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Title	Heavy Metal Concentration in Water and Accumulation in Water Hyacinth Grown in the Tha Chin River
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Department	Environmental Science
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ความเข้มข้นของโลหะหนักในแม่น้ำและการสะสมของโลหะหนักในผักตบชวาที่เจริญเติบโตในแม่น้ำท่าจีน

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ABSTRACT

The Tha Chin River was considered as a contaminated river of heavy metals. Also there was loads of water hyacinth grow along Tha Chin River. In this study, water and water hyacinth were collected from two different stations; Pho Phraya station and Song Phi Nong station. For water quality, the surface water quality standard, COD, TDS, EC, Turbidity, and Salinity were measured. The water quality in Tha Chin River was in an acceptable level except for DO. The trend of heavy metals concentration in Tha Chin River was Zn>Pb>Cd>Cu>Ni and none of heavy metals exceeded water quality. Heavy metals concentration in Song Phi Nong station was higher than heavy metals concentration in Pho Phraya station. Water hyacinth were separated into two parts; roots and shoots. The results showed that water hyacinth tended to accumulate heavy metals in roots rather than shoots. Also the trend of heavy metals in water hyacinth was Cu>Zn>Pb>Ni>Cd. Biomass of water hyacinth in Song Phi Nong station was higher than water hyacinth in Pho Phraya station. Also the results showed that water hyacinth that growth in Song Phi Nong station was accumulated heavy metals more than water hyacinth in Pho Phraya station.

Keyword: Accumulation, Heavy metals, Water Hyacinth, Tha Chin River

หัวเรื่อง	ความเข้มข้นของโลหะหนักและการสะสมของโลหะหนักในผักตบชวาที่เจริญเติบโตในแม่น้ำท่าจีน
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บทคัดย่อ

แม่น้ำท่าจีนเป็นแม่น้ำที่มีการปนเปื้อนของโลหะหนัก และพบผักตบชวาตามชายฝั่งจำนวนมาก ในการศึกษานี้ ได้ทำการเก็บตัวอย่างน้ำ และผักตบชวาจากสองจุด คือ บริเวณประตูระบายน้ำโพธิพระยา และบริเวณอำเภอสองพี่น้อง การวิเคราะห์คุณภาพน้ำนั้นได้มีการใช้เกณฑ์ของมาตรฐานคุณภาพน้ำผิวดิน และพารามิเตอร์อื่นๆ เช่น ปริมาณออกซิเจนที่ใช้ในการย่อยสลายสารอินทรีย์ในน้ำ (COD), ปริมาณของของแข็งที่แขวนลอย (TDS), ค่าการนำไฟฟ้า (EC), ความขุ่น, ความเค็ม คุณภาพน้ำในแม่น้ำท่าจีนอยู่ในเกณฑ์มาตรฐานยกเว้นค่าออกซิเจนละลายน้ำ (DO) แนวโน้มของความเข้มข้นของโลหะหนักในแม่น้ำท่าจีนเป็นไปดังนี้คือ สังกะสี>ตะกั่ว>แคดเมียม>ทองแดง>นิกเกิล นอกจากนี้ไม่มีโลหะหนักตัวไหนที่มีเกินค่ามาตรฐานคุณภาพน้ำผิวดิน และความเข้มข้นของโลหะหนักในน้ำบริเวณอำเภอสองพี่น้องสูงกว่าบริเวณประตูระบายน้ำโพธิ์พระยา ในส่วนของผักตบชวานั้น จะแบ่งพืชเป็นสองส่วน คือ ส่วนราก และส่วนยอด ผักตบชวามีแนวโน้มที่จะสะสมโลหะหนักในส่วนรากมากกว่าส่วนยอด แนวโน้มของการสะสมโลหะหนักในผักตบชวาเป็นไปดังนี้ ทองแดง>สังกะสี>ตะกั่ว>นิกเกิล>แคดเมียม ในส่วนของมวลชีวภาพพบว่า ผักตบชวาบริเวณอำเภอสองพี่น้องมีมวลชีวภาพมากกว่าผักตบชวาบริเวณประตูระบายน้ำโพธิ์พระยา และผักตบชวาที่พบในอำเภอสองพี่น้องมีการสะสมของโลหะหนักทุกตัวมากกว่าผักตบชวาในบริเวณประตูระบายน้ำโพธิพระยา

คำสำคัญ: การสะสม, โลหะหนัก, ผักตบชวา, แม่น้ำท่าจีน

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
DO	Dissolved Oxygen
EC	Electric Conductivity
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TDS	Total Dissolve Solids
TSS	Total Suspended Solids
Cu	Copper
Cd	Cadmium
Pb	Lead
Zn	Zinc
Ni	Nickel

CHAPTER 1

INTRODUCTION

1.1 Background and rationale

Due to population growth and economic development around the world, many vital rivers in developing countries also emerging countries suffer from water pollution. The pressure on the water bodies rise increasingly because the escalation of anthropogenic in river watershed eventually suburb and urban areas (Steinfeld et al., 2006). The Tha Chin River is one of the four major rivers that connects to the Gulf of Thailand. This water basin is a valuable source of water for agriculture, pig farm, livestock farm, aquaculture, and local populace residents (Simachaya, 2003; Veschasit, 2012). In 2000 to 2002, The Tha Chin River was called as the most polluted river in Thailand, the river has also been a center of attention of government and public concern (Simachaya, 2003; Schaffer et al., 2009b). Heavy metal contamination in the aquatic environment due to human activities has become a serious concern in worldwide scale because of their toxicity for aquatic plant, aquatic animals, and human health and their lack of biodegradation (Singh and Prasad, 2015). According to the World Health Organization (WHO, 1984), there are several heavy metals that wild spread in river all around the world, the immediate concern are Cd, Cr, Cu, Pb, Ni, and Zn. However heavy metal pollution in water can result from variable non-point sources or accidental spillages occurring in industrial (Fayed and Abd-El-Shaft, 1985).

There are several methodologies are used for decontamination of heavy metal, including electro dialysis, reverse-osmosis, ion-exchange, adsorption, and other methods. All of these methods used are expensive, energy intensive, and not suitable to use for in-situ treatment. In contrast, phytoremediation is biological remediation which cost effective and none energy uses. Phytoremediation is the use of plants to remove metal from wastewater (Malik, 2007; Mishra and Tripathi, 2008). Several aquatic macrophytes have been used to remove heavy metal from wastewater (Miretzky et al., 2004). Aquatic macrophytes work as biofilters for polluted water, biomonitoring of metals and accumulated metals in their tissue (Dunbabin and Bowmer, 1992; Cardwell et al., 2002). Water Hyacinth (*Eichhornia crassipes*) can be used for phytoremediation due to its dense, its ability to grow in polluted water, capable to accumulate metal, its strong root system that can take up inorganic pollutants (Rezania et al., 2015). There was a study on water hyacinth demonstrated that water hyacinth has a great potential to accumulate heavy metals and remove several of pollutant compared to several aquatic plants (Priya and Selvan, 2017). Moreover water hyacinth can tolerate considerable variation in nutrients, temperature, humidity, illumination, salinity, drought and pH level (Malik, 2007; Hossain et al., 2015).

