REMOVAL PERFORMANCE OF POLLUTANTS FROM INDUSTRIAL WASTEWATER USING *SCIRPUS GROSSUS*

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PUVITHRA A/P MATHURAVEERAN

Thesis submitted in fulfillment of the requirements
for the award of the
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DEDICATION

Special dedications to,

My beloved father, MATHURAVEERAN S/O NADASON

My beloved mother, SIVAPAGIAM D/O KANDASAMY

My beloved siblings, VENMALAR D/O MATHURAVEERAN

THAMARAI D/O MATHURAVEERAN

GANAATIBAN S/O MATHURAVEERAN

My supervisor,Dr Mir Sujaul Islam, UMP Lecturers and all my fellow friends.

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ABSTRAK

Dalam era teknologi moden dan kompleks ini, pencemaran adalah kebimbangan terbesar di dunia. Pencemaran udara, pencemaran air, pencemaran tanah dan banyak lagi telah menjadi masalah yang teruk kepada dunia untuk menangi. Pencemaran air merupakan satu masalah serius di Malaysia dan memberi impak negatif terhadap kelestarian sumber air. 'Phytoremediation' adalah rawatan terbaik untuk air kumbahan tercemar. Rawatan ini adalah murah, mudah untuk penyeleggaraan dan ekonomi. Selain itu, 'phytoremediation' adalah teknologi baru yang harus dipertimbangkan untuk pemulihan tapak tercemar kerana kelebihan estetika dan kebolehgunaan jangka panjang. Objektif projek ini adalah untuk mengenal pasti label bahan pencemar, yang mengandungi air sisa industry untuk maklumat asas dan untuk menentukan keberkesanan 'phytoremediation' *scirpus grossus* untuk mengeluarkan bahan pencemar yang terkandung di dalam air kumbahan. *Scirpus Grossus* digunakan untuk mengetahui keupayaan penyingkiran yang terdapat dalam air sisa industri. Eksperimen ini dijalankan selama satu bulan dengan mengenal pasti parameter in-situ dan ex-situ di Makmal Alam Sekitar Universiti Malaysia Pahang. Air kumbahan telah dikumpulkan dari kawasan kajian dan dianalisis untuk mengumpul data kualiti air. Parameter yang diuji ialah pH, *dissolved oxygen* (DO), suhu, kekeruhan, *Biological Oxygen Demand* (BOD), *Chemical Oxygen Demand* (COD), *Total Suspended Solid* (TSS), *ammoniacal nitrogen*, *cadmium* (Cd), *zinc* (Zn) and *iron* (Fe). Berdasarkan uji kaji, kapasiti penyingkiran lebih tinggi apabila pengenceran 50% pencairan, iaitu untuk kekeruhan, BOD, COD, TSS, *ammoniacal nitrogen* dan Zn adalah 69.33%, 69.92%, 81.48%, 64.63%, 68.36% 64.29% masing-masing. Cd adalah 70.59% untuk pencairan 70% manakala Fe adalah 81.94% untuk 100% tanpa pencairan. *Scirpus Grossus* tidak berkesan tanpa pencairan. Kapasiti penyingkiran adalah lebih tinggi apabila pengenceran 50% air sisa selepas rawatan satu bulan.

ABSTRACT

In this era of complex and modern technology, pollution is the biggest fear in world. Air pollution, water pollution, soil pollution and many more have become a severe problem to the world to cope with. Water pollution is a serious problem in Malaysia and impact negatively on the sustainability of water resources. Phytoremediation is the best treatment for the contaminant wastewater. This treatment is cheap, easy to maintenance and economical. Besides that, phytoremediation is an emerging technology that should be considered for the remediation of contaminated sites because of its aesthetic advantages and long-term applicability. The objectives of this study was to identify the label of pollutant contains in industrial wastewater for baseline information and to determine the effectiveness of phytoremediation plant (*scirpus grossus*) to remove the pollutant contains in wastewater. *Scirpus Grossus* (club-rush) was used to find out removal capacity that contain in industrial wastewater. The experiment was run for one month by identify the in-situ and ex-situ parameters at Environmental Laboratory of Universiti Malaysia Pahang. The wastewater was collected from the study area and was analysed to collect the water quality data. The experiment was carried out for one-month duration with average of 3 measurements for each percentage. The parameters that was tested were pH, dissolved oxygen (DO), temperature, turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), ammoniacal nitrogen, cadmium (Cd), zinc (Zn) and iron (Fe). Based on the experiment, the removal capacity was higher when the 50% dilution of the dilution, which was for turbidity, BOD, COD, TSS, ammoniacal nitrogen and Zn were 69.33%, 69.92%, 81.48%, 64.63%, 68.36%, 64.29% respectively. Cd was 70.59% for 70% dilution while Fe was 81.94% for 100% without dilution. *Scirpus Grossus* was not effective without dilution. The removal capacity was higher when the 50% dilution of the wastewater after one month treatment.

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LIST OF ABBREVIATIONS

AN	Ammoniacal Nitrogen
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
Cd	Cadmium
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
Fe	Iron
Hg	Mercury
Ni	Nickel
Pb	Lead
TSS	Total Suspended Solid
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water can be found all over the place thus it is more than 70 percent of the planet's surface. All living beings on the earth are unable to survive without water. None of us can live without water even for one day. On the earth, there are very less percentage of drinking water. From this, we should understand and save the water and also do not waste the clean water for future generations. The availability of oxygen and water only can be found at earth planet where life is available. Water is a common need for our body plus our life. It is the most demanding requirement in all life especially all the field of work environment such as agriculture, industry, household, domestic and many more. As all know, water does not have odour, colour, shape and taste yet it contributes in all living things. Throughout the world, water is under threat from depletion, pollution and mismanagement affected by human activities. Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels. Water pollution is unsafe to the living beings. Wastewater means "used water from any combination of domestic, industrial, commercial or agricultural activities, surface runoff and any sewer inflow or sewer infiltration (Tilley et al. 2016).

Multidirectional developmental activities, for improved quality of life have increased the quantity of wastes. Thus there are threats due to huge amount of pollutants reaching fresh water sources and make them unfit for human consumption and ecosystem processes. Wastewater discharged from industrial and urban areas can contain a wide variety of pollutants. This means that there will be high pollution level due to huge amounts of heavy metals, salts, nutrients and pathogens. Phytoremediation is an emerging technology that should be considered for the remediation of contaminated sites because of its aesthetic advantages and long-term applicability. This concept is an improvised technique from the wetland system. The system is an alternative in wastewater engineering especially for water treatment process is complete. Plus, wetland system can operate by itself without much maintenance works (Aboyeji and Oluseun, 2013).

Phytoremediation means an environmentally sound technology for pollution prevention, control and remediation. Phytoremediation is the direct use of living green plants for in situ, o in place, removal, degradation, or containment of contaminants in soils, sludge, sediments, surface water and groundwater. Phytoremediation is a low cost, solar energy driven clean up technique. Besides that, it is the most useful at sites with shallow, low levels of contaminants. Other than that, it is useful for treating a wide variety of environmental contaminants and lasts, very effective with, or in some cases in place of mechanical clean-up methods. 'Phyto' means plant which is a generic term for the group of technologies that use plants for remediating soils, sludge, sediments and water contaminated with organic and inorganic contaminants (Agriculture Sciences, 2017)

1.2 Problem Statement

The population of the world has been increasing rapidly and to cope up with this a huge amount of food, energy and employment are required. Industrialization is the easiest way to meet up those demand. Nevertheless, the disposal of industrial wastewater is a great problem throughout the world. It may contain heavy metals as well as other pollutants (Abramov, 2014). The discarding of wastewater from industrial are harmful for the sustainable industrial approach (Changhao, 2013).

Industrialization is one of the major reason effect the water in Malaysia. There are many rivers affected by industrial activities. Semenyih river, Sungai Balok, Tunggak river, Galing river and Tiram river are main affected by industrialization. Thus it has disturbed the clean water or drinking water and it requires water treatment. Other than that, it has been facing problems of water quality status as the purposes and to contribute problem to aquatic environment.

According to previous study, Tiram River also been affected by industrial effluent. The Tiram River feeds into Kuantan River which is main outlet of the city of Kuantan. It receiving the industrial effluent without proper treatment which cause the level of toxic compound is high. Indera Mahkota and Kuantan area are expanding the development of industrial factories for offering job to the community as the number of population grow wider at those areas. Thus, this caused widespread of polluted water. The amount of pollutant discharged to the water can no longer be accommodate by the water ecosystem. The effluent from industries is highly load with bad contaminant which bad odor at certain time. Musty or earth smell usually originating from dissolved solid in the water. Chemical smell can be due to chemical toxic seeping to the river. Besides that, the apparent colour of the river is chalky and milky. It happened from the existence of suspended matter. The way of human sight, the aesthetic value of Tiram River is bad (Asri, 2015)

Based on Mohammed Amjed Hossain and Dr Sujaul Islam Mir, Tunggak river is the major river that contributes in Pahang. This river is adjoining to Gebeng which is the main industrial area in Pahang state. Gebeng town is located near to Kuantan port, the place where industrial progress is developing speedily. These industrial activities are generating discharge that consist of huge concentrations of ordinary and non-ordinary pollutants that affect the water quality of the river. Industries such as medicinal, petrochemical, wooden and mining are the major contributors to the Tunggak river through drain or channels. The water quality becomes highly polluted because it contains nickel (Ni), Mercury(Hg), cadmium (Cd), zinc (Zn), Chromium(Cr), lead (Pb) and copper(Cu).

1.3 Significant of Study

There is still no complete solution for the water pollution at Semenyih river, Sungai Balok, Tunggak river, Galing river, Tiram river and Gebeng river. The research is still on process as the contamination of the river is high. The purpose of this study is to determine the concentration of pollutant that contain in industrial wastewater.

