PERFORMANCE OF WATER HYACINTH FOR REMOVAL OF ORGANIC AND INORGANIC POLLUTANTS FROM INDUSTRIAL WASTEWATER

PAVITHRA A/P ENGITARAVANAN

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : PAVITHRA A/P ENGITARAVANAN

Date of Birth : 13 SEPTEMBER 1994

Title : PERFORMANCE OF WATER HYACINTH FOR REMOVAL OF ORGANIC AND INORGANIC POLLUTANTS FROM INDUSTRIAL WASTEWATER

Academic Session : 2018/2019

I declare that this thesis is classified as:

☐ CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐ RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑ OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
940913-02-5182	DR MIR SUJAUL ISLAM
New IC/Passport Number	Name of Supervisor
Date:	Date:

NOTE: * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree in Bachelors of Civil Engineering.

____

(Supervisor’s Signature)

Full Name : DR MIR SUJAUL ISLAM

Position : SENIOR LECTERUR, FACULTY OF CIVIL ENGINEERING AND EARTH RESOURCES, UNIVERSITI MALAYSIA PAHANG

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : PAVITHRA A/P ENGITARAVANAN

ID Number : AA15253

Date :

PERFORMANCE OF WATER HYACINTH FOR REMOVAL OF ORGANIC AND INORGANIC POLLUTANTS FROM INDUSTRIAL WASTEWATER

PAVITHRA A/P ENGITARAVANAN

Thesis submitted in fulfilment of the requirements
for the award of the degree in
Bachelors of Civil Engineering

Faculty of Civil Engineering & Earth Resources
UNIVERSITI MALAYSIA PAHANG

JANUARY 2019

DEDICATION

I would like to dedicate my gratitude to the almighty, parents, siblings, supervisor and my fellow friends for the encouragement given throughout the completion of this research project.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Dr Mir Sujaul Islam for his continuous support, guidance, critics, immerse knowledge and patience throughout this journey of this thesis. Without his guidance, it would have certainly difficult and impossible to complete my thesis in such progress. Besides, I am indebted to the panels of my undergraduate research project for their insightful comments and encouragement which will further enhance my thesis and the quality of the study.

My heartiest appreciation is also extended to my parents, family and friends for their endless motivation and moral support at all circumstances. My heartfelt gratitude is also dedicated to each soul that has contributed both directly and indirectly for the completion of this research study.

ABSTRACT

Water quality deterioration is one of the major concerns in the world. Rapid industrial and commercial developments are causing tremendous pressure on the water resources. Speedy developments in the industrial sector at Gebeng area threaten the water quality of its two rivers and deteriorating the environmental condition of the areas. Phytoremediation can be defined as the efficient use of plants to remove, detoxify or immobilise environmental contaminants in a growth matrix through the natural biological, chemical or physical activities and processes of the plants. The objectives of this research was to identity the level of organic and inorganic pollutant in industrial wastewater for baseline information and to determine the effectiveness of water hyacinth plant to remove the pollutants contains in wastewater. In this study, the tests and experiments was held in the field level for in-situ data and in the Environmental Laboratory of Universiti Malaysia Pahang for ex-situ data. The wastewater was collected from the study area and was analysed to collect the water quality data. The industrial wastewater which has been collected was poured into the three different containers. All the three containers was treated with water hyacinth with different percentage of wastewater sample. The experiment was carried out for one month duration with average of 3 measurements for each percentage. The parameters that was tested are pH, DO, temperature, turbidity, BOD, COD, TSS, Ammoniacal Nitrogen, Chromium, Copper and Lead. The highest removal efficiency of BOD, COD, TSS, Ammoniacal Nitrogen, Turbidity, Chromium, Copper and Lead was 73.3%, 82.1%, 70.8%, 66.4%, 67.8%, 68.9%, 67.1% and 65.9%. So, 100 % sample with water hyacinth is more efficient compare to 70% sample with water hyacinth and 50% sample with water hyacinth on removing organic and inorganic pollutants in industrial wastewater. Hence, the results proved that phytoremediation using water hyacinth plant is suitable and effective to treat industrial wastewater.

ABSTRAK

Kemerosotan kualiti air adalah salah satu daripada kebimbangan utama di dunia. Perkembangan industri yang pesat adalah salah satu punca kemerosotan kualiti air yang kerap berlaku di Malaysia. Perkembangan yang pesat dalam sektor industri di Gebeng mengancam kualiti air sungai dan keadaan alam sekitar di kawasan tersebut. Fitoremediasi merupakan salah satu cara yang sesuai untuk menangani masalah pencemaran air. Teknologi ini menggunakan tumbuhan untuk menyerap bahan tercemar yang terdapat dalam air yang tercemar. *Water hyacinth* digunakan untuk merawat sampel air yang tercemar dari Gebeng. Objektif kajian ini adalah untuk mengenal pasti tahap pencemaran organik dan bukan organik di dalam air sisa industri sebagai maklumat asas dan untuk menentukan keberkesanan tumbuhan *Water hyacinth* untuk membuang bahan cemar yang terkandung di dalam air sisa. Dalam kajian ini, ujian dan eksperimen telah diadakan di kawasan kajian bagi data in-situ dan di Makmal Alam Sekitar, Universiti Malaysia Pahang untuk data ex-situ. Air sisa dan air suling dikumpulkan dari kawasan kajian dan dianalisis untuk mendapatkan data kualiti air. Air sisa perindustrian yang telah dikumpulkan telah dicurahkan ke dalam tiga bekas yang berbeza. Kesemua tiga bekas dicampur dengan air suling mengikut peratus yang berbeza. Eksperimen telah dijalankan selama sebulan tempoh dengan purata tiga ukuran bagi setiap peratus air sampel. Parameter yang telah diuji adalah *pH, DO*, suhu, kekeruhan, *BOD, COD, TSS, Ammoniacal Nitrogen, Chromium, Copper* dan *Lead*. Kecekapan penyingkiran tertinggi *BOD, COD, TSS, Ammoniacal Nitrogen,* kekeruhan, *Chromium, Copper* dan *Lead* adalah 73.3%, 82.1%, 70.8%, 66.4%, 67.8%, 68.9%, 67.1% and 65.9%. Jadi, 100% sampel dengan *water hyacinth* adalah lebih berkesan berbanding dengan 70% sampel dengan *water hyacinth* dan sampel 50% dengan *water hyacinth* untuk mengurangkan bahan pencemar organik dan bukan organik di dalam air sisa industri. Oleh itu, keputusan daripada eksperimen membuktikan bahawa Fitoremediasi menggunakan tumbuhan *water hyacinth* adalah sesuai dan berkesan untuk merawat air sisa industri.

TABLE OF CONTENT

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
TSS	Total Suspended Solid
Cr	Chromium
Cu	Copper
Pb	Lead
RE	Removal Efficiency
WH1	100% sample water with water hyacinth
WH2	70% sample water with water hyacinth
WH3	50% sample water with water hyacinth

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Water is one of the important needs in human living. The sources are consisting of surface water and groundwater. In natural aquatic ecosystem metals occur in low concentrations normally at the Nano gram to microgram per litre level. In recent time, however the occurrence of metals in excess of natural loads have become a problem of increasing concern. This situation thus arises as a result of the rapid growth in population, increased urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern environmental regulation. The concentrations of heavy metals in water may vary considerably depending an annual and seasonal fluctuation. At low levels, some heavy metals such as copper, zinc and iron are essential for enzymatic activities and many biological processes while other metals such as cadmium, mercury and lead have no known essential role in living organisms and are toxic at even low concentrations.

As Malaysia is fast becoming an industrial country, many of the rivers have become polluted due to the many wastes that have been poured out into the rivers (Afroz et al., 2014). Gebeng one of the industrial clusters in Pahang, Malaysia consists of a large number of petrochemicals, chemicals, metal builders, polymer and other industries. Petrochemical factories produces large amount of wastewater daily. The township is mixed development which comprises commercial and residential unit, boasting of wide range of amenities and facilities. The untreated wastewater consists of heavy metals and other contaminants are being discharged into water system in Gebeng which caused the ecosystem to degrade at fast rate. The extinction of species happens due to unbalanced ecology and toxic which causes economic loss. Industrial wastewater can be determined as the water effluents from industrial sources that may contain hundreds to thousands of chemicals, but only a few are responsible for aquatic toxicity (Loan et al., 2014).

This study focused on the technology that being applied in order to treat the water pollution problem which is caused by the industrial wastewater. There are many methods in order to treat the industrial wastewater depending on the suitability, one of them is phytoremediation. The phytoremediation of metals is a cost-effective green technology based on the use of metal-accumulating plants to remove toxic metals, including radionuclide, from soil and water. Phytoremediation takes advantage of the fact that a living plant can be considered a solar-driven pump, which can extract and concentrate particular elements from the environment. This phytoremediation technology is suitable to be applied in treating the industrial wastewater since it is the emerging clean up technology for contaminated soils, groundwater and wastewater that is both low-tech and low cost.

Phytoremediation is employed to describe the uptake mechanism of both organic and inorganic contaminants. For organic contaminants, it involves phytostabilization, rhizodegradation, rhizofilteration, phytodegradation and phytovolatilization. These mechanisms are related to organic contaminant property are not able to be absorbed into plant tissue and for inorganic, mechanism which can be involved are phytostabilization, rhizofiltration, phytoaccumulation and phytovolatilization. Phytodegradation occurs when metabolic processes with the plant breakdown the organic chemical while phytoaccumulation occurs when typically inorganic compounds are absorbed into the plants system (Taiwo et al., 2015). Among the different remediation techniques, phytoremediation has been proven to have the most effective approach to alleviate the environmental problems associated with contamination. It is eco –friendly, cost effective, not harmful, and not expensive and it allows the treatment of the impacted water without any interruption.

1.2 PROBLEM STATEMENT

Water quality deterioration is one of the major concerns of the world. Rapid industrial and commercial developments are causing tremendous pressure on the water resources. Speedy developments in the industrial sector at Gebeng threaten the water quality of its two rivers and deteriorating the environmental condition of the areas. The random discharge of wastewater and effluents from industries, sewerage treatment plants along the river catchments are impairing the water quality. The Gebeng area is situated in the neck of the South China Sea and the adjacent two rivers flows fall to the sea. The typical tides of the sea cause intrusion of seawater into these two rivers and the water levels usually rise from 0.5 m to 2.5 m and it is likely to be tidal up to 10 km upstream. As a result the industrial effluents that are dumped from the industrial estate can go upward and cause environmental pollution all over the area (Moyo et al., 2013).

Environmental degradation has started here since the inception of the industrialisation in early 1970's when the deforestation and reclaiming was started using fill, quarried from the nearby hilly areas. Due to deforestation and reclamation, the soil of the area has also been contaminated. The process of contamination has been accelerated with the discharge of industrial effluents. Moreover, contamination of soil is a common problem in the surrounding area of any industrial estate like Gebeng. The water pollution and contaminated soil can hamper the regular livelihood of the residential area. By using the polluted water may create various water born disease and other disasters. Therefore, it is essential to assess the water quality, find out the sources of pollution and the water quality trend that can generate important information for the authority concerned or policy makers to take proper action for better management.

Phytoremediation can be defined as the efficient use of plants to remove, detoxify or immobilise environmental contaminants in a growth matrix through the natural biological, chemical or physical activities and processes of the plants. Plants are unique organisms equipped with remarkable metabolic and absorption capabilities, as well as transport systems that can take up nutrients or contaminants selectively from the growth matrix, soil or water. Phytoremediation involves growing plants in a contaminated matrix, for a required growth period, to remove contaminants from the matrix, or facilitate immobilisation or degradation of the pollutants. The plants can be subsequently harvested, processed and disposed.

Plants have evolved a great diversity of genetic adaptations to handle the accumulated pollutants that occur in the environment. Growing and, in some cases, harvesting plants on a contaminated site as a remediation method is a passive technique that can be used to clean up sites with shallow, low to moderate levels of contamination. Phytoremediation can be used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons, and landfill leachates. It can also be used for river basin management through the hydraulic control of contaminants. Phytoremediation has been studied extensively in research and small-scale demonstrations, but full scale applications are currently limited to a small number of projects. Further research and development will lead to wider acceptance and use of phytoremediation. There are several ways in which plants are used to clean up, or remediate, contaminated sites. To remove pollutants from soil, sediment and water, plants can break down, or degrade, organic pollutants or contain and stabilise metal contaminants by acting as filters or traps.

The uptake of contaminants in plants occurs primarily through the root system, in which the principal mechanisms for preventing contaminant toxicity are found. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth, as well as other non-essential contaminants. Researchers are finding that the use of trees is effective in treating deeper contamination because tree roots penetrate more deeply into the ground. In addition, deep-lying contaminated ground water can be treated by pumping the water out of the ground and using plants to treat the contamination.

Plant roots also cause changes at the soil-root interface as they release inorganic and organic compounds in the rhizosphere. These root exudates affect the number and activity of the microorganisms, the aggregation and stability of the soil particles around the root, and the availability of the contaminants. Root exudates, by themselves can increase or decrease directly or indirectly the availability of the contaminants in the root zone of the plant through changes in soil characteristics, release of organic substances, changes in chemical composition, and/or increase in plant-assisted microbial activity. Phytoremediation is an alternative or complimentary technology that can be used along with or, in some cases in place of mechanical conventional clean-up technologies that often require high capital inputs and are labour and energy intensive. Phytoremediation is an in situ remediation technology that utilises the inherent abilities of living plants. It is also an ecologically friendly, solar-energy driven clean-up technology, based on the concept of using nature to cleanse nature.

