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Title	Phytoremediation of secondary canteen wastewater by using water hyacinth (*Eichhornia crassipes*)
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Phytoremediation of secondary canteen wastewater

by using water hyacinth (*Eichhornia crassipes*)

Miss Yanudchara Nuanpan

A Senior Project Submitted in Partial Fulfillment of the Requirements for the

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ชื่อเรื่อง การบำบัดน้ำเสียขั้นที่สองจากโรงอาหารโดยใช้ผักตบชวา

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บทคัดย่อ

จุดมุ่งหมายของการศึกษานี้คือการหาประสิทธิภาพในการบำบัดน้ำเสียขั้นที่สองจากโรงอาหาร โดยใช้ผักตบชวา (*Eichhornia crassipes*) และหาความเข้มข้นของน้ำเสียที่ผักตบชวาสามารถบำบัดได้ดีที่สุด โดยมีการวัดพารามิเตอร์ของน้ำเสียที่ศึกษาก่อนและหลังการบำบัดได้แก่ ความเป็นกรด-ด่าง บีโอดี ซีโอดี ทีเคเอ็น ฟอสฟอรัสทั้งหมด ของแข็งแขวนลอยทั้งหมด น้ำมันและไขมัน ส่วนพารามิเตอร์ของพืชจะทำการศึกษามวลชีวภาพ ปริมาณโปรตีนทั้งหมด และคาร์โบไฮเดรตทั้งหมด น้ำเสียจากโรงอาหารที่เก็บมาจากแหล่งกำเนิดจะนำมาบำบัดขั้นต้นด้วยถ่านชีวภาพ หลังจากนั้นนำมาบำบัดขั้นที่สองโดยการนำน้ำเสียที่ได้มาเจือจางให้มีความเข้มข้นร้อยละ 0, 25, 50, และ 75 จากนั้นจึงนำผักตบชวามาใส่ในชุดทดลองเป็นเวลา 15 วัน ผลการทดลองพบว่าในความเข้มข้นของน้ำเสียร้อยละ 25 ผักตบชวามีประสิทธิภาพในการบำบัดบีโอดี ซีโอดี ทีเคเอ็น ฟอสฟอรัสทั้งหมด ของแข็งแขวนลอยทั้งหมด น้ำมันและไขมันได้ดีที่สุดที่ร้อยละ 93.31, 89.83, 38.97, 76.81, 100 และ 20.90 ตามลำดับ นอกจากนั้นยังพบว่าที่ความเข้มข้นของน้ำเสียร้อยละ 25 มวลชีวภาพของผักตบชวาจะมีการเพิ่มสูงสุดเท่ากับ 5.50 กรัม ส่วนปริมาณโปรตีนและคาร์โบไฮเดรตทั้งหมดของผักตบชวามีปริมาณเพิ่มมากที่สุด 0.59 และ 0.40 กรัมต่อกรัมมวลชีวภาพ ตามลำดับ ดังนั้น การศึกษาครั้งนี้จึงสรุปได้ว่าผักตบชวามีประสิทธิภาพในการบำบัดน้ำเสียขั้นที่สองจากโรงอาหารเมื่อเจือจางให้มีความเข้มข้นของน้ำเสียร้อยละ 25

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Title Phytoremediation of secondary canteen wastewater by using water hyacinth (*Eichhornia crassipes*)

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Project Advisor Associate Professor Naiyanan Ariyakanon, Ph.D.

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Abstract

The objectives of this study were to evaluate the efficiency of water hyacinth (*Eichhornia crassipes*) to treat the secondary canteen wastewater, and to find the optimum concentration of wastewater that suitable for application of water hyacinth. The wastewater parameters before and after treatment were analyzed including pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total kjeldahl nitrogen (TKN), total phosphorus (TP), total suspended solids (TSS), fat oil and grease (FOG). The parameters of plant including biomass, protein content and total carbohydrate were also determined. The canteen wastewater was treated by biochar for primary treatment. Then, the wastewater was diluted at the concentrations of 0%, 25%, 50%, and 75%. The water hyacinth was planted in each treatment for 15 days. The result showed that the maximum removal efficiency of BOD, COD, TKN, TP, TSS, and FOG at the 25% of concentration of wastewater were 93.31%, 89.83%, 38.97%, 76.81%, 100%, and 20.90%, respectively. The highest biomass of water hyacinth was 5.50 g. at the 25% of concentration of wastewater. The protein content and total carbohydrate of water hyacinth were 0.59 and 0.40 g/g biomass respectively, at the 25% of concentration of wastewater. This study concluded that water hyacinth was effective for the treatment of secondary canteen wastewater at the 25% of concentration of wastewater.

Keyword: Phytoremediation / Water hyacinth / Secondary wastewater / Removal efficiency / Canteen wastewater

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Yanudchara Nuanpan

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Sources of domestic wastewater can be divided as residential, commercial, institutional and recreational (Boutin and Eme, 2017). Domestic wastewater has been affected by human use, which has high concentration for oil and grease, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen and phosphorus. When wastewater released into natural body without treatment, it will be affected to aquatic organisms and increased water pollution.

Water treatment technology requires cost. Whether it is a physical treatment such as a settling tank that can precipitate solids effectively in water, or a sand filter that separates the things that larger than its pore from water (Bahgata, Dewedarb, and Zayedc, 1999). The Fenton process is chemical treatment, that can effectively treat organic compound in water by using hydrogen peroxide with ferrous ion as a catalyst (Blanco et al., 2014), or even the most widely used activated sludge system in Thailand. It is costly method and requires specialists. The alternative way is the concept of wastewater treatment using phytoremediation.

Phytoremediation is the technologies that use living plants to clean up soil, air, and water contaminated with hazardous contaminants. Phytoremediation is cost effective and environmental friendly (Newete and Byrne, 2016). Plants have variety of management method. Phytoextraction can be used to treat heavy metals by up taking from the source to be stored as biomass or phytostimulation, which plant stimulate microbial activity to degrade the contaminants and other process. With the phytoremediation process can handle many types of contaminants such as As, Cd, Pb, and Hg as heavy metals, ethion and chlorpyrifos as pesticides, dichloromethane, ethyl acetate, diethyl ether, and acetone as a solvent and including nutrients in wastewater that is needed by plants.

Water hyacinth is one of the most popular plants using for phytoremediation with ability that can treat many pollutants such as Cr, Zn, NO_3, and PO_4 (Mahmood et al., 2005) which is a free floating macrophyte having hairy roots. It can grow easily in polluted wastewater and its pH tolerance is estimated at 5.0-9.0. Thus, it is considered as a potential green phytoremediation method for the removal of pollutants (Gong et al., 2018). Water hyacinth exhibited hyperactive accumulating capacity for nitrogen, and more suitable than water lettuce for the intensive purification of domestic sewage with high nitrogen concentrations (Qin et al., 2016).

1.2 Objectives

1. To determine the efficiency of water hyacinth to treat the secondary canteen wastewater.
2. To find the concentration of canteen wastewater that suitable for water hyacinth treatment.

1.3 Expected outcomes

1. To understand the potential of water hyacinth in secondary canteen wastewater treatment.

1.4 Scopes of the study

1. Water hyacinth was collected from the natural body 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 oil and grease.

3. Wastewater from primary treatment was diluted into 0%, 25%, 50% and 75% by adding tap water. Then, water hyacinth 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

2.1.1 Phytoremediation

Phytoremediation is a type of bioremediation in which plants are used to degrade or immobilize contaminants in water to mitigate the effects of toxic pollutants. This word is from the Greek language, and it refers to restoring contaminated sites through plants. Phytoremediation is an economical and environmentally safe technique in which contaminants are extracted from water (Jiang et al., 2015).

Phytoremediation is an environmentally safe approach that has the potential to use the capacity of plants to accumulate contaminants from the environment, and to degrade or accumulate these toxic pollutants. The accumulation in certain plants leverages their natural ability to render harmless pollutants in soil or water. With the knowledge of molecular and physiological changes, the technology of phytoremediation has been improved, and has emerged as an innovative technique. In the phytoremediation technique, more harmful heavy metals and toxic organic contaminants are targeted. Different types of engineering works and biological strategies have been developed to improve the process of phytoremediation. The feasibility of various plants has been confirmed using phytoremediation for environmental cleanup purposes (Alia, Khanb, and Sajad, 2013).

2.1.2 Phytoremediation technologies

Phytoremediation is recognized as a naturally occurring process and being documented by human more than 300 years ago (Lasat, 2000). Since then, certain plants' capabilities to survive in polluted area and to facilitate pollutants removal from the environment had been exploited by humans. Nevertheless, the scientific studies and relevant development of those plants' abilities had only been conducted since the early 1980's (Paz-Alberto and Sigua, 2013). Kösesakal et al. (2016) defined phytoremediation as the technology which uses plants and rhizospheric microorganisms to remove pollutants in soil, sediment, groundwater, surface water and even chemical pollutants in atmosphere. Placek, Grobelak, and Kacprzak (2016) described phytoremediation as the use of plants and associated microorganisms to immobilize (phytostabilization), remove (phytoextraction), evaporate (phytoevaporation), or degrade (phytodegradation, rhizodegradation) pollutants from soil and water environment.

