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ชื่อโครงการ	Phytoremediation of secondary canteen wastewater by using water lettuce (*Pistia stratiotes* L.)
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Department	Environmental Science
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Phytoremediation of secondary canteen wastewater

by using water lettuce (*Pistia stratiotes* L.)

Miss Puttapatsorn Laohatrakul

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Bachelor of Science Program in Environmental Science

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ชื่อเรื่อง การบำบัดน้ำเสียขั้นที่สองโดยใช้จอก (*Pistia stratiotes* L.)

ชื่อ-สกุล นางสาวพุทธภัสสร เลาหตระกูล รหัสนิสิต 5833332023

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บทคัดย่อ

จุดมุ่งหมายของการศึกษานี้ เพื่อหาประสิทธิภาพในการบำบัดน้ำเสียโรงอาหารขั้นที่สองโดยจอก (*Pistia stratiotes*) น้ำเสียที่นำมาศึกษาเป็นน้ำเสียจากโรงอาหาร และผ่านการบำบัดขั้นที่หนึ่ง ด้วยไบโอชาร์ (Biochar) จากนั้นนำตัวอย่างน้ำมาเจือจางให้มีความเข้มข้น 0%, 25%, 50% และ 75% และใช้จอกในการบำบัดเป็นเวลานาน 15 วัน โดยจะมีการตรวจวัดค่าพารามิเตอร์ในน้ำก่อนและหลังการบำบัด พารามิเตอร์ที่ตรวจวัด ได้แก่ pH, BOD, COD, TKN, TP, TSS และ FOG สำหรับในพืชจะทำการตรวจวัด 3 พารามิเตอร์ ได้แก่ มวลชีวภาพ ปริมาณคาร์โบไฮเดรททั้งหมด และโปรตีนทั้งหมด โดยจะทำการเก็บตัวอย่างพืชและน้ำทุก 3 วัน ได้แก่ วันที่ 0, 3, 6, 9, 12 และ 15 ผลการศึกษาพบว่า ประสิทธิภาพสูงที่สุดในการบำบัดน้ำเสียขั้นที่สองจากโรงอาหาร ในแต่พารามิเตอร์ คือ BOD, COD, TKN, TP, TSS และ FOG เท่ากับ 94.06%, 93.34%, 38.36%, 66.83%, 100% และ 6.45% ตามลำดับ ส่วนพารามิเตอร์ที่ตรวจวัดได้จากพืชพบว่า มวลชีวภาพที่เพิ่มขึ้น มีค่าสูงที่สุดเท่ากับ 1.78 กรัม และมีปริมาณคาร์โบไฮเดรททั้งหมด และโปรตีนทั้งหมดมากที่สุด เท่ากับ 0.35 และ 0.42 กรัมต่อกรัมมวลชีวภาพ จากการศึกษาพบว่า ที่ความเข้มข้น 25% จอกจะมีประสิทธิภาพในการบำบัดน้ำเสียขั้นที่สองจากโรงอาหารได้ดีที่สุด

คำสำคัญ : การบำบัดโดยใช้พืช / จอก / น้ำเสียโรงอาหาร / ประสิทธิภาพการบำบัด

Title Phytoremediation of secondary canteen wastewater treatment by using water lettuce (*Pistia stratiotes* L.)

By Miss Puttapatsorn Laohatrakul

Department Environmental Science

Project Advisor Associate Professor Naiyanan Ariyakanon, Ph.D.

Abstract

The aim of this study was to investigate the removal efficiency of secondary canteen wastewater treatment by using water lettuce (*Pistia stratiotes*). The canteen wastewater was treated by biochar as a primary treatment. After primary treatment, canteen wastewater was diluted at the concentration of 0%, 25%, 50% and 75% and was treated by water lettuce for 15 days. The 7 parameters were determined in canteen wastewater; pH, BOD, COD, TKN, TP, TSS and FOG. For plants, biomass, total carbohydrate and protein content were determined. Water and plant samples were collected every 3 days at day 0, 3, 6, 9, 12 and 15. The results showed that the maximum removal efficiency of BOD, COD, TKN, TP, TSS and FOG at 25% of concentration were 94.06%, 93.34%, 38.36%, 66.83%, 100% and 6.45%, respectively. The highest biomass was 1.775 g (15 days). The maximum total carbohydrate and protein content of water lettuce were 0.35 and 0.42 g/g biomass, respectively. The result indicated that the highest removal efficiency by water lettuce was at 25% of the concentration of canteen wastewater.

Keyword: Phytoremediation / Water lettuce / Canteen wastewater / Removal efficiency

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Puttapatsorn Laohatrakul

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Chapter 1

INTRODUCTION

1.1 Introduction

Domestic wastewater is a common issue, especially for capital city that has a lot of population. The more people live, the more wastewater produced. Domestic wastewater consists of greywater and blackwater. Greywater is the wastewater produced in bathtubs, showers, hand basins, kitchen sinks, dishwashers and laundry machines and blackwater is the wastewater which comes from toilets (Eriksson et al., 2002; Friedler and Hadari, 2006). Several studies have shown that greywater accounts for around 70-75% of the total wastewater production (Friedler, 2004; Jefferson et al., 2004; Li et al., 2008; Donner et al., 2010; Antonopoulou et al., 2013). Qualitative greywater characterization studies have been conducted and several pollutants have been identified in greywater samples such as organic carbon (in terms of COD, BOD_5 or TOC), nutrients (nitrogen, phosphorus and sulfur) and surfactants (Eriksson et al., 2002; Hernandez Leal et al., 2007; Eriksson and Donner, 2009). Domestic wastewater comes from many sources such as houses, hospitals, schools and commercial zones.

Canteen is the one of the many sources of greywater. Because water and food are important to humans. Everyday human has to eat and drink so the food production also food waste generate wastewater. The criteria of canteen wastewater are high oil and grease, high total nitrogen, high total phosphorus, high BOD and COD. There are a lot of methods to treat canteen wastewater such as physical treatment, chemical treatment and biological treatment.

Biological treatment is natural methods that use organisms to treat contaminants in environment. There are many biological methods to treat canteen wastewater such as bioreactor and electrocoagulation. But these treatment systems involve high cost and skillful management. But another interesting biological method is phytoremediation. Phytoremediation, in which plants are used to remediate a medium contaminated, is a well-established environmental protection technique that has received increasing attention since the term has been coined two decades ago (Vamerali et al., 2010). Phytoremediation is the process through which contaminated substrates are ameliorated by growing plants that have the ability to remove the contaminants. Phytoremediation includes processes such as phytostabilization, phytoextraction, phytovolatilization and rhizofiltration (Nakbanpote, Meesungnoen, Prasad, 2016). Phytoremediation is an interesting process because of its low cost and environmental friendliness (Batty and Dolan, 2013). And also decrease human exposure from toxicants. The criteria of plants that use for this process should have high biomass, rapid growth, high nutrient accumulation and wide tolerance to environmental conditions (Rommens et al., 2003).

