrients or organic compound found in the effluent. By implementing this process, the solely usage of water lettuce's effectiveness to remove the nutrients can be studied. This study will look into the removal of Nitrate (NO_3), Ammonia (NH_3), Phosphorus (P), and Chemical Oxygen Demand (COD). All testing are done in triplicates.

3.4.1 Nitrate Determination Method

Method 8039, Cadmium Reduction Method (HR, 0.3 to 30 mg/L NO_3^{-}N)

355 Nitrate HR PP program is selected at the spectrophotometer. 4 square sample cells (cuvette) are filled with 10 mL of sample each. 3 of the sample cells are added with NitraVer 5 Nitrate Reagent Powder Pillow and the remaining one acts as the blank sample (without NitraVer 5 Nitrate Reagent Powder Pillow). Let one-minute reaction period begin and then the sample cells are shaken until the timer expires. Let five-minute reaction period begin until the timer expires. An amber color will develop if nitrate is present. The blank sample cell is wiped and inserted into the cell holder with the fill line facing right. Press zero. Within one minute after timer expires, the 3 prepared sample cells are wiped and inserted into the cell holder with the fill line facing right. Press read and the values are recorded.

3.4.2 Nitrogen, Ammonia Determination Method

Method 8038, Nessler Method (0.02 to 2.50 mg/L NH_3-N)

380 N, Ammonia, Ness program is selected at the spectrophotometer. For blank sample preparation, 25 mL distilled water is measured and filled into a 125 mL conical flask. For sample preparation, 25 mL sample is measured and filled into a 125 mL conical flask. 3 samples are to be made. Three drops each of Mineral Stabilizer and Polyvinyl Alcohol are added into the flasks followed by 1 mL of Nessler Reagent. Let one-minute reaction period begin. 10 mL of both the blank and prepared solutions are poured into 4 square sample cells each. When the timer expires, the blank sample cell is wiped and inserted into the cell holder with the fill line facing right. Press zero. The 3 prepared sample cells are wiped and inserted into the cell holder with the fill line facing right. Press read and the values are recorded.

3.4.3 Phosphorus Determination Method

Method 8190, PhosVer® 3 with Acid Persulfate Digestion Method (0.06 to 3.50 mg/L PO_4^{3-} *or 0.02 to 1.10 mg/L P)*

The experiment is started by pre-heating DRB200 reactor to 150°C. 536 P Total/AH PV TNT program is selected at the spectrophotometer. TenSette® Pipet is used to add 5 mL of sample into the Total and Aci Hydrolyzable Test Vial. 3 samples are to be made. Potassium Persulfate Powder Pillow for Phosphonate is added into the vials by using a funnel. Cap tightly, shake to dissolve and insert into the DRB200. Close the protective cover. A 30-minute heating period will begin. As the timer expires, the hot vials are carefully removed from the reactor and let cool to room temperature. 2 mL of 1.54 N Sodium Hydroxide Standard Solution is added to all 3 vials, capped and mixed. For blank or zero purpose, 1 vial is wiped and inserted into the 16 mm cell holder. Press zero. All 3 vials are then added with PhosVer 3 Powder Pillow using a funnel. Immediately cap tightly and shake to mix for 20-30 seconds. A two-minute reaction period is allowed and samples are read within 2-8 minutes after timer expires. The vials are wiped and inserted into the 16 mm cell holder. Readings are to be recorded.

3.4.4 Chemical Oxygen Demand (COD) Determination Method

The experiment is started by pre-heating DRB200 reactor to 150°C. 2 ml of the samples is measured and poured into the COD vial. 3 samples are to be made. For blank, 2 ml of distilled water is used. The vials are then capped tightly and shaken properly using touch mixer. Heat will be produced due to reaction in the vials indicating exothermic process. The vials will be put into the reactor for 2 hours. After the time passes, the vials will be taken out and left cooled. Readings will be taken using spectrophotometer and recorded.

3.5 ANALYSIS OF RESULTS

Once all the laboratory works are completed, the data from all the nutrients testing will be compiled and analyzed. Apart from the data concerning the nutrients, the growth development of the water hyacinth will also be compiled and analyzed. It is expected that the water hyacinth d are enable to treat and thus reduced the amount of contaminants through the phytoremediation process.

3.6 GANTT CHART AND KEY MILESTONE

The gantt chart and the key milestone of this study is given Table 3.1.

Table 3.1 : Gantt chart for FYP 2.

No.	**Details**	**Week**														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1.	Project work	🟦	🟦	🟦	🟦	🟦	🟦	🟦								
2.	Submission progress report							🟦								
3.	Project work								🟦	🟦	🟦	🟦	🟦	🟦	🟦	
4.	Pre-Sedex										🟦					
5.	Submission of Dissertation (soft bound)													🟦		
6.	Submission of Technical Paper													🟦		
7.	Viva														🟦	
8.	Submission of Dissertation (hard bound)															🟦

Legend 🟦 Process

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will present the results obtained from the laboratory works. It will be divided into four (4) sections. The first part will be the highlighting the results of the influent characteristics for the nutrients throughout the 14 days duration. Then, it is followed by the concentration of the nutrients in both Reactor 1 and Reactor 2 throughout the 14 days duration. Next, will be the percentage removal of the nutrients in both Reactor 1 and Reactor 2 throughout the 14 days duration. Lastly, it will be the results regarding the growth of water lettuce in Reactor 1.

4.2 INFLUENT CHARACTERISTICS

The source of the influent in this study is from the effluent of the sewage treatment plant (STP) in Universiti Teknologi PETRONAS (UTP). The wastewater was characterized and the nutrients (nitrate, ammonia, phosphorus and COD) from the influent were determined.

4.2.1 Nitrate

The influent nitrate concentration is presented in Figure 4.1. It was observed that influent nitrate concentration fluctuated from day 1 to day 7 and was in the range of 2 to 4.8 mg/L. Maximum influent nitrate concentration (4.8 mg/L) was obtained on day 4 at 7 pm.

A similar trend was observed for influent nitrate concentration from day 8 to day 14 as shown in Figure 4.2 except on day 8 with maximum nitrate concentration of 7.1 mg/L at 3 pm. Influent nitrate concentration for other days were in the range 2.9 to 4.5 mg/L at all the time interval investigated.

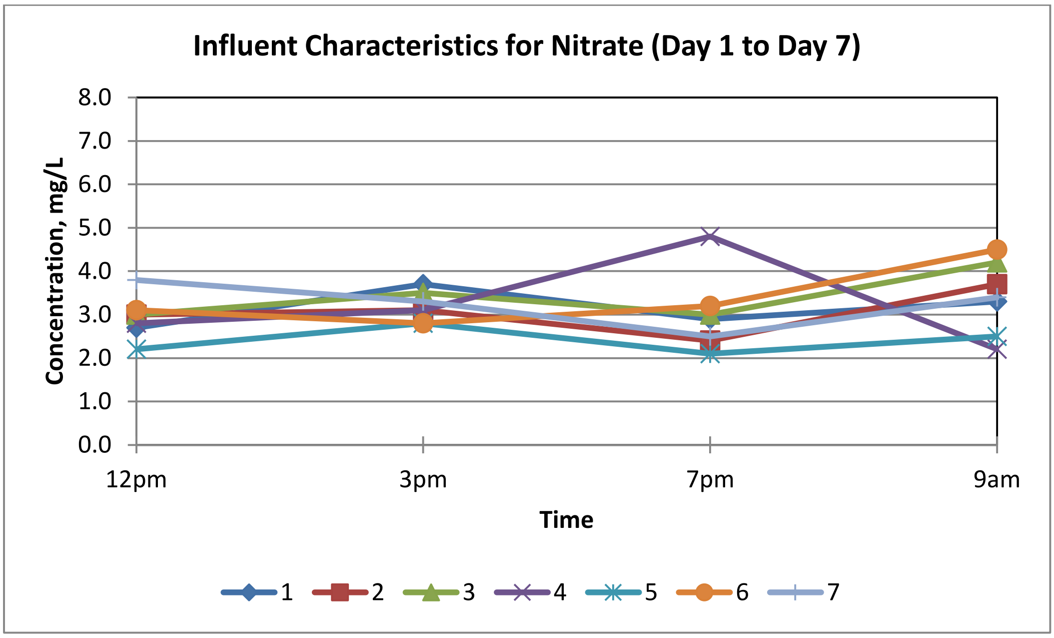


Figure 4.1 : Influent characteristics for nitrate from day 1 to day 7.

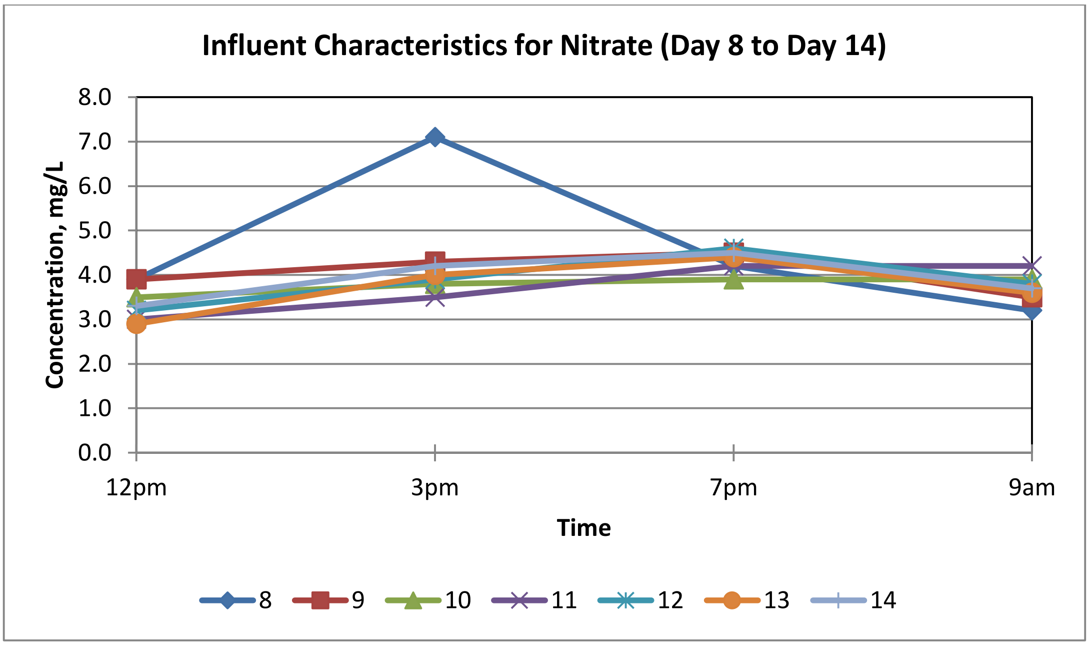


Figure 4.2 : Influent characteristics for nitrate from day 8 to day 14.

4.2.2 Ammonia

Influent ammonia concentration from day 1 to day 7 is presented in Figure 4.3. Ammonia concentration in days 1, 3, 5 and 6 was found to be in the range 0 to 100 mg. However, in days 2, 4 and 7, ammonia concentration in the influent increased and was found to be in the range 0.2 to 1.4 mg/L.

Influent ammonia from day 8 to day 14 (0.3 to 1.0 mg/L) was consistent from 12 pm to 3 pm for all samples as presented in Figure 4.4. However, influent ammonia concentration fluctuated from 7 pm to 9 am and was found in the range 0.11 to 1.20 mg/L for all samples investigated.

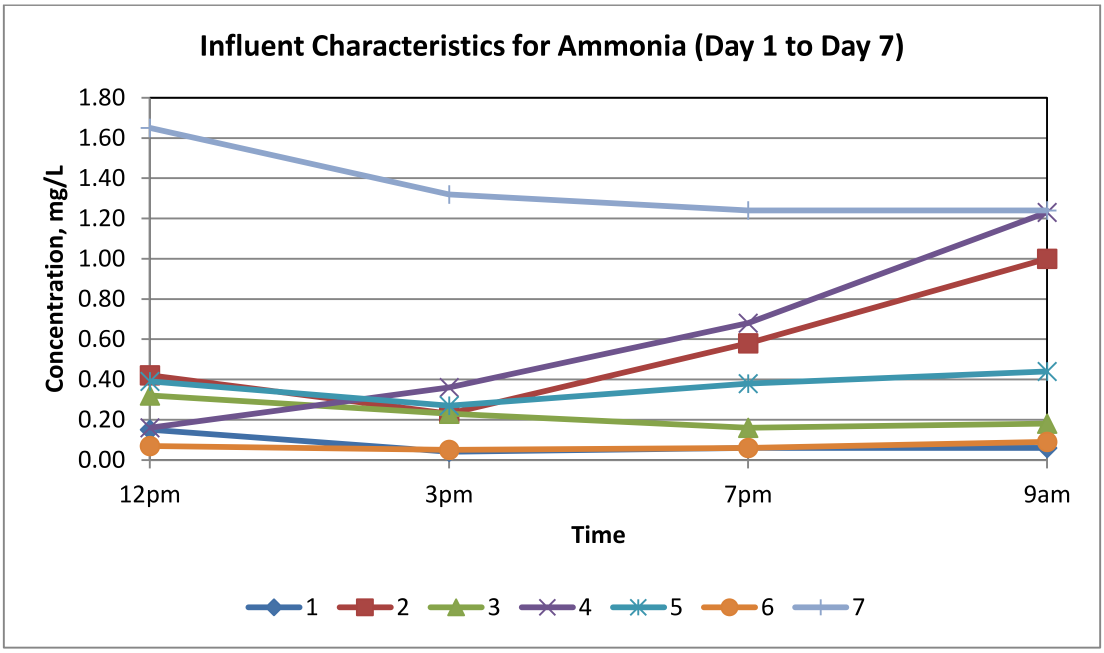


Figure 4.3 : Influent characteristics for ammonia from day 1 to day 7.

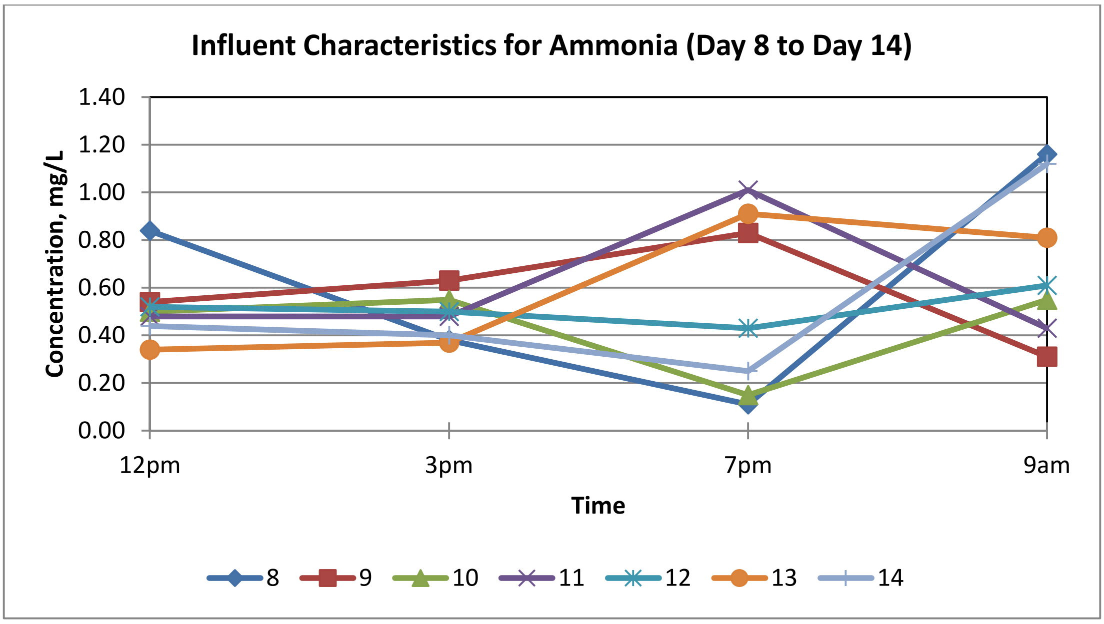


Figure 4.4 : Influent characteristics for ammonia from day 8 to day 14.

4.2.3 Phosphorus

Influent phosphorus concentration from day 1 to day 7 is presented in Figure 4.5. As shown below, influent phosphorus concentration was consistent from day 1 to day 6 for all the time interval investigated and was found to be in the range 2.8 to 3.7 mg/L. However, on day 7, influent phosphorus concentration slightly increased for all the time intervals. The increase was more prominent at 12 pm with an influent phosphorus concentration of about 4.8 mg/L.

Similar trend was observed for influent phosphorus concentration from day 8 to day 14 for all time interval monitored. Influent phosphorus concentration was found to be consistent in the range 3 to 4 mg/L for all the days and time interval monitored as shown in Figure 4.6.

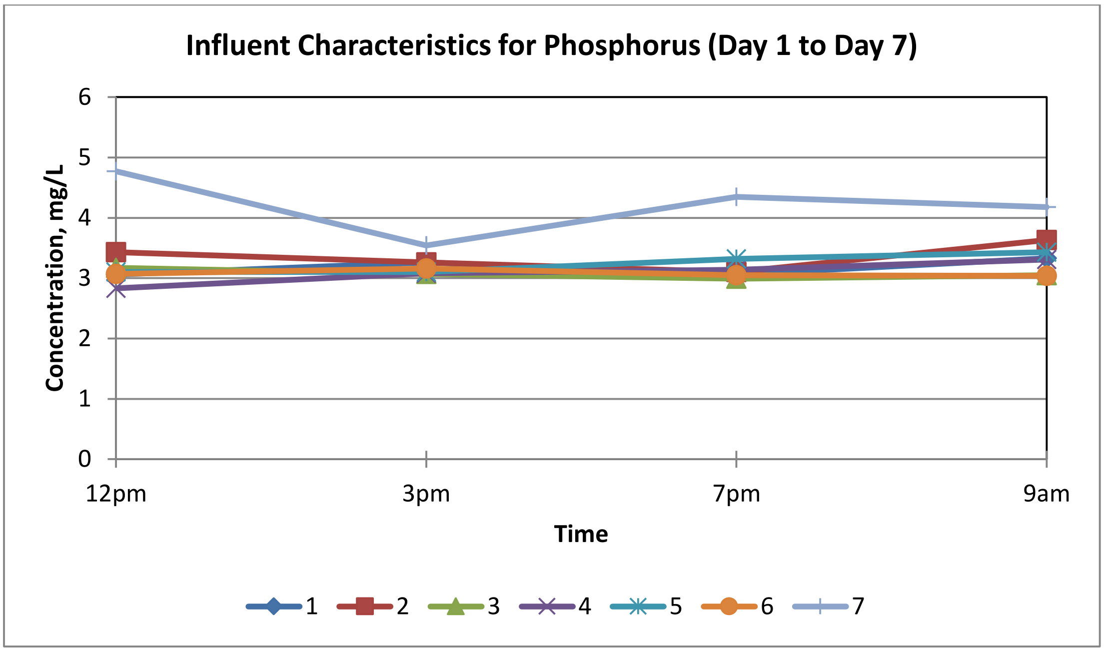


Figure 4.5 : Influent characteristics for phosphorus from day 1 to day 7.