Surface water is being affected by major factor of industrial activities and also effect the surrounding environment. Phytoremediation is a technology to clean the environment from heavy metals contamination. Plants have the benefits to absorb the chemicals from polluted water. The economic success of phytoremediation greatly depends on photosynthetic activity and growth rate of plants. The application of phytoremediation in recent years has improved the environment using efficient and inexpensive in situ methods (Huesemann et al, 2009). Phytoremediation systems is effective as it is cheap, easy process and maintenance also favourably presence. *Scirpus* *grossus* plant, is generally found in tropical and temperate regions. In addition, *Scirpus grossus* is an aquatic nature that have great growth rate and has the capability to reduce contaminants.

1.4 Objectives of Study

The objectives of this project are:

i. To identify the label of pollutant that contain in industrial wastewater for baseline information.

ii. To determine effectiveness of phytoremediation plant '*scirpus grossus*' to remove the pollutant contains in wastewater.

1.5 Scope of Study

Gebeng is an industrial area which consists of multiple industries that contributes pollutants to river nearby that could harm the living things as well as surface water quality of the area. During the previous study, the water samples has been conducted to fulfil the previous objectives. For a duration of one year from February 2012 to January 2013 from ten preselected sampling stations were collected based to the standard design of sample collection. Twenty-four water quality parameters including ten heavy metals were analysed. The water quality model was validated and calibrated with the collected data. Based on the standard method procedures, all testing and analyses were done. Compared with all areas the water qualities at the industrial zone were more deteriorated.

Eichornia Crassipes, Pistia Stratiotes, and *Giant Salvinia* were those plants that have been used to treat and remove heavy metals in Gebeng river that has been in previous research as a phytoremediation method. Phytoremediation process was benefit as plants nutrient utilization method in water and nutrients along the roots. Different parameters were used to observed, regulated and comparisons were made with standard level. Basically, there were many research and different techniques to solve the problems occurred in Gebeng river area. The research, data and results based on the previous analysis were being used to further investigate in future studies as it will give benefit to the environment. Phytoremediation offers significant ecological promise, but it is not a perfect solution. Ecological benefits in one area may create ecological impacts in others.

Negative impacts must be avoided. To assess the appropriateness of any phytoremediation application, media- and contaminant-specific field data must be obtained that can show the rate and extent of degradation or extraction. The existing knowledge base was limited, and specific data were needed on more plants, contaminants, and climate conditions (Oppelt, 2008).

Parameters that had be taken were physical and chemical to get the results. For physical test, temperature, turbidity, pH and dissolved oxygen were tested. Chemical dissolved oxygen, biochemical dissolved oxygen total suspended solid, ammoniacal nitrogen and heavy metals were tested in chemical test. Both physical and chemical study was needed to achieve the objectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Environmental health is differing from organization to organization, even though the basic assumption of same. It concludes with chemical, physical and biological aspect that affect human and also similar aspect impacting behaviors. Besides that, it encloses the judgment and control all the environmental aspect that could affect health. Heavy metals are the highest ranking environmental pollution problem as it damages the lives in water and also human as they use the water as their own purposes.

Based on previous study by Mohammed Amjed, Hossain in 2014, the higher concentration that have been recorded are arsenic, and mercury in Tunggak river and it was conclude as class III and class IV which those category class can’t be used for any purposes except for irrigation. Heavy metals content may cause many effect to human health.

Water quality is being destroyed every single day in this world as it goes through inappropriate disposal and industrial wastes and discharge. Next, the water polluted as the discharge and wastes are not manage according to law or standard provided. As in the Gebeng area of Pahang, the surface water is progressively polluted or contaminated thus due to reduction of proper analysis procedures as the industries are also being gradually growing fast. Two rivers which is Sungai Tunggak and Sungai Balok are those rivers that covered nearly with industrial region and affected by industrial releases (Hossain, 2014).

Phytoremediation is an encouraging benefit method for polluted water, groundwater and wastewater that is both low tech and low cost. Different aquatic plants are being used to conduct a research based on the phytoremediation process. Besides that, phytoremediation is a new technology focus on environmental friendly and economic as well.

2.2 Cause of Water Pollution in Industrial Area

Pollutants enter the water environment from two main types of sources. Point source and nonpoint source are the two types. A single flow such as pipe or drain is defining as point source. Industrial wastes are commonly discharged to rivers and the sea in this way. 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. Urban land use, agricultural land use, and forestry land use are the non-point source that contribute pollutants to the river. Storm water are the major nonpoint source from urban land use the gives pollution impact to the water quality. Storm water is contaminant by car oil, soil and sediment run-off from industries and dust. Pesticides, fertilizers, animal manure and soil washed into streams are non-point from agricultural land use. From forestry non-point source, farming and forestry area that applied pesticides could be polluted the water (Abdullah et al, 2015).

Balok river is the affected by metal pollution that receives from industries area nearby. Balok River originates as Batang Panjang River from the hill to the northwest of Gebeng Industrial area and generally serves the western catchment of this industrial area. The heavy metals that contain in Balok river are zinc, lead, copper, cadmium, nickel and many more. The primary sources of heavy metals in river sediment are chemical leaching of bedrocks, water drainage basins and runoff from river banks. The industrial site is within the Balok River catchment and thus all discharges from the industrial site will enter this river system. Balok River flows along the western boundary of Gebeng industrial area to the south before its confluence into the coastal waters of the South China Sea (Abdullah et al, 2015).

2.3 Industrial Wastewater Quality Studies

The characteristics of industrial wastewater that been evaluated in this research.

2.3.1 Temperature

Temperature explains as the amount of average kinetic energy in the method. Other parameter of water quality could be influence by water temperature. The highest temperature which is 38.45°C has been recorded for surface water near Gebeng area due to the discharge of hot water and effluents from surrounding industries. This high temperature can cause the microbial activity to be increased and decreased dissolved oxygen (Nasly et al, 2013). Based on Enas, 2016, research, the temperature value during the treatment of methylene blue in wastewater using *scirpus grossus* without plant was 29℃ while when use with plant, the range of temperature was between 28.3-29℃. During the research of phytotoxicity test of *scirpus grossus* on diesel-contaminated water using a subsurface flow system by Israa Abdulwahab, 2013, the temperature means values ranged between 24℃ and 28℃.

2.3.2 pH

Measuring acidity and alkalinity are the purpose of pH parameter and is it important. Based on the pH ranges, the toxicity of nutrients and also availability is observed. The growth of algae expanded when the nutrients level is increased as along with increase in pH. At Gebeng river area, the highest pH is 7.76 meanwhile 4.28 is the lowest (Sobahan et al, 2013). In Almaamary, 2016, research says that the average value was raged between 5.9 to 7.6 and did not differ significantly among the treatments. The pH ranged between 8.2-8.6 in water by using plants for treatment of methylene blue in wastewater using *scirpus grossus*.

2.3.3 Dissolved Oxygen

Amount of gaseous oxygen dissolved in the water is define as dissolved oxygen. Oxygen infiltrate in the water through absorption from the atmosphere by fast movement or a waste product of plant photosynthesis. In Gebeng research, the mean dissolved oxygen was 3.65 mg/L. 6.26 mg/L is the highest value and 1.36 mg/L is the lowest value. Decomposition of industrial wastes utilized oxygen and depleting for cooling industrial effluents and hot water are the reasons for DO is lower (Idris, 2013). Adequate dissolved oxygen is important for good water quality and necessary to all forms of life. Fish, plants need oxygen for respiration purposes but it has started to harm the fish and plants since the dissolved oxygen levels are getting low. The DO with *scirpus grossus* is 4.3-4.7 mg/L (Almaamary et al, 2016).

2.3.4 Biological Oxygen Demand

Biological oxygen demand is a measurement of the amount of dissolved oxygen which is used by aerobic microorganisms by decomposing organic matter in water. The higher the BOD value, the higher the amount of organic matter available for oxygen consuming bacteria. A sample is first analyzed and conditioned to ensure favorable growth conditions for bacteria that may include adjustment for pH and neutralization of residual chlorine. Based on Gebeng research, the highest BOD was 34.25 mg/L. The lowest value of BOD was 4.86 mg/L as there were no scope for the intrusion of industrial water, wastes and effluents. It has been found that in dry season comparatively higher BOD was observed than from wet season. At wet season, availability of water and lower temperature whereas during dry season, higher temperature and lower precipitation that means high BOD (Hossain et al, 2014). Based on Almaamary, 2016, research, the BOD value during the treatment of methylene blue in wastewater using *scirpus grossus*, the highest BOD removals was 69% for 400 mg/L.

2.3.5 Chemical Oxygen Demand

Chemical oxygen demand (COD) is a part of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals which is ammonia and nitrite. COD evaluate commonly made on samples of wastewater or natural waters polluted by industrial wastes or by domestic. It is measured under specific conditions of temperature and a particular period of time. COD proportion increases as the contamination level of water increases. It was observed comparatively higher mean COD values from dry season to wet season. Even, the high COD was observed that it was surrounded by many industries and consequently a huge industrial throwing like wastes, hot water and effluents done (Idris et al, 2013). The highest COD removals was 58% for 400 mg/L and lowest COD removals was 21% for 800 mg/L for Almaamary, 2016 research.

2.3.6 Total Suspended Solid

Total suspended solids (TSS) are solid materials, included organic and inorganic which are suspended in the water that included plankton, silt and also industrial wastes. High concentrations of TSS can lower water quality by absorbing light. Water will be warm and lessen the ability of the water to hold oxygen which aquatic life need it. Water that's contains high TSS is harmful for health. At Gebeng area, the lowest value was found 2.33 mg/L but the highest value is 48.66 mg/L because of the assemble of industrial wastes (Hossain et al, 2014).

2.3.7 Turbidity

Turbidity define as measure of relative clarity of a liquid. Optical characteristics of water and as expression of the amour of light that is scattered by material in the water when a light is shined through the water sample. At Gebeng area, the average turbidity of the studied surface water was 27.92 NTU. The higher turbidity was 139.01 NTU due to earth works and cleaning activities of surrounding area and as a high result when clay soil is mixed with water that increased the turbidity (Sobahan et al, 2013).

