# MUNICIPAL WASTEWATER TREATMENT USING CONSTRUCTED WETLAND AND LIMESTONE

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# ABSTRACT

In the present investigation, I report on the results of a system using tanks filled with limestone rocks followed by vegetative tank (water hyacinth) to treat sewerage treatment plant (STP) located at Kampung Melayu, Gambang. Removal of heavy metals, ammonia nitrogen, TSS, $BOD_5$, COD, turbidity from municipal wastewater has been studied. Based on the results, it shows pH, $BOD_5$, Cu, Zn, Fe and Pb tested comply with Standard B in Environmental Quality Act, 1979 but COD, Mn and Total Suspended Solid (TSS) were greater than Standard B. It was indicated that the concentrations of five heavy metals (Zn, Cu, Pb, Fe, Mn) in the wastewater were rather low. After the treatment with limestone and water hyacinth, all these stated parameters comply with Standard B with overall percentage removal were ranged from 30.43 %, to 99.39 %. The result demonstrates that limestone was more effective in contaminant removal in STP but if it was combined together it is such a good combination. Unlike organic pollutants, metals do not undergo degradation and generally need to be removed through highly expensive clean-up methods. The effectiveness of heavy metals removal from municipal wastewater was high, except for manganese with removal of 67.18%. The other metals undergo removals ranged from 97.25 % to 99.39 %. The most effective parameter treated was zinc with the fastest optimum contact time which is 3 days with 87.44% for limestone and 94.22 for water hyacinth tank. Analysis of effectiveness of metals removal during wastewater treatment processes undoubtedly indicates the fundamental role of limestone and constructed wetland with vegetative (water hyacinth) in metals removal.

# ABSTRAK

Dalam penyelidikan ini, saya melaporkan hasil dari sistem yang menggunakan tangki diisi dengan batu kapur dan diikuti dengan tumbuhan (keladi bunting) untuk merawat pusat rawatan air kumbahan (STP) di Kampung Melayu,Gambang. Pengurangan kadar logam berat, ammonia nitrogen, TSS, $BOD_5$, COD, kekeruhan dari air sisa telah dikaji. Penyelidikan ini berkaitan analisis rawatan dengan menggunakan batu kapur dan fitoremediasi. Berdasarkan keputusan yang diperolehi, ini menunjukkan pH,$BOD_5$,Cu,Zn,Fe dan Pb memenuhi Kriteria B dalam Akta Kualiti Persekitaran, 1979 tetapi nilai COD, Mn dan TSS melebihi Kriteria B. Hal ini menunjukkan bahawa kepekatan lima logam berat (Zn, Cu, Pb, Fe, Mn) dalam air sisa agak rendah. Setelah rawatan dengan batu kapur dan keladi bunting, semua parameter lain sesuai dengan Kriteria B dengan pengurangan peratusan keseluruhan dalam lingkungan 30.43% hingga 99.39%. Keputusan kajian menunjukkan bahawa batu kapur lebih berkesan dalam mengurangkan kandungan bahan yang tidak dikehendaki dalam STP tetapi jika kedua-duanya itu digabungkan bersama, ia adalah suatu kombinasi yang lebih bagus. Tidak seperti bahan tercemar organik, logam tidak mengalami penguraian dan perlu disingkirkan melalui kaedah pembersihan yang sangat mahal. Keberkesanan penghilangan logam berat dari air sisa adalah tinggi, kecuali Mn dengan pengurangan sebanyak 67.18%. Logam yang lain mengalami pengurangan dalam lingkungan 97.25% menjadi 99.39%. Parameter yang paling berkesan untuk dirawat adalah Zn dengan masa paling optimum iaitu 3 hari dengan kadar pengurangan sebanyak 87.44% untuk tangki batu kapur dan 94.22 % untuk tangki keladi bunting.Analisis keberkesanan pengurangan kuantiti logam semasa proses pemprosesan air kumbahan tidak diragukan lagi menunjukkan peranan asas dari batu kapur dan tanah becah binaan diisi dengan tumbuhan (keladi bunting) dalam pengurangan kuantiti logam.