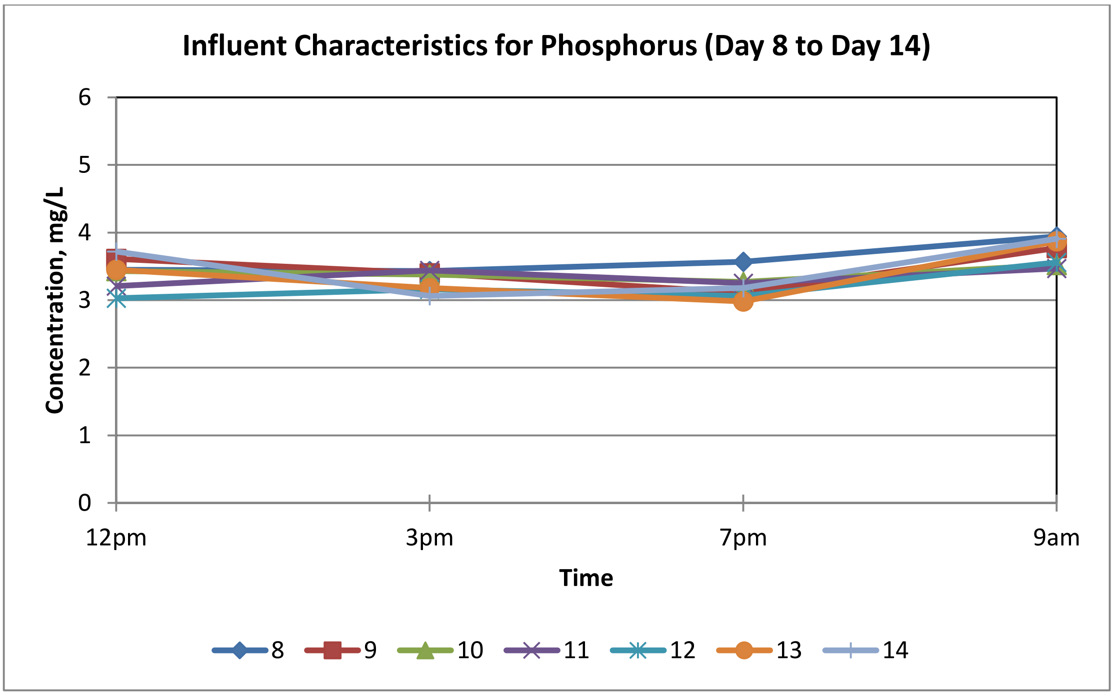


Figure 4.6 : Influent characteristics for phosphorus from day 8 to day 14.

4.2.4 Chemical Oxygen Demand (COD)

Influent chemical oxygen demand (COD) concentration from day 1 to day 7 is presented in Figure 4.7 for all time interval monitored. Influent COD concentration fluctuated throughout the days monitored and was found in the range 5 to 39 mg/L. However, the higher influent COD concentration was more prominent on day 2 and day 3 at 7 pm and 3 pm respectively.

A similar influent COD trend was observed from day 8 to day 14. The influent COD concentration was observed to be in the range 10 to 30 mg/L as shown in Figure 4.8. a higher influent COD concentration was obtained on day 13 (27 and 30 mg/L) at 3 and 7 pm respectively.

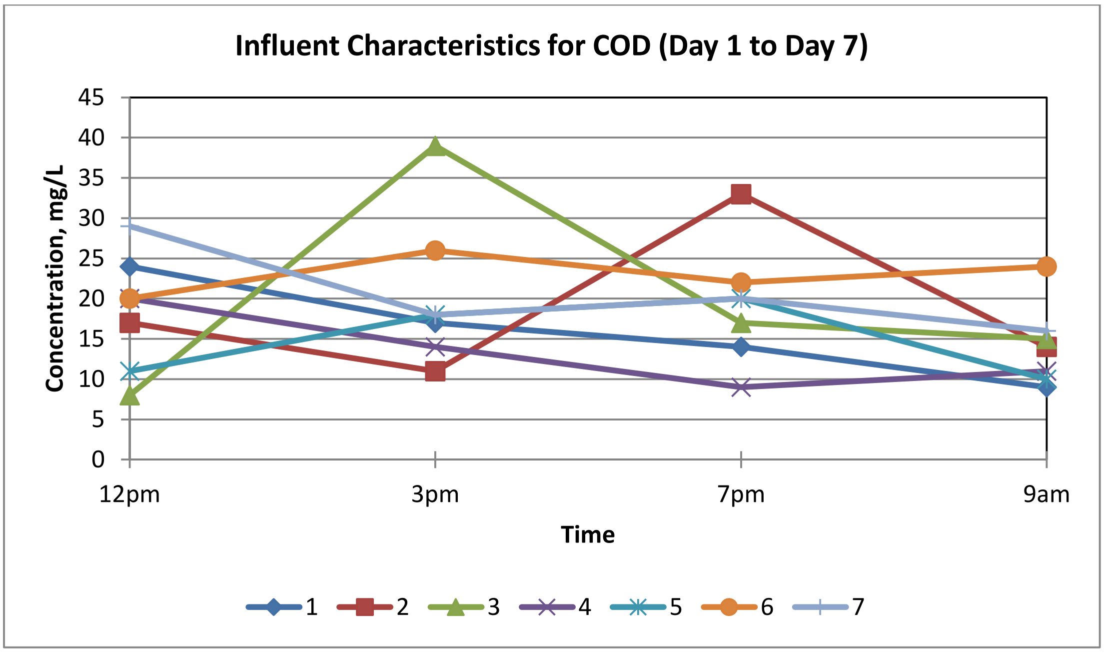


Figure 4.7 : Influent characteristics for COD from day 1 to day 7.

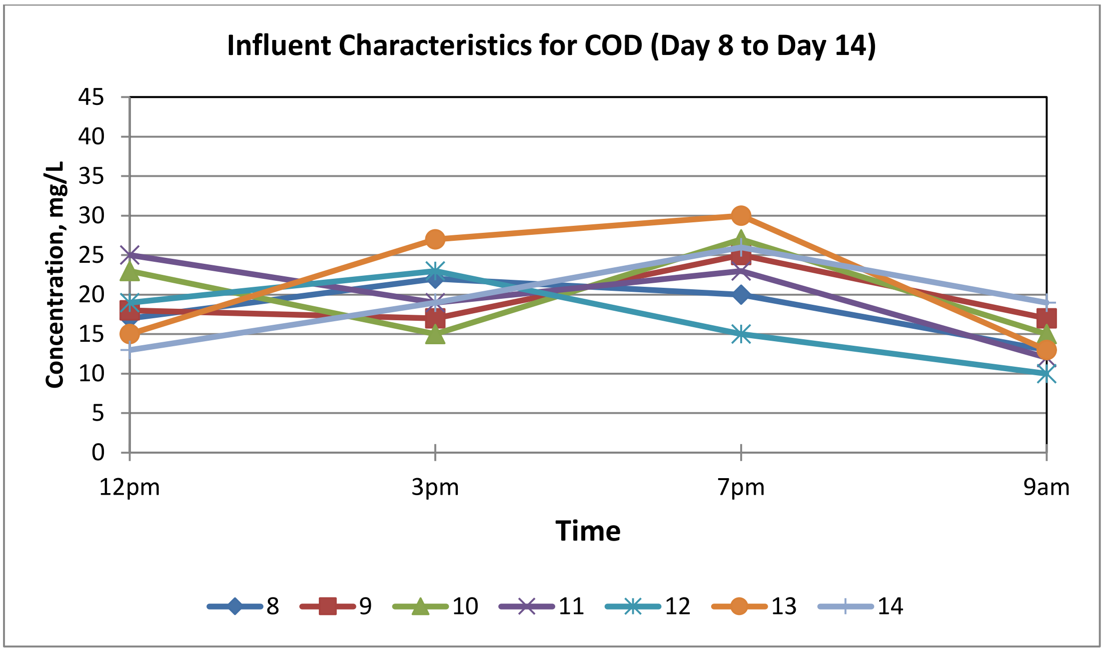


Figure 4.8 : Influent characteristics for COD from day 8 to day 14.

The graphs above represent a 14 day evaluation period of the performance of the Sewage Treatment Plant (STP) in Universiti Teknologi PETRONAS (UTP). Nitrate, ammonia, phosphorus and COD were continuously monitored at timed intervals and their characteristics are summarized in Table 4.1. The Sewage Treatment Plant (STP) in UTP is designed to meet the Standard ‘A’ of Malaysia’s Environmental Quality Act 1974 limits presented in Appendix 1. Therefore, it is necessary that the effluent from the STP does not violate the stipulated guideline.

Table 4.1 : Summary of the influent characteristics.

Nutrient	**Concentration, mg/L From the test**	**Concentration, mg/L Required by DOE (Standard A)**
Nitrate	2.2 – 4.8	10
Ammonia	0.05 – 1.65	5
Phosphorus	3.0 – 4.8	5
COD	8 - 39	120

Comparing the values in Table 4.1, it shows that the influent from the treated wastewater satisfies the Standard ‘A’ and in fact, the influent has much lower concentration of nitrate, ammonia, phosphorus and COD than in the standard itself. This proves that the effluent produced by UTP Sewage Treatment Plant contains low nitrate, ammonia, phosphorus and COD and is safe to be released to water bodies outside.

4.3 TEMPERATURE AND pH

This part presents the temperature and pH taken for influent and both effluent from Reactor 1 and Reactor 2 throughout the experimental process of the study. It is significant to measure and record these as the treatment efficiency of an aquatic plant system also depends on sunlight and temperature (Bal Krishna and Polprasert, 2007).

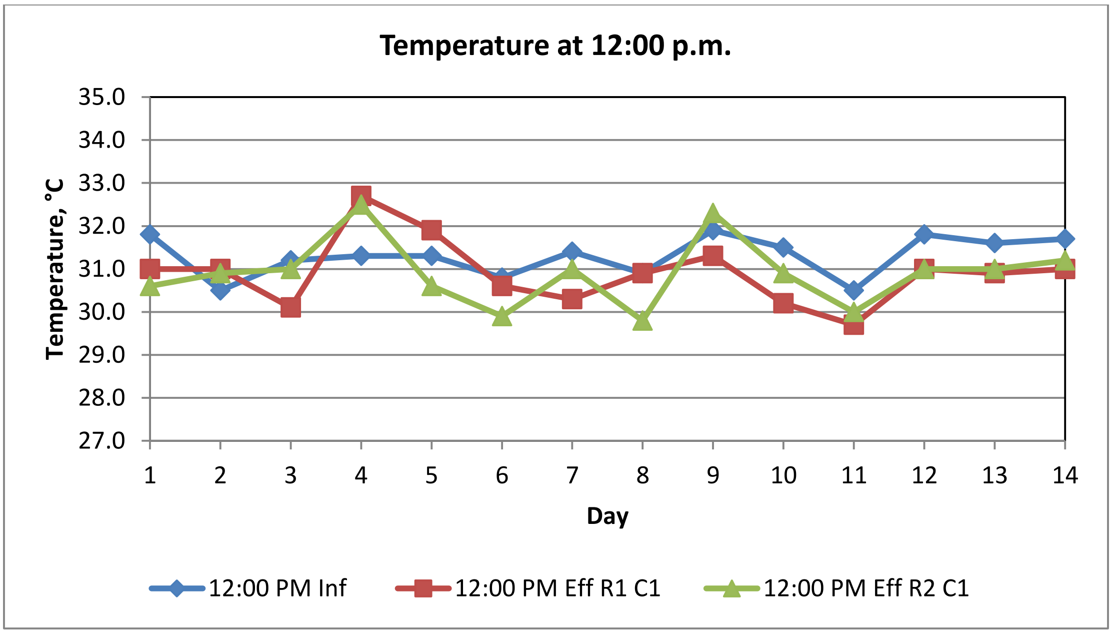


Figure 4.9 : Temperature of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

Figure 4.9 above shows the temperature at 12.00 p.m. where it ranges from 30°C to 33°C. It can be seen that the temperature is quite stable at this hour of the 14 days study with only minimal difference amongst the days.

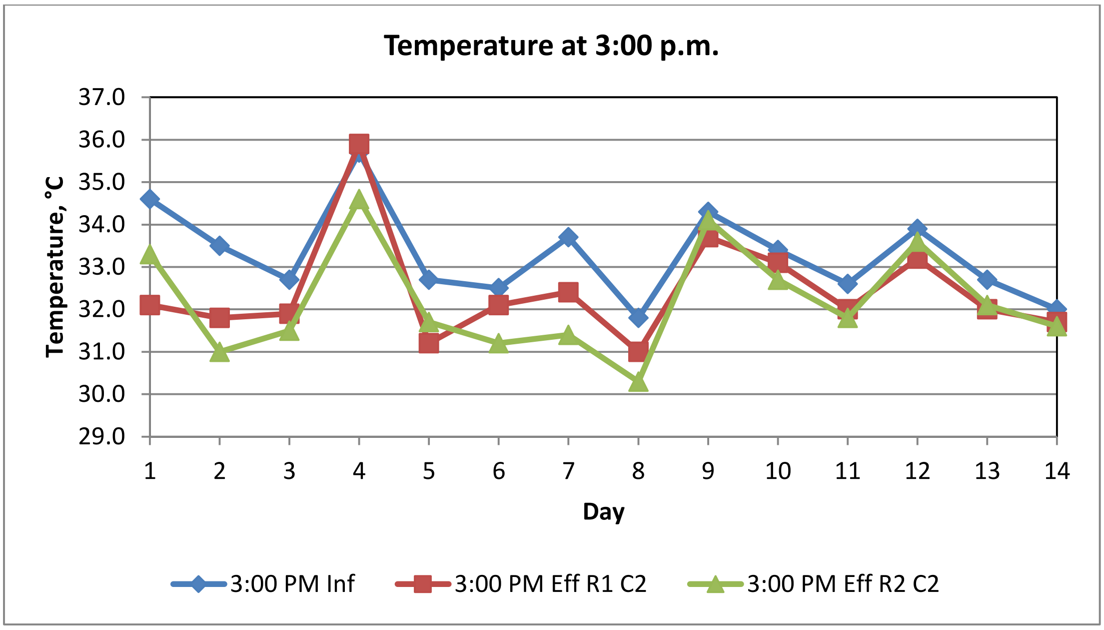


Figure 4.10 : Temperature of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

At 3.00 p.m. the temperature tends to fluctuate from Day 1 to Day 14. The highest temperature was recorded to be on Day 4 at 36°C. This shows that on Day 4, the weather is quite hot than any other days throughout the study.

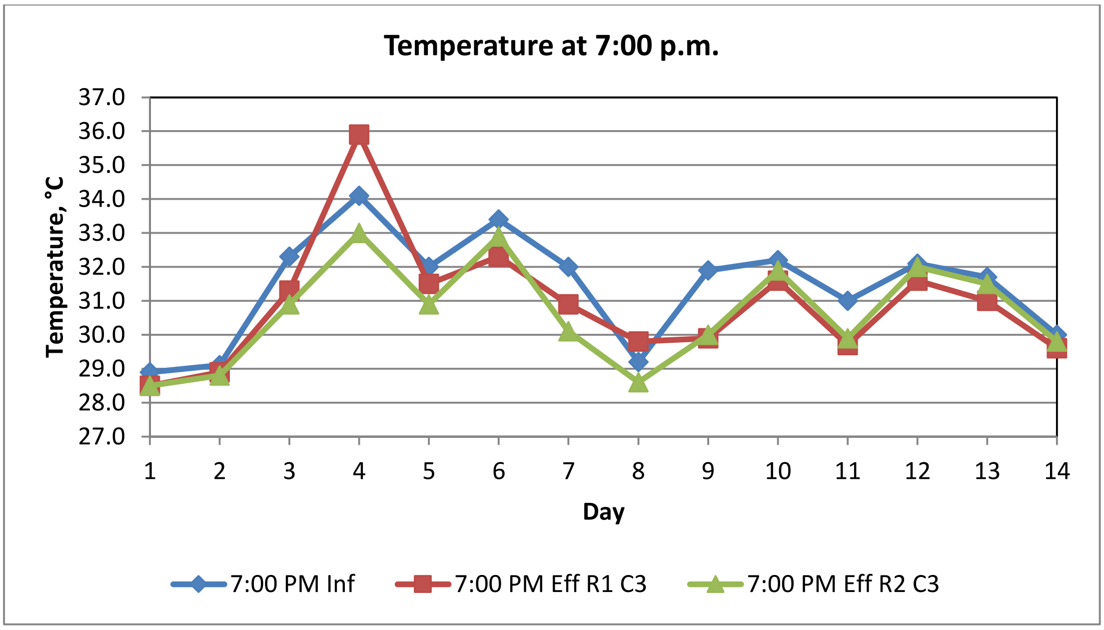


Figure 4.11 : Temperature of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 p.m.

In Figure 4.11, it can be seen that Day 4 once again possesses the highest temperature of 36°C. The lowest temperature recorded was around 28°C which is on Day 1 of the study.

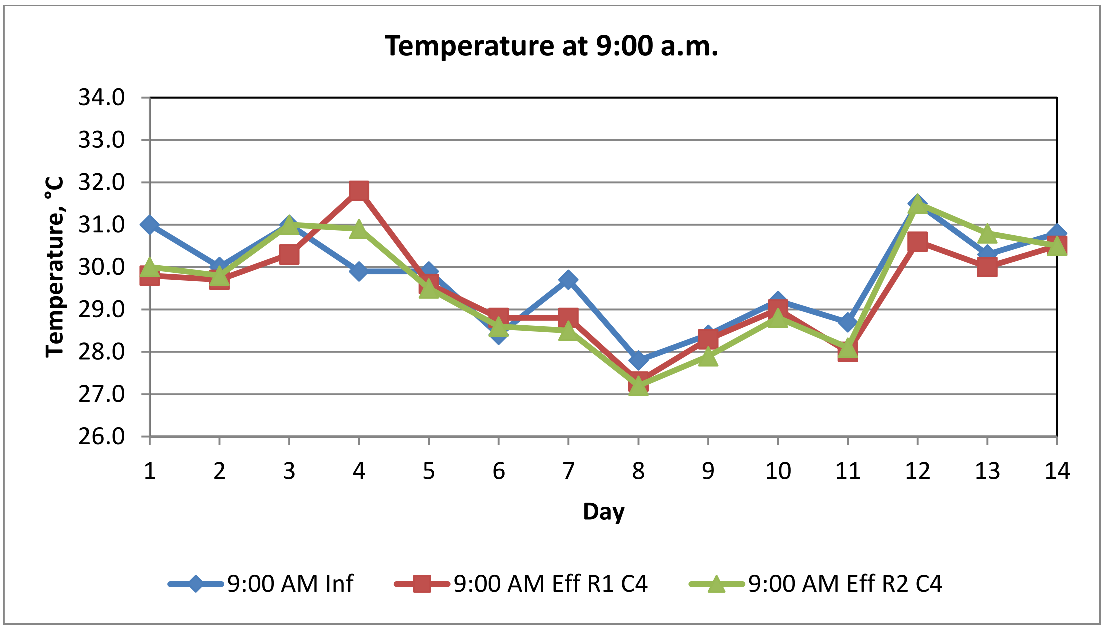


Figure 4.12 : Temperature of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 a.m.

