Nitrogen and Phosphorus Removal from Effluent of Sewage Treatment Plant Using Water Lettuce (*Pistia stratiotes*)

by

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

JANUARY 2008

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2008

ACKNOWLEDGEMENT

In the Name of ALLAH the Most Merciful,

First of all thanks to Allah for the blessings and opportunity given to undertake this project. Without His blessings and mercy, the project will not be successfully completed.

Highest gratitude to the supervisor, Assoc. Prof. Dr Shamsul Rahman Mohamed Kutty for the acceptance of supervising the project, his guidance, encouragement and useful knowledge in overcoming the many problems encountered during this project.

Thanks also to all Civil Engineering Department lecturers and technicians, especially Mr. Anuar for the help and assistance in completion of this project study. Not forgetting the FYP committee and coordinators who are responsible to ensure the success in conducting the final year project for these two semesters.

Last but not least, thanks to everyone who involved directly and indirectly in order to ensure the success of this final year project. Their help, support and guidance are highly appreciated.

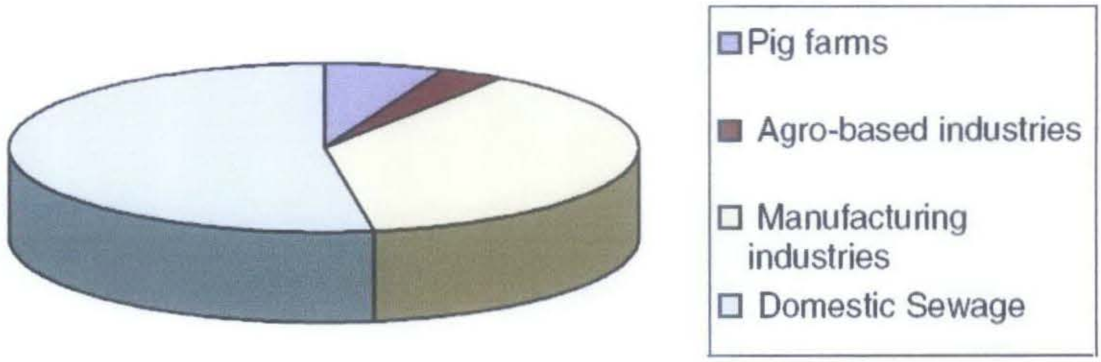


FIGURE 1: Distribution of water pollutants by source DOE, 2004, p.53 [20]

Although our country has wastewater treatment plant, the main problem is it cannot be classified as world class standard. It means some compounds which can harm the environment still exist in the river although wastewater was treated by treatment plant. For example the amount of the nutrient components which are nitrogen and phosphorus still contain in our UTP sludge treatment plant effluent. The main effect is the rivers become toxic to aquatic organisms and polluted to environment life.

1.2 Problem Statement

Eutrophication is frequently a result of nutrient pollution (means an increase in chemical nutrients typically compounds containing nitrogen or phosphorus in an ecosystem) such as the release of sewage effluent and run-off from lawn fertilizers into natural waters (rivers or coasts), where the water becomes cloudy, colored a shade of green, yellow, brown, or red and then the river becomes toxic to aquatic life like fish. Beside that, human society is impacted as well, where health-related problems can occur where eutrophic conditions interfere with drinking water treatment. The main problem which occurs before deciding to have this project is because our UTP Sewage Treatment Plant (STP) effluent still discharged to the nearest river with nitrogen and phosphorus compounds. If we don't take any action to remove this type of compounds, this problem maybe can cause eutrophication to occur.

CHAPTER 2
LITERATURE REVIEW

2.1 Nitrogen and Phosphorus

Nitrogen exists in many forms because of the high number of oxidation states it can assume. In ammonia and organic nitrogen compounds, which are forms most closely associated with plants and animals, its oxidation state is -3. At the other extreme, when nitrogen is in the nitrate form, its oxidation state is +5 [2]. The presence of nitrogen in a wastewater discharge can be undesirable as free ammonia it is toxic to fish and many other aquatic organisms; as ammonia it is an oxygen-consuming compound which will reduce the dissolved oxygen in the river. In all forms, nitrogen can be available as a nutrient to aquatic plants and consequently contribute to eutrophication. Where the nitrate ion it is a potential public health hazard in water consumed by infants [2].

The standard criteria limit for Nitrate-nitrogen in the river according to US Environmental Protection Agency is 10 mg/L, but according to State of the Minnesota River the limit is 6.5 mg/L.

Phosphorus is essential to the growth of algae and other biological organisms. Because of noxious algal blooms that occur in surface water, there is presently much interest in controlling the amount of phosphorus compounds that enter surface waters in domestic and industrial waste discharges and natural runoff like river. Municipal wastewaters may contain from 4 to 16 mg/L of phosphorus [2]. The usual forms of phosphorus that are found in aqueous solutions include:

a. Orthophosphate - Orthophosphoric acid has three hydrogen atoms bonded to oxygen atoms in its structure. All three hydrogens are acidic to varying degrees and can be lost from the molecule as H^+ ions (alternatively referred to as protons) [2]. When all three H^+ ions are lost from orthophosphoric acid, an orthophosphate ion ($PO4^{-3}$) is formed [2].

2.3 Aquatic Plants

Aquatic plants also called *hydrophytic plants* or *hydrophytes* are plants that have adapted to living in or on aquatic environments [5]. Because living on or under the water surface requires numerous special adaptations, aquatic plants can only grow in water or permanently saturated soil [5].

Aquatic plants provide protection and spawning areas for the fish and other aquatic organisms, and they use up nutrients or in other words as nutrients removal agent [5]. Besides that, they also shade sunlight that would otherwise promote the growth of unsightly algae. Aquatic plants also can use up large amounts of carbon dioxide and produce oxygen during daylight hours through the process of photosynthesis [5]. Aquatic plants can be broken down into 3 categories [5]:

i. Floating plants – water lilies, water lettuce, lotus etc.
ii. Submerged plants - elodea, also known as anacharis, and hornwort.
iii. Marginal or bog plants - cattails, sweet flag, rush, and iris.

All plants will need additional nutrients to have lush growth and stimulate flowers. The addition of unnecessary nutrients to the water will promote algae blooms [5]. Potted plants must be provided with the correct balance of nutrients to obtain complete growth and colorful flowers [5].

2.4 Water Lettuce ('Kiambang')

Pistia is a genus of aquatic plant in the family Araceae, comprising a single species, ***Pistia stratiotes,*** often called water cabbage or water lettuce [6]. Its native distribution in uncertain, but probably pantropical; it was first described from the Nile near Lake Victoria in Africa [6]. It is now present, either naturally or through human introduction, in nearly all tropical and subtropical fresh waterways. Water lettuce is not winter-hardy; its minimum growth temperature is 15 °C (59 °F); its optimum growth temperature is 22-30 °C (72-86 °F); its maximum growth temperature is 35 °C (95 °F) [13].

Compare to water hyacinths as it was very widely researched and practically used in many water bodies, it was found that the specific growth rate of water lettuce was slightly higher in dry season, and in rainy season the growth rate of water hyacinths decreased almost 70%, but the rate of water lettuce decreased only 45% [7].

Besides that, water lettuce is often used in tropical aquariums to provide cover for fry and small fish. It is also helpful as it out competes algae for nutrients in the water, thereby preventing massive algal blooms [6].

2.5 Algae

Algae apply to a diverse group of eucaryotic (containing a nucleus enclosed within a well-defined nuclear membrane) microorganisms that share similar characteristics [15]. They are unicellular to multi-cellular plants that occur in freshwater, marine water, and damp environments and range in size from minute phytoplankton to giant marine kelp [15]. Algae possess chlorophyll, the green pigment essential for photosynthesis, and often contain additional pigments that mask the green colour (e.g., fucoxanthin (brown) and phycoerythin (red)) [16] [17]. The lifecycle of algae ranges from simple, involving cell division, to complex, involving alternation of generations. Algae are primary producers of organic matter which animals depend on either directly or indirectly through the food chain (APHA, 1995).

Typically, algae are autotrophic (derive cell carbon from inorganic carbon dioxide), photosynthetic (derive energy for cell production from light), and contain chlorophyll [15]. They are also chemotrophic in terms of nighttime respiration, e.g., metabolism of molecular oxygen (O2). Algae utilize photosynthesis (solar energy) to convert simple inorganic nutrients into more complex organic molecules. Photosynthetic processes results in surplus oxygen and non-equilibrium conditions by producing reduced forms of organic matter, i.e., biomass containing high-energy bonds made with hydrogen and carbon, nitrogen, sulphur, and phosphorus compounds. The organic matter produced serves as an energy source for non-photosynthetic or heterotrophic organisms (animals, including most bacteria, which subsist on organic matter).

CHAPTER 3
METHODOLOGY

3.1 Reactor Setup

The study was carrying out by experimenting sewage treatment plant sample from UTP. Two reactors (Reactor A and B) were made with the dimension is 40 cm x 90cm x 25cm (w x l x h). The volume of the water is 68676 cm^3 [40 cm x 88.5 cm x 19.4 cm (w x l x h)]. Both reactors were divided into three sections (Section 1, Section 2 and Section 3) where the volume of water in every section is 22892 cm^3. After that, the system was setup in the UTP Sewage Treatment Plant near to the drain of effluent. The Reactor A will start with fifteen Water Lettuces (five Water Lettuces in each section), and the Reactor B as the controller.

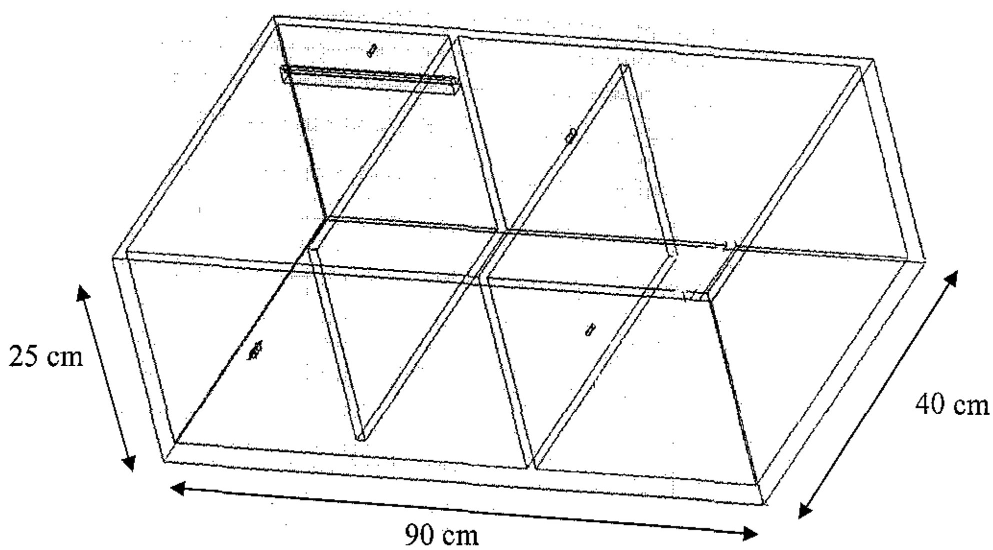


FIGURE 4: 3-D view of the reactor

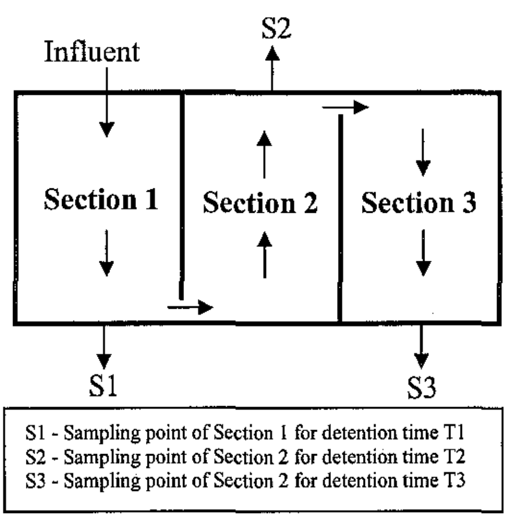


FIGURE 5: Plan view of the reactor

Then, the STP effluent which is an influent of the system was pumped directly from the drain of STP effluent into both reactor, and continuously flow with the rate of 8000 mL/day. The detention time of the whole system (T3) was 9 days (with T1 = 3 days and T2 = 6 days). After that, the effluent point from every section of both reactors will be the sample where the tests were done on them.