1.3 OBJECTIVES OF STUDY

The objectives of this research are listed below:

i. To identity the level of organic and inorganic pollutant in industrial wastewater for baseline information.

ii. To determine the effectiveness of water hyacinth plant to remove the pollutants contains in wastewater.

1.4 SIGNIFICANCE OF STUDY

Rapid development in industrial sector in Malaysia has caused serious environmental problems including water pollution in the country. The Gebeng industrial area is one of the largest industrial estates in Malaysia. Wastewater from this estate is usually pumped out into two rivers, namely Sungai Tunggak and Sungai Balok. Water quality is seriously deteriorated here. Despite the declining process, any in-depth study on industrial pollution at Gebeng as well as in east-coast of peninsular Malaysia was never been done; neither the study of water quality nor on the soil contamination. Prior to this study, a very limited effort and information have been produced regarding treatment of the wastewater of the area. At present the Department of Environment (DOE) is monitoring the Tunggak river water in the downstream region. Those efforts have produced some information but could not indicate the real scenario.

This study gives emphasis on the present status of industrial pollution especially the river water quality of Sungai Tunggak and contamination of the soil of the catchment area using wastewater treatment. The findings of the study will help to adopt adequate measures by the policy makers as well as the environmentalists to prevent further deterioration of the water quality and improve the land use pattern in the Gebeng Industrial Areas. The result of this study can be used as baseline information on river water quality of Sungai Tunggak and can also be used as reference for further research. This study emphasize on phytoremediation technology is suitable to be applied in treating the industrial wastewater since it is the emerging clean up technology for contaminated soils, groundwater and wastewater that is both low-tech and low cost. The aquatic macrophyte called water hyacinth (*Eichhornia crassipes*) is not new in the ecological history of man.

1.5 SCOPE OF STUDY

In this study, the tests and experiments will be held in the field level for *in-situ* data and in the Environmental Laboratory, and Central Laboratory of Universiti Malaysia Pahang. The wastewater and water hyacinth will be collected from the study area and those will be analysed to collect the water quality data. Physicochemical parameters will be analysed in Environmental laboratory and heavy metals will be determined in the Central laboratory. In addition, for the wastewater treatments by water hyacinth (*Eichhornia crassipes*), the outside of environment laboratory will be used. The collected and measured data will be analysed to fulfil the above mentioned objectives. The study will create a database of effectiveness of phytoremediation plant to remove organic and inorganic pollutants contains in wastewater. In addition, to achieve the objectives, wastewater parameters were determined and comparisons were made with standard level.

Moreover, by introducing bio-friendly treatment procedures, less time and comparatively better efficiency were achieved. Besides that, statistical analysis and different techniques were used to find out the sources of pollution. The present study was also involved a comparative study of pollutants including metals pollutants in the wastewater. The research findings and data could act as the base line information for further research and help in the industrial management of nation.

1.6 OUTLINE OF THESIS

This thesis consists of 3 chapters. The first chapter comprises problem statements, objectives, significance and scope of study. The second chapter includes the literature review on industrial wastewater and treatments of wastewater by water hyacinth (*Eichhornia crassipes*). The third chapter describes the materials and methods, studied area and sampling stations. This includes also the sampling frequency, instrument, parameters, water quality index and wastewater treatment techniques

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Water is the natural resources that almost cover 70% off the earths. Water is the most important role in the development community because without water, life maybe not exist in the universe. Water pollution and eutrophication of lakes, rivers, and oceans has been caused by the increased influx of wastewater due to rapid economic, industrial, and agricultural development without construction of appropriate water infrastructure and treatment facilities (Baird and Cann, 2012). Water pollution is a particularly severe problem in developing countries and adequate water quality monitoring is required to understand and manage the water quality. In the 1990s and 2000s, almost 60% of the major rivers were regulated for domestic, agricultural, and industrial purposes, due to water quality degradation by the wastewater from housing, industrial, and business areas.

Once the water is used, wastewater is produced. Wastewater is called as a sewage. Sewage is defined as the effluent from the residential, commercial, institutional and industry. Sewage also has the potential to cause the disease and pollution of the environment. The population of the world has been increasing rapidly and to cope up with this a huge amount of food, energy and employments are required. Industrialization is the easiest way to meet up those demands. Nevertheless, the disposal of industrial wastewater is a great problem throughout the world. It may contain heavy metals as well as other pollutants (Abramov et al., 2014). The dumping of wastewater from the industry could destroy the sustainable industrial approach (Changhao and Zhans, 2013).

Gebeng is a rapidly growing industrial area in Malaysia that has been reported the biggest sources of water pollution due to food and beverage, chemical, textiles, paper, palm oil and rubber processing industries. Such rapid development of industries however has increased the pollution level in surrounding water sheds. Because, most of the wastewater released from the industries contains contaminants and dumped into the surface water (Sujaul et al., 2013). The wastewater of Gebeng industrial estate contains pollutants, higher BOD, COD, TSS and heavy metals (Syukor et al., 2013). Considering the above mentioned problems the present work was undertaken to detect the pollution level and the condition of the water of the study area.

Phytoremediation is solar driven and it works with metals, chemical and petrochemical industries within peninsula's east coast states with solutions to manage schedule waste approved by the Department of Environment. Besides that, the government is responsible for ensuring the state standards for water quality and wastewater treatment are met consistently to ensure the public health and environment. The government should put some efforts on controlling the wastewater pollution. It is important to make an assessment of quality for the best use of water resources distribution and utilisation. It becomes necessary to have an idea of the present and future demand of water for various use.

2.2 CAUSES OF WATER POLLUTION

Industrial water pollution is caused by the discharge of harmful chemicals and compounds into water, which makes it unsuitable for drinking and other purposes. Although 70% of the Earth is covered by water, only water bodies like lakes, ponds, rivers, reservoirs, and streams provide us with fresh water, and so, keeping them clean is an issue of survival not only for humans but for all other forms of life.

Since the industrial revolution, we have achieved a lot; our manufacturing processes have become more efficient and productive, science has become much more advanced, and our life has transformed a great deal. But perhaps nothing comes without a price. All the advancement and development witnessed in the last few centuries have also brought with them a wide spectrum of problems, water pollution being one of them.

Pollution refers to the contamination of the environment by harmful and waste materials, which bring about a significant change in the quality of the surrounding atmosphere. Environmental pollution can be classified as air pollution, water pollution, and noise pollution. Water pollution signifies contamination of water bodies, which makes their water unfit for drinking and other purposes. There are basically five primary sources of water pollution are domestic sewage, agricultural runoff, industrial effluents, wastewater from septic tanks, and storm water runoff.

2.2.1 Point Source

A point source is a single, identifiable source of pollution such as a pipe or a drain. Industrial wastes are commonly discharged to rivers and the sea in this way. High risk point source waste discharges are regulated by EPA through the works approval and licensing system, and associated compliance and enforcement activities.

EPA’s regulation of point source waste discharges has been important in improving the quality of water environment over the past 40 years. No longer do we have raw sewage and abattoir waste continually flowing in our rivers as per the 1970s. Point sources release pollutants from discrete conveyances, such as a discharge pipe, and are regulated by federal and state agencies. The main point source dischargers are factories and sewage treatment plants, which release treated wastewater (EPA, 2012).

2.2.2 Non-point source

Non-point sources of pollution are often termed ‘diffuse’ pollution and refer to those inputs and impacts which occur over a wide area and are not easily attributed to a single source. They are often associated with particular land uses, as opposed to individual point source discharges. Nonpoint source pollution is a combination of pollutants from a large area rather than from specific identifiable sources such as discharge pipes. Runoff is generally associated with nonpoint source pollution, as water is emptied into streams or rivers after accumulating contaminants from sources like gardens, parking lots or construction sites.

2.2.2.1 Urban land use

In our urban areas rainfall run-off as storm water is one of the major nonpoint sources of pollution impacting the water quality of our water way. Storm water from street surfaces is often contaminated with car oil, dust and the faeces of animals and soil and sediment run-off from construction sites, and in industrial areas often contains more toxicants and chemicals. In some outer-urban and urban fringe areas, a reticulated sewerage system is not available so sewage is discharged to onsite wastewater systems and septic tanks. Seepage and surface run-off of septic tank effluents may also be forms of non-point source pollution of streams in these areas.

2.2.2.2 Agriculture land use

In farming areas non-point sources of pollution include pesticides, fertilisers, animal manure and soil washed into streams in rainfall run-off. Where stock are given access to stream banks they may foul the water and accelerate erosion. Pollutants that come from pesticides are used regularly in order to keep crops healthy and free from insects and other pests. Although there are many natural ways to do this that don't involve the use of harsh chemicals, these are often more expensive and many companies won't entertain the idea. Fertilizers are also used to help crops grow. However, practices aren't very healthy in terms of using and disposing of fertilizers.

2.2.2.3 Forestry land use

Forestry operations may contribute to non-point source pollution of streams by increasing soil erosion and sediment run-off. Non-point source pollution is often more difficult to control than point source pollution. In urban areas the provision of reticulated sewerage systems and adequate street cleaning are important measures, while in farming and forestry areas, soil conservation practices and the controlled application of pesticides and fertilisers are necessary if pollution of waterways is to be avoided.

2.3 INDUSTRIAL WASTEWATER QUALITY STUDIES

2.3.1 Temperature

The physical and chemical properties of wastewater changes with the temperature changes. Temperature of water is varied with the time of the day, depth of the water and also with the climatic condition. When the wastewater discharge to water stream, the water temperature will increases. Thus it reduce amount of dissolved oxygen that present it water. It is reported by decomposition of organic matter of effluents, the water temperature increases. Surface water is subjected to the effect of ambient temperatures and can be very warm during summer. But the temperature of wastewater is commonly higher than the water supply because of the addition of warm water from domestic and industrial use.

Water temperature is a physical property expressing how hot or cold water is. As hot and cold are both arbitrary terms, temperature can further be defined as a measurement of the average thermal energy of a substance. Thermal energy is the kinetic energy of atoms and molecules, so temperature in turn measures the average kinetic energy of the atoms and molecules. This energy can be transferred between substances as the flow of heat. Heat transfer, whether from the air, sunlight, another water source or thermal pollution can change the temperature of water (Fondriest Environmental, 2014).

Temperature is an important factor to consider when assessing water quality. In addition to its own effects, temperature influences several other parameters and can alter the physical and chemical properties of water. In this regard, water temperature should be accounted for when determining:

i. Compound toxicity

ii. Dissolved oxygen and other dissolved gas concentrations

iii. Conductivity and salinity

iv. pH

v. Water density

2.3.2 pH

pH is the parameter to measure the acidity and alkalinity of water. The pH 7.0 is neutral, while pH less than 7.0 is alkaline. The availability and toxicity of nutrients is largely dependent on the pH ranges. The presence of higher level of nutrients enhance the growth of algae which ultimately increase pH. The concentration range suitable for the existence of most biological life is relatively narrow, typically between pH 6 to 9.

Wastewater with an extreme concentration of hydrogen ion is difficult to treat by biological. The pH 1.70 to 11.80 was measured from the effluent of a metal finishing Nigerian company (Adakole and Abolude, 2009). As the pH decreases, water becomes more acidic. As water becomes more basic, the pH increases:

i. Many chemical reactions inside aquatic organisms that are necessary for survival and growth of organisms require a narrow pH range.

ii. At the extreme ends of the pH scale, (2 or 13) physical damage to gills, exoskeleton, fins, occurs.

iii. Changes in pH may alter the concentrations of other substances in water to a more toxic form. Examples: a decrease in pH (below 6) may increase the amount of mercury soluble in water. An increase in pH (above 8.5) enhances the conversion of nontoxic ammonia (ammonium ion) to a toxic form of ammonia (un-ionized ammonia).

2.3.3 Dissolved Oxygen (DO)

Dissolved oxygen is the term for atmospheric oxygen that becomes mixed in water and occurs between the water molecules. The presence of oxygen in water is good. Dissolved oxygen is necessary for healthy lakes and rivers. Fish, invertebrates, plants and aerobic bacteria all require oxygen for respiration. Fish will drown in water when the dissolved oxygen levels get too low. The absence of dissolved oxygen in water is a sign of possible pollution. Most dissolved oxygen gets into water from contact with the atmosphere. Waves on lakes and slow moving rivers, water tumbling over riffles or waterfalls on fast moving rivers mixes oxygen into the water. Anything that increases the surface contact of water and the atmosphere will increase oxygen in the water. Plants and algae also add oxygen to the water through photosynthesis. Climate can affect oxygen levels in other ways. During dry seasons water levels decrease and the flow rate or discharge of a river is lower. As the water moves slower, it mixes less with the air and the dissolved oxygen level goes down. During rainy season oxygen levels tends to be higher. When dissolved oxygen levels get lower, they can cause major changes in the types and amounts of aquatic organisms found living in the water. Adakole and Abolude (2009) made a study on effluent characteristics of metal finishing company, Zaria at Nigeria and observed DO level 0.03 to 7.00 mg/L.

2.3.4 Biochemical Oxygen Demand (BOD)

The BOD is the amount of oxygen consumed in the decomposition of organic matter. BOD is an important water quality parameter because it provides an index to assess the effect discharged wastewater will have on the receiving environment. The higher the BOD value, the greater the amount of organic matter or “food” available for oxygen consuming bacteria. If the rate of DO consumption by bacteria exceeds the supply of DO from aquatic plants, algae photosynthesis or diffusing from air, unfavourable conditions occur. Depletion of DO causes stress on aquatic organisms, making the environment unsuitable for life. Further, dramatic depletion can lead to hypoxia or anoxic environments. BOD is also used extensively for wastewater treatment, as decomposition of organic waste by microorganisms is commonly used for treatment.