Temperature at 9.00 a.m. shows stable differences between the temperature for the influent and also effluent of both reactors. However, again at Day 4, the highest temperature is recorded throughout the 14 days of the study period.

Based on Figure 4.9 – 4.12, Day 4 recorded the highest temperature in every graph which significantly shows that on that particular day, the weather is quite hot and sunny as compared to other days. Also noticeable from Day 4, the highest temperature was recorded in the effluent of Reactor 1. This is possible due to the arrangement and location of Reactor 1 which allows Reactor 1 to be exposed more to the sunlight than Reactor 2. The same goes to the temperature of the influent where almost in all graph, the influent recorded higher temperature than the effluent. This is because the influent tank is also more exposed to the sunlight.

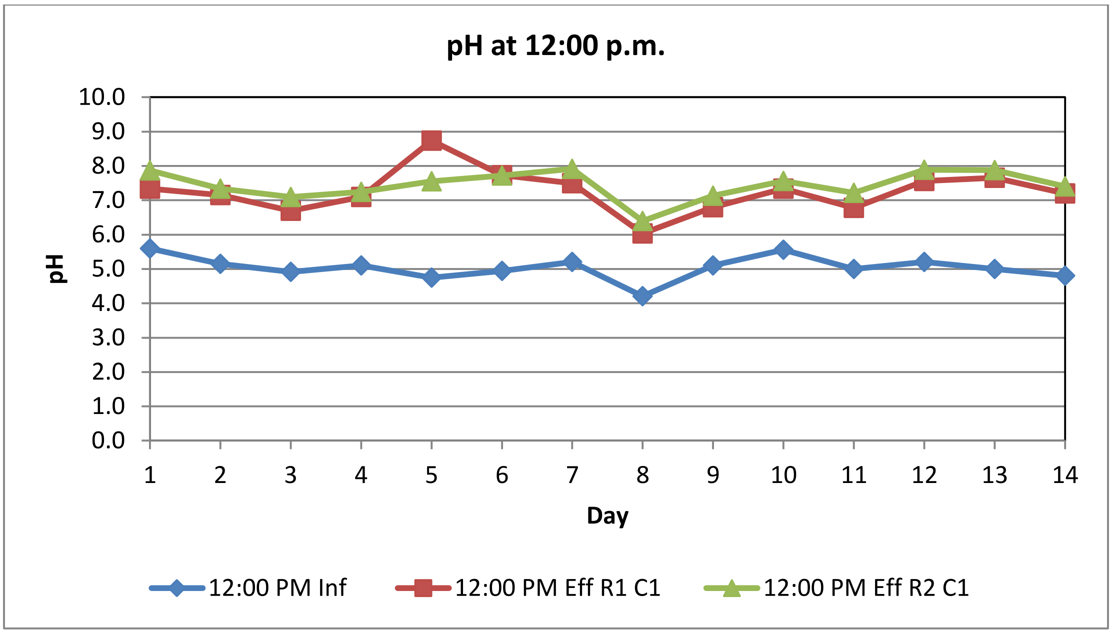


Figure 4.13 : pH of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

Referring to Figure 4.13, the influent pH at 12.00 p.m. is lower than the effluent of both reactors. It is also lower than the neutral pH which is pH 7 indicating that the influent is in the range of alkaline. Another observation can be made is that the pH in effluent of Reactor 1 is slightly lower than Reactor 2 in almost all the 14 days at this hour.

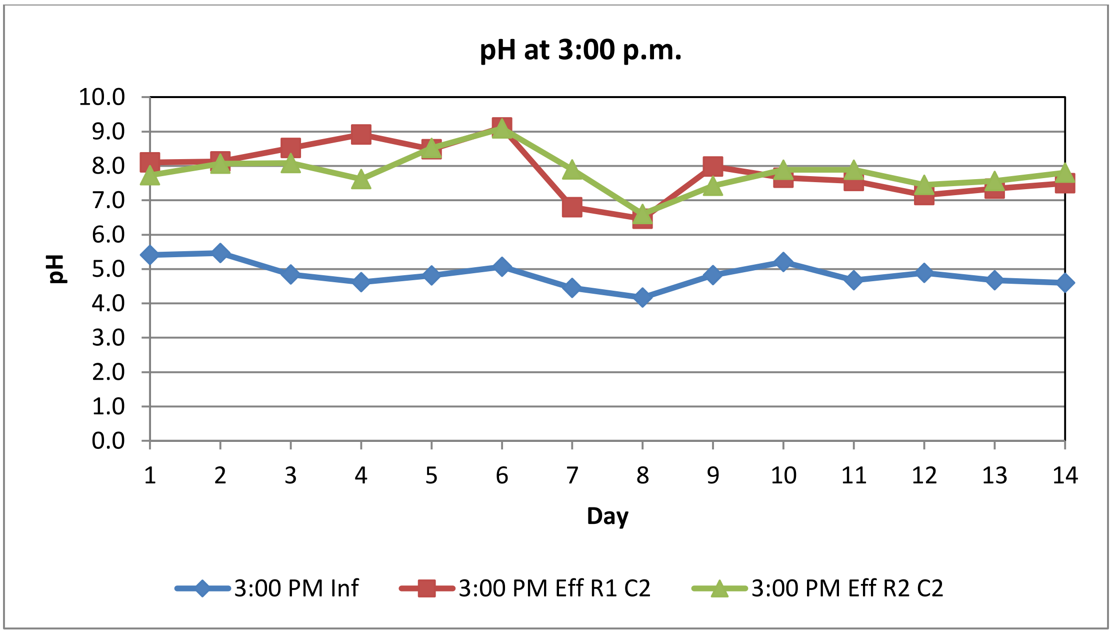


Figure 4.14 : pH of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

Figure 4.14 displays the almost the same trend as in Figure 4.13 whereby the influent has lower pH and is alkaline as compared to the effluent of both reactors. A different trend than in Figure 4.13 can be seen here as from Day 1 to 6, Reactor 1 has higher pH than Reactor 2 and that pH from both reactors are generally higher than pH 7 and is acidic.

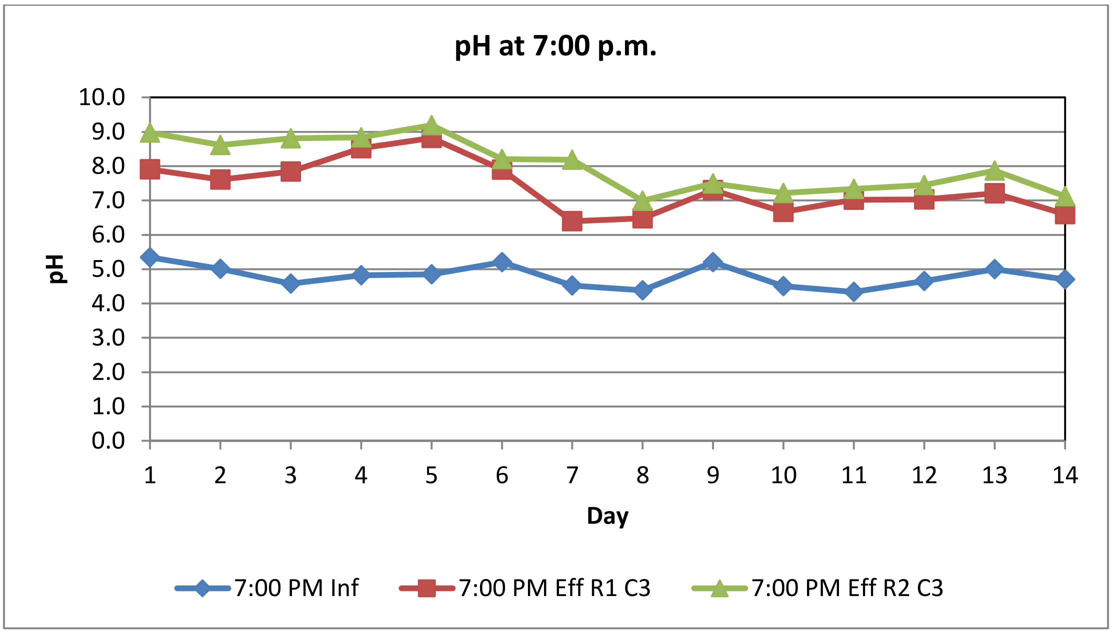


Figure 4.15 : pH of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 p.m.

At 7.00 p.m. similar trend of influent pH was observed. However, the effluent pH of both reactors from Day 1 to 6 are slightly acidic than at Day 7 to 14 which is in the neutral range. Also observed is that pH in Reactor 1 is lower than in Reactor 2 at this hour.

Figure 4.16 shows the same trend of influent pH as well as in both reactors. Not much difference is recorded for pH in the effluent making it to have the most stable pH trend for effluent as compared to the graphs at 12.00, 3.00 and 7.00 p.m.

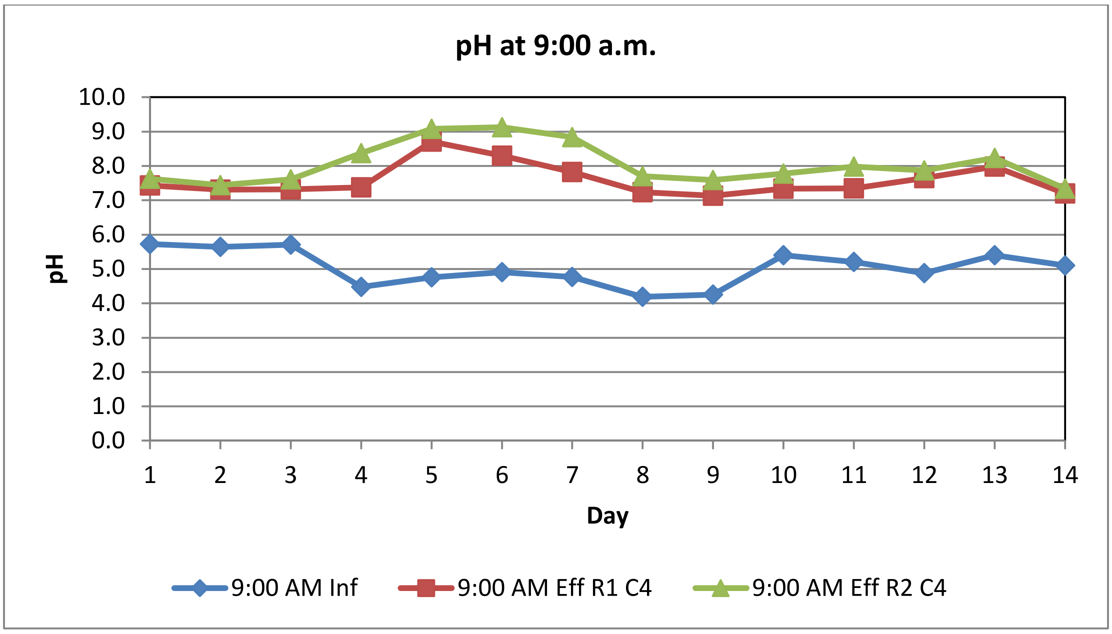


Figure 4.16 : pH of the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 a.m.

Generally, it can be concluded that the influent is alkaline and lower than the effluent in both reactors. Apart from that, effluent pH in Reactor 1 is basically almost all the time lower than in Reactor 2.

4.4 CONCENTRATION OF NITRATE, AMMONIA, PHOSPHORUS AND COD

This part will focus on the results obtained from the laboratory test on the performance of reactor 1 and reactor 2 for nutrient elimination. The parameters (nutrients) for the reactor evaluation are nitrate, ammonia, phosphorus and COD.

4.4.1 Nitrate

The nitrate concentration test was daily conducted in Reactor 1 and Reactor 2 at various time intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for a period of 14 days. Figures 4.17, 4.18, 4.19 and 4.20 show the influent and effluent nitrate concentration in reactor 1 and reactor 2 at timed intervals for the period of 14 days, respectively.

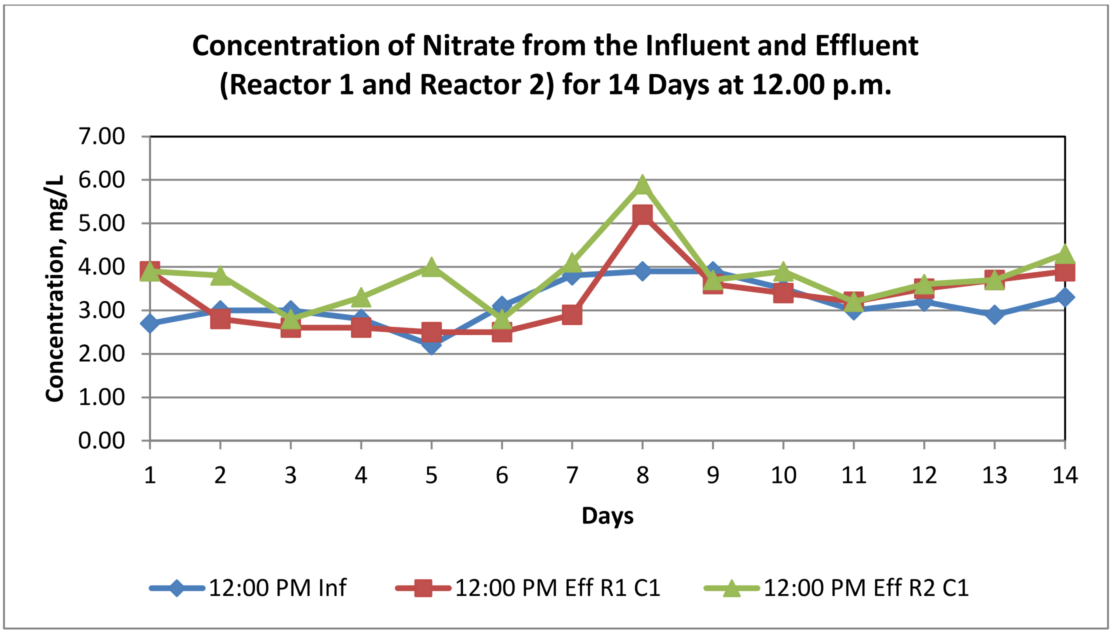


Figure 4.17 : The nitrate concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

As seen in Figure 4.17, nitrate concentration ranges from 2 to 6 mg/L at 12.00 p.m. The highest nitrate concentration recorded was on Day 8 where both reactors were having higher nitrate concentration than the influent. In the early days of the study, Reactor 1 is basically has lower nitrate concentration as compared to when the study is going towards the end. Overall, Figure 4.17 shows that generally, nitrate concentration in effluent of Reactor 2 is higher than the influent as well as effluent of Reactor 1.

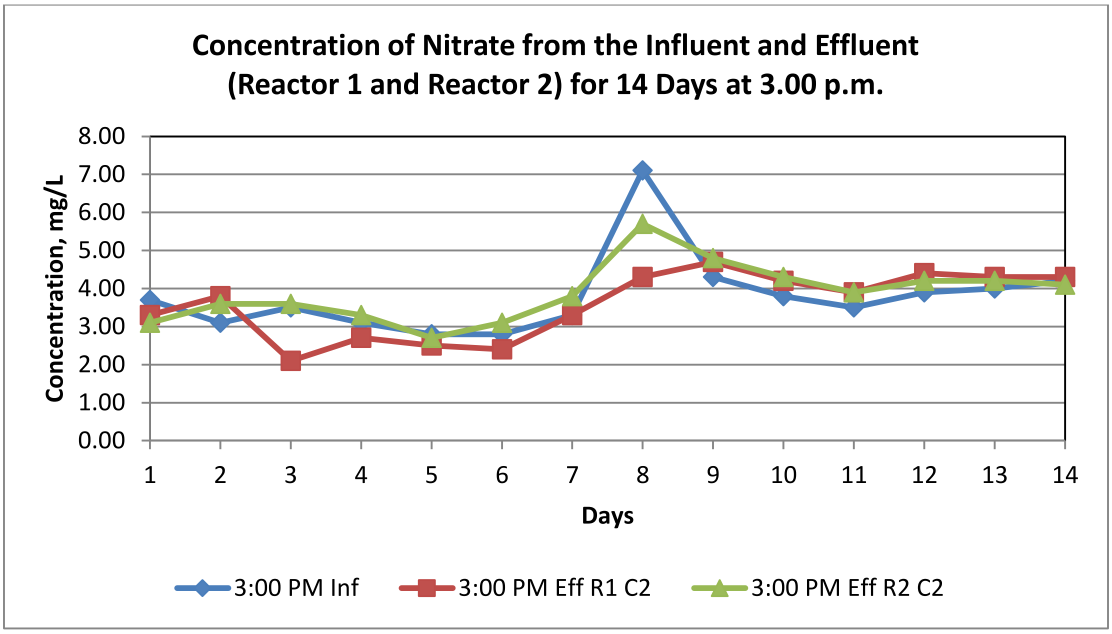


Figure 4.18 : The nitrate concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

At 3.00 p.m. the influent of Day 8 recorded the highest nitrate concentration. Referring to Day 8 itself, it can be seen that the removal of nitrate is obvious where the variance is basically more than 1 and 2 mg/L in both Reactor 2 and Reactor 1 respectively. The whole graph shows that nitrate concentration in Reactor 1 is lower than in Reactor 2 and the influent confirming that there are removal of nitrate in the system.

Unstable nitrate concentration was displayed in Figure 4.19. From Day 1 to 7, nitrate concentration in the influent is lower and unstable than in the effluent of both reactors indicating there is increment of nitrate concentration in both reactors instead of removal but the trend is going stable towards the end of the study. Reactor 2 is found out to have higher concentration than Reactor 1.