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| | | |
|---|---|---|
| $NH_4^+$ | - | Ammonia Nitrogen |
| $Al^{3+}$ | - | Aluminium Ion |
| ALD | - | Anoxic Limestone Drain |
| (aq) | - | Aqueous Stage |
| $HCO^{3-}$ | - | Bicarbonate Ion |
| BOD | - | Biochemical Oxygen Demand |
| $BOD_5$ | - | Biochemical Oxygen Demand at 5 day |
| $CO_3^{2-}$ | - | Carbonate Ion |
| COD | - | Chemical Oxygen Demand |
| Conc. | - | Concentration |
| CW | - | Constructed Wetland |
| Cu | - | Copper |
| Cr (III) | - | Chromium |
| DOE | - | Department of Environmental |
| EPA | - | Environmental Protection Agency |
| FWS | - | Free Water Surface |
| $H^+$ | - | Hydrogen Ion |
| $Fe^{3+}$ | - | Iron ion |
| Pb | - | Lead |
| LS | - | Limestone |
| Mn | - | Manganese |
| Ni | - | Nickel |
| OLC | - | Open Limestone Channels |

| | | |
|---|---|---|
| OLD | - | Oxic Limestone Drain |
| STP | - | Sewerage Treatment Plant |
| (s) | - | Solid Stage |
| SFS | - | Subsurface Flow Systems |
| $SO_4^{2-}$ | - | Sulphate Ion |
| TOC | - | Total Organic Carbon |
| TSS | - | Total Suspended Solids |
| WH | - | Water Hyacinth |
| Zn | - | Zinc |

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# CHAPTER I

# INTRODUCTION

## 1.1 Preamble

During the early days of our nation's history, people living in both the cities and the countryside used cesspools and privies to dispose of municipal wastewater. Cities began to install wastewater collection systems in the late nineteenth century because of an increasing awareness of waterborne disease and the popularity of indoor plumbing and flush toilets. The use of sewage collection systems brought dramatic improvements to public health, further encouraging the growth of metropolitan areas.

The most common form of water pollution control in the Malaysia consists of a system of sewers and wastewater treatment plants. The sewers collect municipal wastewater from homes, businesses, and industries and deliver it to facilities for treatment before it is discharged to water bodies or land, or reused. There are two type of water pollution origin such as point sources and non point sources. Point sources have been indentified include sewage treatment plants, manufacturing and agro-based industries and animal farms. Non point sources are mainly diffuse ones such as agricultural activities and surface runoffs.

From Figure 2.1 DOE complies the statistic sewerage treatment plant have contribute to higher water pollution sources. The percentage of the composition of water pollution comes from sewerage treatment plants (54%), manufacturing industry (38 %), livestock industry; pig farm (5%) and agro based industry (3%). This statistics was got through field survey and questionnaires in 2008. The focused of this study is on the water pollution that caused by the sewage treatment plant.