2.3.8 Ammoniacal Nitrate

Nitrogen is a nutrient for growing of a plant. The chances of algae and weed growth is higher as the concentration of ammonium nitrate is higher and caused eutrophication. Total nitrogen is comprised of ammonia, nitrate, nitrite and organic nitrogen. The highest concentration recorded as Gebeng site was 3.43 mg/L because of dry season and more industrial wastes were accumulated at those areas that increased the amount of ammonium nitrate (Hossain et al, 2014).

2.3.9 Heavy Metals

Majority of heavy metals are essential trace elements for humans, animals and plants in minority amount. Many heavy metals occur naturally but lead, cadmium and nickel are contribution from human.

Cadmium (Cd) the only mineral containing significant quantities of cadmium is greenockite (cadmium sulfide). It is also present in small amounts in sphalerite. Cadmium is a silvery metal with a bluish tinge to its surface. The highest value 0.3007 ppm was recorded at area Gebeng July,2012 which is highly polluted. Due to dry condition and the lesser precipitation, industrial activities and especially the availability of the inflow of effluents caused the contamination of heavy metals like Cd, Cr, Pb, Zn, Ni and Cu.

Iron, Fe is the most used of all the metals including 95% of all the metal tonnage produced worldwide. Combination of low cost and high strength it is indispensable. Most of this iron is found in various iron oxides such as the minerals hematite, magnetite and taconite. Most effective of Fe percentage removal are 139.4% in Gebeng wastewater studies.

Zinc, Zn is a lustrous bluish-white metal. It is a fairly reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen. Zn occurs naturally in water but zinc concentrations are rising unnaturally due to addition of zinc through human activities. Most zinc is added during industrial activities such as coal and waste combustion. Water is polluted with zinc due to the presence of large quantities of zinc in the wastewater of industrial plants. This wastewater is not purified satisfactory. Zinc may also increase the acidity of waters.

2.4 Wastewater Treatment

Plants are playing the important role as remove organic components from wastewater include adsorption. Tunggak river and Balok river have been selected as research area for previous study. To fulfil the objectives, water and soil samples were collected and analyzed. The sources of physicochemical parameters were primarily of the industrial effluents associated with domestic wastewater, and agricultural and urban runoffs. Some parameters with heavy metals contamination were due to natural sources. Many types of plants have been used to conduct the research at many places.

2.4.1 Wastewater Treatment by *Scirpus Grossus*

In the present study, horizontal subsurface flow constructed wetlands was study by using *scirpus grossus* to remediate water contaminated with different diesel concentrations with various aeration rate options for a period of 72 days in a field approach. Aimed to maximize the TPH removal efficiency from water and sand using RSM through a Box-Behnken experimental design by optimizing the diesel concentration, retention time and aeration rate.

2.4.2 Wastewater treatment by Sunflower

Sunflower is the plant that have the ability to take up large amounts of toxic materials from their environment. In fact, sunflowers were planted around the Chernobyl region to remove some of the radioactive isotopes released by a nuclear plant meltdown.

This use of plants to clean up contaminated areas is called phytoremediation. Sunflower easily available and relatively cost-effective to grow and maintain.

2.4.3 Wastewater treatment by water hyacinth

Water hyacinth is able to absorb and translocate the cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), and nickel (Ni) in the plant's tissue as a root or shoot. However, it is 3 to 15 times better to locate the elements into the roots than the shoots. Water hyacinth plants had high bio concentration with low concentrations of the five elements. This shows that water hyacinth can be a promising candidate to remove the heavy metals. This plant also exhibited that Pb accumulated mainly in the roots and the petiole contents comparable at high concentrations than other parts and prolonged immersion.

2.4.4 Wastewater Treatment by *Pistia Stratoites* (water lettuce)

Pistia stratoites (water lettuce) is an aquatic plant that grows rapidly and a high biomass crop with an extensive root system that able to enhance the heavy metals removal. This plant exhibited different patterns to lead removal and although accumulated at high concentrations mainly in the root system. Mohd. Shahrel B Bahradin (2008) found that the constructed wetland containing 15-plants recorded the highest removal with 99.28% for lead removal and 65.89% for cadmium removal at neutral condition (pH 7) showed better removal compared to the base and acidic conditions. The sorption of diluted heavy metal ions, in particular Pb and Cd by dead *P.stratiotes* appear to be an efficient and low cost alternative to be considered in industrial effluent treatment.

2.5 Conclusion

Scirpus grossus can be used to cure wastewater as a phytoremediation treatment as it has been proved in several research by few researchers in Malaysia. This plant can absorb the heavy metal with high removals efficiency. After a long days of wastewater treatment in a subsurface flow system, s*cirpus grossus* has the capability to survive and provide good conditions to the water.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the location, geography, geology, the climatic conditions of the study area and the methodologies of wastewater are studied. Besides that, it had included the methodologies of phytoremediation(plants) of wastewater treatment. The parameters measured, planning of sampling methodology, methods of laboratory analysis, formulas were also discussed in this chapter.

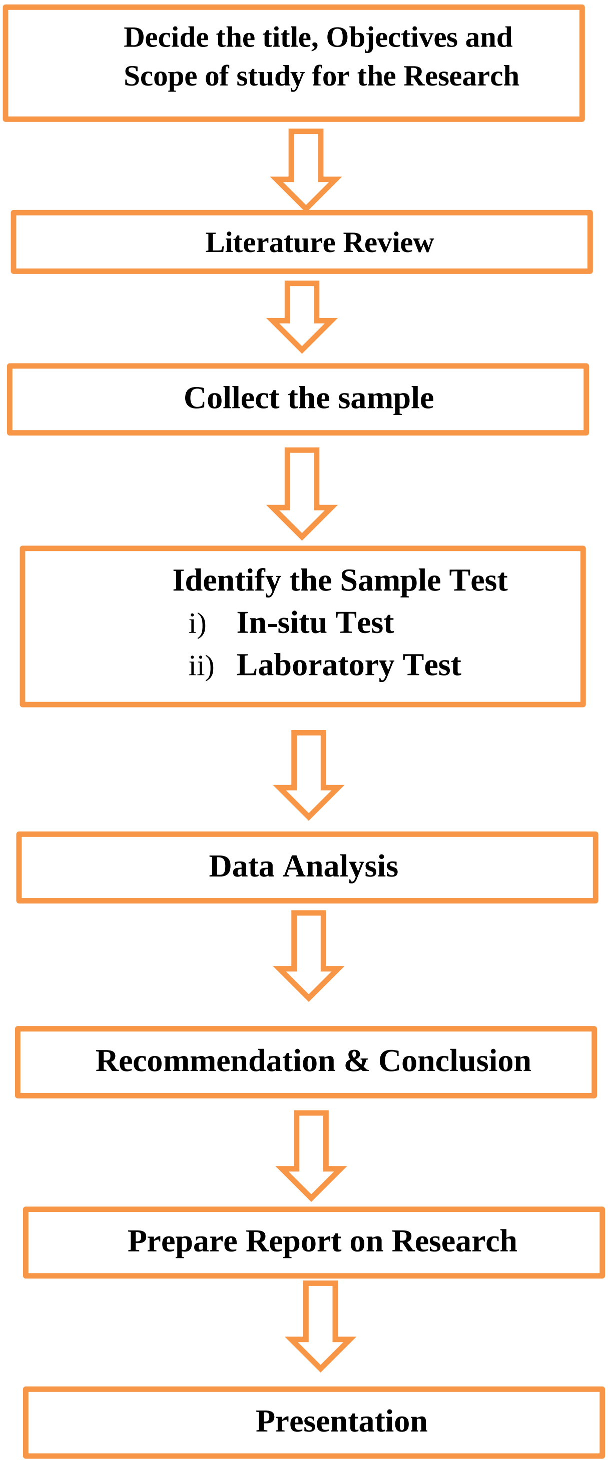
3.2 Study Area

3.2.1 Location and Geography

Balok River had been selected as study area since this river is located nearest to Gebeng industrial area. Gebeng industrial area is rapidly advanced as becoming the leading chemical and petrochemical in Pahang with the good infrastructure and great facilities. Lynax, MTBE-Petronas, Polyplastics Asia Pasific Sdn Bhd are those examples heavy industries located in Gebeng area with petrochemicals, chemicals, metal work industries, oil and gas industries. Balok River originates as Batang Panjang River from the hill to the northwest of Gebeng Industrial area and generally serves the western catchment of this industrial area. The industrial site is within the Balok River catchment and thus all discharges from the industrial site will enter this river system. Balok River flows along the western boundary of Gebeng industrial area to the south before its confluence into the coastal waters of the South China Sea. The primary source of pollution into this river is the drainage discharge from the Gebeng Industrial area along the river channel.

3.3 Flow Chart

Flow chart was needed to show the complete flow of the project from the early stage till the end of the research. Below is the flow chart for this project:



3.4 Sampling Methodology

3.4.1 Industrial Wastewater

The studied industrial wastewater was collected from Balok River which is near to Gebeng industrial area. The containers were rinsed with chromic acids and distilled water before the water samples were taken from the site. The samples were collected for BOD. After sampling, those bottles were immediately placed in icebox and then transferred to the environmental laboratory and preserved in a refrigerator.

Figure 3.1 : Balok River

Source : Turbineman's Log (Balok River) 2016,Kuantan.

3.4.2 *Scirpus Grossus* Sampling

The treatment that conducted throughout this experiment was by using *scirpus grossus* as a phytoremediation method. *Scirpus grossus* was collected nearby the Gambang area to be tested in this experiment.

Figure 3.2 : *Scirpus grossus*

Source : Hai Le (*Scirpus grossus)* 2007,Malaysia.

Figure 3.3 : Phytoremediation method

3.4.2.1 Plants collection and Primary Activities

Plants were washed by distilled water and then placed in a pot for 14 days with distilled water by separate pots. Pots were kept under sunlight for 6 hours every day and the evaporation losses of wastewater were fulfilled by the addition of distilled water. After 14 days, the experiment for treatment was continued.