Plant that use in this study is water lettuce (*Pistia stratiotes* L.). Water lettuce belongs to the Araceae family (Walsh and Maestro, 2014) and is native to South America (Hill, 2003). It has widely applied in wastewater phytoremediation in tropical areas (Putra et al., 2015), great potential in nitrogen and phosphorus removal, significant absorption and enrichment in several heavy metals. So this plant is suitable for this method to treat canteen wastewater.

1.2 Objectives

1. To determine the efficiency of water lettuce that use for secondary canteen wastewater.
2. To find the concentration of canteen wastewater that suitable for water lettuce treatment.

1.3 Expected outcomes

1. To understand the potential of water lettuce in secondary canteen wastewater treatment.
2. The results can explain which concentration that suitable for the canteen wastewater treatment by using water lettuce.

1.4 Scopes of the study

1. Water lettuce was collected from Chulalongkorn university centenary park and grown in the Hoagland No. 2 at least 2 weeks for adaptation.
2. The canteen wastewater was treated by biochar for primary treatment. Then, the water parameters were measured including pH, BOD, COD, TSS, TKN, TP and FOG.
3. Wastewater from primary treatment was diluted into 0%, 25%, 50% and 75% by adding tap water. Then, water lettuce was replaced in each concentration. Plants were harvested and water parameters were analyzed on day 0, 3, 6, 9, 12 and 15.

Chapter 2

LITERATURE REVIEW

2.1 Phytoremediation

Phytoremediation is the use of plants and their associated microbes for environmental cleanup. This technology makes use of the naturally occurring processes by which plants and their microbial degrade and sequester organic and inorganic pollutants. Phytoremediation is an efficient cleanup technology for a variety of organic and inorganic pollutants. There are a lot of organic pollutants that have been successfully phytoremediated such as organic solvents, herbicides, explosives, petroleum hydrocarbons and the fuel additive. Inorganic pollutants occur as natural elements in the earth's crust or atmosphere, and human activities such as mining, industry, traffic, agriculture, and military activities can release contaminants into the environment, leading to toxicity. Inorganics cannot be degraded, but they can be phytoremediated by stabilization or sequestration in harvestable plant tissues. Inorganic pollutants that can be phytoremediated include plant macronutrients such as nitrate and phosphate, plant trace elements, nonessential elements and radioactive isotopes. The removal contaminants are achieved by different mechanisms like phytoextraction , phytostabilisation, rhizofiltration, phytodegradation (Ariyakanon, 2015), rhizodegradation and phytovolatilization (Nakbanpote, Meesungnoen, Prasad and 2016).

Table 2.1 Mechanism and results of phytoremediation processes

Process	Mechanism	Result	Type of contaminant
Phytoextration	Plant absorps contaminants and transfer to upper ground part.	Contaminant in plant will be harvest with plant.	Heavy metals and redioactive contaminants

Process	Mechanism	Result	Type of contaminant
Phytostabilization	Plant absorps contaminants into roots and/or releases enzyme that change chemical properties of soil.	Contaminants will be stabilized and collected in roots or soil.	Heavy metals and redioactive contaminants
Rhizofiltration	Roots collect contaminants and/or precipitate contaminants at rhizosphere zone.	Contaminants will change to immobilization from or be collected in roots.	Heavy metals and Organic contaminants
Phytodegredation	Plant degrades contaminants.	Contaminants will be transform or degrede.	Organic contaminants such as herbicides
Rhizodegredation	microbials in rhizospher will degrede contaminanats	Contaminants will be transform or degrede.	Organic contaminants such as polycyclic aromatic hydrocarbons
Phytovolatilization	Contaminants will be absorbed into plants.	Contaminants will be absorbed and released to atmosphere	Volatile organic compounds and organic contraminants

(Ariyakanon, 2015)

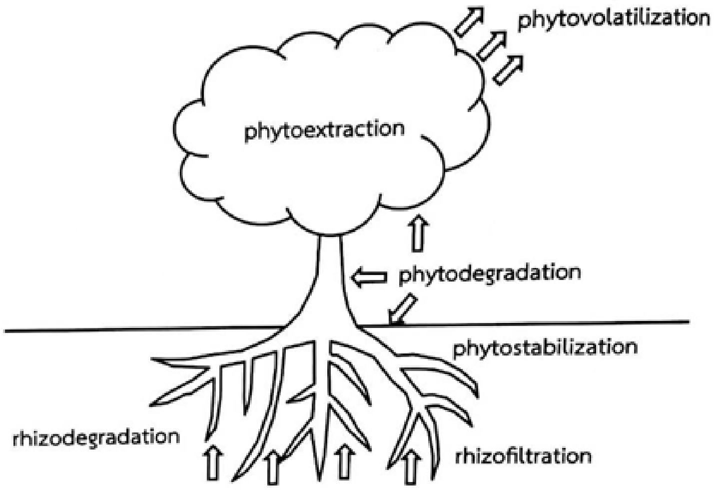

Figure 2.1 Phytoremediation processes (Ariyakanon, 2015)

2.2 Domestic wastewater

Domestic wastewater differs from domestic effluent generated by individual users and emission source. Domestic wastewater consists of two types; greywater and blackwater (Eriksson et al., 2002; Friedler and Hadari, 2006). Greywater includes various emission sources. Effluent charateristic are linked to appliances used to individual patterns: kitchen sink, dishwasher, washing machine, shower, and bath. These uses under two heading: greywater from food-related activities and cleaning, and from personal care, bathroom effluents. Another type of domestic wastewater is blackwater. For blackwater, two modes of effluent collection are considered: collection of whole excretion and water from toilets, and selective collection from source-seperating toilets. Source-seperating toilets allow a seperate collection of yellow water (flush water and urine), brown water (flush water or not. faeaes and toilet paper) and Others (cleaning water in toilets).

Figure 2.2 Classification of Domestic wastewater (Boutin and Eme, 2016)

2.3 Canteen wastewater

Canteen is a place that can generate wastewater by many activities such as cleaning or washing during and after food process. Canteen wastewater is part of greywater because effluent was generated from food-related activities. Canteen wastewater contained fats oils and greases, there are cause of strongly odor and organic contaminants. The average range of values of student canteen wastewater are 545-1630 mg/L of BOD, 124-1320 mg/L of TSS and 415-1970 mg/L of FOG (Lesikar et al., 2004).

2.4 Water lettuce

Water lettuce (*Pistia stratiotes* L.*)* belongs to the Araceae family (Walsh and Maestro, 2014) and considered native to the Pantanal region of South America (Bulletin, 2017). Water lettuce has a tropical and subtropical distribution. *Pistia stratiotes* is a clonal plant that forms small colonies with daughter plants attached to the mother plant through stolons. The upper sides of the leaves are light green, while the undersides are almost white. The floating plants have large feathery root systems which hang freely in the water (Neuenschwander *et al*., 2009). *Pistia stratiotes* grows in slow-moving rivers and reservoirs, irrigation channels, ponds, lakes, canals and ditches (Venema, 2010; Adebayo *et al*., 2011; Hussner *et al*. 2014). The species often find as well as other wetland habitats. Its growth is optimal at temperatures between

22 and 30°C and high-nutrient conditions (Pieterse *et al*., 1981; Henry-Silva *et al*., 2008).