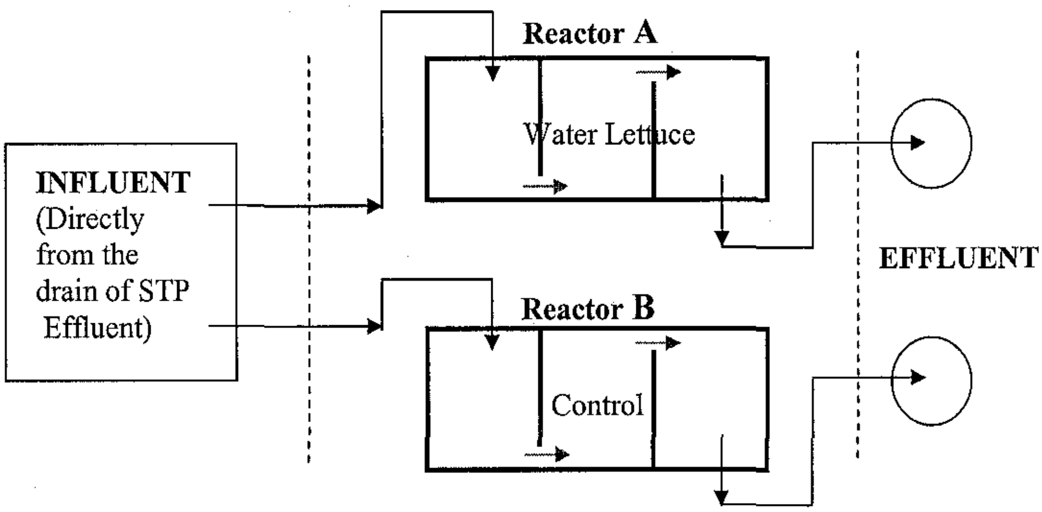


FIGURE 6: Flow of the project system

The samples were taken for sampling every two days for a four-week period and the COD test, Ammonia test, Nitrate test, Phosphorus test was done on those samples. Besides that, the growths of the plants also was monitored to make sure either the plants can live or not by monitoring numbers of new water lettuce and taking the pictures every sampling day.

3.2 Measurement of COD (Standard Method 5220 D)

First, 2 mL of sample was put into a test tube or vial that contained potassium dichromate solution ($K_2Cr_2O_7$) in sulfuric acid. The vial was shaken properly until heat was produced indicating an exothermic process. Then the same procedures were repeated for another sample. Thermo reactor was set at 150 °C. After it heated at elevated temperature, the vials were placed into the thermo reactor for 2 hours together with blank sample and COD standard. Two hours later, after the vials cold in the room temperature, the samples were tested for the COD using spectrophotometer. Three readings were taken and calculated the average for results.

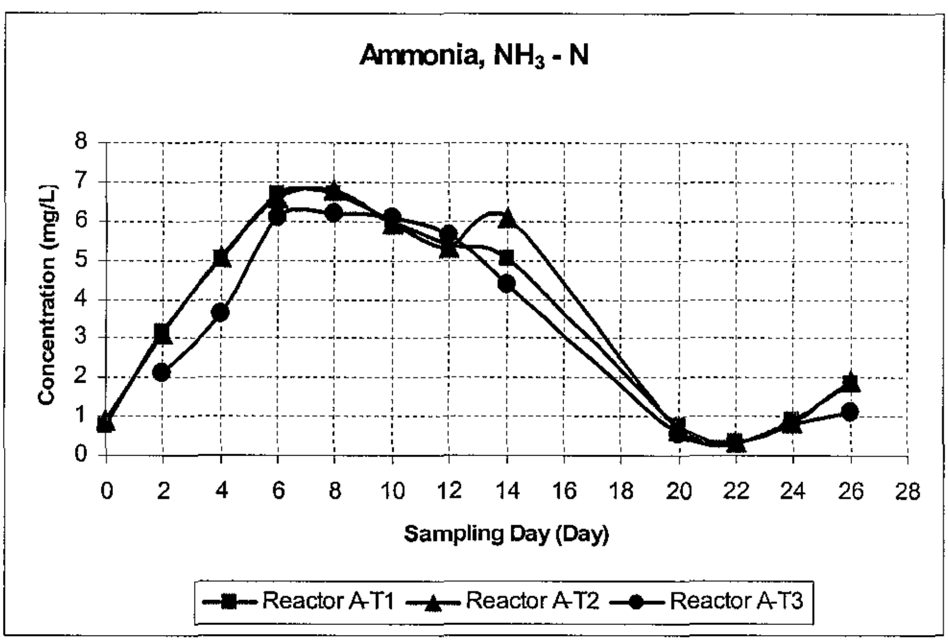
3.3 Measurement of Ammonia (Nessler Method) (Standard Method 4500-NH_3 B & C)

A 50 mL cylinder was filled to the 25 mL mark with the sample. Then, the sample from that cylinder was pour into the 125 mL volumetric flask. Then the same procedures were repeated for the blank preparation by using distilled water instead the sample. After that, three drops of Mineral Stabilizer were added to each volumetric flask, and then both were shaking for several times to mix. After that, three drops of Polyvinyl Alcohol Dispersing Agent also were added to each volumetric flask, and then both were shaking for several times to mix. Then, by using Tensette pipette, 1.0 mL of Nessler Reagent was put into both volumetric flasks. The timer was started for a one-minute reaction period. After that, 10 mL of each solution was pour into a 10 mL square sample cell. When the timer expires, the blank was wiped and inserted into the cell holder of DRB 2500 device with the fill line facing right, and the reading was taken. The same procedures were repeated for another sample. Three readings were taken and calculated the average for results.

From Figure 9, there is no a big difference of COD concentration between detention time T1 and detention time T2 for both reactors. Beside that, from week one to week three the COD of detention time T3 for Reactor A is higher than detention time T1 and detention time T2 for Reactor A. It also happened to Reactor B in week three.

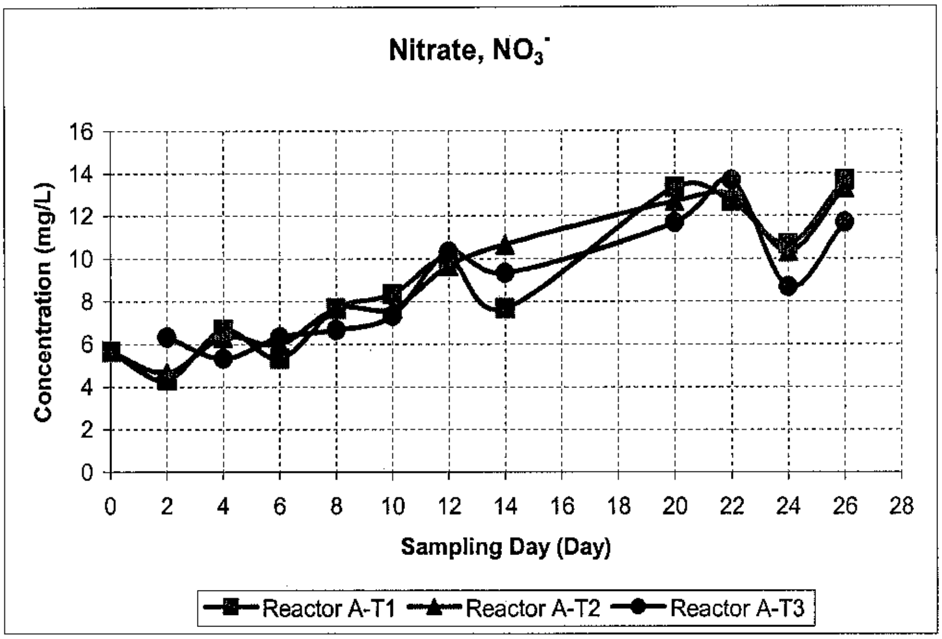
Based on statistical analysis conducted on detention times T1, T2, and T3 of Reactor A and Reactor B for COD concentration at 5% level of significance it was found that there is no significant difference between detention time T1 and detention time T2, detention time T2 and detention time T3, and detention time T1 and detention time T3.