The BOD test is a standardised test that provides information regarding the organic strength of wastewater. Besides that, BOD also is common test used in field of wastewater treatment. The amount of oxygen consumed in a sample within five-day period measured under controlled and standardized condition. The results of BOD tests are not only used to measure efficiency of some treatment facilities, but it also used to determine compliance with wastewater discharge permits. Adakole and Abolude (2009) made a study on effluent characteristics of a metal company, Zaria, Nigeria and found that BOD is 1.22 to 12.40 mg/L. Regulations for BOD will vary by country and region. In general, maximum allowable concentration for direct environmental wastewater discharge fall around 10 mg/L BOD and maximum allowable concentrations for discharge to sewer systems around 300 mg/L BOD.

2.3.5 Chemical Oxygen Demand (COD)

COD is the demand of oxygen for the oxidation of total organic matter. COD proportion increases with the contamination level of wastewater. The COD values are always higher than BOD values. Potassium dichromate has been found to be excellent oxidant in an acidic medium. In some types of wastes, a high degree of correlation curve may be established between COD and BOD test takes about 2.5 hours compared to BOD test. A COD test measures all organic carbon with the exception of certain aromatics which are not completely oxidized in the reaction. COD is a chemically chelated/thermal oxidation reaction, and therefore, other reduced substances such as sulfides, sulfites, and ferrous iron will also be oxidized and reported as COD.

The use of COD results for wastewater compliance monitoring is increasing is to measure oxygen demand, biochemical oxygen demand (BOD) relies on bacteria to oxidize readily available organic matter during a five-day incubation period. COD uses strong chemicals to oxidize organic matter. Generally, COD is preferred to BOD for process control measurements because results are more reproducible and are available in just two hours rather than five days. For industrial samples, COD may be the only feasible test because of the presence of bacterial inhibitors or other chemical interferences, which would interfere with a BOD determination. COD testing also gives the fast measurements required in many treatment systems for informed decisions regarding process control adjustments.

2.3.6 Total Suspended Solids (TSS)

TSS are solids in water that can be trapped by a filter which includes a wide variety of materials, such as silt, decaying plant and animal matter, industrial wastes and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. Total Suspended Solids are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further because warmer waters can hold less DO, and can harm aquatic life in many other ways.

The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water. In the water, the pollutants may be released from the sediment or travel farther downstream. High TSS can cause problems for industrial use, because the solids may clog or scour pipes and machinery. Adakole and Abolude (2009) conducted a study on effluent characteristics of a metal industries, Zaria, Nigeria ad observed TSS 180 to 740 mg/L.

2.3.7 Ammoniacal Nitrogen

The nitrogen is an essential nutrient for plant growth. The higher concentrations of ammoniacal nitrogen accelerate algal and weed growth as well as cause eutrophication. Total nitrogen is comprised of ammonia, nitrite, nitrate and organic nitrogen. Ammonia-nitrogen (NH) is a constituent in raw domestic wastewater. Through the biological nitrification process, ammonia (NH) is oxidized to nitrite, and nitrate by aerobic autotrophic bacteria. Ammonia-nitrogen (NH) is a constituent in raw domestic wastewater. However, the degradation of the organic matter in the biological treatment stage also produce substantial amount of ammonia compounds. Through the biological nitrification process, ammonia (NH) is oxidized to nitrite and nitrate by aerobic autotrophic bacteria. The final output of nitrification process, which is nitrate could be reduced to nitrogen gas through de-nitrification process under anoxic condition.

Nitrification can be achieved in any aerobic-biological process at low organic loadings and where suitable environmental conditions are provided. Nitrifying bacteria are slower growing than the heterotrophic bacteria, which comprises the greater proportion of the biomass in both fixed film and suspended growth systems. The key requirement for nitrification to occur, therefore, is that the process should be so controlled that the net rate of accumulation of biomass, and hence, the net rate of withdrawal of biomass from the system, is less than the growth rate of the nitrifying bacteria. These bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Nitrates may vary in concentrations from 0 to 20 mg/L as N in wastewater effluents.

2.3.8 Heavy Metals

Metal enrichments contribute from industrials effluents, mining activities, urban waste and sewerage treatment plant. The most risky heavy metals is copper and lead because they are accumulated in aquatic ecology and consumed by humans. Heavy metals are regarded as severe pollutants due to their toxicity, persistent and bioaccumulation problem. Cadmium, Cd if highly toxic which is toxic even at very low concentrations. It has lethal and chronic effects on lives and non-degradable. Adakole and Abolude (2009) made a study on effluents characteristics of a metal company, Zaria, Nigeria and found that the Cd concentration is 0.007 to 0.019 mg/L.

Copper, Cu is a very good conductor of heat. The higher content of copper causes anemia, liver failure, kidney failure and intestinal diseases. Adakole and Abolude (2009) made a study on effluents characteristics of a metal company, Zaria, Nigeria and found that the Cu is 5.86 to 12.62 ppm. Nickel, Ni is originated from laterite, pentlandite and pyrhotite. It is good conductor of heat and electricity. The excessive contact of nickel causes kidney failure and even cancer. Adakole and Abolude (2009) made a study on effluents characteristics of a metal company, Zaria, Nigeria and found that the Ni is 11.40 to 12.40 ppm. Lead, Pb have high density, softness, ductility, malleability, poor electrical conductivity compared to other metals. Study has found that wastewater from metal melting, metal products and metal finishing can cause lead pollution.

2.4 WASTEWATER TREATMENT

Bacteria are playing a vital role in removing heavy metal as well as contaminants from wastewater. Firstly, the industrial wastewater treatment at Gebeng started by using water hyacinth, water lettuce and giant salvinia. Syukor et al., 2013 conducted an experiment on petrochemical wastewater of Gebeng by some plants in 2013. Gebeng is a rapidly growing industrial area in Malaysia that has been reported the biggest sources of water pollution due to food and beverage, chemical, textiles, paper, palm oil and rubber processing industries. Such rapid development of industries however has increased the pollution level in surrounding water sheds. Because, most of the wastewater released from the industries contains contaminants and dumped into the surface water (Sujaul et al., 2013). The wastewater of Gebeng industrial estate contains pollutants, viz. higher BOD, COD, TSS and heavy metals (Syukor et al., 2013). Considering the above mentioned problems the present work was undertaken to detect the pollution level and the condition of the water of the study area.

Wastewater treatment is the process of converting wastewater that is no longer needed or is no longer suitable for use which bilge water that can be discharged back into the environment. It's formed by a number of activities including bathing, washing, using the toilet, and rainwater runoff. Wastewater is full of contaminants including bacteria, chemicals and other toxins. Its treatment aims at reducing the contaminants to acceptable levels to make the water safe for discharge back into the environment.

There are three wastewater treatment plants namely chemical or physical treatment plant, and biological wastewater treatment plant. Biological waste water treatment plants use biological matter and bacteria to break down waste matter. Physical waste treatment plants use chemical reactions as well as physical processes to treat wastewater. Biological treatment systems are ideal for treating wastewater from households and business premises. Physical wastewater treatment plants are mostly used to treat wastewater from industries, factories and manufacturing firms. This is because most of the wastewater from these industries contains chemicals and other toxins that can largely harm the environment.

2.4.1 Wastewater treatment by Lemna Minor

In the field of ecotoxicology, Lemna minor has been used for the removal of heavy metals from wastewater and constructed wetlands. These species present the additional advantage of growing under varied climatic conditions with rapid growth rates. Because duckweed is easily raised even in the laboratory, the possible culturing for use as animal feed and for human consumption was also studied. Lemna minor are worldwide distributed in freshwater to brackish estuaries. These are free- floating, easy to culture in laboratory and are convenient plant materials for eco toxicological investigations. In particular, species to investigate heavy model systems to investigate heavy metal induced responses. The accumulation of metals and metalloids in Lemna takes advantage of quality biomass for biosorption on the cell surface and high metabolic mediated incorporation of contaminants into the cells. There are several studies that have shown that most Lemna minor shows an exceptional capability and potential for the uptake and accumulation of heavy metals as well as metalloids, surpassing that of algae and other aquatic macrophytes (Rezania et al., 2015).

There has been a tremendous amount of attention given to the use of biological systems for removal of heavy metals from solutions. More recently, phytoremediation is an emerged as one of the alternative technologies for removing pollutants from the environment. Lemna minor based industrial wastewater treatment systems make realistic solutions to these issues. They are inexpensive to install as well as to operate and maintain, also they do not require imported components. They are functionally simple, yet robust in operation, they can provide tertiary treatment performance equal or superior to conventional wastewater treatment systems now recommended for large scale applications.

2.4.2 Wastewater treatment by Vetiver grass

Vetiver grass a perennial grass, is fast growing grass with a deep root system and high biomass production. Due to its unique morphological characteristics and its tolerance of adverse environmental conditions, it has been used effectively for wastewater treatment. Vetiver grass is not a hydrophyte but it prefers wet and waterlogged habitat where it can grow and develop even though a large portion of its shoots are submerged for relatively long period, normally in water. Many scientists have confirmed that vetiver grass is powerful to remove nitrogen and phosphorus from water and, therefore, is a good plant for purifying eutrophic water.

Vetiver grass is low cost, very effective, rapid growing and deep rooting system as well as it has phytoremediation abilities. Many waste disposal in Thailand and it has been conclude that vetiver grass has a higher capability in absorption of heavy metals. It prevailed from the study on the eflluents from textile mills by Nanda et al., (2011) that vetiver grass can reduce 67.47 % BOD, 46.20 % COD from this experiment.

2.4.3 Wastewater Treatment by water hyacinth

Water hyacinth is a wild fern belonging to the family pontederiaceae found abundantly in various tropical and sub-tropical countries of Latin America and the Caribbean, Africa, Southeast Asia and the Pacific. Generally, the level of reproduction of water hyacinth has been very high in countries where the plant has recently been introduced and this has been attributed, to a large extent, to the eutrophication in water bodies and the absence of natural enemies of the plant. The weed has attracted significant attention as the world's worst invasive aquatic plant due to its extremely rapid proliferation and congests growth. In many places, the weed presents serious challenges in navigation, irrigation, and power generation. The explosive nature of water hyacinth growth and its related problems have called for serious efforts to control its spread. Management strategies have taken a physical, chemical or biological approach (Shahabaldin et al., 2015).

Water hyacinth, among other aquatic macrophytes, has been shown to possess a great potential to remove pollutants when being used as a biological filtration system. It contains many polyfunctional metal-binding sites for both cationic and anionic metal complexes. Potential metal cation-binding sites of algal cell components include carboxyl, amine, imidazole, phosphate, sulphate, sulfhydryl, hydroxyl and chemical functional groups contained in cell proteins and sugars (Mohamad and Latif, 2010). The weed could remove several heavy metals and other pollutants. Recorded achievements triggered efforts directed towards the utilization of water hyacinth in phytoremediation. Therefore, it is imperative to know the level at which water hyacinth *(Eichornia crassipes)* is effective in cleaning up heavy metal in water and determine the highest concentration of heavy metal absorption by the water hyacinth.

Mohamad, H.H. and Latif, P.A (2010) conducted an experiment on the treatment of synthetic effluents by water hyacinth and detected Cd and Zn removal. Mishra, V.K. and Tripathi, B.D (2008) used water hyacinth for the treatment of coal mining effluent and observed 70.5, 69.0, 76.9, 66.4, 65.3 and 55.4 % removal of Fe, Cr2, Cu, Cd, Zn and Ni respectively. The water hyacinth can absorb heavy metals very well. Mokhtar et al., (2011) worked on Lerma River water and reported water hyacinth has large fibrous root system and contact areas which can accumulate heavy metals in large percentage.

2.5 CONCLUSION

In this chapter, the studies of industrial wastewater and its treatment in worldwide context reviewed. The high biochemical oxygen demand, chemical oxygen demand, total suspended solids, dissolved oxygen, pH, turbidity and ammoniacal nitrogen indicates the organic wastes are dumped from the industries. The wastewater treatment by phytoremediation are vital because they are environment friendly, low cost and it is a good and important strategy to improvise the wastewater treatment.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

In this chapter, the location, geography, geology, the climatic conditions of the study area and the methodologies of wastewater, surface water, sediments and water quality index are described. Moreover, it also includes the methodologies of wastewater treatment by phytoremediation. In addition, the selection of monitoring stations, parameters measured, planning of sampling methodology and sampling frequencies, methods of laboratory analysis, statistical analysis, contamination intensity, different procedures, formulas, guidelines to evaluate pollution and kinetics study also discussed.