Figure 2.3 Water lettuce (www.thepondguy.com, 2019)

2.5 Applications of water lettuce for wastewater treatment

Water lettuce is an alien plant. Theses plant has been widely applied in wastewater phytoremediation in subtropical and tropical areas (Putra et al., 2015). *P. stratiotes* is widely used for phytoremediation of metals, chemical products, oil, removal of pharmaceuticals and personal care products or for urban sewage treatment because of highly growth, great potential in nitrogen and phosphorus removal (Lu et al., 2010), fast growth rate, big biomass production (Reddy and Sutton 1984) and significant absorption (Lu et al., 2011).

Water lettuce is popular for inorganic contaminants because they are good metal accumulators and can be harvested easily. Also work well for organics remediation because of high levels of organic-degrading enzymes also rhizofiltration involves aeration.

Water lettuce shows rapid growth in domestic wastewater treatment especially in wastewater that organic matters is already mineralized. *Pistia* stratiotes can therefore withdraw nitrogen from polluted water especially under optimum condition to produce a high biomass. *Pistia* practically doubles its biomass in just over 5 days; triples in 10 days, duadruples in 20 days and has its original biomass multiplied by a factor of

9 in less than a month. The system that uses water lettuce for phytoremediation of domestic sewage found water lettuce improves some water parameters; turbidity, PO_4^{2-}, COD, BOD_5, suspended solids, dissolved oxygen and NO_3^-) by more than 70% (FONKOU, 2002).

Chapter 3
MATERIALS AND METHODS

3.1. Wastewater sampling and preparation

Water samples were collected at the Chulachakrabongse building in Chulalongkorn University. The canteen wastewater was collected from wastewater treatment tank by using dipper and collected in 20 liters High density polyethylene (HDPE) gallons (30 L). After the collection, canteen wastewater samples were treated by biochar as a primary treatment. The biochar made from crushed corn core that pyrolyzed at 400 $^{\circ}$ C for 1 hour. The whole of canteen wastewater was mixed with biochar in ratio of 1g biochar per 20 mL of canteen wastewater and preserved at room temperature for 2 days, this condition was appropriate as stated by Soonkee.,2018. After the primary treatment the water samples were filtered by 0.05 mm mesh for removed biochar from the water samples. Then, the water samples were diluted for 25%, 50% and 75% by adding the tap water for the secondary treatment.

3.2. Plant collection and preparation

Water lettuce was collected at Chulalongkorn university centenary park (13°44’20”N 100°31’27”E). Then the plants were disinfected by immersion in 0.01% (v/v) Clorox bleach to eliminate adhering algae and insect larva for 2 min, rinsed with distilled water for 5 min and then thoroughly cleaned under gentle running water. Plants will be selected and cultivated by using Hoagland solution No.2 for 2 weeks. Plant selection by used gravimetric method. Water lettuce weight about 40±4 g/plants were selected for this experiment.

Figure 3.1 Location of plants collection

3.3. Experimental design

The experiment was studied at fourth floor of Environmental Science building, faculty of Science, Chulalongkorn university (13°44’13”N 100°31’53”E). The selected plants were planted in different dilutions (0%, 25%, 50% and 75%) of canteen wastewater. Dilution of 0% of canteen wastewater concentration used tap water and other concentrations were prepared by diluted canteen wastewater with tap water as 25%, 50% and 75% concentration. This study used glass containers for canteen wastewater and plants. Each sample was done in tripicate. Plants and water samples were collected and analyzed every three days at day 0, 3, 6, 9, 12 and 15.

Figure 3.2 Location of experimental site (13°44’13”N 100°31’53”E)

The experiment was designed as follow:

T1 : Tap water and water lettuce

T2 : 25% concentration of canteen wastewater and water lettuce

T3 : 50% concentration of canteen wastewater and water lettuce

T4 : 75% concentration of canteen wastewater and water lettuce

Table 3.1 Experimental Design

Day	Concentration of canteen wastewater			
	0% (T1)	25% (T2)	50% (T3)	75% (T4)
0	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
3	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
6	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
9	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
12	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
15	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■

3.4. Water samples and plants analysis

Water samples were collected and analyzed for 7 parameters; pH, Biochemical Oxygen Demanded (BOD), Chemical Oxygen Demanded (COD), Total Suspended Solid (TSS), Fats Oil and Greases (FOG), Total Kjeldahl Method (TKN) and Total Suspended Solid (TSS). The plants were collected and weighted as fresh weight before dried at $65\ ^{\circ}C$ in oven for 24 hours and then plant samples were analyzed other 2 parameters; total carbohydrates and protein content.

Table 3.2 Water samples analytical methods

Parameters	Analytical Methods
pH	pH Meter
Biochemical Oxygen Demanded	Azide Modification
Chemical Oxygen Demanded	Close Reflux
Total Suspended Solid	Glass Fiber Filter Disc
Fat Oil and Greases	Soxhlet Extraction
Total Kjeldahl Nitrogen	Kjeldahl Method
Total Phosphorus	Ascorbic Acid Colorimetric Method

Table 3.3 Plants analytical methods

Parameters	Analytical Methods
Biomass	Gravimetric Method
Total Carbohydrates	Phenol-Sulfuric Acid Colorimetric Method
Protein Content	Kjeldahl Method

Protein content was calculated as total nitrogen x 4.64 (g/g biomass)

where total nitrogen calculated as follow:

$$\frac{(ml\ of\ titrated\ H2SO4 - ml\ of\ H2SO4\ titrated\ for\ blank) x\ 1.4007}{Weight\ of\ sample\ in\ grams}$$

Statistical analysis analyzed with SPSS program. One-way ANOVA test was used to compare the different of each parameter (pH, BOD, COD, TSS, FOG, TKN, TP, biomass, total carbohydrate and protein content) at each time (days) and different concentration of canteen wastewater at 95% confidence level.

Treatment efficiency was calculated as the percentage of removal of each parameter as follow:

$$\text{Removal efficiency} = \frac{Ci - Ce}{Ci} x\ 100$$

When Ci is concentration of influent and Ce is concentration of effluent

Table 3.4 The results of each parameter after treated by biochar

Parameter	**Unit**	**Concentration**	**Standard***
pH	-	5.99	5-9
BOD	mg/L	1428.33	30
COD	mg/L	2167.00	-
TSS	mg/L	451.33	40
TKN	mg/L	3.13	35
TP	mg/L	173.09	-
FOG	mg/L	92.50	20

Chapter 4

RESULTS AND DISCUSSION

4.1 pH

The results showed that pH values increased in every concentration (0%, 25%, 50% and 75%) of canteen wastewater. Every concentration showed the highest pH value at the last day (for concentration of 75% the last day of experiment was day 12 because a set of plant almost die in day 6 so plants were collected in day 6. pH range between 6.46-7.90 of 0% concentration, 6.90-8.76 of 25% concentration, 6.48-8.70 of 50% and 6.13-8.55 of 75% concentration. Figure 4.1 showed a similar trend of 25%, 50% and 75% concentration that raise rapidly from day 0-3 and slightly increase from day 3 to 15. Increasing pH was attributed to the fact that plant was release chemical into the wastewater for absorbed nutrients in wastewater as stated by Mahmood et al., 2005.