1.2 Objective

1.2.1 To determine water quality and concentration of Cu, Cd, Zn, Pb, and Ni in the Tha Chin River.

1.2.2 To evaluate heavy metals accumulation in roots and shoots of water hyacinth.

1.3 Scope

1.4.1 The water quality of Tha Chin River including temperature, Dissolved Oxygen (DO), Electric conductivity (EC), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolve Solids (TDS), Total Suspended Solids (TSS), pH, salinity and turbidity of river were measured.

1.4.2 The concentration of Cu, Cd, Pb, Zn, and Ni in water hyacinth and water in the Tha Chin River were analyzed.

1.4 Benefits

1.5.1 To evaluate the heavy metal concentration in the Tha Chin River and water hyacinth.

1.5.2 To clarify the accumulation of heavy metals in each part of water hyacinth.

CHAPTER 2

LITERATURE REVIEW

2.1 Wastewater in the Tha Chin River

The Tha Chin River is one of four major rivers connect to the Gulf of Thailand, is a part of the Central Plains of Thailand, an area of roughly 12,000 km^2. There are more over 2.5 million population along the river (Simachaya, 2003; PCD et al., 1997). The Tha Chin River is a branch of Chao Phraya River. The origin of the river is in Chainat province, approximately 180 km to Bangkok, around 320 km to the Gulf of Thailand, through four provinces of Chainat, Suphanburi, Nakhon Pathom, and Samut Sakhon (REO5, 2004).

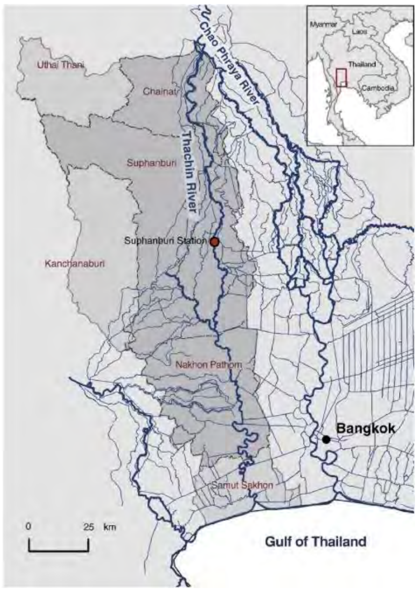


Figure.2.1 Tha Chin River Basin and its main provinces (Schaffner, 2009).

Economic activities along Tha Chin River have increasingly developed during the last decades, it comes with amounts of contaminated wastewater discharge into the rivers which becomes a problem of water pollution. According to Pollution Control Department (1997), several parts of Tha Chin River had water quality below the standards for many water quality parameters. Some numeric studies stated that major cause of water quality in Tha Chin River was untreated wastewater discharge from various sources; agriculture, aquaculture, animal husbandry, community local residences, and industry, all these activities conduct the river into organic and inorganic contaminated water, overloading of nutrients water, toxic wastewater (Meksumpon, 2008).

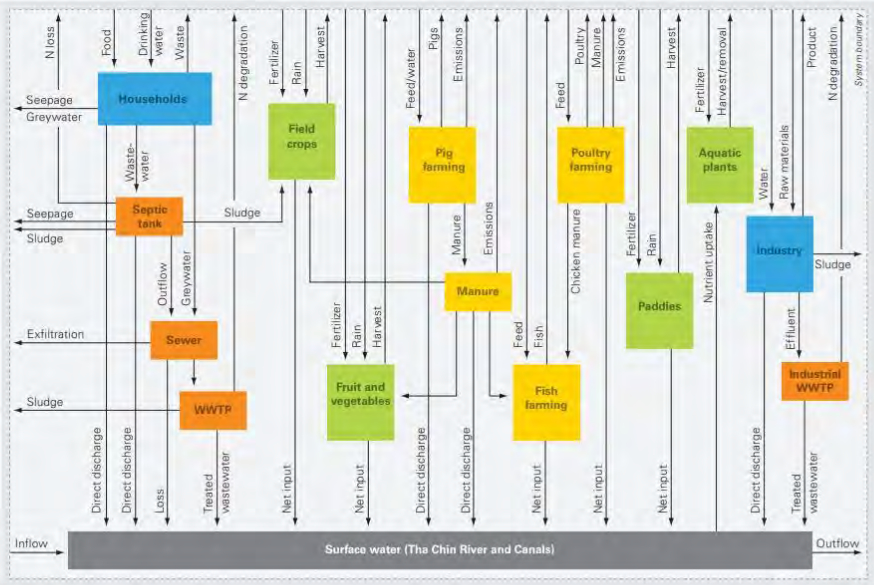


Figure 2.2 Diagram of discharges and treated wastewater among the Tha Chin River (Schaffner, 2007).

2.1.1 Partition of Tha Chin River

The Tha Chin River is located in the middle of Thailand. It is the same river basin as west part of Chao Phraya river basin. Pollution Control Department determine Tha Chin River into three parts as northern part, middle part, and southern part. The northern part is located in hillside area and the level of water are not high while the middle part and the southern part are alluvial plains which connect to Mae Klong river basin. The Tha Chin River is the right branch of Chao Phraya River, starting at Makham Tao Subdistrict, Wat Sing District, Chainat and flow through Suphanburi and Nakhon Pathom out to the Gulf of Thailand at Samut Sakhon (PCD, 1994).

Table 2.1 Each parts of Tha Chin River

Part	Province	Place
Northern Tha Chin River	Chainat to Suphanburi	Kong-suk Sisawad bridge
		Phopraya floodgate
Middle Tha Chin River	Suphanburi to Nakhon Pathom	End of town in Suphaburi
		Chedi Bucha Canal
Southern Tha Chin River	Nakhon Pathom to Samut Sakhon	In front of Nakhon Chai Si District Office
		Estaury of Tha Chin River

2.1.2 Water Quality Index in Tha Chin River

Water quality index (WQI) indicate to the situation of river which considered by five parameters; Dissolved Oxygen, Biochemical Oxygen Demand, Total Coliform Bacteria, Fecal Coliform Bacteria, and Ammonia-Nitrogen. WQI can be classified by the score between 0 – 100 with the following criteria.

Table 2.2 Water Quality Index Criteria

Score	Descriptor Categories	Class
90 - 100	Very Good	1
71 – 90	Good	2
61 – 70	Medium	3
31 - 60	Poor	4
0 - 30	Very Poor	5

There are water monitoring along the Tha Chin River four times a year; February, May, July, and November by Nakhon Pathom environmental office. As a determination of the Tha Chin river by pollution control department, the southern part of the Tha Chin River is classified as class 2 which mean the river are capable to receive discharge from some anthropogenic and can be utilized in several kinds such as consumption, aquatic animal conservation, aquaculture, swimming and water sports. The middle part of the Tha Chin River is classified in class 3 which mean the river can derive discharges from anthropogenic and can be utilized as consumption and agriculture. Lastly, the southern part of the Tha Chin River is classified into class 4 which mean this part can receive some discharges from anthropogenic and can be utilized for consumption and industrial (PCD, 1994).