4.3.2 Ammonia Results for Detention Time T1, T2 andT3

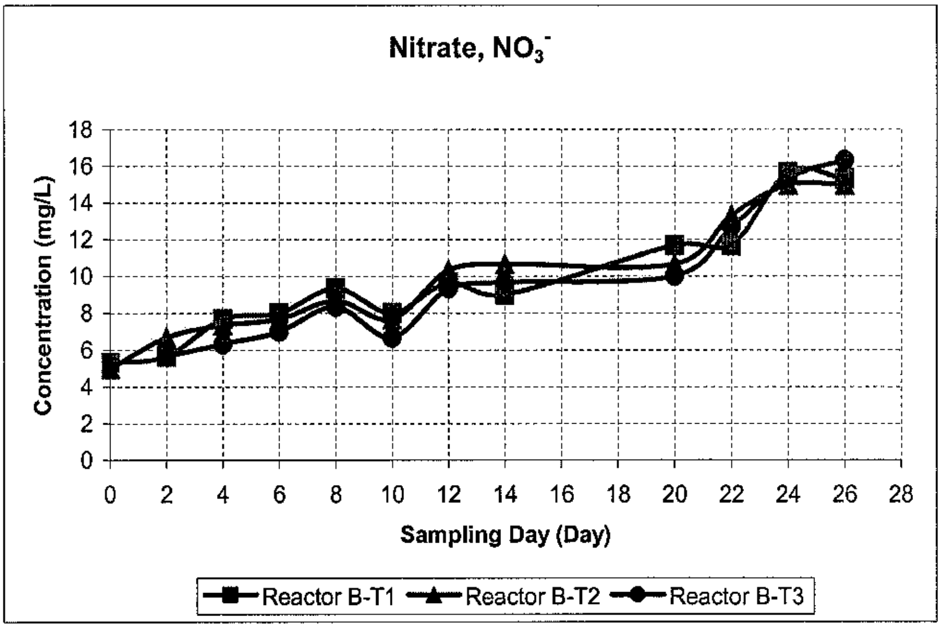


(a) Reactor A

4.3.3 Nitrate Results for Detention Time T1, T2 and T3



(a) Reactor A

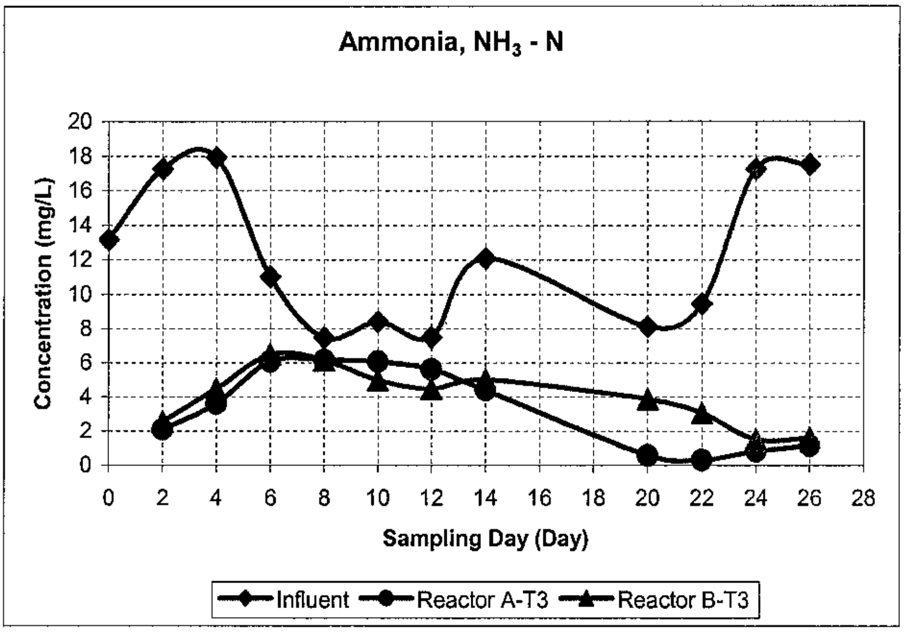


(b) Reactor B

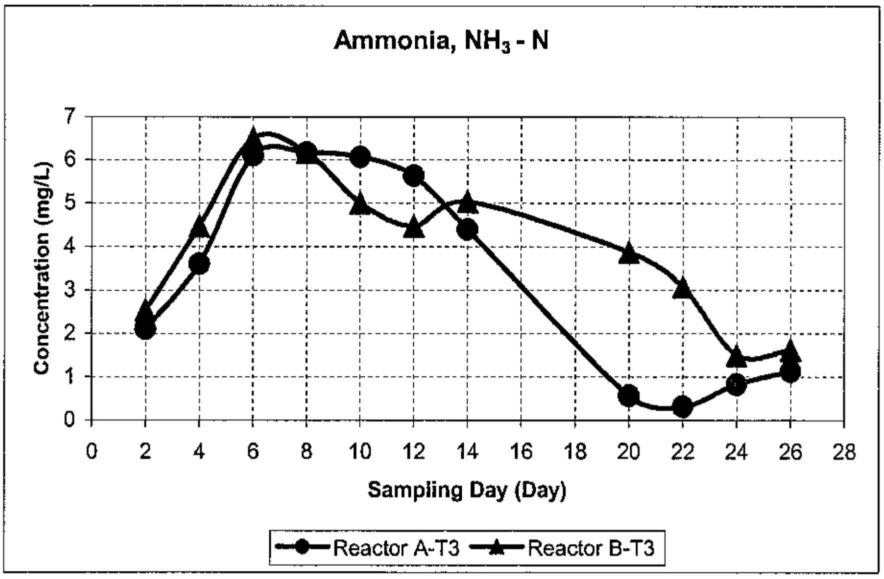
FIGURE 11 (a) and (b): Nitrate (mg/L NO_3^- - N) vs Sampling day (Day) of detention time T1 = 3 days, T2 = 6 days and T3 = 9 days of Reactor A and B

From Figure 11, there is no a big difference of Nitrate concentration between detention time T1, T2, and T3 for both reactors. But, by time goes on the Nitrate concentration of detention time T3 mostly is slightly lower than the detention time T1 and T2 for both reactors.

4.4.2 Ammonia Results at Detention time of T3 = 9 days



(a)



(b)

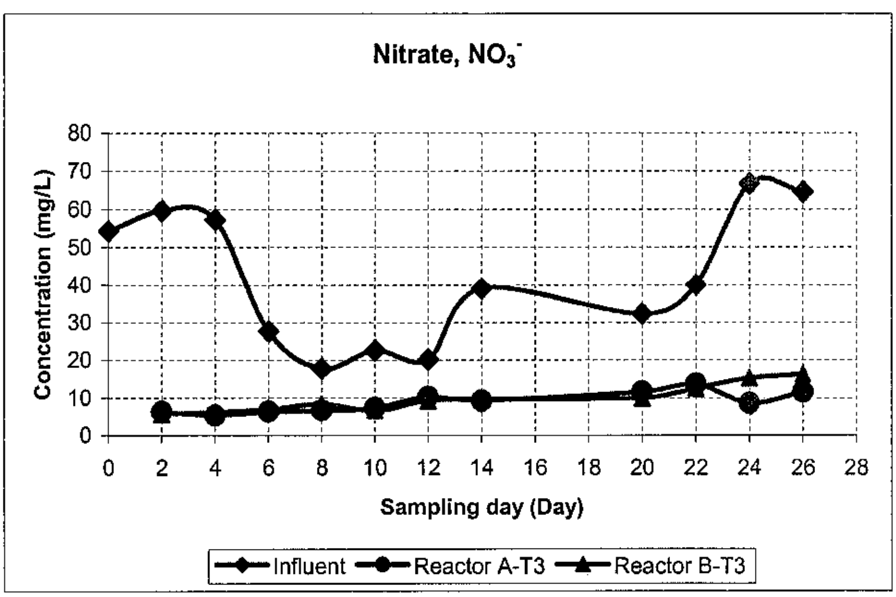
FIGURE 14 (a) and (b): Ammonia (mg/L NH_3-N) vs Sampling day (Day) of Reactor A and B at detention time T3 = 9 days

From Figure 14, it looks like there was no removal of ammonia for Water Lettuce Effluent in week one; it is because maybe the plants need to stabilize themselves with new water condition. After two weeks, there is a drastic decrement of the ammonia until Day 21 the concentration is just below 1.0 mg/L NH_3-N. After that, the concentration of ammonia was constant between 0 to 2 mg/L NH_3-N. With the average concentration of ammonia of influent is 12.27 mg/L NH_3-N, the average percentage of Ammonia that has been removed by water lettuce (at detention time T3 = 9 days) is about 73% *(Appendix A)*. This is due to the process of ammonia oxidation (Nitrification) [1];

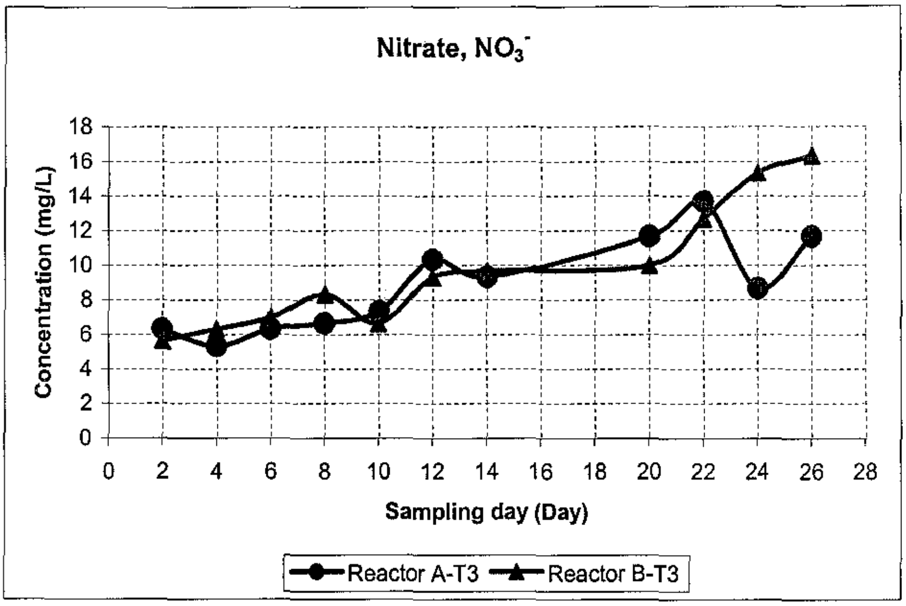
$$NH_3 + H^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

Besides that, after two weeks it shown that the removal efficiency of Ammonia by Reactor A (Water Lettuce) is more than Reactor B. But, based on statistical analysis conducted on the Ammonia of effluent (at T3 = 9 days) of Reactor A and Reactor B at 5% level of significance it was found that there is no significant difference between Ammonia of the Reactor A and Reactor B. It shown that maybe the uptake of Ammonia by the water lettuce (Reactor A) is slightly same as the uptake of Ammonia by the algae in the control reactor (Reactor B).

4.4.3 Nitrate Results at Detention time of T3 = 9 days



(a)



(b)

FIGURE 15 (a) and (b): Nitrate (mg/L NO_3^- - N) vs Sampling day (Day) of Reactor A and B at detention time T3 = 9 days

From Figure 15, by time goes on the concentration of nitrate for Reactor A (Water Lettuce) and Reactor B (control) effluent were increased. After two weeks the concentration of nitrate for Reactor A (Water Lettuce) effluent was constantly between 10 to 15 mg/L $N0_3^-$-N. At the end, the Nitrate of Reactor A was decreased and constantly between 8 to 12 mg/L $N0_3$.⁻N. With the average concentration of Total Nitrate of influent is 40.78 mg/L $N0_3^-$-N *(Appendix A)*, the average percentage of Nitrate that has been removed by water lettuce (at detention time T3 = 9 days) is about 78% *(Appendix A)*.

Besides that, it shown that the removal efficiency of Nitrate by Reactor A (Water Lettuce) is slightly same as Reactor B. Based on statistical analysis conducted on the Nitrate of effluent (at T3 = 9 days) of Reactor A and Reactor B at 5% level of significance it was found that there is no significant difference between Nitrate of the Reactor A and Reactor B. It shown that maybe the uptake of Nitrate by the water lettuce (Reactor A) is slightly same as the uptake of Nitrate by the algae in the control reactor (Reactor B).