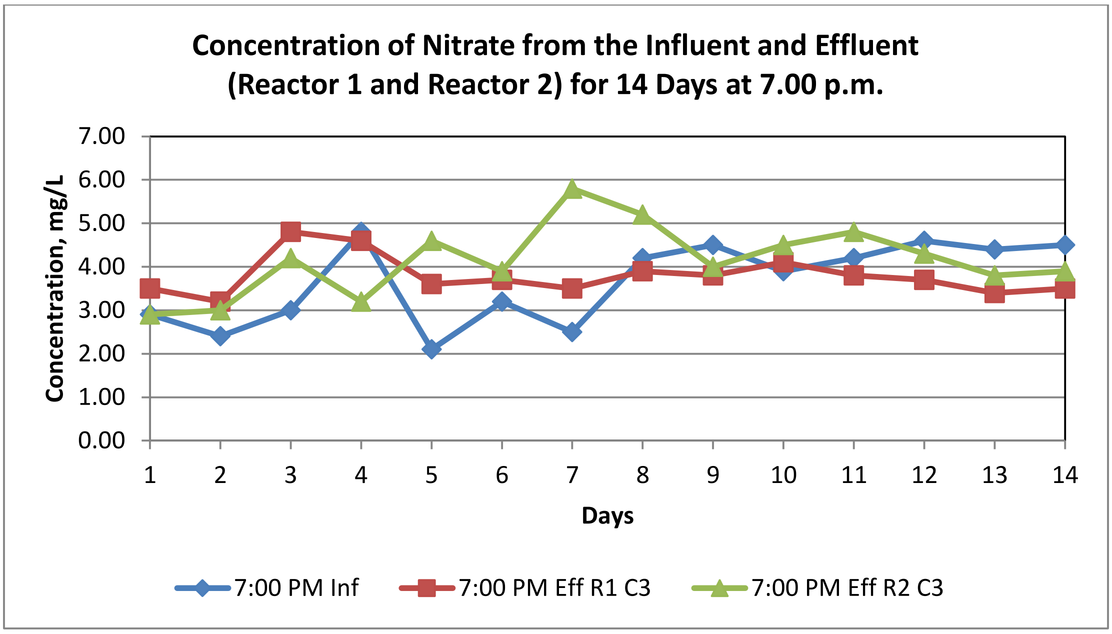


Figure 4.19 : The nitrate concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 p.m.

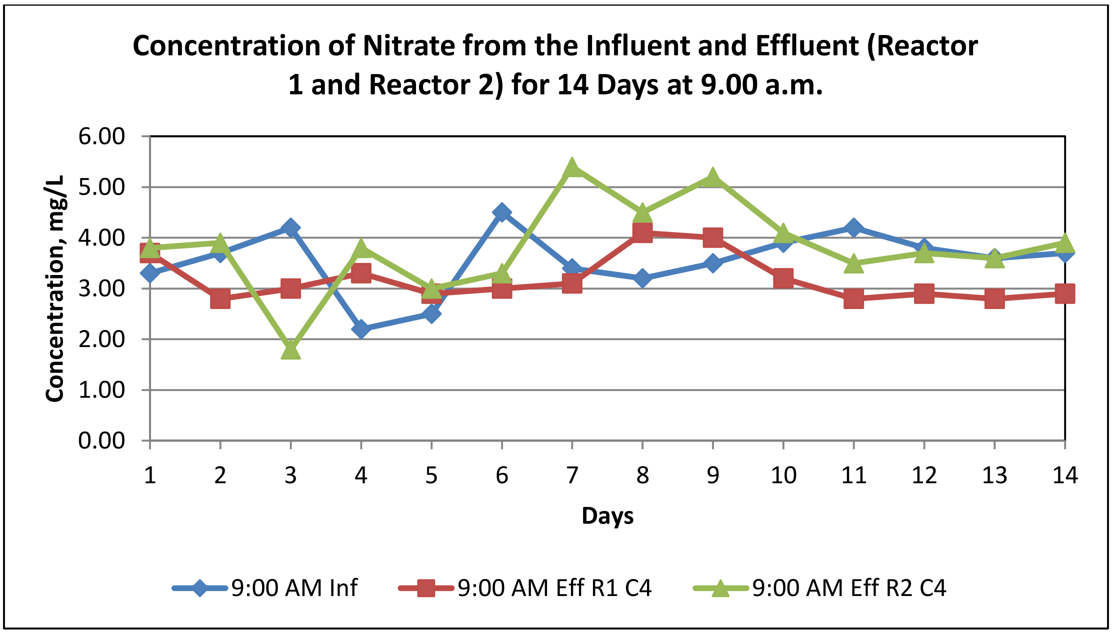


Figure 4.20 : The nitrate concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 a.m. (the following day).

Figure 4.20 shows unstable concentration of nitrate recorded in the influent as well as effluent of both reactors. From Day 1 to 9, the graph shows a lot of peak with nitrate concentration increases in some of the days. However, towards the end of the study period, the concentration seems to be quite stable and constant with nitrate concentration in effluent of Reactor 1 is lower than in Reactor 2 and influent.

Nitrate is one of the inorganic non-metallic constituents that are present in water and is naturally occurring form of nitrogen found in soil. Generally, based on the graphs above, the effluent nitrate concentration in all 4 compartments of Reactor 1 is lower than Reactor 2. At some days, both reactors have slight increase in the effluent nitrate concentration compared to the influent nitrate concentration.

The presence of nitrate, NO_3^- is basically due to nitrification. Nitrification is the autotrophic oxidation of the ammonia, first to nitrite and then to nitrate and could expressed as follows:

$$Nitrification : NH_4 \rightarrow NO_2^- \rightarrow NO_3^- \qquad (2)$$

Ammonia is at first oxidized to nitrite by ammonia-oxidizing bacteria i.e nitrosomonas and nitrite to nitrate by nitrite-oxidizing bacteria i.e nitrobacter. This process results in the nitrate concentration found in the effluent or water. Therefore, the more ammonia is oxidized, the more nitrate is produced. However, in order for this process to happen, nitrifier must also be present in the system by which in this study, the system itself has already has the microorganisms coming in from the influent.

Vyzamal (1995) sum up that nitrification is influenced by temperature, pH, alkalinity of the water, inorganic C source, moisture, microbial population and concentration of ammonium-N and dissolved oxygen. Optimum temperature for nitrification in pure culture ranges from 25°C to 35°C (Vyzamal, 2005) and Paul and Clark (1996) pointed out that optimum pH values may vary from 6.6 to 8.0 but an acclimatized system can be operated at a much lower pH value (Cooper et. al., 1996).

Simultaneously, denitrification process also occurs in the same system. Denitrification consists of the microbiological reduction of nitrate and nitrite to a gaseous nitrogen compound and could be expressed as follows :

$$Denitrification : NO_3^- \rightarrow N_2 \qquad (3)$$

Since the influent is taken from the treated effluent, it is known that nitrate and ammonia are already present in the system. Accordingly, some microorganisms or bacteria could exist in the system from the previous wastewater treatment process. Lee, et al. (2009) reported that plant uptake and microorganism activities around the rhizome are the nitrogen removal processes in the wetland system. Wetzel (2001) mentioned that nutrients are assimilated from the sediments by emergent and rooted floating-leaved macrophytes and from free the water in the free-floating macrophytes.

This justifies the better performance of reactor 1 when compared to reactor as shown in Figures 4.17 - 4.20 respectively. Reactor 1 was filled with water lettuce, an aquatic macrophyte in every compartment. When nitrification and denitrification process happens in the system, the last form produced is nitrogen gas. The element nitrogen is essential to growth of microorganisms, plants and animals (Metcalf and Eddy, 2004).

Thus, the macrophyte in Reactor 1 use up the nitrogen in its growth process causing lower concentration in the reactor.

4.4.2 Ammonia

Investigation of the reactor performance for ammonia elimination was conducted at timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for reactor 1 and reactor 2 for a period of 14 days and presented in Figures 4.21, 4.22 4.23 and 4.24.

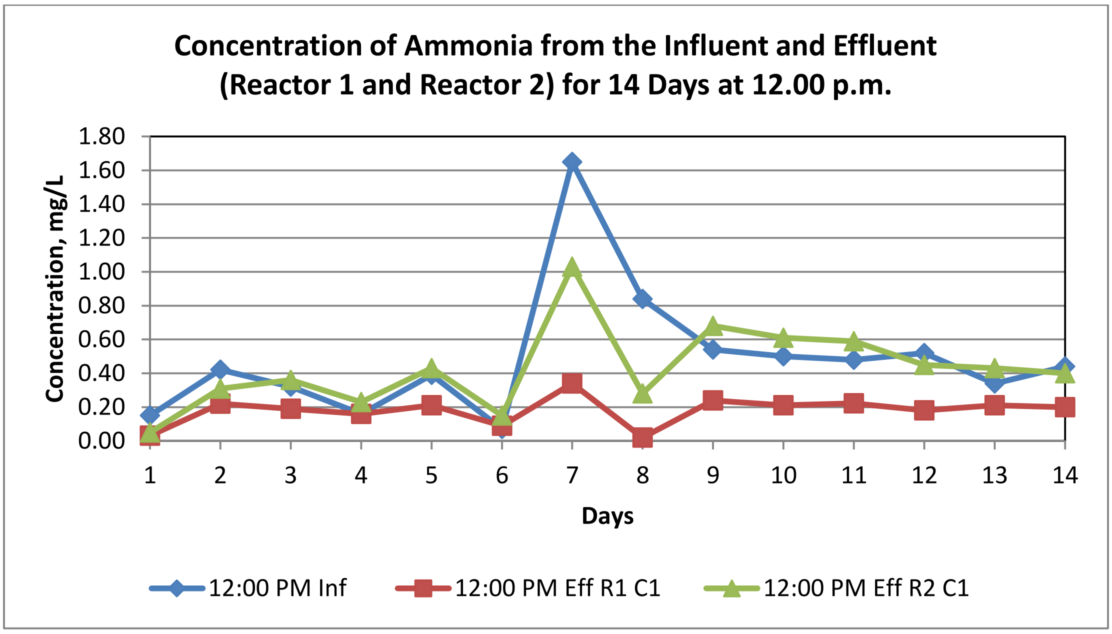


Figure 4.21 : The ammonia concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

Figure 4.21 shows ammonia concentration throughout the study at this hour ranges from 0 to 0.5 mg/L except for Day 7. Most of the time, ammonia concentration in effluent of Reactor 1 is lower than the influent and in Reactor 2. The highest removal recorded was at Day 7 where the influent was 1.65 mg/L and reduced to 0.34 mg/L in Reactor 1. Also can be seen from the graph is that there is not much removal or uptake in Reactor 2 compared to Reactor 1. Low ammonia concentration in the influent is due to most people in UTP are either at work or taking their lunch time and therefore, less people is going to the lavatory.

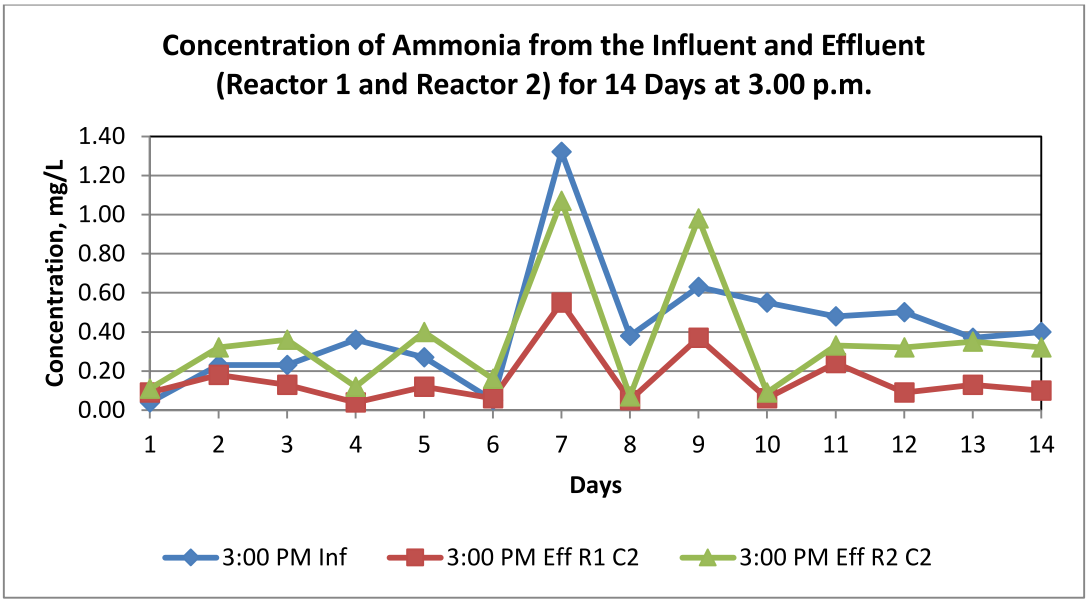


Figure 4.22 : The ammonia concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

Based on Figure 4.22, it can be observed that ammonia concentration in effluent of Reactor 1 is always lower than influent and in Reactor 2. Fluctuations can be seen in the influent as well as Reactor 2. On Day 7 itself, the concentrations in influent and effluents spike up than the other days. There is a number of ammonia in the influent at 3.00 p.m. and is possibly due to frequent usage of lavatory as it is just after lunch time at this particular time of the day.

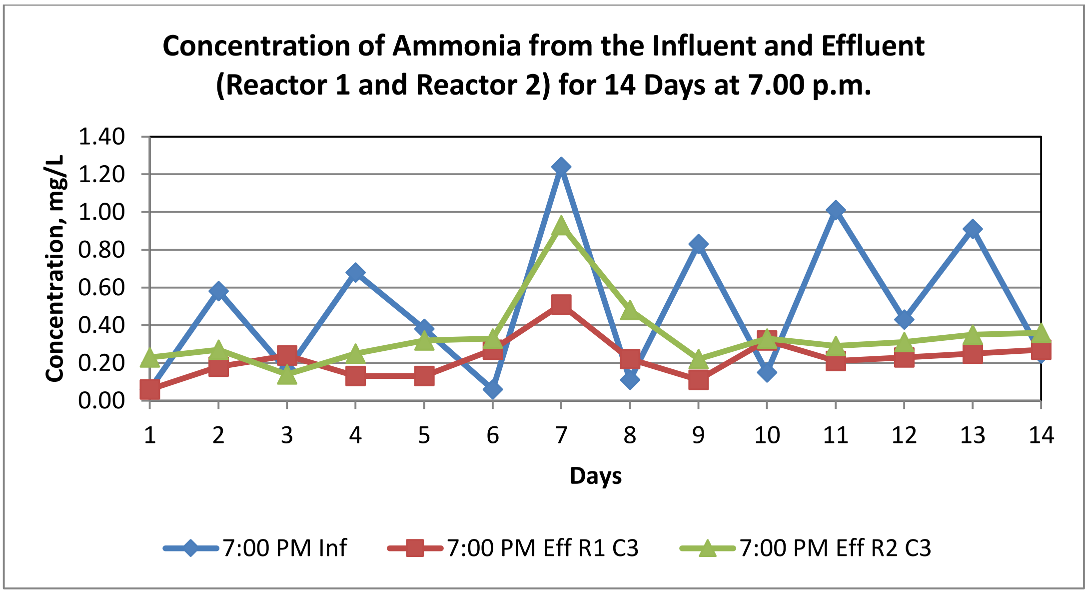


Figure 4.23 : The ammonia concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 p.m.

Ammonia concentration in influent trend line shows fluctuation or unstable concentration from Day 1 towards the end of the study at 7.00 p.m. Based on the graph, low ammonia concentration is found in effluent of Reactor 1 even though it is high in the influent. This shows the occurrence of ammonia removal or uptake by the plant in Reactor 1. Possible reason of having fluctuations in the influent is that at this particular hour, most students are taking their shower after having sports or getting ready to go to their night classes causing high activity in the lavatory or washroom. Day 7 shows the highest peak of concentration recorded at 7.00 p.m.

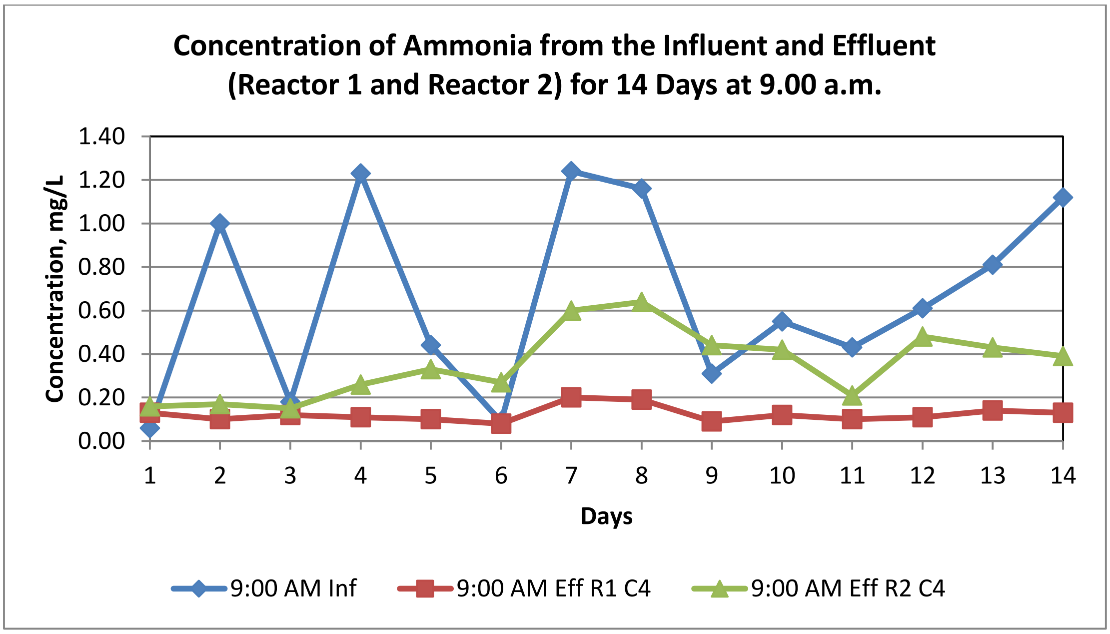


Figure 4.24 : The ammonia concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 a.m. (the following day).

From Figure 4.24, ammonia concentration in effluent of Reactor 1 is the most stable and low than in influent and Reactor 2. The influent is having fluctuations in the concentration suggesting that it is due to the high usage of the lavatory or washroom as people are getting ready for their daily activities such as going for classes. Referring to concentration in Reactor 1, it indicates removal of ammonia is occurring throughout the study period.

From the obtained results, it was observed that Reactor 1 has lower and stable concentration of ammonia in the effluent as compared to influent and Reactor 2. Another trend shown by the graphs is that the effluent ammonia concentration in both reactors is generally lower than the influent ammonia concentration. This indicates the removal of ammonia in both reactors.