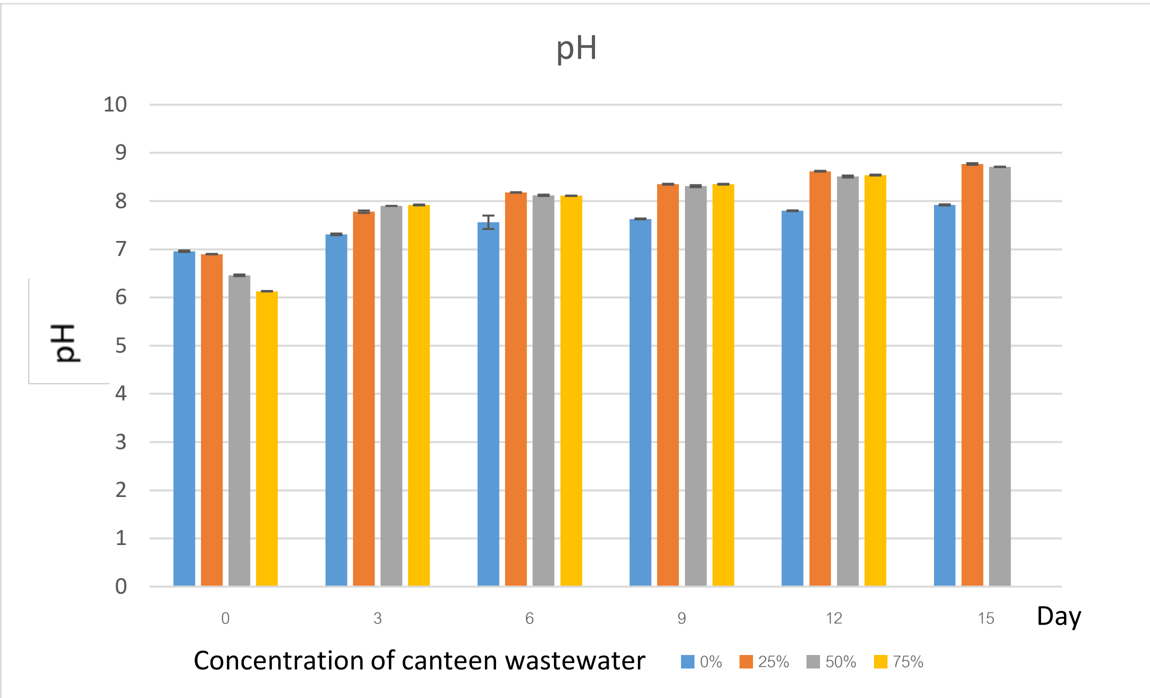

Figure 4.1 pH of the 2nd canteen wastewater at difference concentration

4.2 Biochemical oxygen demand

The results showed that Biochemical Oxygen Demand (BOD) decreased in every concentration of canteen wastewater as shown in figure 4.2. At 0% of concentration, BOD decreased from 4.17 to 2.08 mg/L. The decreasing trend of 25%, 50% and 75% of concentration were significantly difference (at $p < 0.05$) excepted comparison between day 12 and 15 of 25% concentration, day 6 and 9, 12 and 15 of 50% concentration and no significantly difference for 75% concentration (compared between the difference of concentration in each day in the same concentration) at $p<0.05$. BOD was dropped because of rhizodegradation, microorganism that lived at root zone of *Pistia stratiotes* degraded organic contraminants (Mahmood et al., 2005) in canteen wastewater also transform organic matters to available forms, that plants absorbed and grown (increase biomass) so this effect to BOD values.

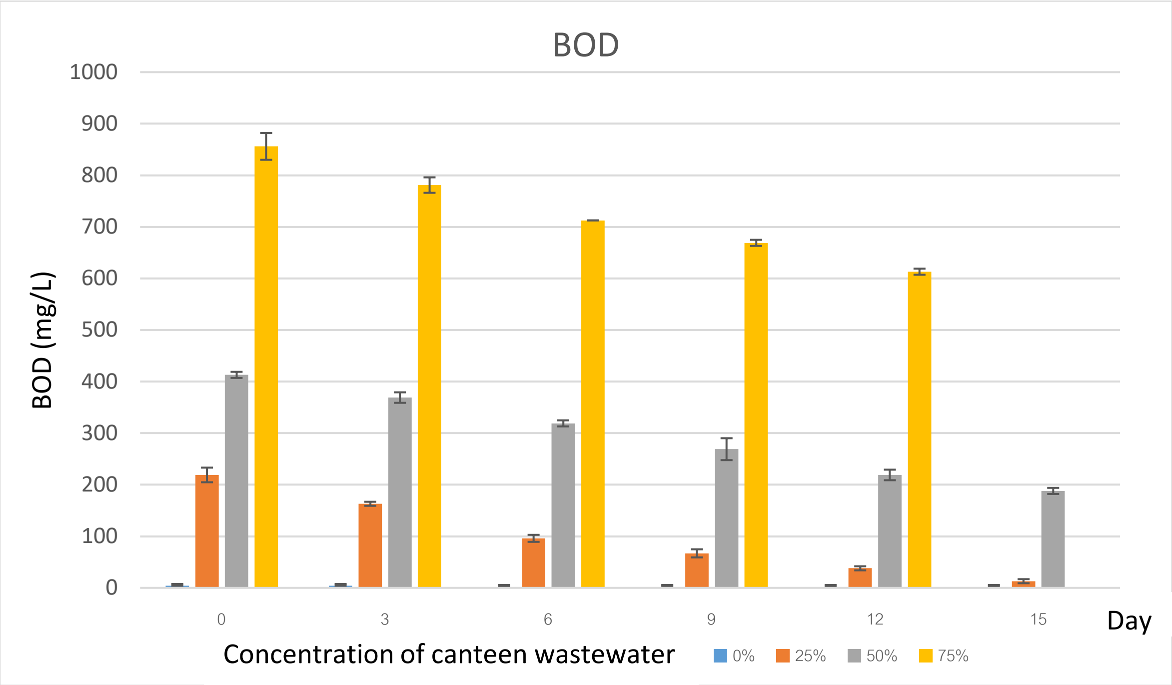

Figure 4.2 BOD of the 2nd canteen wastewater at difference concentration

4.3 Chemical oxygen demand

The results showed that COD at 25%, 50% and 75% of concentration were slightly drop and significantly difference at $p<0.05$ excepted comparison between day 0 and 3, day 9 and 12 of 25% concentration, day 0 and 3, day 9 and 12, day 12 and 15 of 50% concentration, day 0 and 3, day 9 and 12 of 75% concentration (compared between the difference of concentration in each day in the same concentration) at $p<0.05$. Decreasing trends of COD similar to BOD values, lower COD is attributed to the microbial action at root zone to degraded organic matter, that was attributed to decreasing COD in the wastewater. Dipu et al., reported 59% of COD removal by Pistia stratiotes.