3.2 RESEARCH FLOW CHART

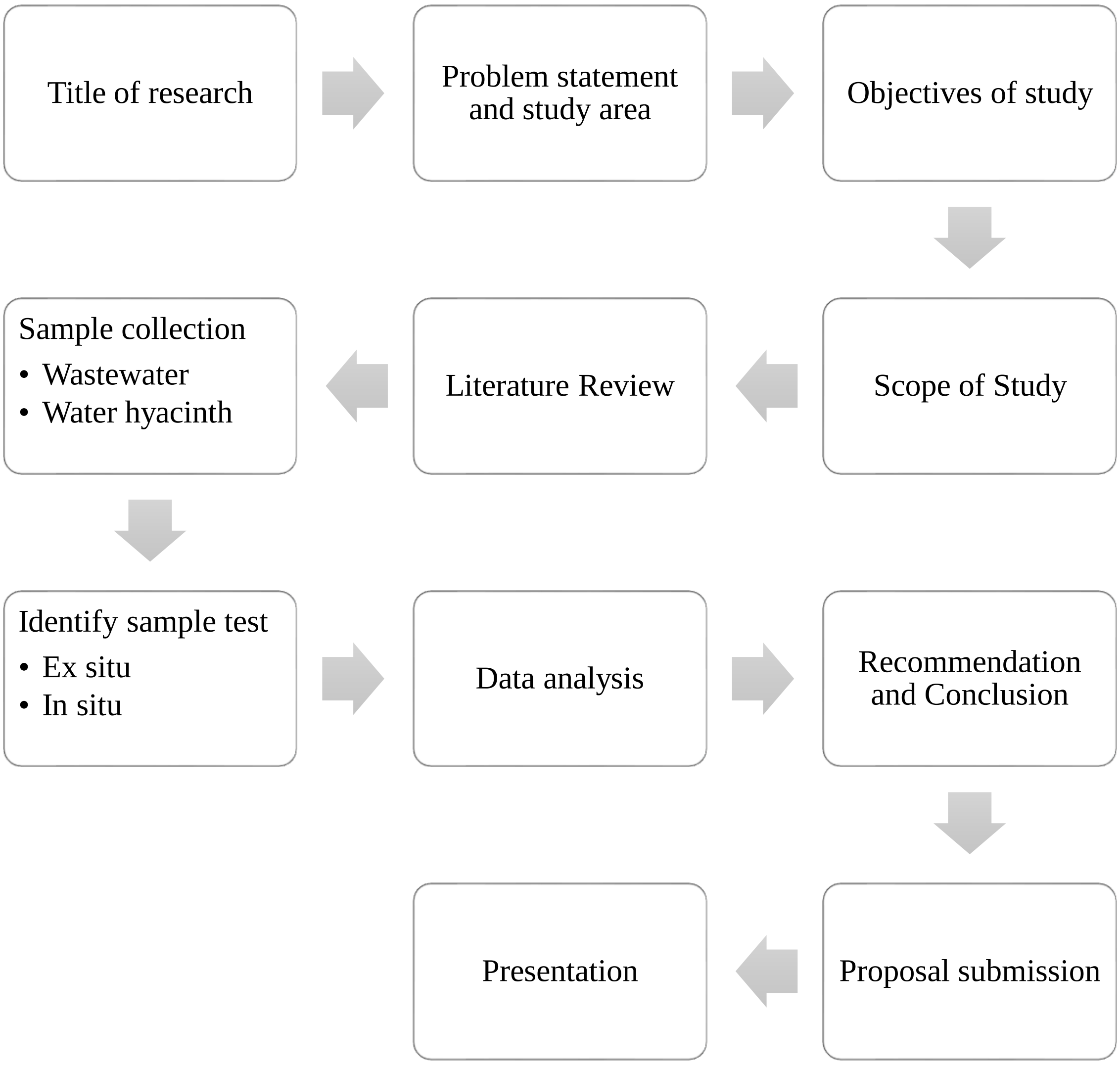

Figure 3.1: Flow of the research

3.3 STUDY AREA

3.3.1 Location and Geography

Gebeng industrial estate is the study area of this research. It is one of the potential industrial areas of Malaysia. The industrial park is situated between the coordinates of 03 º 59 ' 12 " N and 103 º 22 ' 32 " E. Gebeng town is about 20 km far from Kuantan city and near Kuantan port. The two rivers namely Balok and Tunggak are flowing through the industrial area which ended into the South China Sea. It prevailed that before industrialization Gebeng was a green valley included into Paya Tanah Merah forest. Now the forests are very much vulnerable and located in the coastal areas.

Industrial development in Gebeng area has been started since 1970s. Initially the small scale industries like wood processing, metal ducting, concrete ducting, pipe coating facility, detergent were the main industries. But since 1990s the medium and large scale industries started their journey those are petrochemicals, chemicals, metal builders, polymers, metal works factories, steel industries, air products, energy, oil and gas industries. The heavy industries are active in Gebeng area such as Lynas, MTBE-Petronas, Polyplastics Asia Pacific Sdn. Bhd, BP chemicals, Kaneka, Eastman chemicals, Palm oil factories.

3.4 SAMPLING METHODOLOGY

3.4.1 Industrial wastewater collection

The studied industrial wastewater was collected from Gebeng industrial area with coordinates of 3° 59' 16" N and 103° 23' 18" E. The bottles and containers are cleaned and rinsed with distilled water. The samples was collected for BOD using dark bottles. The samples are stored in icebox and transferred to refrigerator with temperature below 4 ^{0}C. pH and dissolved oxygen was determined instantly after the storage.

Figure 3.2: Industrial wastewater was collected for studies

3.4.2 Water hyacinth collection

The water hyacinth was washed thoroughly by distilled water. The samples were kept in distilled water for 14 days in different containers. The containers are placed at suitable area for treatment.

Figure 3.3: Water Hyacinth

3.4.3 Method of treatment

A total 10 L of water was used in each container for the experiment. The composition of the treatment media are shown in table 3.1. The wastewater was diluted to different percentage to see the removal efficiency of the plants.

Table 3.1 Method of treatment

Treatment	**Ratio of Dilution**	**Treatment Period**
100% of sample water (WH1)	10 L of wastewater	$0^{th,}$ 2^{nd} and 4^{th} week
70% of sample water (WH2)	7 L of wastewater + 3 L of distilled water	$0^{th,}$ 2^{nd} and 4^{th} week
50% of sample water (WH3)	5 L of wastewater + 5 L of distilled water	$0^{th,}$ 2^{nd} and 4^{th} week

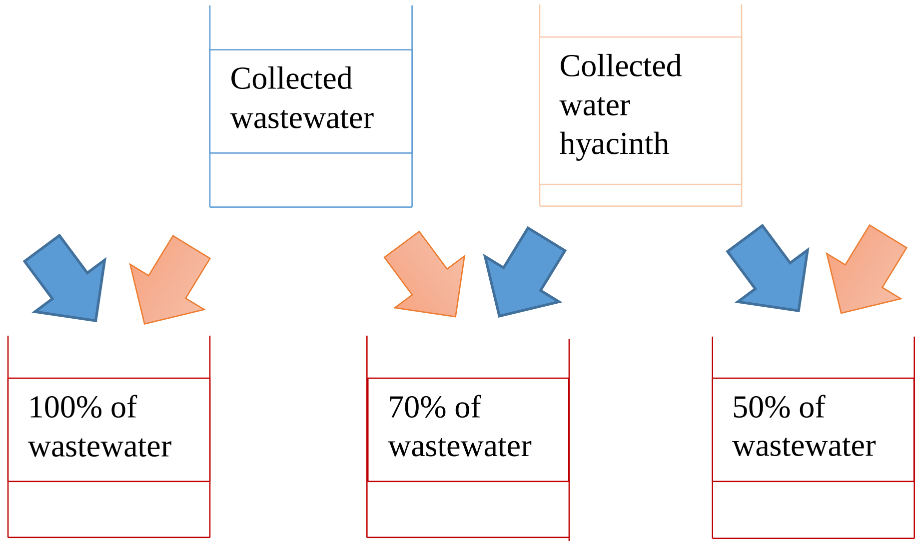

Figure 3.4: Schematic drawing

Figure 3.5: Water hyacinth placed in container with sample for treatment

3.4.4 Method of experiment

3.4.4.1 In situ Method

This method explained as the treatment of the wastewater at the study area. In the study area, all the tanks that been used for this phytoremediation study were located near the Environmental Laboratory of Faculty Civil Engineering and Earth Resources in University Malaysia Pahang. The wastewater for this study took from the industrial activity effluent at industrial area in Gebeng, Kuantan, Pahang. The industrial wastewater that had been collected was poured into the 3 different containers. All 3 containers were treated with water hyacinth with different percentage of wastewater. The experiment was carried out for one month duration with average of 3 measurements for each percentage. The first amount reading were compared to the last readings in order to get the different value. The parameters which was tested using in situ method are shown in table 3.2.

3.4.4.1.1 Dissolved Oxygen (DO)

The initial DO of each dilution was determined and the dilutions was incubated for five days at 20°C. At the end of the incubation period, the final DO of the dilution was obtained and the depletion of each dilution was calculated using below formula:

DO depletion = *Initial DO - Final DO*

Table 3.2: In-Situ Test

Parameter	**Equipment**	**Unit**
pH	YSI 6600 M (Multi-parameter Display System)	-
Temperature	YSI 6600 M (Multi-parameter Display System)	ºC
Dissolved oxygen (DO)	YSI 6600 M (Multi-parameter Display System)	mg/L
Turbidity	HACH,2100P,Turbidimeter	NTU

3.4.4.2 Ex situ method

Ex situ is the experiment done in the laboratory. This method was done two week once to analyse the chemical characteristics of the industrial wastewater based on certain parameters. The parameters are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammoniacal Nitrogen (NH_3-N), heavy metals such as Chromium (Cr), Copper (Cu) and Lead (Pb). In order to analyse and collecting data, 3 samples were taken from the study area. 3 containers was filled with the industrial wastewater and the water hyacinth plant. The experiment was done in the Environmental Laboratory of Faculty Civil Engineering and Earth Resources. Some of the experiment that involved is taken much long time than expected. The parameters are shown in table 3.3.

3.4.4.2.1 Biochemical Oxygen Demand (BOD)

$$BOD_5 = \frac{Di - Df}{P} \tag{3.1}$$

where;

Di is initial dissolved oxygen (DO) of the diluted water sample about 15 minutes after preparation

Df is final dissolved oxygen (DO) of the diluted wastewater sample after incubation for 5 days

P decimal fraction of wastewater sample

3.4.4.2.2 Total Suspended Solids (TSS)

$$\text{mg total suspended solids/L} = \frac{(A-B)\times 1000}{sample\ volume, mL} \tag{3.2}$$

where;

A = weight of filter + dried residue, mg, and

B = weight of filter, mg

Table 3.3: Ex-Situ Test

Parameter	**Method**	**Equipment**	**Unit**
Total Suspended Solid (TSS)	Gravimetric method (method 2540D, APHA, 2005)	Analytical balance. Oven, filter paper, aluminium dishes, suction flask, desiccator	mg/L
Biochemical Oxygen Demand (BOD_5)	Method 5210B (APHA, 2005)	YSI 5100 Dissolved Oxygen Meter	mg/L
Chemical Oxygen Demand (COD)	COD Reactor Digestion Method (HACH Method 8000; Wawelength 380	HACH Direct Reading Spectrophotometer, Model DR 5000	mg/L
Ammoniacal Nitrogen (NH_3-N)	Nessler method (HACH Method 8038; Wawelength 380)	HACH Direct Reading Spectrophotometer, Model DR 5000	mg/L

3.5 REMOVAL EFFICIENCY (R)

$$R = (C_0 - C)/C_0 \times 100\% \qquad (3.3)$$

where;

C_0 is the influent concentration and

C is the effluent concentration

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

Water is the most delicate part of the environment which is essential for human and industrial development. In the last few decades the demand of fresh water rises tremendously due to increasing population and rapid industrialization (Yisa and Jimoh, 2010). Due to the addition of industrial effluents containing organic pollutant and heavy metals into the river water the quality of water is deteriorating. The examples of heavy metals are copper, zinc, cadmium, mercury, lead, arsenic and many other harmful substances. Kumar et al. (2008) worked on the wastewater of Mongolpuri industrial area of Delhi in India and had the opinion that the addition of different chemicals by various industries caused complex to the nature where the COD concentration has been detected higher. The dumping of wastewater from the industry could destroy the sustainable industrial approach. Malaysia has a number of industrial estates all over the country of which Gebeng is one and main industrial area in Kuantan, Pahang. It is located near Kuantan Port. Since 1970s the area is increasing with industrialization. Including petrochemical, multifarious industries are been established in this area. The real scenario is the rapid developments including the petrochemical, metal work, palm oil and steel industries are generating effluents which contain high concentrations of conventional and non-conventional pollutants that deteriorating the water quality of the river. Wastewater from these industries contain pollutants such as high level of BOD, COD, TSS and heavy metals (Arun, 2017). In this chapter we will discuss the results obtained during the experiment.