Table 2.3 Water Quality Index of the Tha Chin River

Part	Province	WQI
Northern Tha Chin River	Chainat to Suphanburi	2
Middle Tha Chin River	Suphanburi to Nakhon Pathom	3
Southern Tha Chin River	Nakhon Pathom to Samut Sakhon	4

2.1.3 Sources of Heavy Metals

An increasing of industries, agricultures, traffic have conducted to loads of heavy metals releasing to environment especially in soil and water. Generally, most of rivers have received metal contamination from various anthropogenic sources, including industries, residential wastewater, treated sewage discharges, agriculture. In the Tha Chin river, there were agriculture occupies around 52% of the basin’s area (REO5, 2003). Many fields in agriculture used intensive of pesticide and fertilizer for high crop productions especially on rice yield. Another crops alongside of the river are sugar crane, cassava and corn. For animal husbandry, pig farming cover up to

15% of national pork manufacturing (DLD, 2004). Poultry production come up with 6% (DLD and PCD, 2002). As a result of wastewater discharge from several industry around the Tha Chin River, the water quality index was bellowed the standard particularly the southern part of the river has the lowest scale of the criteria due to high nutrients levels and oxygen depletion (Simachaya, 2003).

According to the Land Development Department report, the largest sector of land use utilization is agricultural lands follow up with community areas (Table 2.4).

Table 2.4 Utilization of Land Use in the Tha Chin River

District	Types of Land Use	Zone	
		Rai	Percentage
Chainat	Community Areas	159,509	10.33
	Agriculture Areas	1,242,903	80.52
	Forest Areas	45,454	2.95
	Water Areas	68,238	4.42
	Miscellaneous area	27,487	1.78
	Total	**1,543,591**	**100.00**
Suphanburi	Community Areas	276,955	8.27
	Agriculture Areas	2,486,977	74.25
	Forest Areas	402,580	12.02
	Water Areas	115,972	3.46
	Miscellaneous area	66,271	2.00
	Total	**3,348,755**	**100.00**
Nakhon Pathom	Community Areas	292,550	21.58
	Agriculture Areas	912,766	67.34
	Forest Areas	-	-
	Water Areas	50,689	3.74
	Miscellaneous area	99,217	7.34
	Total	**1,355,204**	**100.00**
	Community Areas	138,745	25.44

Samut Sakhon	Agriculture Areas	307,311	56.37
	Forest Areas	20,608	3.78
	Water Areas	22,708	4.17
	Miscellaneous area	55,845	10.24
	Total	545,217	100.00

2.2 Heavy metals

Heavy metals is an inorganic pollutant that persist in environment, hard to vanish from river, and none biodegradation, therefore, it tends to accumulate in various types of components (Chandra et al., 1997). The heavy metals have highly toxic to the nature also aquatic plants and aquatic animal as well as humans. The most common and chief pollutants among several heavy metals in wastewater are Cd, Pb, Cu, Zn, and Ni. This is a serious problem of contaminated water in worldwide scale and still unrestrained because the lack of awareness and strict regulation of policy (Akpor and Muchie, 2010). In general toxicity of metals, heavy metals have a potential carcinogenicity in humans and capable to enter the food chain. Besides, nickel have been linked with cancers referred from human population (Mahurpawar, 2015). Heavy metals are also acknowledged as the major causes of several symptoms such as skin diseases, asthma, dehydration, respiratory problems and excretory systems in human.

Recently many studies reported that some heavy metals in river are exceeded the standard of water quality in many tributaries of Thailand especially the areas that have intensive of industries. There was a study investigated that the contamination of mercury in mussels, mullets and sediments were higher than the acceptable limits which this problems might effect on humans health due to the toxicity of heavy metal. Also in the industrial areas south of Bangkok, Chao Pharaya River contained heavy metals higher than the background stations. (Menasveta, 1981).

2.3 Phytoremediation

Phytoremediation interpreted as ‘‘the efficient use of plants to remove, detoxify or immobilize environmental contaminants” (UNEP, 2019). Phytoremediation is an ecological and advantageous technique that use plants to remediate soil, water, sediments and surface which contaminated to toxic metals, organics and radionuclide. It is a low cost and conventional clean-up technology. Aquatic macrophytes have an ability to uptake pollutants also detoxification by various mechanism (Pradhan et al., 1998). There are many mechanisms that plants can utilize remediation such as phytoextraction (phytoaccumulation), phytopumping, phytostabilization, phytotransformation (degradation), phytovolatilization and rhizodegradation.

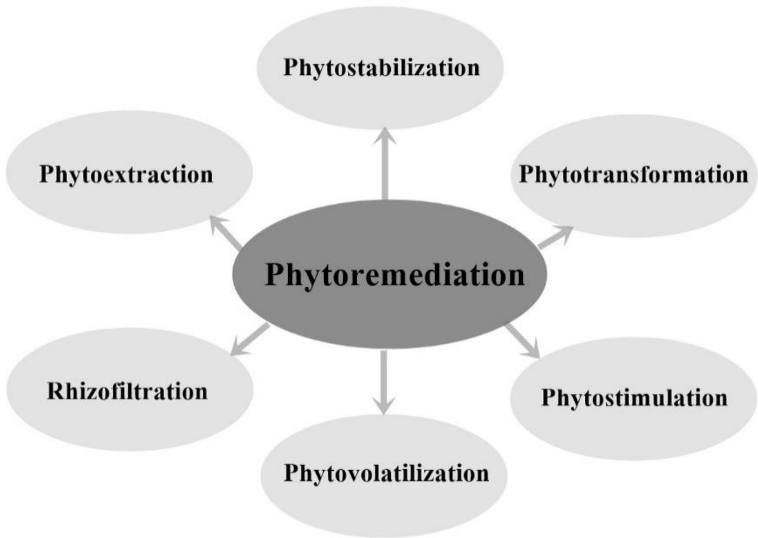


Figure 2.3 Phytoremediation diagram

During phytoremediation process, there might be some factors effect on the efficiency of phytoremediation such as temperature, pH, salinity, and other metals. The ability of phytoremediation also depends on plant characteristic like type of roots, system, and enzymes (Susarla et al., 2002). This technology has high efficiency to clean up the contaminated water. Treatment of wastewater by plants has been used since 300 years ago (Carolin et al., 2017). There are various species have been reported for their efficiency to accumulate heavy metals from contaminated water

(Prasad, 2007). For the first step is identification and screening for the plant that suitable to remediate the propose pollutant. The plants should be fast growing, easily to harvest (Stefani et al., 2011).

2.4 Water Hyacinth

Figure 2.4 Water Hyacinth in the Tha Chin River

Water Hyacinth originated in the rain forest of Amazon river and first recorded as invasive plant in Nile River at the late 18th century till present (Hill et al., 1997). It was planted as an ornament during late 19th century and after that it was widely spread into various countries around the world (Ojeifo et al., 2002). Water Hyacinth (*Eichhornia crassipes*) has broad leaves and raise above the surface water (Adegunloye et al., 2013). It has long spongy and bulbous stalks, each plant has six to ten leaves which attach to well-developed root system. The color of roots depend on the media, free floating water hyacinth has purple color roots while planted water hyacinth in soil has white color (Penfound and Earle, 1948). The flower of water hyacinth has purple or pink color.

Water hyacinth is an ideal candidate for phytoremediation due to its fast-growing, tolerant to heavy metals, free floating hydrophyte, and ability to accumulate heavy metals (Rezania et al., 2015). Water Hyacinth is an invasive aquatic plant also known as world’s worst aquatic weed due to its dense and impermeable floating mat on water surface. It can tolerate a polluted water also endure a broad range of environmental conditions; temperature, humidity, pH, salinity, wind, current and drought (Hossain, 2015). Water Hyacinth cause biodiversity impacts by displacing native plants because the plant can reproduce by seeds and one plant can produce up to 5000 thousand seeds while the seeds remain in water or sediment last for 20 years. Due to the dense of its roots and leaves, change in water chemistry, the light are not able to penetrate to the water, birds and other fauna incapable to access the water, prevention of oxygen exchange, large amount of mats decaying vegetation which result in oxygen depletion and lead to unsuitable habitat for aquatic animals.