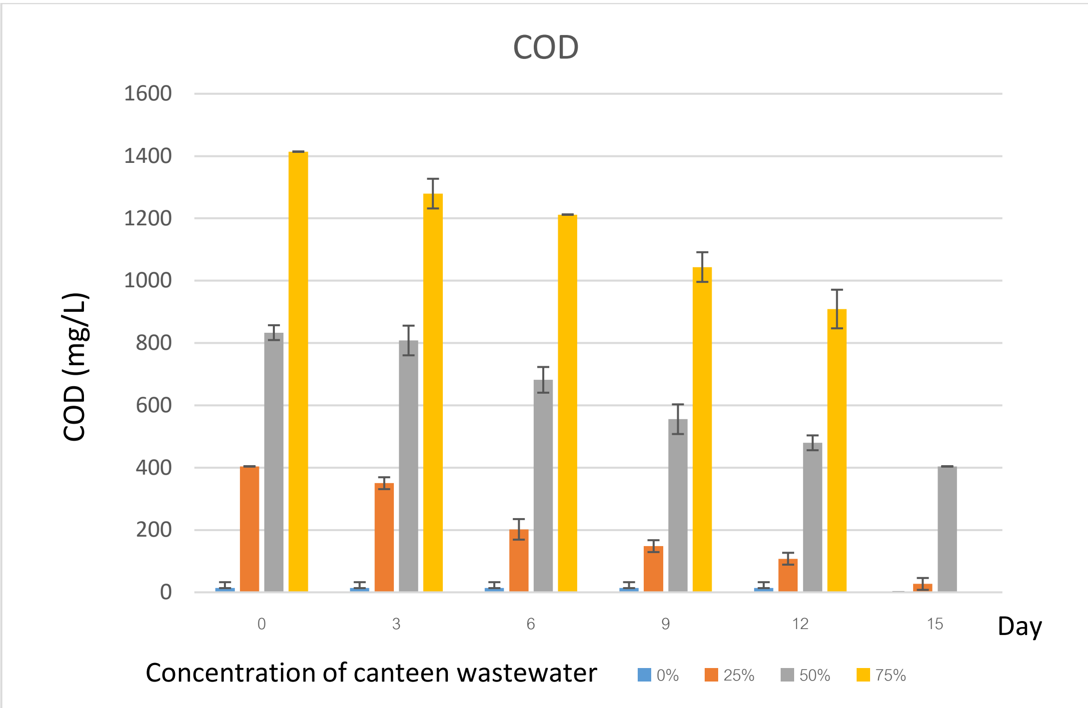

Figure 4.3 COD of the 2nd canteen wastewater at difference concentration

4.4 Total kjeldahl nitrogen

The results showed in figure 4.4, decreasing of TKN of every concentration of canteen wastewater was significantly difference (at $p<0.05$) excepted in 50% concentration that was compared between day 0 and 3, day 6 and 9 also day 12 and 15, there are no significantly difference (at $p<0.05$). TKN values decreased because of plant absorption. TKN is the method to find organic nitrogen, ammonia (NH_3) and ammonium (NH_4^+). Water lettuce is reported to reduce the ammonium ions from the water as it utilizes ammonium (NH_4^+) prior to nitrate (NO_3^-) as nitrogen source (Gupta, Roy and Mahindrakar, 2012). Also water lettuce uptakes nitrogen in inorganic form for growth thus the absorption of *Pistia stratiotes* can withdraw nitrogen from wastewater.

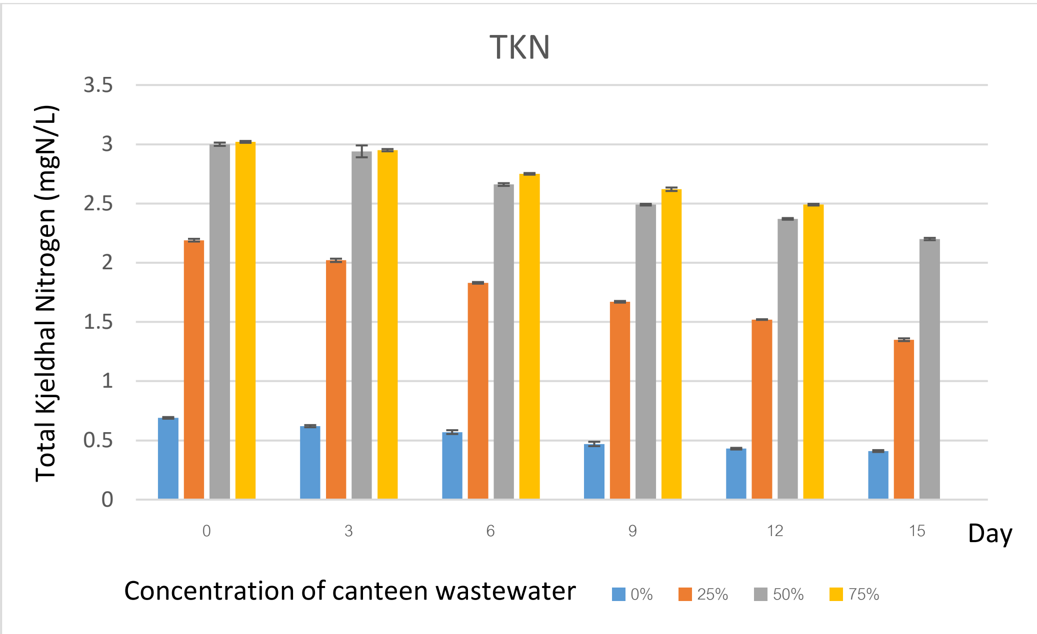

Figure 4.4 of the 2nd canteen wastewater at difference concentration

4.5 Total phosphorus

The results showed that TP decreased in every concentration of canteen wastewater. There was significantly difference (at $p<0.05$) of TP that was compared between the difference of concentration in each day in the same concentration. Total phosphorus decreased because water lettuce can absorb phosphorus in wastewater by uptake nutrient through roots. Phosphorus plays an important role in an array of cellular processes, including maintenance of membrane structures, synthesis of biomolecules and formation of high-energy molecules. It also helps in cell division, enzyme activation/inactivation and carbohydrate metabolism (Razaq et al. 2017). Plants uptake phosphorus in inorganic form so the value of total phosphorus decreased. At concentration of 25%, 50% and 75%, TP value trends was similar, TP values rapidly dropped between day 0 to day 3 but after day 3 TP slightly decreased as shown in figure 4.5.