According to Lu et al. (2010), there are three principles for operating an aquatic phytoremediation system: (1) identification and implementation of efficient aquatic plant systems; (2) uptake of dissolved nutrients including N, P and metals by the growing plants; and (3) harvest and beneficial use of the plant biomass produced from the remediation system. In order to ensure optimum plant density, the regular harvest of grown-up biomass from waterbodies is necessary. Otherwise, the dead plant tissue will decompose and subsequently release the stored nutrients back to the environment.

2.1.3 Phytoremediation mechanism

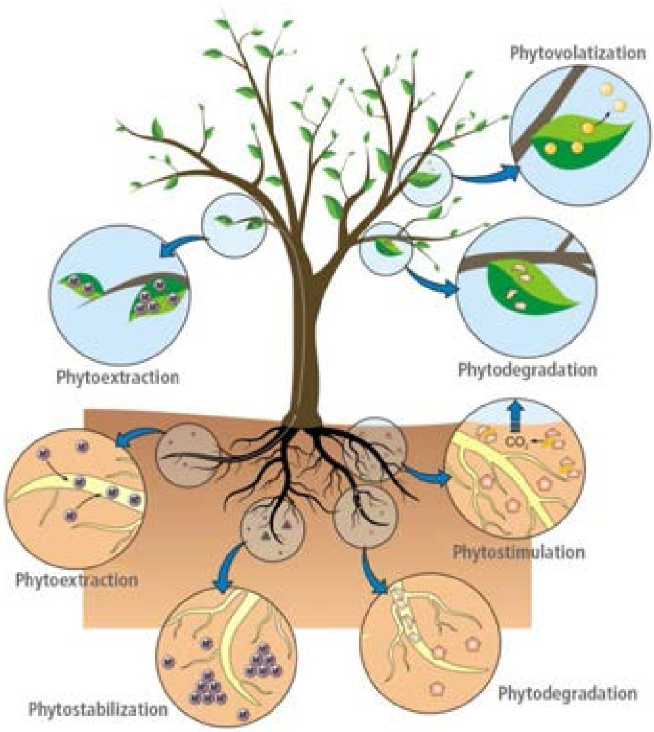

Figure 2.1 Phytoremediation mechanisms (Favas *et al*., 2014)

In general, there are five types of phytoremediation mechanisms for pollutants removal, namely phytovolatilization, phytodegradation, phytoextraction, rhizofiltration and phytostabilization (Gomes, 2012). Phytovolatilization is the extraction and subsequent compounds release in gaseous form from the foliage into atmosphere. Phytodegradation is the conversion of organic pollutants into non-toxic forms by plants and associated microorganisms which occurs at rhizosphere or plant internal. Meanwhile, phytoextraction is the natural ability of plant to take up substances (e.g. organic compounds) from the environment and followed by sequestration of those substances inside plant cells. Rhizofiltration is the sorption of contaminants onto root surface or other plants parts, or the precipitation in the root zone. Lastly, phytostabilization is the immobilization of compounds in surrounding environment through the binding of the contaminants and chemicals released by plant. Depending on the type of pollutants to be remediated by plants, the mechanisms used are also different, as described in (Table 2.1).

Table 2.1 Difference phytoremediation mechanisms used to remediate varying pollutants.

Type of contaminants	Mechanisms	Reference
Organic compounds	Phytoextraction: Direct uptake and accumulation of contaminants and metabolism in plant tissues	(Gomes, 2012), (Llyas and Masih, 2017), (Valipour *et al.*, 2014)
	Phytovolatilization: transpiration of volatile organic compounds (VOC) through the leaves	
	Rhizosphere bioremediation: release of exudates that stimulate microbial activity and biochemical transformations in the soil	
	Phytotransformation: Enhancement of mineralization into relatively nontoxic constituents such as carbon dioxide, nitrate, chlorine and ammonia at the root-soil interface	
Nitrogen	Biological: ammonification, nitrification, denitrification, plant uptake, biomass assimilation, dissimilatory nitrate reduction	(Fox *et al.*, 2008), (Lu *et al.*, 2010), (Fazal, 2015), (Bohutskyi, 2015), (Morand *et al.*, 2011)
	Physico-chemical: ammonia volatilization, adsorption	

2.2 Wastewater

2.2.1 Domestic wastewater

Domestic wastewater has been split into two main categories: blackwater and greywater. So, set out to characterize domestic effluent more finely in terms of specific pollution emission sources: urine, faeces, toilet paper, cooking, bathroom and laundry effluent, etc.

The characterization of domestic wastewater by emission source implies differentiating all source locations where wastewater is produced at household scale.

Figure 2.2 Classification of domestic wastewater (Boutin and Eme, 2017)

Greywater includes various emission sources. These uses are divided under two headings: (i) greywater from food-related activities and cleaning (kitchen and laundry activities), and (ii) greywater from personal care, bathroom effluents. (Boutin and Eme, 2017)

In domestic wastewater, solids are about 50% organic. This fraction is generally of animal or vegetable life, dead animal matter, plant tissue, or organisms, but it may also include synthetic (artificial) organic compounds. These are substances that contain carbon, hydrogen, and oxygen, some of which may be combined with nitrogen, sulfur, or phosphorous. The principal organic compounds present in domestic wastewater are proteins, carbohydrates, and fats together with the products of their decomposition. These compounds are subject to decay or decomposition through the activity of bacteria and other living organisms and are combustible; that is, they can be ignited or burned. Since the organic fraction can be driven off at high temperatures, they are sometimes called volatile solids. (Muralikrishna and Manickam, 2017)

2.2.2 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).

2.3 Water hyacinth

2.3.1 Water hyacinth

Figure 2.3 Water Hyacinth

Eichhornia crassipes, commonly known as water hyacinth, is a type of floating aquatic macrophyte (Fox et al, 2008). Due to its characteristics of rapid proliferation, adaptation to a wide range of environmental condition and large nutrient uptake capacity, water hyacinth is considered as the suitable candidate for phytoremediation process (Rezania et al, 2015). Water hyacinth is proven effective in removing various contaminants present in wastewater such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), turbidity, heavy metals and nutrients.

2.3.2 Applications of water hyacinth for wastewater treatment

The chemical composition of water hyacinth consists of 95% water and 5% of dry matter with high hemicellulose and cellulose content (Sindhu et al., 2017). Water hyacinth is highly temperature-dependent species and it can be found in subtropical and tropical regions (Vymazal, 2010). However, water hyacinth cannot be found at the coastal area since the high salinity is the limiting factor towards the growth of water hyacinth (Batanouny and El-Fiky, 1975). The seeds of water hyacinth remain viable below the water under unfavorable conditions (e.g. low temperature and light intensity) for up to 20 years, making weed intervention methods complicated. Due to the extremely fast growth rate of water hyacinth species, a small number of water hyacinth can grow and proliferate to become a large number until covering the whole water surface in a short period of time. Rezania et al. (2015) reported that the coverage of water hyacinth over the water surface prevents the penetration of the sunlight and oxygen through the water surface, which consequently retards the photosynthesis of underwater aquatic plants to produce oxygen to support the aquatic life. Thus, the control of water hyacinth growth is very important to prevent the damage to the aquatic system. There are several approaches to control the growth of water hyacinth, which include mechanical, chemical and biological control methods (Ndimele, Kumolu-Johnson and Anetekhai, 2011). Other than non-environmental friendly and not cost effective, there is also limited success achieved since it is still impossible to eradicate the whole water hyacinth species from the waterbodies (Mayo and Hanai, 2017).

However, prevention of the water hyacinth spread is still achievable through those control mechanisms. Instead of finding ways to eradicate the water hyacinth, making use of water hyacinth in beneficial ways to social and environment is the better option (Rai, 2016). For instance, water hyacinth is widely used in phytoremediation process to clean up the varying pollutants in domestic and industrial wastewater. During early 1970s, as application of phytoremediation in wastewater treatment was in its early stage, water hyacinth had been reported to be used to treat various types of wastewater such as digested sugar factory wastes, dairies, palm oil production, distillery, natural rubber production, tannery, textile, electroplating, pulp and paper production, pesticide production and heavy metals.