Based on Figure 4.21 – 4.24, there is a particular day where the ammonia concentration recorded spiked up higher than usual which is on Day 7. O This suggests that on Day 7, the effluent coming out from the treatment plant is not as clear as any other normal days. Possible reason to this is that the microbes in the aeration tank are not utilizing the nitrogen for their growth causing high nitrogen which consequently contributing to high ammonia in the effluent.

As previously stated, nitrification and denitrification process may cause the reduction or increment of ammonia, nitrate and nitrogen in the system. In this case, ammonia is reduced and when compared with the graphs of nitrate concentration, ammonia has lower values than the nitrate concentration in the system even though nitrate is also reduced in the system itself.

Oxidation of ammonia to nitrate results in decreased of ammonia concentration in the reactors while nitrate concentration is increased. Accordingly, reduction of nitrate through denitrification results to decrease of nitrate concentration in both reactors while nitrogen gas is released.

4.4.3 Phosphorus

Investigation of the reactor performance for phosphorus elimination was conducted at timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for reactor 1 and reactor 2 for a period of 14 days and presented in Figures 4.25, 4.26, 4.27 and 4.28.

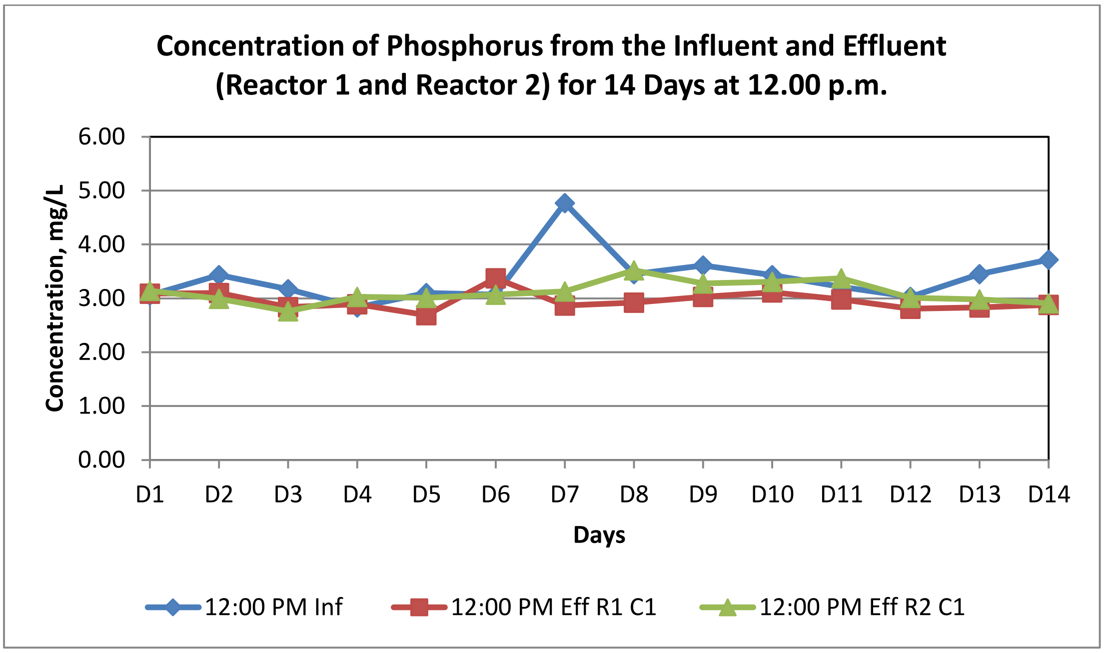


Figure 4.25 : The phosphorus concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

Figure 4.25 shows that there is not much different in the concentration. All are having almost the same phosphorus concentration. However, generally, Reactor 1 is having lower phosphorus concentration than influent and Reactor 2. Phosphorus concentration ranges from 3 to 5 mg/L in accordance to this graph.

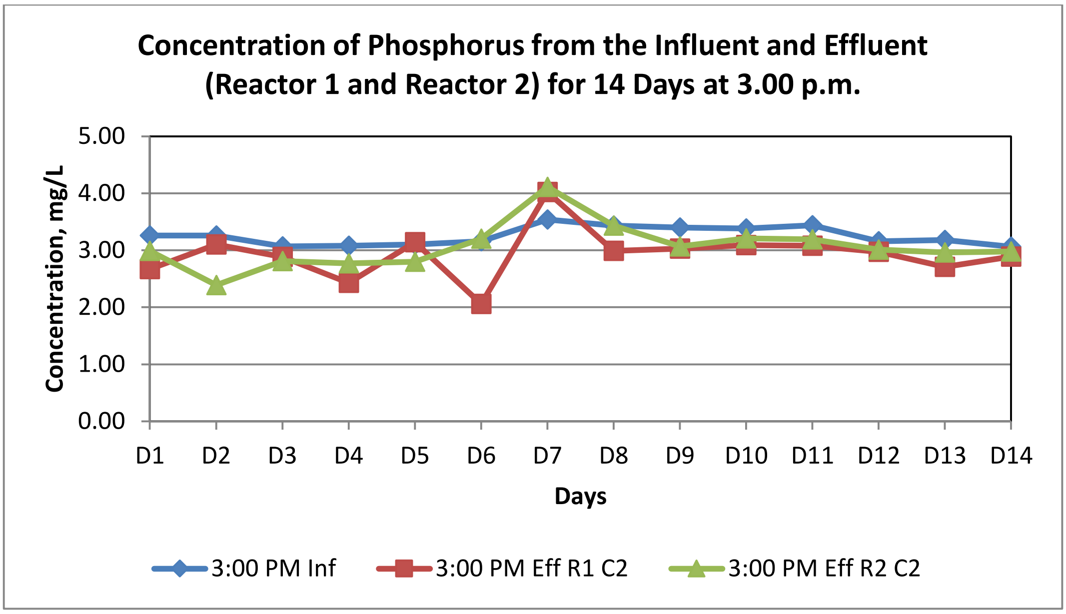


Figure 4.26 : The phosphorus concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

As shown in the graph, phosphorus is high in the influent and effluent of Reactor 1 is having lower concentration than influent as well as Reactor 2. However, on Day 2 and 5, it can be seen that Reactor 1 is having higher phosphorus than in Reactor 2. Day 7 once again recorded the highest phosphorus concentration in Figure 4.26. Overall, not much difference in the concentration is recorded.

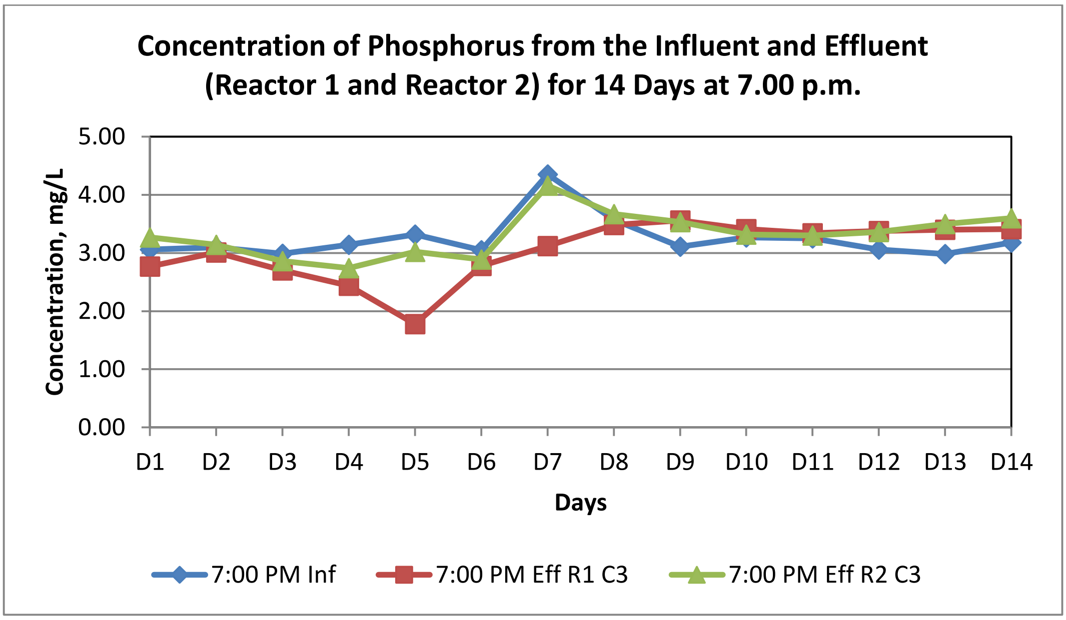


Figure 4.27 : The phosphorus concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 pm.

From Figure 4.27, the highest removal is recorded at Day 5 with Reactor 1 having 2 mg/L compared to 3 mg/L in the influent. Day 7 again recorded the highest phosphorus concentration in the influent and effluent of Reactor 2 but the removal rate in effluent of Reactor 1 is quite high. Day 9 until Day 14, it can be observed with very little difference that phosphorus concentration in both reactors is higher than the influent.

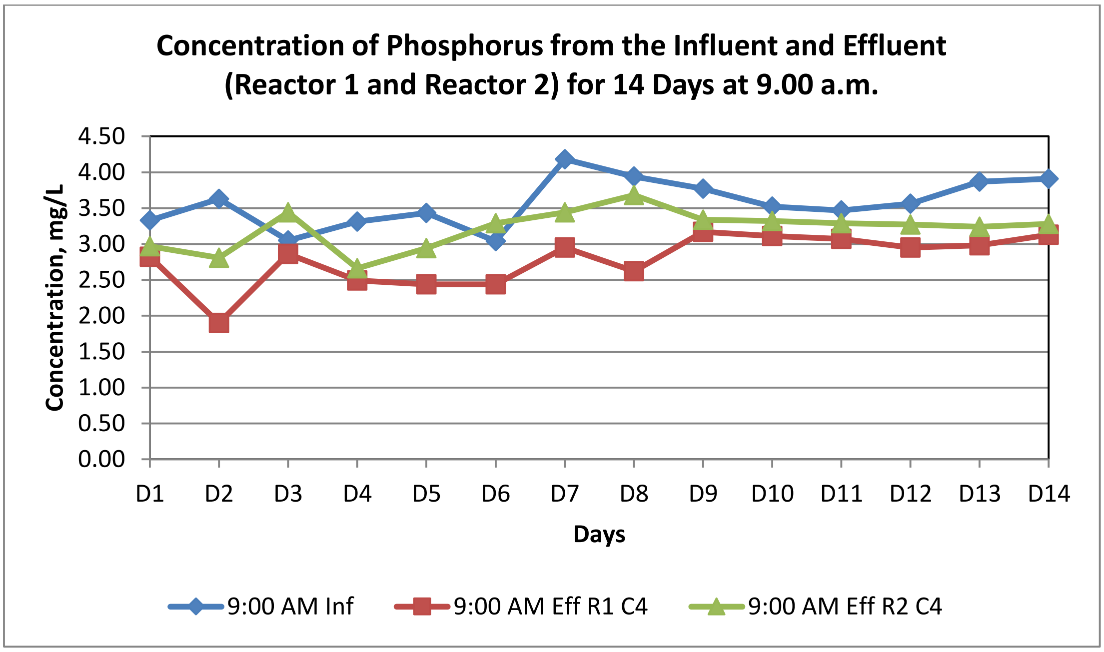


Figure 4.28 : The phosphorus concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 am (the following day).

Figure 4.28 display a quite different trend of graph where the difference in phosphorus concentration can be seen clearly. Highest removal of phosphorus was recorded on Day 2 while on Day 7, the influent has high concentration of phosphorus. This graph indicates that phosphorus removal is more significant in the reactor having water lettuce which is Reactor 1.

On the whole, Reactor 1 showed better phosphorus elimination performance when compared with Reactor 2 at all timed interval for a period of 14 days as shown from Figure 4.25- 4.28. As mentioned in ammonia above, Day 7 is having higher concentration of ammonia and phosphorus. The possibility of this to occur is that due to less microorganism activities in the aeration tank where the microbes are not utilizing the phosphorus well. This is related to the C:N:P ratio in the treatment system itself.

Phosphorus is an intermediate product of nitrification or denitrification processes and serves as nutrient for microorganisms. This could be due to the presence of the water lettuce in this reactor. The roots of plants, especially aquatic macrophytes, both emergent and submerged, work as a giant biological filter that removes organic matter of all kinds. At the same time, microorganisms residing in the submerged roots in the wastewater are degrading other pollutants that are later absorbed by the plants (de-Bashan and Bashan, 2004). Phosphorus is also needed by plant and also microorganisms in the system for their growth. Not much removal is generally seen from the results suggesting that only a small amount of microorganism is present in the system that phosphorus is only used by water lettuce to grow.

In a related study, an assessment of the contribution of *duckweed Lemna gibba*, a marcrophyte, and its associated microorganisms (algae and bacteria forming an attached biofilm) to remove nutrients showed that the biological floating mat complex (plants and microbes) is responsible for removing up to 75% of the nutrients in the wastewater. The macrophyte contributed up to 52% of phosphorus removal by its own growth; the associated organisms and microorganisms removed the rest (Korner and Vermaat, 1998).

In this study, the phosphorus elimination, especially by Reactor 1 could be attributed to filtering capacity of the water lettuce roots and its associated microorganisms.

4.4.4 Chemical Oxygen Demand (COD)

Investigation of the reactor performance for chemical oxygen demand (COD) elimination was conducted at timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for Reactor 1 and Reactor 2 for a period of 14 days and presented in Figures 4.29, 4.30, 4.31 and 4.32.

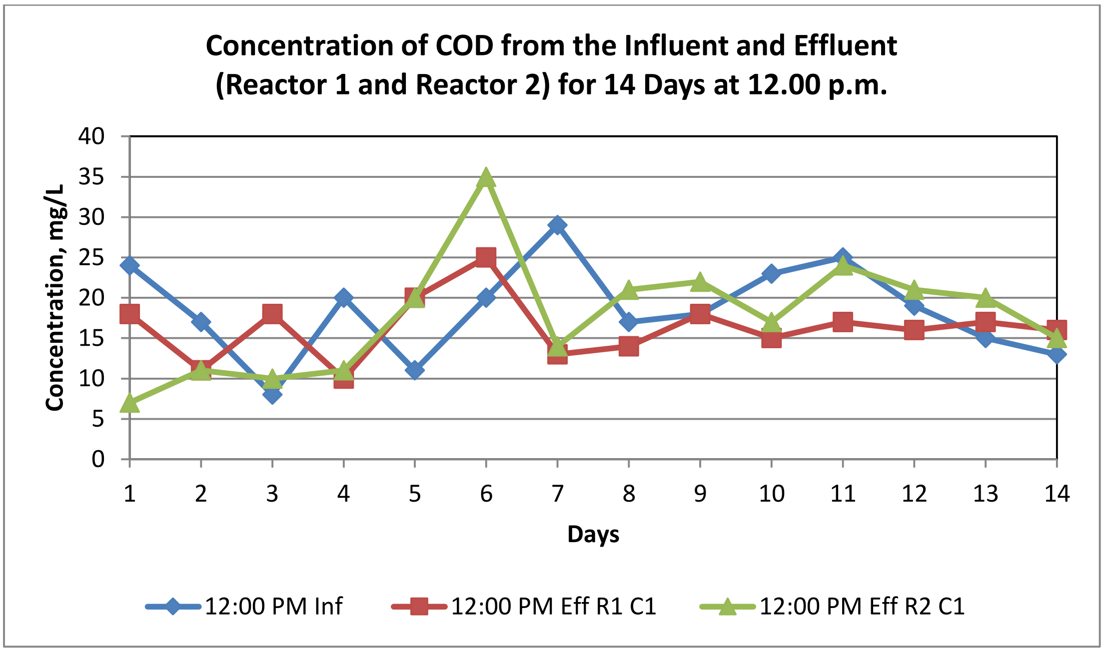


Figure 4.29 : The COD concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 12.00 p.m.

COD concentration at 12.00 p.m. is found out to be unstable throughout the study period. In the early days of the study, it can be seen that the concentration is quite not constant compared towards the end of the study period.

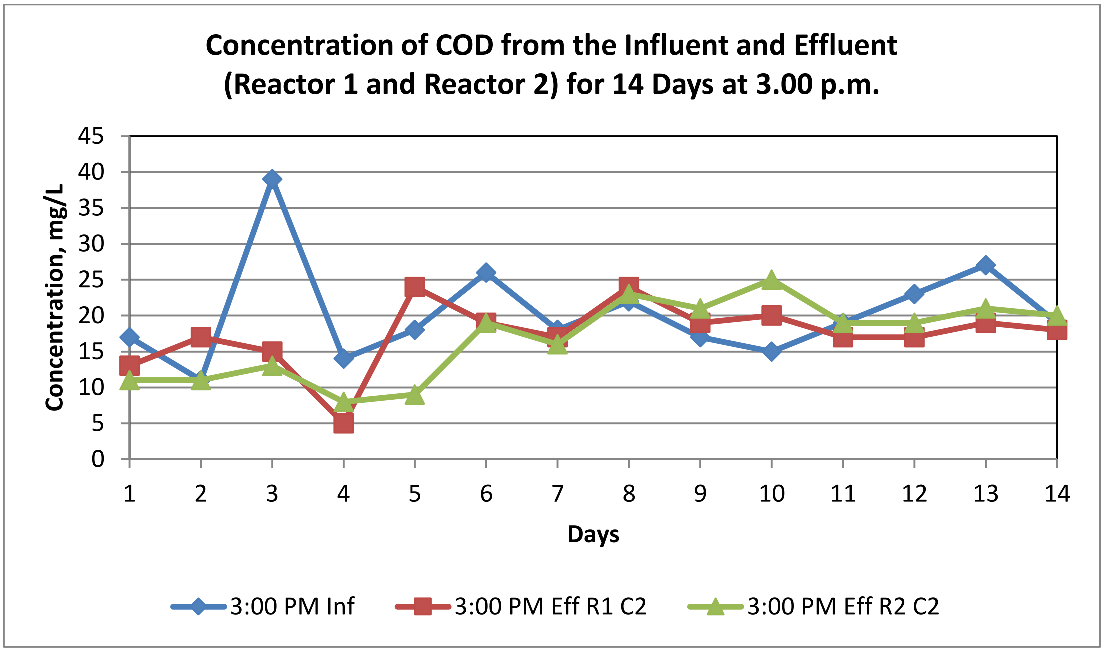


Figure 4.30 : The COD concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 3.00 p.m.

In Figure 4.30, it shows that the results are better compared to Figure 4.29 where there is not much spikes in the graph. However, the COD reading is still unstable throughout the process.