2.4.1 Accumulation of water hyacinth

Hyperaccumulation is a phytoremediation process. It is plant accumulation of metal from metal substrates. Hyperaccumulation method involves contaminant uptake by roots come after harvesting and disposal of plant biomass (Ukiwe et al., 2008). Water Hyacinth is suitable for use as hyperaccumulator of pollutants because it has a potential to uptake and accumulate heavy metals also toxic elements from industrial and domestic discharges (Ogunlade, 1992; Sharma et al., 2016). There are several studies on water hyacinth used to remediate various polluted sites and contaminated water (Muramoto and Oki, 1983; De Souza et al., 1999; Soltan and Rashed, 2003). Moreover, after remediated process of phytoremediation, heavy metal residues and non-degradable materials in water hyacinth can be recovered to use once again (Isarankura-Na-Ayudhya et al., 2007). The further uses of water hyacinth is not only phytoremediation but also regenerate of biogas, production of animal feed, biological fertilizer (Rezania., 2015).

2.5 Application of water hyacinth for wastewater

In abandoned e-waste recycling sites pollutes heavy metals into water surrounding the sites. The study investigated the capacity of water hyacinth on remediating contaminated sites by measuring the accumulation and translocation of heavy metals in water hyacinth also examined the concentration of heavy metals in sediment. The concentration of 12 heavy metals (Ag, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Sn, Tl and Zn) were analyzed by an inductively coupled plasma mass spectrometer. The results show that the root of water hyacinth has the highest accumulation of heavy metal, also the accumulation capacity of water hyacinth along the river increased the uptake of Ag, Co, Mn, Ni, Sn, and Tl with the contamination level while the amount of heavy metals have the translocation lower than 1. This findings indicate that water hyacinth can remove heavy metals from the contaminated sites (Du et al., 2020).

Several unnecessary heavy metals such as Pb, Hg, Cr, and Cd are polluted into biotic and abiotic environment, are also effect to human health. Water hyacinth (*Eichhornia crassipes*), Duckweed (*Spirodela polyrhiza*), and Water lettuce (*Pistia stratiotes*) were chosen as remediation plants for remediate contaminated water of Ramsar wetland (Loktak Lake, India). Three floating plants were experimented in 140 L tanks that filled with 100 L water from Loktak Lake. Seven heavy metals (Fe, Cu, Cd, Cr, Zn, Ni, and As-semi metal metalloid) were analyzed by means of atomic absorption spectrophotometry (AAS). After 15 days, plants were harvested to find the accumulated value of heavy metals in plants. Water samples were analyzed for heavy metals 4 times (day 4, 8, 12, 15). The investigation shown that water hyacinth is the most efficient accumulator followed by water lettuce and duckweed respectively, also water hyacinth has the highest translocation factor for Cu (Rai, 2019).

In a tannery wastewater site which contaminated by deep blue color, acidic pH, higher value of total dissolve solid, and lower value of dissolve solid has investigated by filtration of water hyacinth. In experiment, water hyacinth were collected from suburb Konapara in Bangladesh. The sample were separated into shoot parts and rest parts and dried in oven after that dry water hyacinth were grinded by mortar. The detection of Cu and Cr were analyzed by atomic absorption spectrophotometry (AAS). The finding shown that an adsorbent capacity of raw water hyacinth for Cr and Cu was found 99.98% and 99.96% for standard solution and 98.83% and 99.59% for tannery effluent, respectively. Hence it indicates that Cr and Cu removing by water hyacinth were satisfactory (Sarkar et al., 2017).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study sites and sampling method

3.1.1 Water sampling

To investigate accumulation of heavy metals by water hyacinth, water sample collecting areas were the same place as water hyacinth sampling. Water sampling were collected by Kemmerer at two different areas. The water were collected below water surface 30 centimeter. In this study, the standard source of the Tha Chin River is a Pho Phraya floodgate (L1), located in the highest point of the study area. The contaminated source is Song Phi Nong canel (L2) which located in the middle point of the Tha Chin River. After collecting water sampler, the water sample were separated into two parts, the first part is for analyzing of wastewater quality (table 3.2) and another part for analyzing of heavy metals in wastewater (table 3.4).

Figure 3.1 Water sampling and plant sampling sites

3.1.2 Plant sampling

Water hyacinth were collected as whole plant from each sites and were kept in plastic bag then carefully transported to the laboratory. The plant sampling were collected by simple random sampling because there is an equal probability of choosing each quadrat from the fields being collected.

3.2 Analysis of wastewater quality

For analyzing wastewater quality, some parameters were measured on sites and some parameters were measured in laboratory (table 3.2). After water sample were carried to the laboratory, water sample were immediately analyzed the parameters of BOD, COD, TDS and SS.

Table 3.2 Parameter and methods of wastewater analysis

In situ	Parameter	Method
	Temperature	Thermometer
	pH	Electrometric pH meter
	DO (Dissolved Oxygen)	Azide Modification
	EC (Electric Conductivity)	Conductivity meter
	Salinity	Salinity meter
Ex situ	**Parameter**	**Method**
	BOD (Biological Oxygen Demand)	Azide Modification
	COD (Chemical Oxygen Demand)	Close Reflux
	TDS (Total Dissolved Solids)	Gravimetric method
	TSS (Total Suspended Solids)	Grass Fiber Filter Disc

3.3 Analysis of heavy metals in plants

By the time plant samples arrived the laboratory, all plants samples were carefully washed with tap water then followed by deionized water. Water hyacinth were separated into two parts; roots and shoots. Then water hyacinth were measured wet weight of all samples and were measured the length of water hyacinth. Then, all samples was placed in the oven at 65 Celsius within 48 hour and weight the dry water hyacinth. All dry samples were grinded into powder by grinder and then filtered by 0.5 mm sieve. After all, extract the sample by using 0.5 gram of water hyacinth powder and mix with 10 ml of nitric acid (HNO_3) 65% then put it into microwave digester (Ethos One, China) at the temperature of 175 C and 1000 watts power, use 25 minute. Filter the extraction with whatman filter paper no.42 to remove colloid out of the extraction to prevent the blog of colloid in the next process. The concentration of heavy metals in samples were carried out by atomic absorption spectrophotometer (AAS). In order to determine the accuracy of the process, all samples were analyzed in triplicate.