After 1980s, the information regarding this topic was limited probably due to the uneconomical system issue. However, researches on water hyacinth as a phytoremediating plant was later revitalized at 2000s to explore the efficiency on treating various types of wastewater to remove both organic and inorganic contaminants. The examples of studies which made use of water hyacinth for water remediation included domestic wastewater (Kumari and Tripathi, 2014), industrial wastewater (Polomski et al, 2009), mixed domestic and industrial wastewater (Chunkao, Nimpee, and Duangmal, 2012), eutrophic lake (Wang et al, 2012), river water (Moyo et al, 2013), heavy metals contaminated wastewater (Gupta and Balomajumder, 2015) and radioactive wastewater (Saleh, 2012). Numerous types of industrial wastewater have been studied previously for water hyacinth-based phytoremediation process, which included agriculture eutrophic wastewater (Wenwei et al, 2016), pretreated swine effluent (Gupta and Balomajumder, 2015), paper industry effluent, petrochemical wastewater, metallurgic wastewater (Maine et al, 2006), fertilizer manufacturing wastewater (Soltan and Rashed, 2003), mines wastewater (Saha, Shinde, and Sarkar, 2017) and different wastewater sources (dairy farm, dairy processing plant, banana paper plant and landfill) (Nahlik and Mitsch, 2006). Besides, several studies have employed water hyacinth to remove radionuclides, ethions (Xia and Ma, 2006), herbicides, pharmaceuticals and personal care products (PPCPs) as well as to degrade polycyclic aromatic hydrocarbons (PAHs) (Ochekwu and Madagwa, 2013).

CHAPTER 3

MATERIALS AND METHODS

3.1 Wastewater preparation

Canteen wastewater was collected from the septic tank at Chulachakrabonse Building (Figure 3.1), Faculty of Science, Chulalongkorn University by using dipper and collected in 20 liters High density polyethylene (HDPE) gallons for 30 liters. Then, wastewater was pre-treatment with biochar from corn cobs that pyrolyzed at 400°C for 1 hour before treatment with phytoremediation. The whole of canteen wastewater was mixed with 1.7 kg of biochar and preserved at room temperature for 2 days (Soonkee, 2018). After that, the water samples were filtered by 0.05 mm mesh for removed biochar from the water samples. Then, the 7 parameters of water were analyzed (Table 3.2) for 100% of concentration of wastewater, and the water samples were diluted for 25%, 50% and 75% by adding the tap water for the secondary treatment.

Figure 3.1 septic tank at Chulachakrabonse Building

3.2 Experimental plants

Water hyacinth was collected from natural ponds at Tha Chin river, Nakhon Pathom province (13°44’39” N 100°15’34” E) (Figure 3.2). 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. Water hyacinth chose with size 45.0 ± 4.5 g, by used gravity method, which has a bud for cultivating the next generation.

Figure 3.2 Location of water hyacinth collecting

After pre-treatment by biochars, experimental will be designed as followed (Table 3.1);

T1: secondary wastewater (2^{nd} WW) with 75% dilution + water hyacinth

T2: secondary wastewater (2^{nd} WW) with 50% dilution + water hyacinth

T3: secondary wastewater (2^{nd} WW) with 25% dilution + water hyacinth

T4 (Control): Tap water + water hyacinth

Each sample is repeated triplicate and collected in 0, 3, 6, 9, 12, and 15 day after the starting of the treatment as (Table 3.1)

Table 3.1 Experimental setup

Day \ concentration of wastewater	plant+ 2^{nd} WW 75%	plant+ 2^{nd} WW 50%	plant+ 2^{nd} WW 25%	plant+ 2^{nd} WW 0%
0	3	3	3	3
3	3	3	3	3
6	3	3	3	3
9	3	3	3	3
12	3	3	3	3
15	3	3	3	3

3.3 Wastewater and plant analysis

Wastewater and plants were determined in day 0, 3, 6, 9, 12 and 15 (Table 3.1). The parameters of water including pH, Biochemical Oxygen Demanded (BOD), Chemical Oxygen Demanded (COD), Total Kjeldahl Method (TKN), Total Phosphorus (TP), Total Suspended Solid (TSS), and Fats Oil and Greases (FOG) as shown in Table 3.2 and the parameters of plant including biomass, protein content and total carbohydrate as shown in Table 3.3.

Table 3.2 Parameters and analytical methods of canteen wastewater

Parameters	**Analyzed method**
pH	pH meter
BOD	Azide modification
COD	Close reflux
TKN	Kjeldahl method
TP	Ascorbic acid colorimetric method
TSS	Glass fibre filter disc
FOG	Soxhlet extraction

Table 3.3 Parameters and analytical methods of water hyacinth

Parameters	Analyzed Method
Biomass	Gravimetric method
Protein content	Kjeldahl method
Total carbohydrate	Phenol-sulfuric acid colorimetric method

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

where total nitrogen calculated as follow:

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

3.4 Data analysis

One-Way ANOVA test was used to determine the different of each parameter (pH, BOD, COD, TKN, TP, TSS, FOG, Biomass, protein content, total carbohydrate) and time from different concentration of secondary canteen wastewater, which are treated by aquatic plants at the 95% confidence level.

Treatment efficiency was calculated as the percentage of removal for each parameter as follows

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

Ci = the influent concentrations

Ce = the effluent concentrations

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Physical and chemical properties of secondary canteen wastewater

Canteen wastewater before treated with biochar was dark brown, unpleasant odor, and the most of fat oil and grease. After treatment with biochar, the turbidity, odor, and fat oil and grease in wastewater decreased.

Table 4.1 Physical and chemical properties of wastewater

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

***Mean Standard from Pollution Control Department in 2005**

The chemical characteristics were analyzed by using standard method. The result showed the physical and chemical properties in (Table 4.1) the parameters, which exceed the standard for control of wastewater discharge from wastewater treatment system are BOD, COD, TSS, TP, and FOG. While pH and TKN are lower than the acceptable limit by classification of class B.

4.2 The efficiency of secondary canteen wastewater treatment by water hyacinth

4.2.1 pH

The pH in secondary canteen wastewater was in the acceptable limit before the experiment (Table 4.1). The result showed that pH in secondary canteen wastewater in every concentration with water hyacinth has already pH in the range of standard between 5 – 9. That pH values increased in every concentration of canteen wastewater. 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 3-15.

Many proposals have been put forward to explain the possible mechanism involved in the water hyacinth-based treatment systems. The presence of aquatic macrophytes in water body alters the physiochemical environment of the water body. The presence of other aquatic photosynthetic autotrophs can deplete dissolved CO_2 in water during the period of high photosynthetic activity (Mahmood et al, 2005).

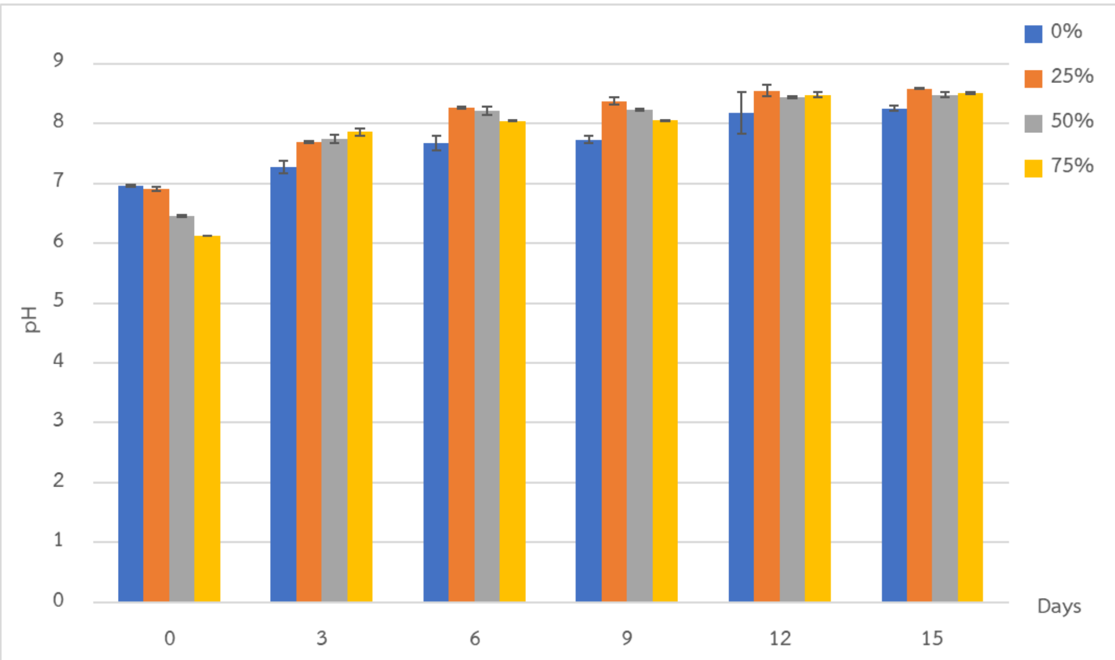

Figure 4.1 pH of secondary canteen wastewater treatment by water hyacinth

4.2.2 Biochemical oxygen demand

The result showed that BOD after the treatment by water hyacinth in every concentration decreased (Figure 4.2). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 93.31%, 77.84%, and 61.04%, respectively. At 25% and 75% concentration of wastewater, each day the BOD decreased significantly in plant systems ($P<0.05$).