Besides that, it shown that the removal efficiency of Phosphorus by Reactor A (Water Lettuce) is more than Reactor B (control). Based on statistical analysis conducted on the Phosphorus of effluent (at T3 = 9 days) of Reactor A and Reactor B at 5% level of significance it was found that there is a significant difference between Phosphorus of the Reactor A and Reactor B. It shown that maybe the uptake of Phosphorus by the water lettuce (Reactor A) is higher than the uptake of Nitrate by the algae in the control reactor (Reactor B).

4.5 Uptake Rate by Water Lettuce

4.5.1 Nitrate Uptake Rate

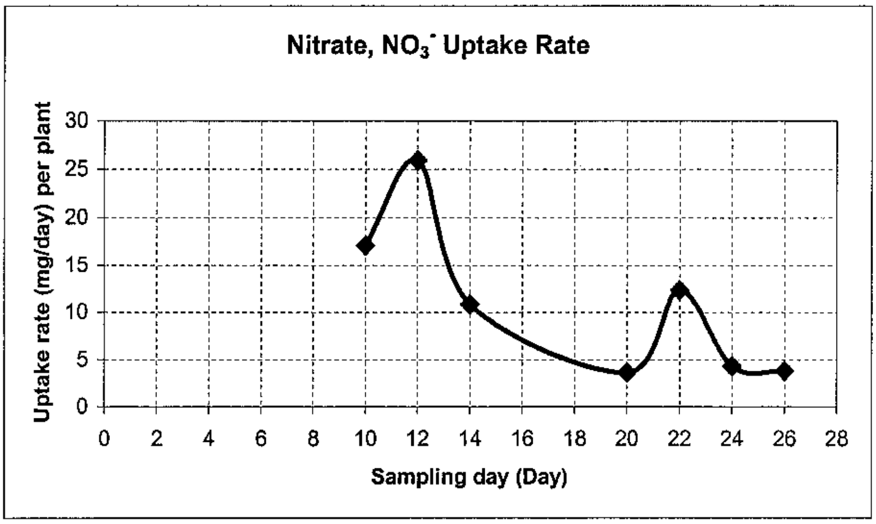


FIGURE 17: Nirate, NO_3^- uptake rate (mg/day) per plant vs Sampling Day (Day)

From Figure 17, it shown the uptake rate of nitrate per one plant at detention time T3 = 9 days. The maximum uptake rate of nitrate by one Water Lettuce is about 25 mg/day at Day 12. The values of uptake rate seem not constant since it depends on the concentration of nitrate at that day and the number of plants at that day.

4.5.2 Phosphorus Uptake Rate

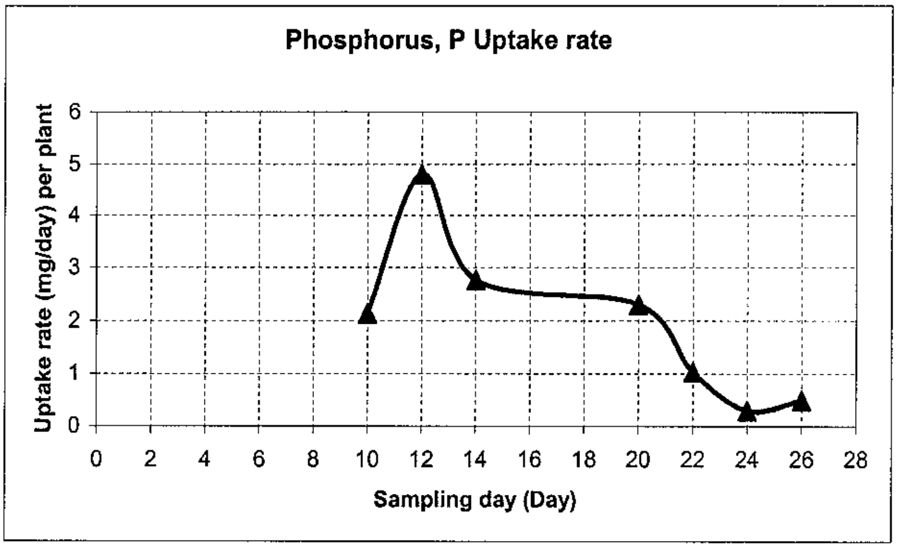


FIGURE 18: Phosphorus uptake rate (mg/day) per plant vs Sampling Day (Day)

From Figure 18, it shown the uptake rate of phosphorus per one plant at detention time T3 = 9 days. The maximum uptake rate of phosphorus by one Water Lettuce is about 5 mg/day at Day 12. Beside that, by time goes on the uptake rate was decreased day by day. It is because, the number of plant have increased. Since the number of plant is higher than before, the uptake rate per one plant will decreased.

4.6 Plants Growth Monitoring

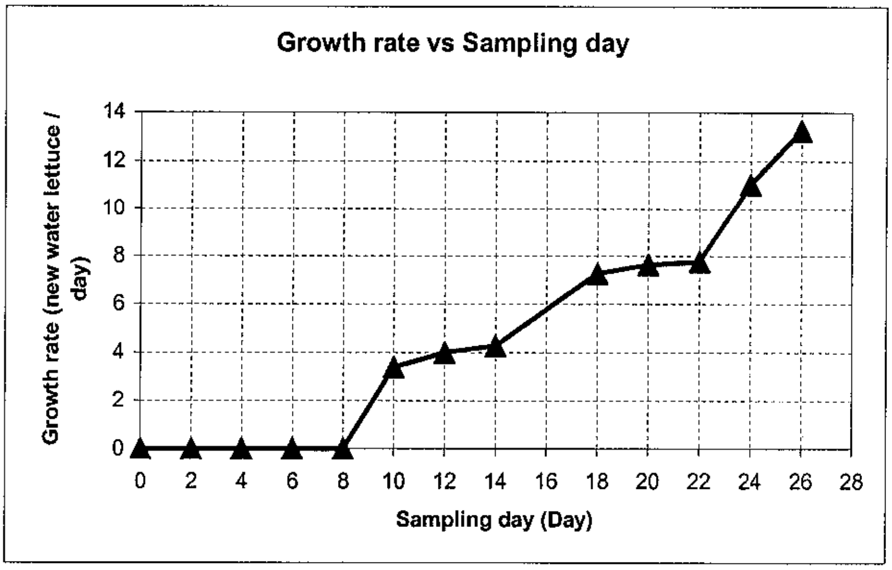
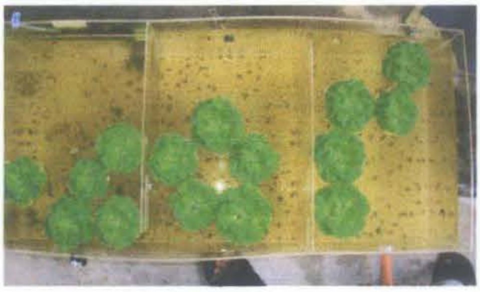
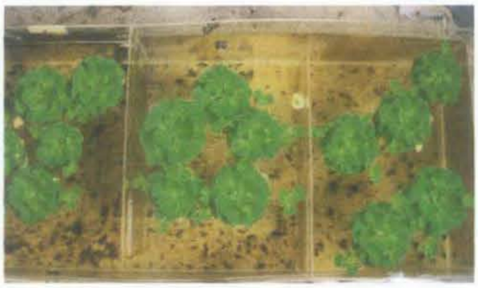


FIGURE 19: Growth Rate vs Sampling Day

From FIGURE 19, it shown about the growth rate of water lettuce along 26 days. Water lettuces started to growth after Day 8, and then the growth rate was increased constantly from Day 10 with 7.65 water lettuces/day until Day 26 with 13.27 water lettuces/day.



(a) Day 6



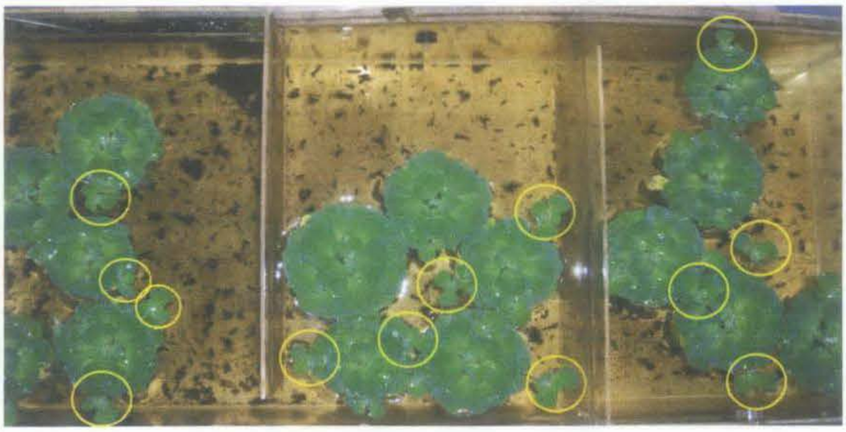
(b) Day 12

(c) Day 18

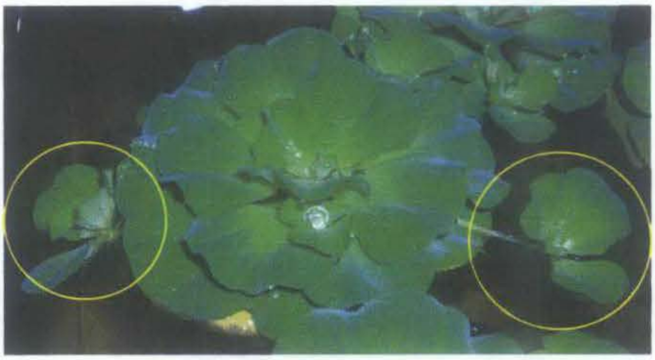
(d) Day 26

FIGURE 20: Sequence of the Water Lettuce Growth; (a) Day 6, (b) Day 12, (c) Day 18, (d) Day 26

From the FIGURE 20, it shows about the sequence of the Water Lettuce growth at Day 6 until Day 26. From the picture (a) and (e), we can see that after 26 days the water lettuce had growth well.



(a)



(b)

FIGURE 21 (a) and (b): Water Lettuce starting to produce numbers of new Water Lettuce at Day 10.

Besides that, from FIGURE 21, since Day 10 all the Water Lettuce starting to produce numbers of new Water Lettuce. So, from this observation, it can be concluded that the Water Lettuce actually can survive in wastewater condition with high amount of nutrients.

