PHYTOREMEDIATION PROCESS IN WASTEWATER TREATMENT USING VETIVER GRASS (*Vetiveria Zizanoides*)

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PHYTOREMEDIATION PROCESS IN WASTEWATER TREATMENT USING VETIVER GRASS (*Vetiveria Zizanoides*)

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Thesis submitted in fulfillment of the requirements
for the award of the
B. Eng (Hons) Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest gratitude to my research supervisor, Dr Mir Sujaul Islam for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give her time so generously has been very much appreciated. Besides, his patience and support helped me overcome many crisis situations and also helped me to coordinate my project especially in writing this report. I also sincerely thanks for the time spent for giving opinions, proofreading and correcting the writing in my thesis.

I am particularly grateful for the assistance given by the UMP staff in Environmental Laboratory for the permission to use all required equipment and related materials during completing my research experiments. A special thanks to laboratory assistants, Madam Norazimah binti Abdul Aziz (Environmental Laboratory) and Mr. Qari bin Mohd Nor (Environmental Laboratory)

Furthermore, I wish to acknowledge the help provided by my friends during this research in progress which is my love, my friends that give me lot of motivation Haziq Hasalan and Bidin, and also for those involved indirectly to assist me during conducting experiments for this research. I'm sincerely thanks for the time that they spent in helping to complete the task with me.

Finally, I must express my very profound gratitude to my beloved family especially my mom and dad, Hastariah Binti Mohtar and Fauzi bin Sani, for their patience, sacrifice and love in my life. I am grateful that my family show their patience and caring to me as I felt stress and confused in completing the research and thesis. They gave me the maximum love and guidance to me which supporting me to complete all the tasks in order to achieve my goals. I really appreciated and thanks them for understanding me and supporting all the time in completing my thesis.

ABSTRAK

Pada era globalisasi kini dengan penduduk yang semakin meningkat, pencemaran air menjadi isu pencemaran yang serius dan perlu mengambil tindakan untuk mengekalkan kualiti air bersih di Malaysia. *Phytoremediation* adalah salah teknologi hijau yang boleh digunakan dalam pemulihan air kumbahan tercemar. Kajian ini bertujuan untuk mengkaji kualiti air sisa berdasarkan parameter BOD, COD, DO, Kekeruhan, TSS, Ammonia Nitrat, nilai pH dan logam berat terpilih. Selain itu, kajian ini dijalankan untuk menentukan kecekapan dan prestasi rumput vetiver sebagai ejen phytoremediation. Pengambilan racun *vetiver grass* dilakukan di Makmal Alam Sekitar dan analisis logam berat dilakukan dengan menggunakan pencernaan asid dan Spektrometri Penyerapan Atom. Kajian ini mengambil masa 3 minggu untuk mengumpul data dan melakukan ujian makmal. Kepekatan air kumbahan adalah 100%, 75% dan 50%. Keputusan diperoleh dari 100%, 75% dan 50% air sisa menunjukkan bahawa penyingkiran prestasi adalah tertinggi pada kepekatan 75% air kumbahan. Peratusan penyingkiran bagi BOD (62.87%, 82.11% dan 58.74%), COD (56.41%, 64.87% dan 57.14%), DO (75.2%, 79.76% dan 75.40%), Kekeruhan (26.44%, 29.44%), TSS (65.47%, 72.90% dan 71.88%), ammonia nitrat (86.36%, 93.75% dan 85.19%), nilai pH (23.36%, 23.86% dan 21.48%). Bagi logam berat terpilih Zinc (3.22%, 4.98% dan 3.04%), Lead (14.83%, 15.86% dan 13.10%), Tembaga (20.69%, 35.48% dan 23.33%) juga telah dicatatkan. Eksperimen dilakukan selama 3 minggu. Oleh itu, kajian ini menunjukkan keberkesanan penggunaan rumput vetiver sebagai agen phytoremediation dalam rawatan air sisa dalam proses phytoremediation.

ABSTRACT

During this era of globalization with the growing population, water pollution had become serious pollution issues and it needs to take action for maintain the quality of fresh water in Malaysia. Phytoremediation is a green technology that can use in remediation of polluted wastewater. This research was aimed to investigate the quality of wastewater based on parameter of BOD, COD, DO, Turbidity, TSS, Ammonia Nitrate, pH value and selected heavy metals. Besides, this research was conducted to determine the efficiency and performance of vetiver grass as phytoremediation agent. Pollutant uptake of vetiver grass was conducted in Environmental Laboratory and heavy metal analysis was done by using acid digestion and Atomic Absorption Spectrometry. This research took 3 weeks of collecting data and do the laboratory test. The concentration of wastewater were 100%, 75% and 50%. The results were obtained from 100%, 75% and 50% of wastewater showed that the performance removal was highest at 75% concentration of wastewater. The removal percentage for BOD (62.87%, 82.11% and 58.74%), COD (56.41%, 64.87% and 57.14%), DO (75.2%, 79.76% and 75.40%), Turbidity (26.44%, 29.44% and 25.47%), TSS (65.47%, 72.90% and 71.88%), ammonia nitrate (86.36%, 93.75% and 85.19%), pH value (23.36%, 23.86% and 21.48%). For the selected heavy metals Zinc (3.22%, 4.98% and 3.04%), Lead (14.83%, 15.86% and 13.10%), Copper (20.69%, 35.48% and 23.33%) were recorded also. The experiments were conducted for 3 weeks. Therefore, this research had shown the effectiveness of using vetiver grass as phytoremediation agent in wastewater treatment in phytoremediation process.

TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS **ii**

ABSTRAK **iii**

ABSTRACT **iv**

TABLE OF CONTENT **v**

LIST OF TABLES **viii**

LIST OF FIGURES **ix**

LIST OF ABBREVIATIONS **xi**

CHAPTER 1 INTRODUCTION

1.1 Introduction 1

1.2 Problem Statement 2

1.3 Research Objectives 4

1.4 Scope of Study 5

1.5 Significance of Research 6

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction 7

2.2 Water Pollution 8

2.3 Domestic Waste Water 9

2.3.1 Domestic Wastewater Parameters 10

2.3.2 Biological Oxygen Demand 13

2.3.3 Chemical Oxygen Demand 14

2.3.4 Dissolved Oxygen 14

2.3.5 Total Suspended Solids 14

2.3.6 pH Value 15

2.3.7 Temperature 15

2.3.8 Turbidity 15

2.3.9 Nitrogen as Ammoniacal Nitrogen 16

2.4 Phytoremediation 16
2.4.1 Phytoextraction 18
2.4.2 Phytodegradation 18
2.4.3 Rhizofiltration 18
2.4.4 Phytostabilization 19
2.4.5 Phytovolatilization 19
2.5 Heavy Metals 19
2.5.1 Zinc (Zn) 20
2.5.2 Copper (Cu) 20
2.5.3 Lead (Pb) 20
2.6 Vetiver Grass 20
2.6.1 Phytoremediation Potential on Vetiver Grass 21

CHAPTER 3 METHODOLOGY

3.1 Introduction 24
3.2 Plant and Sample Collection and Preparation 26
3.3 Sample Preparation for Phytoremediation 27
3.4 Analysis of Wastewater 29
3.4.1 In-Situ Test 29
3.4.2 Laboratory Test 29
3.4.2.1 Bioological Oxygen Demand 30
3.4.2.2 Chemical Oxygen Demand 32
3.4.2.3 Total Suspended Solids 33
3.4.2.4 Nitrogen as Ammoniacal Nitrogen 34
3.5 Heavy Metals Analysis 36
3.6 Calculation Removal Efficiency 37
3.7 Recording Data 37

CHAPTER 4 RESULT AND DISCUSSION

4.1 Introduction 38
4.2 Quality of Effluent Using Phytoremediation 39

4.3 Analysis of Results 40

4.3.1 pH Value 40

4.3.2 Temperature 42

4.3.3 Turbidity 44

4.3.4 Dissolved Oxygen 46

4.3.5 Total Suspended Solids 48

4.3.6 Biochemical Oxygen Demand (BOD) 50

4.3.7 Chemical Oxygen Demand (COD) 52

4.3.8 Ammoniacal Nitrogen 54

4.3.9 Lead 56

4.3.10 Copper 58

4.3.11 Zinc 60

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction 62

5.2 Conclusion 63

5.3 Recommendation 65

REFERENCES 66

APPENDIX A 70

APPENDIX B 71

APPENDIX C 72

APPENDIX D 73

APPENDIX E 74

APPENDIX F 75

APPENDIX G 76

APPENDIX H 77

APPENDIX I 78

LIST OF TABLES

Table 2.1	Classkification of Wastewater Treatment Facilities in Malay Peninsula (December 2008)	**10**
Table 2.2	The Relationship Between Treatment Process and The Quality of Treated Wastewater	**11**
Table 2.3	Quality Standards for Wastewater Discharged from New Treatment Plants	**12**
Table 2.4	Quality Standard of Wastewater Discharged from Treatment Facilities Before January 1999	**12**
Table 2.5	Quality Standard of Wastewater Discharged fFrom Treatment Facilities After January 1999	**13**
Table 2.6	Previous Study on Phytoremediation Process Using Vetiver Grass	**23**
Table 3.1	Instrument and Method for In-Situ Test	**29**
Table 3.2	Instrument and Method for Laboratory Test	**30**
Table 3.3	Recording Data	**37**
Table 4.1	Quality and Level Effluent Released	**39**

LIST OF FIGURES

Figure 1.1	Phytoremediation Process	3
Figure 2.1	Water Quality Basins in Peninsular Malaysia (2006)	9
Figure 2.2	Process That Involved in Phytoremediation Process	17
Figure 2.3	Multiple Benefits of Vetiver Grass	22
Figure 3.1	Methodology Flow Chart	26
Figure 3.2	Plant and Sample Preparation	27
Figure 3.3	Sample Preparation for Phytoremediation Process	28
Figure 3.4	BOD Apparatus	31
Figure 3.5	COD Apparatus	31
Figure 3.6	Total Suspended Solid Test Apparatus	33
Figure 3.7	Ammoniacal Nitrogen Reading by Using DR5000	34
Figure 3.8	Heavy Metals Test by Using Method of AAS	35
Figure 4.1	Result of pH Value Against Time Duration	40
Figure 4.2	Removal Efficiency Graph for pH Value	40
Figure 4.3	Result of Temperature Value Against Time Duration	42
Figure 4.4	Removal Efficiency Graph for Temperature Value	42
Figure 4.5	Results of Turbidity Value Against Time Duration	44
Figure 4.6	Removal Efficiency Graph for Turbidity	44
Figure 4.7	Results of Dissolved Oxygen Against Time Duration	46
Figure 4.8	Removal Efficiency Graph for Dissolved Oxygen	46
Figure 4.9	Results of Total Suspended Solids Against Time Duration	48
Figure 4.10	Removal Efficiency Graph for Total Suspended Solids	48
Figure 4.11	Results of Biochemical Oxygen Demand Against Time Duration	50
Figure 4.12	Removal Efficiency Graph for Biochemical Oxygen Demand	50
Figure 4.13	Results of Chemical Oxygen Demand Against Time Duration	52
Figure 4.14	Removal Efficiency Graph for Chemical Oxygen Demand	52
Figure 4.15	Results of Ammonia Nitrate Against Time Duration	54
Figure 4.16	Removal Efficiency Graph for Ammonia Nitrate	54
Figure 4.17	Results of Lead Against Time Duration	56
Figure 4.18	Removal Efficiency Graph for Lead	56

Figure 4.19	Results of Copper Against Time Duration	58
Figure 4.20	Removal Efficiency Graph for Copper	58
Figure 4.21	Results of Zinc Against Time Duration	60
Figure 4.22	Removal Efficiency Graph for Zinc	60

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
AN	Ammoniacal Nitrogen
APHA	American Public Health Association
As	Arsenic
BOD	Biochemical Oxygen Demand
Cd	Cadmium
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
DW	Distilled Water
EC	Electrical Conductivity
FE	Iron
HACH DR 5000	Spectrophotometer Procedures Manual
HM	Heavy Metals
H_2SO_4	Sulphuric Acid
K	Potassium
ICP-MS	Inductive Coupled Plasma-Mass Spectrometry
IWK	Indah Water Konsortium
Mg	Magnesium
Mg/L	Milligram per litre
Na	Sodium
NH3-N	Ammoniacal Nitrogen
NH_4^+	Ammonia Ion
NO^2	Nitrate
NTU	Nephelometric Turbidity Units
NWQS	National Water Quality Standard
O_2	Oxygen

pH	Potential Hydrogen
$PO^{3}-_{4}$	Phosphate
TSS	Total Suspended Solid
μs/cm	Microsiemens per centimetre
VG	Vetiver Grass
WQI	Water Quality Index
WW	Waste Water
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water is an essential component for survival of living things in the Earth. It contains of minerals, which is important for living things such as human beings, plant and aquatic life. Besides, water is mainly used for drinking, bathing, fisheries and other domestic purposes. But currently with rapid urbanization and population growth nowadays, phenomenon of water pollution had increasingly widespread in the world today. Some of causes of water pollution in this world because industrial waste, sewage and wastewater, mining activities, marine dumping and others activities causes that may influenced water pollution. Rapid development has produced great amounts of human wastes, including domestic, industrial, commercial and transportation wastes which inevitably ends up in the water bodies (Yuk Feng Huang *et al*. 2015). Sewage and wastewater caused pollution because its bring bacteria and harmful chemicals that may cause serious of health problems. Around 2.2 million individuals a year kick the bucket from diarrheal illnesses caused by drinking sullied water and poor cleanliness. As effect of this pollution, the leading cause of deaths and diseases, as reported during the United Nations World Water Day released on March 22, 2010.

Phytoremediation is the removal or controlling of various types of pollutants from the environment by using green plants (Aly Valderrama *et al.* 2012). This process had been paid attention few decades ago because of its environmental-friendly technique and also it use of least cost. In Malaysia, there are few of plant that been used for this process such as Vetiver Grass (Vetiveria Zizanioides), Salvia Minima (Water Spangles), Myriophyllum aquaticum (Parrot's Feather), Neptunia Oleracea (Water Mimmosa), and Pistia Statiotes (Water

Lettuce). Each of this plant contained of their own adaption mechanism which make them enabling to survive under highly polluted environment, some of this. Besides phytoremediation agent known as hyperaccumulators. This mean that they can survive and thrive in heavy metal that contaminated even though the soil contained high level of metal in their tissues**.** In this research, I had choose Vetiveria Zizanioides or known as vetiver grass as phytoremediation agent to treat wastewater treatment system.

1.2 Problem Statement

During this era of globalization with the growing population today, water pollution had become a serious pollution issue and it needs to take action for maintain the quality of fresh water in our country. In Malaysia, other than industrial waste and burning of fossil fuels, sewage and wastewater also include in the main of water pollution. It became main of pollution because they did not treat well before it disposed to ocean or river. According to ministry of environment, sewage and wastewater includes of dissolved contaminants, suspended solids and microorganisms. This ingredients that contained in wastewater might be harmful for all living things in the earth. As effect of this pollution, the leading cause of deaths and diseases, as reported during the United Nations World Water Day released on March 22, 2010. Among of disease that can caused of death from water pollution such as chlorea, diarhea, and malaria. Although the water is treated first before being discharged for human consumption, to remove the metals to meet the recommended level using the current traditional methods is quite challenging (Halizah Awang *et al*. 2015).

Phytoremediation of contaminated soils is generally believed to occur through one or more of the following mechanisms or process which phytoextraction, phytostabilization, phytodegradation, phytovolatilization, rhizofiltration and rhizodegradation (Kokyo Oh *et al.* 2014). In Figure 1.1 it shows the phytoremediation process that involved.

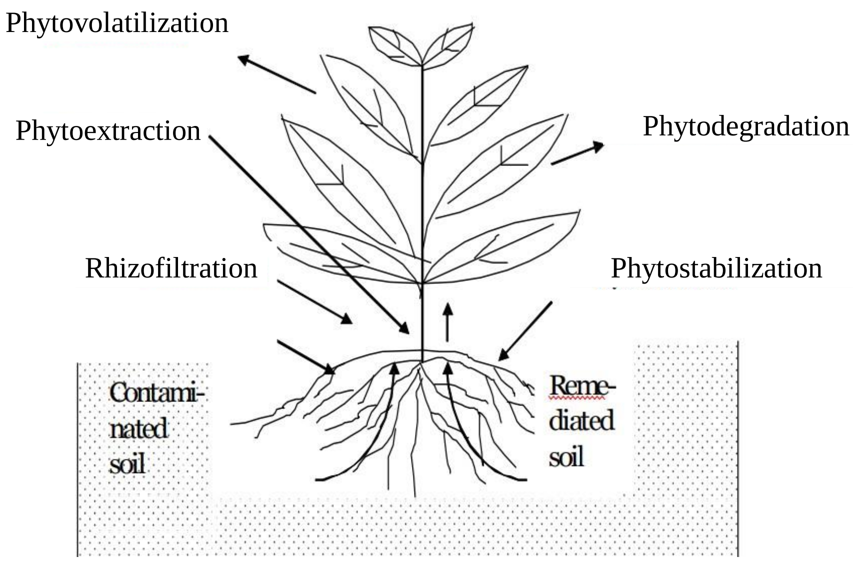

Figure 1.1 Phytoremediation Process

By using this technology, it may remove harmful chemicals that contained from the ground. This is because the roots of the plants absorb water and nutrients from polluted soil, groundwater and streams.

Besides, with the increasing of population growth of each year we should have a proper and proactive system of wastewater treatment to maintain and improve the quality of water. By having better of wastewater treatment system, it can guarantee that each of living things will get better quality of water for daily use. In fact, they also will have better of health in their life.

1.3 Objective

The objectives of this research are :

i) To investigate the quality of wastewater based on parameter of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolve oxygen (DO), total suspended solids, turbidity, pH value and selected heavy metal.

ii) To determine the efficiency and performance of vetiver grass as phytoremediation agent.

1.4 Scope of research

The aim of this study is to use available of local plants in Malaysia that can be use in treatment of wastewater in Gebeng, Pahang. The process would help in reducing the organic constituents of the water such as BOD, COD, DO, total suspended solids, turbidity, pH value and also selected heavy metal. The heavy metal and organic constituents of the water will be determined using water and wastewater standard method. Heavy metal that been choose in this research Plumbum (Pb), Copper (Cu) and Zin (Zn)

This experiment will be conducted in the Environment Laboratory Universiti Malaysia Pahang, Malaysia and using Vetiveria Zizanoides (Vetiver Grass) as phytoremediation agent in this research. Based from the results that will be obtain from the experiment, we will identify the performance and efficiency of vetiver grass as phytoremediation agent.

Based on this experiment, it will identify the efficiency of this local plants on the treatment performance and also to ascertain their heavy metal removal efficiency. From the results that will obtain, if this plants has the effectiveness it will be used for pretreatment option in wastewater treatment in the industrial area in Gebeng, Pahang.

