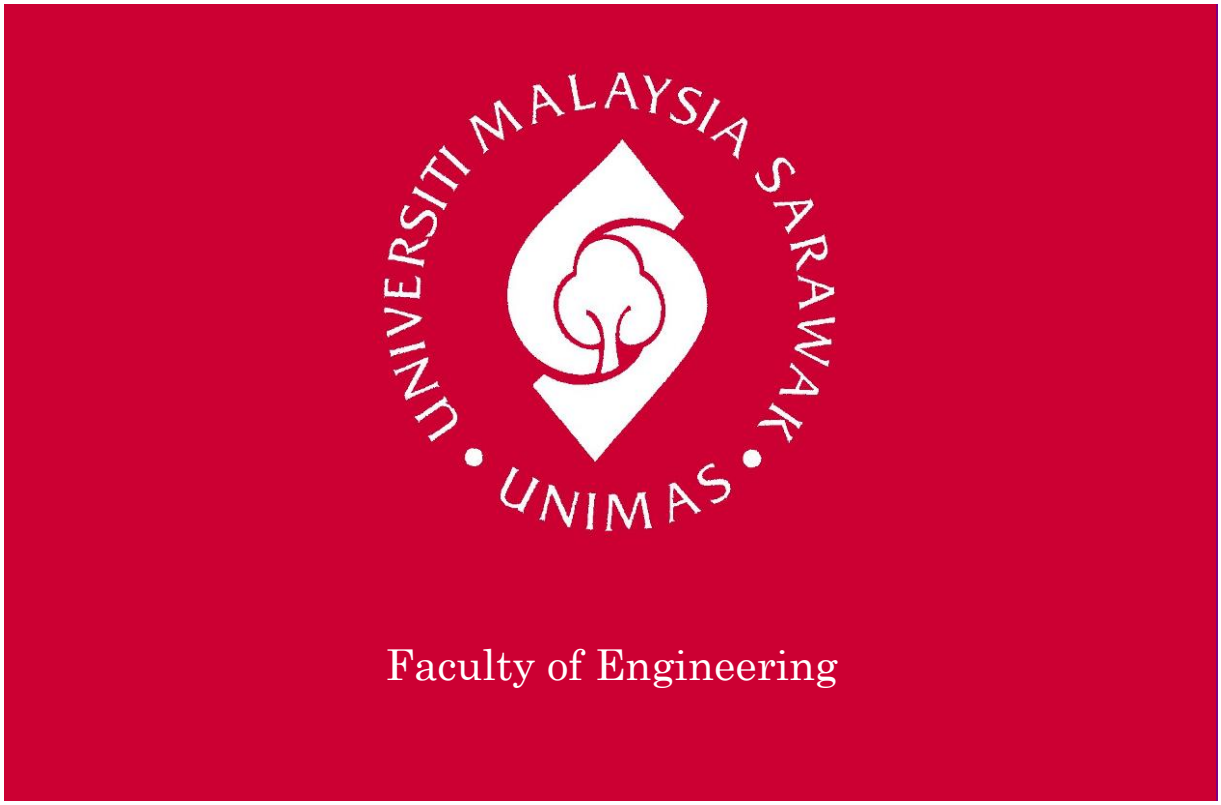

PHYTOREMEDIATION IN REMOVAL OF AMMONIACAL NITROGEN BY USING *EICCHORNIA CRASSIPES*

Rasyidah Binti Abdul Rahman

Bachelor of Engineering with Honours
(Chemical Engineering)
2018

UNIVERSITI MALAYSIA SARAWAK

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ASSOC. PROF. DR SHANTI FARIDAH SALLEH
(Supervisor)

25TH MAY 2018
Date

PHYTOREMEDIATION IN REMOVAL OF AMMONIACAL NITROGEN BY USING *EICCHORNIA CRASSIPES*

RASYIDAH BINTI ABDUL RAHMAN

A dissertation submitted in partial fulfillment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Chemical Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2018

Dedicated to my beloved parents, supervisor who always encourage and advices me upon completion of this report

ACKNOWLEDGEMENT

First of all, the author would like to express her gratitude towards the individuals, parties and organization that have contributed and shows the unending support throughout the completion of this research study. This gratitude is extended to the staff and lecturers of Department of Chemical Engineering and Energy Sustainability, Universiti Malaysia Sarawak. Next, she would like to thank her supervisor, Assoc. Prof. Dr. Shanti for the guidance, advices and support in the completion of the research study. Besides, she would also like to express her gratitude towards Lennevey Kinidi, senior cum co-supervisor for the guidance throughout the research study. Last but not least, the author would like to express her thankfulness toward her parents, and her best friend especially Allene, Dunstan and Samantha, who had support and helped upon completion of this research.