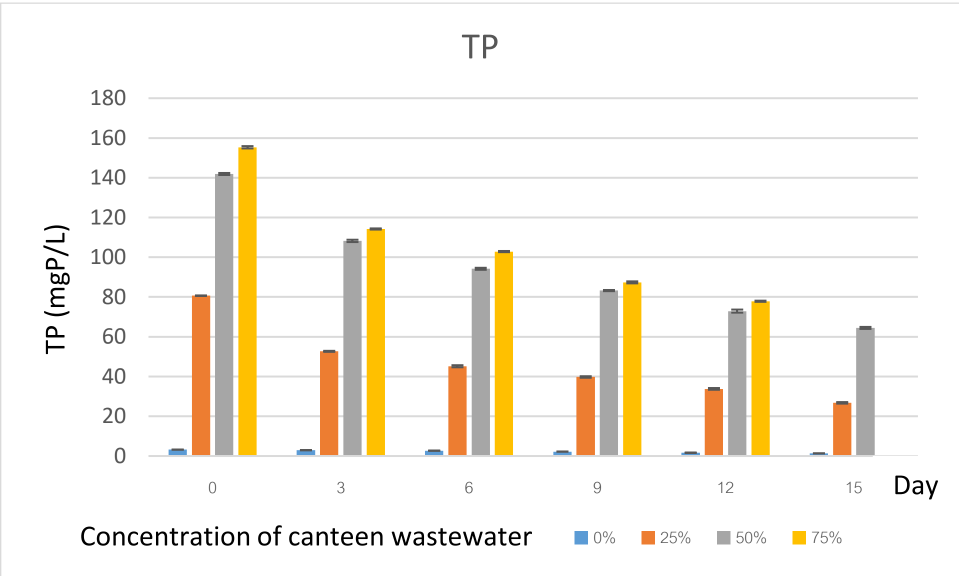

Figure 4.5 TP of the 2nd canteen wastewater at difference concentration

4.6 Total suspended solids

TSS of 0% concentration showed 0 mg/L since the first day until the last of experiment. But others concentration, TSS decreased slowly as shown in figure 4.6, there were significantly difference (at $p<0.05$) when compared between the difference of concentration in each day in the same concentration. This affect happened because the rhizofiltration of water lettuce roots played important roles in intercepting and filtering contraminants (Qin, et al., 2016) also decreasing of TSS was attributed to natural sedimentation of suspended solids.

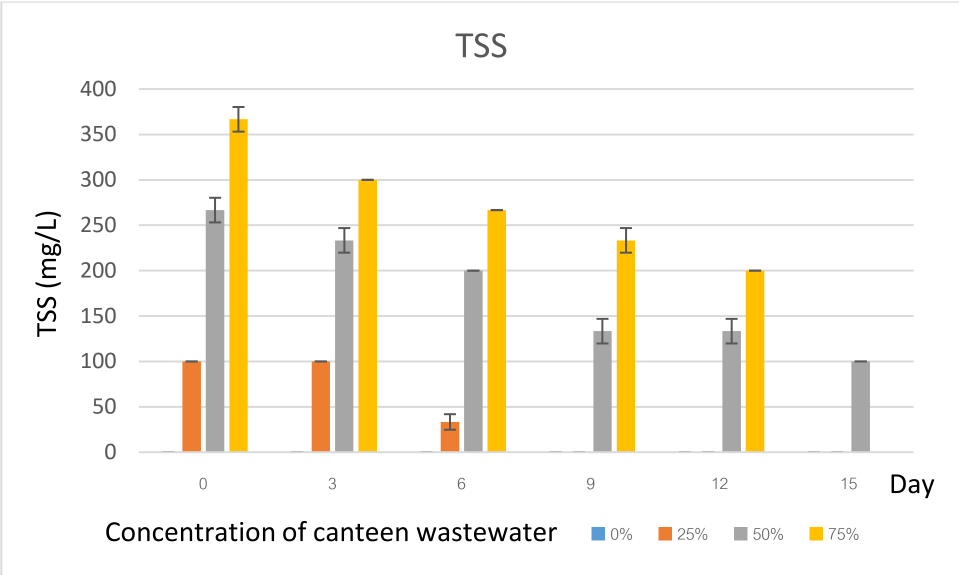

Figure 4.6 TSS of the 2nd canteen wastewater at difference concentration

4.7 Fat oil and grease

Fat oil and grease slightly decreased because fat oil and grease are substance that difficult to degrade so the values of fat oil and grease almost stable from day 0 to last day of experimentation at every concentration of canteen wastewater (25%, 50% and 75%) excepted 0% concentration because FOG was constant (0 mg/L since the experiment was started). FOG values decreased from 31 to 29 of 25% concentration, 64.67 to 64 of 50% concentration and 76.33 to 76 of 75% concentration. The amount of FOG at 25%, 50% and 75% was no significantly difference at $p<0.05$ excepted in 25% of concentration; between day 0 and 9, day 0 and 12 also between day 0 and 15 (compared between the difference of concentration in each day in the same concentration).

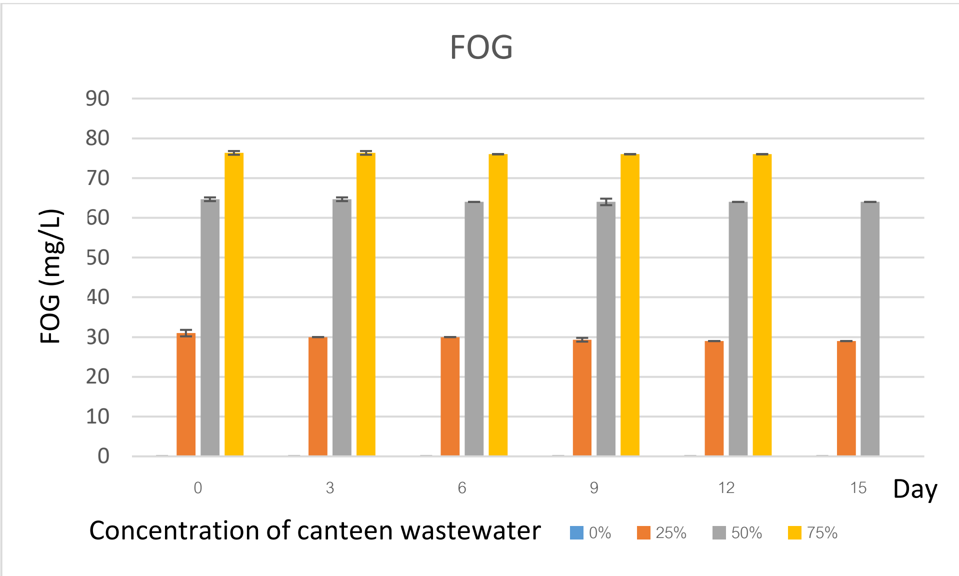

Figure 4.7 FOG of the 2nd canteen wastewater at difference concentration

4.8 Plant biomass

Biomass of water lettuce increased at every concentration of canteen wastewater. At 25% of concentration showed the highest increasing biomass (1.775 g) and 0% of concentration showed the lowest increasing biomass (0.28 g) in last day (day 15). Trends of increasing biomass was shown in figure 4.8. Biomass at 25% of concentration increased rapidly but other concentrations were slightly rising from day 0 to 15, biomass were significant difference at $p<0.05$ excepted in 75% of concentration that compared between day 6 and 9, no significantly difference at $p<0.05$. Biomass increased because plant uptake nutrients from wastewater for growth.