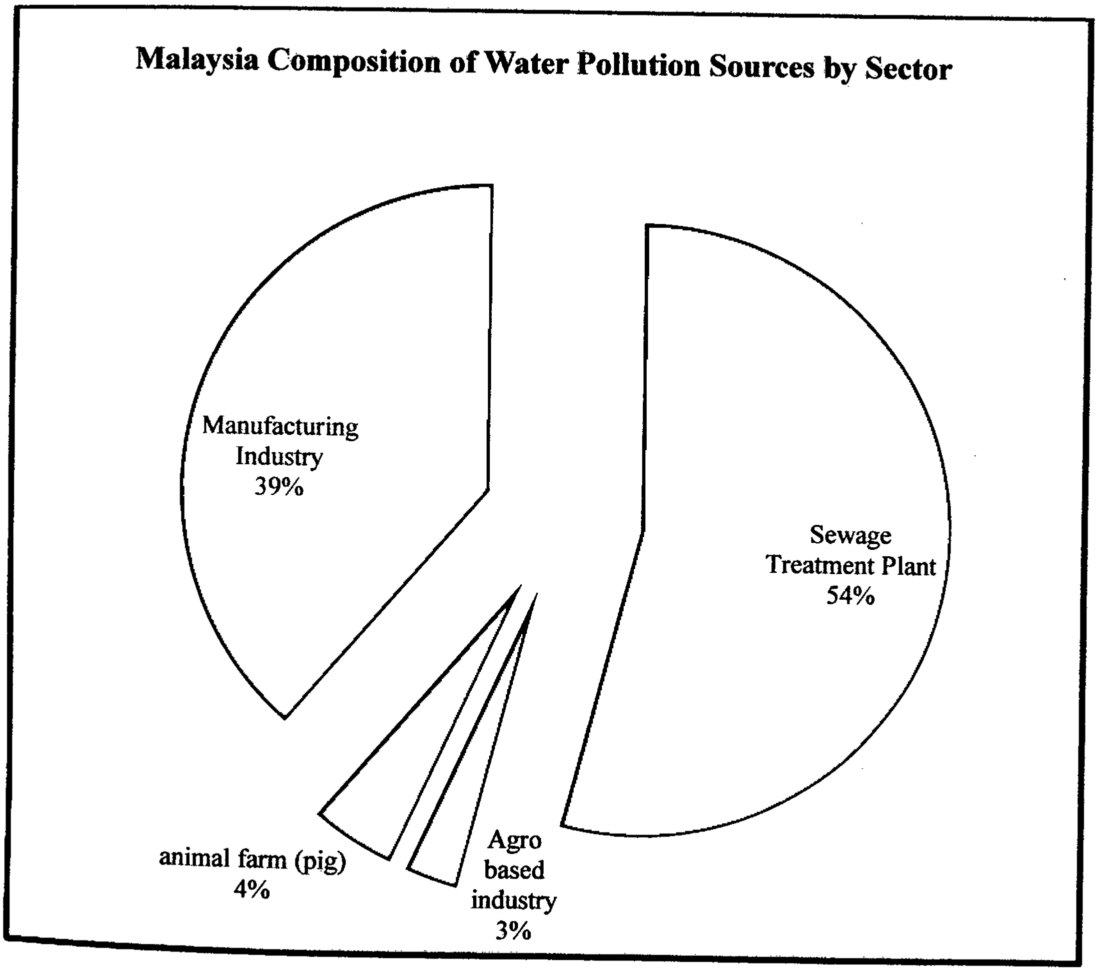


**Figure 1.1:** Malaysia Composition of Water Pollution Sources by Sector

**Source:** Department of Environmental, 2008

In Malaysia, the discharge of untreated sewage into bodies of water creates many problems to the public health and environment especially. In Malaysia there are no advance sewerage systems to treat sewage. It can be seen today where 72 percent of the river in our country are polluted and within this about 65 percent of all pollution loads has been identified as raw sewage (Shahrul, March 2004).

Today, a wide range of treatment technologies are available for use in our efforts to restore and maintain the chemical, physical, and biological integrity of the nation's waters. During the past 20 years, considerable interest has been expressed in the potential use of a variety of natural biological systems to help purify water in a controlled manner. These natural biological treatment systems include various forms of ponds, land treatment and wetlands systems. As a result of both extensive research efforts and practical application of these technologies, considerable insight has been gained into their design, performance, operation and maintenance.

## 1.2 Problem Statement

Protection of public health is the fundamental purpose of waste treatment. Environmental protection is the second major purpose. It is the responsibility of the engineers, scientists and public officials involved to ensure that waste treatment systems achieve this goal.

Many municipal wastewater treatment plants are presently unable to meet the effluent limits established by Environmental Quality Act 1974 (Sewage and Industrial Effluents) 1979. This problem is especially severe for smaller municipalities that do not have the financial resources necessary to build, operate and maintain even conventional wastewater treatment facilities. There is a critical need to develop and demonstrate low-cost and simple wastewater treatment technologies that are suitable for use in these communities.

Two factors had encouraged engineers to consider natural processes such as constructed wetland systems, aquatic plant systems in treating wastewater. Firstly, the increasing demands of drinking water at a time when the low water sources have already been used. The second factor is the increasing volume of biological and chemical wastes that potentially enter the surface water system from wastewater treatment plants (USEPA, Principles of Environmental Impact Assessment Review, 1998).