APPENDICES

APPENDIX – A

1. The average of percentage removal of COD;

- The average concentration of COD for Influent =

(24+60.67+68.67+36+43+30.67+50.67+41+44.67+63.33+78.33+84.67)/12 =

52.14 mg/L

- The average concentration of COD for Water Lettuce Effluent =

(43+41+42.33+34+27.67+39.33+34+30+25+23+25.67)/11 = 33.18 mg/L

- So, The average of percentage removal of COD;

= [(52.14 – 33.18)/52.14] x 100%

= **36.36%**

2. The average of percentage removal of Ammonia;

- The average concentration of Ammonia for Influent =

(13.17+17.27+17.93+11.03+7.47+8.40+7.5+12.10+8.13+9.47+17.27+17.53)/12 =

12.27 mg/L

- The average concentration of Ammonia for Water Lettuce Effluent =

(2.10+3.60+6.10+6.17+6.07+5.63+4.40+0.57+0.32+0.83+1.13)/11 = 3.36mg/L

- So, The average of percentage removal of Ammonia;

= [(12.27 – 3.36)/12.27] x 100%

= **72.62%**

3. The average of percentage removal of Nitrate;

- The average concentration of Nitrate for Influent = The average concentration of TOTAL Nitrate for Influent;

- TOTAL Nitrate for Influent = Nitrate of influent sample + Nitrate from nitrification process;

$$NH_3 + H^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

14 + (1x3) = **17 mg/L** 14 + (16x3) = **62 mg/L**

- From the equation above, 17 mg/L Ammonia will produce 62mg/L Nitrate.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this project, water sample for influent was taken from UTP Sewage Treatment Plant (STP). The scope of study here is to test the effectiveness of Water Lettuce *(Pistia stratiotes)* in removing the nitrogen and phosphorus and its survival in wastewater condition. From the results obtained, as for the nitrogen and phosphorus removal, Water Lettuce has removed Chemical Oxygen Demand (COD), Ammonia, Nitrate, and Phosphorus up to 36%, 73%, 78% and 57% respectively. Beside that, Water Lettuce has shown that it can live in wastewater condition with the maximum growth rate at Day 26 about 13.27 water lettuces/day.

From here, it can be concluded that the Water Lettuce *(Pistia stratiotes)* as one of the aquatic plant had shown good perspective to become the nitrogen and phosphorus remover for UTP STP effluent. Beside that, Water Lettuce *(Pistia stratiotes)* can survive perfectly in wastewater condition which contain high amount of nutrients.

5.2 Recommendations

From the results, it is recommended that the Water Lettuce can be used to treat our STP effluent which contain high amount of nutrients (Nitrogen and Phosphorus). Since only a small amount of it is needed to obtain the desired results, the economics factor also favors its application.

For further study, it is recommended to make an analysis on the maximum loading of nutrient that Water Lettuce can take. By doing this analysis, the flow rate of the system have to increase bite by bite in a period of time to determine the maximum flow rate that can achieve. Beside that, since its take 2 to 3 weeks for water lettuce to stabilize in wastewater condition, so it is recommended that to do 8-week period of sampling day instead 4-week period in order to get the better results.

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APPENDICES

APPENDIX – A

1. The average of percentage removal of COD;

- The average concentration of COD for Influent =

(24+60.67+68.67+36+43+30.67+50.67+41+44.67+63.33+78.33+84.67)/12 = 52.14 mg/L

- The average concentration of COD for Water Lettuce Effluent =

(43+41+42.33+34+27.67+39.33+34+30+25+23+25.67)/11 = 33.18 mg/L

- So, The average of percentage removal of COD;

= [(52.14 – 33.18)/52.14] x 100%

= **36.36%**

2. The average of percentage removal of Ammonia;

- The average concentration of Ammonia for Influent =

(13.17+17.27+17.93+11.03+7.47+8.40+7.5+12.10+8.13+9.47+17.27+17.53)/12 = 12.27 mg/L

- The average concentration of Ammonia for Water Lettuce Effluent =

(2.10+3.60+6.10+6.17+6.07+5.63+4.40+0.57+0.32+0.83+1.13)/11 = 3.36mg/L

- So, The average of percentage removal of Ammonia;

= [(12.27 – 3.36)/12.27] x 100%

= **72.62%**

3. The average of percentage removal of Nitrate;

- The average concentration of Nitrate for Influent = The average concentration of TOTAL Nitrate for Influent;

- TOTAL Nitrate for Influent = Nitrate of influent sample + Nitrate from nitrification process;

$$NH_3 + H^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

14 + (1x3) = **17 mg/L** 14 + (16x3) = **62 mg/L**

- From the equation above, 17 mg/L Ammonia will produce 62mg/L Nitrate.

- So, the average concentration of Nitrate from Nitrification process = [Average NH_3 of Influent – Average NH_3 Water Lettuce Effluent] x (62/17) = [12.27-3.36] x (62/17) = 32.50 mg/L

- The average concentration of Nitrate of Influent sample = (6.33+4.33+5+9.67+13+14+13.33+11+4.67+6.67+6.67+4.67)/12 = 8.28 mg/L

- Total Nitrate for Influent = 32.50 + 8.28 = 40.78 mg/L

- The average concentration of Nitrate for Water Lettuce Effluent = (6.33+5.33+6.33+6.67+7.33+10.33+9.33+11.67+13.67+8.67+11.67)/11 = 8.85 mg/L

- So, The average of percentage removal of Nitrate;

= [(40.78 – 8.85)/40.78] x 100%

= **78.30%**

4. The average of percentage removal of Phosphorus;

- The average concentration of Phosphorus for Influent = (7.07+9.57+11.60+7.77+8.20+7.10+9.00+6.10+6.90+8.60+11.83+12.23)/12 = 8.83 mg/L

- The average concentration of Phosphorus for Water Lettuce Effluent = (2.57+4.43+5.17+5.07+3.03+2.90+3.10+3.67+3.97+4.07+3.57)/11 = 3.78 mg/L

- So, The average percentage of Phosphorus that has been removed;

= (8.83 – 3.78)/8.83 x 100%

= **57.20%**

APPENDIX – B

Table 1 Organic pollution load discharged according to sector 1990–1993

Year	1990		1991		1992		1993	
Sector	BOD load	Population equivalent	BOD load	Population equivalent	BOD load	Population equivalent	BOD load	Population equivalent
Agro-based industry	15	0.3	12	0.24	30	0.60	28	0.56
Manufacturing industries	25	0.50	25	0.50	27	0.54	77	1.54
Animal husbandry	65	1.30	65	1.30	211	4.20	230	4.60
Population (sewage)	380	7.60	385	7.70	481	9.63	698	13.96
Total	485	9.7	487	9.74	749	14.97	1,033	20.66

Source: Adapted from table 6.28 for Department of Environment: Environmental Quality Data (1992–1995)

Table 2: Water Quality Criteria

Parameter	Criteria Values (mg/L)
Nitrate - Nitrogen	10
Total Phosphorus	0.1

Source: Quality Criteria for Water, 1986: US Environmental Protection Agency, EPA

Parameter	Criteria Values (mg/L)
Nitrate - Nitrogen	6.5
Total Phosphorus	0.26

Source: State of the Minnesota River: 2002 Surface Water Quality Monitoring

Table 3: Growth Rate of Water Lettuce after 26 days

Day	No. of New water lettuce	Growth rate (no. of new water lettuce/day)
0	0	0
2	0	0
4	0	0
6	0	0
8	0	0
10	34	3.40
12	48	4.00
14	60	4.29
18	131	7.28
20	153	7.65
22	171	7.77
24	265	11.04
26	345	13.27

Table 4: Nitrate Uptake Rate per Water Luttuce

Sampling Day,i	Influent, $I_{(i-8)}$ (mg/day)	Effluent, E_i (mg/day)	Uptake rate by plants (mg/day) $[I_{(i-8)} - E_i]$	No. of plants, N in 1day $[(N_i - N_{(i-2)})/2]$	Uptake rate per one plant (mg/day)
10	477.25	58.64	418.61	25	17.09
12	458.10	82.64	375.46	15	25.89
14	221.20	74.64	146.56	14	10.86
20	161.20	93.36	67.84	19	3.67
22	312.66	109.36	203.30	17	12.32
24	305.00	69.36	235.64	55	4.32
26	275.00	93.36	181.64	48	3.82

Table 5: Phosphorus Uptake Rate per Water Luttuce

Sampling Day,i	Influent, $I_{(i-8)}$ (mg/day)	Effluent, E_i (mg/day)	Uptake rate by plants (mg/day) $[I_{(i-8)} - E_i]$	No. of plants, N in 1day $[(N_i - N_{(i-2)})/2]$	Uptake rate per one plant (mg/day)
10	76.56	24.24	52.32	25	2.14
12	92.8	23.2	69.60	15	4.80
14	62.16	24.8	37.36	14	2.77
20	72	29.36	42.64	19	2.30
22	48.8	31.76	17.04	17	1.03
24	49	32.56	16.44	55	0.30
26	52	28.56	23.44	48	0.49

APPENDIX – C: Statistical Analysis

APPENDIX – C1: COD for Reactor A and Reactor B between detention time T1 = 3 days, detention time T2 = 6 days, and detention time T3 = 9 days.

COD at detention time T1 compare with COD at detention time T2 for Reactor A

COD A-T1	COD A-T2
37.33	38.33
41.33	37.67
36.67	38
33.33	34.67
30.67	29
27	27
33	31.67
28.33	28
30	28
25	27
24	23.33
25.67	25.33

t-Test: Two-Sample Assuming Equal Variances

	COD A-T1	*COD A-T2*
Mean	31.0275	30.66667
Variance	29.63574773	27.70728
Observations	12	12
Pooled Variance	28.67151326	
Hypothesized Mean Difference	0	
df	22	
t Stat	0.165065749	
P(T<=t) one-tail	0.43519979	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.870399581	
t Critical two-tail	2.073875294	

Since -2.0739 < t Stat < 2.0739, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T1 and COD at T2 of the Reactor A at 5% level of significance.

COD at detention time T2 compare with COD at detention time T3 for Reactor A

COD A-T2	COD A-T3
38.33	
37.67	43
38	41
34.67	42.33
29	34
27	27.67
31.67	39.33
28	34
28	30
27	25
23.33	23
25.33	25.67

t-Test: Two-Sample Assuming Equal Variances

	COD A-T2	*COD A-T3*
Mean	30.66666667	33.1818182
Variance	27.70727879	54.7891964
Observations	12	11
Pooled Variance	40.60343001	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.94559646	
P(T<=t) one-tail	0.177554237	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.355108474	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T2 and COD at T3 of the Reactor A at 5% level of significance.

COD at detention time T1 compare with COD at detention time T3 for Reactor A

COD A-T1	COD A-T3
37.33	
41.33	43
36.67	41
33.33	42.33
30.67	34
27	27.67
33	39.33
28.33	34
30	30
25	25
24	23
25.67	25.67

t-Test: Two-Sample Assuming Equal Variances

	COD A-T1	*COD A-T3*
Mean	31.0275	33.1818182
Variance	29.63574773	54.7891964
Observations	12	11
Pooled Variance	41.61358041	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.80004673	
P(T<=t) one-tail	0.216320735	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.432641471	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T1 and COD at T3 of the Reactor A at 5% level of significance.