In sewage systems, the root structures of water hyacinth (and other aquatic plants) provide a suitable environment for aerobic bacteria to function. Aerobic bacteria feed on nutrients and produce inorganic compounds which in turn provide food for the plants. The plants grow quickly and can be harvested to provide rich and valuable compost (PN and Madhu, 2011).

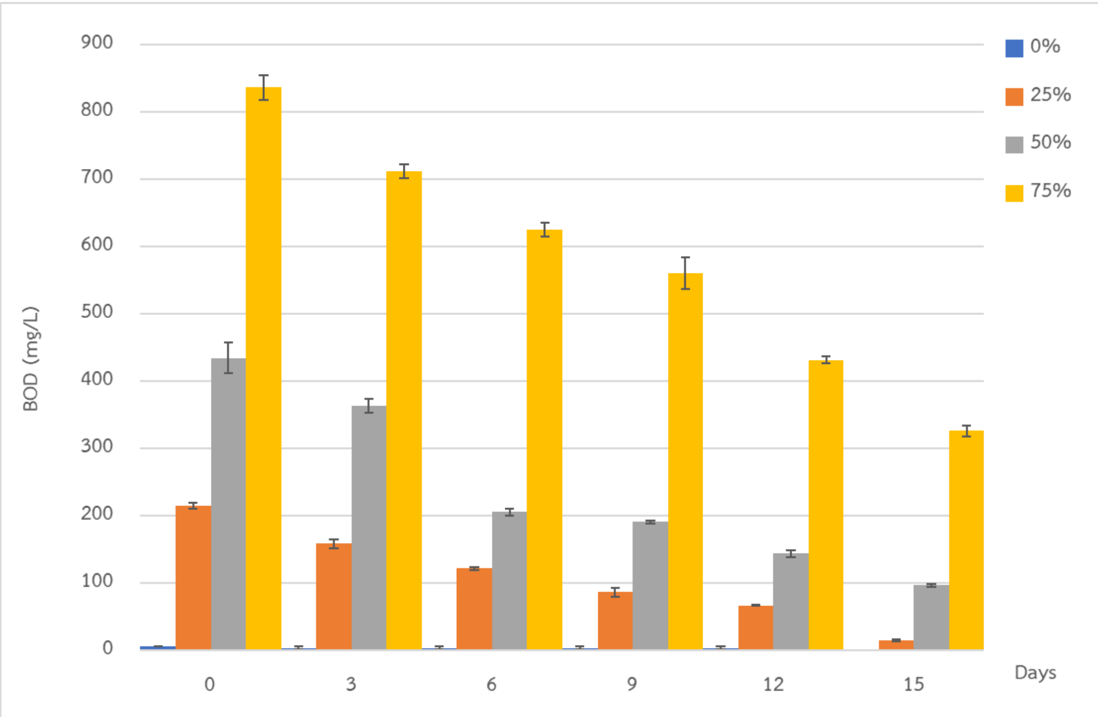

Figure 4.2 BOD of secondary canteen wastewater treatment by water hyacinth

4.2.3 Chemical oxygen demand

The result showed that COD after the treatment by water hyacinth in every concentration decreased (Figure 4.3). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 89.83%, 73.10%, and 69.63%, respectively. At 25% and 50% concentration of wastewater, each day the COD decreased significantly in plant systems ($P<0.05$).

The significant reduction of COD during the growth period is because the crop root mats were fully developed and the filtration capacity of the roots of suspended solids and the absorption of dissolved nutrients were increased (Ghaly, Kamal, and Mahmoud 2005).

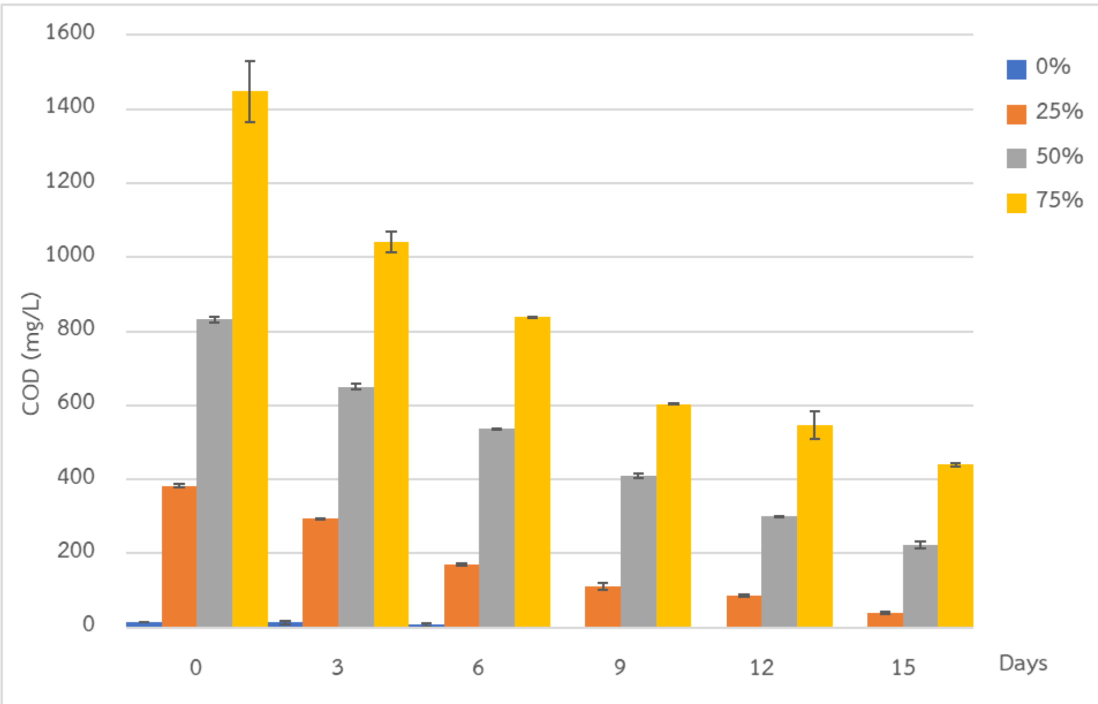

Figure 4.3 COD of secondary canteen wastewater treatment by water hyacinth

4.2.4 Total kjeldahl nitrogen

The result showed that TKN after the treatment by water hyacinth in every concentration decreased (Figure 4.4). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 38.97%, 29.58%, and 22.43%, respectively. At 25% concentration of wastewater, the TKN decreased significantly in plant systems (P<0.05). Throughout the 12 days of experiment, the BOD concentration was significantly different from each other (P<0.05).

It is known that water hyacinth is famous for the treatment of nutrients such as nitrogen. Uptake through the root system, nitrogen is used to create biomass.

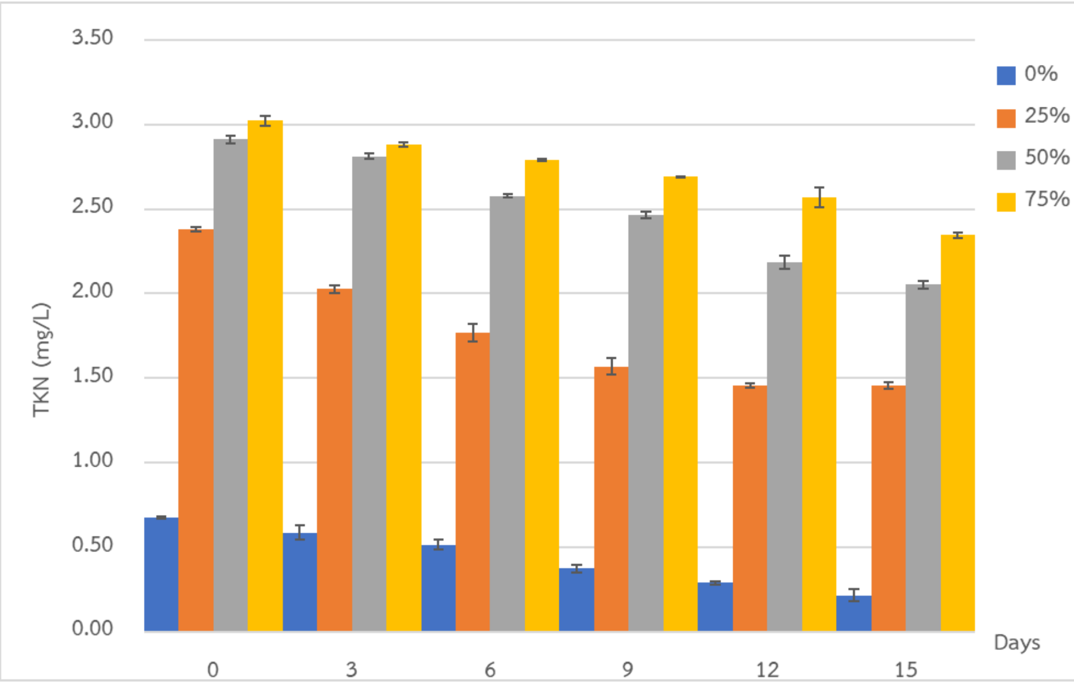

Figure 4.4 TKN of secondary canteen wastewater treatment by water hyacinth

4.2.5 Total phosphorus

The result showed that TP after the treatment by water hyacinth in every concentration decreased (Figure 4.5). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 76.81%, 67.33%, and 66.24%, respectively. Each concentration, the TP decreased significantly in plant systems (P<0.05), and was significantly different from each other (P<0.05).