1.5 Significance of research

This study found that Gebeng, Pahang is polluted due to human activities especially in the residential areas which is it is acidic and high in metals such as Zn, Cu, Mn and Zn. Based on the parameter of BOD and COD, DO, total suspended solids, turbidity pH value and also selected heavy metal it can be determine the water quality of wastewater in Gebeng, Pahang, Malaysia. From the aquatic plant that have in Malaysia which is vetiver grass that will be use in this research, it will identify the efficiency and performance of this aquatic plant as phytoremediation agent. Benefits that can obtained from this research is, we can perform wastewater treatment using natural resources without using the chemicals and also using low cost.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Wastewater is water whose physical, chemical or biological properties have been changed as a result of the introduction of certain substances which render it unsafe for some purposes such as drinking (Peace Amoatey & Richard Bani, 2011). In this day, mostly people will discharge their waste into the water. Some of this waste include of hair, shampoo, detergent, fat, households cleaners and others. This kind of waste that had been discharge to water may make people ill and also can damage of environment because of their chemical properties that contained in the waste.

In order to fulfilling the purpose of drinking, bathing, washing and others activities that involved in our daily life, it is very necessary for us to have clean and fresh water. The quality of water is affected by human activities and is declining due to the rise of urbanization, population growth, industrial production, climate change and other factors (Halder & Islam, 2015). To enhance production cops in agricultural field, they are using high use of fertilizers, insecticides and pesticides that can cause high level of water pollution. Because of this contamination, many of animals and plants species had lost their habitats.

Phytoremediation is one of the biological methods that can be used in remediation of polluted sites in situ (Milena Materac *et al.* 2015). This process is a generic term which using plants for clean up contaminated soils and water. Using plant for reduce the contaminant because it can break down or degrade organic pollutants, or remove and stabilize metal pollutants by acting as filters or traps. After this plant had absorbed the contaminant, the water pollution would be reduced and it will be safe for living things use for their daily activities.

2.2 Water Pollution

Water pollution is a serious problem in Malaysia and impacts negatively on the sustainability of water resources (Rafia Afroz *et al*. 2014). Besides, it also gives negative impact to other living things in this earth such as plants, people's health and also country's economy because of this water pollution. Thus, it reduces the water availability considerably. Polluted waters are not treatable for consumption because of it need high cost to treat it. Furthermore in these days, Malaysia became one of the better a developing country where the new development and construction is taking place in almost every place in this country. It is a good progress to realize the advancement for Malaysia becomes a better country however this rapid development has produced great amounts of human wastes, including domestic, industrial, commercial and transportation wastes which inevitably ends up in the water bodies. All of this types of waste that does not treated well made the increases of water pollution in Malaysia. Based on Figure 2.1 it shows the Water Quality Basins in Peninsular Malaysia (2006).

Figure 2.1: Water Quality Basins in Peninsular Malaysia (2006)

2.3 Domestic Wastewater

Nowadays, we need clean water supply in order to essential and maintaining a healthy community. For water supply there is two sources which is from the surface water and from ground water. In this area of globalization nowadays, as increase of population growth there is also increase in wastes from human activities that contaminate to the water supply. Waste-water generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds (Tukar *et al.* 2011). Thus for treatment the water supply from be worst and make bad effect to the consumers, water treatment will play important role to make sure water supply need to be clean and safe for public demand. Clean means that the water need to be colorless, odorless, tasteless and no suspended solids. While for safe, the water contain should have no pathogen, microorganism, no dangerous organic/inorganic and less mineral substances. Wastewater can be described as in the figure below

When water is used for domestic activities, it charges with various inorganic and organic compounds and becomes domestic wastewater (Narcis *et al.* 2011). For domestic wastewater they are two categories that can be classified which is brown wastewater and black wastewater. For brown wastewater it is include waste that is come from the kitchen, bath and laundry. While for black wastewater this waste include in urine, faeces and toilet paper

2.3.1 Domestic Wastewater Parameters

The wastewater parameters are commonly used for identification pollution index in the water bodies. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity (Tiwari, 2015). In order to treat wastewater it can be vary from conventional centralized systems to entirely decentralized and clustered systems. According to (José de Anda *et al.* 2018) centralized systems, which are usually publicly owned, collect and treat large volumes of wastewater for entire large communities, thus requiring large pipes, major excavations, and manholes for access. While decentralized systems collect, treat, and reuse/dispose of treated wastewater on site or near the generation point, centralized systems often reuse/dispose of treated wastewater far from the generation point.

According to Indah Water Konsortium (IWK) Table 1 shows the classification of public and private wastewater systems that treats grey and black water through proper treatment facilities or septic tanks. In Table 2.1 shows the Classification of wastewater treatment facilities in Malay Peninsula in December 2008.

Table 2.1 Classification of wastewater treatment facilities in Malay Peninsula (December 2008)

Wastewater Treatment Facilities	Quantity/Length	Population Equivalent (PE)
Regional STPs (Public)	74	5,600,000
Multipoint STPs (Public)	5,148	12,300,000
Pumping Stations (PS)	668	3,600,000
Private STPs	3,415*	2,000,000*
Communal Septic Tanks (CST)	3,635	434,000
Individual Septic Tanks (IST)	1,100,000	5,500,000
Pour flush (PF)	761,000	3,800,000
Sludge Treatment Facilities (STF)	40	—
Sewer Networks (km)	14, 000	—

*based on identified Private Plants

IWK reported the characteristics of BOD: 200 mg/L < BOD < 400 mg/L while for SS: 200 mg/L < SS < 350 mg/L. Table 2 shows the relationship between treatment processes and the quality of treated wastewater. Standard A refers to applies to the upstream side of the water intake. Table 2.2 shows the relationship between treatment processes and the quality of treated wastewater

Table 2.2 The relationship between treatment processes and the quality of treated wastewater

Treatment process		Effluent quality	
		BOD (mg/L)	SS (mg/L)
Activated sludge process or similar treatment process		10-30	15-40
Aerated lagoon		20-80	40-100
Stabilization pond process		20-100	30-150
Imhoff tank		50-150	30-150
Individual household septic tank		150-200	50-100
Reference Discharged effluent quality standards	Standard A	20	50
	Standard B	50	100

Based on the Environmental Standards for Water Quality enforced in 2009, Table 2.33 indicates quality standards for wastewater discharged from new treatment plants, Table 2.44 presents the standards permitted before January 1999 while Table 2.5 shows the standards defined after January 1999.

Table 2.3 Quality standards for wastewater discharged from new treatment plants

APPENDIX K1

Extracted from Environmental Quality (Sewage) Regulations 2009 (PU(A) 432)

SECOND SCHEDULE
(Regulation 7)
ACCEPTABLE CONDITIONS OF SEWAGE DISCHARGE OF STANDARDS A AND B

(i) New sewage treatment system

	Parameter	Unit	Standard A	Standard B
	(1)	(2)	(3)	(4)
(a)	Temperature	°C	40	40
(b)	pH Value	-	6.0-9.0	5.5-9.0
(c)	BOD5 at 20°C	mg/L	20	50
(d)	COD	mg/L	120	200
(e)	Suspended Solids	mg/L	50	100
(f)	Oil and Grease	mg/L	5.0	10.0
(g)	Ammonical Nitrogen (enclosed water body)	mg/L	5.0	5.0
(h)	Ammonical Nitrogen (river)	mg/L	10.0	20.0
(i)	Nitrate – Nitrogen (river)	mg/L	20.0	50.0
(j)	Nitrate – Nitrogen (enclosed water body)	mg/L	10.0	10.0
(k)	Phosphorous (enclosed water body)	mg/L	5.0	10.0

Note : Standard A is applicable to discharges into any inland waters within catchment areas listed in the Third Schedule, while Standard B is applicable to any other inland waters or Malaysian waters.

Table 2.4 Quality standards of wastewater discharged from treatment facilities before January 1999

(ii) Existing sewage treatment system (approved before January 1999)

This category refers to all sewerage treatment systems which were approved before the Guidelines for Developers: Sewerage Treatment Vol. IV, 2nd edition and were enforced by the Department of Sewerage Service, Ministry of Housing and Local Government, beginning January 1999. Below are the acceptable conditions for sewerage discharge according to type of sewage treatment systems:

	Parameter	Unit	Communal Septic Tank A	Communal Septic Tank B	Imhoff Tank A	Imhoff Tank B	Aerated Lagoon A	Aerated Lagoon B	Oxidation Pond A	Oxidation Pond B	Mechanical System A	Mechanical System B
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(a)	BOD_5 at 20°C	mg/L	200	200	175	175	100	100	120	120	60	60
(b)	COD	mg/L	-	-	-	-	300	300	360	360	180	240
(c)	Suspended Solids	mg/L	180	180	150	150	120	120	150	150	100	120
(d)	Oil and Grease	mg/L	-	-	-	-	-	-	-	-	20	20
(e)	Ammoniacal Nitrogen	mg/L	-	-	100	100	80	80	70	70	60	60

Note :

1. Standard A is applicable to discharge into any inland waters within catchment areas listed in the Third Schedule, while Standard B is applicable to any other inland water or Malaysian waters.
2. These standards are applicable to the sewerage treatment systems that may have been constructed prior to 1999 based upon approval given by other agency, other than the Department of Sewerage Services, Ministry of Housing and Local Government.

Table 2.5: Quality standards of wastewater discharged from treatment facilities after January 1999

APPENDIX K1

(iii) Existing sewage treatment system (approved after January 1999)

All sewerage treatment systems which were approved after the Guidelines for Developers: Sewerage Treatment Vol. IV, 2nd edition and were enforced by the Department of Sewerage Service, Ministry of Housing and Local Government, beginning January 1999 and up to date of coming into operation of these Regulations.

Parameter	*Unit*	*Standard* A	B
(a) BOD_5 at 20°C	mg/L	20	50
(b) COD	mg/L	120	200
(c) Suspended Solids	mg/L	50	100
(d) Oil and Grease	mg/L	20	20
(e) Ammoniacal Nitrogen	mg/L	50	50

Note:

Standard A is applicable to discharge into any inland waters within catchment areas listed in the Third Schedule, while Standard B is applicable to any other inland waters or Malaysian waters.

Below are the parameter that involved to determine the water quality of the wastewater:

2.3.2 Biological Oxygen Demand (BOD)

Biochemical oxygen measures the amount of oxygen that microorganisms consume while decomposing organic matter, it also measures the chemical oxidation of inorganic matter (Sagar, 2015). BOD reading will showed the amount of the dissolved oxygen that we need to consumed in biochemical decomposition of organic compound. Moreover, BOD reading also need in oxidation of some inorganic materials such as sulphate and iron. Results of BOD are expressed in mg/L which is microorganisms of BOD will takes to a long time which is in 20 days at 20°C.

2.3.3 Chemical Oxygen Demand (COD)

COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water (Patil. P.N, 2012). Other than BOD, COD also measure organic material that contaminated in water. This reading will be recorded in mg/L. Furthermore, COD is commonly used to define the strength of wastewaters. The National Water Quality Standard (NWQS) has set the threshold level of COD for surface water in Malaysia is 50.00 mg/L.

2.3.4 Dissolve Oxygen (DO)

Analysis of dissolved oxygen is to measures the amount of gaseous oxygen (O_2) that dissolved in a gaseous solution. An oxygen gets into water by diffusion from the surrounding air by aeration process. Which is rapid movement and a waste product of photosynthesis. By present of the dissolved oxygen in water, it can be used for living things that live in water such as fish and zooplankton to survive.

Dissolve gaseous form of oxygen is define as DO. DO enters water by diffusion from the atmosphere and as a by- product of photosynthesis by algae and plants (S.P. Gorde *et al*. 2013). DO is categorized as important parameters in environmental, this because DO reading will affect the growth, survival, distributions, and physiology of aquatic organisms. The concentration of DO may be vary with the reading of concentration of 0 mg/L to 18 mg/L. if the concentration of DO less than 2 mg/L, it will be indicate as poor water quality in that area. Besides, low water quality would have difficulty in maintaining of sensitive aquatic life.

2.3.5 Total Suspended Solids

Total suspended solids (TSS) are regarded as type of pollution because their high concentration in water is capable to affect growth and reproduction rates of aquatic flora and fauna, and reduce water quality for domestic use (Chun Chai, 2015). Solids that left in water after the water is filtered using filtration method or solids that been dried using evaporated method is called as TSS. It is measured in mg/L (organic + inorganic) or measure in mS/m for conductivity.

2.3.6 pH value

pH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range (Tiwari, 2015). Other than that, pH also defined as the negative log of the hydrogen-ion activity. The scale of pH value commonly in ranges of 0 to 14. When pH value more than 7.0 it is considered as alkaline or basic. While pH value is below than 7 it is considered as acidic which mean that its contains high of H+. pH value will be neutral when it is 7. For Malaysia Rivers, the threshold level by National Water Quality Standard (NWQS) is 5.00-
9.00.

2.3.7 Temperature

Temperature is includes in physical wastewater quality parameter. To measure the temperature reading it need to use Digital Thermometer. This digital thermometer will immersed into the sample and then the reading will be recorded. The temperature reading of the location will different according to the season. If the season in wet condition, thus the temperature will be low. While if the season in dry season, the temperature will be high.

2.3.8 Turbidity

Turbidity is a measure of the cloudiness/clarity of water. Cloudiness is caused by suspended solids mainly soil particles (sand, silt, clay), microscopic plants and animals that are suspended in the water column (Kale, 2016). Measurements results of turbidity measured in Nephelometric turbidity units (NTU). There is different in each indicator in each level of turbidity. If the level of turbidity in the moderately low levels, it means that it is healthy and well-functioning ecosystems. While, higher level of turbidity indicates that there is problems with stream systems. It means that, it consists of higher levels of parasites, viruses and also some bacteria.

2.3.9 Nitrogen as Ammoniacal Nitrogen

Ammonia, which is soluble, exists in equilibrium as both molecular ammonia (NH_3) and as ammonia in the form of the ammonium ion (NH_4^+) (Purwono *et al*. 2017). Ammonia is a nutrient that contains nitrogen and hydrogen. Sum of both NH_3 and NH_4^+ will be total ammonia. Total ammonia is what is be measure analytically in water. This nutrient concentration will depends on the pH value and temperature. If its shows high of temperature and pH value, thus it means that the formation of the molecular ammonia is a toxic. Increasing in toxicity because of higher ionised ammonia that influence from higher pH. Disinfection process must be form because of wastewater still contains pathogenic micro-organisms even though there is nitrogen removal process of black water and greywater. Presence of pathogenic micro-organism will contribute to the human health problems. By using phytoremediation process, it can remove the presence of pathogenic micro-organisms and then will increase the health level of human.

2.4 Phytoremediation

Phytoremediation (phyto, meaning "plant", and remedium, meaning "restoring balance") is a cleanup green technology, which involves the use of plants and their associated rhizospheric microbes for treating environmental contaminants such as Heavy Metals (HMs), organic compounds or radioactive elements, in soil, groundwater or industrial wastes (Singh H, 2017) Phytoremediation is process that using green plant to remove the contaminant that have in water. In phytoremediation, it can be classified into several respective areas such as phytoextraction, phytodegradation, rhizofiltration, phytostabilization, and phytovolatilization. The advantages in using phytoremediation process it is an effective cleanup technology. This is because this process will remove various type pollutant that contained in water which is organic and inorganic. Figure 2.2 shows the process that involved in phytoremediation process.

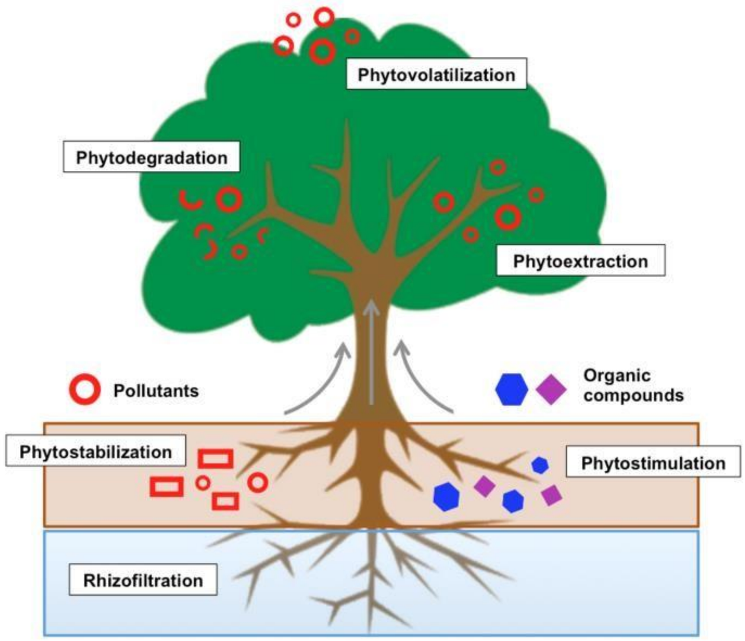

Figure 2.2: Process That Involved in Phytoremediation Process

All of organic compounds contain carbon combination with one or more elements. This organic compound have properties such as have lower melting and boiling point. It is also not so soluble in water and have high of molecular weight. This organic compound usually will serve as a food source for microorganisms. Effect of present organic compound it will reduce of DO in water which is can destroying aquatic life and also damaging ecosystem. Besides, some of this organic compound can caused cancer because of present of Trihalomethane (THM-carciogenec). It is produced when natural organic compound combine with chlorine that added to water and wastewater treatment plants for disinfection purposes. Inorganic compounds will dissociate into electrically charged atoms referred to as ions when it is placed in water. It can be classified into two classes which metal and non-metal. Effect of presentation in water it can cause diseases and aesthetic. Besides, it also can disturb human activities such as the formation of scale in boiler system and excessive usage of soap.

2.4.1 Phytoextraction

Otherwise called phytoaccumulation, this procedure incorporates the extraction of lethal metals from soil and water without aggravating its respectability (Chauhan, 2015). With the application of plant translocation, the root plant will play a role to accumulate the heavy metal. In this process, it is depends on the plant's natural ability to accumulate the substances such as heavy metals from environment. After that, this plant will isolate it in their cells until the plant can be collect.

2.4.2 Phytodegradation

Phytodegradation is the process where the partial or complete degradation of contaminants takes place inside the plant or within the rhizosphere and is driven by plant enzymes (Zhou Qixing *et al*. 2011). Examples of enzymes that involved in this process Cytochrome P450s, peroxidases, peroxygenases, laccases, phosphatases, nitroreductases and dehalogenases.

2.4.3 Rhizofiltration

Rhizofiltration is the utilization of a symbiotic relationship between plants and microorganisms to decompose organic contaminants in the rhizosphere (Tamara Jakovljević *et al*., 2016). In this process, the roots of the plants will degrade the contaminant that occurs in soil into the other compound.