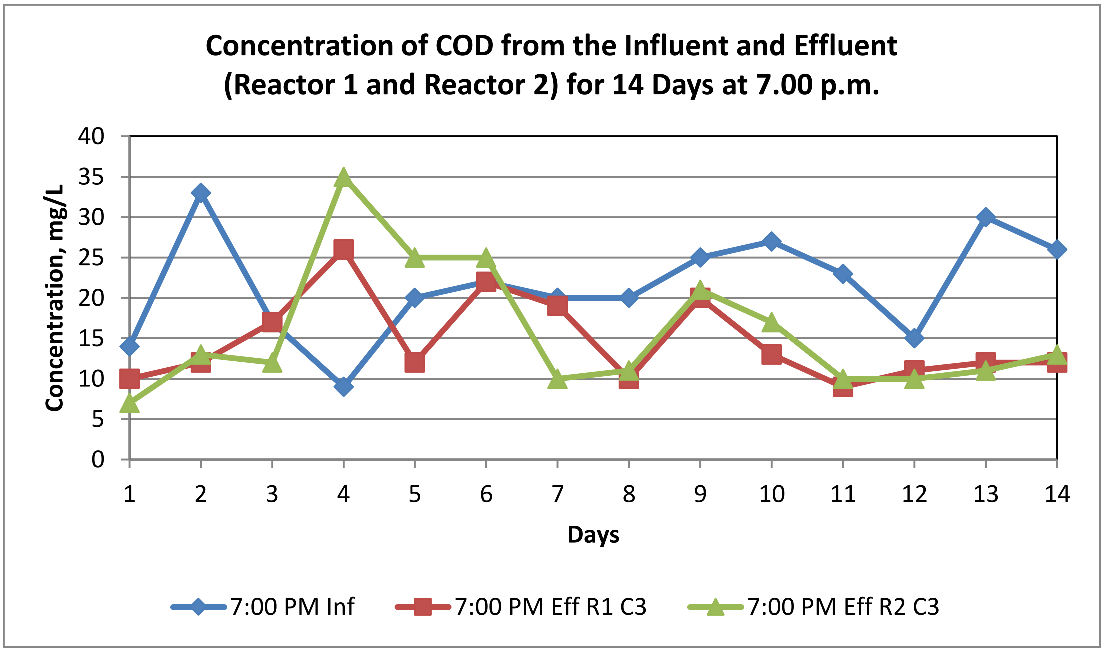


Figure 4.31 : The COD concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 7.00 p.m.

Based on figure above, low COD concentration is detected in the effluent starting on Day 7 to day 14. However, COD concentration basically is still unstable in this graph.

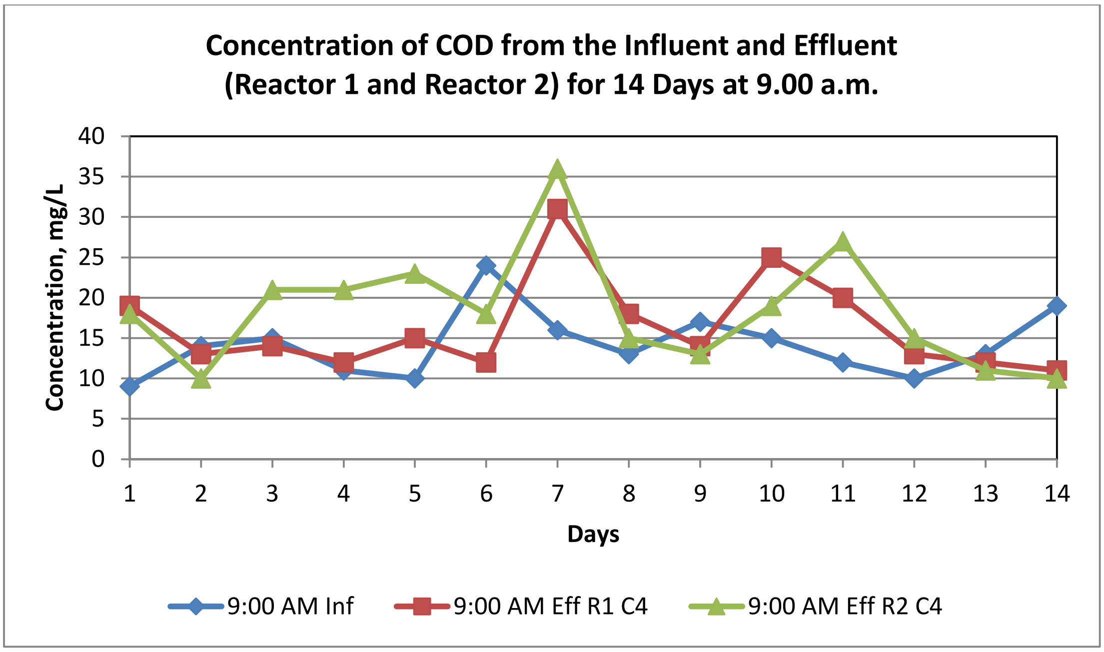


Figure 4.32 : The COD concentration from the influent and effluent (from both reactors) for the duration of 14 days, obtained at 9.00 a.m. (the following day).

For figure 4.32, it can be observed that once again, the COD reading is not stable from the start towards the end.

Generally, based on Figure 4.29 – 4.32, Chemical oxygen demand (COD) concentration is found out to be unstable in all days. Elimination was more prominent for Reactor 1 when compared with Reactor 2, although most COD removal for both reactors is negative. This could be as a result of low influent COD concentration. However, as shown in Figures 4.29 – 4.32, COD removal in reactor could be attributed to the formation of biofilm by microorganisms at the root of the water lettuce plant. This forms a complexation that promotes microbial degradation of organic matter (Lim et al., 2003). In reactor 2 (unplanted), similar COD removal trend was observed. This is in agreement with previous findings in literature where little or no difference was observed for COD removal from planted and unplanted wetlands (Wolverton et al. 1983, Roser et al. 1987).

4.5 PERCENTAGE REMOVAL OF NITRATE, AMMONIA, PHOSPHORUS AND COD

This section will highlight the results obtained from the laboratory test on the efficiency removal of the nutrients from the effluent in Reactor 1 and Reactor 2. The capacity of the system to remove the nutrients (nitrate, ammonia, phosphorus and COD) will be presented in percentage.

4.5.1 Nitrate

The percentage removal calculations were applied to nitrate removal in Reactor 1 and Reactor 2 at various timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for a period of 14 days as presented in Figures 4.33, 4.34, 4.35 and 4.36.

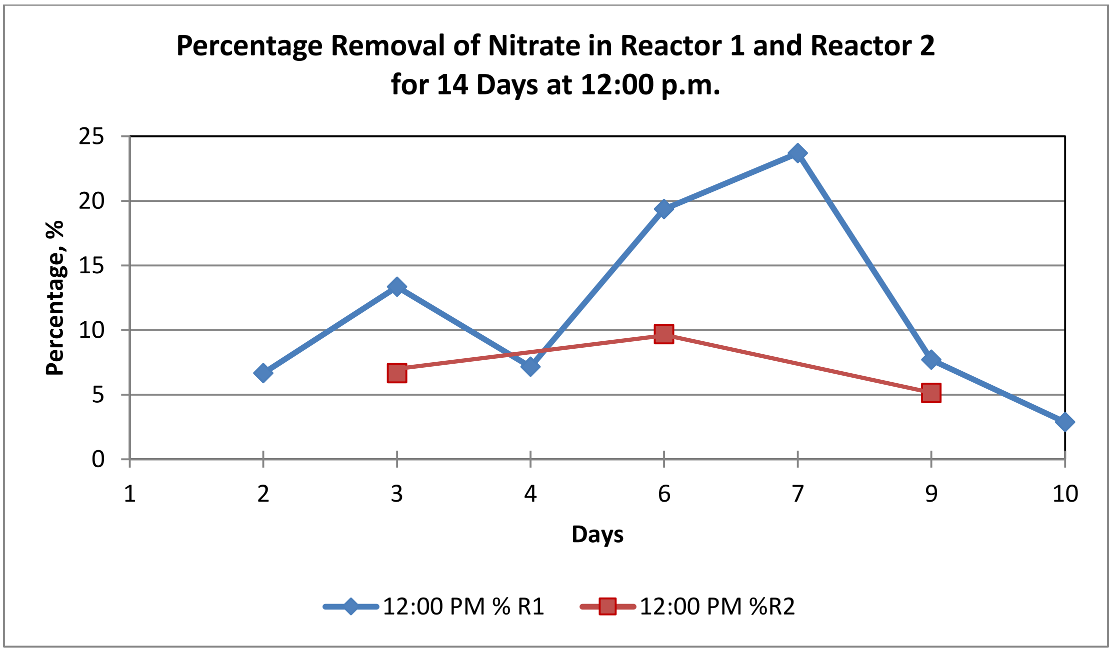


Figure 4.33 : Percentage removal of nitrate from Reactor 1 and Reactor 2 for 14 days obtained at 12.00 p.m.

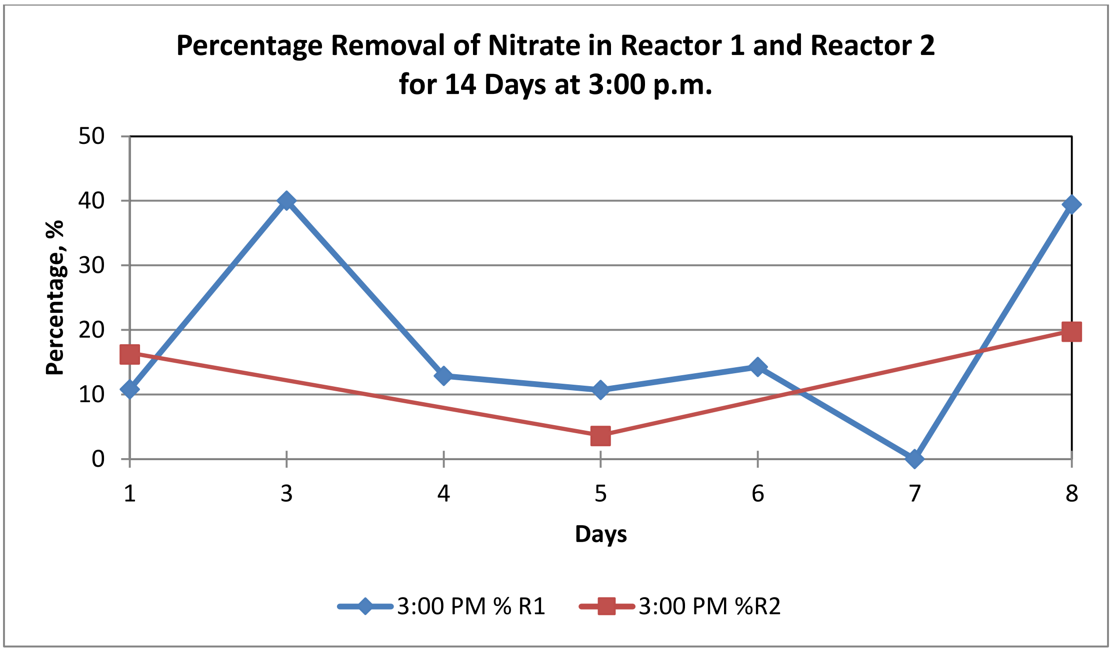


Figure 4.34 : Percentage removal of nitrate from reactor 1 and reactor 2 for 14 days obtained at 3.00 p.m.

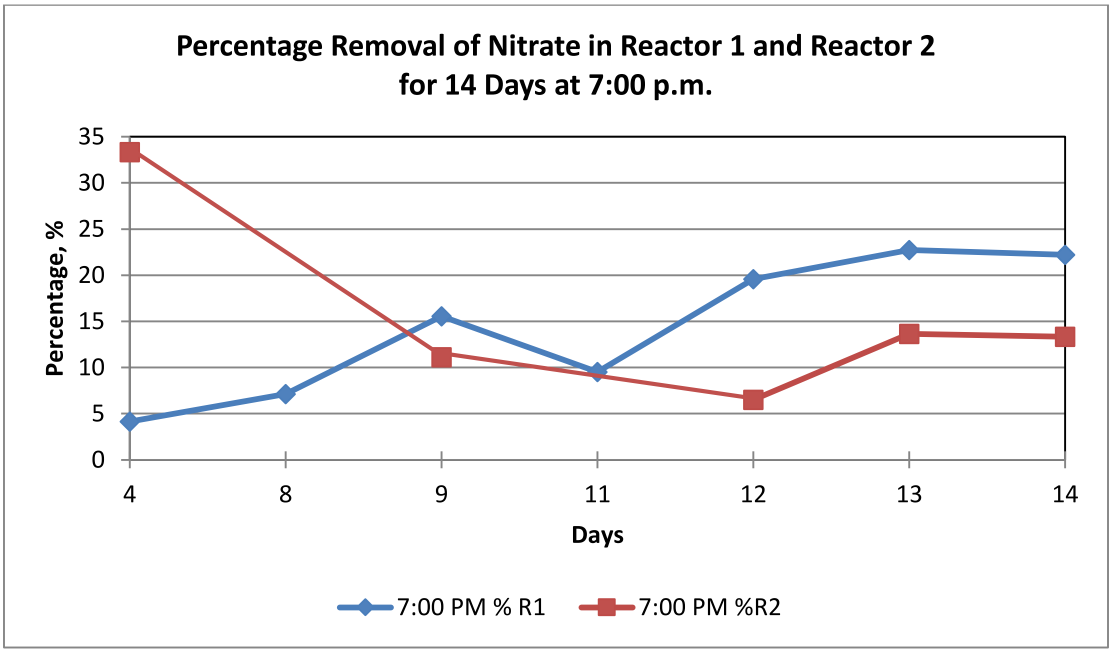


Figure 4.35 : Percentage removal of nitrate from reactor 1 and reactor 2 for 14 days obtained at 7.00 p.m.

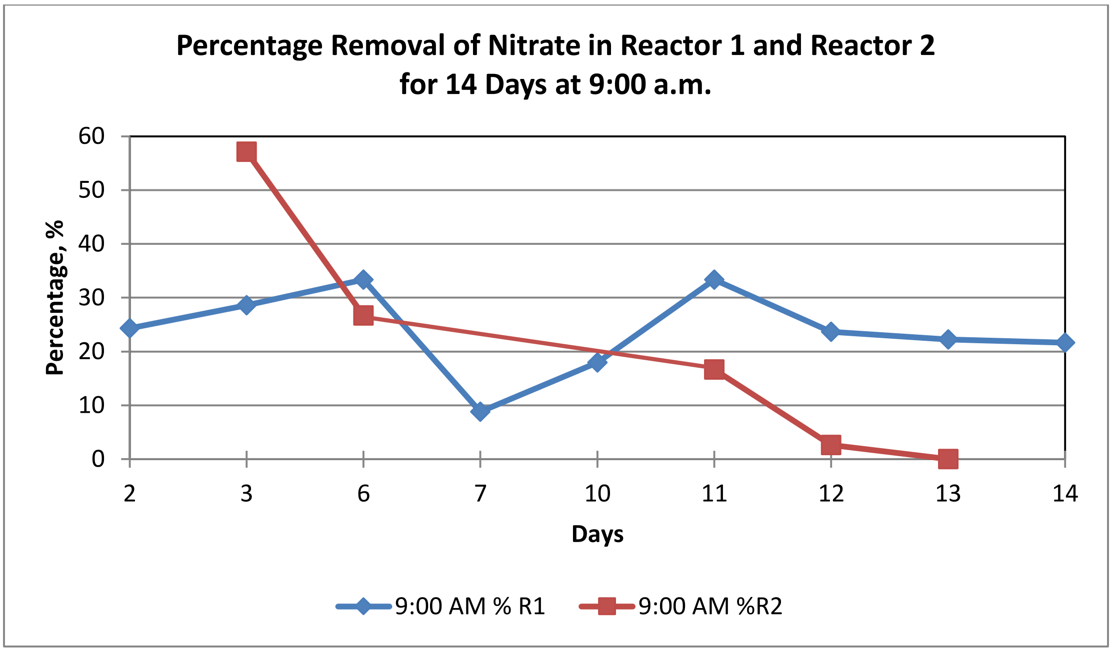


Figure 4.36 : Percentage removal of nitrate from reactor 1 and reactor 2 for 14 days taken at 9.00 a.m., the following day.

Table 4.2 : Average percentage removal of nitrate.

Time	**Average Percentage Removal, %**	
	R1	**R2**
12.00 p.m.	12	7
3.00 p.m.	15	8
7.00 p.m.	15	16
9.00 a.m.	24	26
∑	***66***	***57***

Nitrate removal in both Reactor 1 and Reactor 2 was more prominent in the initial stages of the experiment. The nitrate removal of efficiency was found within the range of 20 – 40 % for Reactor 1 for all timed intervals investigated for the period of 14 days whereas a removal efficiency of about 20 – 37 % was obtained for Reactor 2 as shown in Figures 4.33 – 4.36. Table 4.2 shows that removal of nitrate in Reactor 1 is higher than Reactor 2.

Higher nitrate removal at the initial stage could be to compensate the starving period that the plant undergone during acclimation. Thereafter, due to low organic matter concentration in the influent wastewater, concentration gradient affected nitrate uptake by the plants.

4.5.2 Ammonia

The percentage removal calculations were applied to ammonia removal in Reactor 1 and Reactor 2 at various timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for a period of 14 days as presented in Figures 4.37, 4.38, 4.39 and 4.40.

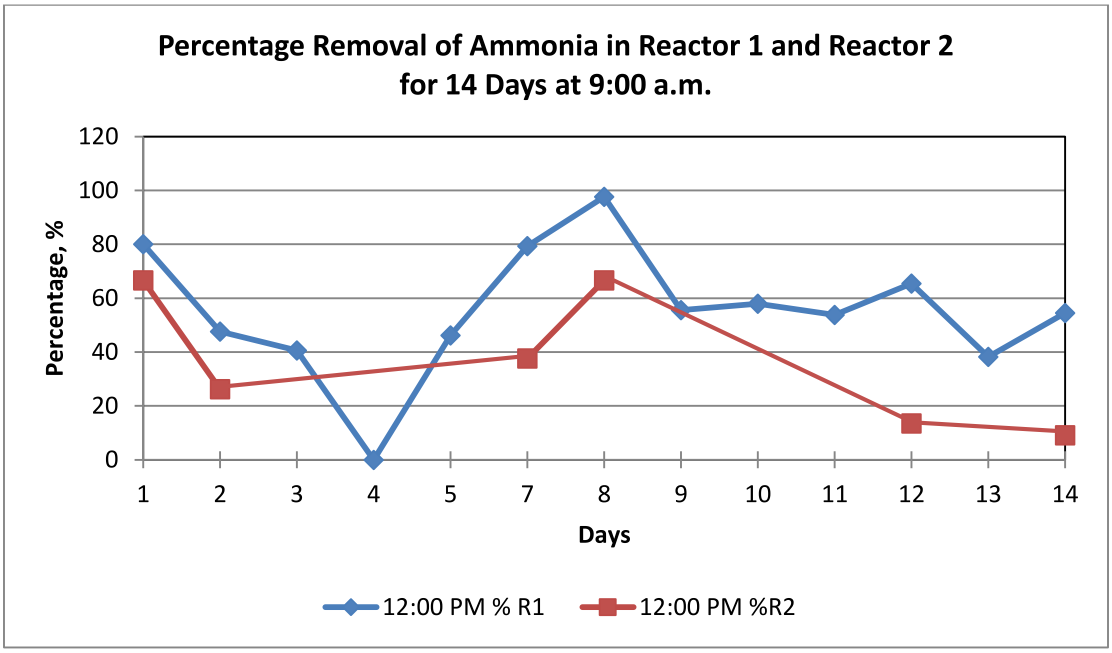


Figure 4.37 : Percentage removal of ammonia from reactor 1 and reactor 2 for 14 days obtained at 12.00 p.m.