ABSTRAK

Penjanaan sisa air kotor di Malaysia telah meningkat berikutan perkembangan pesat dalam sektor perindustrian dan juga pertumbuhan populasi manusia. Rawatan air buangan secara tradisional telah diabaikan kerana kosnya yang tinggi, pembuangan bahan cemar yang tidak berkesan dan juga kesan negatif rawatan terhadap alam sekitar serta menjejaskan ekosistem. Oleh itu, teknologi hijau diperlukan untuk rawatan yang lebih selamat yang kos efektif serta mesra alam untuk merawat air kumbahan. *Phytoremediation* boleh ditakrifkan sebagai salah satu cara pemulihan air kotor dengan membuang bahan pencemar menggunakan tumbuhan akuatik yang juga dikelaskan sebagai teknologi hijau. Dalam kajian ini, tumbuhan yang akan digunakan adalah *Eichhornia Crassipes* yang juga dikenali sebagai keladi bunting. Keladi bunting telah dikenal pasti berpotensi dan berkesan dalam penyingkiran bahan pencemar seperti logam organik dan bukan organik, berat, dan juga bahan pencemar biologi. Kajian ini memberi tumpuan kepada tindak balas *phytoremediation* dalam penyingkiran *ammoniacal nitrogen* khususnya menggunakan parameter yang telah dipilih iaitu umur tumbuhan kajian serta *pH* air buangan. *The experimental design is done by using Central Composite Design of Response Surface Methodology*. Selain itu, ujian toleransi juga dijalankan untuk memerhatikan ketahanan tumbuhan ke arah satu set *initial concentration of ammoniacal nitrogen*. Kajian ini dijalankan untuk memerhatikan prestasi dan kesesuaian *phytoremediation* dalam merawat bahan pencemar untuk loji rawatan air sisa industri dan sama ada ia boleh mencapai had pelepasan piawai untuk *ammoniacal nitrogen* di bawah Peraturan Kualiti Alam Sekeliling (Industrial Effluent) 2009.

Kata Kunci: Rawatan air buangan, *Phytoremediation, Eichhornia Crassipes,* Keladi Bunting, *Ammoniacal nitrogen, Response Surface Methodology*

ABSTRACT

Generation of wastewater in Malaysia has been increased due to the rapid development in industrial sector and also increasing human population. Traditional wastewater treatment has been disregard due to its high cost, ineffective removal of contaminants and also the negative impact of the treatment towards the environment, and living organism. Thus, a green technology is needed for a safer treatment which is cost effective and environmental friendly to treat the wastewater. Phytoremediation can be defined as remediating wastewater by removal of contaminants using aquatic macrophyte which is also classified as green technology. In this research, selected macrophyte is *Eichhornia Crassipes* also known as Water Hyacinth. *Eichhornia Crassipes* has been identified a potential and effective in removal of contaminants such as organic and inorganic, heavy metals, and also biological contaminants. This study focuses on the response of phytoremediation in removal of ammoniacal nitrogen specifically on selected parameter which are on the age of the plant and pH of the wastewater. The experimental design is done by using Central Composite Design of Response Surface Methodology. In addition, tolerance test is also conducted to observe the tolerance of the plants towards a set range of initial ammoniacal nitrogen concentration. This study is conducted to observe the performance and suitability of phytoremediation in treating the contaminants for industrial wastewater treatment plant, and hence its feasibility in complying to the standard discharge limit for ammoniacal nitrogen under Environmental Quality (Industrial Effluent) Regulations 2009.

