ADSORPTION TREATMENT OF PULAU BURUNG SANITARY LANDFILL LEACHATE USING ZEOLITE

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SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA

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By

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ABSTRAK

Majoriti bahan larut resapan di Malaysia mengandungi nitrogen ammonium yang tinggi, yang menghalang proses rawatan biologi dan memudaratkan sungai. Bahan larut resapan disifatkan sebagai cecair tercemar yang keluar daripada air yang meresap melalui tapak pelupusan. Cecair tercemar yang dihasilkan oleh tapak pelupusan sisa pepejal perbandaran (SPP) mempunyai kesan yang besar terhadap air permukaan dan air bawah tanah. Oleh itu, untuk melindungi alam sekitar, adalah penting untuk merawat air larut resapan tapak pelupusan tersebut. Kajian ini menyiasat komposisi air larut resapan dari Tapak Pelupusan Sanitari Pulau Burung (TPSPB). Dalam eksperimen makmal, zeolit digunakan untuk mengeluarkan komponen kimia tertentu daripada air larut resap ini, termasuk COD, zarah terampai, zink dan kekeruhan. Ini dilakukan untuk menilai kecekapan rawatan penjerapan. Menurut data eksperimen kajian penjerapan, dos 1.0 g zeolit pada pH 4 merupakan keadaan yang optimum untuk mengeluarkan COD ke tahap di mana ia memenuhi keperluan undang-undang untuk pembuangan di seluruh sistem kumbahan perbandaran. Kecekapan penghapusan COD adalah pada 43.0%. Dalam pada itu, dari segi kekeruhan, optimum zeolit yang digunakan untuk mengeluarkannya sehingga 61.26 peratus ialah pada 3g apabila cecair air larut resap tersebut ialah pH 12. Oleh itu, kesimpulan bahawa teknik penjerapan yang digunakan oleh zeolit untuk merawat larut resapan adalah berjaya dalam kajian kelompok ini.

ABSTRACT

The majority of landfill leachates in Malaysia are high in ammonium nitrogen, which hinders biological treatment processes and harms rivers. Landfill leachates are described as the contaminated liquid that emerges from water percolating through a landfill. Leachate produced by a landfill for municipal solid waste (MSW) has a substantial impact on both surface water and groundwater. Therefore, in order to protect the environment, it is crucial to treat landfill leachate. This study investigates the composition of leachate from the Pulau Burung Sanitary Landfill (PBSL). In a lab experiment, zeolite was used to remove specific chemical components from the leachate, including COD, suspended particles, zinc, and turbidity. This was done to evaluate the efficiency of the adsorption treatment. According to the data of the study's adsorption experiments, the dosage of 1.0 g of zeolite at a pH 4 provided the optimal operating conditions for removing COD to the point where it satisfies the legal requirements for discharge throughout the entire system of municipal sewage. The COD elimination efficiency was at a 43.0 %. In the meantime, in terms of the turbidity, the optimum of zeolite to utilize in order to remove it up to 61.26 percent was 3g when the pH was 12. Hence, the conclusion that the adsorption technique used by the zeolite to treat the leachate was successful in these batch studies.

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LIST OF ABBREVIATIONS AND SYMBOLS

SPP	Sisa Pepejal Perbandaran
TPSPB	Tapak Pelupusan Sanitari Pulau Burung
PBSL	Pulau Burung Sanitary Landfill
MSW	Municipal Solid Waste
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
NTU	Nephelometric Turbidity Unit
SS	Suspended Solid
CACC	Corncob Derived Activated Carbon
Zn	Zinc
ZP	Zeta Potential
PS	Particle Size
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
CO_2	Carbon Dioxide
H_2SO_4	Sulphuric Acid
PO_4	Phosphate
$MgSO_4$	Magnesium Sulphate
NaOH	Sodium Hydroxide
$CaCl_2$	Calcium Chloride
$FeCl_3$	Iron III Chloride

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, rapid increases in both municipal and industrial solid waste output have been attributed to a variety of factors, including population and industry growth, technological advancements, higher living standards, shifts in productivity and consumption habits, and a variety of other factors. All of this waste will be disposed of in a landfill after it has been further processed. Leachate will be produced as a result of the landfilling process. Leachate is a fluid that percolates through landfills and into the environment. When liquids in trash break down, it is produced. It is also produced by outside water, such as precipitation, which percolates through the waste and into the environment (Jayawardhana et al., 2016).