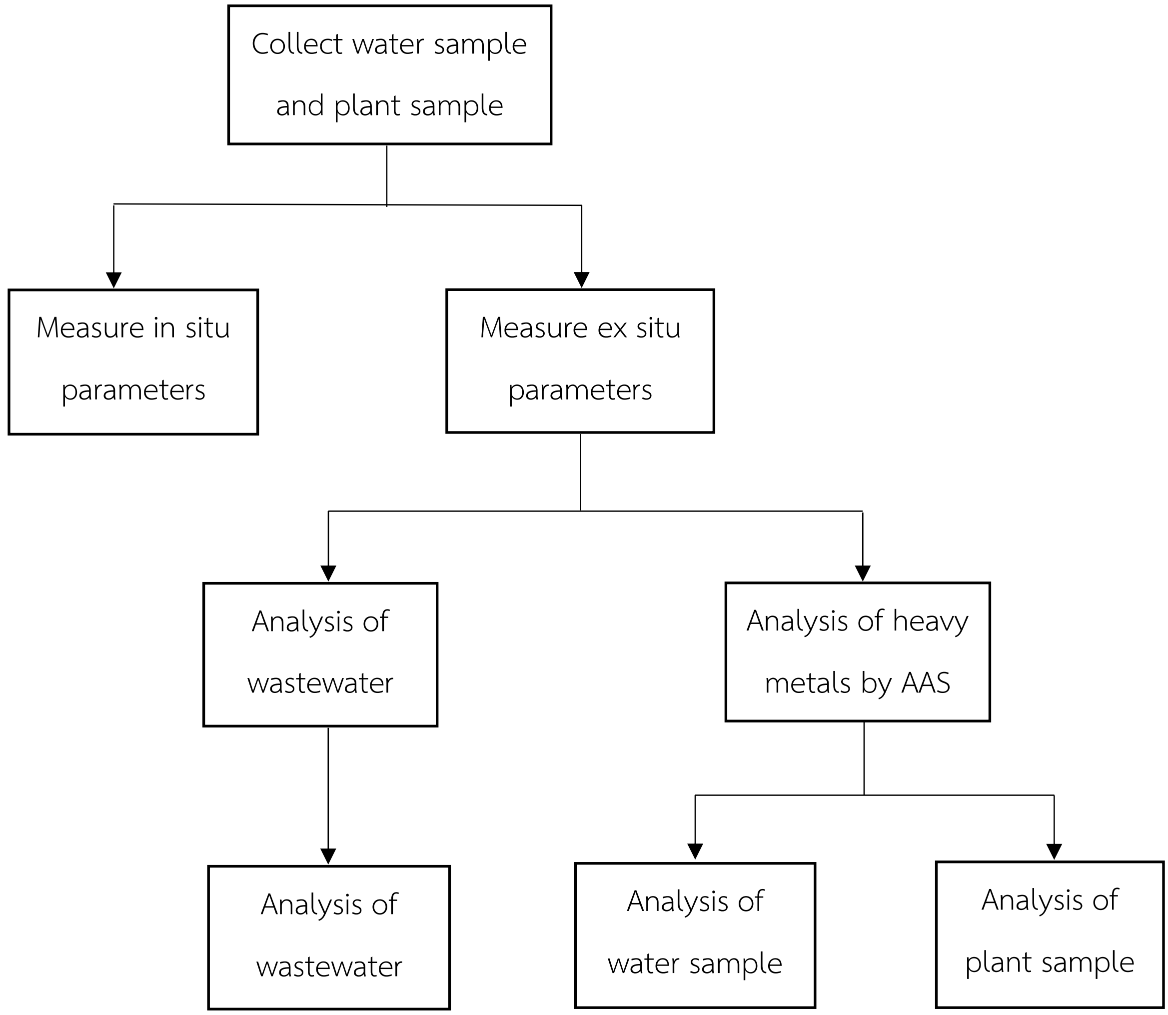
3.4 Analysis of heavy metals in wastewater

After water sample were carried to the laboratory, 45 mL of water sample were mixed with 5 ml of 65% nitric acid (HNO_3) in vessel. Then, the vessel was put in microwave digester (Ethos One, China). The condition was set for the temperature at 175 C and the power at 1000 watts and use 30 minute (EPA 3015, 1994). After that filter the extraction with whatman filter paper no.42 to remove colloid out of the extraction. The concentration of heavy metal in water sample was determined by using atomic absorption spectrophotometer (AAS). For the accuracy, the sample were analyzed in triplicate.

3.5 Data Analysis

In this experiment, all data were analyzed by using one-way ANOVA (SPSS for windows 10 version 22)

3.6 Summary of experiment



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Water quality in the Tha Chin River

According to Pollution Control Department (PCD), the Pho Phraya station located in the northern part of Tha Chin River which defined as class 2 and Song Phi Nong station located in the middle part of Tha Chin River was classified as class3.

Water quality of Tha Chin River in water hyacinth field, the temperature in Song Phi Nong station (33.1^{o}C) was higher than Pho Phraya station (31.6^{o}C). The pH value of water in Pho Phraya station (6.2) was lower than in Song Phi Nong station (6.4). The pH value of both station was in the range of pH standard. Dissolve Oxygen (DO) in Pho Phraya station was higher than Song Phi Nong station, the value was 5.4 and 3.3 mg/L, respectively. Also, both DO value were lower than the criteria. Biochemical Oxygen Demand (BOD) in Pho Phraya station was 1.40 mg/L and was higher than BOD in Song Phi Nong station that was 1.15 mg/L. None of BOD value exceed the water quality standard. Chemical Oxygen Demand (COD) in Pho Phraya and Song Phi Nong station were 16 mg/L. Total Dissolve Solid (TDS) in Pho Phraya was lower than TDS in Song Phi Nong station, the value were 137 and 227 mg/L, respectively. The Electric Conductivity (EC) in Pho Phraya station was higher than Song Phi Nong station, the value were 1012 and 574 (µs/cm) respectively. The turbidity in Pho Phraya station was higher than Song Phi Nong station, the value were 23.9 and 11.7 (NTU) respectively. The salinity in Pho Phraya station was higher than Song Phi Nong station, the value were 0.5 and 0.2 (%) respectively.

In overall, water quality of the Tha Chin River was in a good criteria comparing of parameters (Table 4.1) to surface water quality standard in Thailand. Every parameters except DO was in the water quality criteria.

Table 4.1 Water quality in Tha Chin River compare to Water quality standard

parameter	Station		Standard Value for Class	
	Pho Phraya	Song Phi Nong	Class 2	Class 3
Color	Yellowish green	Yellowish green	n’	n’
Temperature ©	31.6	33.4	n’	n’
pH	6.2	6.4	5-9	5-9
DO (mg/L)	5.4	3.3	≥6	≥4
BOD (mg/L)	1.40	1.15	≤1.5	≤2.0
COD (mg/L)	16	16	None	None
TDS (mg/L)	137	227	None	None
Electric Conductivity (µs/cm)	1012	574	None	None
Turbidity (NTU)	23.9	11.7	None	None
Salinity (%)	0.5	0.2	None	None

Remark: n’ = naturally but changing not more than 3° C

4.2 Heavy metals concentration in the Tha Chin River

The results showed that the heavy metals concentration in Tha Chin River (Figure 4.1). The horizontal axis represented the type of heavy metal and the vertical axis represented the concentration of heavy metals. The heavy metals concentration in Pho Phraya station was less contaminated than Song Phi Nong station except for Cu. The highest concentration of heavy metal was 0.103 mg/L in Song Phi Nong while the lowest concentration was 0.003 mg/L for Ni in Pho Phraya station and Ni was non-detectable in Pho Phraya station. The trend of heavy metals concentration in the Tha Chin River showed that Zn>Pb>Cd>Cu>Ni. In Song Phi Nong station, Cd, Pb and Zn were higher than Pho Phraya station significantly ($P \geq 0.05$). None of heavy metals in this study exceeded water quality standard in Thailand. Referring to World Health Organization, the concentration of Cd and Pb in Tha Chin River exceed WHO permissible value and WHO desirable value. Likewise, Ni concentration in Song Phi Nong station also exceed WHO desirable value but not exceed WHO permissible value. None of the rest heavy metals concentration exceed WHO permissible value and WHO desirable value (Table 4.2).