Keyword: Wastewater treatment, Phytoremediation, *Eicchornia Crassipes*, Water Hyacinth, Ammoniacal Nitrogen, Response Surface Methodology

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LIST OF SYMBOLS

%	-	Percentage
˚C	-	Celcius
g	-	Gram
kg/dm^3	-	Kilogram Per Decimetre Cube
L	-	Litre
m	-	Metre
mg/L	-	Milligram Per Litre
mg/ml	-	Milligram Per Millilitre

ABBREVIATIONS

AAS	-	Atomic Absorption Spectrophotometer
AN	-	Ammoniacal Nitrogen
ANOVA	-	Analysis of Variance
Be	-	Beryllium
BOD	-	Biological Oxygen Demand
CMP	-	Chemical Mechanical Planarization
COD	-	Chemical Oxygen Demand
Cs	-	Cesium
Cu	-	Copper
DO	-	Dissolved Oxygen
Fe	-	Ferrum
GEIB	-	Biological Invansion Speacialist Group
MIDA	-	Malaysian Investment Development Authority
Mn	-	Manganese
Mo	-	Molybdenum
NH_3	-	Ammonia
NH_4^+	-	Ammonium ion
Pd	-	Palladium
Pt	-	Platinum
Ra	-	Radium
RSM	-	Response Surface Methodology
Sr	-	Strontium
TSS	-	Total Suspended Solid
U	-	Uranium
Zn	-	Zinc

CHAPTER 1

INTRODUCTION

1.1 Background of study

Water pollution has been treated as a common thing in a developed country due to the economic blooming especially in industrial activities. The negligence by the human, worsen the ecosystem when the major concerned is only on the production profit and not on the overall process.

High level of the heavy metals produced in the effluent and discharged from industry can cause severe health problem as it is considered as toxic even in a low concentration and prone to affect the food chain (Vasanthy, Sangeetha, & Kalaiselvi, 2004). As for example, when the effluent discharged into the stream, in which the living aquatic animal will affected, then the fish is caught by human at the containment area, the toxic has been transferred along the food chain.

In Malaysia, the discharged condition has been stated in Environmental Quality (Industrial Effluent) Regulations 2009. In Fifth Schedule, the acceptable condition for discharged is mainly on the concentration of heavy metals, BOD level, concentration of ammoniacal nitrogen, and TSS. Meanwhile, COD level is stated in Seventh Schedule. As stated in Fifth Schedule, acceptable limit for BOD_5 at 20˚C is 50 mg/L and for ammoniacal nitrogen is at 20 mg/L. As for the limit for COD, it is dependent on the specific trade or industry in which if it is not specified the limit is at 200 mg/L for standard B. This regulations must be abide to reduce the impact of water pollution and to avoid any action taken to the premises.

Phytoremediation is one of the technique for wastewater treatment in which it is classified as green technology which reduces the negative impact to the environment

compared to other technology in treating the industrial effluent as it uses plants to degrade, assimilate, metabolize or detoxify contaminants (Muthunarayanan, Santhiya, Swabna, & Geetha, 2011). The phytoremediation uses plants in the removal of the contaminant in the effluent including enhancing BOD, COD, TSS, DO and other chemical and biological contents in the water. It is a favourable technology and a few studies conducted has proved it to be an effective method to treat wastewater, cost-effective and an environmental friendly technology (Rezania, Md Din, et al., 2015).

This research is focusing on the phytoremediation by using macrophyte specifically on water hyacinth (*Eichhornia Crassipes)* due to its ability in effective removal of pollutants such as total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, heavy metals and other biology and chemical contaminant in industrial effluent. Besides, characteristic of water hyacinth which has high growth rate, high absorption of pollutant, low operation cost and renewability make it as suitable technology for phytoremediation (Rezania, Ponraj, et al., 2015). For example, according to Victor, Séka, Norbert, Sanogo and Celestin in (2016), the percentage reduction of ammonia treated by water hyacinth and water lettuce is 74.58% and 58.87% respectively.