3.4.2.2 Treatment of Wastewater by Plants

A total of 10 Liter of sample wastewater was used in each container for the experiment. The composition of the treatment media is shown in Table 3.1. the wastewater was diluted to different percentage to see the metal removal efficiency of the plant.

Table 3.1: Treatment Method

TREATMENT	RATIO OF DILUTION	TREATMENT PERIOD
Scirpus grossus	10 L wastewater	0^{TH} , 2^{ND} & 4^{TH} week
Scirpus grossus	7 L Wastewater + 3 L Distilled Water	0^{TH} , 2^{ND} & 4^{TH} week
Scirpus grossus	5 L Wastewater + 5 L Distilled Water	0^{TH} , 2^{ND} & 4^{TH} week

3.4.3 Measurement of Elements

3.4.3.1 In-Situ Measurements

Table 3.2: In-Situ Measurements

Parameter	Equipment/Instruments	Unit
Total Suspended Solids (TSS) (mg/L)	Gravimetric method (method 2540D, APHA, 2005)	Analytical balance, oven, filter paper, aluminium dishes, suction flask, desiccator
Temperature	YSI 6600 M (Multi-parameter Display System)	℃
Turbidity	HACH, 2100P, Turbidimeter	NTU

3.4.3.2 Ex-Situ Measurements

Table 3.3: Ex-Situ Measurements

Parameter	Method	Equipment/Instruments
Biochemical Oxygen Demand (BOD)	Method 5210 B (APHA, 2005)	YSI 5100 Dissolved Oxygen Meter
Chemical Oxygen Demand (COD)	COD Reactor Digestion Method (HACH Method 8000; wavelength	HACH Direct Reading Spectrophotometer, Model DR 5000
Ammoniacal Nitrogen (NH)	Nessler method (HACH Method 8038; wavelength 380)	HACH Direct Reading Spectrophotometer, Model DR 5000
pH	YSI 6600 M (Multi-parameter Display System)	mg/L
DO	YSI 6600 M (Multi-parameter Display System)	mg/L

3.5 Removal Equation

Formula used for the calculation of removal efficiency.

REMOVAL EFFICIENCY (RE)
R = (CO – C) / CO X 100%

Where:
CO is the influent concentration
C is the effluent concentration

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Industrialization had been demand by customer's requirement these days.

4.2 Treatment Method

Table 4.1: Treatment Method

Treatment	Ratio of Dilution	Treatment Period
100%	10L wastewater	$0^{TH,}$ 2^{ND} & 4^{TH} week
70%	7L wastewater + 3L distilled water	$0^{TH,}$ 2^{ND} & 4^{TH} week
50%	5L wastewater + 5L distilled water	$0^{TH,}$ 2^{ND} & 4^{TH} week

4.3 Wastewater Characteristics and Parameters

4.3.1 Characteristics of the Industrial Wastewater (100 %)

Table 4.2: Characteristics of the industrial wastewater

PARAMETERS	0^{TH} **WEEK**	2^{ND} **WEEK**	4^{TH} **WEEK**
pH	12.5	6.9	6.52
Temperature,°C	27.4	28.7	28.4
Biological Oxygen Demand (BOD), mg/L	15.6	10.71	5.89
Chemical Oxygen Demand (COD), mg/L	201	82	41
Total Suspended Solids (TSS), mg/L	1.002	0.582	0.447
Ammoniacal Nitrogen, mg/L	4.23	2.36	1.55
Dissolved Oxygen (DO), mg/L	2.7	7.9	8.3
Turbidity, NTU	24.2	13.4	10.1
Iron (Fe), mg/L	4.436	2.055	0.801
Cadmium (Cd), mg/L	0.019	0.011	0.008
Zinc (Zn), mg/L	0.019	0.013	0.008

4.3.2 Wastewater Treatment by *Scirpus Grossus* (70 %)

Table 4.3: Characteristics of industrial wastewater after treated with *Scirpus Grossus*

PARAMETERS	0^{TH} **WEEK**	2^{ND} **WEEK**	4^{TH} **WEEK**
pH	12.3	6.6	6.3
Temperature, ℃	27.2	28.6	28.2
Biological Oxygen Demand (BOD), mg/L	13.2	9.72	4.28
Chemical Oxygen Demand (COD), mg/L	179	75	38
Total Suspended Solids(TSS), mg/L	0.096	0.061	0.040
Ammoniacal Nitrogen, mg/L	3.98	2.16	1.37
Dissolved Oxygen (DO), mg/L	3.2	7.6	8.7
Turbidity, NTU	22.1	10.6	7.7
Iron (Fe), mg/L	2.117	0.916	0.503
Cadmium (Cd), mg/L	0.017	0.009	0.005
Zinc (Zn), mg/L	0.016	0.011	0.007

4.3.3 Wastewater Treatment by *Scirpus Grossus* (50 %)

Table 4.4: Characteristics of industrial wastewater after treated with *Scirpus Grossus*

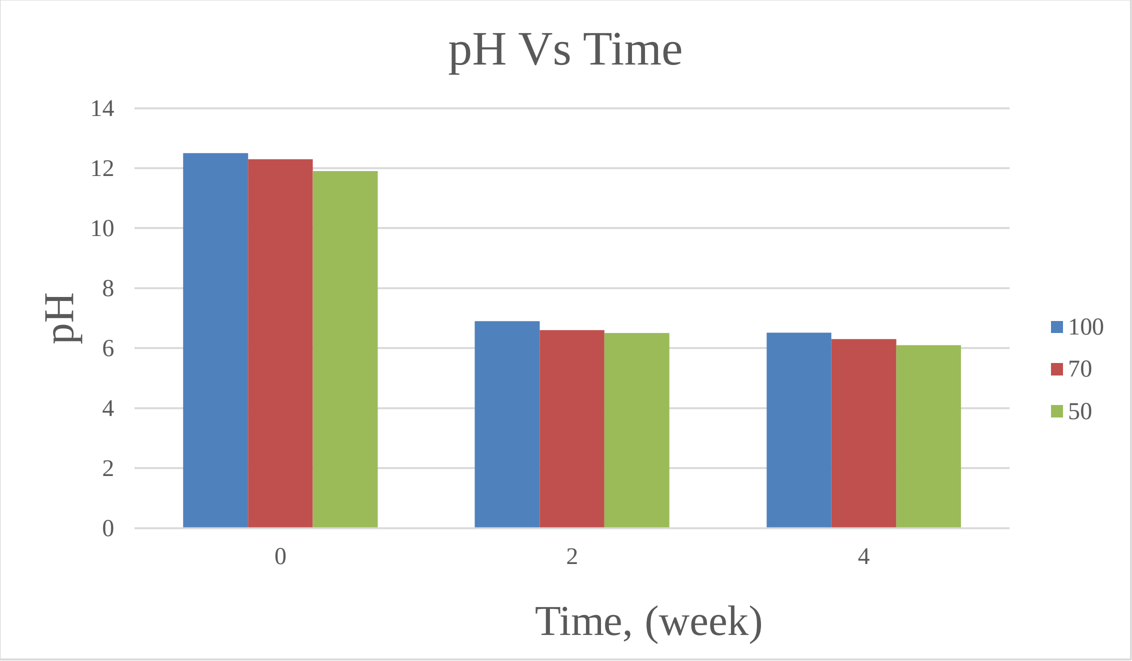
PARAMETERS	0^{TH} WEEK	2^{ND} WEEK	4^{TH} WEEK
pH	11.9	6.5	6.1
Temperature, °C	27.1	28.7	28.2
Biological Oxygen Demand (BOD), mg/L	12.9	8.27	3.88
Chemical Oxygen Demand (COD), mg/L	162	71	30
Total Suspended Solids (TSS), mg/L	0.082	0.050	0.029
Ammoniacal Nitrogen, mg/L	3.54	1.64	1.12
Dissolved Oxygen (DO), mg/L	3.5	8.24	8.12
Turbidity, NTU	20.9	9.1	6.41
Iron (Fe), mg/L	1.966	0.711	0.409
Cadmium (Cd), mg/L	0.015	0.010	0.006
Zinc (Zn), mg/L	0.014	0.008	0.005

4.3.3.1 Discussion

Scirpus Grossus was kept in distilled water for 2 weeks for the growth of roots before treated in wastewater. The initial reading of wastewater was taken on day. The pH value recorded during in-situ test.

4.3.4 pH

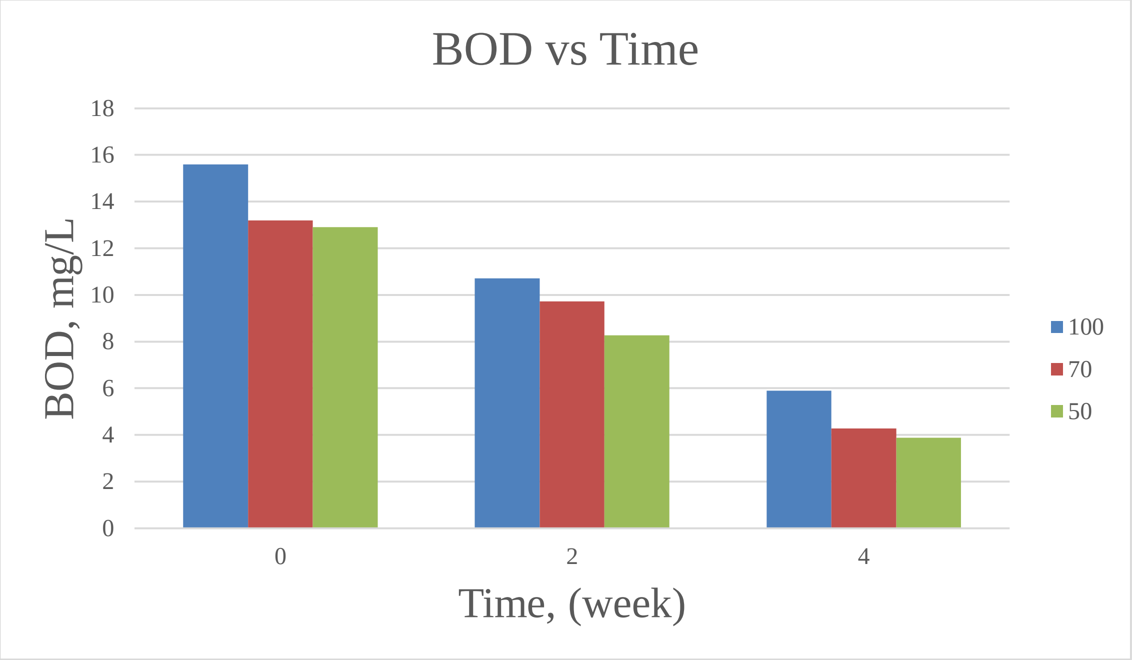
It is well known that pH plays vital role in the chemistry of water. The pH values measured for all samples were shown in Figure 4.4.