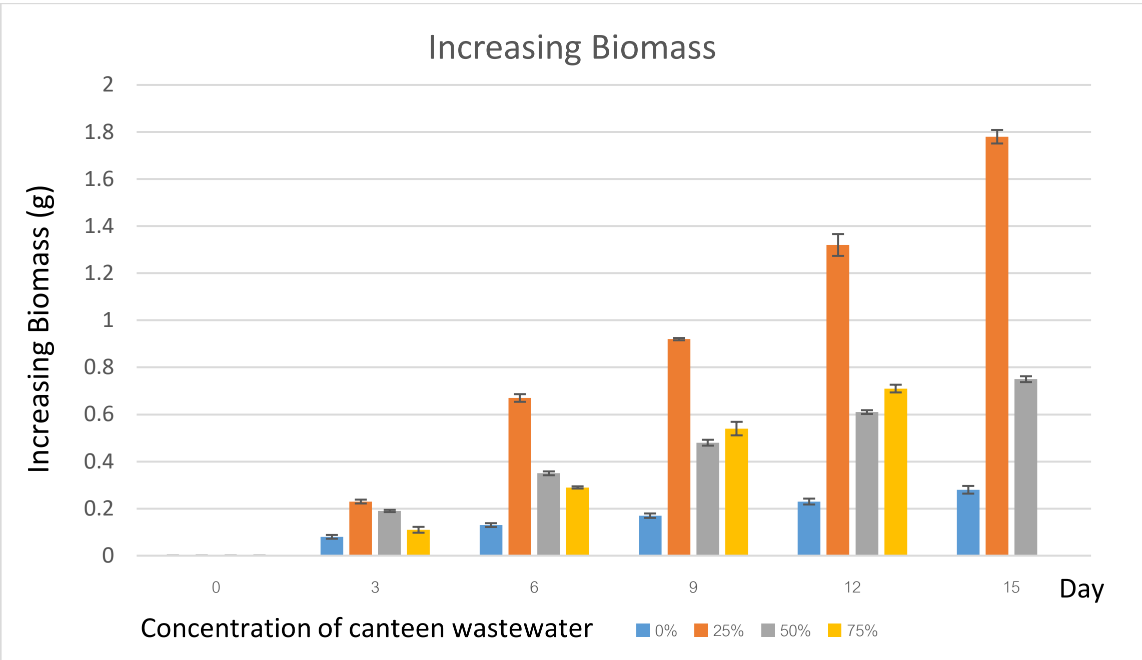

Figure 4.8 Biomass of the 2nd canteen wastewater at difference concentration

4.9 Total carbohydrate

The results showed increasing trends of total carbohydrates at all of concentrations. The highest value in last day was found at 25% of concentration that related to biomass and the lowest total carbohydrate was found at 0% of concentration, related to biomass too. There was significantly difference of carbohydrate at 0%, 25% and 75% (compared between the difference of concentration in each day in the same concentration) at $p<0.05$. Total carbohydrate value related to biomass because plant stem will produce carbohydrate for grow up so if biomass is rising, total carbohydrate will rise too. Also water lettuce uptake macronutrient such as phosphorus in wastewater that is an important role for cellular processes. It helps in cell division, enzyme activation/inactivation and carbohydrate metabolism in plant (Razaq et al. 2017) that effect to increasing of total carbohydrate.

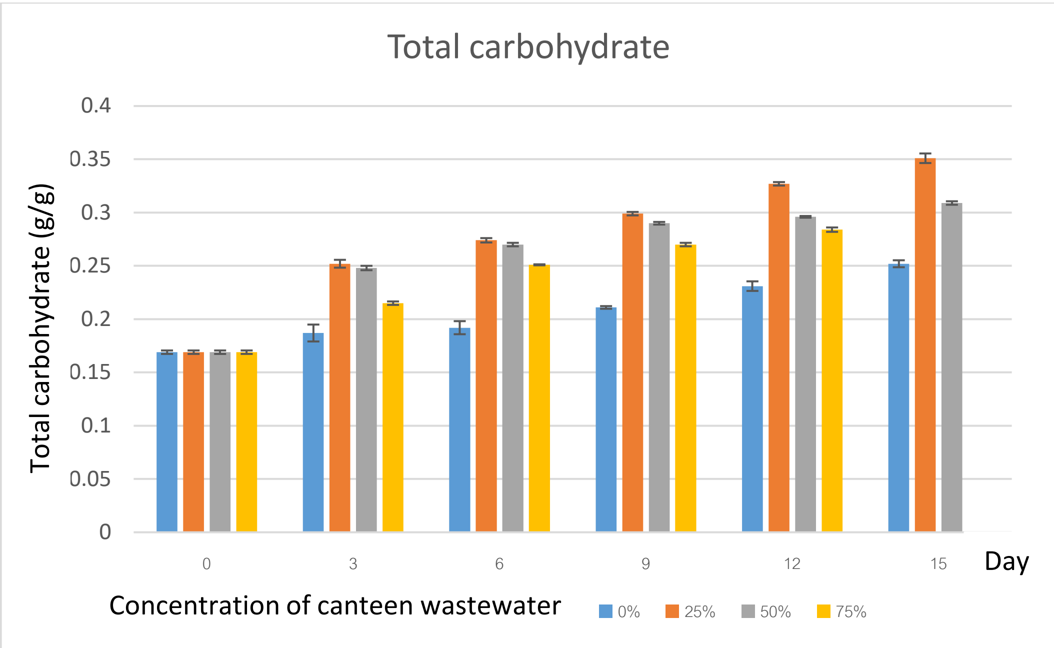

Figure 4.9 Total Carbohydrate of the 2nd canteen wastewater at difference concentration

4.10 Protein content

Protein contents were similarly to total carbohydrate because increasing of biomass affect to protein content values. Plants uptake nutrient for wastewater for grow up, nutrients such as inorganic nitrogen were absorbed and used for produced protein in stem so protein content relate to biomass like total carbohydrates. The highest protein was found at 25% of concentration and the lowest shows at 0% of concentration in last day, significantly different at $p<0.05$ (compared between the difference of concentration in each day in the same concentration).