The cost to construct and operate wastewater treatment facilities that accomplish advanced treatment in terms of further $BOD_5$ or nitrogen removal is high as compared to the cost of primary and secondary treatment. The search for a different approach for polishing effluent and for nutrient removal has caused renewed interest in land application and wetlands application of effluent from conventional wastewater treatment facilities. Compared to conventional systems, natural systems use less electrical energy and require less labour for operation (U.S. Environmental Protection Agency, 1998). This natural or constructed system is added by natural gravel or limestone to make it better to become water treatment facilities with low cost and easy to construct.

Additionally, the used of water hyacinth plants in the constructed wetland because of their characteristics such as fast growth, rapid reproduction, can be found in many subtropical and tropical parts of the world (e.g. Malaysia) and also high-biomass producers. Several studies on *Echorrnia Crassipes* or known as water hyacinth species reported these plants are not hyperaccumulators, however, it has a deep root apparatus and can tolerate and/or accumulate a range of heavy metals in their aerial portion. Given this, they are often utilized to reduce the metal concentration of soils, sediments and waters, in both natural and constructed wetlands (Cooper, Job, Green and Shutes, 1996).

Besides that, the used of low cost coarse media such as limestone which also can be used as an alternative approach to remove heavy metals from municipal wastewater. They have proven that each solution of cadmium (Cd), lead (Pb), zinc (Zn), nickel (Ni), copper (Cu) and chromium (Cr(III)) at a final pH of 8.5, limestone has significantly removed more than 90% of most metals followed by 80% and 65% removals using crushed bricks and gravel, respectively. The removal by aeration and settlement methods without solid media was less than 30% (Aziz, Adlan, & Ariffin, 26 November 2006).

The removal behaviour of these metals indicated that rough solid media with the presence of carbonate were beneficial for the removal process. Adsorption and precipitation as metals oxide and probably as metals carbonate were among the two mechanisms that contributed to the removal of metals from solution.

## 1.3 Aim, Objective, and Scope of Study

### 1.3.1 Aim

The aim of this study is to provide alternative solution for the treatment of municipal wastewater with water hyacinth and limestone that offer less expensive treatment for sewerage treatment plant.

### 1.3.2 Objective

The objectives of the present study are:

i. To evaluate all the parameter required such as pH, turbidity, $BOD_5$, COD, TSS, ammonia nitrogen and heavy metal such as Zinc, Copper, Lead, Manganese and Iron in the municipal wastewater.

ii. To examine and compare the effectiveness of limestone with the presence of constructed wetland to improve municipal wastewater quality

iii. To explore the optimum contact time for limestone and water hyacinth to treat municipal wastewater.

### 1.3.3 Scope

The scope of this study consists of through experimental work using limestone and water hyacinth. Municipal wastewater from sewerage treatment plant will be used in this experiment. This effectiveness is also depended on specific required parameters such as pH, Total Suspended Solid (TSS), turbidity, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonia nitrogen, heavy metals such as Zinc, Copper, Iron, Manganese, and Lead of municipal wastewater before and after treatment.

# CHAPTER II

# LITERATURE REVIEW

This chapter includes literature review of municipal wastewater, limestone, constructed wetland and water hyacinth.

## 2.1 Overview of Municipal Wastewater

Wastewater is any water that has been adversely affected in quality by processes or materials are those that are derived from human activities. This municipal wastewater is collected in sewer system. There are two types of sewer system which is combined system and separated system so called sanitary sewers where storm water and dry weather flow is transported into separated pipes. Combined sewer systems were designed to provide storm drainage from streets and roofs to prevent flooding in cities.

Many of the earliest sewer systems were combined sewers, designed to collect both sanitary wastewater and storm water runoff in a single system. Later, pipelines were added to carry domestic wastewater away from homes and businesses. Early sanitarians thought that these combined systems provided adequate health protection.

## 2.2 Sources of Municipal Wastewater

Municipal comprises liquid waste discharged by domestic residences, commercial properties, industry, and agriculture and normally generated from toilets, sinks and bathrooms. Storm water is also classified as wastewater. Storm water is usually comes from rainwater. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants (UN Department of Technical Cooperation for Development, 1985; Abdel-Ghaffar *et al.*, 1988) and concentrations resulting from the mixing of wastewaters from different sources (Shahrul, March 2004).