Graph 4.1: Graph of pH value against treatment period

The pH value of the wastewater sample was recorded 12.5, 12.3, 11.9 for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the pH recorded are 6.9 for 100%, 6.6 for 70% and 6.5 for 50%. There were significant decreases of pH level in week 4 compare to initial and 2nd week in all samples. In 4th week, the pH value was 6.5 for 100%, 6.3 for 70% and 6.1 for 50%. This shows the pH water can be used to kill off bacteria in wastewater. Extreme levels, presence of particulate matters, accumulation of toxic chemicals and increasing alkalinity levels are common problems in wastewater.

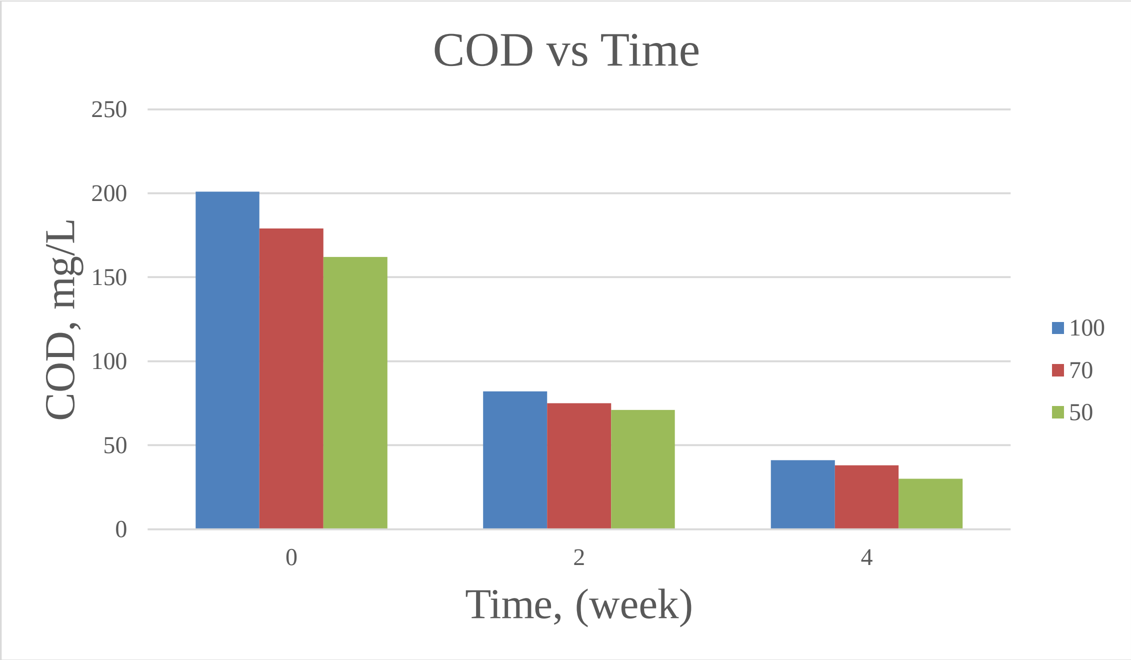
4.3.5 Biological Oxygen Demand



Graph 4.2: Graph of BOD against treatment period

The BOD value of the wastewater sample was recorded for 15.6 mg/L, 13.2 mg/L, 12.9 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the BOD recorded are 10.71 mg/L for 100%, 9.72 mg/L for 70% and 8.27 mg/L for 50%. There were significant decreases of BOD level in week 4 compare to initial and 2nd week in all samples. In 4th week, the BOD value was 5.89 mg/L for 100%, 4.28 mg/L for 70% and 3.88 mg/L for 50%. This shows the BOD level decreases as the presence of bacteria working to decompose this waste decreases due to the treatment.

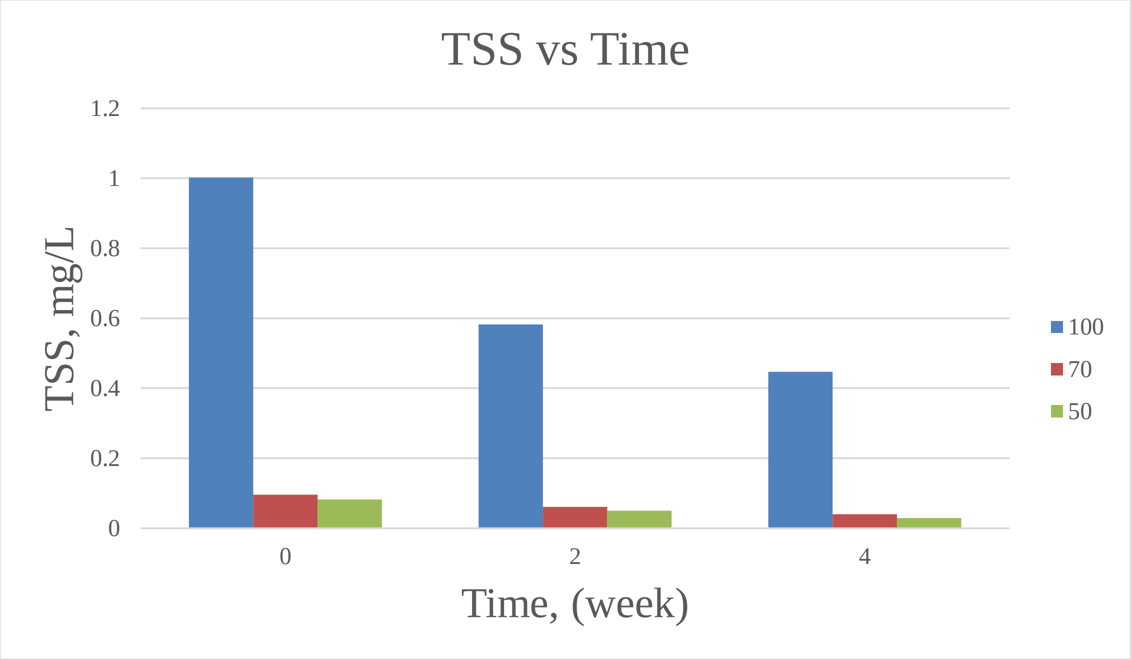
4.3.6 Chemical Oxygen Demand



Graph 4.3: Graph of COD against treatment period

The COD value of the wastewater sample was recorded for 201 mg/L, 179 mg/L, 162 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the COD recorded are 82 mg/L for 100%, 75 mg/L for 70% and 71 mg/L for 50%. There were significant decreases of BOD level in week 4 compare to initial and 2nd week in all samples. In 4th week, the BOD value was 41 mg/L for 100%, 38 mg/L for 70% and 30 mg/L for 50%. This shows the COD level decreases as the amount of organic matter in wastewater decreases and it is a measurement of the oxygen equivalent of the materials present in the wastewater that are subject to oxidation by a strong chemical oxidant.

4.3.7 Total Suspended Solids

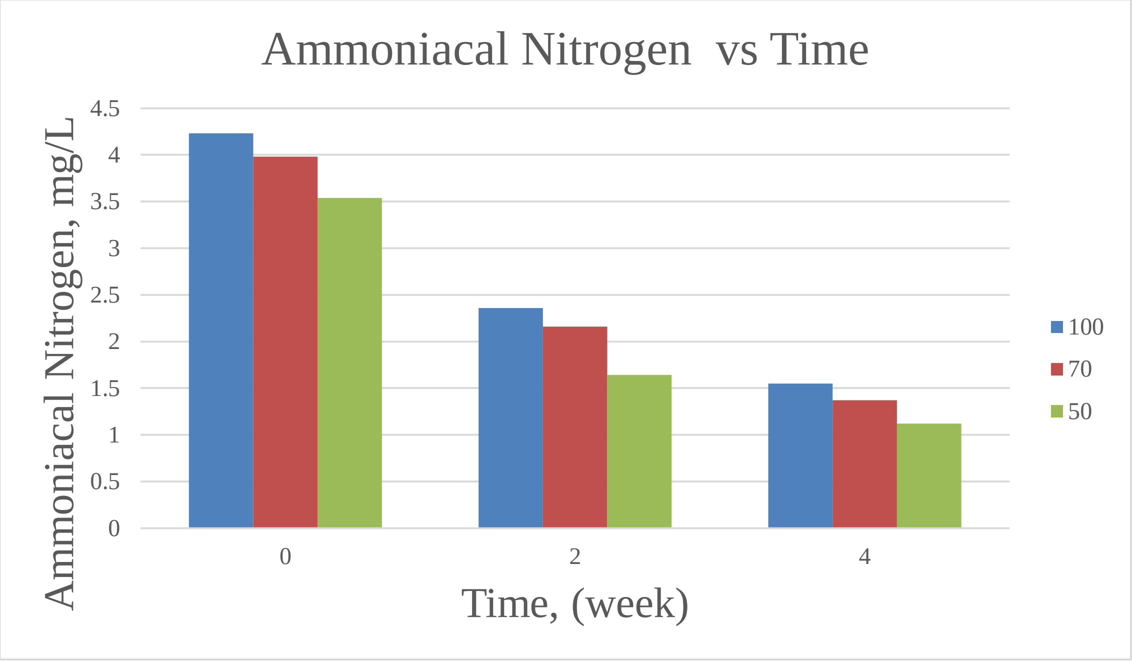


Graph 4.4: Graph of TSS against treatment period

The TSS value of the wastewater sample was recorded for 1.002 mg/L, 0.096 mg/L, 0.082 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the TSS recorded are 0.582 mg/L for 100%, 0.061 mg/L for 70% and 0.050 mg/L for 50%. There were significant decreases of TSS level in week 4 compare to initial and 2nd week in all samples. In 4th week, the TSS value was 0.447 mg/L for 100%, 0.040 mg/L for 70% and 0.029 mg/L for 50%. This shows the concentrations of TSS level decreases as the amount of organic matter in wastewater decreases and also increase the water quality.