COD at detention time T1 compare with COD at detention time T2 for Reactor B

COD B-T1	COD B-T2
36	33
40	41.67
45.33	44.67
54.33	53.33
41.67	42
42.33	43.33
49.67	46.33
41	40.67
33.33	34.33
31	30.33
33.33	32.67
34.33	33.33

t-Test: Two-Sample Assuming Equal Variances

	COD B-T1	*COD B-T2*
Mean	40.19333333	39.6383333
Variance	50.37842424	48.1090333
Observations	12	12
Pooled Variance	49.24372879	
Hypothesized Mean Difference	0	
df	22	
t Stat	0.193728334	
P(T<=t) one-tail	0.424083083	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.848166167	
t Critical two-tail	2.073875294	

Since -2.0739 < t Stat < 2.0739, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T1 and COD at T2 of the Reactor B at 5% level of significance.

COD at detention time T2 compare with COD at detention time T3 for Reactor B

COD B-T2	COD B-T3
33	
41.67	41
44.67	44.67
53.33	50.67
42	45.33
43.33	43
46.33	60.33
40.67	44.33
34.33	40
30.33	33
32.67	32.33
33.33	33.67

t-Test: Two-Sample Assuming Equal Variances

	COD B-T2	*COD B-T3*
Mean	39.63833333	42.5754545
Variance	48.10903333	68.1059673
Observations	12	11
Pooled Variance	57.63138283	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.92686268	
P(T<=t) one-tail	0.182264199	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.364528397	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T2 and COD at T3 of the Reactor B at 5% level of significance.

COD at detention time T1 compare with COD at detention time T3 for Reactor B

COD B-T1	COD B-T3
36	
40	41
45.33	44.67
54.33	50.67
41.67	45.33
42.33	43
49.67	60.33
41	44.33
33.33	40
31	33
33.33	32.33
34.33	33.67

t-Test: Two-Sample Assuming Equal Variances

	COD B-T1	*COD B-T3*
Mean	40.19333333	42.5754545
Variance	50.37842424	68.1059673
Observations	12	11
Pooled Variance	58.8201114	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.74408746	
P(T<=t) one-tail	0.232534384	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.465068768	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between COD at T1 and COD at T3 of the Reactor B at 5% level of significance.

APPENDIX – C2: Ammonia for Reactor A and Reactor B between detention time T1 = 3 days, detention time T2 = 6 days, and detention time T3 = 9 days.

Ammonia at detention time T1 compare with Ammonia at detention time T2 for Reactor A

NH3-N A-T1	NH3-N A-T2
0.73	0.93
3.17	3.13
5.03	5.07
6.67	6.6
6.7	6.77
5.97	5.93
5.37	5.33
5.03	6.07
0.73	0.63
0.36	0.35
0.89	0.88
1.88	1.93

t-Test: Two-Sample Assuming Equal Variances

	NH3-N A-T1	*NH3-N A-T2*
Mean	3.544166667	3.635
Variance	6.299626515	6.603481818
Observations	12	12
Pooled Variance	6.451554167	
Hypothesized Mean Difference	0	
df	22	
t Stat	-0.087596893	
P(T<=t) one-tail	0.465494763	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.930989525	
t Critical two-tail	2.073875294	

Since -2.0739 < t Stat < 2.0739, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T1 and Ammonia at detention time T2 at 5% level of significance.

Ammonia at detention time T2 compare with Ammonia at detention time T3 for Reactor A

NH3-N A-T2	NH3-N A-T3
0.93	
3.13	2.1
5.07	3.6
6.6	6.1
6.77	6.17
5.93	6.07
5.33	5.63
6.07	4.4
0.63	0.57
0.35	0.32
0.88	0.83
1.93	1.13

t-Test: Two-Sample Assuming Equal Variances

	NH3-N A-T2	*NH3-N A-T3*
Mean	3.635	3.356363636
Variance	6.603481818	5.902685455
Observations	12	11
Pooled Variance	6.269769264	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.266584603	
P(T<=t) one-tail	0.396194589	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.792389177	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T2 and Ammonia at detention time T3 at 5% level of significance.

Ammonia at detention time T1 compare with Ammonia at detention time T3 for Reactor A

NH3-N A-T1	NH3-N A-T3
0.73	
3.17	2.1
5.03	3.6
6.67	6.1
6.7	6.17
5.97	6.07
5.37	5.63
5.03	4.4
0.73	0.57
0.36	0.32
0.89	0.83
1.88	1.13

t-Test: Two-Sample Assuming Equal Variances

	NH3-N A-T1	*NH3-N A-T3*
Mean	3.544166667	3.356363636
Variance	6.299626515	5.902685455
Observations	12	11
Pooled Variance	6.110606962	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.182005062	
P(T<=t) one-tail	0.428662089	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.857324178	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T1 and Ammonia at detention time T3 at 5% level of significance.

Ammonia at detention time T1 compare with Ammonia at detention time T2 for Reactor B

NH3-N B-T1	NH3-N B-T2
1.03	1.37
4	3.57
5.97	6.03
7.17	7.07
6.57	6.77
4.97	5.07
4.7	4.67
4.07	5.33
4.03	3.97
3.43	3.47
1.97	1.9
2.81	2.52

t-Test: Two-Sample Assuming Equal Variances

	NH3-N B-T1	*NH3-N B-T2*
Mean	4.226666667	4.311666667
Variance	3.276151515	3.399978788
Observations	12	12
Pooled Variance	3.338065152	
Hypothesized Mean Difference	0	
df	22	
t Stat	-0.113958611	
P(T<=t) one-tail	0.455152103	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.910304207	
t Critical two-tail	2.073875294	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T1 and Ammonia at detention time T3 at 5% level of significance.

Ammonia at detention time T2 compare with Ammonia at detention time T3 for Reactor B

NH3-N B-T2	NH3-N B-T3
1.37	
3.57	2.53
6.03	4.47
7.07	6.5
6.77	6.17
5.07	5
4.67	4.47
5.33	5.03
3.97	3.87
3.47	3.07
1.9	1.5
2.52	1.62

t-Test: Two-Sample Assuming Equal Variances

	NH3-N B-T2	*NH3-N B-T3*
Mean	4.311666667	4.020909091
Variance	3.399978788	2.841389091
Observations	12	11
Pooled Variance	3.133983694	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.39346465	
P(T<=t) one-tail	0.348971306	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.697942613	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T2 and Ammonia at detention time T3 at 5% level of significance.

Ammonia at detention time T1 compare with Ammonia at detention time T3 for Reactor B

NH3-N B-T1	NH3-N B-T3
1.03	
4	2.53
5.97	4.47
7.17	6.5
6.57	6.17
4.97	5
4.7	4.47
4.07	5.03
4.03	3.87
3.43	3.07
1.97	1.5
2.81	1.62

t-Test: Two-Sample Assuming Equal Variances

	NH3-N B-T1	*NH3-N B-T3*
Mean	4.226666667	4.020909091
Variance	3.276151515	2.841389091
Observations	12	11
Pooled Variance	3.069121789	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.281366132	
P(T<=t) one-tail	0.390591699	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.781183397	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Ammonia at detention time T1 and Ammonia at detention time T3 at 5% level of significance.

APPENDIX – C3: Nitrate for Reactor A and Reactor B between detention time T1 = 3 days, detention time T2 = 6 days, and detention time T3 = 9 days.

Nitrate at detention time T1 compare with Nitrate at detention time T2 for Reactor A

NO3 A-T1	NO3 A-T2
5.67	5.67
4.33	4.67
6.67	6.33
5.33	6
7.67	7.67
8.33	7.67
10	9.67
7.67	10.67
13.33	12.67
12.67	13
10.67	10.33
13.67	13.33

t-Test: Two-Sample Assuming Equal Variances

	NO3 A-T1	*NO3 A-T2*
Mean	8.834166667	8.9733333
Variance	10.29708106	9.3382242
Observations	12	12
Pooled Variance	9.817652652	
Hypothesized Mean Difference	0	
df	22	
t Stat	-0.10879452	
P(T<=t) one-tail	0.457175843	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.914351687	
t Critical two-tail	2.073875294	

Since -2.0739 < t Stat < 2.0739, therefore accept Ho=0, and conclude that there is NO significant difference between Nitrate at detention time T1 and Nitrate at detention time T2 at 5% level of significance.

Nitrate at detention time T2 compare with Nitrate at detention time T3 for Reactor A

NO3 A-T2	NO3 A-T3
5.67	
4.67	6.33
6.33	5.33
6	6.33
7.67	6.67
7.67	7.33
9.67	10.33
10.67	9.33
12.67	11.67
13	13.67
10.33	8.67
13.33	11.67

t-Test: Two-Sample Assuming Equal Variances

	NO3 A-T2	*NO3 A-T3*
Mean	8.973333333	8.8481818
Variance	9.338224242	7.3744364
Observations	12	11
Pooled Variance	8.403087157	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.103428381	
P(T<=t) one-tail	0.459302183	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.918604365	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Nitrate at detention time T2 and Nitrate at detention time T3 at 5% level of significance.

Nitrate at detention time T2 compare with Nitrate at detention time T3 for Reactor B

NO3 B-T2	NO3 B-T3
5	
6.67	5.67
7.33	6.33
7.67	7
8.67	8.33
7.67	6.67
10.33	9.33
10.67	9.67
10.67	10
13.33	12.67
15	15.33
15	16.33

t-Test: Two-Sample Assuming Equal Variances

	NO3 B-T2	*NO3 B-T3*
Mean	9.834166667	9.7572727
Variance	10.69182652	13.061202
Observations	12	11
Pooled Variance	11.82010047	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.05358023	
P(T<=t) one-tail	0.478888029	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.957776058	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Nitrate at detention time T2 and Nitrate at detention time T3 at 5% level of significance.

Nitrate at detention time T1 compare with Nitrate at detention time T3 for Reactor B

NO3 B-T1	NO3 B-T3
5.33	
5.67	5.67
7.67	6.33
8	7
9.33	8.33
8	6.67
9.67	9.33
9	9.67
11.67	10
11.67	12.67
15.67	15.33
15.33	16.33

t-Test: Two-Sample Assuming Equal Variances

	NO3 B-T1	*NO3 B-T3*
Mean	9.750833333	9.7572727
Variance	10.99409924	13.061202
Observations	12	11
Pooled Variance	11.9784338	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.004457261	
P(T<=t) one-tail	0.498242852	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.996485704	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Nitrate at detention time T1 and Nitrate at detention time T3 at 5% level of significance.

APPENDIX – C4: Phosphorus for Reactor A and Reactor B between detention time T1 = 3 days, detention time T2 = 6 days, and detention time T3 = 9 days.