In Song Phi Nong station has higher concentration of heavy metals due to in Song Phi Nong station had derived discharges much more than in Pho Phraya station. According to pollution control department, Song Phi Nong station located in the middle part of Tha Chin River, are defined WQI as 3 which mean it capable to receive discharges more than Pho Phraya station which located in the northern part of Tha Chin River that has WQI as 2 (PCD, 1994). Nevertheless, heavy metals concentration did not exceed the water quality standards because of the amount of discharges were still underneath of pollution control department.

Table 4.2 Heavy metals concentration in the Tha Chin River compare to surface water quality standard in Thailand and World Health Organization

Parameter	**Station**		**Water quality Standard* (mg/L)**	**WHO permissible value (mg/L)**	**WHO desirable value (mg/L)**
	Pho Phraya	**Song Phi Nong**			
Cu	0.006	0.005	0.1	2.0	1.0
Cd	0.011	0.012	0.05	0.003	0.002
Pb	0.030	0.040	0.05	0.01	0
Zn	0.061	0.103	1.0	3.0	3.0
Ni	0	0.003	0.1	0.07	0.02

Remark; * = Surface Water Quality Standard from the Ministry of Natural Resources and Environment (PCD, 1994).

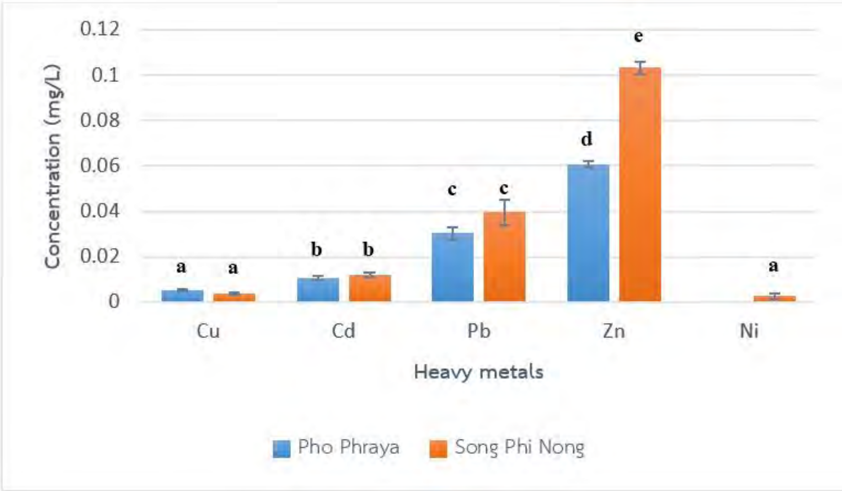


Figure 4.1 Heavy metals concentration in the Tha Chin River

4.3 Heavy metals accumulation in water hyacinth

The average concentration of each heavy metals in water hyacinth (whole plant) was shown in figure 4.2. The horizontal axis was type of heavy metal and the vertical axis was concentration of heavy metals. As a contaminated point, water hyacinth in Song Phi Nong station had higher accumulation of all heavy metals rather than water hyacinth in Pho Phraya floodgate station except for Cd that could not be detected in any part of water hyacinth. The highest concentration in water hyacinth was Cu 517.77 mg/kg at Song Phi Nong station and the lowest concentration in water hyacinth was Ni 12.49 mg/kg at Pho Phraya station. Cd could not be detected in water hyacinth in any station. The trend of heavy metal accumulation in water hyacinth was Cu>Zn>Pb>Ni>Cd.

In Pho Phraya river station had lower heavy metals concentration than Song Phi Nong station. Therefore, heavy metals accumulation in water hyacinth at Song Phi Nong station had higher accumulation more than heavy metals accumulation in water hyacinth at Pho Phraya station, meaning that water hyacinth increased heavy metals accumulation with the contamination level in water. Factor that might effect on heavy metals accumulation is pH, in Pho Phraya station has pH as 6.2 which lower than pH in Song Phi Nong station that had pH as 6.4. Another factor that might effect on plant accumulation is biomass, biomass of water hyacinth in Pho Phraya station was 56.92 g/m^2 and lower than biomass of water hyacinth in Song Phi Nong station 104.36 g/m^2. There was a study investigated that in water hyacinth uptake of Zn, Cu, Pb, and Cd, at pH 8 had higher removal efficiency rate more than pH 6, and increase in plant biomass advocated higher removal (Smolyakov, 2012). Likewise, an increase biomass of water hyacinth leads to an increase removal percentage and removal rate of arsenic from water (Alvarado, 2008).

The reason that aquatic plants can act as natural resource to remediate contaminated sites because its ability to absorb heavy metals from water (Singh et al., 2011; Isiuku and Ebere, 2019). Among several aquatic plants, water hyacinth has a great potential to accumulate heavy metals and remove several of pollutant (Priya and Selvan, 2017). There is also an investigation that support present study, the study on heavy metal phytoremediation by water hyacinth reported that the accumulation of Cu in water hyacinth was the highest level while Cd was the least level of accumulation (Liao and Cheng, 2004).

There is a demonstration that aquatic plant with high-growth-rate like water hyacinth has a potential to remove metals from wastewater due to it has mechanism that capable to tolerance to heavy metals (Malar et al., 2014). Water hyacinth have been considered as absorbent for remediating wastewater that contaminated of heavy metals (Mahamadi and Nharingo, 2007). As a common invasive plant that distribute in global (Thamaga and Dube, 2018), water hyacinth may be cultivated to decrease heavy metals concentration in contaminated sites. It can also use as biological monitor to monitor metals pollution (Zaranyika et al., 1994).

Table 4.3 Biomass of water hyacinth

Part	Station	
	Pho Phraya	Song Phi Nong
Roots (g/m^2 DW)	23.16	23.16
Shoots (g/m^2 DW)	33.76	81.20
Total (g/m^2 DW)	56.92	104.36

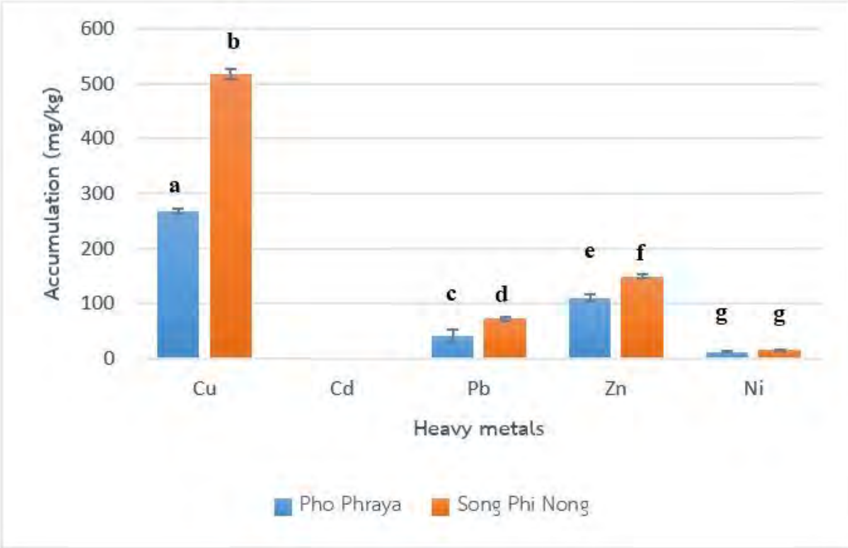


Figure 4.2 Heavy metals accumulation in water hyacinth (whole plant)

4.4 Heavy metals tend to accumulate in roots rather than shoots

Regardless of all sampling points, the roots of water hyacinth had higher accumulation of heavy metals rather than shoots in every heavy metal (Figure 4.3 - 4.6). The results showed the heavy metals accumulation in water hyacinth in roots and shoots. The horizontal axis was the part of water hyacinth and the vertical axis was the accumulation of each heavy metals.