The macro nutrients in plant growth are inevitable nitrogen, phosphorus, and potassium, which is observed by the phosphorus removal efficiency of water hyacinth spawned in many researches 23.02% of total phosphorus was remove in duck farm wastewater and 56.6% in domestic wastewater in continuous system (Rezania et al, 2016).

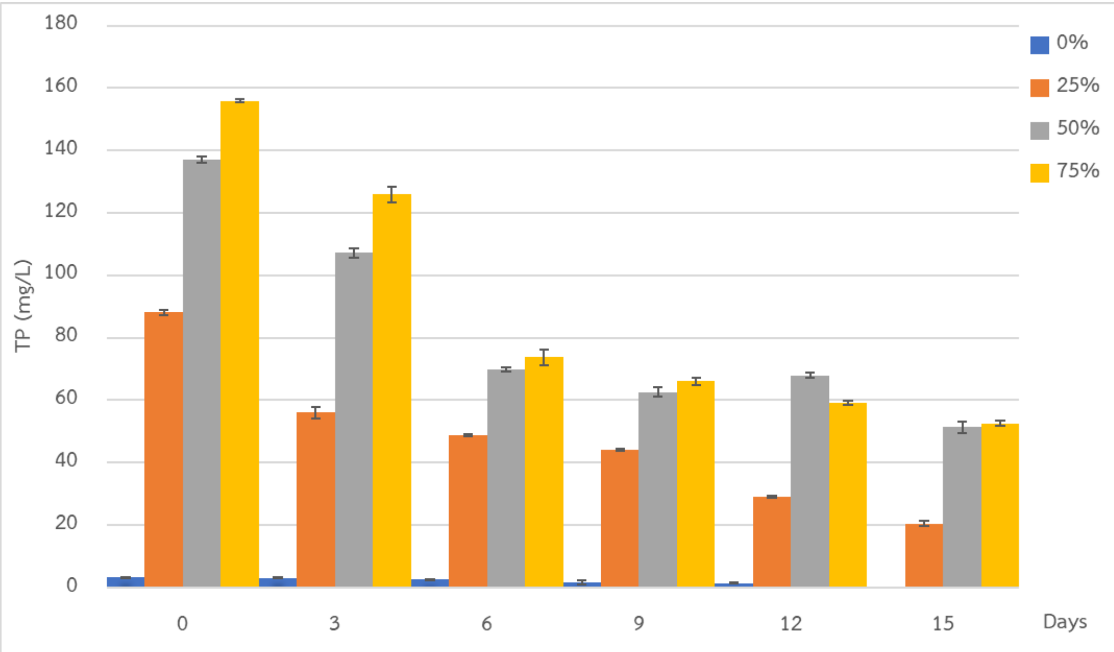

Figure 4.5 TP of secondary canteen wastewater treatment by water hyacinth

4.2.6 Total suspended solid

The result showed that TSS after the treatment by water hyacinth in every concentration decreased (Figure 4.6). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 100%, 97.55%, and 87.73%, respectively. At 25% concentration of wastewater at first day was significantly decreased into day 9 in plant systems ($P<0.05$).

In terms of bacterial reduction by water hyacinth-based systems, two theories exist. First, bacteria are trapped in the rhizosphere of the macrophytes with TSS, and second, water hyacinth may secrete chemical substances having bacteriostatic effects (Mahmood et al, 2005). Experiments have shown that bacteria and microorganisms are abundant in the subsurface root zone (rhizosphere) of the macrophytes and that reductions occur as the water passes through the rhizosphere complex of the floating macrophytes.

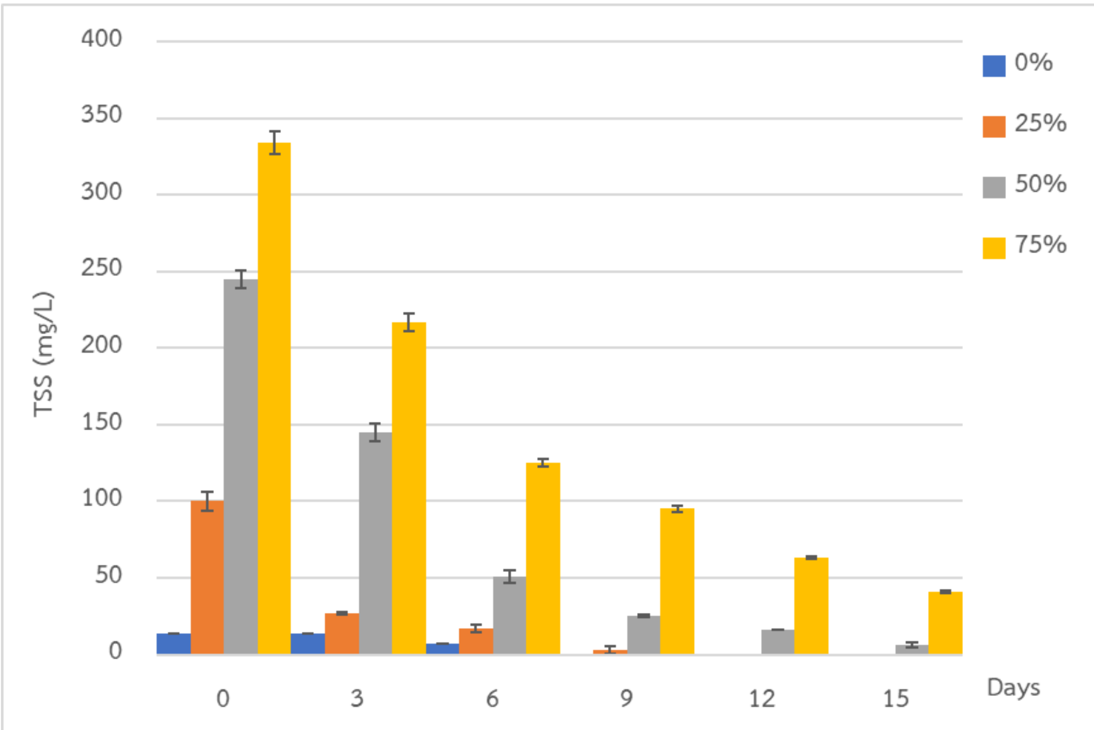

Figure 4.6 TSS of secondary canteen wastewater treatment by water hyacinth

4.2.7 Fat oil and grease

The result showed that FOG after the treatment by water hyacinth, the results represented that the phytoremediation system were not significantly different (Figure 4.7). The efficiency of treatment by water hyacinth at the concentrations of 25%, 50% and 75% were 20.90%, 10.85%, and 8.50%, respectively. However, the FOG in 25% concentration of wastewater at first day was lower significantly from last day ($P<0.05$).

Water hyacinth treat FOG by absorbing a large particle in terms of TSS binding with FOG. In this study, FOG reduced slightly before stable because the molecules of FOG are large that plant cannot absorb. Fat, oil, and grease have the complex structure that takes a long time to decompose in biological process.