4.3.8 Ammoniacal Nitrogen

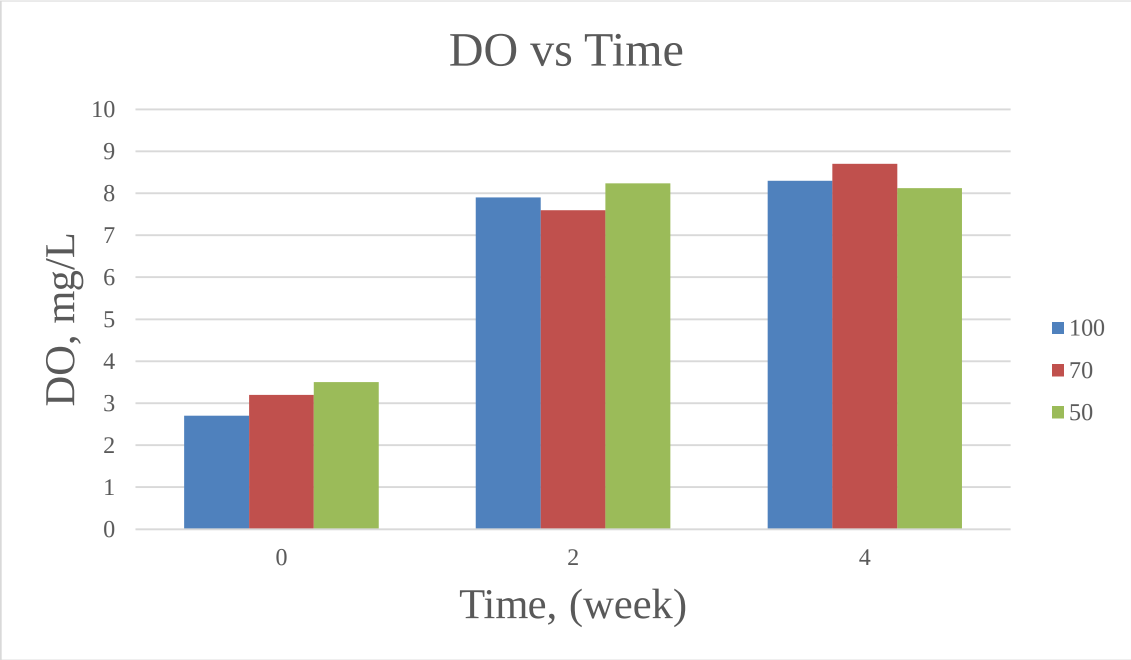
The analyses results of ammoniacal nitrogen of the industrial wastewater were recorded from beginning of the treatment to the end of the studies. The results as follows:



Graph 4.5: Graph of Ammoniacal Nitrogen against treatment period

The ammoniacal nitrogen value of the wastewater sample was recorded for 4.23 mg/L, 3.98 mg/L, 3.54 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the ammoniacal nitrogen recorded are 2.36 mg/L for 100%, 2.16 mg/L for 70% and 1.64 mg/L for 50%. There were significant decreases of ammoniacal nitrogen level in week 4 compare to initial and 2nd week in all samples. In 4th week, the ammoniacal nitrogen value was 1.55 mg/L for 100%, 1.37 mg/L for 70% and 1.12 mg/L for 50%. This shows the ammoniacal nitrogen level decreases as the amount of organic matter in wastewater decreases from this treatment.

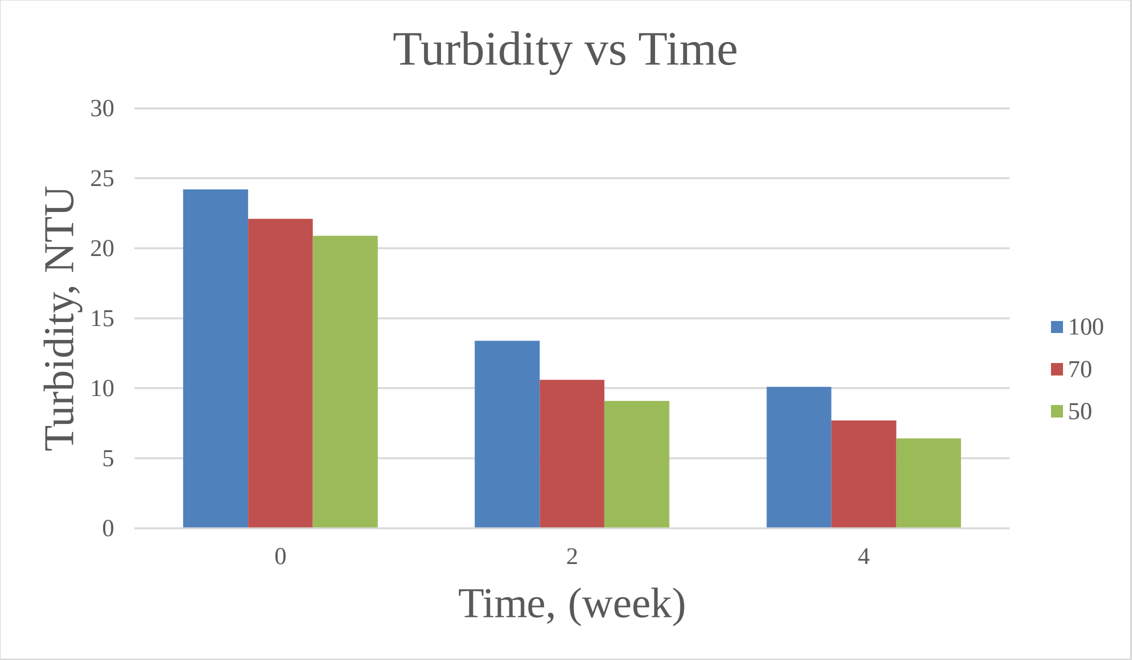
4.3.9 Dissolved Oxygen



Graph 4.6: Graph of DO against treatment period

The DO value of the wastewater sample was recorded for 2.7 mg/L, 3.2 mg/L, 3.5 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the DO recorded are 7.9 mg/L for 100%, 7.6 mg/L for 70% and 8.24 mg/L for 50%. There were significant increases of DO level in week 4 compare to initial and 2nd week in all samples. In 4th week, the DO value was 8.3 mg/L for 100%, 8.7 mg/L for 70% and 8.12 mg/L for 50%. This shows the DO level increases, thus the results of BOD decreases from this treatment.

4.3.10 Turbidity

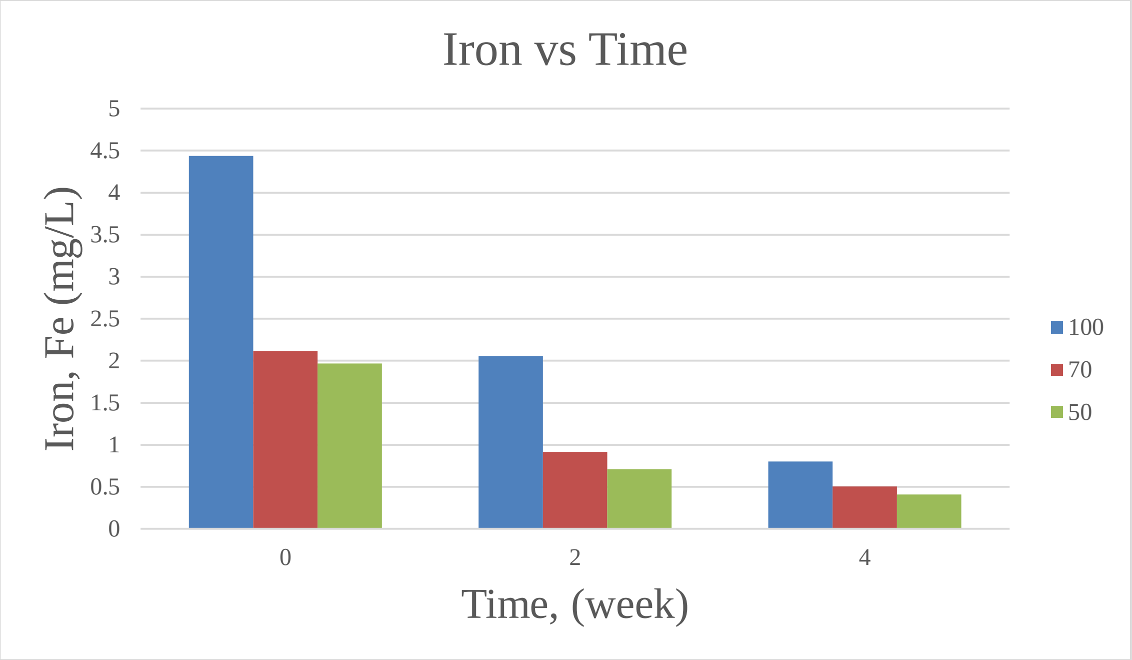


Graph 4.7: Graph of turbidity against treatment period

The turbidity value of the wastewater sample was recorded for 24.2 NTU, 22.1 NTU, 320.9 NTU for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the turbidity recorded are 13.4 NTU for 100%, 10.6 NTU for 70% and 9.1 NTU for 50%. There were significant decreases of turbidity level in week 4 compare to initial and 2nd week in all samples. In 4th week, the turbidity value was 10.1 NTU for 100%, 7.7 NTU for 70% and 6.41 NTU for 50%. This shows the turbidity level decreases as the cloudiness or haziness of the fluid low.