4.2 RESULTS

4.2.1 Wastewater Characteristics and Parameters

Table 4.1: Characteristics of the 100 % industrial wastewater with water hyacinth (WH1)

PARAMETERS	0^{TH} WEEK	2^{ND} WEEK	4^{TH} WEEK
pH	12.5	7.2	6.1
Temperature, °C	27.4	27.9	27.3
Dissolved Oxygen (DO), mg/l	2.7	8.2	9.87
Turbidity, NTU	24.2	15.2	7.8
Total Suspended Solids (TSS), mg/l	0.096	0.068	0.028
Biochemical Oxygen Demand (BOD), mg/l	15.6	9.02	4.17
Chemical Oxygen Demand (COD), mg/l	201	79	36
Ammoniacal Nitrogen, mg/l NH3-N	4.23	2.83	1.42
Chromium (Cr), mg/l	0.072	0.041	0.025
Copper (Cu), mg/l	0.079	0.049	0.026
Lead (Pb), mg/l	0.082	0.047	0.028

Table 4.2: Characteristics of the 70 % industrial wastewater with water hyacinth (WH2)

PARAMETERS	0^{TH} WEEK	2^{ND} WEEK	4^{TH} WEEK
pH	12.3	6.9	6.05
Temperature, °C	27.2	27.5	26.9
Dissolved Oxygen (DO), mg/l	3.2	8.34	10.01
Turbidity, NTU	22.1	13.2	7.4
Total Suspended Solids (TSS), mg/l	0.094	0.065	0.031
Biochemical Oxygen Demand (BOD), mg/l	13.2	8.53	4.01
Chemical Oxygen Demand (COD), mg/l	179	82	35
Ammoniacal Nitrogen, mg/l NH3-N	3.98	2.62	1.53
Chromium (Cr), mg/l	0.064	0.036	0.023
Copper (Cu), mg/l	0.067	0.038	0.024
Lead (Pb), mg/l	0.079	0.051	0.029

Table 4.3: Characteristics of the 50 % industrial wastewater with water hyacinth (WH3)

PARAMETERS	**0^{TH} WEEK**	**2^{ND} WEEK**	**4^{TH} WEEK**
pH	11.9	6.7	6.01
Temperature, °C	27.1	27.8	27.2
Dissolved Oxygen (DO), mg/l	3.5	8.8	9.98
Turbidity, NTU	20.9	12.7	6.4
Total Suspended Solids (TSS), mg/l	0.091	0.062	0.027
Biochemical Oxygen Demand (BOD), mg/l	12.9	6.45	3.67
Chemical Oxygen Demand (COD), mg/l	162	83	32
Ammoniacal Nitrogen, mg/l NH3-N	3.54	2.32	1.31
Chromium (Cr), mg/l	0.061	0.032	0.019
Copper (Cu), mg/l	0.064	0.034	0.022
Lead (Pb), mg/l	0.073	0.046	0.029

4.3 DISCUSSION

4.3.1 pH

It is well known that pH plays a vital role in the chemistry of water. The pH values measured are shown in the Figure 4.1

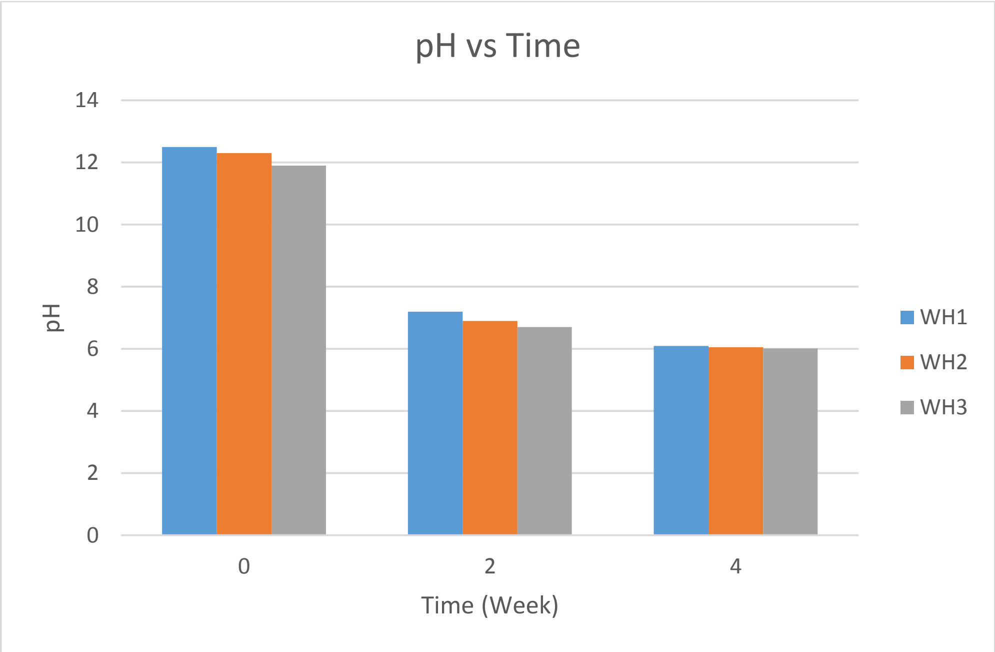

Figure 4.1: Graph pH against time

The pH value of the wastewater sample was recorded 12.5 in WH1, 12.3 in WH2 and 11.9 in WH3 at the beginning of the study. In the second week of the experiment, the pH recorded in sample WH1, WH2, and WH3 are 7.2, 6.9, and 6.7. In the 4^{th} week, pH recorded in sample WH1, WH2, and WH3 are 6.1, 6.05 and 6.01. From the graph above, the samples become less acidic for all the samples at the end of the experiment.

4.3.2 Temperature

The analysed results of temperature of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.2

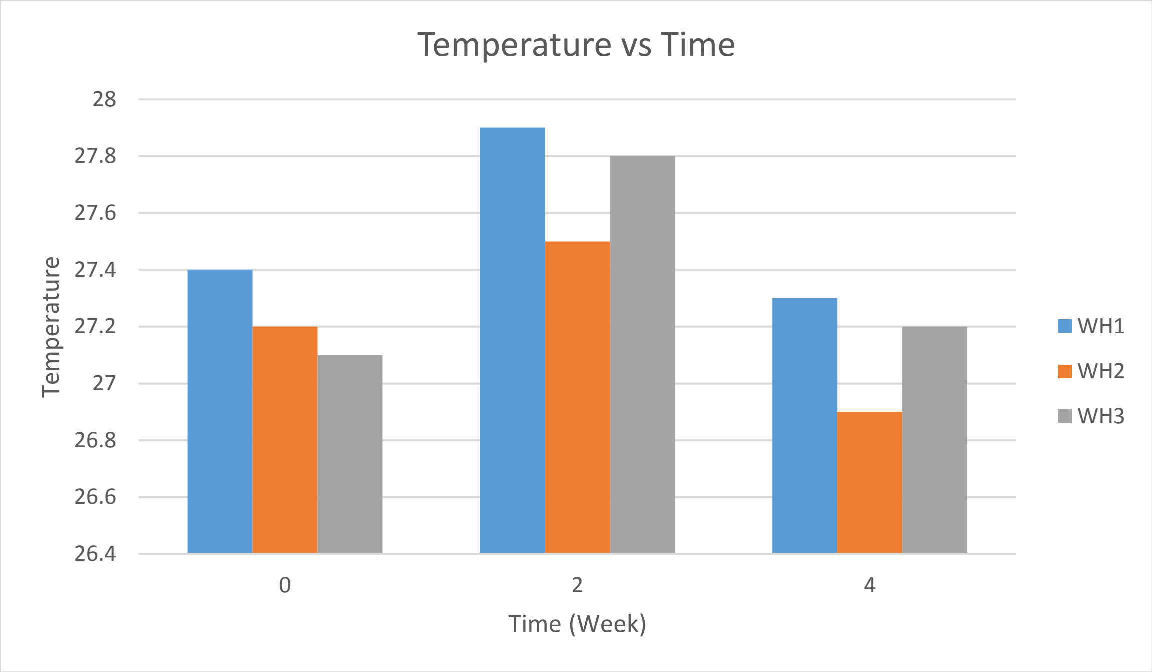

Figure 4.2: Graph temperature against time

The studies industrial wastewater temperature for initial week for WH1, WH2 and WH3 was 27.4°C, 27.2°C and 27.1°C. For the 2nd week results, the temperature increases gradually compared to initial week. The results for WH1, WH2 and WH3 are 27.9°C, 27.5°C and 27.2°C. The temperature for the 4th week decreases from the 2nd week as the results for WH1, WH2 and WH3 are 27.3°C, 26.9°C and 27.2°C. The highest temperature was recorded during the studies was WH1, 27.9°C and the lowest was WH2, 26.9°C. The changes in temperature is caused by the weather condition throughout the experiment has been conducted.

4.3.3 Dissolved Oxygen (DO)

The analysed results of DO of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.3

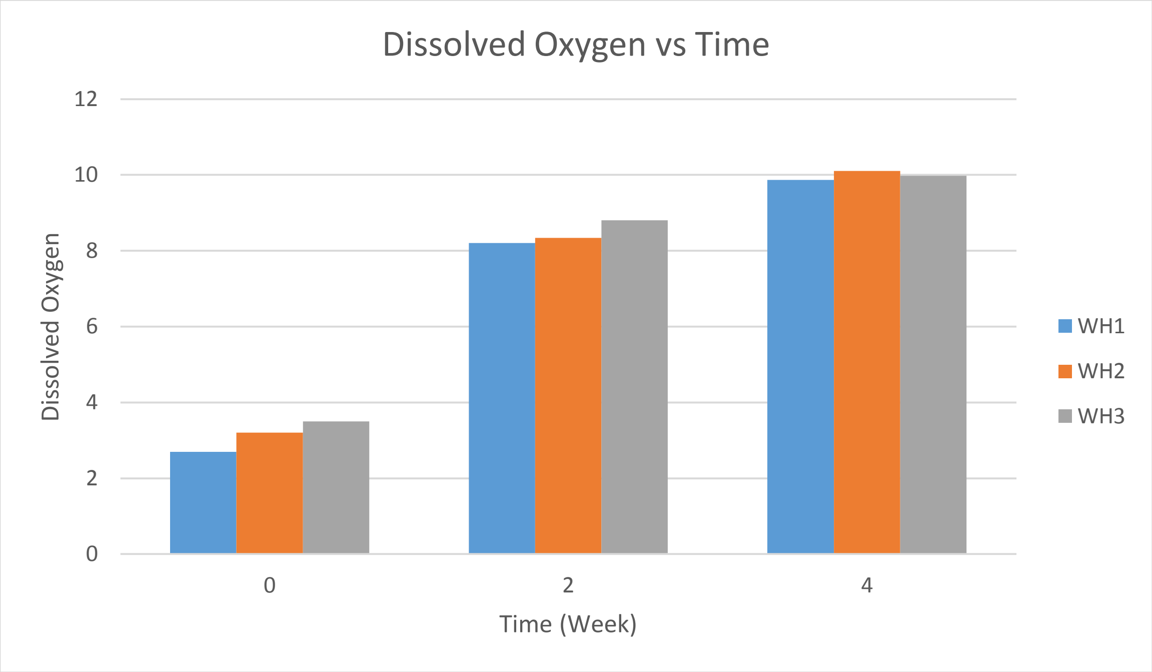

Figure 4.3: Graph Dissolved Oxygen against time

The dissolved oxygen concentration level at the beginning of the experiment for WH1, WH2 and WH3 was 2.7 mg/l, 3.2 mg/l and 3.5 mg/l. The DO level increases gradually from the initial week. The results for 2nd week for WH1, WH2 and WH3 was 8.2 mg/l, 8.34 mg/l and 8.8 mg/l. The DO level in all samples increases constantly till the end of the experiment as the final result of DO for WH1, WH2 and WH3 are 9.87 mg/l, 10.1 mg/l and 9.98 mg/l. The DO level in all samples increases gradually because of the oxidation of inorganic matters decreases. BOD and COD levels will gradually decreases with DO level.

4.3.4 Turbidity

The analysed results of turbidity of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.4

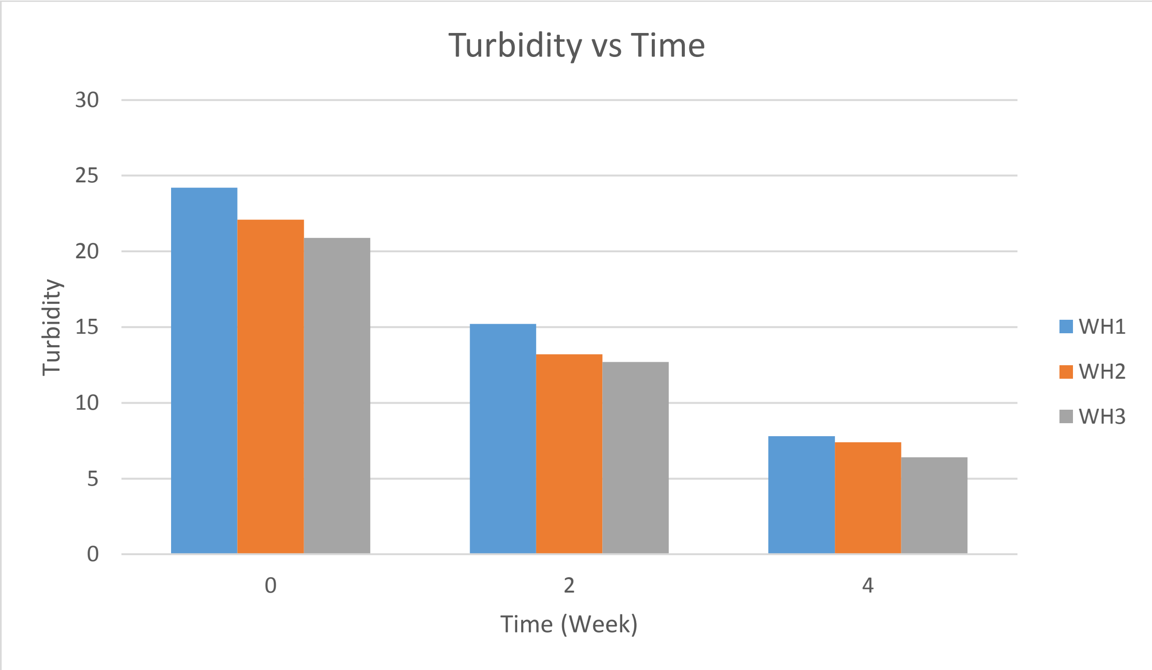

Figure 4.4: Graph turbidity against time

The turbidity level at the beginning of the experiment for WH1, WH2 and WH3 was 24.2 NTU, 22.1 NTU and 20.9 NTU. The turbidity level for 2nd week decreases gradually as the results for WH1, WH2 and WH3 was 15.2 NTU, 13.2 NTU and 12.7 NTU. The final turbidity result decreases constantly from 2nd week data. The results for WH1, WH2 and WH3 was 7.8 NTU, 7.4 NTU and 6.4 NTU. The highest turbidity level that has been obtained from the graph was WH1, 7.8 NTU and the lowest was WH3, 6.4 NTU. Turbidity is caused by large number of particles and the significant decrease which has been shown by graph is because the plant roots have absorbed the particles.