Phosphorus at detention time T1 compare with Phosphorus at detention time T2 for Reactor A

P A-T1	P A-T2
2.47	2.93
3.17	2.97
4.63	4.6
5.23	5.2
5.23	5.33
3.3	3.23
3.27	3.3
2.9	2.77
3.83	4.03
4.23	4
4.63	4.57
4.13	4.07

t-Test: Two-Sample Assuming Equal Variances

	P A-T1	*P A-T2*
Mean	3.918333333	3.91666667
Variance	0.827360606	0.78344242
Observations	12	12
Pooled Variance	0.805401515	
Hypothesized Mean Difference	0	
df	22	
t Stat	0.004549023	
P(T<=t) one-tail	0.498205708	
t Critical one-tail	1.717144187	
P(T<=t) two-tail	0.996411415	
t Critical two-tail	2.073875294	

Since -2.0739 < t Stat < 2.0739, therefore accept Ho=0, and conclude that there is NO significant difference between Phosphorus at detention time T1 and Phosphorus at detention time T2 at 5% level of significance.

Phosphorus at detention time T2 compare with Phosphorus at detention time T3 for Reactor A

P A-T2	P A-T3
2.93	
2.97	2.57
4.6	4.43
5.2	5.17
5.33	5.07
3.23	3.03
3.3	2.9
2.77	3.1
4.03	3.67
4	3.97
4.57	4.07
4.07	3.57

t-Test: Two-Sample Assuming Equal Variances

	P A-T2	*P A-T3*
Mean	3.916666667	3.77727273
Variance	0.783442424	0.74584182
Observations	12	11
Pooled Variance	0.765537374	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.381666235	
P(T<=t) one-tail	0.353271765	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.70654353	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Phosphorus at detention time T2 and Phosphorus at detention time T3 at 5% level of significance.

Phosphorus at detention time T2 compare with Phosphorus at detention time T3 for Reactor B

P B-T2	P B-T3
2.33	
3.1	4.4
5.4	4.9
6.5	6.13
6.03	5.53
4.17	4.1
4.37	4.13
4.23	4.17
6.13	6.17
6.53	6.23
6.17	6.1
6.53	6.37

t-Test: Two-Sample Assuming Equal Variances

	P B-T2	*P B-T3*
Mean	5.124166667	5.29363636
Variance	2.093735606	0.92038545
Observations	12	11
Pooled Variance	1.534997439	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.327688555	
P(T<=t) one-tail	0.373195801	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.746391603	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Phosphorus at detention time T2 and Phosphorus at detention time T3 at 5% level of significance.

Phosphorus at detention time T1 compare with Phosphorus at detention time T3 for Reactor B

P B-T1	P B-T3
2.27	
3.13	4.4
5.47	4.9
6.57	6.13
5.9	5.53
4.23	4.1
4.37	4.13
4.2	4.17
6.07	6.17
6.63	6.23
6.27	6.1
6.67	6.37

t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	5.148333333	5.29363636
Variance	2.183178788	0.92038545
Observations	12	11
Pooled Variance	1.581848629	
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.276767607	
P(T<=t) one-tail	0.392332209	
t Critical one-tail	1.720743512	
P(T<=t) two-tail	0.784664417	
t Critical two-tail	2.079614205	

Since -2.0796 < t Stat < 2.0796, therefore accept Ho=0, and conclude that there is NO significant difference between Phosphorus at detention time T1 and Phosphorus at detention time T3 at 5% level of significance.

Nitrate of Reactor A compare with Nitrate of Reactor B at T3 = 9 days

NO_3^- A-T3	NO_3^- B-T3
6.33	5.67
5.33	6.33
6.33	7
6.67	8.33
7.33	6.67
10.33	9.33
9.33	9.67
11.67	10
13.67	12.67
8.67	15.33
11.67	16.33

t-Test: Two-Sample Assuming Equal Variances

	NO_3^- A-T3	*NO_3^- B-T3*
Mean	8.848181818	9.75727273
Variance	7.374436364	13.0612018
Observations	11	11
Pooled Variance	10.21781909	
Hypothesized Mean Difference	0	
df	20	
t Stat	-0.666974999	
P(T<=t) one-tail	0.256205168	
t Critical one-tail	1.724718004	
P(T<=t) two-tail	0.512410336	
t Critical two-tail	2.085962478	

Since -2.086 < t Stat < 2.0786, therefore accept Ho=0, and conclude that there is NO significant difference between Nitrate at T3 of the Reactor A and Reactor B at 5% level of significance.

Phosphorus of Reactor A compare with Phosphorus of Reactor B at T3 = 9 days

P A-T3	P B-T3
2.57	4.4
4.43	4.9
5.17	6.13
5.07	5.53
3.03	4.1
2.9	4.13
3.1	4.17
3.67	6.17
3.97	6.23
4.07	6.1
3.57	6.37

t-Test: Two-Sample Assuming Equal Variances

	P A-T3	*P B-T3*
Mean	3.777272727	5.29363636
Variance	0.745841818	0.92038545
Observations	11	11
Pooled Variance	0.833113636	
Hypothesized Mean Difference	0	
df	20	
t Stat	-3.89612233	
P(T<=t) one-tail	0.00044843	
t Critical one-tail	1.724718004	
P(T<=t) two-tail	0.000896859	
t Critical two-tail	2.085962478	

Since t Stat < -2.086, therefore reject Ho=0, and conclude that there is a significant difference between Phosphorus at T3 of the Reactor A and Reactor B at 5% level of significance.

APPENDIX - D

Flow Rate,Q = 5.56 mL/minute = 8000mL/day **V_R = 68.676 L** **V1,V2 = 22.892 L**

T1 =V_1/Q = 2.9 days = 3 days **V_R = Volume of reactor**

T2 =V_1+V_2/Q = 5.7 days = 6 days **V_1 = Volume of Section 1**

T3 =V_R/Q = 8.6 days = 9 days **V_2 = Volume of Section 2**

DAY	DATE	Sample	I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
		TEST							
0	21/02/2008	COD (mg/L)							
		1	25	40.00	40	36	31		
		2	23	36	38	36	33	-	-
		3	24	36	37	36	35		
		AVERAGE	24.00	37.33	38.33	36.00	33.00	-	-
		Ammonia (mg/L NH_3-N)							
		1	13.2	0.7	0.9	1	1.6		
		2	13.2	0.7	1.1	1	1.2	-	-
		3	13.1	0.8	0.8	1.1	1.3		
		AVERAGE	13.17	0.73	0.93	1.03	1.37	-	-
		Phosphorus (mg/L PO_4^{3-})							
		1	7.2	2.4	3	2.1	2.4		
		2	6.9	2.4	3.00	2.4	2.3	-	-
		3	7.1	2.6	2.80	2.3	2.3		
		AVERAGE	7.07	2.47	2.93	2.27	2.33	-	-
		Nitrate (mg/L NO_3^- - N)							
		1	8	5	6	5	4		
		2	6	6	6	5	6	-	-
		3	5	6.00	5	6	5		
		AVERAGE	6.33	5.67	5.67	5.33	5.00	-	-
			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
2	23/02/2008	COD (mg/L)							
		1	59	42.00	38	40	42	40	41
		2	62	42	37	40	41	44	42
		3	61	40	38	40	42	45	40
		AVERAGE	60.67	41.33	37.67	40.00	41.67	43.00	41.00
		Ammonia (mg/L NH_3-N)							
		1	17.1	3.1	3.2	4.1	3.6	2.1	2.5
		2	17.3	3.2	3	4	3.6	2.1	2.6
		3	17.4	3.20	3.2	3.9	3.5	2.1	2.5
		AVERAGE	17.27	3.17	3.13	4.00	3.57	2.10	2.53
		Phosphorus (mg/L PO_4^{3-})							
		1	9.7	3	2.9	3	3.1	2.5	4.4
		2	9.4	3.3	3.00	3.2	3	2.6	4.5
		3	9.6	3.2	3.00	3.2	3.2	2.6	4.3
		AVERAGE	9.57	3.17	2.97	3.13	3.10	2.57	4.40
		Nitrate (mg/L NO_3^- - N)							
		1	5	5	4	6	6	7	5
		2	4	4	4	6	7	6	6
		3	4	4	6	5	7	6	6
		AVERAGE	4.33	4.33	4.67	5.67	6.67	6.33	5.67

			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
4	25/02/2008	COD (mg/L)							
		1	67	38.00	37	45	42	42	45
		2	70	36	38	47	47	40	43
		3	69	36	39	44	45	41	46
		AVERAGE	**68.67**	**36.67**	**38.00**	**45.33**	**44.67**	**41.00**	**44.67**
		Ammonia (mg/L NH_3-N)							
		1	17.8	5	5.1	6	6.1	3.6	4.4
		2	17.9	4.9	5.1	5.9	6	3.6	4.4
		3	18.1	5.20	5	6	6	3.6	4.6
		AVERAGE	**17.93**	**5.03**	**5.07**	**5.97**	**6.03**	**3.60**	**4.47**
		Phosphorus (mg/L PO_4^{3-})							
		1	11.7	4.7	4.6	5.5	5.5	4.4	4.9
		2	11.6	4.6	4.50	5.5	5.3	4.4	5
		3	11.5	4.6	4.70	5.4	5.4	4.5	4.8
		AVERAGE	**11.60**	**4.63**	**4.60**	**5.47**	**5.40**	**4.43**	**4.90**
		Nitrate (mg/L NO_3^- - N)							
		1	5	6	6	7	7	5	6
		2	5	7	7	8	8	6	7
		3	5	7	6	8	7	5	6
		AVERAGE	**5.00**	**6.67**	**6.33**	**7.67**	**7.33**	**5.33**	**6.33**
			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
6	27/02/2008	COD (mg/L)							
		1	40	33.00	33	53	54	40	50
		2	38	32	35	55	53	43	52
		3	30	35	36	55	53	44	50
		AVERAGE	**36.00**	**33.33**	**34.67**	**54.33**	**53.33**	**42.33**	**50.67**
		Ammonia (mg/L NH_3-N)							
		1	11.1	6.7	6.7	7.1	7.1	6.1	6.5
		2	11	6.7	6.6	7.2	7	6.1	6.4
		3	11	6.60	6.5	7.2	7.1	6.1	6.6
		AVERAGE	**11.03**	**6.67**	**6.60**	**7.17**	**7.07**	**6.10**	**6.50**
		Phosphorus (mg/L PO_4^{3-})							
		1	8	5.4	5.2	6.6	6.4	5.3	6.2
		2	7.6	5.1	5.3	6.4	6.5	5.1	6.1
		3	7.7	5.2	5.1	6.7	6.6	5.1	6.1
		AVERAGE	**7.77**	**5.23**	**5.20**	**6.57**	**6.50**	**5.17**	**6.13**
		Nitrate (mg/L NO_3^- - N)							
		1	11	5	6	8	8	6	7
		2	9	5	6	8	7	6	7
		3	9	6	6	8	8	7	7
		AVERAGE	**9.67**	**5.33**	**6.00**	**8.00**	**7.67**	**6.33**	**7.00**