2.4.4 Phytostabilization

Phytostabilization, where plants are used to stabilize rather than clean contaminated soil (A. Vasavi *et al*. 2010). This mean that, in this process it involved the stabilization of heavy metals that have in the root or soil surface and it will reduce the amount of heavy metal mobility. In addition, this process will prevent migration of the target pollutants into groundwater, thus preventing adverse effects on the ecosystem (Qixing *et al*, 2011). As result of this process, the soluble metals that have in root or soil surface it will be insoluble metal after undergoes this process.

2.4.5 Phytovolatilization

Phytovolatilisation are removal processes employing metabolic capabilities of plants and associated rhizosphere microorganisms to transform pollutants into volatile compounds that are released to the atmosphere (Wenzel, 2009). This process is related to phytodegradation because both process will absorb the contaminant into the plant, but in this process it will release the contaminants through the evapo-transpiration process after the modification of plant.

2.5 Heavy Metal

The term ‘‘heavy metal’’ refers to any metal and metalloid element that has a relatively high density ranging from 3.5 to 7 g cm3 and is toxic or poisonous at low concentrations, and includes mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), zinc (Zn), nickel (Ni), copper (Cu) and lead (Pb) (Gautam, 2014). The presence of heavy metal can be found everywhere in the environment. It could be contributed by anthropogenic or by natural state. Anthropogenic activities include from paints and pigments, waste soils, municipal wastewater and other activities that relate. Meanwhile, natural state from water, air and soil.

Nowadays, environmental pollution that caused from toxic heavy metals became dangerous issue that caused worried to worldwide. This is because it would bring forth adverse effects to environment from the toxic of heavy metals especially in agriculture sector in terms of biomass, soil fertility and crop yields. In addition, heavy metal that came from iron ore operation will affect the environment and aquatic life in lake and it would lead to accumulation and biomagnification process occur in food chain.

2.5.1 Zinc (Zn)

Zinc (Zn) is an important of mineral that need in living organisms, this is because Zn exist in most cell for human metabolism. Usually this mineral could be found in air, water and soil. With the decomposition into sediment that binds together with organic and inorganic matter, Zn mostly could be found in water. In other hand, Zn is considered to be relatively non-toxic, especially if taken orally. However, excess amount can cause system dysfunctions that result in impairment of growth and reproduction (Jiwan *et al*, 2011). If take over dose of Zn in our daily activities, we might exposed to dangerous illness such as diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anemia.

2.5.2 Copper (Cu)

Copper (Cu) is a fundamental substance to human life, however in high measurements it can bring about iron deficiency, liver and kidney harm, and stomach and intestinal disturbance (Mitra, 2014). Cu can be found in water and food. It can’t be found in the air because it has low concentration in the atmosphere.

Due to anthropogenic activities, concentration of Cu had been increased rapidly in the environment field. As we know, Cu is one of the minerals that we required as well as plant. This is because, it will produce energy production for the biochemical reaction in human. Other than that, Cu also can produce melamin. Presence of melamin is good in human body because it can repair and maintain connective tissue in heart and atteries. Although it is good, too much of Cu will be problem to living things and its known as trace element. Trace element means that element that could be harmful to living things even though the elements have low concentration.

2.5.3 Lead (Pb)

Lead is an element with atomic number 32 and after iron, is the most commonly used metal. Lead has entered agricultural products due to the use of chemical fertilizers, herbicides, sewage treatment and contamination of soil by sewage (Hashemi M *et al*. 2017)**.** Even though it have low concentration of toxic, it can lead to blood poisoning in children. Pb can enter into human body through inhalation and ingestion.

2.6 Vetiver Grass

Vetiver or khus (Vetiveria zizanioides) is a tall, perennial grass which grows wild in drier, periodically flood inundated tracts, of western and north-central India (D. Balasankar *et al*. 2013). It has short rhizomes and a massive, finely structured root system (J. Janngam *et al*. 2010). Characteristics of roots that have in vertiver grass is its's deep root. Because of this deep root systems it makes vetiver grass can tolerance due to extreme drought weather until 6 months of duration droughts. Besides, it can remains at its position even though there is heavy and strong water flow. Other than that, characteristics of vetiver grass, it its highly resistant due to diseases, fire, heavy metals and pets.

As a plant that be useful for agricultural and biological engineering, vetiver grass have characteristics such as it seed can be sterile and the plant did not produce stolons and rhizoms which it can be invasive or weedy. Besides, its crown must be located below soil surface so it can resist fire and overgrazing. Other than that, vetiver grass have exhibitxerophytic and hydrophtic characteristics that can make it survive due to forces of nature.vetiver grass is capable to grow in wide range of climates. It resist from -15°C to more than 55°C and can resist of 300 mm of rainfall to 6000 mm of rainfall. Figure below show multiple benefits of vetiver grass systems, source (Joice K Joseph *et al*. 2017). Figure 2.3 shows the multiple benefits in vetiver grass.

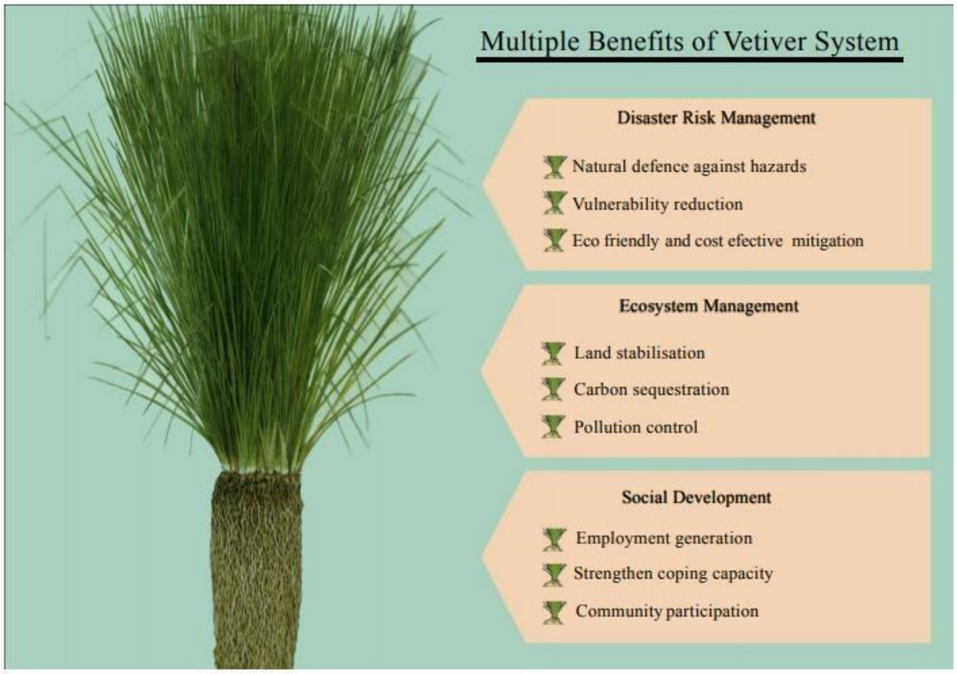

Figure 2.3 Multiple Benefits of Vetiver Grass

2.6.1 Phytoremediation potential of Vetiver Grass

Vetiver grass has undergone lot of studies on its capable in phytoremediation process. Based on the studies it shows that vetiver grass have an ability on pollutant removal in organic and inorganic materials that have in environment. Besides from the studies also show that, vetiver grass can prevent and treating contaminated water. It can eliminate or reduce the volume of wastewater and can improve the quality of polluted water and wastewater. Other than that, vetiver grass also can prevent and treating contaminated land. Its mean that it can controlling off site pollution and also absorbing heavy metals and other pollutants. Furthermore, vetiver grass can treating other nutrients and also other pollutants that have in wastewater and leachate. Table 2.6 shows on previous studies on phytoremediation process using vetiver grass

Table 2.6: Previous Studies on Phytoremediation Process using Vetiver Grass

Type of sources	Type of pollutant	Finding / highlights	References
Palm Oil Mill Effluent (POME)	BOD, COD	BOD in low concentrations (90%), high concentration (60%) & control (no plant) is 15% COD reduction was 94 % (low concentration), 39% (high concentration) & 12% (control) Treatment : low concentration > high concentration	Darajeh *et al*. 2014
Treatment Metal	Heavy metals Cu, Fe, Mn, Pb, Zn	Vetiver grass was found effective in removing heavy metals (Cu, Fe, Mn, Pb, Zn), but the rate of removal and metal accumulation depend on the plant root length and density and the concentration of heavy metals. Longer plant root length and higher vetiver density increased the uptake of heavy metals except for Fe at low pollutant concentration but the effects become less apparent at high metal concentration	Suelee *et al*. 2017
Hydroponic and pot study	Pb	Vetiver grass can be used to enhance pb phytoextraction from contaminated soil in association with AM fungus	Punamiya *et al.* 2010
Remediation of Contaminated Soil	Trichloroethylene	It was indicated that vetiver grass had an efficiency to translocate TCE from root to shoot. TCE was analyzed from soil left in the pots.	J. Jangaam *et al.* 2010
Hydroponic Technique	Mercury, lead, synthetic dye coliform bacteria.	Vetiver grass is highly capable of reducing coliform bacterial counts by 100% for 6 months of planting. Mercury and lead in was found to be decreased by 100% by planting Vetiver grass for 4 months. From the UV-vis spectral analysis, a reduction in dye removal was also observed by planting VG for 6 months in the wastewater.	N. Girija *et al. 2016*

CHAPTER 3

METHODOLOGY

3.1 Introduction

Generally, research methodology explained about the laboratory test method that used along in this research. It is a flow of research and detail from the start until the end of the research implementation.

To make sure this research process are in the good progress, a flow chart is needed as it is an important part in this research. From this flow chart, the preparation that needs and the planning for this research to be carry out will be run smoothly. Based on the all of information that had been gather from the books, journal, thesis and website will make more understanding to complete this research.

The objectives for this research is to investigate the quality of wastewater based on parameter of BOD, COD, DO, total suspended solids, pH value and selected heavy metals. Based on the results that had obtained from the waste water parameter, the efficiency and performance of vetiver grass as phytoremediation agent had be determine. Figure 3.1 shows methodology flow chart in this research.

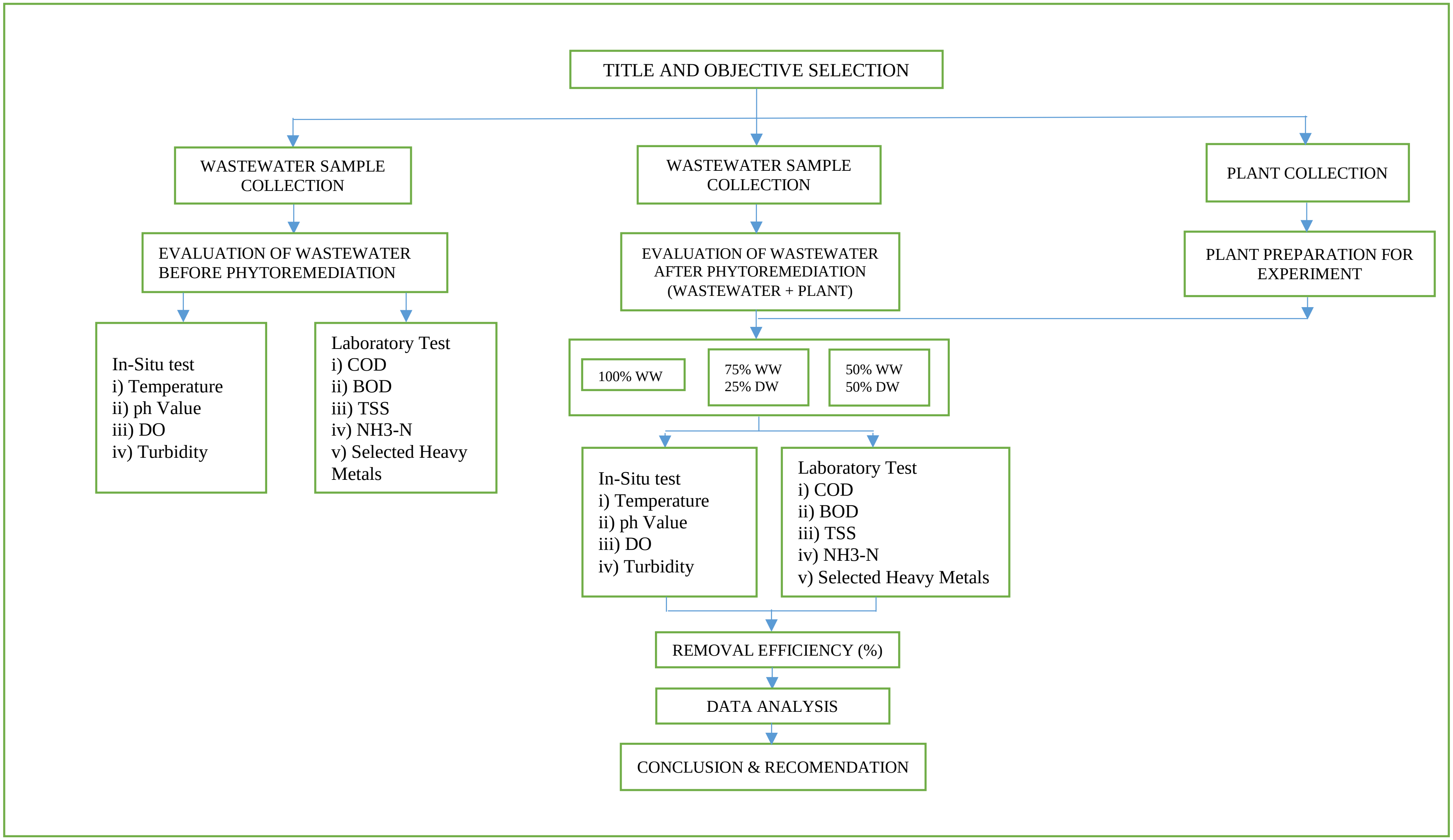

Figure 3.1: Methodology Flow Chart

3.2 Plant and Sample Collection and Preparation

Vetiver Grass or its scientific name known as *Vetiveria Zizanoides*, was used in this research. This plant was collected from Gambang which are this plant are located along the roadside heading to Pahang Matriculation College. Usually, most of this plant are planted at the slope of mountain, near the road or at the lake and swampy area.

The minimum amount that require to use this plant in this research about 20 VG slips in this research. To collect this plant it must be the complete plant which is included with its root. Normally, the length root of this plant is about 10 cm while its shoot length about 20 cm. With this length of roots, this plant can reach 3-4m of rooting depth in the first year and can highly resistance to the fire. After collected the plant and then all of the plant need to wash with tap water first to clean the plant from the soil that have at root during collection plant. After that the plant had washed with the tap water, it will be washed with the distilled water. Next, the plant will preserved with distilled water in the pot for one week.

In this research, wastewater in Gebeng, Pahang residential area was used. This sample collection were took from sewerage Gebeng, Pahang. This wastewater collection are needed to use in this research as to identify the potential of VG as phytoremediation agent. About 30 L of wastewater need to collect from the residential area to use in this research. Based on the results of this research, it will compare and bound to Malaysia Water Quality Standards. In Figure 3.1 shows the plant and sample preparation in this research.

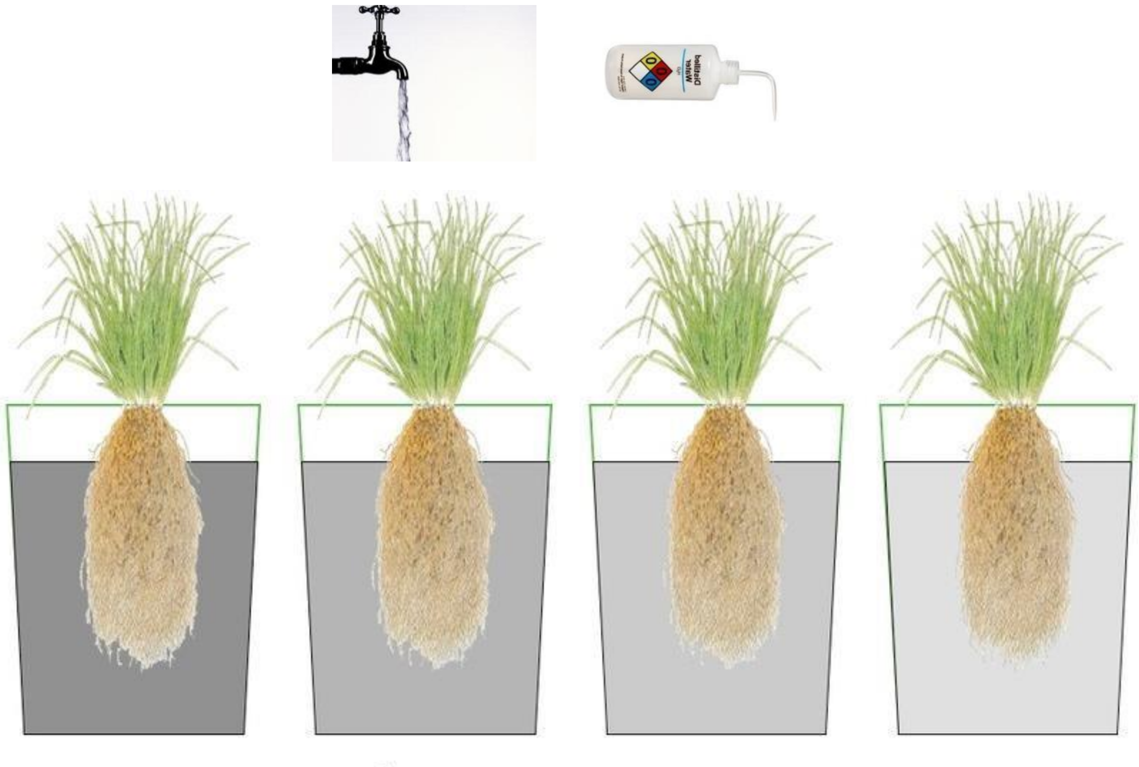

Figure 3.2 Plant and Sample Preparation

3.3 Sample Preparation for phytoremediation

Wastewater that had been collected from sewerage Gebeng, Pahang will put in the 3 pot with contained distilled water and VG. Each of the pot will be mark at 10L of level pot. The percentage of distilled water and wastewater that be used will be different for each pot. For the first pot, it contained 50% of wastewater and 50% of distilled water. This is mean in the first pot it will have 5L of distilled water and another 5L of wastewater. For the second pot, 75% of wastewater will be used which its contained 7.5L and for distilled water it contained 2.5L of distilled water which is 25%. For the last pot, the pot will contained 100% of wastewater. The aim for the different percentage of wastewater and distilled water in every pot because to identify the performance of vetiver grass for remove pollutant that contained in wastewater.