4.3.5 Total Suspended Solid (TSS)

The analysed results of TSS of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.5

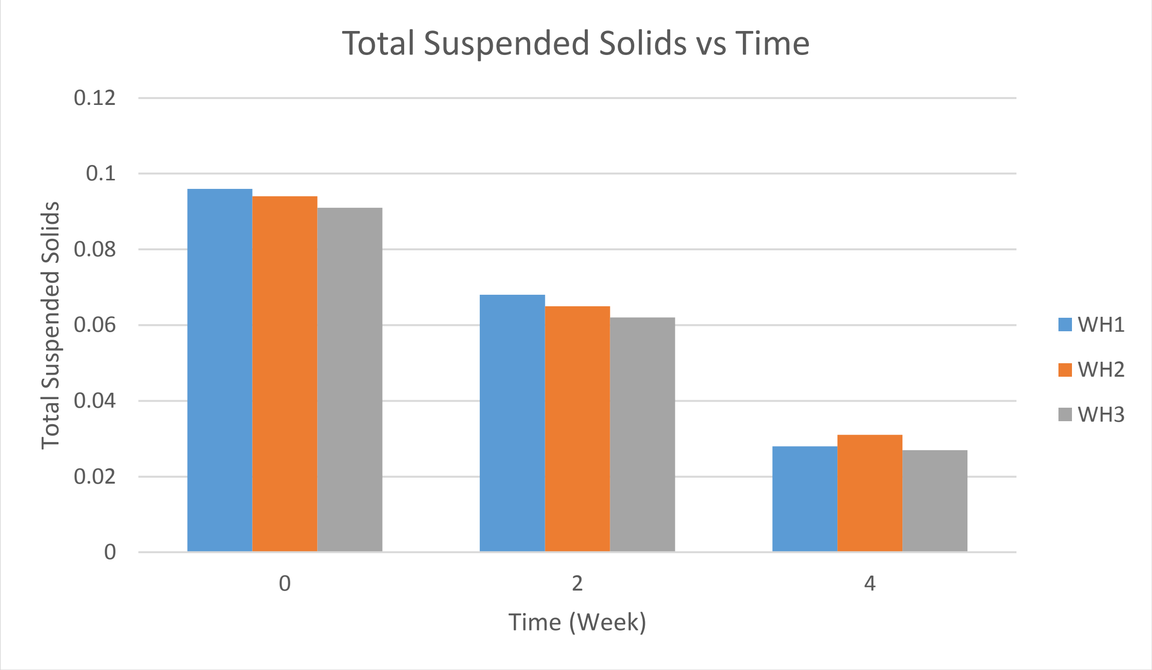

Figure 4.5: Graph Total Suspended Solids against time

The overall TSS concentration for this experiment lie between the ranges of 0.027 mg/l to 0.096 mg/l. The initial week TSS reading for WH1, WH2 and WH3 was 0.096 mg/l, 0.094 mg/l and 0.091 mg/l. There was a reduction in the TSS level for 2nd week compare to initial week and the results for WH1, WH2 and WH3 was 0.068 mg/l, 0.065 mg/l and 0.062 mg/l. And the final week result was the least TSS level for all 3 samples which was 0.028 mg/l, 0.031 mg/l and 0.027 mg/l. The water hyacinth plant absorbed the particles which make TSS level decreases constantly as shown in above graph.

4.3.6 Biochemical Oxygen Demand (BOD)

The analysed results of BOD of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.6

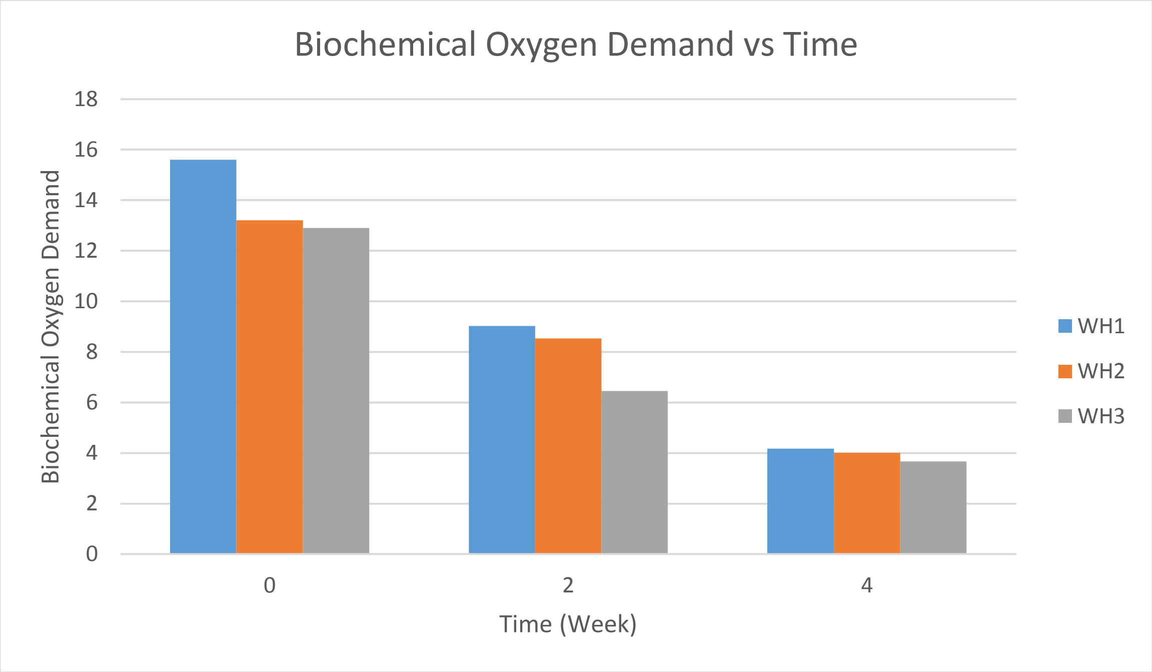

Figure 4.6: Graph Biochemical Oxygen Demand against time

The BOD results for initial week of WH1, WH2 and WH3 was 15.6 mg/l, 13.2 mg/l and 12.9 mg/l. In 2nd week, the BOD level reading recorded was 9.02 mg/l, 8.53 mg/l and 6.45 mg/l for WH1, WH2 and WH3. The high BOD reduction which has been plotted was on final week where the results was 4.17 mg/l, 4.01 mg/l and 3.67 mg/l for WH1, WH2 and WH3. The highest BOD level throughout the experiment was 15.6 mg/l for WH1 and 3.67 mg/l for WH3. The BOD level was high on the initial reading because of the presence of bacteria in industrial wastewater. The bacteria will consume oxygen and decompose waste in the wastewater. As the waste is started to consume by bacteria, the BOD level starts to decrease.

4.3.7 Chemical Oxygen Demand (COD)

The analysed results of COD of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.7

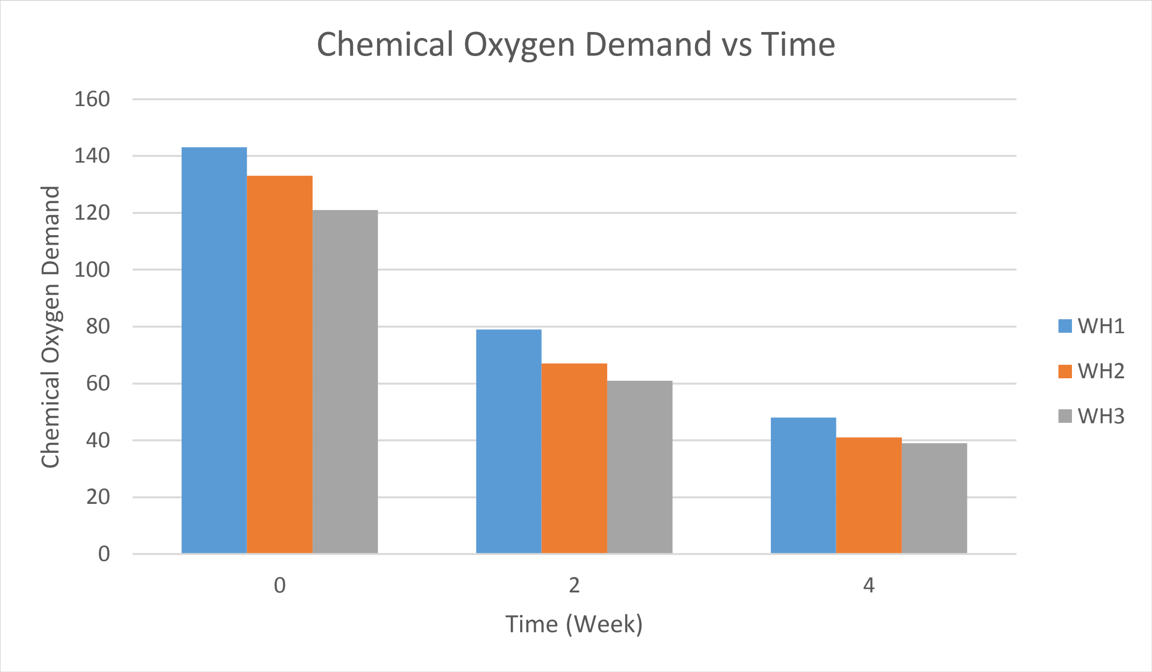

Figure 4.7: Graph Chemical Oxygen Demand against time

The COD content at the beginning of the experiment for WH1, WH2 and WH3 was 143 mg/l, 133 mg/l and 121 mg/l. All the samples COD level decreases gradually until the end of the experiment. The 2nd week results was 79 mg/l, 67 mg/l and 61 mg/l. And the final result for COD level was 48 mg/l, 41 mg/l and 39 mg/l. The range of COD level throughout the experiment drops tremendously. The reduction of dissolved oxygen which lead to anaerobic condition and makes the COD level decreases.

4.3.8 Ammoniacal Nitrogen

The analysed results of Ammoniacal Nitrogen of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.8

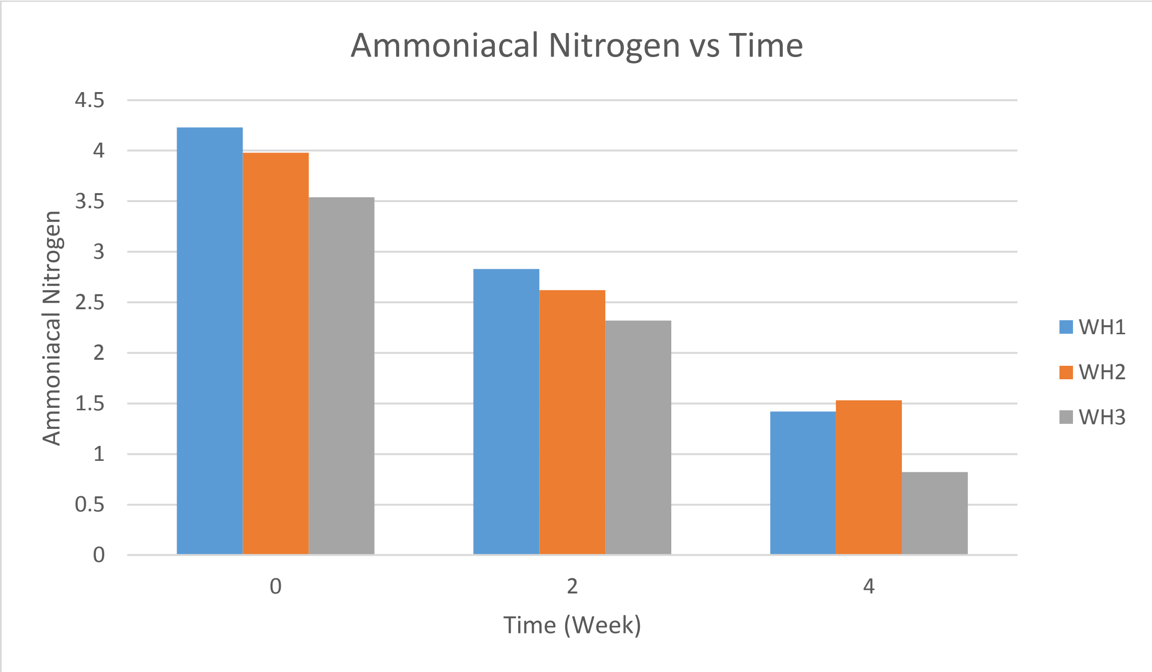

Figure 4.8: Graph Ammoniacal Nitrogen against time

The ammoniacal nitrogen is vital because of higher concentration of ammoniacal nitrogen can cause eutrophication. The initial week of ammoniacal nitrogen for WH1, WH2 and WH3 was 4.23 mg/l NH_3-N, 2.83 mg/l NH_3-N and 1.42 mg/l NH_3-N. The result decreases gradually compared to initial week which was 3.98 mg/l NH_3-N, 2.62 mg/l NH_3-N and 1.53 mg/l NH_3-N. There was a great reduction of ammoniacal nitrogen content in 4th week for WH3, 1.31 mg/l NH_3-N. The 4th week result for WH1 and WH2 was 3.54 mg/l NH_3-N and 2.32 mg/l NH_3-N. Water hyacinth absorbed the ammonia compound during the experiment which makes the graph decreases constantly.