In this study, contaminated liquids produced by the percolation of water through a landfill at the Pulau Burung Sanitary Landfill (PBSL) in Nibong Tebal, Pulau Pinang, are defined as those produced by the percolation of water through a landfill. By creating a controlled tipping procedure in 1991, this site was developed into a semi-aerobic sanitary landfill Level II. By adopting regulated tipping and leachate recirculation, it was upgraded to a sanitary landfill Level III in 2001 (Kamaruddin et al., 2016). Since municipal solid waste (MSW) landfill leachate contains high concentrations of refractory chemicals, treatment of MSW landfill leachate results in low percentages of nutrient removal. As a result of these considerations, specific physical, chemical, and biological procedures for the treatment of raw landfill leachate have been developed and implemented. Poor treatment of the leachate will cause environmental pollution. In order to lessen the negative environmental impact of landfill leachate, it is necessary to treat the water.

Due to the enormous amount of organic and inorganic pollutants included in landfill leachates, adsorbents with the ability to remove a variety of contaminants are required. Zeolites, which have an aluminosilicate molecular structure with weak cationic bonding sites, are the most frequent and widely available natural ion exchangers ("Zeolites for Cleaner Technologies," 2003). The use of zeolite as a treatment step is used in the study, which employs an adsorption process to reduce all of the chemical and biological constituents present in the leachate. The hydrophilic surface of zeolite, along with its cationic exchange ability and regularly aligned molecular pores, makes it an effective adsorbent for metal ions and ammonia in leachate (Turki et al., 2015). According to Mojiri et al. (2015) mentioned that zeolite has a reasonable ability to adsorb metals (copper, cadmium, lead, and zinc), which could be useful for eliminating toxicants.

Turbidity, chemical oxygen demand (COD), suspended solid and zinc were all measured for leachate characterization, meanwhile for the adsorbent characterization, the zeta potential will be measured in this research.

1.2 Problem Statement

The management of the landfill area is one of the environmental issues that everyone should be concerned about. This is due to the fact that poorly managed landfills can offer significant health hazards, such as pollution, radiation, noise, land use patterns, working conditions, and climate change. The leachate from a landfill, which runs into the environment, has the potential to damage groundwater, surface waterways, and soil, providing a health and environmental risk. The leachate should be treated to minimise or remove impurities in order to protect the environment from any difficulties that could have a substantial impact on the community.

In addition, the leachate contains significant levels of heavy metal ions hence, it is difficult to treat landfill leachate using biological methods because of the high COD/BOD ratio, high ammonium content, and the presence of heavy metal ions in the leachate (Mojiri et al., 2015). Before allowing the leachate to enter natural waterbodies, it is customarily necessary to remove organic material in the form of COD and ammonium. Thus, this study will evaluate the application of a physical-chemical approach to the treatment of landfill leachate because it is both cost effective and efficient.

1.3 Objectives

There are two objectives that need to be achieved at the end of this research:

i. To determine the effect of zeolite dose used and pH at constant contact time on adsorption of pollutant by adsorbent to lower the chemical parameters like turbidity, COD, suspended solid and zinc values.

ii. To evaluate the efficiency of zeolite adsorption performance to reduce landfill leachate contaminants by assessing the deficiencies of turbidity, COD, suspended solid and zinc values.

1.4 Research Aim

One of the environmental issues that everyone should be worried about is landfill management. This is because poorly managed landfills can provide serious health risks, including pollution, radiation, noise, land use patterns, working conditions, and climate change. A landfill's leachate, when released into the environment, has the potential to harm groundwater, surface waterways, and soil, posing a health and environmental hazard. To safeguard the environment from any problems that could have a significant impact on the community, the leachate should be treated to reduce or remove pollutants.

1.5 Scope of Study

A study's scope indicates the amount to which the research area will be studied in the work, as well as the parameters that will be employed to conduct it. This kind of scope of study will help the researchers achieve the few objectives that must be accomplished in this study.

To begin, this study was conducted at the Pulau Burung Sanitary Landfill in Nibong Tebal, Pulau Pinang. The landfill site is chosen after considering the amount of incoming municipal and non-hazardous solid waste on a daily basis. Around 1800 tonnes of it were dumped in the landfill, resulting in increased leachate production (Kamaruddin et al., 2016). According to a recent literature review, the current state of the leachate at the Pulau Burung Sanitary Landfill contains highly undesirable untreated leachate in the surface or groundwater. Those leachates could pose an environmental hazard to the surface and ground water as it percolates through the soils and subsoil, causing negative effects on receiving waters.