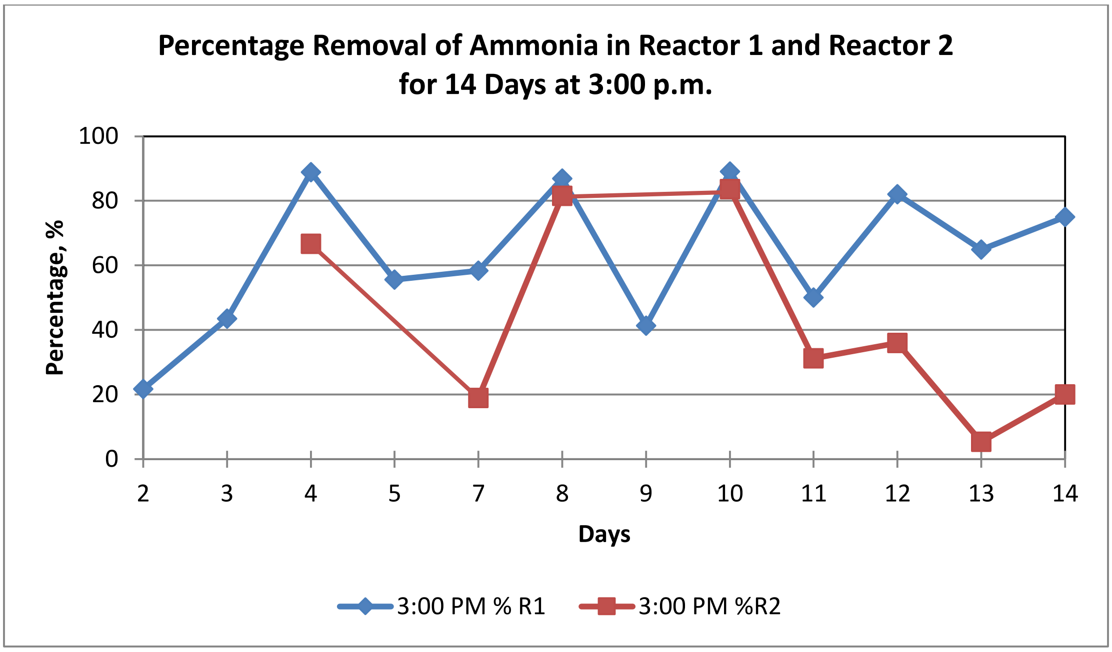


Figure 4.38 : Percentage removal of ammonia from Reactor 1 and Reactor 2 for 14 days obtained at 3.00 p.m.

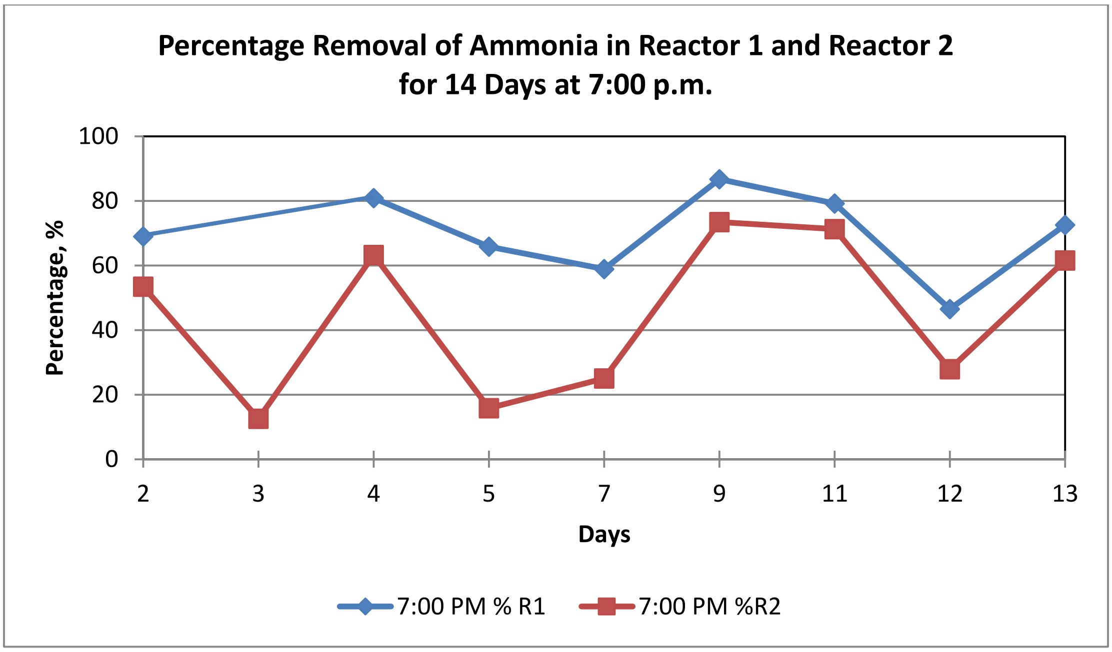


Figure 4.39 : Percentage removal of ammonia from Reactor 1 and Reactor 2 for 14 days obtained at 7.00 p.m.

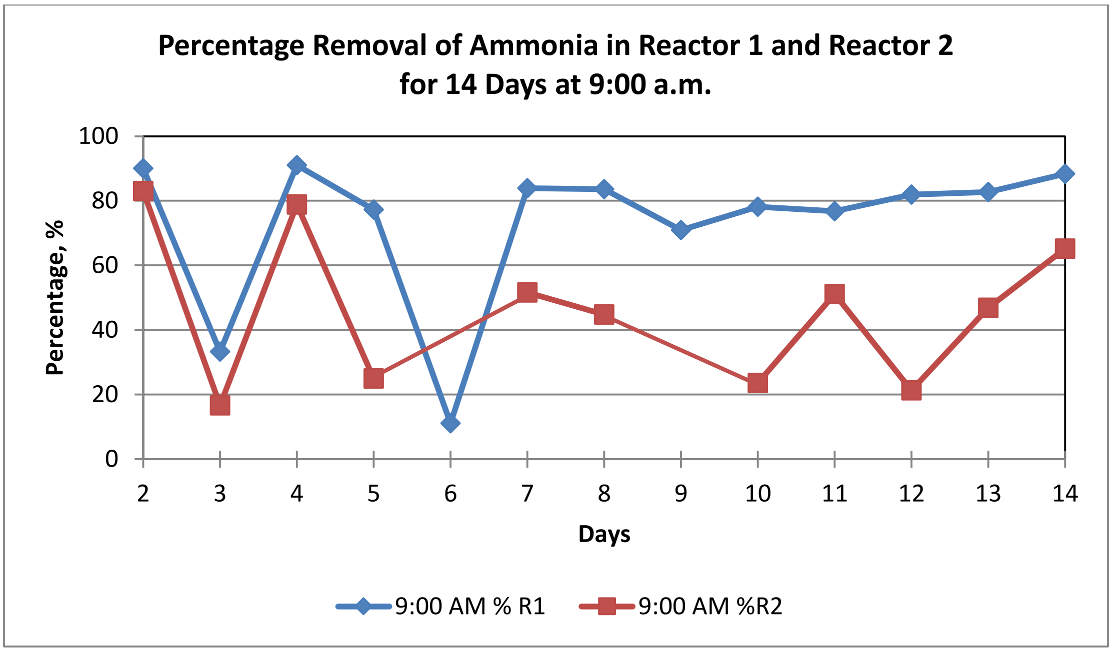


Figure 4.40 : Percentage removal of ammonia from Reactor 1 and Reactor 2 for 14 days obtained at 9.00 a.m., the following day.

Table 4.3 : Average percentage removal of ammonia

Time	**Average Percentage Removal, %**	
	R1	**R2**
12.00 p.m.	55	37
3.00 p.m.	63	43
7.00 p.m.	70	45
9.00 a.m.	73	46
$\sum$	***261***	***171***

High ammonia removal efficiency was obtained for both Reactor 1 and Reactor 2 at all experimental conditions as shown in Figures 4.37 – 4.40. However, Reactor 1 showed higher ammonia removal efficiency as a result of the presence of the water lettuce plant. The ammonia removal efficiency in Reactor 1 was in the range 30 – 95% whereas ammonia removal in Reactor 2 was in the range 30 – 80 % at all experimental conditions.

Higher ammonia removal in Reactor 1 could be explained thus: At the root or soil interface, atmospheric oxygen is transferred to the root zone through the wetland plants thus creating an aerobic layer similar to that existed at the media or water or media or air interface. Nitrification process occurs in the aerobic rhizosphere where ammonia is oxidized to nitrate which is either taken up by the plants or diffuses into the reduced zone to be converted to N_2 or N_2O by denitrification (Lim et al., 2001).

4.5.3 Phosphorus

The percentage removal calculations were applied to phosphorus removal in Reactor 1 and Reactor 2 at various timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for a period of 14 days as presented in Figures 4.41, 4.42, 4.43 and 4.44.

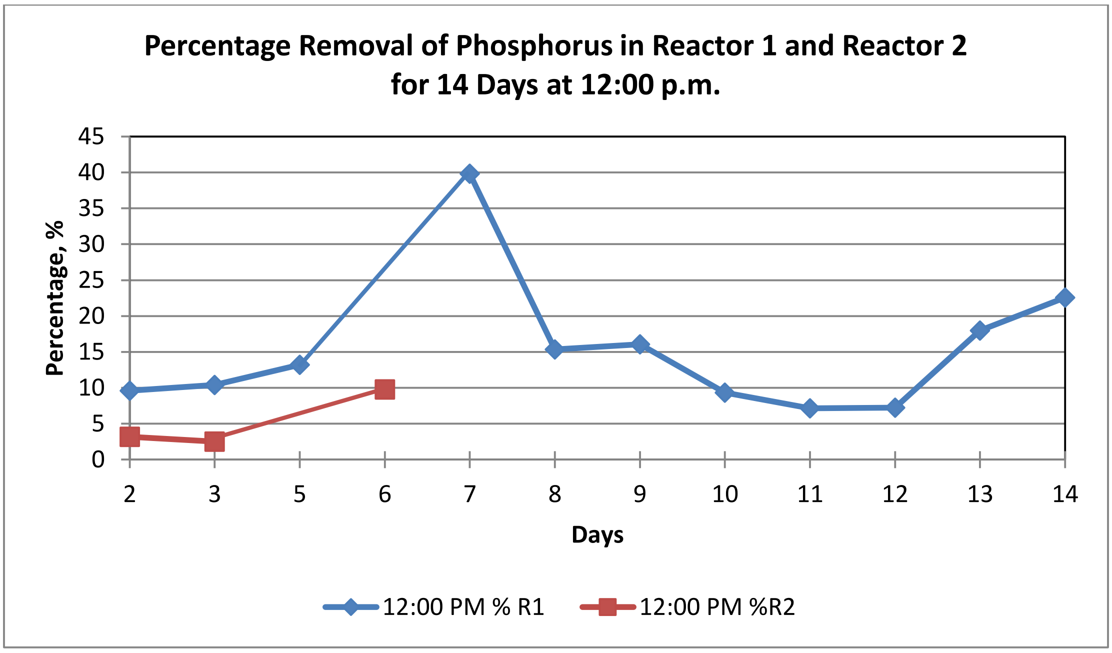


Figure 4.41 : Percentage removal of phosphorus from Reactor 1 and Reactor 2 for 14 days obtained at 12.00 p.m.

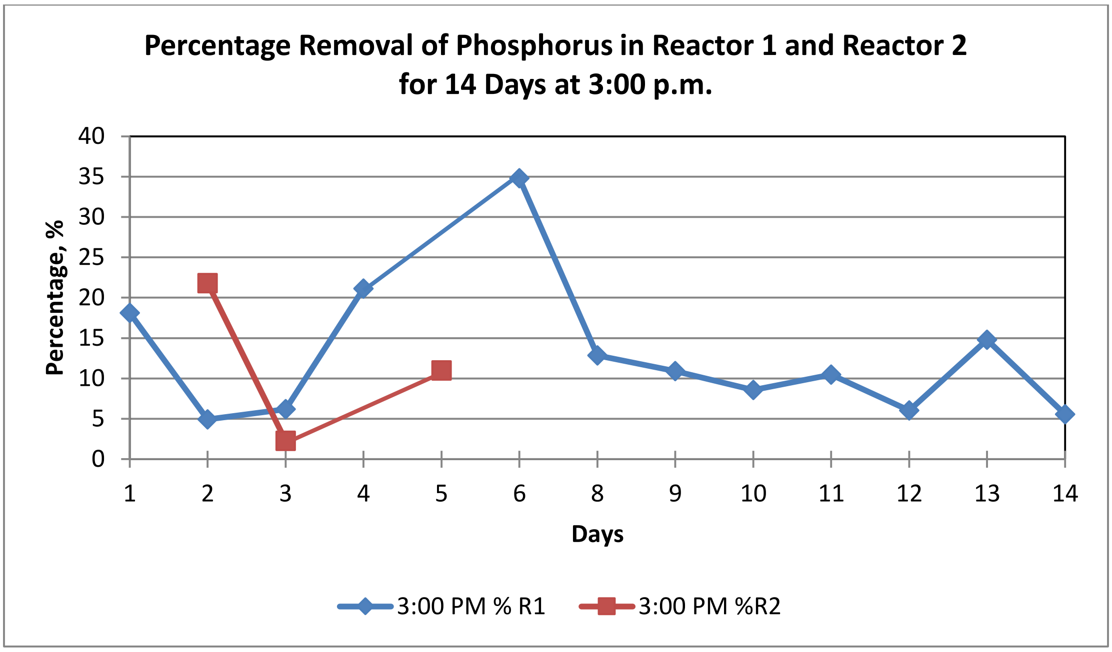


Figure 4.42 : Percentage removal of phosphorus from Reactor 1 and Reactor 2 for 14 days obtained at 3.00 p.m.

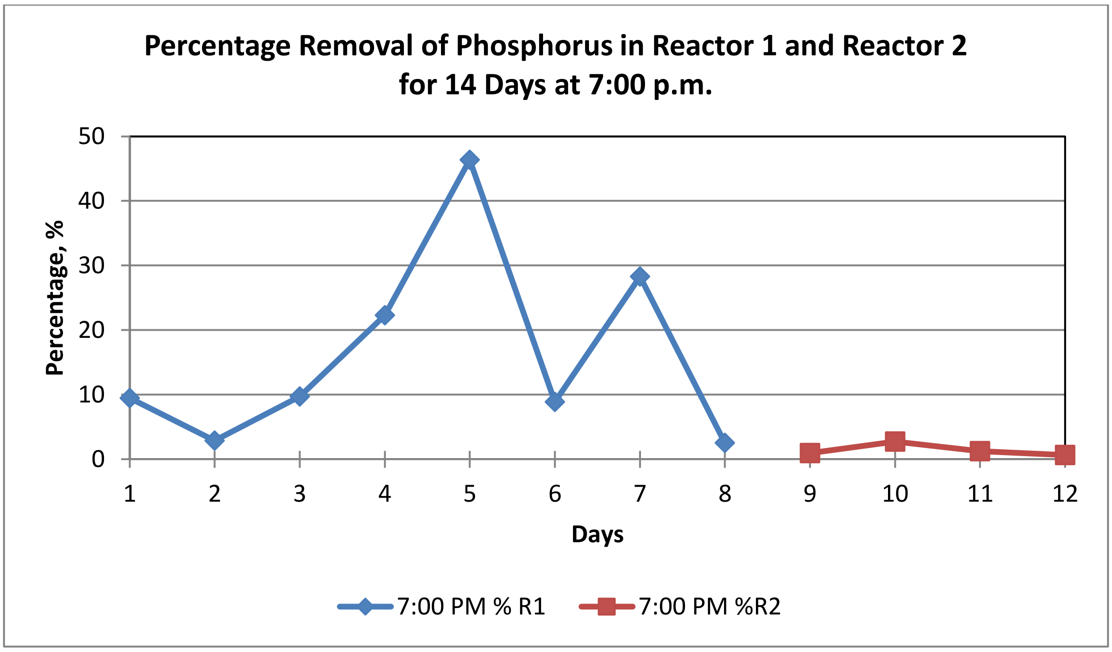


Figure 4.43 : Percentage removal of phosphorus from Reactor 1 and Reactor 2 for 14 days obtained at 7.00 p.m.

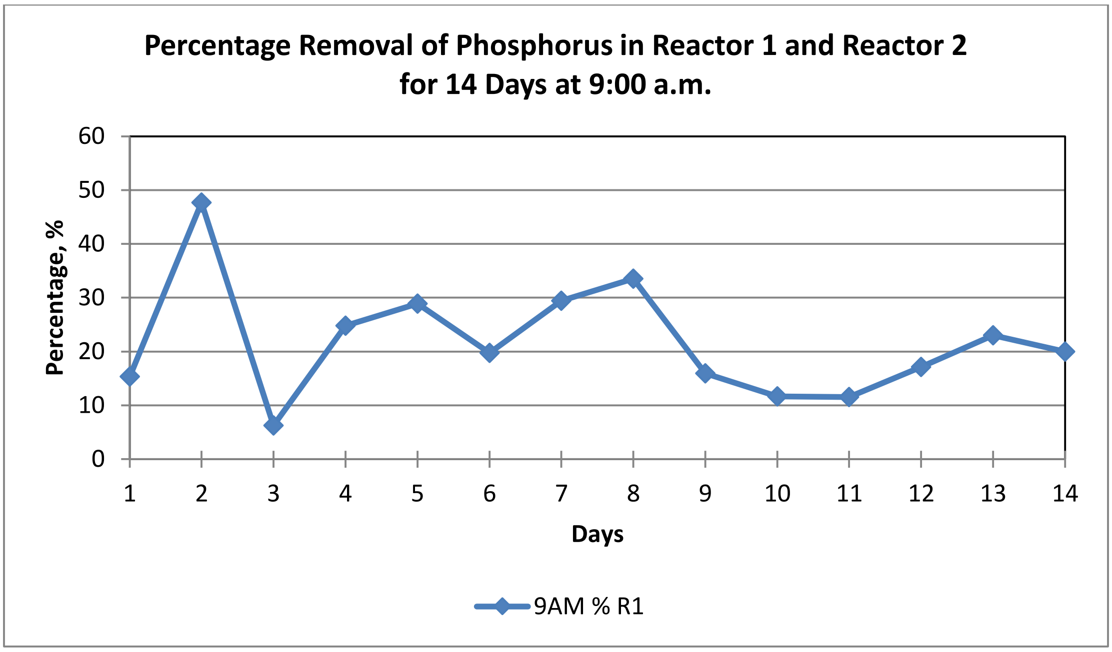


Figure 4.44 : Percentage removal of phosphorus from Reactor 1 and Reactor 2 for 14 days obtained at 9.00 a.m., the following day.