4.3.9 Chromium (Cr)

The analysed results of Cr of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.9

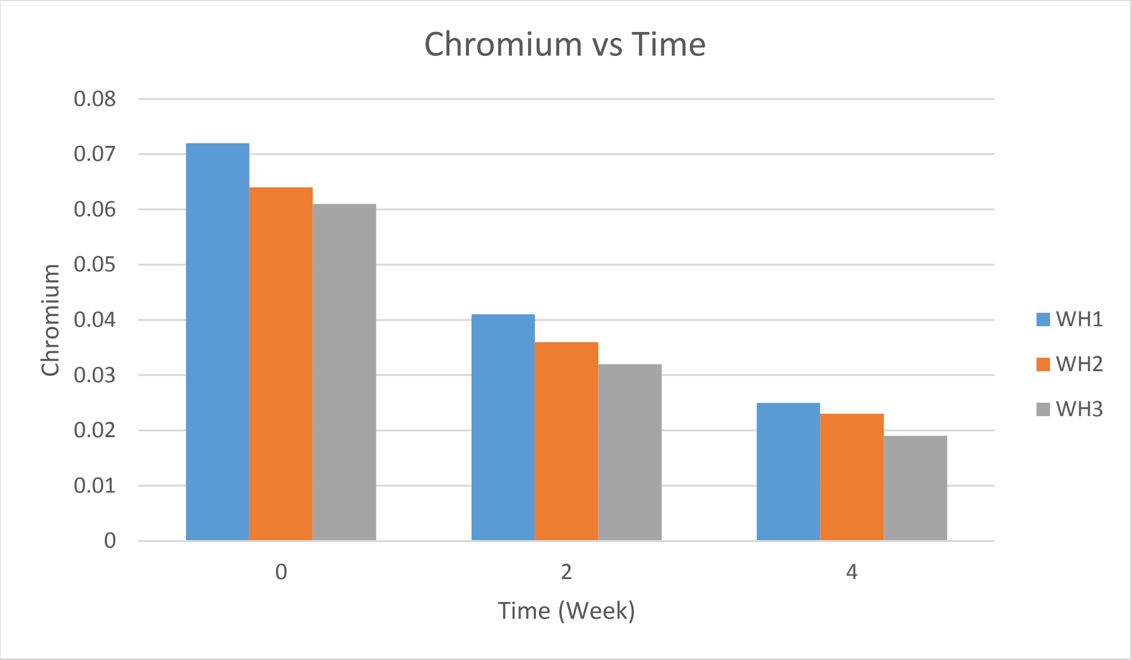

Figure 4.9: Graph Chromium against time

The Cr content at the beginning of the experiment for WH1, WH2 and WH3 was 0.072 mg/l, 0.041 mg/l and 0.025 mg/l. All the samples Cr level decreases gradually until the end of the experiment. The 2nd week results was 0.064 mg/l, 0.036 mg/l and 0.023 mg/l. And the final result for Cr level was 0.061 mg/l, 0.032 mg/l and 0.019 mg/l for WH1, WH2 and WH3 respectively. The range of Cr level throughout the experiment drops slightly. The reduction of Chromium level due to adsorption of heavy metals by water hyacinth plant.

4.3.10 Copper (Cu)

The analysed results of Cu of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.10

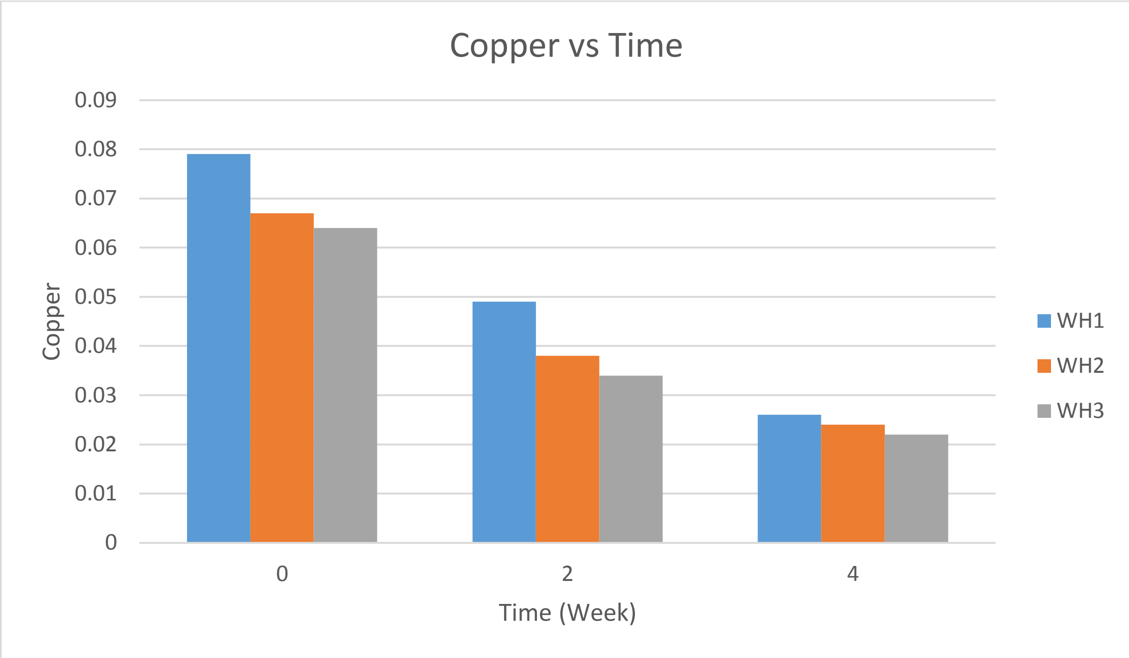

Figure 4.10: Graph Copper against time

The Cu content at the beginning of the experiment for WH1, WH2 and WH3 was 0.079 mg/l, 0.049 mg/l and 0.026 mg/l. All the samples Cu level decreases gradually until the end of the experiment. The 2nd week results was 0.067 mg/l, 0.038 mg/l and 0.024 mg/l. And the final result for Cu level was 0.064 mg/l, 0.034 mg/l and 0.022 mg/l for WH1, WH2 and WH3 respectively. The range of Cu level throughout the experiment drops slightly. The reduction of Copper level due to adsorption of heavy metals by water hyacinth plant.

4.3.11 Lead (Pb)

The analysed results of Pb of the industrial wastewater were recorded from the beginning of the treatment to the end of the studies as per Figure 4.11

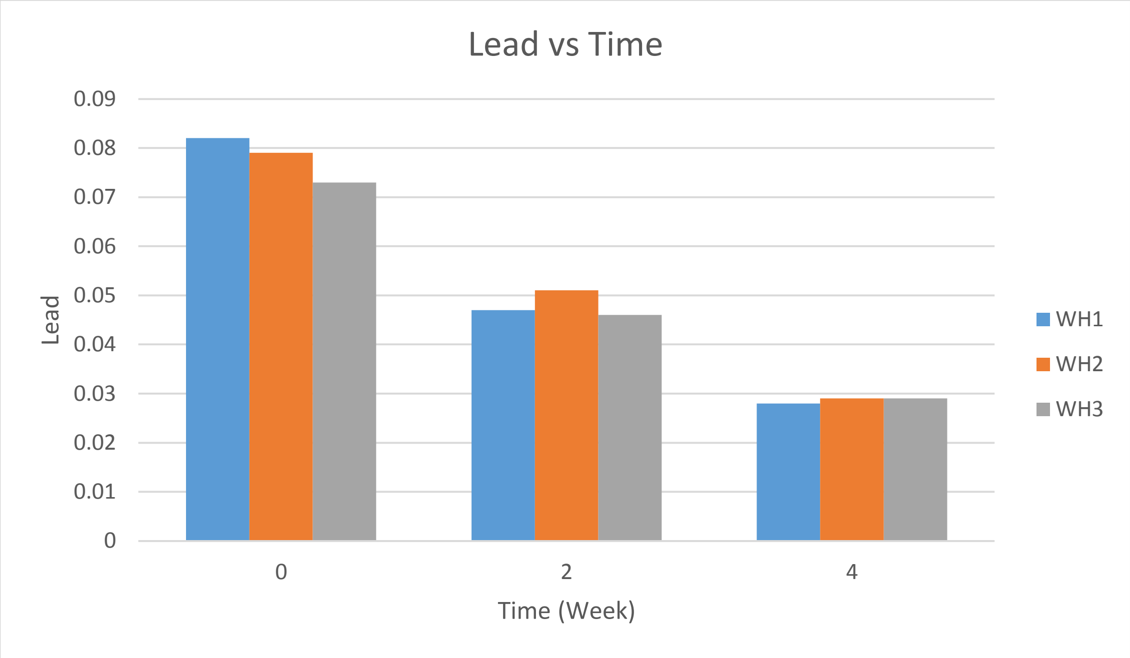

Figure 4.11: Graph Lead against time

The Pb content at the beginning of the experiment for WH1, WH2 and WH3 was 0.082 mg/l, 0.047 mg/l and 0.028 mg/l. All the samples Pb level decreases gradually until the end of the experiment. The 2nd week results was 0.079 mg/l, 0.051 mg/l and 0.029 mg/l. And the final result for Pb level was 0.073 mg/l, 0.046 mg/l and 0.029 mg/l for WH1, WH2 and WH3 respectively. The range of Pb level throughout the experiment drops slightly. The reduction of Lead level due to adsorption of heavy metals by water hyacinth plant.

4.4 REMOVAL EFFICIENCY

4.4.1 Biochemical Oxygen Demand (BOD)

Table 4.4: BOD removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	42.2
	WH2	35.4
	WH3	50.0
4	WH1	73.3
	WH2	69.6
	WH3	71.6

Sample WH1 have higher BOD removal efficiency compare to WH2 and WH3. The BOD removal efficiency for WH1, WH2 and WH3 was 73.3%, 69.6% and 71.6%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing BOD level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of BOD level on 100% of wastewater sample without adding any distilled water into it.

4.4.2 Chemical Oxygen Demand (COD)

Table 4.5: COD removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	60.7
	WH2	54.2
	WH3	48.8
4	WH1	82.1
	WH2	80.4
	WH3	80.2

Sample WH1 have higher COD removal efficiency compare to WH2 and WH3. The COD removal efficiency for WH1, WH2 and WH3 was 82.1%, 80.4% and 80.2%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing COD level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of COD level on 100% of wastewater sample without adding any distilled water into it

4.4.3 Total Suspended Solids (TSS)

Table 4.6: TSS removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	29.2
	WH2	30.9
	WH3	31.9
4	WH1	70.8
	WH2	67.0
	WH3	70.3

Sample WH1 have higher TSS removal efficiency compare to WH2 and WH3. The TSS removal efficiency for WH1, WH2 and WH3 was 70.8%, 67% and 70.3%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing TSS level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of TSS level on 100% of wastewater sample without adding any distilled water into it.

4.4.4 Ammoniacal Nitrogen

Table 4.7: Ammoniacal Nitrogen removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	33.1
	WH2	34.2
	WH3	34.5
4	WH1	66.4
	WH2	61.6
	WH3	63.0

Sample WH1 have higher Ammoniacal Nitrogen removal efficiency compare to WH2 and WH3. The Ammoniacal Nitrogen removal efficiency for WH1, WH2 and WH3 was 66.4%, 61.6% and 63%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing Amooniacal Nitrogen level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of Ammoniacal Nitrogen level on 100% of wastewater sample without adding any distilled water into it.

4.4.5 Turbidity

Table 4.8: Turbidity removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	37.2
	WH2	40.3
	WH3	39.2
4	WH1	67.8
	WH2	66.5
	WH3	69.4

Sample WH1 have higher turbidity removal efficiency compare to WH2 and WH3. The turbidity removal efficiency for WH1, WH2 and WH3 was 67.8%, 66.5% and 69.4%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing turbidity level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of turbidity level on 100% of wastewater sample without adding distilled water into it.

4.4.6 Chromium (Cr)

Table 4.9: Cr removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	43.1
	WH2	43.8
	WH3	47.5
4	WH1	65.3
	WH2	64.1
	WH3	68.9

Sample WH1 have higher Cr removal efficiency compare to WH2 and WH3. The Cr removal efficiency for WH1, WH2 and WH3 was 65.3%, 64.1% and 68.9%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing Cr level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of Cr level on 100% of wastewater sample without adding distilled water into it.

4.4.7 Copper (Cu)

Table 4.10: Cu removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	38.0
	WH2	43.3
	WH3	46.9
4	WH1	67.1
	WH2	64.2
	WH3	65.6

Sample WH1 have higher Cu removal efficiency compare to WH2 and WH3. The COD removal efficiency for WH1, WH2 and WH3 was 67.1%, 64.2% and 65.6%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing Cu level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of Cu level on 100% of wastewater sample without adding distilled water into it.

4.4.8 Lead (Pb)

Table 4.11: Pb removal efficiency

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
2	WH1	42.7
	WH2	35.4
	WH3	37.0
4	WH1	65.9
	WH2	63.3
	WH3	60.3

Sample WH1 have higher Pb removal efficiency compare to WH2 and WH3. The Pb removal efficiency for WH1, WH2 and WH3 was 65.9%, 63.3% and 60.3%. So, the 100% wastewater sample (WH1) treated by water hyacinth is more effective on removing Pb level compare to 70% of wastewater sample (WH2) and 50% of wastewater sample (WH3). Water hyacinth able to remove high percentage of Pb level on 100% of wastewater sample without adding distilled water into it.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

It has been observed that phytoremediation of wastewater using the floating plant system is a predominant method which is economic to construct, requires little maintenance and increase the biodiversity. Their treatment capabilities depend on different factors like climate, contaminants of different concentrations, temperature, and many other factors. The removal efficiency of contaminants like Total Suspended Solids, Biochemical Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen, Ammoniacal Nitrogen and heavy metals varies from plant to plant. Plant growth rate and hydraulic retention time can influence the reduction of contaminants. Therefore, an available knowledge and techniques for removal of water contaminants and advances in wastewater treatment can be integrated to assess and control water pollution. The main objective in this technology is to make sure the water hyacinth plant potentially remove the contaminant from the industrial wastewater.