There was a study demonstrated that water hyacinth accumulated higher concentration of heavy metals in roots rather than shoots by treated water hyacinth with various heavy metals (Soltan and Rashed, 2003). Water hyacinth were examined as a better accumulation plant of metals in roots portions compared to water milfoil and water lettuce (Qian et al., 1999). There is also another study well explained why roots has a better accumulation of metals rather than shoots, the studies investigated that metals were uptake by roots via plasma membrane involving cationic channel like calcium and inhibit its translocation to shoots, Roots keep the cations by binding with cell wall, hence, it is flavor to store metals in root system. This mechanism provided averting effect of metals by avoiding toxic metals from interacting more with other plant parts (Skinner et al., 2007). The heavy metals uptake efficiency of water hyacinth and other macrophytes depended on several factors like plant species, different organs, season, pH, metal concentration (Tokunaga, 1976). Furthermore, increasing of pH levels at 6 and 8 led to an increasing of concentration in roots and concentration in shoots (Aisen, 2010).

4.4.1 Cu accumulation in water hyacinth

The results showed that Cu accumulation in water hyacinth roots and shoots of both Pho Phraya and Song Phi Nong station (figure 4.2). The horizontal axis is part of water hyacinth and the vertical axis is Cu accumulation in water hyacinth. The highest Cu accumulation level was 427.11 mg/kg of water hyacinth roots at Song Phi Nong station while the least level of Cu accumulation was 34.73 mg/kg of water hyacinth shoots at Pho Phraya station. In Tha Chin River, Cu concentration at Pho Phraya station was higher than Cu concentration at Song Phi Nong station but Cu accumulation of water hyacinth in Pho Phraya station has less Cu accumulation value compared to water hyacinth in Song Phi Nong station. The reason that water hyacinth in Pho Phraya has cu accumulation less than water hyacinth in Song Phi Nong station may be the biomass of water hyacinth in Song Phi Nong station was higher than water hyacinth in Pho Phraya station.

When the concentration of Cu rises above optimal level, it becomes toxic in plant tissues (Lombardi and Sebastiani, 2005). Rhizofiltration may be the main mechanism for Cu accumulation as Cu is more localized in macrophyte roots. The study of phytoaccumulation of heavy metals by water hyacinth showed at low concentration, water hyacinth was more efficient to accumulate heavy metals (Zhu et al., 2009). It indicated that water hyacinth was capable to remove Cu at lower concentrations (Mokhtar, 2011). Many studies concluded that metals accumulation usually take place in roots of plants because of the mobility of metals to transport from roots to shoots was slow (Chandra and Kulshreshtha, 2004).

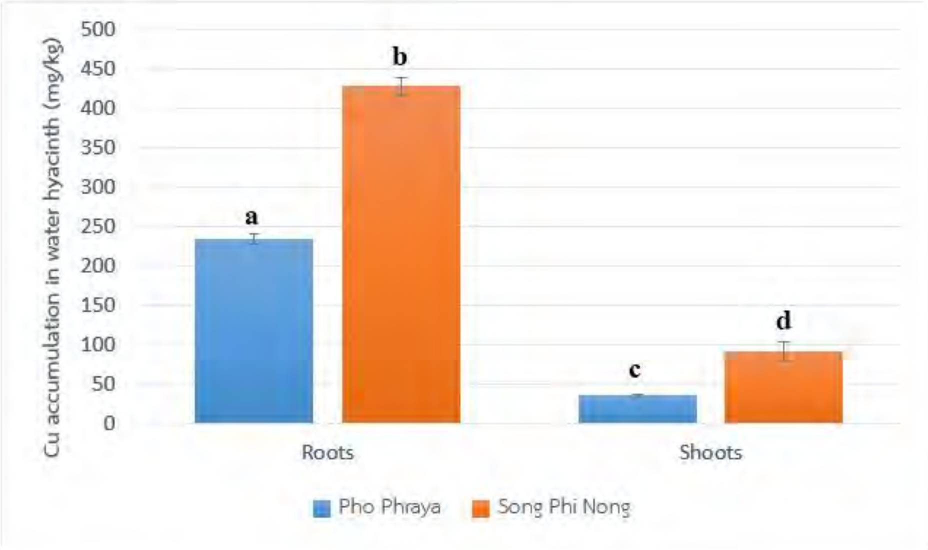


Figure 4.3 Cu accumulation in water hyacinth

4.4.2 Cd accumulation in water hyacinth

Cd is the most toxic metal from all of these five heavy metals. It was no detectable of Cd in water hyacinth both roots and shoots but it was detectable of Cd in river, this due to the concentration of Cd in water hyacinth was less than the least detectable value. Which mean Cd accumulation in water hyacinth was quite low.

Plant normally uptake heavy metal like Cd from water through roots and whole plant performed as an active site for absorption (Yoshida, 1999). Cd can be stored in roots and translocated into shoots and other parts of plant by xylem and vessels and they mostly deposited in vacuoles. Heavy metal sequestration in vacuole is one of the way to eliminate heavy metal from cytosol (Assuncao et al, 2003; Majeti, 2004; Jabeen et al, 2009; Rahman and Hasegawa, 2011). The compartmentalization of metals in vacuoles is a part of tolerance mechanism in metal hyperaccumulators.

4.4.3 Pb accumulation in water hyacinth

The result showed that Pb accumulation in water hyacinth roots and shoots of both Pho Phraya and Song Phi Nong station (figure 4.4). The horizontal axis was part of water hyacinth and the vertical axis was Pb accumulation in water hyacinth. The highest Pb accumulation level was 39.39 mg/kg of water hyacinth roots at Song Phi Nong station but it was not much difference if compare to roots in Pho Phraya station (39.11 mg/kg). While the least level of Pb accumulation was 2.39 mg/kg of water hyacinth shoots at Pho Phraya station. Hence, water hyacinth in Song Phi Nong station has greater Pb accumulation than water hyacinth in Pho Phraya station. Increasing of heavy metal in the environment generally increase Pb accumulation in plant as reported pea leaves and maize (Bharti and Singh, 1993).