Pot 1

100% Wastewater

Pot 2

75% Wastewater

and

25% Distilled Water

Pot 3

50% Wastewater

and

50% Distilled Water

Figure 3.3 Sample Preparation for Phytoremediation Process

3.4 Analysis of Wastewater

To measure the concentration of pollutants present in wastewater, all of this sample that related in this research had been analysed in Environmental Engineering Laboratory. There are two types of parameter that involved in this research which is in-situ test and ex-situ test.

3.4.1 In-situ test parameter

In- situ test was conducted to determine five parameter which are pH, dissolved oxygen (DO), temperature, and turbidity. Table 3.1 shows the instrument and method use for In-Situ Test.

Table 3.1 Instrument and Method for In-Situ Test

Parameter	**Instrument**	**Unit**
pH	YSI 6600-V2 multiparameter sounde	-
Temperature	YSI 6600-V2 multiparameter sounde	°C
Conductivity	YSI 6600-V2 multiparameter sounde	µS/cm
Turbidity	HACH Model 2100 P-Turbidity	NTU
DO	YSI 6600-V2 multiparameter sounde	mg/L

3.4.2 Laboratory test

Ex-situ test during this research had been conducted in environment engineering laboratory university Malaysia Pahang. Test that included in this research include of Chemical Oxygen Demand, Biochemical Oxygen Demand test, Total Suspended Solid test Ammoniacal Nitrogen test and selected heavy metal test. Table 3.2 shows the instrument and method for laboratory test.

Table 3.2: Instrument and Method for Laboratory Test

No	Parameter	Unit	Method Use	Standard Code APHA/HACH
1	BOD	mg/L	Azide Modification Method	APHA 5210 B#
2	COD	mg/L	Apen Reflux Method	APHA 5220 B#
3	TSS	mg/L	Gravimetric Method	APHA 2005
4	Nitrogen as Ammoniacal Nitrogen	mg/L	Salicylate Method1	HACH DR5000 Method 8155
5	Pb	mg/L	Dithizone Method	APHA 3500-Pb(B)#
6	Zn	mg/L	Dithizone Method	APHA 3500-Zn(B)#
7	Cu	mg/L	Dithizone Method	APHA 3500-Cu(B)#

3.4.2.1 Biological Oxygen Demand

BOD test involves the determination of oxygen uptake by bacteria under standard condition. This standard condition is for 5 day incubation at 20°C of temperature. BOD is the amount of oxygen that required by bacteria in order to stabilize organic matter under aerobic condition. In aerobic process (O_2 is present), heterotrophic bacteria oxidise about 1/3 of the colloidal and dissolved organic matter to stable end product (CO_2 + H_2O) and convert the remaining into new microbial cells that can be removed by wastewater setting. To ensure that DO will present throughout the test period for strong wastewater sample, it need to be dilute in keeping the solubility of oxygen. The BOD apparatus were show in Figure 3.4

$$BOD_5 = \frac{D_1 - D_2}{P} \tag{3.1}$$

Where,

D_1 = DO value in initial sample.

D_2 = DO value in final sample

P = Dilution factor.

$$P = \frac{Volume\ of\ sample}{Volume\ of\ sample + Volume\ of\ distilled\ water}$$

Figure 3.4 BOD Apparatus

3.4.2.2 Chemical Oxygen Demand

COD test can use to determine the organic strength in wastewater. Compared to BOD test, COD test can be completed more quick which in only for time in 3 hours duration compared to BOD need to wait for 5 days duration. The basis of the test that all of organic compound that include of some exceptions, can be oxidizing agents under highly acidic conditions. Generally, COD test used for determine the strength of industrial wastewater that is high of toxicity for BOD test. Equation 3,2 shows the equation for COD. In Figure 3.5 shows the COD apparatus

$$COD = \frac{8000\,(a-b)}{\forall} \times normality\ of\ Fe(NH_4)_2(SO_4)_2 \tag{3.2}$$

Where

a = amount of ferrous ammonium sulphate titrant added to blank, mL

b = amount of titrant added to sample, mL

$\forall$ = volume of sample, mL

8000= multiplier to express COD in mg/L of oxygen.

Figure 3.5 COD Apparatus

3.4.2.3 Total Suspended Solids

Solids suspended in water may consist of inorganic and organic particles or of immiscible liquids. A suspended solid are objectionable in water as it is aesthetically displeasing and provides sites chemical and biological agents. Most suspended solids can be removed from water by filtration. Portion of the total solids retained on the filter with a specified pore size (1.58µm), measured after being dried at 105°C. High concentrations of suspended solids will lower water quality by blocking sunlight from reaching submerged vegetation. As the amount of sunlight passing through the water is reduced, then lessen the ability of the water to hold oxygen that is necessary for aquatic life. Total suspended solids equation was show in equation 3.3. In Figure 3.6 shows the apparatus of total suspended solid

$$Total\ Suspended\ Solids = \frac{(A-B)}{C} \tag{3.3}$$

where

A = weight of filter and dish + residue

B = weight of filter and dish

C = volume of sample filtered

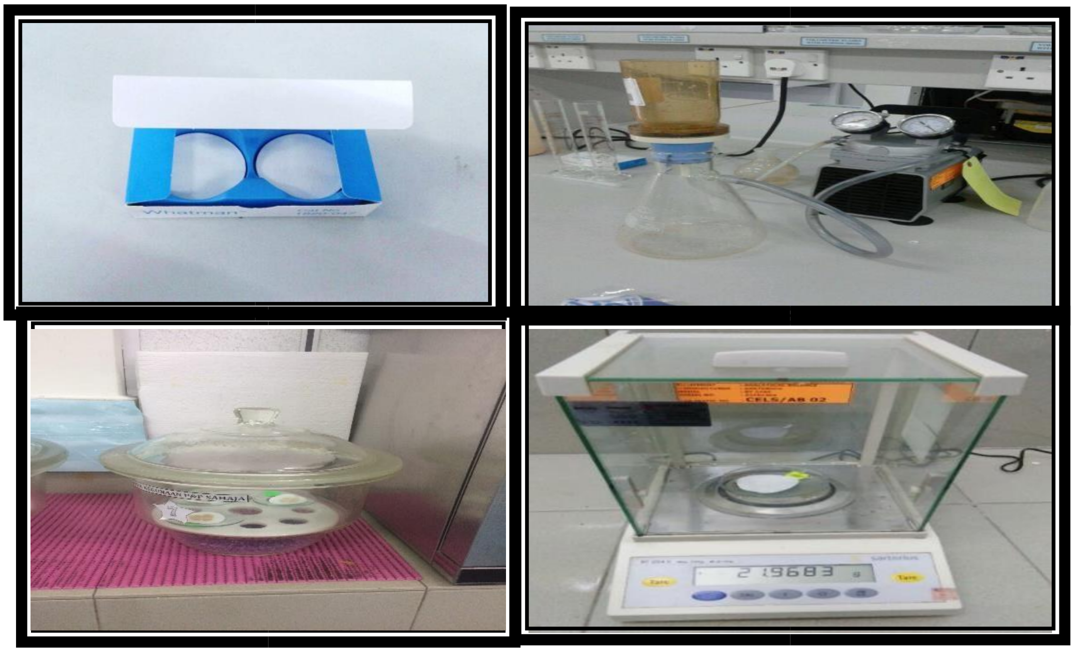

Figure 3.6 Total Suspended Solid Test Apparatus

3.4.2.4 Nitrogen as Ammoniacal Nitrogen

The Ammoniacal Nitrogen was followed Salicylate Method1 (0.01 to 0.50 mg/L NH3–N) based on HACH DR5000 Method 8155. The amount of Ammoniacal Nitrogen in a sample can be obtained by using equation in 3.4. Figure 3.7 shows the Ammoniacal Reading by Using DR 5000.

$$NH_3 - N = \frac{TAN \times 10^{pH}}{e^{\left(\frac{6344}{273+°C}\right)} + 10_{pH}} \tag{3.4}$$

Where,

NH_3-N = ammonia concentration as nitrogen

(mg/L) TAN = total ammonia nitrogen

concentration (mg/L) pH = pH value

°C = temperature

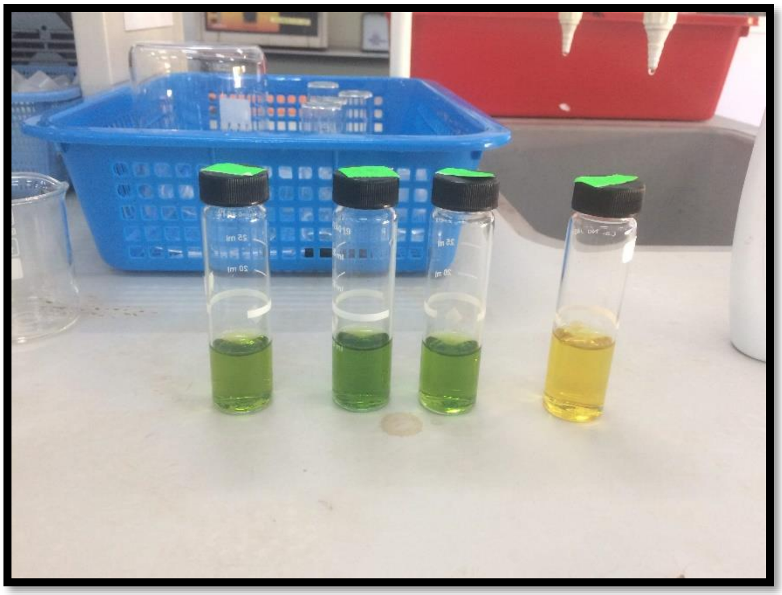

Figure 3.7 Ammoniacal Reading by Using DR 5000

3.5 Heavy Metal Analysis

For heavy metals, there are two method that can use for analysing in the research which is Atomic Absorption Spectroscopy (AAS) and Inductive Coupled Plasma-Mass Spectrometry (ICP-MS). But in during this research conducting only AAS method was used to analyse heavy metals which is AAS method. This method was used to analyse for a few targeted heavy metals which are Copper (Cu), Lead (Pb) and Zinc (Zn). For heavy metals were test by using method of AAS in Figure 3.8

Figure 3.8 Heavy Metals Test by Using Method of AAS

3.6 Calculation Removal Efficiency

The purpose of a wastewater treatment plant is to remove contaminants in the influent. Therefore, the percent removal efficiency formula is frequently used to calculate the performance of the plant to assess how much contaminants were removed. The following is the formula for percent removal efficiency. The influent and effluent concentrations are the two values that are entered into the formula to obtain the answer.

$$\%\ Removal\ Efficiency = \frac{Initial\ Reading\ \left(\frac{mg}{L}\right) - Final\ Reading\ \left(\frac{mg}{L}\right)}{Initial\ Reading\ \left(\frac{mg}{L}\right)} \tag{3.4}$$

3.7 Recording data

The data will be collected by using Table 3.3

Table 3.3: Recording Data

Week	Reading		
	50% wastewater + 50% distilled water	75% wastewater + 25% distilled water	100% wastewater
0			
1			
2			
3			

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter it will discussed the results of study that have been carried out by experimentally by using wastewater sample that located in industrial are in Gebeng, Pahang. The purpose of doing this experiment are to determine the quality of wastewater and also to determine the efficiency and performance of vetiver grass as phytoremediation agent.

There are two test that had been done which are in-situ test and laboratory test. Parameter that had been test for physical parameter are, temperature, turbidity, and TSS. Chemical parameter that had been test are pH, Ammoniacal Nitrogen (NH_3-N), DO, BOD, COD oil and grease and heavy metals. For heavy metals, substances that had been used are Zinc (Zn), Copper (Cu), and Lead (Pb)**.** All of this test that involved are related to each other in order to determine the effectiveness of the materials towards the effluent. From the data, the graphs are plotted by using Microsoft Excel program and result for each parameter should be within range that has been classified in Water Quality Index.

4.2 Quality of Effluent Using Phytoremediation

In this research, sewage water in industrial area in Gebeng, Pahang was used as sample wastewater for effluent. There are three different sample of wastewater concentration in this research. The purpose of different concentration of wastewater to identify the best performance of concentration for phytoremediation process. The quality and level of effluent released were showed in Table 4.1

Table 4.1: Quality and Level of Effluent Released

Parameter	Unit	Industrial Effluent		
		100%WW	75%WW	50%WW
pH value	-	9.22	9.12	9.03
DO	mg/L	5.84	3.84	4.96
BOD	mg/L	9.7	10.0	11.15
COD	mg/L	39	37	35
TSS	mg/l	169	155	128
Ammonia Nitrate	mg/L	0.44	0.32	0.27
Pb	mg/L	0.445	0.454	0.435
Cu	mg/L	0.058	0.062	0.060
Zn	mg/L	0.465	0.462	0.46

4.3 Analysis of Results

4.3.1 pH value

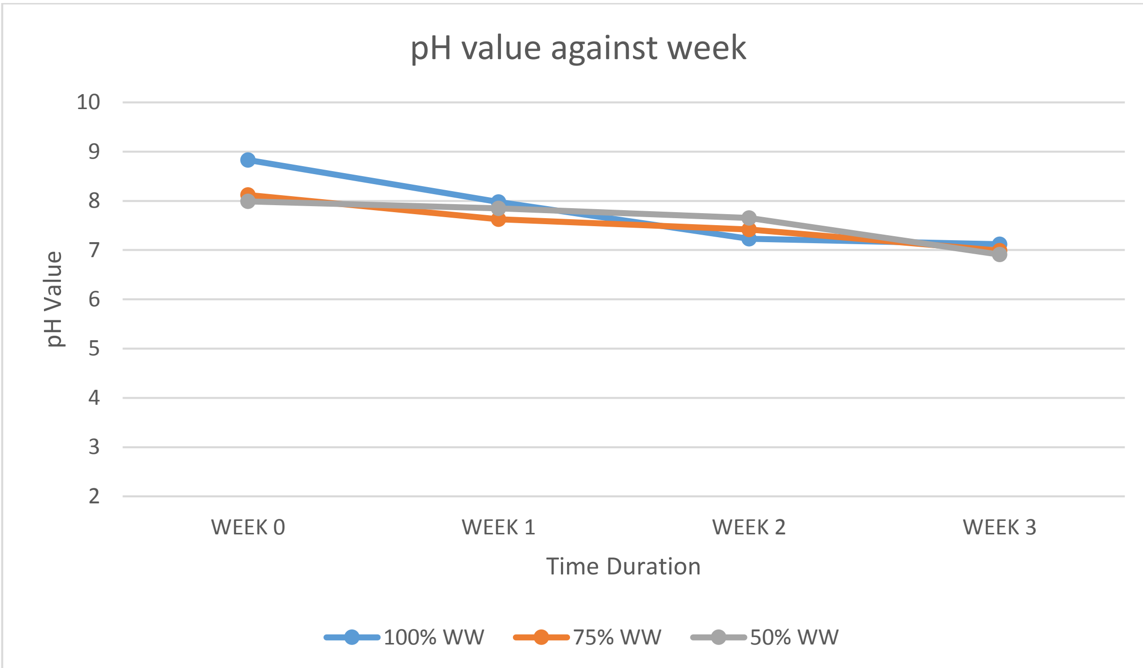

Figure 4.1 Result of pH Value against Time Duration

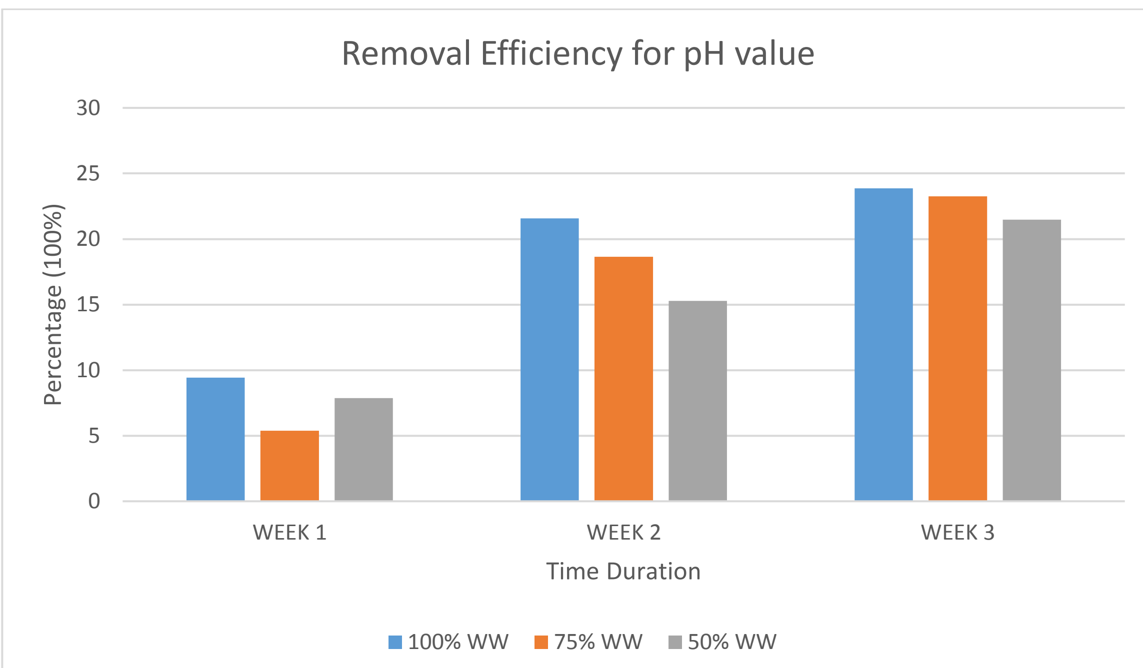

Figure 4.2 Removal Efficiency Graph for pH Value

Figure 4.1 show the result of pH value for three weeks while in Figure 4.2 shows the removal efficiency graph for pH value. As stated in Third Schedule of Environmental Quality, Sewage and Industrial Effluent Regulation 1979, the pH value of the treated effluent should be in the range of 6.0 – 9.0 before it is discharge to the river.

Based on the results of pH value for all of three different concentrations it shows that pH value reading for initial week for 100% sample of wastewater is 9.22 which is the industrial wastewater sample is in alkali. Then the reading was decreased to 8.35 with 9.44% of removal efficiency in week 1. For the next week, this sample also showed decreasing with pH value of 7.23 and the removal efficiency for week 2 is 21.58%. While for week 3 pH value had been decreased to 7.02 with 23.86% of removal efficiency.

For the second pot which contained 75% of wastewater sample and 25% of distilled water, also showed the decreasing pattern of pH value. pH value for initial week is 9.12 then the pH value was decreased to 8.63 with 5.37% of percentage removal on week 1. On the next week, percentage removal was increased to 18.64% which is pH value was decreased from 8.63 to 7.42. At the end of week 3 pH value keep decreasing to 6.99 which is its percentage removal increased to 22.36%.