Table 4.4 : Average percentage removal of phosphorus

Time	Average Percentage Removal, %	
	R1	**R2**
12.00 p.m.	14	5
3.00 p.m.	13	12
7.00 p.m.	16	2
9.00 a.m.	22	0
∑	***65***	***19***

Phosphorus removal was more prominent in Reactor 1 than in Reactor 2. Reactor 1 showed significant phosphorus removal in all experimental conditions as shown in Figures 4.41 – 4.44. A maximum phosphorus removal efficiency of about 45% was obtained for Reactor 1 (Figure 4.41). Effective phosphorus removal in reactor has been attributed to the filtering capacity of water lettuce roots to remove organic matter.

4.5.4 Chemical Oxygen Demand (COD)

The percentage removal calculations were applied to COD removal in Reactor 1 and Reactor 2 at various timed intervals (12.00 pm, 3.00 pm, 7.00 pm and 9.00 am) for a period of 14 days as presented in Figures 4.45, 4.46, 4.47 and 4.48.

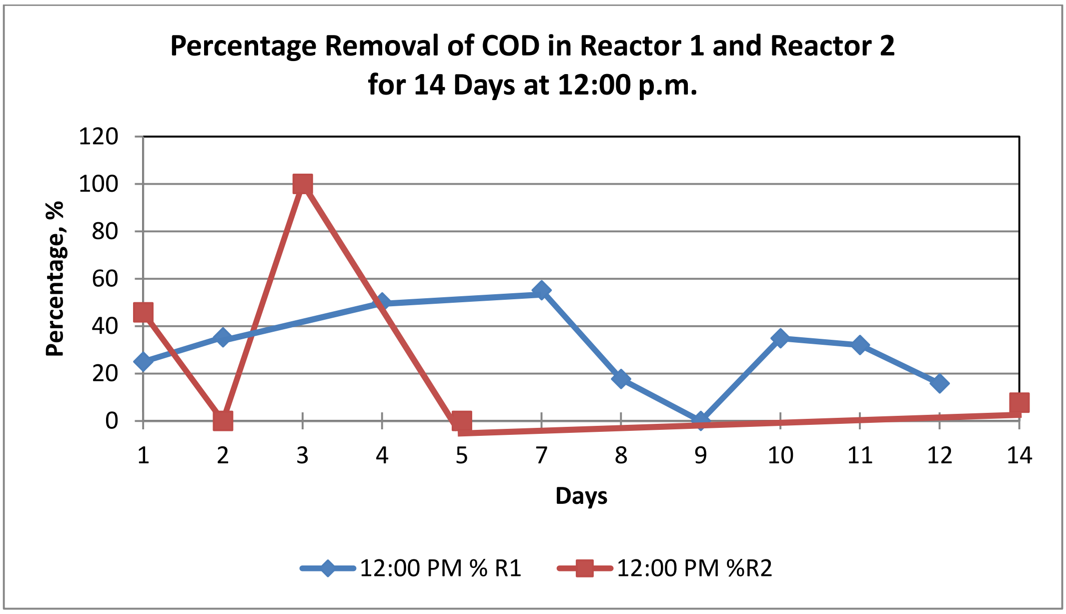


Figure 4.45 : Percentage removal of COD from Reactor 1 and Reactor 2 for 14 days obtained at 12.00 p.m.

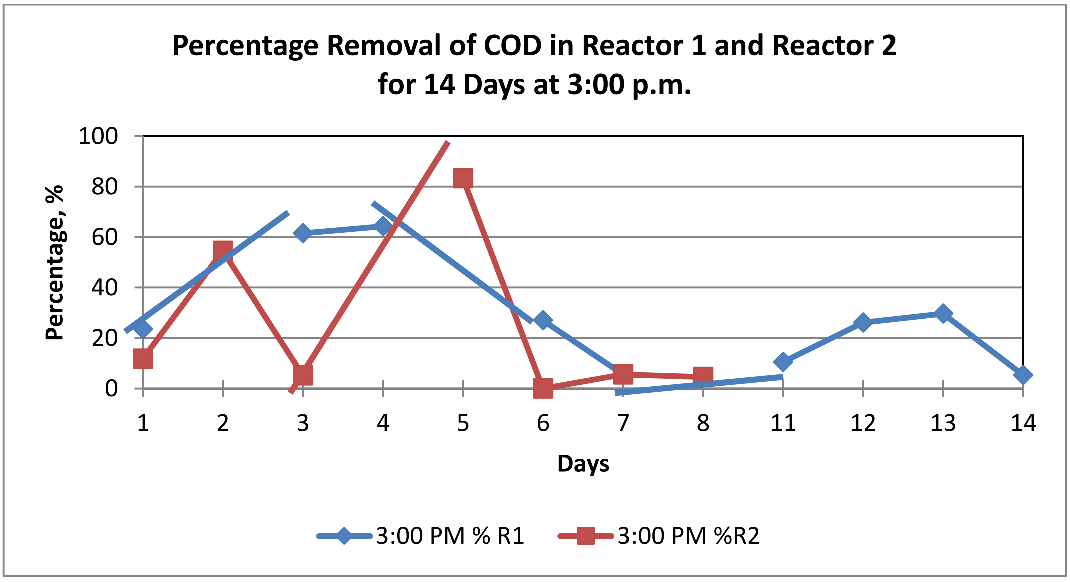


Figure 4.46 : Percentage removal of COD from Reactor 1 and Reactor 2 for 14 days obtained at 3.00 p.m.

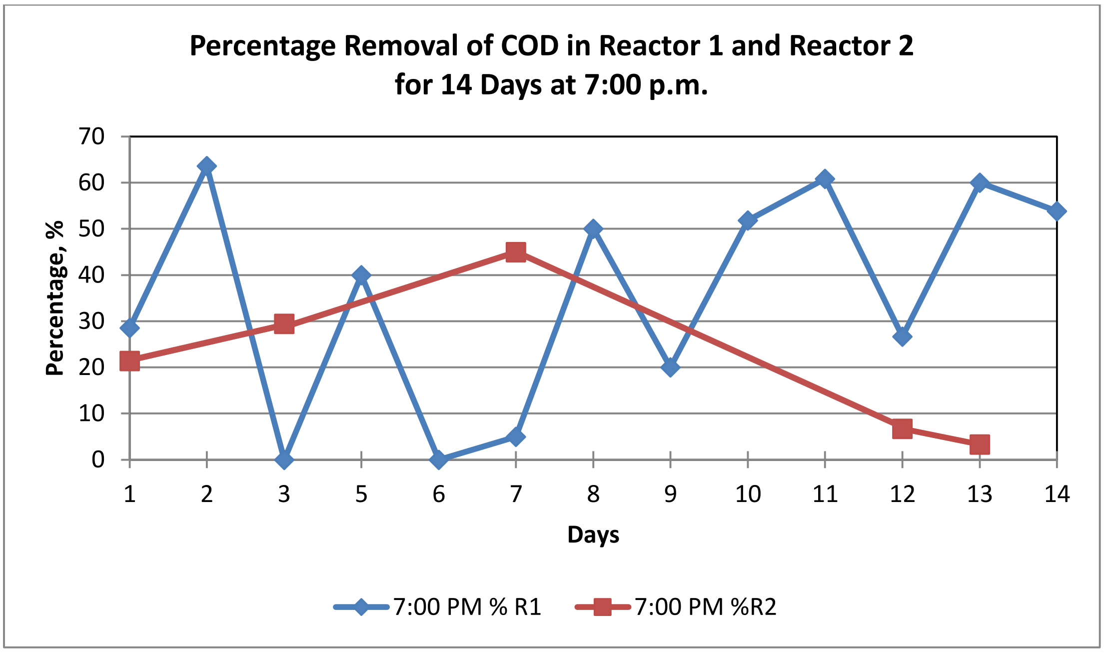


Figure 4.47 : Percentage removal of COD from Reactor 1 and Reactor 2 for 14 days obtained at 7.00 p.m.

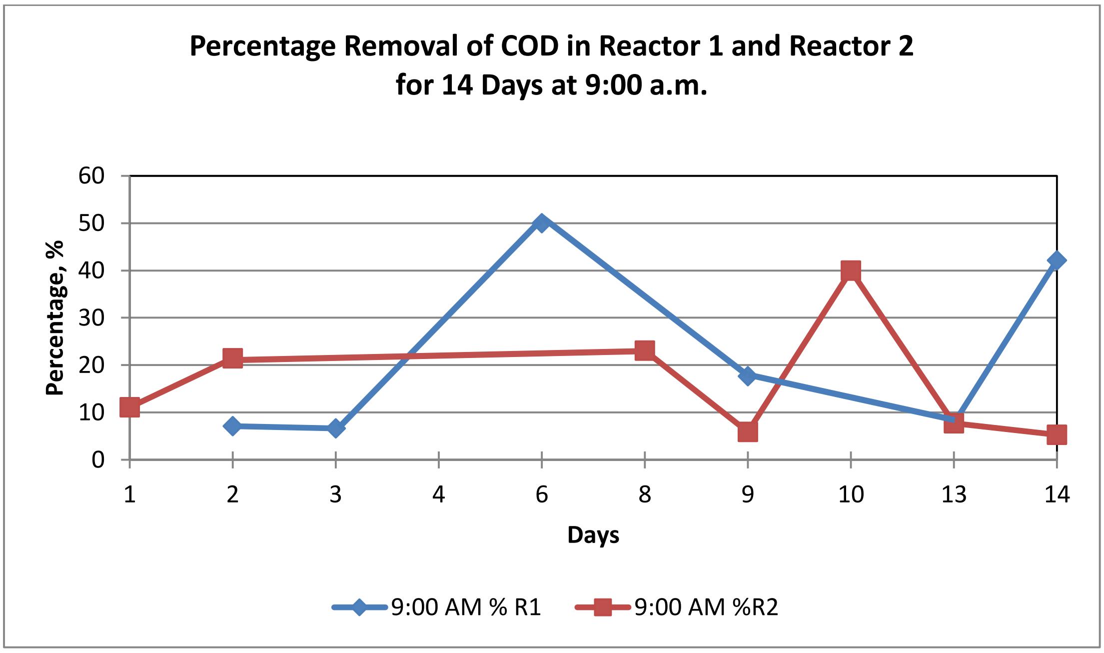


Figure 4.48 : Percentage removal of COD from Reactor 1 and Reactor 2 for 14 days obtained at 9.00 a.m., the following day.

Table 4.5 : Average percentage removal of COD

Time	**Average Percentage Removal, %**	
	R1	**R2**
12.00 p.m.	33	51
3.00 p.m.	28	28
7.00 p.m.	23	21
9.00 a.m.	22	16
∑	***106***	***116***

COD removal efficiencies is almost the same for Reactor 1 and Reactor 2 for all experimental conditions investigated. COD removal for Reactor 1 was in the range 20 – 50 % (Figures 4.45 – 4.48). COD removal in Reactor 1 has been attributed to strong complexation or chelation by the water hyacinth root that promotes microbial degradation of organic matter (Lim et al., 2003).

4.6 GROWTH OF WATER LETTUCE

In this study, only Reactor 1 is planted with the water lettuce whereas Reactor 2 is used for control purposes. 30 g of fresh water lettuce was initially put into Reactor 1 and the growth was observed throughout the experimental duration.

Table 4.6 shows the percentage growth of the water lettuce in Reactor 1 from Day 1 to Day 14. Water lettuce shows very impressive growth percentages of more than 90% in all compartments. The significance of observing the growth percentage is that it proves that the water lettuce is actually taking up the nutrients in Reactor 1. Consequently, the growth assists in the removal of nutrient from the system as the water lettuce needs nutrients especially nitrogen and phosphorus to grow.

Table 4.6 : Percentage growth of water lettuce

Compartment	**Initial weight of water lettuce, I_W (g)**	**Final weight of water lettuce, F_W (g)**	**$F_W - I_W$ (g)**	**Water lettuce growth percentage, %**
C1	30	450	420	93
C2	30	400	370	93
C3	30	500	470	94
C4	30	1300	1270	98

Both ammonia and nitrate in the end will produce nitrogen in which nitrogen and phosphorus are essential for plants, animals and microorganism to grow. Various aquatic macrophytes such as water lettuce (Pistia Stratiotes), water hyacinth (Eichhornia Crassipes), duckweed (Lemma spp.), cattail (Typha Latifolia and reed (Phragmites Communis) have been applied to remove nitrogen and phosphorus from water based on previous studies that verified their ability to survive in nutrient-laden environments and grow strong roots (Li, et. al., 2008). Sooknak and Wilkie (2004) stated that those plants' growth is rapid and effective to provide potential alternatives for treating sewage and industrial effluents.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Nutrients are necessity for any living things to grow and evolve in their life cycle. In wastewater, it is common to find nutrients like nitrogen and phosphorus in which these nutrients are important for the growth of bacteria or microorganisms and also aquatic plants.

Based on the study that has been conducted, it can be concluded that *Pistia Stratiotes* or water lettuce is effective in nutrients removal in the treated wastewater system. Higher removal rate is achieved in Reactor 1 containing water lettuce throughout the study period compared to the influent and Reactor 2 (control).

Growth percentage of the water lettuce is also observed throughout the study in relation to nutrient uptake by the aquatic plant in Reactor 1. In line with the nutrients removal rate in Reactor 1, the water lettuce growth percentage is more than 90% in every compartment and thus, this indicates that water lettuce is actually utilizing the nutrients in the treated wastewater for its growth. Therefore, both objectives are achieved.

5.2 RECOMMENDATION

For future study, it is recommended that the study is done by combining two or more aquatic plants in the same system. This is to check on the removal efficiency of whether one or a mixture of aquatic plant works better than the other in removing the nutrients in wastewater. In addition, future research may also be done using the influent or raw wastewater rather than using the treated effluent.

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APPENDIX 1

Environmental Requirements: A Guide For Investors

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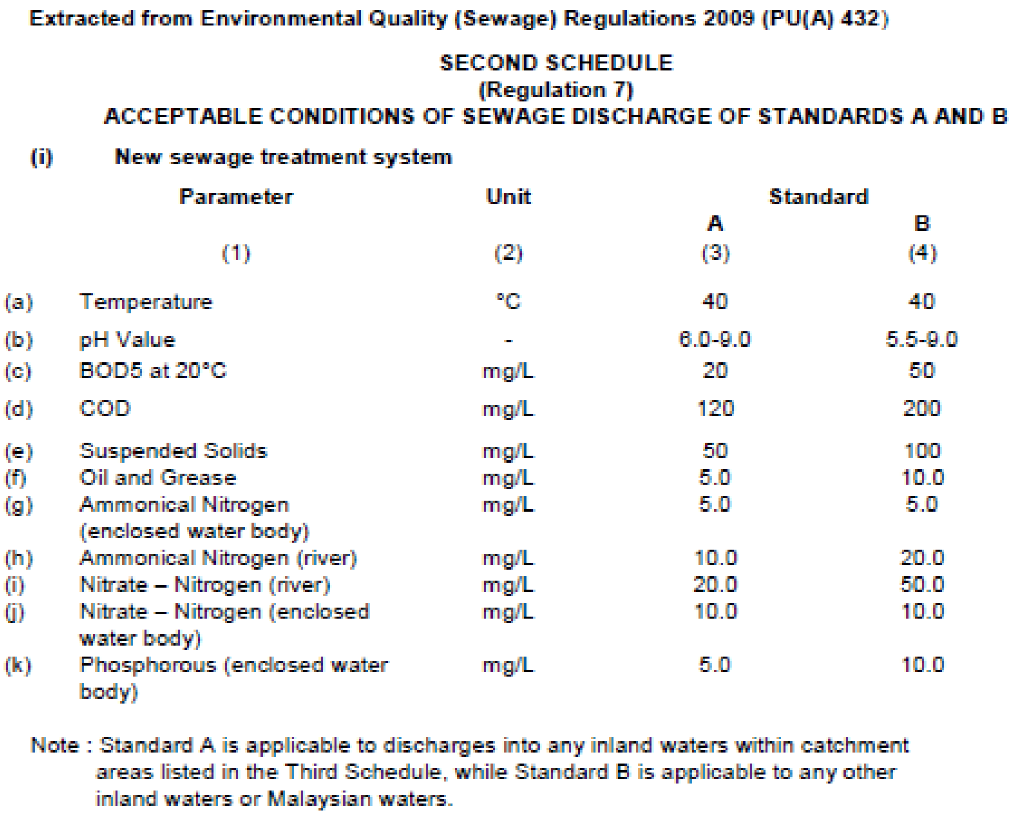

Extracted from Environmental Quality (Sewage) Regulations 2009 (PU(A) 432)

SECOND SCHEDULE
(Regulation 7)
ACCEPTABLE CONDITIONS OF SEWAGE DISCHARGE OF STANDARDS A AND B

(i) New sewage treatment system

	Parameter	**Unit**	**Standard**	
			A	**B**
	(1)	(2)	(3)	(4)
(a)	Temperature	°C	40	40
(b)	pH Value	-	6.0-9.0	5.5-9.0
(c)	BOD5 at 20°C	mg/L	20	50
(d)	COD	mg/L	120	200
(e)	Suspended Solids	mg/L	50	100
(f)	Oil and Grease	mg/L	5.0	10.0
(g)	Ammonical Nitrogen (enclosed water body)	mg/L	5.0	5.0
(h)	Ammonical Nitrogen (river)	mg/L	10.0	20.0
(i)	Nitrate – Nitrogen (river)	mg/L	20.0	50.0
(j)	Nitrate – Nitrogen (enclosed water body)	mg/L	10.0	10.0
(k)	Phosphorous (enclosed water body)	mg/L	5.0	10.0

Note : Standard A is applicable to discharges into any inland waters within catchment areas listed in the Third Schedule, while Standard B is applicable to any other inland waters or Malaysian waters.