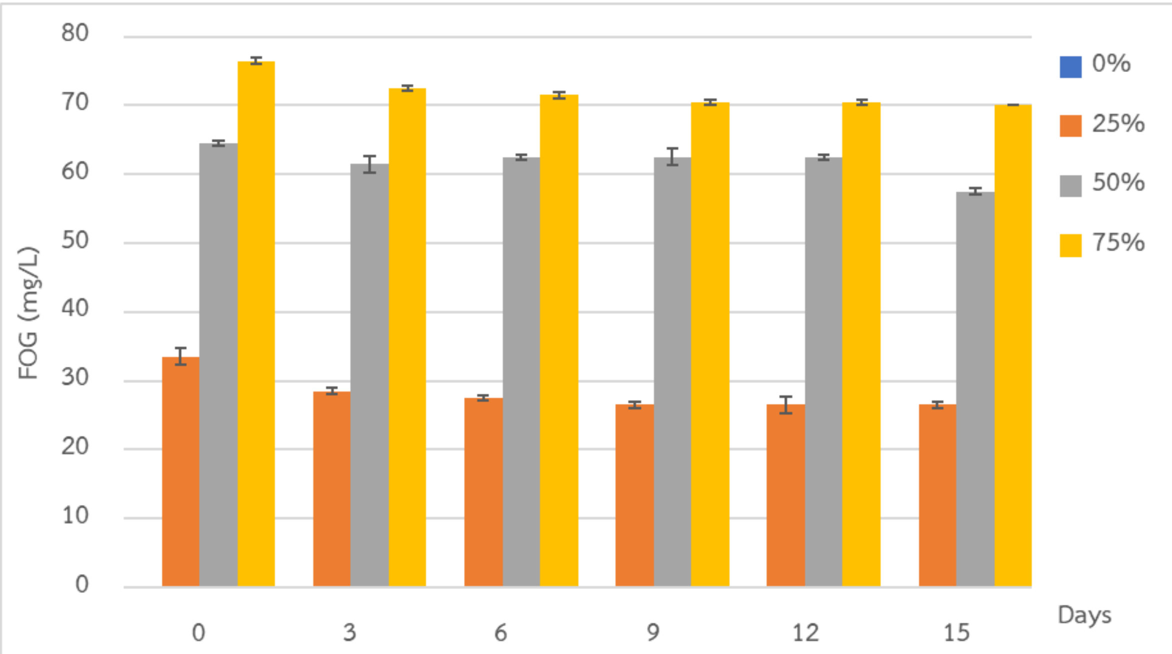

Figure 4.7 FOG of secondary canteen wastewater treatment by water hyacinth

4.3 Biomass of water hyacinth

The result showed that the biomass of water hyacinth grown in concentration of 0%, 25%, 50%, and 75% of secondary canteen wastewater significantly increased ($P<0.05$) (Figure 4.8).

Biomass of water hyacinth is important for improving soil structure and nutrient by composting. Water hyacinth can retain amount of nutrient such as nitrogen, phosphorus, and potassium. Composting water hyacinth takes a short period less than 30 days. It may depend on many factors such as temperature, microorganisms, etc. The faster decomposition method is to reduce the size or increase the surface area of water hyacinth by shredding. That can help farmer improve soil condition in developing countries (Newete and Byrne, 2016)

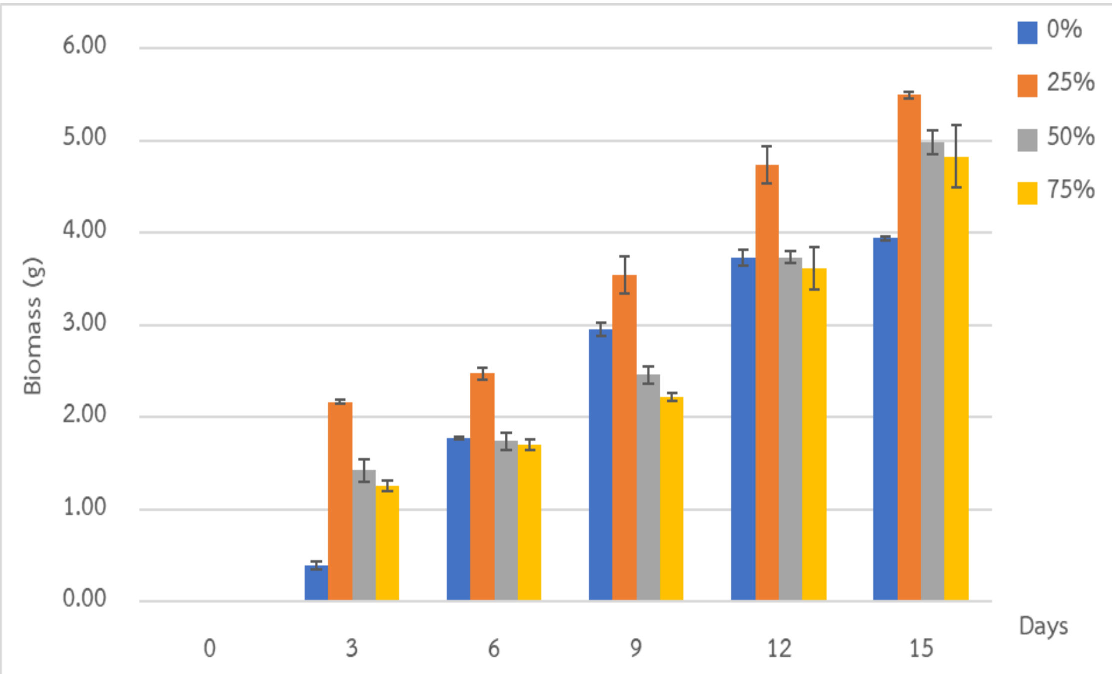

Figure 4.8 Biomass of secondary canteen wastewater treatment by water hyacinth

4.4 Protein content and total carbohydrate in water hyacinth

The result showed that the protein content (Figure 4.9) and total carbohydrate (Figure 4.10) of water hyacinth growth in concentration of 0%, 25%, 50%, and 75% of secondary canteen wastewater significantly increased for protein content ($P<0.05$), and for total carbohydrate. It assumed that the plant accumulated more peptide from the uptake of nitrate and ammonia from treated wastewater and represented more energy storage molecules in the plant. Maximum protein content and total carbohydrate increase up to 31.02% and 48.48%.

Water hyacinth contains high content of water and mineral make it is not suitable for all animals but can help the nutrient problem in animals feed but if make it into dry matter, water hyacinth will be good quality protein source for some non-ruminant.

Water hyacinth can be used for making fertilizer, it is ideal for composting, mixing with molasses and pig manure in ratio of 85:10:5. Microbial decomposition breaks down the fats, lipids, proteins, sugars, and starches in piles and with temperature in tropical zone will accelerate the process (Mathur, 2017).

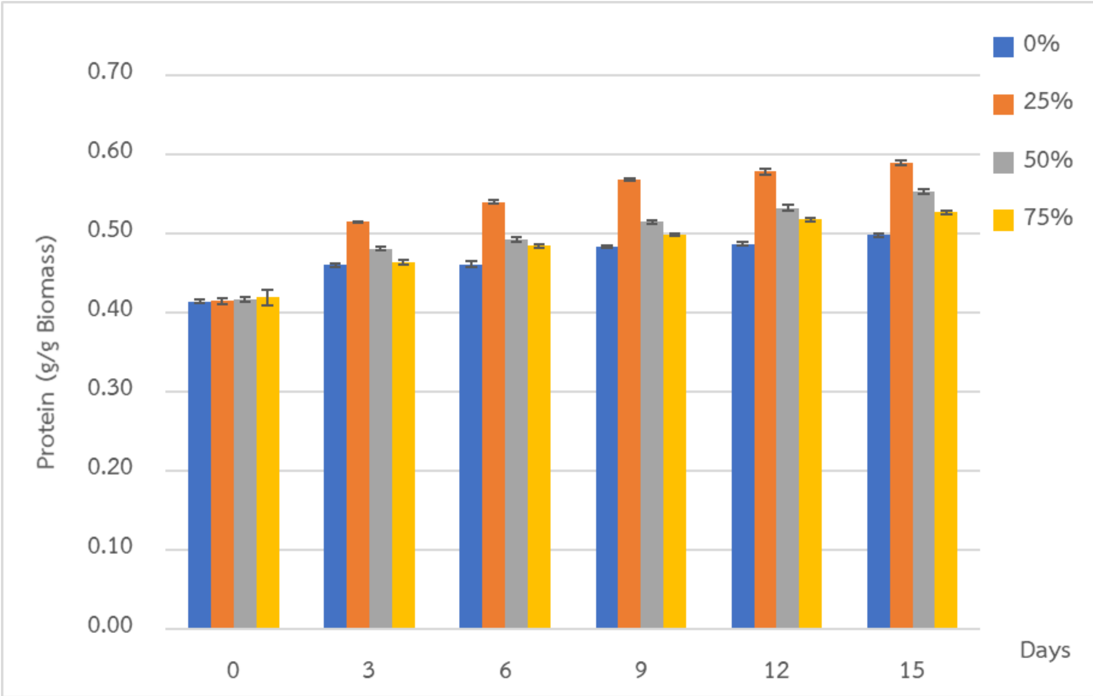

Figure 4.9 Protein content of secondary canteen wastewater treatment by water hyacinth