While for the third pot, the concentration of wastewater sample had been reduced to 50% and it contained 50% of distilled water. The initial pH value for this pot was 9.03 which is less compared to other pot but this pH value also not in the standard of Environmental Quality. In the first week of phytoremediation process, pH value had been dropped to 8.32 with 7.86% of removal efficiency. It keep decreasing on the next week with 15.28% removal percentage. On the week 3 it shows that the removal percentage increased to 21.48%.

Based on the different sample of wastewater it shows that 75% of wastewater sample have the most decreasing of pH value reading compared to other sample with pH value of 6.99 at week 3. So for the pH value 75% sample of wastewater shows the better performance on reducing the pH value which is it’s have 23.36% of removal efficiency compared to 75% sample of wastewater and 50% sample of wastewater. Thus it shows that by Vetiver Grass can be use as phytoremediation agent to reduce pH value for industrial wastewater.

4.3.2 Temperature

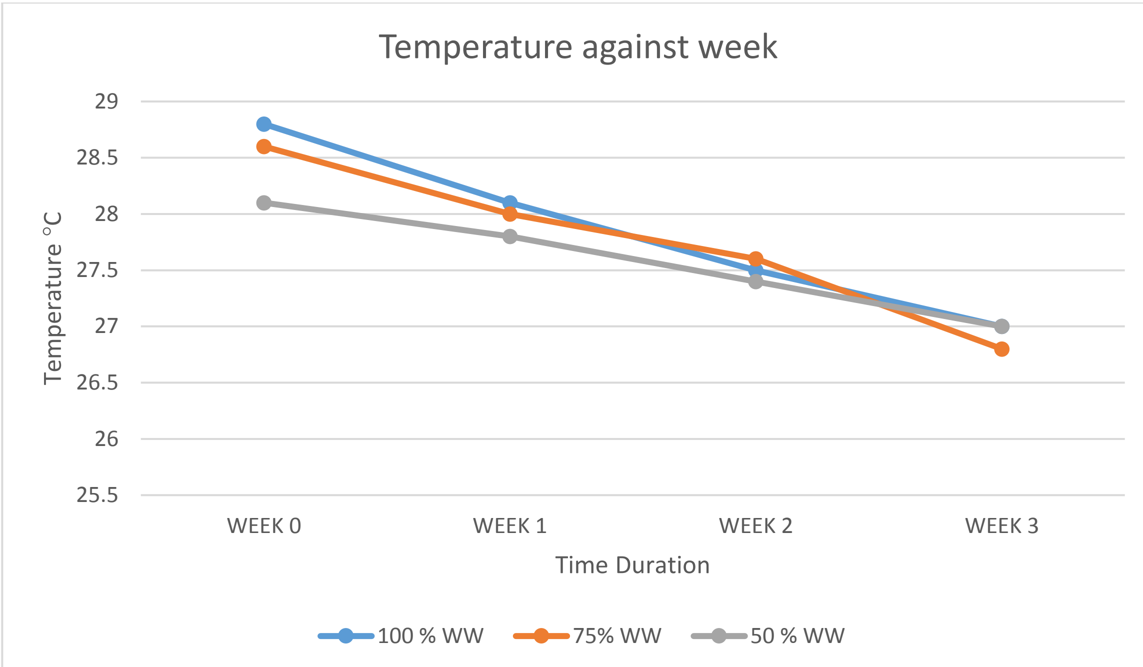

Figure 4.3 Result of Temperature Value against Time Duration

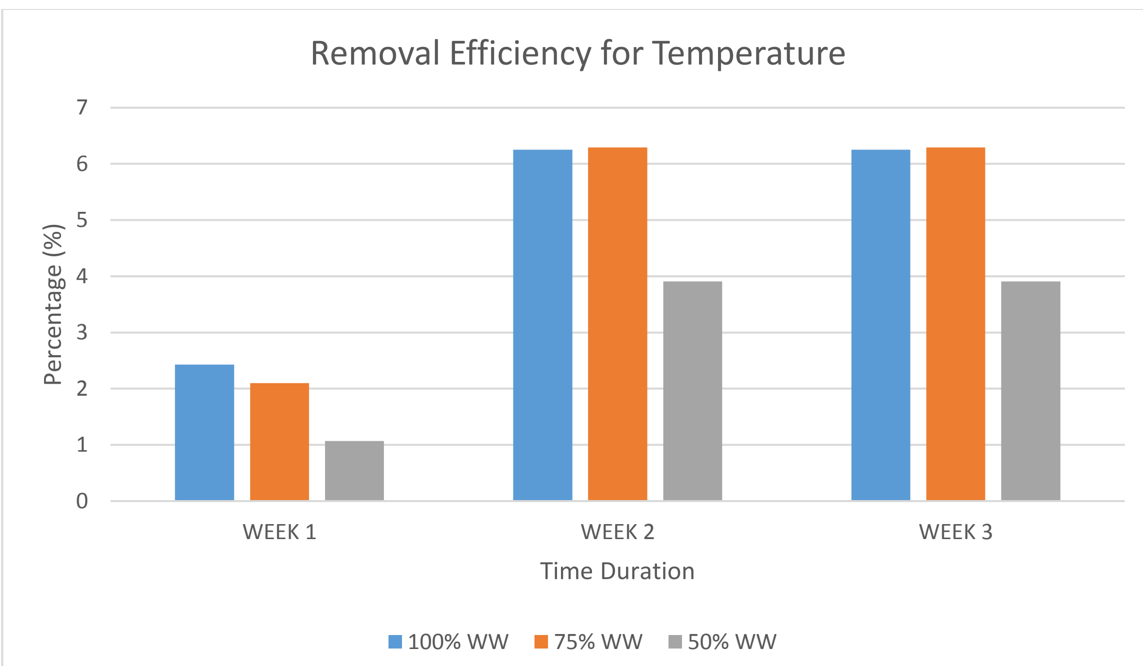

Figure 4.4 Removal Efficiency Graph for Temperature

The results of temperature had shown in Figure 4.3 while for removal efficiency for temperature showed in 4.4. Temperature is physical water quality parameter. Temperature is one of the most important parameters in natural surface water system. It becomes an important indicator for identifying healthy or poor water conditions. Most of the chemical reactions that occur in natural system is effect by temperature.

For the initial week, the temperature for pot 1, pot 2 and pot 3 was 28.8°C, 28.6 °C and 28.1 °C. On the next week, the temperature for all pot showed decreasing temperature which is for pot 1 28.1°C, 28°C for pot 2 and 27.8°C for pot 3.

Based on the results obtained, the temperature for pot 2 show the highest of removal percentage for the final week which is 6.29%. While for the least removal efficiency was in pot 3. The removal efficiency for pot 3 was 3.91%. For pot 1 with 100% of concentration wastewater, the removal efficiency was 6.25%.

The average of temperature during this research in progress was 28°C from the initial week until the third week. The temperature did not show high of decreasing temperature because of during this research in progress there were in hot weather. Even though there were in hot weather, but the plant still alive until the end of the week. So it showed that Vetiver Grass can stay alive in hot temperature and this plant can be as phytoremediation agent.

4.3.3 Turbidity

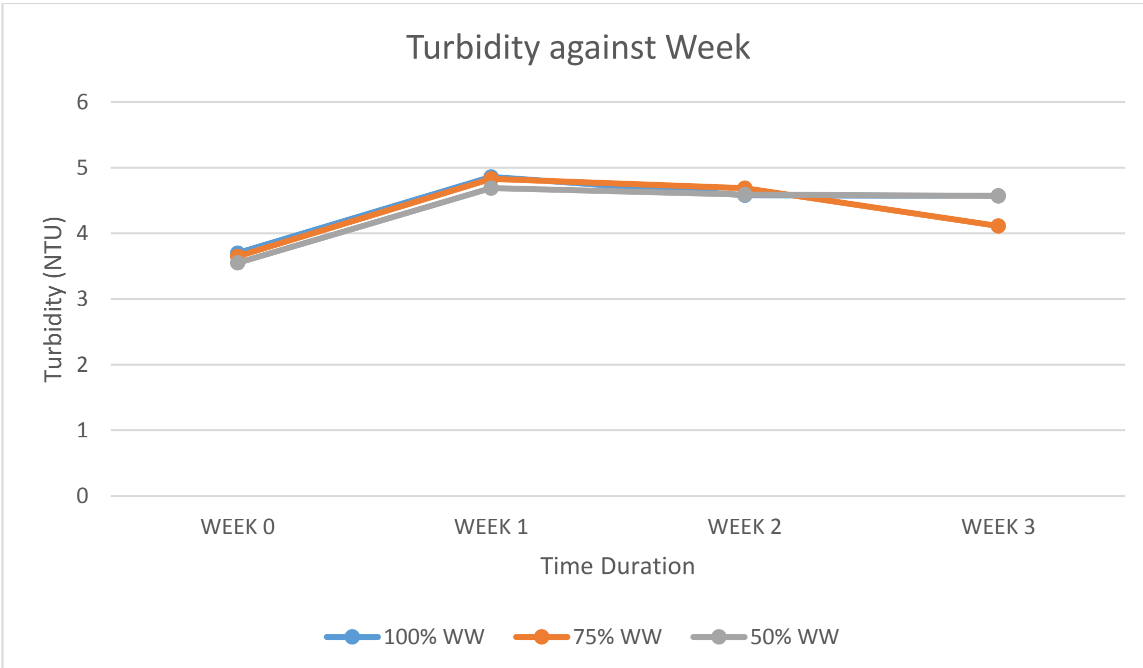

Figure 4.5 Results of Turbidity Value against Time Duration

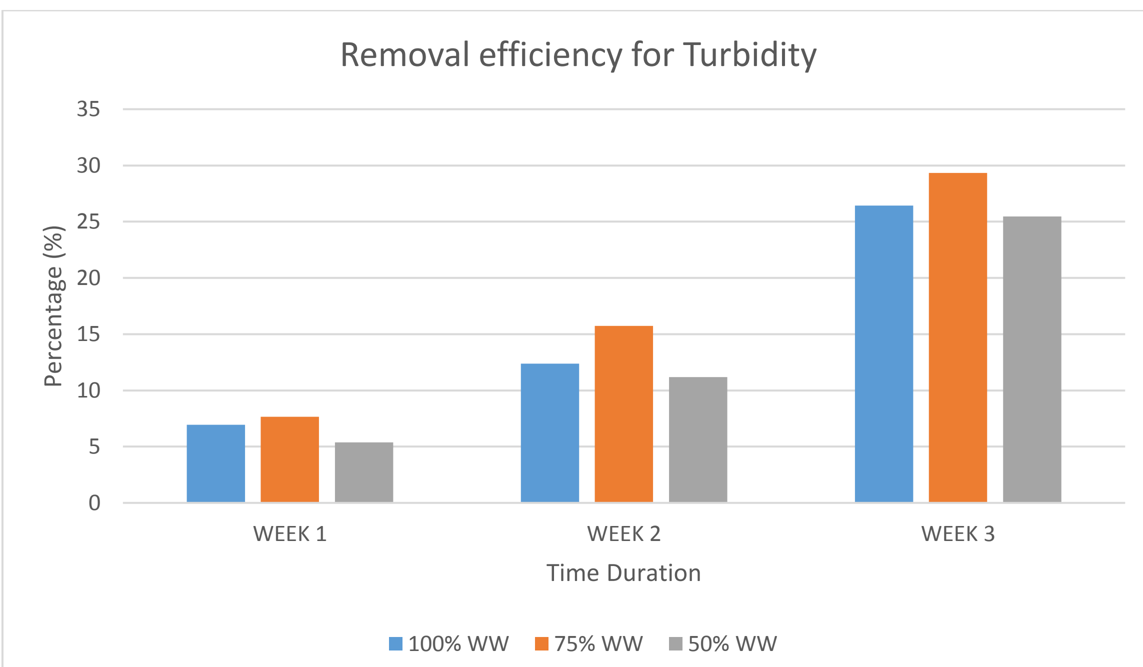

Figure 4.6: Results of Turbidity Value Against Time Duration

Results of turbidity were showed in Figure 4.5 while for removal efficiency were showed in Figure 4.6. Turbidity is a test for water clarity where it is usually disturbed by the suspended solid and plankton that are suspended in water column. Low levels of turbidity may indicate a healthy, well-functioning ecosystem, with balance of food chain in an ecosystem. However, high levels of turbidity, gives problem towards the ecosystem.

The initial data for turbidity for pot 1 was 4.69 NTU, pot 2 4.96 NTU and for pot 3 was 4.83 NTU. Based on the graph above it showed that the turbidity for all of the pot on the week 1 had been decreased from the initial week. For pot 1, it had decreased from 4.69 NTU to 4.39 NTU. While for pot 2, the data reduced to 4.58 NTU and for pot 3 it decreased to 4.57 NTU.

Meanwhile for the next week, it shows that turbidity that have in pot 1 still in decreasing value to 4.11 NTU which is it removal percentage 12.37% compared to previous week was 6.40%. Turbidity in pot 3 also showed decreasing data from 4.57 NTU to 4.29 NTU with its removal percentage 1.18 %. For pot 2, it showed that the removal efficiency in week 2 were the highest removal efficiency compare to other pot which is its removal efficiency was 15.73%. The turbidity in pot 3 were decreased from 4.58 NTU to 4.18 NTU.

In week 3, turbidity of all the pot still showed the decreasing of their value. In pot 1 with 100% of concentration sample of wastewater it showed that the plant had decreased the turbidity in the pot from previous week which is 4.11 NTU to 3.45 NTU. While in the pot 2, it showed that the turbidity had decreased more compared to pot 1 which is the data decreased from 4.18 NTU to 3.5 NTU with 29.44% of removal efficiency. In pot 3, it also showed that the decreasing of turbidity with 4.29 NTU to 3.6 NTU in week 3.

Based on the results of turbidity from this research, it shows that the highest percentage of removal efficiency is in pot 2 with 75% of concentration wastewater sample. The removal efficiency pattern for this parameter were increased from week 1 until week 3. Thus it shows that, Vetiver Grass can reduce the turbidity of wastewater sample and it can act as phytoremediation agent.

4.3.4 Dissolved Oxygen

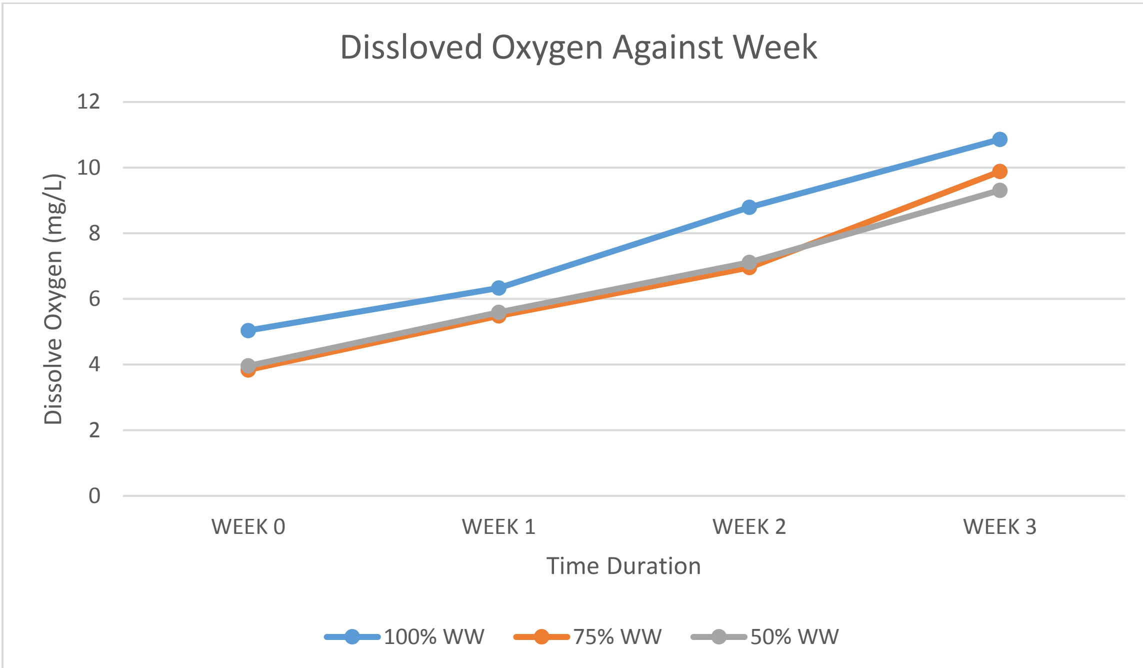

Figure 4.7 Results of Dissolved Oxygen Value Against Time Duration

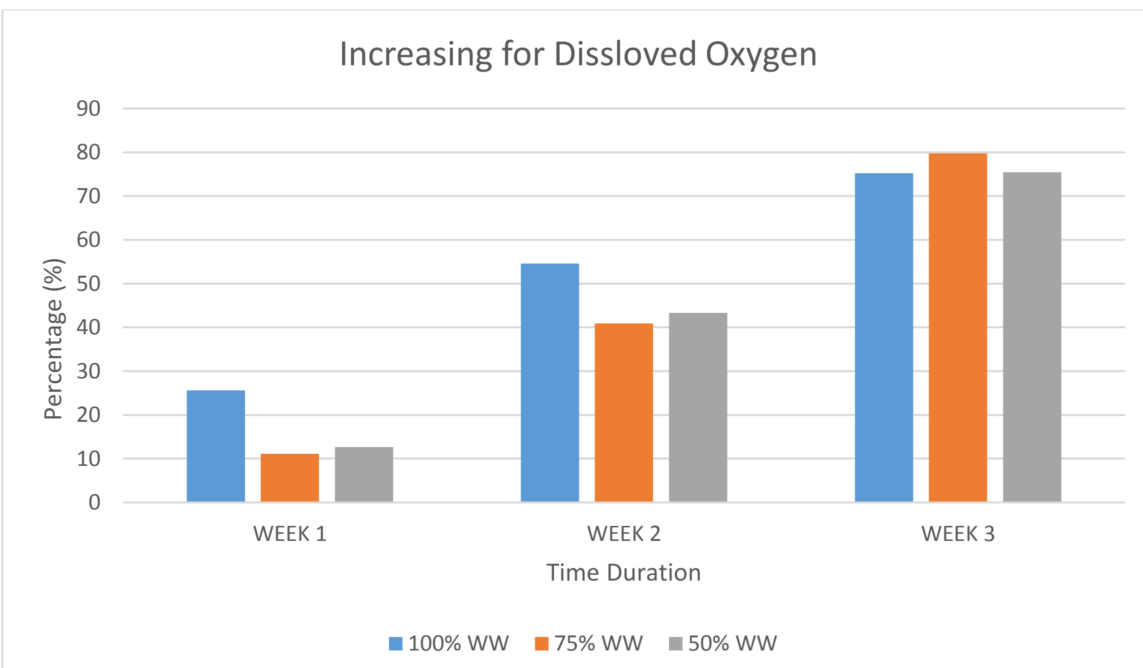

Figure 4.8 Removal Efficiency for Dissolved Oxygen

Dissolved oxygen (DO) is the amount of molecular oxygen dissolved in water and one of the most parameter which affects the health of aquatic ecosystem. Results of DO in this research had shown in Figure 4.7 while for the removal efficiency in Figure 4.8 According to the study by Mir Sujaul Islam et al., 2012, the DO values were low during rainy season which is from September to December 2006. The main factors that influent the value of DO were photosynthetic activities, seasonal variables and the decomposition of organic matter.