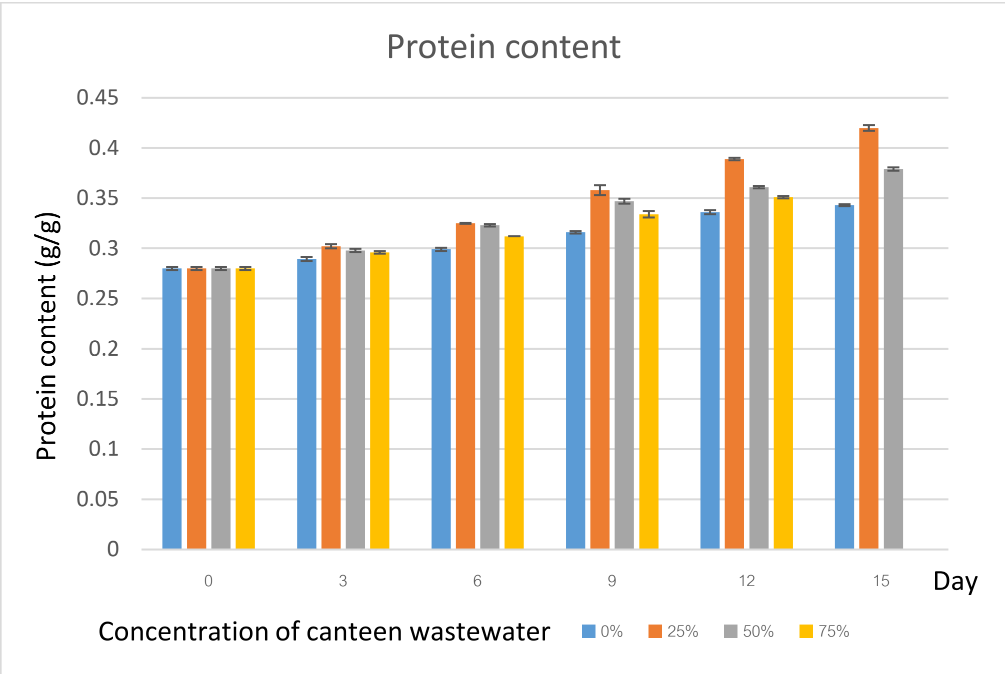

Figure 4.10 Protein content of the 2nd canteen wastewater at difference concentration

4.11 Removal efficiency of water lettuce for canteen wastewater treatment

The removal efficiency of each parameter and each concentration of canteen wastewater treated by water lettuce were shown in Figure 4.11. The highest removal efficiency of BOD at 25% of concentration were 94.09%. The removal efficiency at the 50% and 75% of concentration were 54.45% and 28.39%, respectively. The removal efficiency of COD at 25%, 50% and 75% of concentration were 93.34%, 51.51% and 26.19%, respectively. The TKN removal efficiency at 25%, 50% and 75% of concentration were 38.36%, 26.67% and 17.55%, respectively. The TP removal efficiency of water lettuce at the concentration of 25%, 50% and 75% were 66.83%, 54.58% and 49.87%, respectively. The removal efficiency of TSS at concentration of 25%, 50% and 75% were 100%, 62.50% and 45.46%. The removal efficiency of FOG at 25%, 50% and 75% of concentration were 6.45%, 1.04% and 0.43%, respectively.

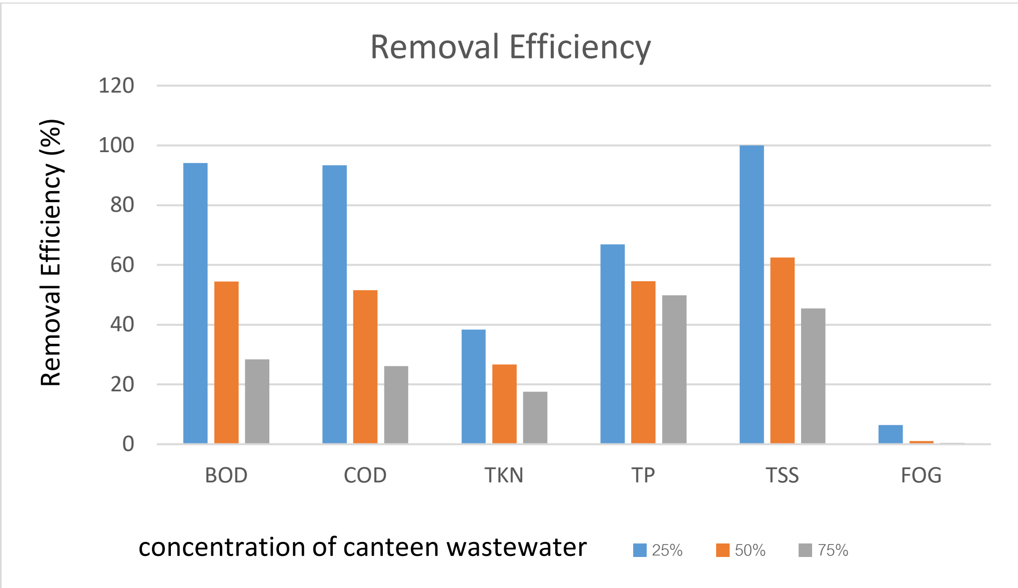

Figure 4.11 Removal efficiency of the 2nd canteen wastewater by using water lettuce

Chapter 5

CONCLUSIONS

5.1 pH

pH values of every concentration (0%, 25%, 50% and 75%) of canteen wastewater increased and showed the highest value in last day of experimentation.

5.2 BOD

The highest removal efficiency of BOD by water lettuce was 94.06% at 25% of concentration of canteen wastewater and the lowest was 28.39% at 75% of concentration, there were significantly difference at $p<0.05$.

5.3 COD

The highest removal efficiency of COD was 93.34% at 25% of concentration. The lowest was 26.19% at 75% of concentration, there were significantly difference at $p<0.05$.

5.4 TKN

The highest removal efficiency of TKN was 38.36% at 25% of concentration and the lowest was 17.55% at 75% of concentration, there were significantly difference at $p<0.05$.

5.5 TP

The highest removal efficiency of TP was 66.83% at 25% of concentration and the lowest was 49.87% at 75% of concentration that significantly difference at $p<0.05$.

5.6 TSS

The highest removal efficiency of TSS was 100% at 25% of concentration of canteen wastewater and the lowest was 45.46% at 75% of concentration, there were significantly difference at $p< 0.05$.

5.7 FOG

The highest removal efficiency of FOG was 6.45% at 25% concentration of canteen wastewater and the lowest was 0.43% at 75% of concentration, there were significantly difference at $p<0.05$.

5.8 Biomass

Biomass of water lettuce of all concentration increased. The maximum weight increased 1.775 g (15 days) at 25% of concentration.

5.9 Total carbohydrate

The highest total carbohydrate was 0.35 g/g biomass in day 15 at 25% of concentration. The lowest was 0.28 g/g biomass in day 12 at 75% of concentration, there were significantly difference at $p<0.05$.

5.10 Protein content

The highest protein content was 0.42 g/g biomass at 25% of concentration. The lowest protein content was 0.35 g/g biomass at 75% of concentration that significantly difference at $p<0.05$.

From the results, the efficiency of secondary canteen wastewater by using water lettuce showed the highest removal efficiency of BOD, COD, TKN, TP, TSS and FOG at 25% of concentration of canteen wastewater. Also biomass, total carbohydrate and protein content at 25% of concentration showed the highest value too.

The limitation of phytoremediation of secondary canteen wastewater was 75% of concentration because of high concentration of nutrients in canteen wastewater that effect to water lettuce. A set of water lettuce in 75% of concentration was died in day 6 so there were collected in that day and made 75% of concentration finished in day 12. Thus the limitation of concentration was 75% of canteen wastewater (12 days) and 25% of concentration of canteen wastewater was the recommended concentration for phytoremediation by using water lettuce for 15 days of experiment.

In this study, 25% of concentration shown the highest efficiency of phytoremediation of canteen wastewater by using water lettuce. The values of each parameter were compared to water quality of building wastewater standard in class B of pollution control department and all of parameter were accepted, excepted FOG value was 29 mg/L that over the standard (20mg/L).

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