1.2 Problem statement

Various wastewater treatment plant has been used for the past few years in the industries, however, most of the technology are not cost effective and some are not optimal for treating the industrial effluent. A green technology has been introduced in which it utilize plants in the remediation of the industrial effluent which is also known as phytoremediation (Lehocky et al., 2009). The studies regarding phytoremediation has been conducted in the recent year which involved various macrophyte such as water hyacinth (*Eichhornia Crassipes),* water lettuce (*Pistia stratiote),* duckweeds and etc. The industrial sectors are attracted in using the phytoremediation techniques as it is eco-friendly technology and also cost effective. The chemicals or contaminants absorbed by the plant is converted in the form of gas which will be released into the air as the process of transpiration by the plant (Tangahu et al., 2011). Besides, the industry should obeyed the discharged limit sets by the government which has been stated in Environmental Quality (Industrial Effluent) Regulations 2009. The acceptable condition

for discharge of industrial effluent or mixed effluent is mentioned in the regulations which is stated in Fifth Schedule whereby, the limits for BOD_5 at 20˚C is 20 mg/L and 50 mg/L for standard A and B respectively. As for the ammoniacal nitrogen, the limits for standard A and B are 10 mg/L and 20 mg/L respectively. Meanwhile, the COD limit are stated in Eighth Schedule which gives 80 mg/L for standard A and 200 mg/L for standard B. Thus, the industry must abide the regulations on the condition for discharge of industrial effluent to avoid any action that may affected the industry. Apart from that, most of the research found specifically comparing two macrophyte in the remediation and only a few studies has been conducted to determine the optimum condition.

There are scarce study for the optimal condition especially on the effect of pH of wastewater and age of plants, thus this study would focused on the certain condition with specified macrophyte which is water hyacinth (*Eichhornia Crassipes)*. A study in phytoremediation has been conducted in China in which the macrophyte used was Eichhornia Crassipes shows nitrogen concentration decreases from 2.1 mg/L to 0.5 mg/L and the transparency of the water turbidity increased significantly reaching the depth of 1.8 m after growing it for 44 days (Fang et al., 2007). That is how in this research, the chosen macrophyte is Eichhornia Crassipes due to its high removal efficiency of the contaminant, and apart from that due to its abundance in the research area.

1.3 Aim of research

The research's aim is to study the phytoremediation of wastewater by using selected aquatic macrophyte which is *Eichhornia Crassipes* by manipulating the key parameter which includes age of plants and pH of the wastewater.

1.4 Scope of research

The scope of this research is focusing on the optimum conditions for phytoremediation especially on age of plants and pH of the wastewater by using specified macrophyte which is *Eichhornia Crassipes.*

1.5 Objectives of research

The objectives of the research which focusing on achieving the aim are elaborate as follows:

A. To study the removal of contaminant from industrial effluent using phytoremediation

Phytoremediation techniques is used in the wastewater treatment which focusing on one macrophyte which is *Eichhornia Crassipes***.** This study is conducted to study the removal of contaminant which is ammoniacal nitrogen (AN).

B. To observe the tolerance of *Eichhornia Crassipes* at various initial concentration of ammoniacal nitrogen

Experiment is conducted to observe and conclude the tolerance of *Eichhornia crassipes* in various initial concentration which ranging from low to high whereby the macrophyte is observed and measured by the life cycle of the plant and the removal rates of ammoniacal nitrogen until the plant dies or achieved in 14 days.

C. To study the response in phytoremediation with different range parameter by using *Eichhornia Crassipes* in terms of the percentage removal of ammoniacal nitrogen

The parameters used in this study is pH of wastewater and age of plants. The response of phytoremediation in terms of percentage removal of ammoniacal nitrogen is calculated based on the changes in initial concentration of ammoniacal nitrogen. The highest percentage removal is determined as the optimum point.

CHAPTER 2

LITERATURE REVIEW

2.1 Phytoremediation

In this remediation, green plants is utilized as it has the ability to uptake and hyperaccumulate heavy metals, and toxic substance from soil and water through the roots and concentrate them in roots, stems and leaves (Dar, Kumawat, Singh, & Wani, 2011).

Phytoremediation is a preferred wastewater treatment technology as it is classified as a green technology. Apart from that, it uses biological method in the remediation. It is one of the approved technology in wastewater treatment as it listed in top 20 of Spain's GEIB (Biological Invansion Specialist Group) (Téllez et al., 2008). The technology in the phytoremediation involved an outstanding and selective capabilities which also involved phytodegradation, phytostabilization, phytoextraction, rhizofiltration, and phytovolatilization. The effect of mechanical aeration has improved the removal rates compared to controlled and normal condition which recorded removal rates of AN for 10 mg/L in 8 days (Mahmud, Lee, & Goh, 2017).