The content of DO in industrial wastewater sample for 100%, 75% and 50% of concentration was 5.04 mg/L, 3.84 mg/L and 3.96 mg/L. On the next week, all of the wastewater sample had increased. For 100% of concentration it had increased to 6.33 mg/L with the removal efficiency -25.595%. While for 75% concentration the removal efficiency was more higher compared to other which is -41.162%. For 50% of concentration the dissolved oxygen increased from 3.96 mg/L to 5.59 mg/L.

Based on the result in week 2, dissolved oxygen for pot 1 show increasing of content from 6.33 mg/L to 8.79 mg/L thus it made the removal efficiency increased to 74.405%. For pot 2, the removal efficiency also shows the increasing of data which is it increased to -81.250% with the concentration 6.96 mg/L of dissolved oxygen. Meanwhile in pot 3 the removal efficiency was -79.545% and its concentration was 7.11 mg/L.

In the last week of collecting data which is the final week, it shows that pot 2 with 75% concentration of wastewater sample showed the highest removal efficiency with 157.292% and its final concentration was 9.88 mg/L. For the least of removal efficiency for dissolved oxygen is in pot 1 which is the removal efficiency was 115.476% and the concentration from 5.04 mg/L to 10.86 mg/L.

Based on the result above it shows the potential of vetiver grass is increased from its initial value of wastewater sample. It’s mean that vetiver grass had a potential in phytoremediation process as it can increase the concentration of dissolved oxygen in wastewater sample thus it produced increasing pattern in removal efficiency in this parameter. In this research it showed that the highest of removal efficiency was in pot 2 which is it contained 25% of distilled water and 75% of wastewater which is the removal efficiency for this pot was 157.29%

4.3.5 Total Suspended Solids

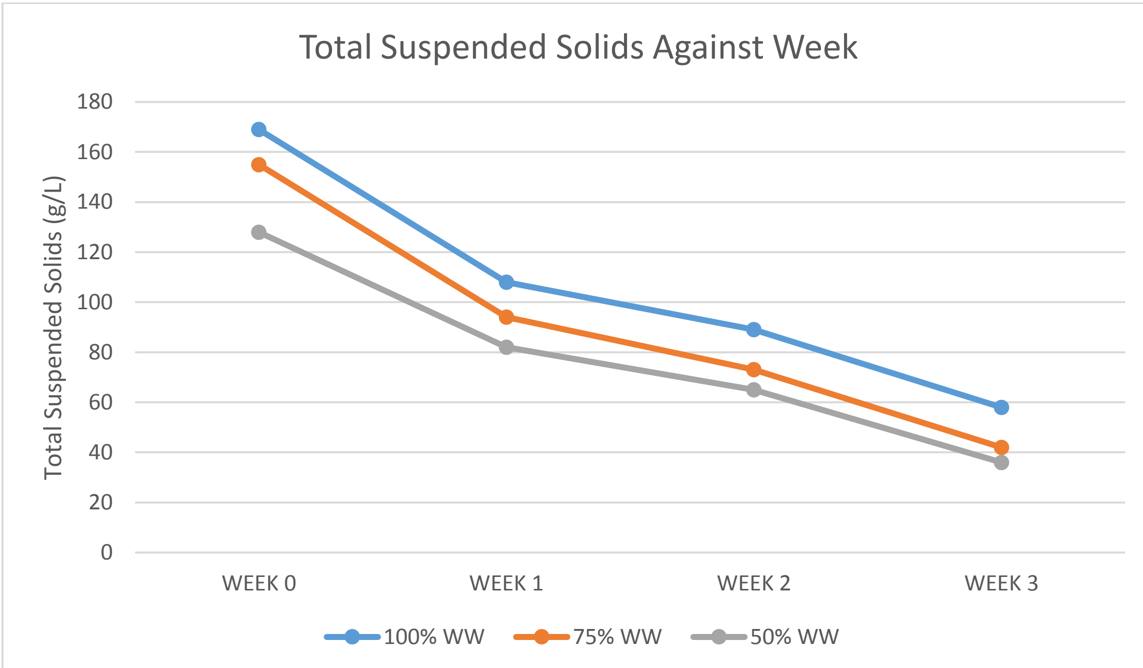

Figure 4.9 Results of Total Suspended Solids Against Time Duration

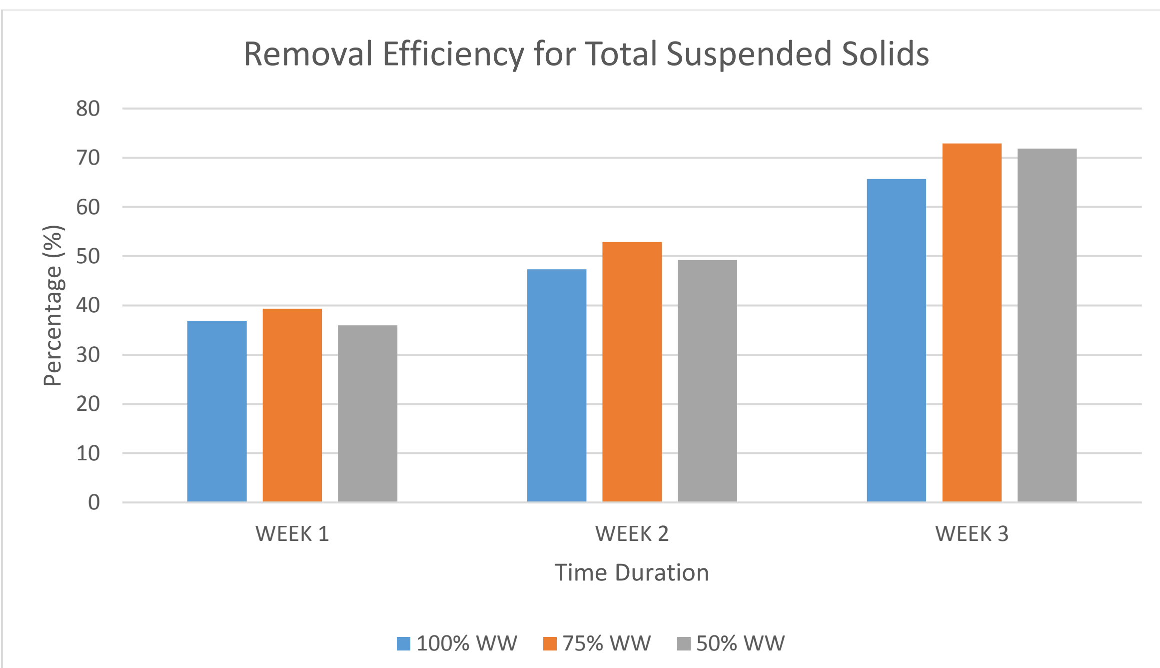

Figure 4.10 Removal Efficiency for Total Suspended Solids

Referring to Figure 4.9 is the results of total suspended solids and Figure 4.10 is the removal efficiency for total suspended solids. The results of all the wastewater sample has shown decreasing data in total suspended solids. While in the Figure 4.10 which is the removal efficiency graph it showed that the highest of removal efficiency for TSS is in pot 2. The initial value for TSS in pot 2 is 155g/L and it was decreased to 42 g/L at the end of week 3. From the results the removal efficiency had increased from 39.36% to 72.90%.

In the other hand, pot 1 and pot 3 also showed the decreasing of TSS. For pot 1 it had been decreased from 168 g/L in the initial week to 58 g/l at the end of the week research. Based on this results it shown that the removal efficiency for pot 1 was increase from 35.71% to 65.58%, while in pot 3, it increased from 35.94% to 71.88% of removal efficiency.

Results of TSS is important in determine the water quality because it is the indicator of the solids that have in the water. If the TSS value is higher it means that the water quality at that place is in poor condition. As the results of TSS in the wastewater sample showed the decreasing of value, so using the Vetiver Grass with 75% concentration of wastewater sample and 25% of distilled water showed the best of removal efficiency for TSS.

4.3.6 Biochemical Oxygen Demand (BOD)

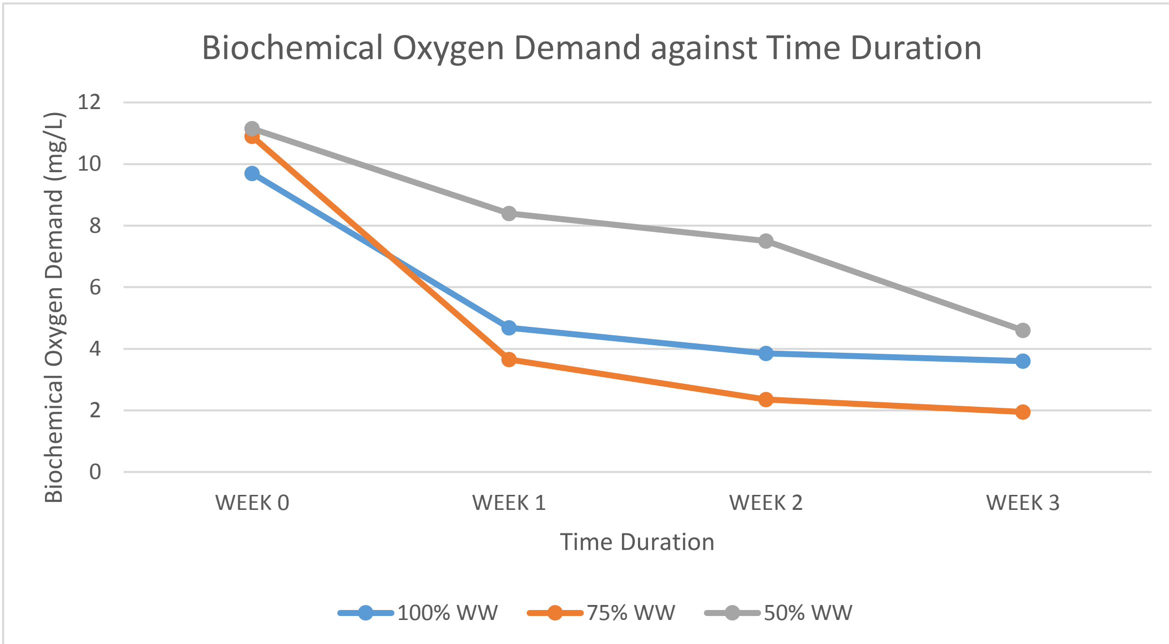

Figure 4.11: Results of Biochemical Oxygen Demand Against Time Duration

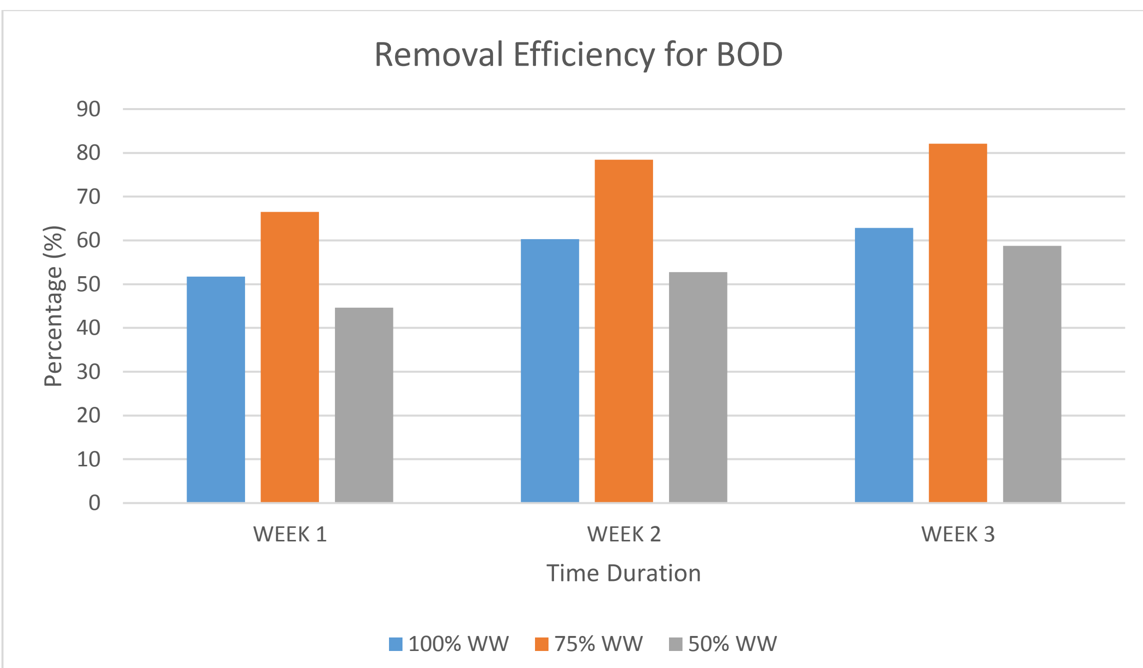

Figure 4.12 Removal Efficiency for Biochemical Oxygen Demand

Biochemical Oxygen Demand is defined as the quantity of the molecular oxygen consumed by the microorganisms present in a sample in a given time. It also a parameter that to determine how fast biological organisms are use up oxygen in a body of water. There is two type of BOD which is BOD for 3 days and BOD for 5 days. For the most widely used is for BOD 5 day. Which is it will measure the oxygen consumed by the microorganism to break down organic matter in water If there is high concentration of BOD it means that there will be less oxygen and oxygen is essential for survival of aquatic life. In Figure 4.11 shows the results for three weeks data collection while in Figure 4.12 shows the removal efficiency for BOD

Figure 4.3.9 shows the line graph that had been decreasing BOD from the initial week until the third week. Based on the graph above, it shows that beaker that contained 75% of wastewater and 25% of distilled water the most efficient concentration for phytoremediation process using vetiver grass. While for the removal efficiency it shows that at the end of the week which is in week 3, it removes 82.11% of removal efficiency. Thus, it shows that by using vetiver grass in wastewater treatment process can reduce the BOD.

Based on the line graph above, the least efficient for this research on removing BOD is using 50% of wastewater sample and 50% of distilled water. This is because, the wastewater sample is low compared to other sample thus the plant can’t get the nutrient from the water. So it will reduce the performance in phytoremediation process. For this pot, on 58.74% of removal efficiency for this beaker. It shows 30% of difference from pot 2.

By using vetiver grass with concentration of 75% of wastewater sample and 25% of distilled water, it reduces high of BOD that contained in wastewater sample. From that it shows that performance of vetiver grass as phytoremediation agent are perform well in this research with 82.11% of removal efficiency. If the time duration were longer than three week the removal efficiency will be more higher compared to this removal efficiency.

4.3.7 Chemical Oxygen Demand (COD)

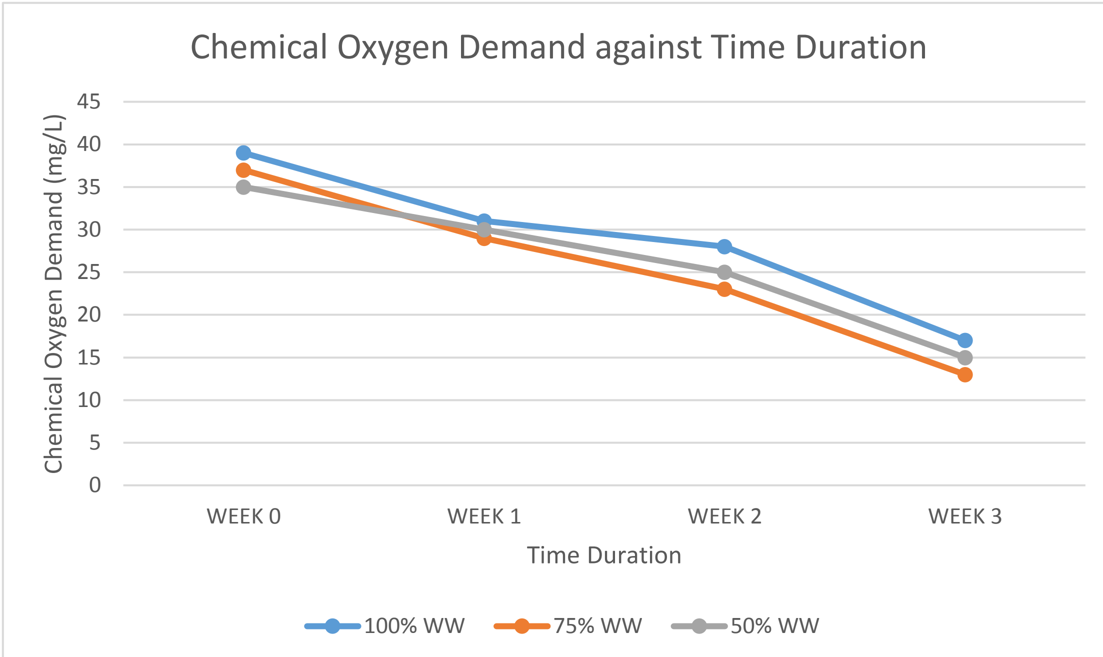

Figure 4.13: Results of Chemical Oxygen Demand Against Time Duration

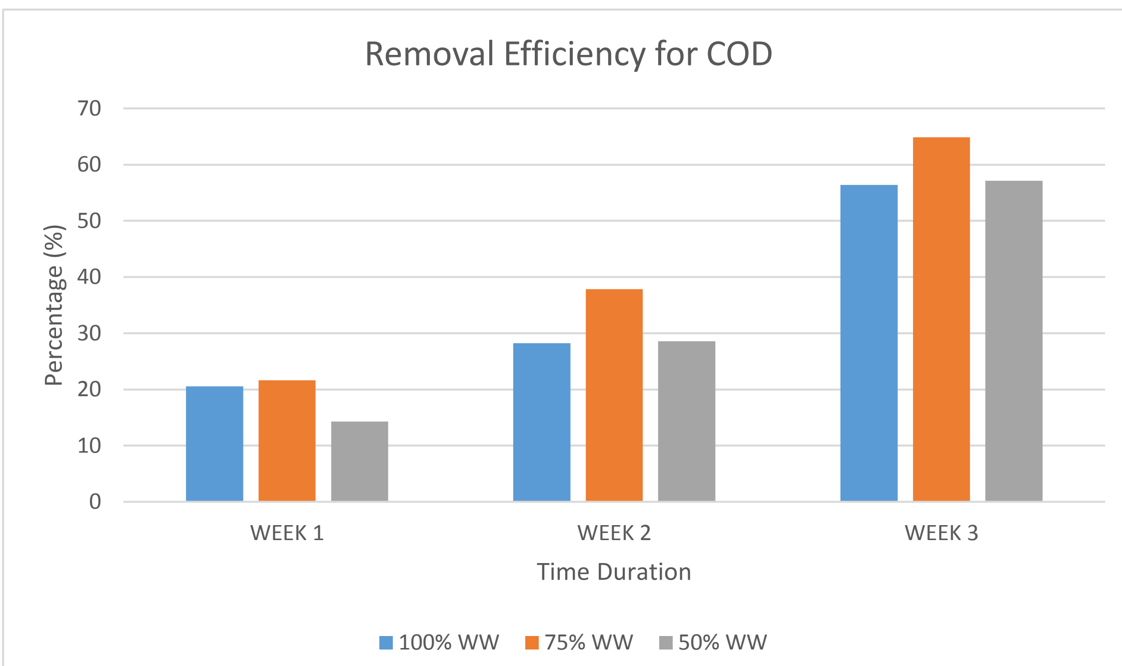

Figure 4.14: Removal Efficiency Graph of Chemical Oxygen Demand

From figure 4.13 shows the results obtained after three weeks of research progress while Figure 4.14 shows the removal efficiency for COD for this research. In Figure 4.13, all three lines representing different concentration of wastewater sample that contained vetiver grass which is 100% wastewater sample, 75% wastewater sample and 50% wastewater sample shows decreasing value of value Chemical Oxygen Demand of the wastewater sample after period of 3 weeks of phytoremediation process. Based on the line graph above, 100% of wastewater shown value of COD decreasing from 39 mg/L to 17 mg/L. For 75% of wastewater shown decreasing from 37 mg/L to 13 mg/L. While for 50% of wastewater sample reducing from 35mg/L to 15 mg/L.