5.1.1 Wastewater Treatment

Phytoremediation is one of the biological wastewater treatment methods, and is the concept of using plants-based systems and microbiological processes to eliminate contaminants in nature. All the parameters that has been observed meets Standard A of Environment Quality Standard, Malaysia except for Dissolved Oxygen as the reading that obtained was 10 mg/l where it had supposed to be 9 mg/l. So, the data that obtained for DO was incorrect. The reasons whys the data is incorrect is because of uncalibrated DO Meter and the changes in temperature, salinity and pressure.

The phytoremediation treatments which has been carried out throughout this one month period shows an appreciable removal efficiency results. In the treatment using 100% of wastewater sample (WH1), the results for BOD, COD, TSS, Ammoniacal Nitrogen, Turbidity, Chromium, Copper and Lead was 73.3%, 82.1%, 70.8%, 66.4%, 67.8%, 65.3%, 67.1% and 65.9%. In the treatment using 70% of wastewater sample (WH2), the results for BOD, COD, TSS, Ammoniacal Nitrogen, Turbidity, Chromium, Copper and Lead was 69.6%, 80.4%, 67%, 61.6%, 66.5%, 64.1%, 64.2% and 63.3%. In the treatment using 50% of wastewater sample (WH3), the results for BOD, COD, TSS, Ammoniacal Nitrogen, Turbidity, Chromium, Copper, and Lead was 71.6%, 80.2%, 70.3%, 63%, 69.4%, 68.9%, 65.6% and 60.3%.

The highest removal efficiency for BOD was WH1, 73.3%, COD was WH1, 82.1%, TSS was WH1, 70.8%, Ammoniacal Nitrogen was WH1, 66.4%, turbidity was WH3, 69.4%, Chromium was WH3, 68.9%, Copper was WH1, 67.1%, and Lead was WH1, 65.9%. From the discussion, it’s clearly observed that 100 % sample with water hyacinth (WH1) is more efficient compare to 70% sample with water hyacinth (WH2) and 50% sample with water hyacinth (WH3). The percentage of removal of WH1 for turbidity was 67.8% where it is still less than WH3, 69.4% but the removal efficiency is more than 50%. So we can use WH1 to remove the turbidity level as well as it is also has a very good removal percentage. As for Chromium, the percentage removal for WH1 was 65.3% and it was quite good enough to remove the Chromium level in the industrial wastewater as the result obtained was 0.025 mg/l where it is within the standard of 0.05 mg/l. In conclusion, water hyacinth plant is more efficient and works better on 100% sample of industrial wastewater without any additional of distilled water in it. So, by just placing the water hyacinth plant only in the industrial wastewater will provide better phytoremediation treatment and able reduce the pollutants.

5.2 RECOMMENDATIONS

5.2.1 Inventory Management and Improved Operations

The measures such as purchasing of fewer toxic and more non-toxic production materials, implementation of employees’ training and management feedback, inventorisation and tracing of all raw materials, and improving material receiving, storage, and handling practices.

5.2.2 Recycle and Reuse

It's one of the important points that help in preventing the hazardous waste. It includes installation of closed-loop systems, recycling off site for use, and exchange of wastes.

5.2.3 Modification of Equipment

Use the high efficient machinery or equipment that produce minimal or no wastes. Other measures need to be implemented such as the modification of existing equipment to enhance recovery or recycling options, redesigning of equipment or production lines to produce less waste, improving an operating efficiency of equipment, and maintaining strict preventive maintenance program.

5.2.4 Change in Production Processes

A small change in production process could improve the overall hazardous condition in a big way. Hazardous waste is a nuisance not only for the environment but it also affects the human health. Some of the steps include the segregation of wastes by type for recovery, substitution of non-hazardous for hazardous raw materials, elimination of sources of leaks and spills, separation of hazardous from non-hazardous wastes, redesigning or reformulation for products to be less hazardous, and optimization of reactions and raw material use. The above-mentioned initiatives could help in achieving the eco-friendly goal of waste minimization at source only.

5.2.5 Implementation of Waste Management at Source

It is possible to cut down waste generation at source by simple, inexpensive measures modifying production processes, through changes in raw materials/ product design and by employing recovery/recycling and reuse techniques. To avoid treatment through utilization of waste, it is important from the environmental pollution view point as well as for the benefit of entrepreneurs to recycle and reuse the wastes generated by an adoption of certain process change or by use of low/no-waste generation technology. Waste minimization can be practiced at various places in the industrial processes. Waste minimization requires careful planning, creative problem evolving, changing in attitude, sometimes capital investment, and most important a real commitment (Kamlesh Jolapara, 2017).

5.2.6 Monitoring and supervision

A regular monitoring should be introduced and the monitoring should be carried out by the industry experts together with the ecologists. An environment protection strategy on the basis of monitoring and evaluation has to be established. Industries in Gebeng must obey the Environment Quality (Industrial Effluent) Regulations 2009, Malaysia and actions have to be taken if irregularities are found.

REFERENCES

Abramov, V.O., Abramova , A.V., Keremetin ,P.P., Mullakaev ,M.S., Vexler ,G.B., Timothy, J. and Mason , T. J. 2014. Ultrasonically improved galvano-chemical technology for the remediation of industrial wastewater. *Ultrason. Sonochem.* 21: 812-818.

Adakole , J.A. and Abolude, D.S. 2009. Studies on Effluent Characteristics of a Metal Finishing Company. Zaria-Nigeria, *Research Journal of Environmental and Earth Science.* 1(2): 54-57

Afroz, R., Masud, M.M., Akhtar, R., and Duasa, J.B. 2014. Water Pollution Challenges and future Direction for Water Resource Management Policies in Malaysia. *Environ Urban Asia*. 5(1): 63-81.

Arun Thangamani. 2017. Effectiveness of bioremediation process for industrial wastewater treatment. B.Eng. Thesis. Universiti Malaysia Pahang.

Baird, C. and Cann, M. 2012. Environmental Chemistry, 3rd ed.; W.H. Freeman Publishers: *New York, NY, USA*: 407–454.

Changhao, L.B. and Zhans, K. 2013. Industrial ecology and water utilization of the marine chemical industry. A case study of Hai Hua Group (HHG), Chine, *Resources conservation and recycling* 70: 78-85.

Environment Protection Authority Victoria. 2012. Point and nonpoint sources of water pollution http://www.epa.vic.gov.au/your-environment/water/protecting-victorias-waters/point and-nonpoint-sources-of-water-pollution

Fondriest Environmental. 2014. Inc. “Water Temperature.” Fundamentals of Environmental Measurements http://www.fondriest.com/environmental-measurements/parameters/water-quality/water-temperature/

Kamlesh Jolapara. 2017. Futureentech Technology, Environment, Humanity, Lifestyle, How to Control and Prevent the Industrial Waste to Improve the Environment? https://www.futureentech.com/2017/02/how-to-control-and-prevent-industrial.html

Kumar,A., Yadav, A.K., Sreekrishnan, T.R., Satya, S., and Kaushik C.P.2008. Treatment of low strength industrial cluster wastewater by anaerobic hybrid reactor. *Bioresources Technology.* 99: 3123-3129

Loan, N.T., Phuong, N.M., Anh, N.T.N. 2014. The role of aquatic plants and microorganisms in domestic wastewater treatment. *Environ Eng Manage Jour.* 13 (8): 2031-2038.

Mishra, V.K. and Tripathi, B.D. 2008. Concurrent removal and accumulation of heavy metals by the three aquatic macrophytes. *Bioresource Technol.* 99: 7091 – 7097.

Mohamad, H.H. and Latif, P.A. 2010. Uptake of Cadmium and Zinc from synthetic effluents by water hyacinth. *Environment Asia.* 3(1): 36 – 42

Mohktar, H, Morad, N. and Fizri, F.F.A. 2011. Hyper accumulation of copper by two species of aquatic plants, International conference on environment science and engineering. Universiti Sains Malaysia.

Moyo, P., Chapungu, L., Mudzengi, B. 2013. Effectiveness of water Hyacinth (Eichhornia crassipes) in remediating polluted water: The case of Shagashe river in Masvingo, Zimbabwe. *Adv Appl Sci Res* 4 (4): 55-62.

Nanda, M., Sharma, D. and Kumar, A. 2011. Removal of heavy metals from industrial effluent using bacteria. *International journal of environment sciences.* 2(2): 781-787

Rezania, S., Ponraj, M., Talaiekhozani, A., Mohamad, S.E., Dinm M.F.M., Taib, S.M., Sabbagh, F., Sairan, F.M. 2015. Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater. *J Environ Manage* 163: 125-133.

Shahabaldin Rezania, Mohd Fadhil Md Din, Shazwin Mat Taib, Farrah Aini Dahalan, Ahmad Rahman Songip, Lakhweer Singh and Hesam Kamyab. 2015. The efficient Role of Aquatic Plant (Water Hyacinth) in Treating Domestic Wastewater in Continuous System, *International Journal of Phytoremediation.* 18(7): 679-685

Sujaul, I., Hossain, M., Nasly, M.A. and Sobahan, M.A. 2013. Effect of industrial pollution on the spatial variation of surface water quality. *Am. J. Environ. Sci.* 9: 120-129.

Syukor A, Zularisam A.B.W., Ideris Z, Ismid M.M., Suryati S.S.M. and Hasmanie A.H. 2013. Treatment of industrial wastewater at Gebeng area using Eichornia crassippes, Pistia stratiotes and Salvinia molesta. *Adv. Environ. Biol.* 7: 3802-3807.

Taiwo, I., Babajide, and Osunkiyesi. 2015. Phytoremedia tion of Heavy Metals (Cu, Zn, and Pb) Contaminated Water Using Water Hyacinth (Eichornia Crassipes). *IOSR Journal of Applied Chemistry*. 8: 65-72

Yisa, J. and T. Jimoh.2010. Analytical studies on water quality index of river Landzu. *Am. J. Applied Sci.*, 7: 453-458.

APPENDICES

APPENDIX A

STANDARD FOR INDUSTRIAL EFFLUENT OR MIXED EFFLUENT OF STANDARD A & B PARAMETER UNIT STAND

Parameter	Unit	Standards	
		A	B
Temperature	C	40	40
pH Value	-	6.0-9.0	5.5-9.0
BOD5 at 20C	mg/l	20	50
COD	mg/l	50	100
Suspended Solids	mg/l	50	100
Mercury	mg/l	0.005	0.05
Cadmium	mg/l	0.01	0.02
Chromium, Hexavalent	mg/l	0.05	0.05
Arsenic	mg/l	0.05	0.10
Cyanide	mg/l	0.05	0.10
Lead	mg/l	0.10	0.5
Chromium, Trivalent	mg/l	0.20	1.0
Copper	mg/l	0.20	1.0
Manganese	mg/l	0.20	1.0
Nickel	mg/l	0.20	1.0
Tin	mg/l	0.20	1.0
Zinc	mg/l	1.0	1.0
Boron	mg/l	1.0	4.0
Iron (Fe)	mg/l	1.0	5.0
Phenol	mg/l	0.001	1.0
Free Chlorine	mg/l	1.0	2.0
Sulphide	mg/l	0.50	0.5
Oil and Grease	mg/l	Not Detectable	10.0

Source: Environmental Quality (Industrial Effluent) Regulation 2009, Malaysia

APPENDIX B

INDUSTRIAL WASTEWATER TREATMENT RESULT FOR 1 MONTH PERIOD

pH

WEEK	WH1	WH2	WH3
0	12.50	12.30	11.90
2	7.20	6.90	6.70
4	6.10	6.05	6.01

Temperature

WEEK	WH1	WH2	WH3
0	27.4	27.2	27.1
2	27.9	27.5	27.8
4	27.3	26.9	27.2

Dissolved Oxygen (DO)

WEEK	WH1	WH2	WH3
0	2.70	3.20	3.50
2	8.20	8.34	8.80
4	9.87	10.10	9.98

Turbidity

WEEK	WH1	WH2	WH3
0	24.20	22.10	20.90
2	15.20	13.20	12.70
4	7.80	7.40	6.40

Total Suspended Solid (TSS)

WEEK	WH1	WH2	WH3
0	0.096	0.094	0.091
2	0.068	0.065	0.062
4	0.028	0.031	0.027

Biochemical Oxygen Demand (BOD)

WEEK	WH1	WH2	WH3
0	15.60	13.2	12.90
2	9.02	8.53	6.45
4	4.17	4.01	3.67

Chemical Oxygen Demand (COD)

WEEK	WH1	WH2	WH3
0	201	179	162
2	79	82	83
4	36	35	32

Ammoniacal Nitrogen

WEEK	WH1	WH2	WH3
0	4.23	3.98	3.54
2	2.83	2.62	2.32
4	1.42	1.53	1.31

Chromium

WEEK	WH1	WH2	WH3
0	0.072	0.064	0.061
2	0.041	0.036	0.032
4	0.025	0.023	0.019

Copper

WEEK	WH1	WH2	WH3
0	0.079	0.067	0.064
2	0.049	0.038	0.034
4	0.026	0.024	0.022

Lead

WEEK	WH1	WH2	WH3
0	0.082	0.079	0.073
2	0.047	0.051	0.046
4	0.028	0.029	0.029

APPENDIX C

REMOVAL EFFICIENCY FORMULA

R = $(C_0 - C)/C_0 \times 100\%$

where;

C_0 is the influent concentration and

C is the effluent concentration

APPENDIX D