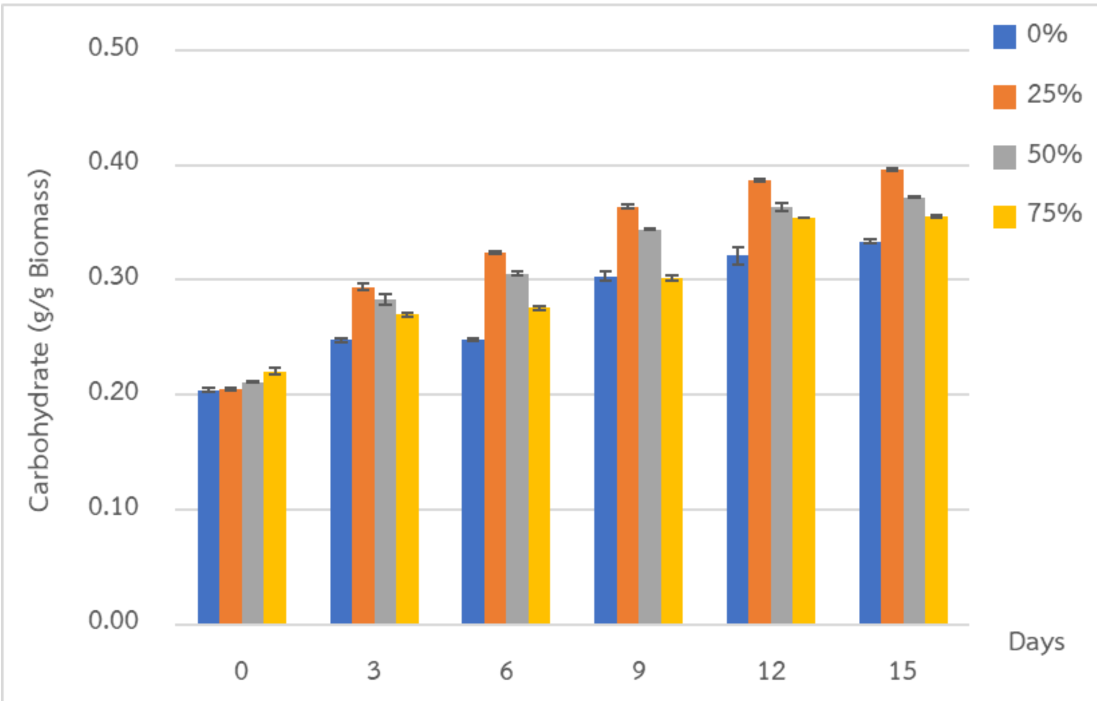

Figure 4.10 Total carbohydrate of secondary canteen wastewater treatment by water hyacinth

4.5 Removal efficiency of water hyacinth for canteen wastewater treatment

The removal efficiency of each parameter and each concentration of canteen wastewater treated by water hyacinth were shown in Figure 4.11. The highest removal efficiency of BOD, COD, TSS, TKN, TP, and FOG at 25% of concentration were 93.31%, 89.83%, 100%, 38.97%, 76.81%, and 20.90%.

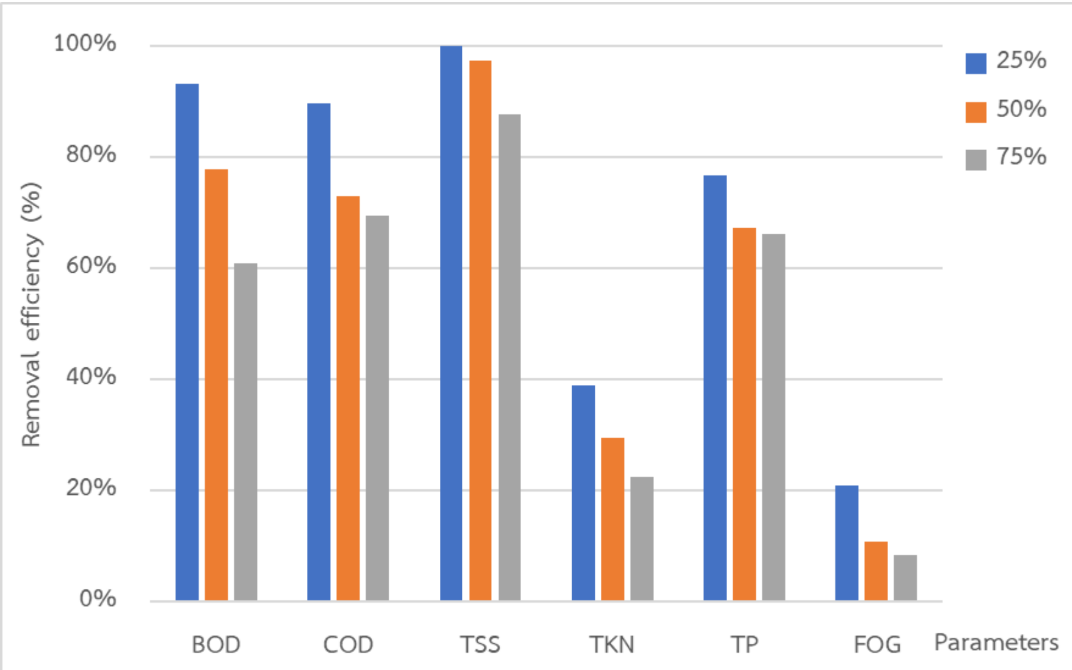

Figure 4.11 Removal efficiency of water hyacinth for canteen wastewater treatment

CHAPTER 5

CONCLUSIONS

5.1 The efficiency of secondary canteen wastewater treatment by water hyacinth

5.1.1 pH

The pH at all concentration were 5-9, which is most favorable for growth of water hyacinth.

5.1.2 Biochemical oxygen demand

The maximum removal efficiency of BOD was 93.31% at 25% concentration of wastewater, and the minimum was 61.04% at 75% concentration of wastewater.

5.1.3 Chemical oxygen demand

The maximum removal efficiency of COD was 89.83% at 25% concentration of wastewater, and the minimum was 69.63% at 75% concentration of wastewater.

5.1.4 Total kjeldahl nitrogen

The maximum removal efficiency of TKN was 38.97% at 25% concentration of wastewater, and the minimum was 22.43% at 75% concentration of wastewater.

5.1.5 Total phosphorus

The maximum removal efficiency of TP was 76.81% at 25% concentration of wastewater, and the minimum was 66.24% at 75% concentration of wastewater.

5.1.6 Total suspended solid

The maximum removal efficiency of TSS was 100% at 25% concentration of wastewater, and the minimum was 87.73% at 50% concentration of wastewater.

5.1.7 Fat oil and grease

The maximum removal efficiency of FOG was 20.90% at 25% concentration of wastewater, and the minimum was 8.50% at 50% concentration of wastewater.

This study showed that water hyacinth was a macrophyte species which can be applied for secondary wastewater treatment. This plant showed good performance at 25% concentration of BOD, COD, TKN, TP, TSS, and FOG.

5.2 Biomass of water hyacinth

In this study indicated that water hyacinth had potential to grow in secondary canteen wastewater at the highest concentrations.

5.3 Protein content and total carbohydrate in water hyacinth

Protein content and total carbohydrate of water hyacinth showed the ability of animals feed solving the lack of animal protein and can be used for fertilizer.

REFERENCES

Alia, H., Khanb, E., & Sajad, M.A. Phytoremediation of heavy metals-Concepts and applications, Chemosphere. (2013): 869-881.

Anandha Varun, R., & Kalpana, S. Performance analysis of nutrient removal in pond water using Water Hyacinth and Azolla with papaya stem, International Research Journal of Engineering and Technology. 2(1), (2015): 444-448.

Bahgata, M., Dewedarb, A., & Zayedc, A.z Sand-filters used for wastewater treatment: buildup and distribution of microorganism. Water Research 33 (1999): 1949-1955.

Batanouny, K. H., & El-Fiky, A. M. The water hyacinth (Eichhornia crassipes Solms) in the Nile system, Egypt, Aquatic Botany. 1, (1975): 243-252.

Blanco, J., Torrades, F., Moron, M., Agnesa, M.B., & Montano, J.C. Photo-Fenton and sequencing batch reactor coupled to photo-Fenton processes for textile wastewater reclamation: Feasibility of reuse in dyeing processes. Chemical Engineering Journal 240 (2014): 469-475.

Bohutskyi, P., Liu, K., Nasr, L.K., Byers, N., Rosenberg, J. N., Oyler, M.J., Betenbaugh, G. A., & Bouwer, E. J. Bioprospecting of microalgae for integrated biomass production and phytoremediation of unsterilized wastewater and anaerobic digestion centrate, Applied microbiology and biotechnology. (2015): 6139-6154.

Boutin, C., & Eme, C. Domestic Wastewater Characterization by Emission Source, IWA on Small Water and wastewater Systems. (2017): 1-9.

Chunkao, K., Nimpee, C., & Duangmal, K. The King's initiatives using water hyacinth to r emove heavy metals and plant nutrients from wastewater through Bueng Makkasan in Bangkok, Thailand, Ecological Engineering. 39, (2012): 40-52.