Meanwhile, from figure 4.14 showed the removal efficiency for this phytoremediation process. It showed that 75% concentration of wastewater sample showing the highest removal efficiency. The removal efficiency from the initial week until the third week is 64.87% of removal. For 100% wastewater the removal were 56.14% and for the 50% of wastewater show 57.14% of removal. Which is from this results, it shows that Vetiver Grass can be act as phytoremediation agent for the industrial wastewater sample.

Environmental Quality Act 1964 for sewage and industrial effluent has set that the standards of COD is 50 mg/L for standard A and 100 mg/L for standard B part per million for the maximum levels of oxygen demand for all of the discharge wastewaters in APPENDIX C. From the research that had been done it shows that by using phytoremediation process using vetiver grass the effluent of wastewaters are in Standard A which is the COD reading were below 50 mg/L.

Therefore, the performance and the workability of vetiver grass in remediating the wastewaters through the phytoremediation process was proven. Even though, there are different concentration of wastewater, but all of the beaker were reduced the COD reading at the end of the week. For the best concentration in reduced COD that contained in wastewater is using 75% wastewater sample and 25% of distilled water.

4.3.8 Ammonia Nitrate

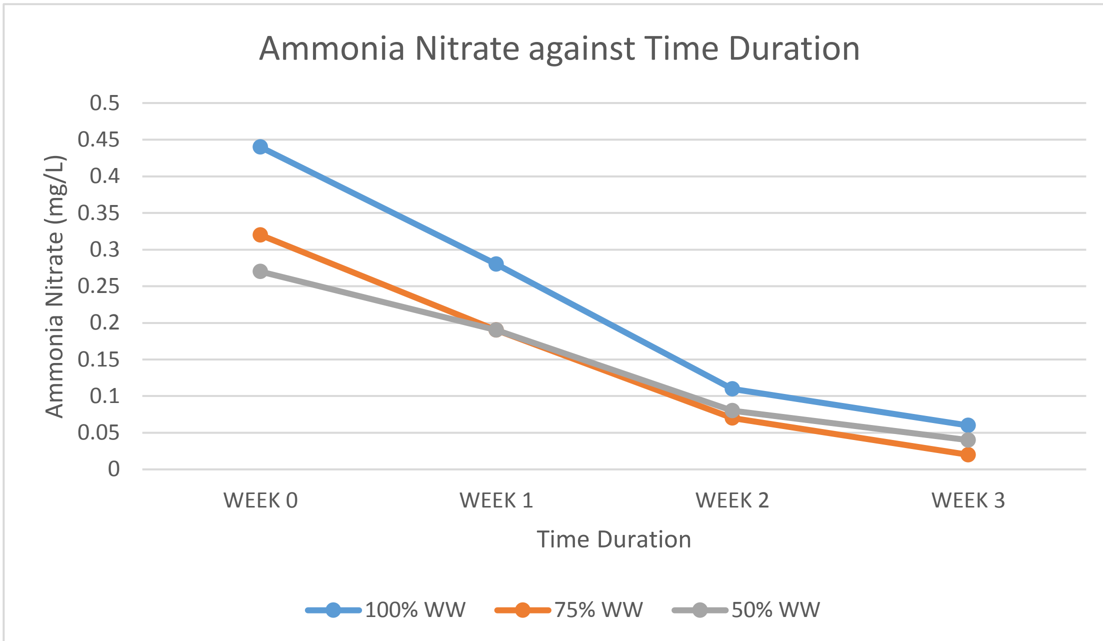

Figure 4.15: Results of Ammonia Nitrate Against Time Duration

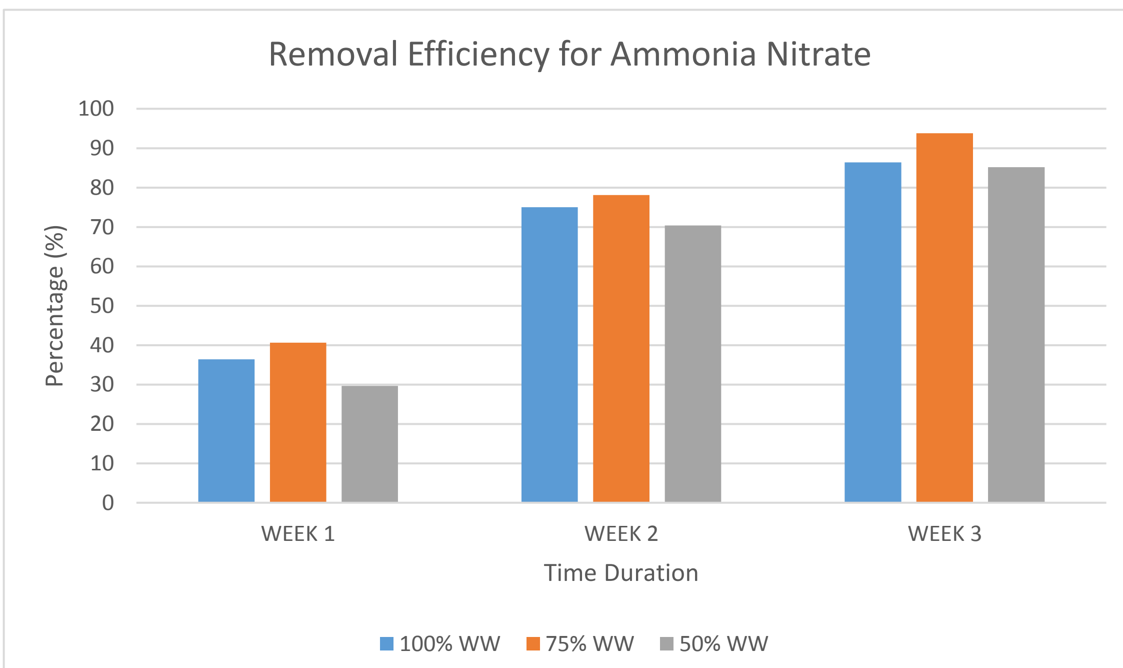

Figure 4.16: Removal Efficiency Graph of Ammonia Nitrate

Based on the Figure 4.15 it shows that the trend of decreasing the contained of ammonia in the wastewater sample. The removal efficiency graph we shown in Figure 4.16. The initial reading for 100% concentration of wastewater was 0.44 mg/L. Then the reading was dropped to 0.28 mg/L in the first week. In this week the removal efficiency for the process was 36.36%. On the next week, the reading still in decreased pattern which is 0.11 mg/L with 75% of removal efficiency. Meanwhile on the third week which is the last week of reading were taken, the reading is 0.37 mg/L.

The initial reading of 75% of wastewater sample was 0.32 mg/L and then the reading decreased to 0.19 mg/L. The removal efficiency for the week 1 was 40.63% and the next week the removal efficiency increased 78.13%. On the third week, ammonia in this wastewater sample decreased to 0.02 mg/L with the 93.75% of removal efficiency. From Figure 4.3.14, it shown that 75% of wastewater sample show the highest of removal efficiency.

For 50% of wastewater sample, also showed the decreasing in wastewater sample which is for 0.27 mg/L for the initial week, 0.19 mg/L for week 1, 0.08 mg/L for week 2 and 0.04 mg/L for the third week. Removal efficiency for week 1 was 29.63% and then it was increased to 70.37%. On the third week, removal efficiency of ammonia nitrate that contained in this wastewater was 85.18%.

Based on the Figure 4.16 the trend for removal efficiency was in increasing of removal efficiency started from the first week until the third week. It’s mean that by using vetiver grass in industrial wastewater sample it reduced the ammonia that contained in the industrial wastewater. Thus it shows that the performance of vetiver grass that can be reduced ammonia in wastewater sample.

4.3.9 Lead

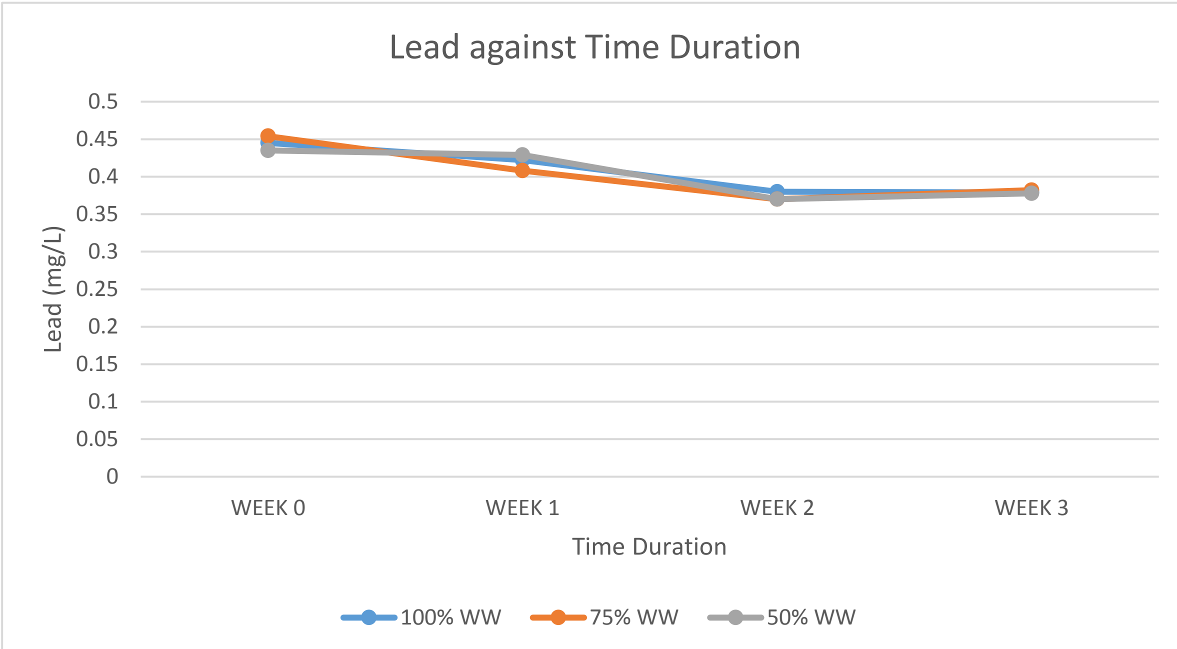

Figure 4.17: Results of Lead Against Time Duration

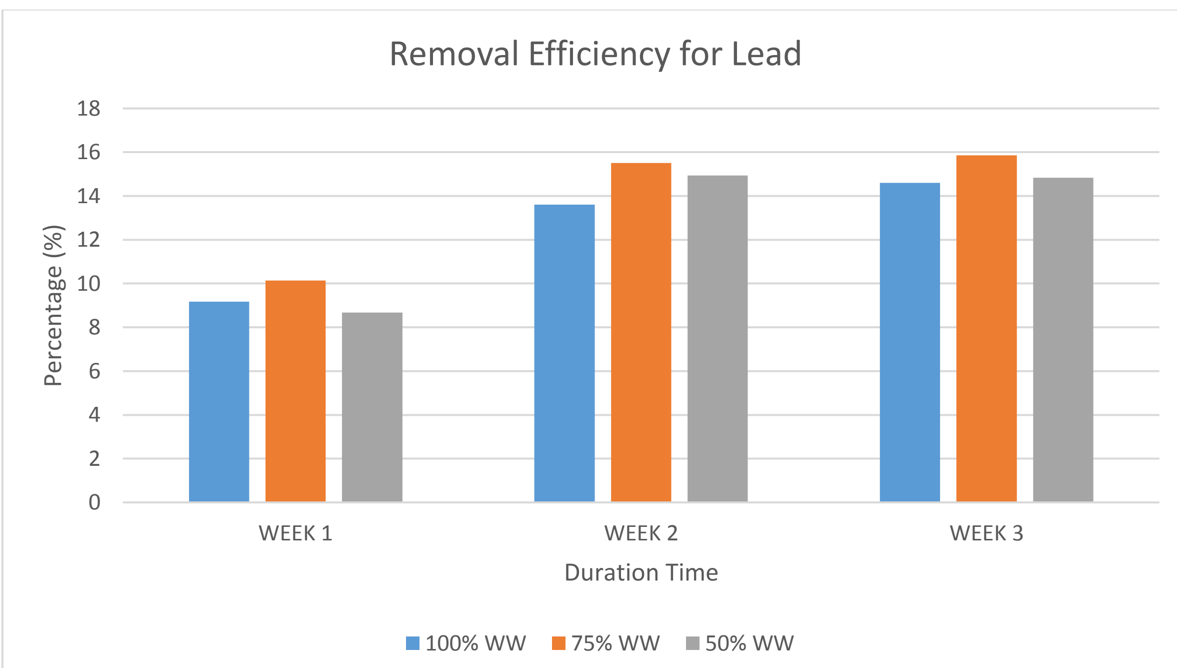

Figure 4.18: Removal Efficiency Graph of Lead

Referring to the Figure 4.17 shows the results obtained for Lead and Figure 4.18 is the removal efficiency for Lead for three weeks. The amount of lead contaminant can be seen clearly decreased from time to time along the period of phytoremediation process in Figure 4.17. Based on this results it shows that all of the three different concentration have the potential in removing lead metal from industrial wastewater effluent. Even though all of the different concentration have potential in phytoremediation process, it have different strength of ability in removing the lead that contained in wastewater.

In Figure 4.18 showed the removal efficiency of three different concentration of wastewater sample from week 1 until week 3. Based on the graph above, 75% of wastewater has the highest potential in removing lead metal, where the removal is 15.86% of removal. Which is the initial reading for lead is 0.454 mg/L and then it decreased to 0.382 mg/L.

Meanwhile for 100% wastewater sample concentration also showed decreasing value of lead from initial week until the third week. For this sample, the lead had been decreased from 0.445 mg/L to 0.379 mg/L. The removal for this concentration was 14.831%. For pot 3 which is 50% of wastewater sample showed the decreased data from 0.435 mg/L to 0.378 mg/L. Compared to other pot, this pot showed the least of removal efficiency which is 13.10%.

From the data of Lead above, it shows that vetiver grass have a good performance in removing of Lead metal in industrial wastewater. There were least data of removal efficiency because of vetiver grass not suitable for removing Lead in the wastewater. But, this plant still can act as phytoremediation agent in phytoremediation process.

4.3.10 Copper

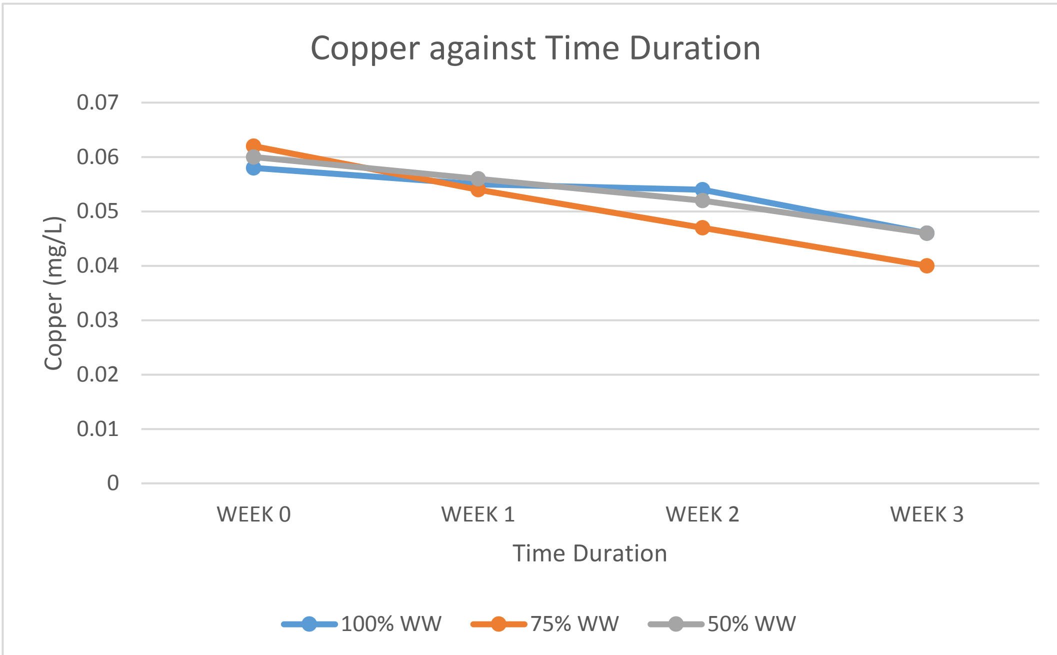

Figure 4.19: Results of Copper Against Time Duration

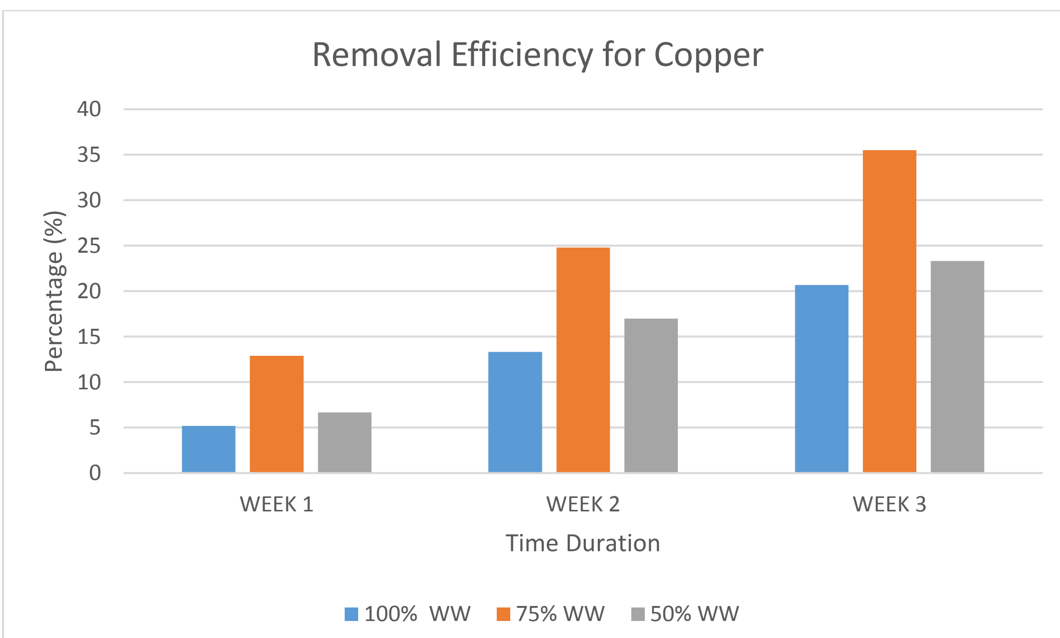

Figure 4.20 Removal Efficiency Graph of Copper

The results obtained from this research had been shown in Figure 4.19 while in Figure 4.20 is the removal efficiency for Copper. Based on the results of Copper metal for all of three different concentration it shows that the reading for initial week for 100% sample of wastewater is 0.058 mg/L and then the reading was decreased to 0.055 with 5.17% of removal efficiency in week 1. For the next week, this sample showed decreasing value to 0.054 mg/L and the removal efficiency for week 2 is 6.987%. While for week 3 pH value had been decreased to 0.046 mg/L with 20.69% of removal efficiency.