Heavy metal in the municipal wastewater may originate from industrial processing, runoff from mining operations and atmospheric deposition from incinerator emissions and other processes (Fukue, Sato, & Mulligan). Most petroleum refineries, chemical and petrochemical plants (Beychok, Milton, 1967; Tchobanoglous, Burton and Stensel, 2003) have onsite facilities to treat their wastewaters so that the pollutant concentrations in the treated wastewater comply with the local and/or national regulations regarding disposal of wastewaters into community treatment plants or into rivers, lakes or oceans.

## 2.3 Composition and Characteristics of Municipal Wastewater

Sewage contains 99 % of liquid and 1 % of solids that carry waste from several different kinds from the community. Therefore, it may contain industrial and agricultural wastewater as well. Most of the substances found as pollutant in municipal wastewater can be categorized as to be whether chemical, physical or biological characteristics.

The principal contaminants of municipal wastewater fall into the following categories nutrients such as nitrogen, phosphorus, pathogenic organisms, heavy metals, and trace organics. The pathogens include bacteria, viruses, protozoa and helminths (Feachem *et al.*, 1983; Shahrul, March 2004). The heavy metals include cadmium, copper, chromium, lead, mercury, selenium, iron and zinc that come from industrial sewer. Trace organics include highly stable synthetic compounds especially chlorinated hydrocarbons (Shahrul, March 2004). Table 2.1 shows major constituent of typical municipal wastewater collected in sewer system:

**Table 2.1:** Major Constituents of Typical Municipal Wastewater (Influent)

| Constituent | Concentration, mg/l | | |
|---|---|---|---|
| | **Strong** | **Medium** | **Weak** |
| Total solids | 1200 | 700 | 350 |
| Dissolved solids (TDS) | 850 | 500 | 250 |
| Nitrogen (as N) | 85 | 40 | 20 |
| Suspended solids | 350 | 200 | 100 |
| Alkalinity (as $CaCO_3$) | 200 | 100 | 50 |
| $BOD_5$ | 300 | 200 | 100 |

**Source:** UN Department of Technical Cooperation for Development, 1985

Depending on the concentration of constituents, sewage is classified as strong, medium and weak; the higher of the concentration of waste matters in sewage, the stronger it said to be.

### 2.3.1 Chemical Characteristics

The chemical characteristics of municipal wastewater can be adversely affecting the environment. There are two types of chemical characteristics of municipal. There are organic and inorganic compounds. Abdel-Ghaffar *et al.*, 1988 summarized that municipal wastewater also contains a variety of inorganic substances from domestic and industrial sources (see Table 2.2), including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc.

**Table 2.2:** Chemical Composition of Municipal Wastewaters in Alexandria and Giza, Egypt (Abdel-Ghaffar *et al.*,1988)

| Constituent | Alexandria | | Giza | |
|---|---|---|---|---|
| | Unit | Concentration | Unit | Concentration |
| pH | - | 7.80 | - | 7.1 |
| $Na^{2+}$ | me/l | 24.60 | mg/l | 205 |
| $Ca^{2+}$ | me/I | 1.50 | mg/l | 128 |
| Mg | me/I | 3.20 | mg/l | 96 |
| $K^+$ | me/I | 1.80 | mg/l | 35 |
| $Cl^-$ | me/I | 62.00 | mg/l | 320 |
| $SO_4^{2-}$ | me/I | 35.00 | mg/l | 138 |
| $HCO_3^-$ | me/I | 6.60 | - | - |
| $NH_4^+$ | mg/l | 2.50 | - | - |
| $NO_3$ | mg/l | 10.10 | - | - |
| P | mg/l | 8.50 | - | - |
| Mn | mg/l | 0.20 | mg/l | 0.7 |
| Cu | mg/l | 1.10 | mg/l | 0.4 |
| Zn | mg/l | 0.80 | mg/l | 1.4 |
| EC | dS/m | 3.10 | dS/m | 1.7 |
| SAR | - | 9.30 | - | 2.8 |

#### 2.3.1.1 Organic Compounds

All organic compounds in wastewater contain carbon in combination with one or more element. It can be classified into biodegradable organics and non-biodegradable organics. Organic compound such as protein, carbohydrates, fats, oils and grease surfactant can deplete oxygen level and give odour. Shahrul (March 2004)