4.3.11 Heavy Metals

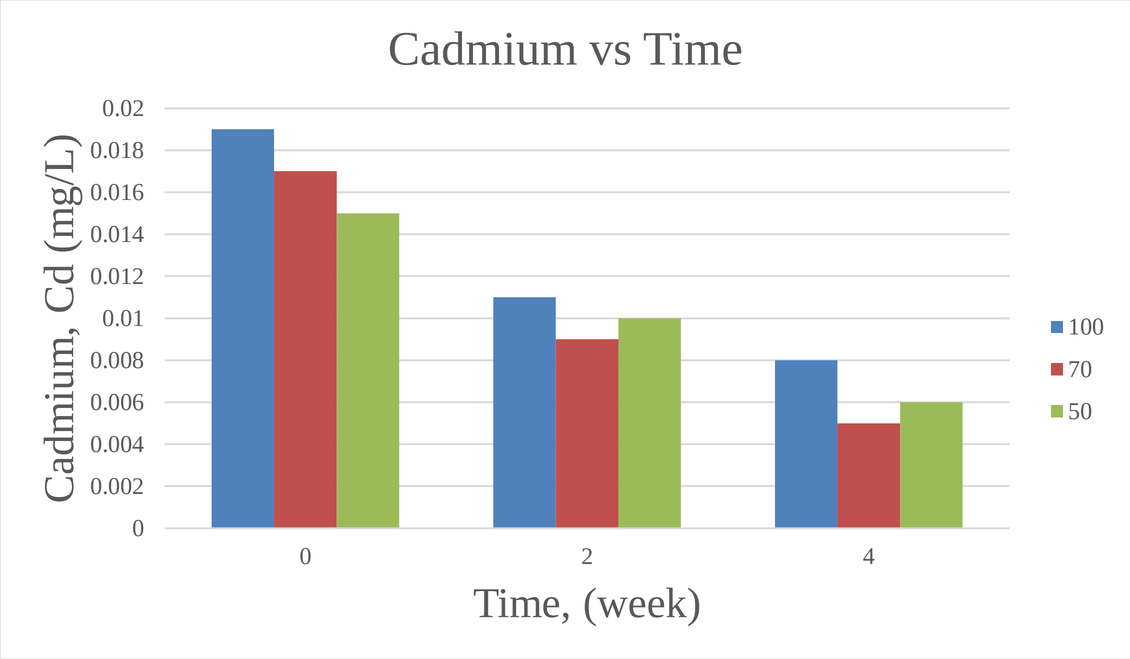
4.3.11.1 Iron, Fe



Graph 4.8: Graph of Iron content against treatment period

The Iron content value of the wastewater sample was recorded for 4.436 mg/L, 2.117 mg/L, 1.966 mg/L for 100%, 70% and 50% samples in all samples at initial of the studied. In 2nd week, the Iron content recorded are 2.055 mg/L for 100%, 0.916mg/L for 70% and 0.711 mg/L for 50%. There were significant decreases of Iron content level in week 4 compare to initial and 2nd week in all samples. In 4th week, the Iron content value was 1.55 mg/L for 100%, 0.503 mg/L for 70% and 0.409 mg/L for 50%. This shows the Iron content decreases from this treatment.

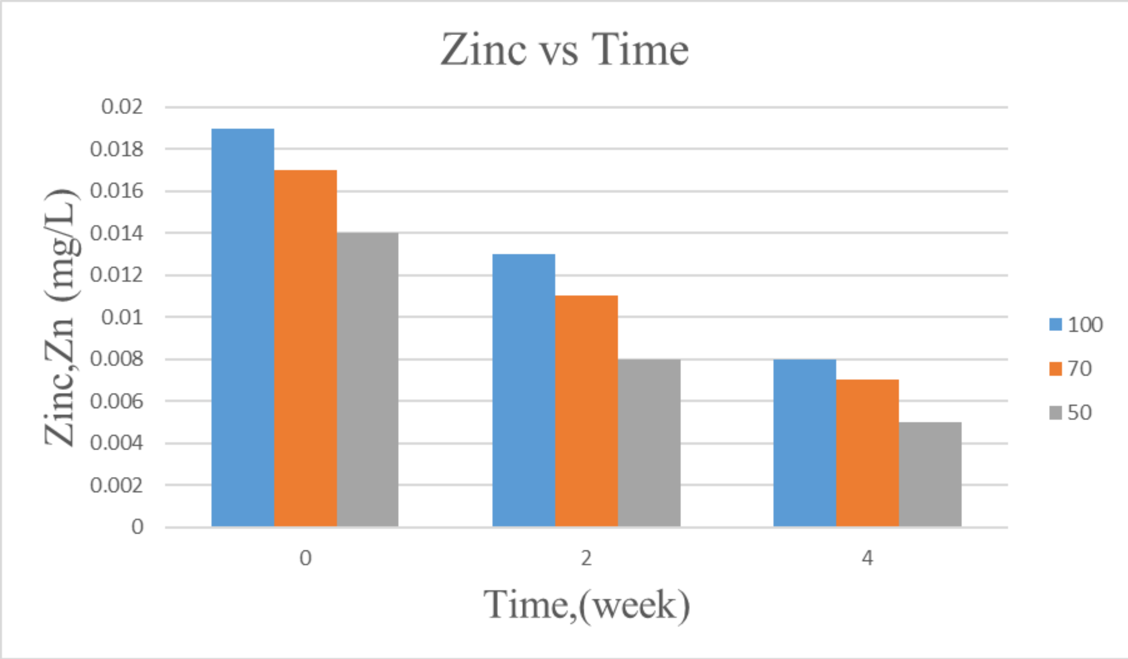
4.3.11.2 Cadmium, Cd



Graph 4.9: Graph of Cadmium content against treatment period

The Cadmium content value of the wastewater sample was recorded for 0.019 mg/L, 0.017 mg/L, 0.015 mg/L for 100%, 70% and 50% samples in all samples at initial of the studied. In 2nd week, the Cadmium content recorded are 0.011 mg/L for 100%, 0.009 mg/L for 70% and 0.010 mg/L for 50%. There were significant decreases of Cadmium content level in week 4 compare to initial and 2nd week in all samples. In 4th week, the Cadmium content value was 0.008 mg/L for 100%, 0.005 mg/L for 70% and 0.006 mg/L for 50%. This shows the Cadmium content level decreases from this treatment.

4.3.11.3 Zinc, Zn



Graph 4.10: Graph of Zinc content against treatment period

The Zinc content value of the wastewater sample was recorded for 0.019 mg/L, 0.016 mg/L, 0.014 mg/L for 100%, 70% and 50% samples at initial of the studied. In 2nd week, the Zinc content recorded are 0.013 mg/L for 100%, 0.011 mg/L for 70% and 0.008 mg/L for 50%. There were significant decreases of Zinc content level in week 4 compare to initial and 2nd week in all samples. In 4th week, the Zinc content value was 0.008 mg/L for 100%, 0.007 mg/L for 70% and 0.005 mg/L for 50%. This shows the Zinc content level decreases from this treatment.

4.4 Removal Efficiency

4.4.1 Biological Oxygen Demand

Table 4.5: BOD removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	31.35
	70%	26.36
	50%	35.89
4	100%	62.24
	70%	67.58
	50%	69.92

The removal efficiency of BOD for 100% for 2nd week is 31.35% and for 4th week is 62.24%. Whereas for 70% is 26.36% at 2nd week and 67.58% at 4th week. At 50%, for 2nd week is 35.89% and 4th is 69.92%. From here, it is concluding that the highest removal efficiency is 50% which is 69.92% at 4th week.

4.4.2 Chemical Oxygen Demand

Table 4.6: COD removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	59.20
	70%	58.10
	50%	56.17
4	100%	79.60
	70%	78.77
	50%	81.48

The removal efficiency of COD for 100% for 2nd week is 59.20% and for 4th week is 79.60%. Whereas for 70% is 58.10% at 2nd week and 78.77% at 4th week. At 50%, for 2nd week is 56.17% and 4th is 81.48%. From here, it is concluding that the highest removal efficiency is 50% which is 81.48% at 4th week.

4.4.3 Total Suspended Solids

Table 4.7: TSS removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	41.92
	70%	36.46
	50%	39.02
4	100%	55.39
	70%	58.33
	50%	64.63

The removal efficiency of TSS for 100% for 2nd week is 41.92% and for 4th week is 55.39%. Whereas for 70% is 36.46% at 2nd week and 58.33% at 4th week. At 50%, for 2nd week is 39.02% and 4th is 64.63%. From here, it is concluding that the highest removal efficiency is 50% which is 64.63% at 4th week.

4.4.4 Ammoniacal Nitrogen

Table 4.8: Ammoniacal nitrogen removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	44.21
	70%	45.73
	50%	53.67
4	100%	63.36
	70%	65.58
	50%	68.36

The removal efficiency of AN for 100% for 2nd week is 44.21% and for 4th week is 63.36%. Whereas for 70% is 45.73% at 2nd week and 65.58% at 4th week. At 50%, for 2nd week is 53.67% and 4th is 68.36%. From here, it is concluding that the highest removal efficiency is 50% which is 68.36% at 4th week.

4.4.5 Turbidity

Table 4.9: Turbidity removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	44.63
	70%	52.04
	50%	55.46
4	100%	58.26
	70%	65.16
	50%	69.33

The removal efficiency of turbidity for 100% for 2nd week is 44.63% and for 4th week is 58.26%. Whereas for 70% is 52.04% at 2nd week and 65.16% at 4th week. At 50%, for 2nd week is 55.46% and 4th is 69.33%. From here, it is concluding that the highest removal efficiency is 50% which is 69.33% at 4th week.

4.4.6 Heavy Metal (Iron, Fe)

Table 4.10: Iron content removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	53.67
	70%	56.73
	50%	63.84
4	100%	81.94
	70%	76.24
	50%	79.20

The removal efficiency of heavy metal iron, Fe for 100% for 2nd week is 53.67% and for 4th week is 81.94%. Whereas for 70% is 56.73% at 2nd week and 76.24% at 4th week. At 50%, for 2nd week is 63.84% and 4th is 79.20%. From here, it is concluding that the highest removal efficiency is 100% which is 81.94% at 4th week.