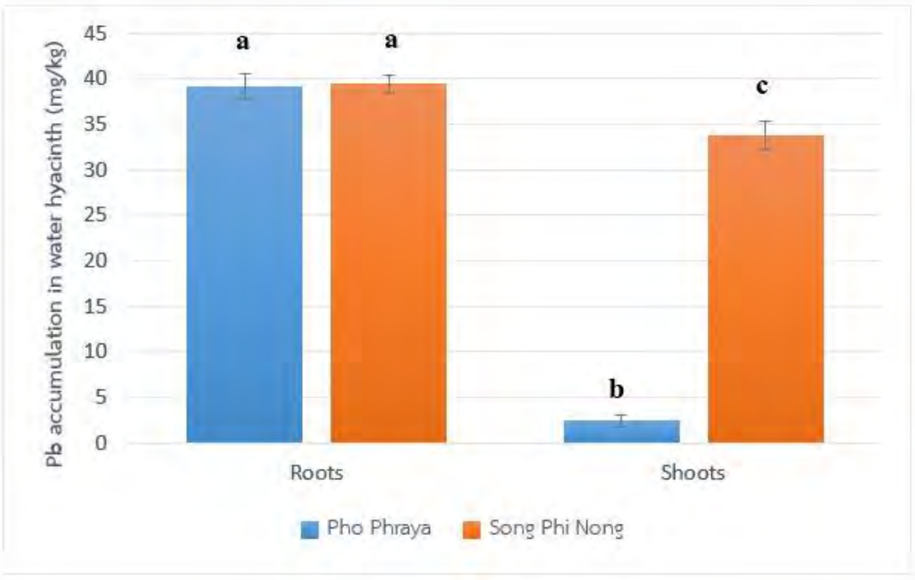


Figure 4.4 Pb accumulation in water hyacinth

4.4.4 Zn accumulation in water hyacinth

The result showed that Zn accumulation in water hyacinth roots and shoots of both Pho Phraya and Song Phi Nong station (figure 4.5). The horizontal axis was part of water hyacinth and the vertical axis was Zn accumulation in water hyacinth. The highest Zn accumulation level was 97.22 mg/kg of water hyacinth roots at Song Phi Nong station while the least level of Zn accumulation was 38.01 mg/kg of water hyacinth shoots at Pho Phraya station. Water hyacinth in Song Phi Nong has higher potential of Zn accumulation.

There is a study support the present result that Zn accumulation in leaf tissue of Indian mustard increased as concentration increased (Chaudhry, 2020). Another study investigated that water hyacinth capable to remove zinc oxide (ZnO), the results also showed that it was accumulated in roots, stems and leaves as 954.83 ± 73.69, 129.11± 5.93 and 61.44 ± 3.13 mg/kg, respectively. The ZnO accumulation trend was roots>stems>leaves (Bookrue and Ariyakanon, 2017).

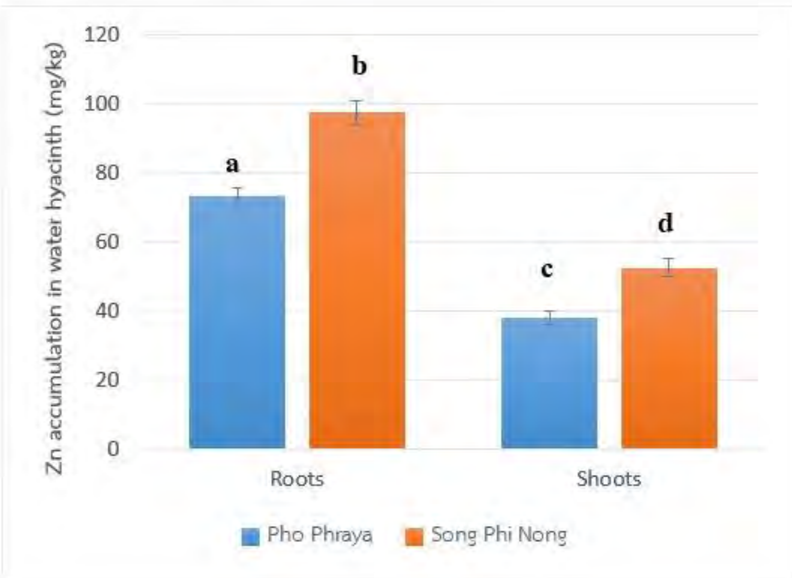


Figure 4.5 Zn accumulation in water hyacinth

4.4.5 Ni accumulation in water hyacinth

Ni is a micronutrient that is necessary in plants. The result showed that Ni accumulation in water hyacinth roots and shoots of both Pho Phraya and Song Phi Nong station (figure 4.6). The horizontal axis was part of water hyacinth and the vertical axis was Ni accumulation in water hyacinth. The highest Ni accumulation level was 11.98 mg/kg of water hyacinth roots at Song Phi Nong station but it was not much difference if compare to roots in Pho Phraya station (11.25 mg/kg). While the least level of Ni accumulation was 1.24 mg/kg of water hyacinth shoots at Pho Phraya station. Ni accumulation of water hyacinth shoots at Song Phi Nong station was 3.42 mg/kg. Water hyacinth in Song Phi Nong has higher potential of Ni accumulation than water hyacinth in Pho Phraya station.

There was a study of heavy metal in water spinach, the study showed that Ni was accumulated in roots more than aerial part (Rattanapaiboon, 2015).

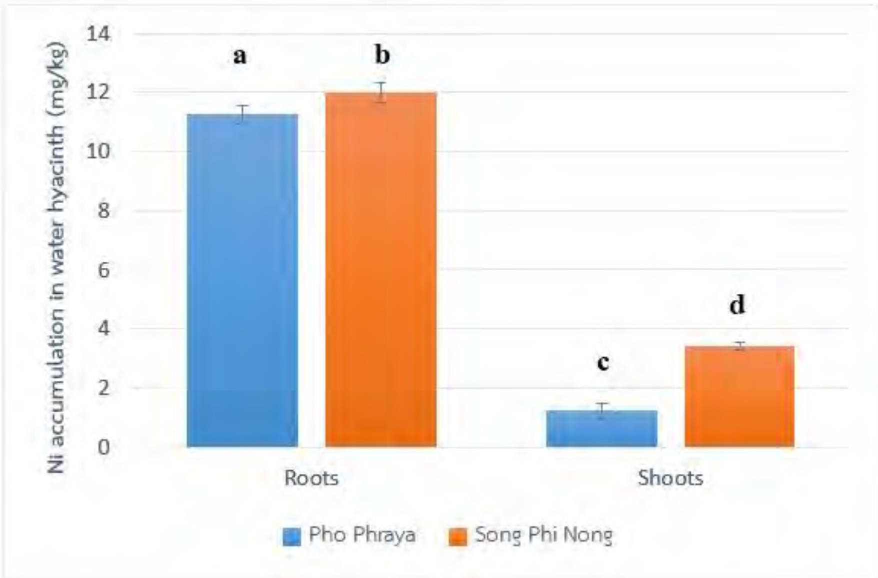


Figure 4.6 Ni accumulation in water hyacinth

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In overall, water quality of the Tha Chin River was in a good criteria and every parameters except DO was in the water quality criteria. None of heavy metals in this study exceeded water quality standard in Thailand. In Pho Phraya river station had lower heavy metals concentration than Song Phi Nong station. Therefore, heavy metals accumulation in water hyacinth at Song Phi Nong station had higher accumulation more than heavy metals accumulation in water hyacinth. Hence, Water hyacinth increased heavy metals accumulation with the contamination level in water. Heavy metals tend to accumulate in roots rather than shoots.

5.2 Recommendations

5.2.1 Water hyacinth capable to accumulate heavy metals from Tha Chin River and every parameters for surface water quality were meet the acceptable level of the standard except DO so for the sustainable uses, the government need to manage Tha Chin River basin in a proper way.

5.2.2 Due to water hyacinth has rapid growth rate and high reproduction. The future study could be strategies to control water hyacinth or utilization of water hyacinth.

5.2.3 Other plants that are invasive species or not edible should be used to study on accumulation efficiency to utilize the plants.

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