Favas, P. J., Pratas, J., Varun, M., D'Souza, R., & Paul, M. S. Phytoremediation of soils contaminated with metals and metalloids at mining areas: potential of native flora. Environmental risk assessment of soil contamination, 3, (2014): 485-516.

Fazal, S., Zhang, B., & Mehmood, Q. Biological treatment of combined industrial wastewater, Ecological Engineering. (2015): 551-558.

Fox, L. J., Struik, P. C., Appleton, B. L., & Rule, J. H. Nitrogen phytoremediation by water hyacinth (Eichhornia crassipes (Mart.) Solms). Water Air and Soil Pollution. (2008): 199-207.

Ghaly, A. E., Kamal, M., & Mahmoud, N. S. Phytoremediation of aquaculture wastewater for water recycling and production of fish feed, Environment International. 31(1), (2005): 1-13.

Gomes, H. I. Phytoremediation for bioenergy: challenges and opportunities, Environmental Technology Reviews. (2012): 59-66.

Gong, Y., Zhou, X., Ma, X., & Chen, J. Sustainable removal of formaldehyde using controllable water hyacinth. Journal of Cleaner Production. 181, (2018): 1-7.

Gupta, A., & Balomajumder, C. Removal of Cr (VI) and phenol using water hyacinth from single and binary solution in the artificial photosynthesis chamber. Journal of Water Process Engineering, 7, (2015): 74-82.

Jiang, Y., Lei, M., Duan, L., & Longhurst, P. Integrating phytoremediation with biomass valorisation and critical element recovery: A UK contaminated land perspective, Biomass and Bioenergy. (2015): 328-339.

Kösesakal, T., Ünal, M., Kulen, O., Memon, A., & Yüksel, B. Phytoremediation of petroleum hydrocarbons by using a freshwater fern species Azolla filiculoides Lam, International Journal of Phytoremediation. 18, (2016) 467–476.

Kumari, M., & Tripathi, B. D. Effect of aeration and mixed culture of Eichhornia crassipes and Salvinia natans on removal of wastewater pollutants, Ecological Engineering. 62, (2014): 48-53.

Lasat, M.M. Phytoextraction of metals from contaminated soil: a review of plant/ soil/metal interaction and assessment of pertinent agronomic issues, Journal of Hazardous Substance Research. 2, (2000): 1–25.

Lesikar, B. J., Garza, O. A., Persyn, R. A., Anderson, M. T., & amp; Kenimer, A. L. Food service establishments wastewater characterization. In On-Site Wastewater Treatment X, 21-24 March 2004, (2004): 1.

Llyas, H., & Masih, I. The performance of the intensified constructed wetlands for organic matter and nitrogen removal: A review, Journal of environmental management. (2017): 372-383.

Lu, Q., He, Z. L., Graetz, D. A., Stoffella, P. J., & Yang, X. Phytoremediation to remove nutrients and improve eutrophic stormwaters using water lettuce (Pistia stratiotes L.), Environmental Science and Pollution Research. 17, (2010): 84-96.

Maine, M. A., Sune, N., Hadad, H., Sánchez, G., & Bonetto, C. Nutrient and metal removal in a constructed wetland for wastewater treatment from a metallurgic industry, ecological engineering. 26(4), (2006): 341-347.

Mahmood, Q., Zheng, P., Islam, E., Hayat, Y., Hassan, M. J., Jilani, G., & Jin, R. C. Lab scale studies on water hyacinth (Eichhornia crassipes Marts Solms) for biotreatment of textile wastewater, Caspian Journal of Environmental Sciences. 3(2), (2005): 83-88.

Mayo, A. W., & Hanai, E. E. Modeling phytoremediation of nitrogen-polluted water using water hyacinth (Eichhornia crassipes), Physics and Chemistry of the Earth. Parts A/B/C, 100, (2017): 170-180.

Moyo, P., Chapungu, L., & Mudzengi, B. Effectiveness of water hyacinth (Eichhornia crassipes) in remediating polluted water: the case of Shagashe river in Masvingo, Zimbabwe, Advances in Applied Science Research. 4(4), (2013): 55-62.

Muralikrishna, LV., & Manickam, V. Wastewater Treatment Technologies. Environmental Management. (2017): 249-293.

Nahlik, A. M., & Mitsch, W. J. Tropical treatment wetlands dominated by free-floating macrophytes for water quality improvement in Costa Rica, Ecological Engineering. 28(3), (2006): 246-257.

Neweta, SW., & Byrne, MJ. The capacity of aquatic macrophytes for phytoremediation and their disposal with specific reference to water hyacinth. Environmental Science and Pollution Research 23 (2016): 10630-10643.

Ndimele, P. E., Kumolu-Johnson, C. A., & Anetekhai, M. A. The invasive aquatic macrophyte, water hyacinth {Eichhornia crassipes (Mart.) Solm-Laubach: Pontedericeae}: problems and prospects, Research Journal of Environmental Sciences. 5(6), (2011): 509-520.

Ochekwu, E. B., & Madagwa, B. Phytoremediation potentials of water Hyacinth. Eichhornia crassipes (mart.) Solms in crude oil polluted water, Journal of Applied Sciences and Environmental Management. 17(4), (2013): 503-507.

Paz-Alberto, A.M., & Sigua, G.C. Phytoremediation a green technology to remove environmental pollutants, American Journal of Climate Change2. (2013): 71–86.

Placek, A., Grobelak, A., & Kacprzak, M. Improving the phytoremediation of heavy metals contaminated soil by use of sewage sludge, International Journal of Phytoremediation. 18, (2016): 605–618.

PN, A. M. L., & Madhu, G. Removal of heavy metals from waste water using water hyacinth, International Journal on Transportation and Urban Development. 1(1), (2011): 48.

Polomski, R. F., Taylor, M. D., Bielenberg, D. G., Bridges, W. C., Klaine, S. J., & Whitwell, T. Nitrogen and phosphorus remediation by three floating aquatic macrophytes in greenhouse-based laboratory-scale subsurface constructed wetlands, Water Air Soil Pollution. 197(1-4), (2009): 223-232.

Qin H., Zhang Z., Liu M., Liu H., Wang Y., Wen X., Zhang Y., & Yan S. Site test of phytoremediation of an open pond contaminated withdomestic sewage using water hyacinth and water lettuce. Ecological Engineering. 95, (2016): 753–762.

Rai, P. K. Eichhornia crassipes as a potential phytoremediation agent and an important bioresource for Asia Pacific region, Environmental Skeptics and Critics. 5(1), (2016): 12.

Rezania, S., Ponraj, M., Talaiekhozani, A., Mohamad, S. E., Din, M. F. M., Taib, S. M., & Sairan, F. M. Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater, Journal of environmental management. 163, (2015): 125-133.

Saha, P., Shinde, O., & Sarkar, S. Phytoremediation of industrial mines wastewater using water hyacinth, International journal of phytoremediation. 19(1), (2017): 87-96.

Saleh, H. M. Water hyacinth for phytoremediation of radioactive waste simulate contaminated with cesium and cobalt radionuclides, Nuclear Engineering and Design. 242, (2012): 425-432.

Sindhu, R., Binod, P., Pandey, A., Madhavan, A., Alphonsa, J. A., Vivek, N., & Faraco, V. Water hyacinth a potential source for value addition: an overview, Bioresource technology. 230, (2017): 152-162.

Soltan, M. E., & Rashed, M. N. Laboratory study on the survival of water hyacinth under several conditions of heavy metal concentrations, Advances in environmental research. 7(2), (2003): 321-334.

Soonkee, W. Application of biochar derived from agriculture wastes for wastewater treatment, Faculty of science, Chulalongkorn University. (2018).

Valipour, A., Hamnabard, N., Woo, K. S., & Ahn, Y. H. Performance of high-rate constructed phytoremediation process with attached growth for domestic wastewater treatment: effect of high TDS and Cu, Journal of environmental management. (2014): 1-8.

Vymazal, J. Constructed wetlands for wastewater treatment, Water. 2(3), (2010): 530-549.

Wang, Z., Zhang, Z., Zhang, J., Zhang, Y., Liu, H., & Yan, S. Large-scale utilization of water hyacinth for nutrient removal in Lake Dianchi in China: the effects on the water quality, macrozoobenthos and zooplankton, Chemosphere. 89(10), (2012): 1255-1261.

Wenwei, W. U., Ang, L. I. U., Konghuan, W. U., Lei, Z. H. A. O., Xiaohua, B. A. I., Kun-zhi, L. I., & Limei, C. H. E. N. The physiological and biochemical mechanism of nitrate-nitrogen removal by water hyacinth from agriculture eutrophic wastewater, Brazilian Archives of Biology and Technology. 59, (2016): 1-10

Xia, H., & Ma, X. Phytoremediation of ethion by water hyacinth (Eichhornia crassipes) from water, Bioresource Technology. 97(8), (2006): 1050-1054.

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