4.4.7 Heavy Metal (Cadmium, Cd)

Table 4.11: Cadmium content removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	42.11
	70%	47.06
	50%	33.33
4	100%	57.89
	70%	70.59
	50%	60.00

The removal efficiency of heavy metal cadmium, Cd for 100% for 2^{nd} week is 42.11% and for 4^{th} week is 57.89%. Whereas for 70% is 47.06% at 2^{nd} week and 70.59% at 4^{th} week. At 50%, for 2^{nd} week is 33.33% and 4^{th} is 60.00%. From here, it is concluding that the highest removal efficiency is 70% which is 70.59% at 4^{th} week.

4.4.8 Heavy Metal (Zinc, Zn)

Table 4.12: Zinc content removal efficiency during the treatment

Week	Sample	Removal Efficiency, %
2	100%	31.58
	70%	31.25
	50%	42.86
4	100%	57.89
	70%	56.25
	50%	64.29

The removal efficiency of heavy metal zinc, Zn for 100% for 2^{nd} week is 31.58% and for 4^{th} week is 57.89%. Whereas for 70% is 31.25% at 2^{nd} week and 56.25% at 4^{th} week. At 50%, for 2^{nd} week is 42.86% and 4^{th} is 64.29%. From here, it is concluding that the highest removal efficiency is 50% which is 64.29% at 4^{th} week.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Gebeng is a small town and major contribute industrial area in Kuantan District, Pahang, Malaysia that increasing day by day. Gebeng that consist of small and medium scale of industries measures higher contaminants, heavy metals and water pollutions based on wastewater research done. Phytoremediation treatment was found as an environmental solution to treat industrial wastewater.

5.1.1 Wastewater Treatment

Phytoremediation is a hopeful technology and valuable method that deal with plants to devalue, absorb, metabolize or become free from harmful contaminants. As the roots of plants grow, it can treat the wastewater at a certain stage. *Scirpus grossus* were used to treat the industrial wastewater. The removal of heavy metals which is Zinc, Iron and cadmium from wastewater by *scirpus grossus* were 64.29% at 50%, 81.94% at 100% and 70.59% at 70% respectively in month. Thus, phytoremediation had proven that this treatment can be shown appreciable removal efficiency. Besides that, the BOD, COD, TSS, turbidity, and ammoniacal nitrogen decrease and the removal efficiency is effective at 50%. From all this studies, *scripus grossus* concluded that this plants can be used to treat wastewater with dilution of distilled water as the better removal efficiency for most of pollution. 4^{th} week was optimum time to removal all pollutant based on this research. The greater removal efficiency was handle or controlled due to adaption procedure. Based on the effluent standard, this research had reached Standard A with the results from the experiments and parameters.

5.2 Recommendations

The following recommendation were concluding for secure the study area from the environment influence.

5.2.1 Wastewater and Wastes

Industrial wastewater should be discard in authorize methods. Accepted recycling method should be developed and followed. The wastewater from each and every places need to inspected to identify the sources of contaminants. Instead disposal to the river nearby, the solid wastes should be treated or recycled for sustainable industrial commence that few industries are interconnected by mass and energy streams.

5.2.2 Disposal of Plants after treatment

Since heavy metals are sensitivity, the plants used for treatment need to be disposed in proper way to minimize environmental impact and are sustainable. Environmentally friendly system need to be approach and apply. the used experimented plants should be thrown into industries boiler.

5.2.3 Pollution Monitoring and Supervision

Regular monitoring need to be introduced and the monitoring have to be done by the industry specialist together with the ecologists. An environment protection on the basis of monitoring and evaluation has to be established. Industry in Gebeng are compulsory to obey the Industrial Effluent, Environment Quality Regulations 2009, Malaysia and actions should be taken if irregularities are found.

5.2.4 Protected Area Design and Management

Future management are recommended to care the existing forests and aquatic eco-system. A bioregional approach is advised for the whole Gebeng industrial area and also surrounding areas under a form of management. A great plan has to be pull out and manage effectively to achieve the statement.

5.2.5 Cross-sectorial Management

The concerned government agencies and department, non- government agencies and experts have to work in a team to avoid the problems of environment destroy. This have to be manage the whole industrial area in Gebeng effectively and efficiently.

5.2.6 Afforestation Activities

Afforestation activities should be started. Each and all industry has to be create a green belt by introducing various heavy metal-tolerant plants and after treatments the wastewater have to be discharged through the green areas.

5.2.7 Zoning of the Area

It is compulsory to divide the total land in industrial and the total areas. All industries have to confined to a particular area. For the industrial dumping separate pond are needed to be create. The water bodies and river have to protected by creating a buffer zone.

5.2.8 Further Studies

An integrated management programme have to carried out in order to check on the rapid industrial development and its impacts on all components of environment. The suggested studies are as follows:

1. Industrial effects on soils and plants have to be evaluated through integrated studies in the study area.

2. Industry impacts on sea fishes and other animals need to bring under studies.

Wastewater and treatment are compulsory to carried out a research on it for future development and environment care.

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APPENDICES

APPENDIX A

ACCEPTABLE LIMITS FOR DISCHARGE OF INDUSTRIAL EFFLUENTS OF STANDARD A & B PARAMETER UNIT STANDARD

Parameter	Unit	Standard A	Standard B
(i) Temperature	°C	40	40
(ii) pH Value		6.0 - 9.0	5.5 - 9.0
(iii) BOD5 at 20°C	mg/l	20	50
(iv) COD	mg/l	50	100
(v) Suspended Solids	mg/l	50	100
(vi) Mercury	mg/l	0.005	0.05
(vii) Cadmium	mg/l	0.01	0.02
(viii) Chromium, Hexavalent	mg/l	0.05	0.05
(ix) Arsenic	mg/l	0.05	0.10
(x) Cyanide	mg/l	0.05	0.10
(xi) Lead	mg/l	0.10	0.5
(xii) Chormium, Trivalent	mg/l	0.20	1.0
(xiii) Copper	mg/l	0.20	1.0
(xiv) Manganese	mg/l	0.20	1.0
(xv) Nickel	mg/l	0.20	1.0
(xvi) Tin	mg/l	0.20	1.0
(xvii) Zinc	mg/l	1.0	1.0
(xviii) Boron	mg/l	1.0	4.0
(xix) Iron (Fe)	mg/l	1.0	5.0
(xx) Phenol	mg/l	0.001	1.0
(xxi) Free Chlorine	mg/l	1.0	2.0
(xxii) Sulphide	mg/l	0.50	0.50
(xxiii) Oil and Grease	mg/l	Not detectable	10

Source : Environmental Quality (Industrial Effluent) Regulations 2009,Malaysia.

APPENDIX B

INDUSTRIAL WASTEWATER TREATMENT RESULT FOR 1 MONTH PERIOD (100%)

PARAMETERS	0^{TH} **WEEK**	2^{ND} **WEEK**	4^{TH} **WEEK**
pH	12.5	6.9	6.52
Temperature,℃	27.4	28.7	28.4
Biological Oxygen Demand (BOD), mg/L	15.6	10.71	5.89
Chemical Oxygen Demand (COD), mg/L	201	82	41
Total Suspended Solids (TSS), mg/L	1.002	0.582	0.447
Ammoniacal Nitrogen, mg/L	4.23	2.36	1.55
Dissolved Oxygen (DO), mg/L	2.7	7.9	8.3
Turbidity, NTU	24.2	13.4	10.1
Iron (Fe), mg/L	4.436	2.055	0.801
Cadmium (Cd), mg/L	0.019	0.011	0.008
Zinc (Zn), mg/L	0.019	0.013	0.008

INDUSTRIAL WASTEWATER TREATMENT RESULT FOR 1 MONTH PERIOD (70%)

PARAMETERS	0^{TH} **WEEK**	2^{ND} **WEEK**	4^{TH} **WEEK**
pH	12.3	6.6	6.3
Temperature, ℃	27.2	28.6	28.2
Biological Oxygen Demand (BOD), mg/L	13.2	9.72	4.28
Chemical Oxygen Demand (COD), mg/L	179	75	38
Total Suspended Solids(TSS), mg/L	0.096	0.061	0.040
Ammoniacal Nitrogen, mg/L	3.98	2.16	1.37
Dissolved Oxygen (DO), mg/L	3.2	7.6	8.7
Turbidity, NTU	22.1	10.6	7.7
Iron (Fe), mg/L	2.117	0.916	0.503
Cadmium (Cd), mg/L	0.017	0.009	0.005
Zinc (Zn), mg/L	0.016	0.011	0.007

INDUSTRIAL WASTEWATER TREATMENT RESULT FOR 1 MONTH PERIOD (50%)

PARAMETERS	0^{TH} **WEEK**	2^{ND} **WEEK**	4^{TH} **WEEK**
pH	11.9	6.5	6.1
Temperature, ℃	27.1	28.7	28.2
Biological Oxygen Demand (BOD), mg/L	12.9	8.27	3.88
Chemical Oxygen Demand (COD), mg/L	162	71	30
Total Suspended Solids (TSS), mg/L	0.082	0.050	0.029
Ammoniacal Nitrogen, mg/L	3.54	1.64	1.12
Dissolved Oxygen (DO), mg/L	3.5	8.24	8.12
Turbidity, NTU	20.9	9.1	6.41
Iron (Fe), mg/L	1.966	0.711	0.409
Cadmium (Cd), mg/L	0.015	0.010	0.006
Zinc (Zn), mg/L	0.014	0.008	0.005

APPENDIX C

REMOVAL EQUATION

REMOVAL EFFICIENCY (RE)

R = (CO – C) / CO X 100%

Where:

CO is the influent concentration

C is the effluent concentration

APPENDIX D

Balok River

Scirpus Grossus

Phytoremediation Method