As compared to other technologies which brings a lot of drawbacks, there are a few advantages of phytoremediation which makes it as an alternative for wastewater treatment (Farraji, 2014):

a) Cost effective

b) Available in-situ and ex-situ operation

c) Source of energy is from solar

d) Produce biomass for renewable energy

e) Effective removal of various type of pollutants or contaminants

Apart from that, phytoremediation is capable in removing 100% of Total Suspended Solids (TSS) and 98.74% COD removal (Mahmud et al., 2017). The mechanism of aquatic plants in removal of heavy metal is by biosorption which is also classified as extracellular accumulation or precipitation, cell surface sorption or precipitation, and intracellular accumulation (R. A. Shah, Kumawat, Singh, & Wani, 2010). Determining the removal efficiency (%) is by using **Equation 2.1** below (Valipour, Raman, & Ahn, 2015).

$$removal\ efficiency\ (\%) = \frac{Ci - Ce}{Ci} \times 100\% \qquad \textbf{Eq 2.1}$$

Where, C_i is influent concentration and C_e is effluent concentration. Meanwhile, for BOD and COD removal, best-fit curved lined which shows the percentage reduction efficiency can be used for statistical analysis of the remediation.

2.1.1 Rhizofiltration

Rhizofiltration is one of the process occurring during the phytoremediation where the contaminant is removed via the plants roots either from groundwater, surface water and wastewater (Dhir, 2013). It utilizes plant roots to absorb, concentrate, and precipitate the contaminants (Rawat, Fulekar, & Pathak, 2015). Rhizofiltration allows in-situ operation which helps to minimize the impact to the environment, however, it is only effective when the concentration of contaminants is low and the volume of water is large.

The efficiency of the mechanism is affected by the ability of the roots to produce certain metals where it helps the plant to absorb the heavy metals in the roots, stem and leaves. In addition, pH surrounding the roots has the potential to cause the metals to precipitate on the roots surface and as the roots become saturated with heavy metals, the whole plant are harvested for disposal (Rawat et. al., 2015).

2.1.2 Phytovolatilization

Phytovolatilization is the process where the contaminants absorbed by the plant is transformed into volatile form which will be released by transpire into the air (Farraji, 2014). This technology involved pollutants being absorbed into the tissues of the plant

as a volatile form or volatile degradation product is transpired with water vapor from the leave (Etim, 2012).

Plants species with relatively high transpiration rates and has the ability to overcome stomata closure through sufficient irrigation improves the efficiency of the volatilization process (Nwoko, 2010). Phytovolatilization process transform high to less toxic substances. The drawbacks of this technology is most likely to be recycled by precipitation and will be redeposit back to the lakes and ocean (EPA, 2000).

2.1.3 Phytodegradation

Phytodegradation is one of the mechanism in phytoremediation where it involved the breaking down of complex organic molecules to simple molecules where it is absorbed into plant tissues (Trapp, Köhler, Larsen, Zambrano, & Karlson, 2001). It has the ability in remediate organic contaminants, such as chlorinated solvents, herbicides, and munitions, besides it is also able to degrade contaminants in soil, sediment, or groundwater (EPA, 2000). As in the phytoremediation process, the contaminants degraded after the uptake by the plant. In contrast with phytoextraction and phtovolatilization, it happened only when the contaminants' solubility and hydrophobic ability is in certain range, then the uptake by the plant will occur.

2.1.4 Phytoextraction

Phytoextraction or known as phytoaccumulation can be define as the ability of the plant to uptake and translocate metal contaminants by the roots from the soil. Phytoextraction is primarily for treatment of contaminated soil where it uses plants to absorb, concentrate, and precipitate toxic metals from the roots which then moves to the stem, shoots and until it reaches the leaves of the plant. **Figure 2.1** shows the nickel phytoextraction mechanism.

Since the phytoextraction involved in remediating toxic metals from the contaminated soil, the contaminated plant should be harvested and disposed properly. However there are several factor which limits the metal phytoextraction, which are listed as follows (Etim, 2012):

a) The bioavailability within rhizosphere
b) Rate of metals uptake by the roots of the plant