For the second pot which contained 75% of wastewater sample and 25% of distilled water, also showed the decreasing pattern of Copper metal. The reading for this element in initial week was 0.062 mg/L then it's was decreased to 0.054 mg/ L with 12.90% of percentage removal on week 1. On the next week, percentage removal was increased to 24.19% which is the Copper decreased from 0.054 mg/L to 0.047 mg/L. At the end of week 3 this metal keep decreasing it's concentration to 0.04 which is its percentage removal increased to 35.48%.

While for the third pot, the concentration of wastewater sample had been reduced to 50% and it contained 50% of distilled water. The initial Copper metal value for this pot was 0.435 mg/L which is less compared to other. In the first week of phytoremediation process, the concentration of this metal had been dropped to 0.419 mg/L with 6.67% of removal efficiency. It keep decreasing on the next week with 24.19% removal percentage. On the week 3 it shows that the removal percentage increased to 35.48%.

Based on the different sample of wastewater it shows that 75% of wastewater sample have the most decreasing of Copper that contained in wastewater compared to other sample with the concentration value of 0.046 mg/L at week 3. So for the 75% sample of wastewater shows the better performance on reducing the Copper metal which its have 35.48% of removal efficiency compared to 100% sample and 50% sample of wastewater. Thus it shows that by vetiver grass can be use as phytoremediation agent to reduce Copper metal for industrial wastewater.

4.3.11 Zinc

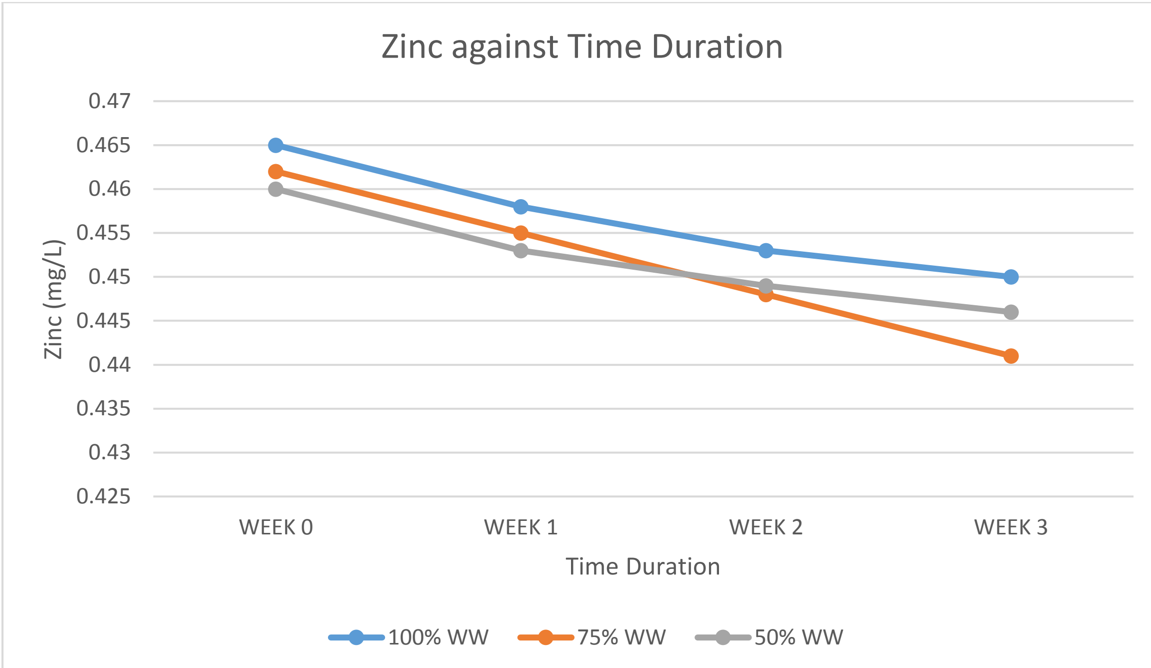

Figure 4.21: Results of Zinc Against Time Duration

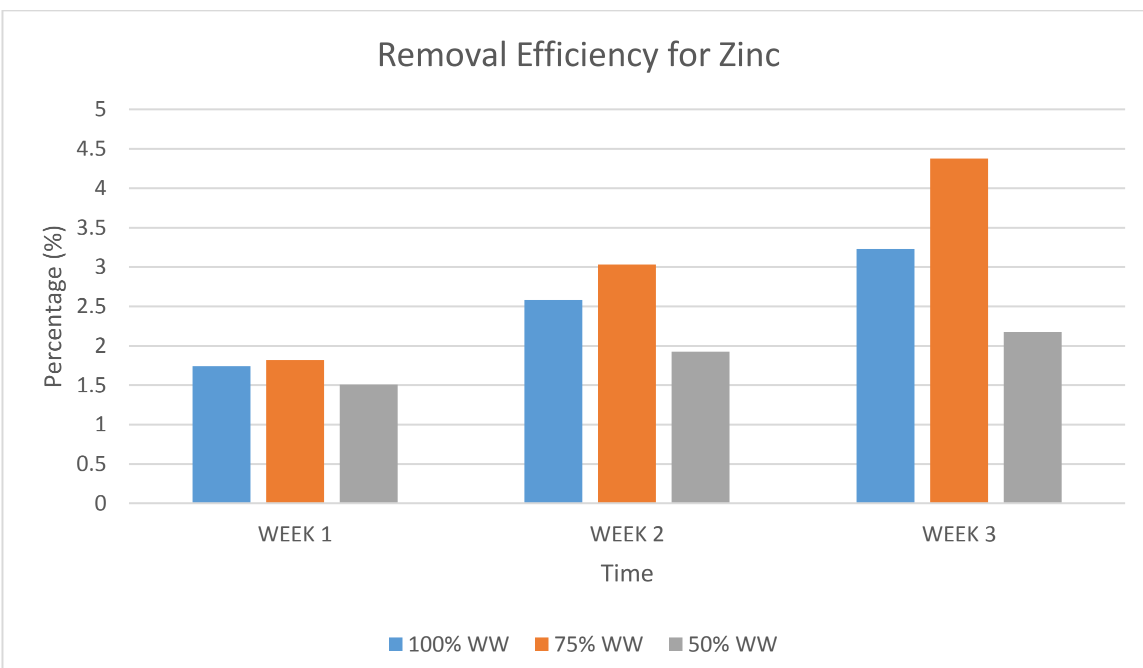

Figure 4.22 Removal Efficiency Graph of Zinc

Referring to Figure 4.21 shows the results obtained for three weeks of research while for the removal efficiency graph are in Figure 4.22. Based on the Figure 4.20, the concentration of zinc contaminant can be seen decreased from time to time along the period of the phytoremeditaion process. Based on the graph it shows that all of three different concentration of wastewater have potential in removing zinc metal from industrial wastewater. Because of different concentration of wastewater, thus the performance of vetiver grass in removing zinc metal will be difference.

Based on the result, the most efficiency concentration wastewater sample for phytoremediation process using vetiver grass is using 75% industrial wastewater in removing zinc metal, where the removals range from the initial reading 0.462 mg/L to 0.439 mg/L, followed by 100% wastewater with decreased zinc value from 0.465 mg/L to 0.45 mg/L. Meanwhile for 50% wastewater zinc reduced from 0.46 mg/L to 0.446 mg/L.

In industrial wastewater that contained zinc had become as an increasing problem and from that it will produce toxic effect on biological system that had been reported by various people. By using phytoremediation process in this research, it had been proven that this plant had potential in removing the presence of zinc in wastewater.

CHAPTER 5

CONCLUSION

5.1 Introduction

In this chapter will contained two parts which is conclusion and recommendation to improve and better research for the next research. The contained of the conclusion and recommendation were from the scope of research and objective from this research. Objective of doing this research to investigate the quality of wastewater based on parameter of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolve oxygen (DO), Total Suspended Solids, pH value and selected heavy metal. To determine the efficiency and performance of vetiver grass as phytoremediation agent.

5.2 Conclusion

Vetiver grass had been identified as a potential plat that can be used in phytoremediation process. This is because it have long of root length, fast growing and could live in vary weather. This plant had been choose to determine its potentiality in phytoremediation agent.

For the pH value, this plant had removed 23.86% of removal for 75% of wastewater. In 100% and 50% of wastewater it had removed 23.36% and 21.48% respectively. All of this concentration of water successful to neutralize the wastewater sample from high range of alkali. While for the dissolved oxygen, at the end of week 3, this plant with 75% of wastewater sample had removed 79.76%. This value of removal percentage almost achieve 80% which is good performance as phytoremediation agent to remove the parameters. The removal efficiency for this parameter in negative value because of the increasing of DO that contained in wastewater sample. As the increasing of oxygen in wastewater thus it can produce more oxygen that contained in wastewater.

On the other hand of removal turbidity in wastewater sample, vetiver grass had successful removed 29.44% of contained turbidity of sample wastewater. This is because that this roots plant did not decay during this process and the refill of distilled water to obtained 10L in the beaker. By that, it reduced the turbidity that contained in wastewater and had proved that this plant can reduce the turbidity in wastewater sample. For total suspended solids, this plant removed 72.9% of removal for 75% of wastewater. As turbidity of the wastewater sample can be decreased, thus the total suspended solids for this sample also reduced.

From results obtained, vetiver grass with 75% of wastewater sample could remove 82.11% of BOD. From the results that had obtained, this plant had a good performance to remove BOD that contained in wastewater and it could prove that this plant can be use as phytoremediation agent in phytoremediation process. While for COD, it removed 56.41%, 64.87% and 57.14% respectively for 100%, 75%, and 50% of wastewater sample.

Based on all of the parameter above, the highest percentage of removal efficiency was in remove Ammonia Nitrate in wastewater sample. From the result that obtained from this research, this plant could remove 93.75% for 75% of wastewater. While for 100% and 50%, it remove 86.36% and 85.19% respectively. From this removal percentage it shows that vetiver grass had better performance in removing Ammonia Nitrate with higher of removal efficiency.

In this research, heavy metal that had been choose were Copper, Zinc and Lead. Among this three heavy metals, this plant show better removal in Copper. It removed 35.48% using 75% wastewater and 25% distilled water. It is was the higher of removal efficiency for the heavy metals. For Zinc it remove 4.98% of removal efficiency in week 3 while 15.86% for Lead.

As a conclusion, the best concentration for this phytoremediation process using vetiver grass is by to using 75% of wastewater and 25% of distilled water. Based on all results of parameters that had been done, this concentration were the highest of removal efficiency compared to 100% and 50% of wastewater.

5.3 Recommendation

A problem is an obstacle which makes it difficult to achieve a desired goal, objective or purpose. It refers to a situation, condition or issue that is yet unresolved. In a bound sense, a problem exists when an individual becomes aware of a significant difference between what is desired. During the research in progress, there are some problems occurred.

By doing this research the problem occurred is when to put the plant in the pot and the suitable place to put the beaker. vetiver grass is plant that is have long leaf, so the suitable pot to put this plant were hard to find. While for the suitable place to put the beaker were in problem because of limited space that have. The pot were put not in horizontally thus the water level were not accurate. So in future, should prepare better place for the research progress place.

The problem is the present of rain when this research is in progress. Because of the rain it could affected the results of this research because of the nutrients that contained in the rain. The place of the beaker not fully covered by the roof. So when rain, it could entered to the beaker. Besides the rain, extremely hot weather were occurred during this research. Thus it make the water level were rapidly decreased. So in order to keep the plant alive, ensure that the level of water always at the mark.

Another problem that occurred during this research were the presents of larva in the wastewater sample. Because of the presents of them it would affect the inconsistency results of dissolved oxygen and also turbidity. To overcome this problem in future, small amount of water repellent should be added into the sample. By put that in wastewater sample, it could avoid the larva to alive in the sample.

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APPENDIX A

100 % of wastewater Sample

PARAMETERS	0TH WEEK	1ST WEEK	2ND WEEK	3RD WEEK
pH	9.22	8.35	7.23	7.04
Temperature, ℃	28.8	28.1	27.5	27
Dissolved Oxygen (DO), mg/l	5.04	6.33	8.79	10.86
Turbidity, NTU	4.69	4.39	4.11	3.45
Total Suspended Solids (TSS), mg/l	169	108	89	58
Biochemical Oxygen Demand (BOD), mg/l	9.7	4.68	3.85	3.6
Chemical Oxygen Demand (COD), mg/l	39	31	28	17
Ammoniacal Nitrogen, mg/l NH3-N	0.44	0.28	0.11	0.06
Lead, Pb	0.445	0.422	0.38	0.379
Copper, Cu	0.058	0.055	0.054	0.046
Zinc, Zn	0.465	0.458	0.453	0.45

APPENDIX B

75 % of wastewater

PARAMETERS	0TH WEEK	1ST WEEK	2ND WEEK	3RD WEEK
pH	9.12	8.63	7.42	6.99
Temperature, ℃	28.6	28	27.6	26.8
Dissolved Oxygen (DO), mg/l	3.84	5.49	6.96	9.88
Turbidity, NTU	4.96	4.58	4.18	3.5
Total Suspended Solids (TSS), mg/l	155	94	73	42
Biochemical Oxygen Demand (BOD), mg/l	10.9	3.65	2.35	1.95
Chemical Oxygen Demand (COD), mg/l	37	29	23	13
Ammoniacal Nitrogen, mg/l NH3-N	0.32	0.19	0.07	0.02
Lead, Pb	0.454	0.408	0.37	0.382
Copper, Cu	0.062	0.054	0.047	0.04
Zinc, Zn	0.462	0.455	0.448	0.439

APPENDIX C

50 % of wastewater

PARAMETERS	0TH WEEK	1ST WEEK	2ND WEEK	3RD WEEK
pH	9.03	8.32	7.65	7.09
Temperature, ℃	28.1	27.8	27.4	27
Dissolved Oxygen (DO), mg/l	3.96	5.59	7.11	9.31
Turbidity, NTU	4.83	4.57	4.29	3.6
Total Suspended Solids (TSS), mg/l	128	82	65	36
Biochemical Oxygen Demand (BOD), mg/l	11.15	8.4	7.5	4.6
Chemical Oxygen Demand (COD), mg/l	35	30	25	15
Ammoniacal Nitrogen, mg/l NH3-N	0.27	0.19	0.08	0.04
Lead, Pb	0.435	0.419	0.37	0.378
Copper, Cu	0.06	0.056	0.052	0.046
Zinc, Zn	0.46	0.453	0.449	0.446

APPENDIX D

pH Value

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	**100%**	**9.44**
	75%	**5.37**
	50%	**7.86**
2	**100%**	**21.58**
	75%	**18.64**
	50%	**15.28**
3	**100%**	**23.36**
	75%	**23.86**
	50%	**21.48**

Temperature

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	**100%**	**2.43**
	75%	**2.10**
	50%	**1.07**
2	**100%**	**6.25**
	75%	**6.29**
	50%	**3.91**
3	**100%**	**6.25**
	75%	**6.29**
	50%	**3.91**

APPENDIX E

Dissolved Oxygen

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	-25.595
	75	-11.134
	50	-12.702
2	100	-43.347
	75	-54.563
	50	-40.891
3	100	-75.198
	75	-79.757
	50	-75.403

Turbidity

WEEK	**SAMPLE**	**REMOVAL EFFICIENCY (%)**
1	**100**	**6.397**
	75	**7.661**
	50	**5.383**
2	**100**	**12.367**
	75	**15.726**
	50	**11.180**
3	**100**	**26.439**
	75	**29.435**
	50	**25.466**

APPENDIX F

Total Suspended Solids

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	35.714
	75	39.355
	50	35.938
2	100	47.024
	75	52.903
	50	49.219
3	100	65.476
	75	72.903
	50	71.875

BOD

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	51.753
	75	66.514
	50	24.664
2	100	60.309
	75	78.440
	50	32.735
3	100	62.887
	75	82.110
	50	58.744

APPENDIX G

COD

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	20.513
	75	21.622
	50	14.286
2	100	28.205
	75	37.838
	50	28.571
3	100	56.410
	75	64.865
	50	57.143

Ammonia Nitrate

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	36.364
	75	40.625
	50	29.630
2	100	75.000
	75	78.125
	50	70.370
3	100	86.364
	75	93.750
	50	85.185

APPENDIX H

LEAD, Pb

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	5.169
	75	10.132
	50	3.678
2	100	14.607
	75	18.502
	50	14.943
3	100	14.831
	75	15.859
	50	13.103

Copper, Cu

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	5.172
	75	12.903
	50	6.667
2	100	6.897
	75	24.194
	50	13.333
3	100	20.690
	75	35.484
	50	23.333

APPENDIX I

Zinc, Zn

WEEK	SAMPLE	REMOVAL EFFICIENCY (%)
1	100	1.505
	75	1.515
	50	1.522
2	100	2.581
	75	3.030
	50	2.391
3	100	3.226
	75	4.978
	50	3.043