			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
8	29/02/2008	**COD** (mg/L)							
		1	45	31.00	28	40	42	35	44
		2	43	31	30	42	43	34	46
		3	41	30	29	43	41	33	46
		AVERAGE	**43.00**	**30.67**	**29.00**	**41.67**	**42.00**	**34.00**	**45.33**
		Ammonia (mg/L NH_3-N)							
		1	7.5	6.7	6.7	6.7	6.8	6.2	6.1
		2	7.5	6.7	6.80	6.5	6.7	6.1	6.2
		3	7.4	6.7	6.80	6.5	6.8	6.2	6.2
		AVERAGE	**7.47**	**6.70**	**6.77**	**6.57**	**6.77**	**6.17**	**6.17**
		Phosphorus (mg/L PO_4^{3-})							
		1	8	5.3	5.4	5.9	6	5	5.5
		2	8.3	5.1	5.40	5.8	6	5.2	5.5
		3	8.3	5.3	5.20	6	6.1	5	5.6
		AVERAGE	**8.20**	**5.23**	**5.33**	**5.90**	**6.03**	**5.07**	**5.53**
		Nitrate (mg/L $N0_3^-$ - N)							
		1	12	8	9	10	8	7	8
		2	14	7	7	9	9	7	9
		3	13	8	7	9	9	6	8
		AVERAGE	**13.00**	**7.67**	**7.67**	**9.33**	**8.67**	**6.67**	**8.33**
			I	**A-S1**	**A-S2**	**B-S1**	**B-S2**	**A-S3**	**B-S3**
10	02/03/2008	**COD** (mg/L)							
		1	29	26.00	25	42	43	28	43
		2	29	27	28	43	43	28	42
		3	34	28	28	42	44	27	44
		AVERAGE	**30.67**	**27.00**	**27.00**	**42.33**	**43.33**	**27.67**	**43.00**
		Ammonia (mg/L NH_3-N)							
		1	8.4	6	5.9	5	5.1	6	5.1
		2	8.41	5.9	5.9	4.9	5	6.1	5
		3	8.39	6.00	6	5	5.1	6.1	4.9
		AVERAGE	**8.40**	**5.97**	**5.93**	**4.97**	**5.07**	**6.07**	**5.00**
		Phosphorus (mg/L PO_4^{3-})							
		1	6.8	3.3	3.2	4.2	4.2	3	4.1
		2	7.3	3.4	3.30	4.2	4.1	3	4
		3	7.2	3.2	3.20	4.3	4.2	3.1	4.2
		AVERAGE	**7.10**	**3.30**	**3.23**	**4.23**	**4.17**	**3.03**	**4.10**
		Nitrate (mg/L $N0_3^-$ - N)							
		1	13	8	7	8	7	8	7
		2	15	9	8	8	8	7	6
		3	14	8	8	8	8	7	7
		AVERAGE	**14.00**	**8.33**	**7.67**	**8.00**	**7.67**	**7.33**	**6.67**

			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
12	04/03/2008	COD (mg/L)							
		1	50	33.00	32	49	45	41	62
		2	53	32	30	49	47	38	60
		3	49	34	33	51	47	39	59
		AVERAGE	**50.67**	**33.00**	**31.67**	**49.67**	**46.33**	**39.33**	**60.33**
		Ammonia (mg/L NH_3-N)							
		1	7.4	5.4	5.3	4.7	4.7	5.6	4.5
		2	7.6	5.4	5.3	4.7	4.7	5.6	4.4
		3	7.5	5.30	5.4	4.7	4.6	5.7	4.5
		AVERAGE	**7.50**	**5.37**	**5.33**	**4.70**	**4.67**	**5.63**	**4.47**
		Phosphorus (mg/L PO_4^{3-})							
		1	9.1	3.2	3.2	4.5	4.3	2.8	4.1
		2	8.9	3.4	3.40	4.2	4.4	3	4.1
		3	9	3.2	3.30	4.4	4.4	2.9	4.2
		AVERAGE	**9.00**	**3.27**	**3.30**	**4.37**	**4.37**	**2.90**	**4.13**
		Nitrate (mg/L $N0_3$- - N)							
		1	12	9	9	10	10	11	9
		2	15	10	10	9	11	10	10
		3	13	11	10	10	10	10	9
		AVERAGE	**13.33**	**10.00**	**9.67**	**9.67**	**10.33**	**10.33**	**9.33**
			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
14	06/03/2008	COD (mg/L)							
		1	41	27.00	27	40	40	33	45
		2	42	29	28	42	40	35	44
		3	40	29	29	41	42	34	44
		AVERAGE	**41.00**	**28.33**	**28.00**	**41.00**	**40.67**	**34.00**	**44.33**
		Ammonia (mg/L NH_3-N)							
		1	12	5	6.1	4.1	5.4	4.4	5
		2	12.2	5.1	6.1	4.1	5.2	4.4	5
		3	12.1	5.00	6	4	5.4	4.4	5.1
		AVERAGE	**12.10**	**5.03**	**6.07**	**4.07**	**5.33**	**4.40**	**5.03**
		Phosphorus (mg/L PO_4^{3-})							
		1	6.1	2.8	2.7	4.3	4.3	3.1	4.2
		2	6	3	2.80	4.1	4.2	3	4.1
		3	6.2	2.9	2.80	4.2	4.2	3.2	4.2
		AVERAGE	**6.10**	**2.90**	**2.77**	**4.20**	**4.23**	**3.10**	**4.17**
		Nitrate (mg/L $N0_3$- - N)							
		1	10	8	11	8	11	10	10
		2	12	8	10	10	11	9	9
		3	11	7	11	9	10	9	10
		AVERAGE	**11.00**	**7.67**	**10.67**	**9.00**	**10.67**	**9.33**	**9.67**

			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
20	12/03/2008	COD (mg/L)							
		1	45	29.00	27	33	35	30	40
		2	44	30	29	34	34	29	39
		3	45	31	28	33	34	31	41
		AVERAGE	44.67	30.00	28.00	33.33	34.33	30.00	40.00
		Ammonia (mg/L NH_3-N)							
		1	8.12	0.7	0.6	4	4	0.6	3.9
		2	8.13	0.7	0.7	4.1	4	0.5	3.8
		3	8.14	0.80	0.6	4	3.9	0.6	3.9
		AVERAGE	8.13	0.73	0.63	4.03	3.97	0.57	3.87
		Phosphorus (mg/L PO_4^{3-})							
		1	6.8	3.9	4	6.1	6.2	3.7	6.2
		2	7	3.8	4.10	6	6.1	3.6	6.1
		3	6.9	3.8	4.00	6.1	6.1	3.7	6.2
		AVERAGE	6.90	3.83	4.03	6.07	6.13	3.67	6.17
		Nitrate (mg/L $N0_3$- - N)							
		1	5	13	12	11	10	12	9
		2	4	14	13	12	11	12	11
		3	5	13	13	12	11	11	10
		AVERAGE	4.67	13.33	12.67	11.67	10.67	11.67	10.00
			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
22	14/03/2008	COD (mg/L)							
		1	64	24.00	26	31	30	26	33
		2	64	25	27	32	31	25	34
		3	62	26	28	30	30	24	32
		AVERAGE	63.33	25.00	27.00	31.00	30.33	25.00	33.00
		Ammonia (mg/L NH_3-N)							
		1	9.5	0.36	0.36	3.4	3.5	0.32	3.1
		2	9.4	0.36	0.35	3.4	3.5	0.31	3
		3	9.5	0.36	0.35	3.5	3.4	0.32	3.1
		AVERAGE	9.47	0.36	0.35	3.43	3.47	0.32	3.07
		Phosphorus (mg/L PO_4^{3-})							
		1	8.5	4.2	4	6.6	6.5	4	6.2
		2	8.6	4.2	3.90	6.6	6.6	3.9	6.3
		3	8.7	4.3	4.10	6.7	6.5	4	6.2
		AVERAGE	8.60	4.23	4.00	6.63	6.53	3.97	6.23
		Nitrate (mg/L $N0_3$- - N)							
		1	7	13	13	12	13	14	13
		2	6	13	13	12	14	13	13
		3	7	12	13	11	13	14	12
		AVERAGE	6.67	12.67	13.00	11.67	13.33	13.67	12.67

			I	A-S1	A-S2	B-S1	B-S2	A-S3	B-S3
24	16/03/2008	**COD** (mg/L)							
		1	76	24.00	25	33	31	24	32
		2	81	25	22	33	34	22	32
		3	78	23	23	34	33	23	33
		AVERAGE	**78.33**	**24.00**	**23.33**	**33.33**	**32.67**	**23.00**	**32.33**
		Ammonia (mg/L NH_3-N)							
		1	17.3	0.89	0.89	2	1.8	0.84	1.5
		2	17.3	0.9	0.88	1.9	1.9	0.83	1.4
		3	17.2	0.89	0.87	2	2	0.83	1.6
		AVERAGE	**17.27**	**0.89**	**0.88**	**1.97**	**1.90**	**0.83**	**1.50**
		Phosphorus (mg/L PO_4^{3-})							
		1	11.8	4.6	4.5	6.3	6.1	4.1	6.2
		2	11.9	4.6	4.60	6.2	6.2	4	6.1
		3	11.8	4.7	4.60	6.3	6.2	4.1	6
		AVERAGE	**11.83**	**4.63**	**4.57**	**6.27**	**6.17**	**4.07**	**6.10**
		Nitrate (mg/L $N0_3$- - N)							
		1	6	10	10	16	16	9	16
		2	7	11	11	15	14	8	15
		3	7	11	10	16	15	9	15
		AVERAGE	**6.67**	**10.67**	**10.33**	**15.67**	**15.00**	**8.67**	**15.33**
			I	**A-S1**	**A-S2**	**B-S1**	**B-S2**	**A-S3**	**B-S3**
26	18/03/2008	**COD** (mg/L)							
		1	85	26.00	25	34	33	26	34
		2	84	25	25	34	34	26	33
		3	85	26	26	35	33	25	34
		AVERAGE	**84.67**	**25.67**	**25.33**	**34.33**	**33.33**	**25.67**	**33.67**
		Ammonia (mg/L NH_3-N)							
		1	17.6	1.88	1.93	2.8	2.51	1.13	1.62
		2	17.5	1.89	1.93	2.81	2.53	1.13	1.63
		3	17.5	1.88	1.94	2.82	2.52	1.12	1.62
		AVERAGE	**17.53**	**1.88**	**1.93**	**2.81**	**2.52**	**1.13**	**1.62**
		Phosphorus (mg/L PO_4^{3-})							
		1	12.2	4.2	4.1	6.8	6.5	3.6	6.5
		2	12.2	4.1	4.10	6.6	6.6	3.6	6.4
		3	12.3	4.1	4.00	6.6	6.5	3.5	6.2
		AVERAGE	**12.23**	**4.13**	**4.07**	**6.67**	**6.53**	**3.57**	**6.37**
		Nitrate (mg/L $N0_3$- - N)							
		1	4	14	14	16	14	12	17
		2	5	14	13	15	15	11	16
		3	5	13	13	15	16	12	16
		AVERAGE	**4.67**	**13.67**	**13.33**	**15.33**	**15.00**	**11.67**	**16.33**