There are other methods or treatment tests that may be used to treat the leachate, such as coagulant/flocculation, air stripping, and membrane treatment, but in this study, only the adsorption test treatment was evaluated and used to treat the leachate. The purpose for concentrating on just one treatment, the adsorption test, to treat the leachate is to save cost. The adsorption test is based on the idea that contaminants are transported from the liquid phase to the solid surface via physical and chemical interactions. This treatment has the advantages of being both cost-effective and efficient. Higher removal efficiencies by means of adsorption treatment, as reported by several authors, demonstrate that this procedure is more reliable than the other. According to a recent literature analysis, the maximum removal rates for COD and NH_4^+-N were 86 percent and 92 percent, respectively, for combined ozone- granular activated carbon (GAC) adsorption treatment (Kurniawan et al., 2006). However, this test has its own set of drawbacks, including the fact that it can be quite costly at times due to the high adsorbent dosage required for treatment.

In this research, zeolite was the sole adsorbent used to remediate the leachate. The zeolite is chosen based on a few factors, including the ease with which the adsorbent can be obtained. Apart from that, the zeolite's hydrophilic surface, cationic exchange capacity, and consistently aligned molecular pores make it an efficient adsorbent for metal ions and ammonia in leachate (Turki et al., 2015). According to Mojiri et al. (2015) stated that zeolite has a reasonable capacity for adsorption of metals (copper, cadmium, lead, and zinc), which could be advantageous for toxicant elimination.

1.6 Limitations

There are various study limitations that have been identified in this study. The following are the study's limitations for this research:

i. This study only examines the effect of zeolite dose used and pH at constant contact time on adsorption of pollutant by adsorbent.
ii. This study only examines the effectiveness of adsorption performance of zeolite to reduce contaminants of landfill leachate.

1.7 Research Significant

Overall, the significant of this research study was to improve leachate treatment at landfills, particularly at the Pulau Burung Sanitary Landfill. This study used the adsorption method of zeolite as the adsorbent to treat leachate at a landfill, and it was also done to see how successful zeolite's adsorption performance was at reducing pollutants in landfill leachate. The characteristics of the zeolite, such as zeta potential was determined in this study as it is important to see how the zeolite performs in treating the leachate. Using zeolite to remediate leachate can improve wastewater quality and lessen environmental issues. Ammonia and other inorganic contaminants may be eliminated from landfill leachate using inexpensive natural zeolites by ion exchange.

1.8 Dissertation Outline

This thesis has been categorized into five chapters:

Chapter 1: Introduction – This chapter gives an overview of the thesis including the problem statement, objectives of this research and dissertation outline.

Chapter 2: Literature Review – This chapter reviews information about the study that is based on prior research that is used as a source for this study.

Chapter 3: Methodology – This chapter explained the details of methodology used in the study including type of instrument, software and method of analysis used.

Chapter 4: Results and Discussion – This chapter visualised and discuss the result obtained presented by graphs, tables and figures.

Chapter 5: Conclusion and Recommendations – Conclusions are made based on the study objectives and the outcomes. On the basis of the findings and observations, recommendations were made.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Landfill waste undergoes physical, chemical, and biological changes, resulting in the solubilization or suspension of large quantities of organic matter in the liquid phase, known as leachate. The composition of the leachate can be influenced by the characteristics of the waste, the circumstances of the landfill (such as temperature, pH, moisture content, age, and landfill geometry), the properties of the water entering the landfill, and the type of soil nearby. Older landfill leachates are high in ammonium nitrogen, low in biodegradable carbon, and have a near neutral pH.

The discharge of leachates from landfills can have an impact on ground water or surface water due to ammonia toxicity and the consumption of oxygen via nitrification; it can also contribute nutrients for lake eutrophication. Leachate from older landfills (>10 years) has a significantly low ratio of biological oxygen demand (BOD) to chemical oxygen demand (COD), usually 0.124, indicating that the organics in the leachate are poorly biodegradable (Kamaruddin et al., 2016). Conventional biological wastewater treatment methods may be ineffective in treating this type of leachate because a high concentration of ammonia in the leachate hinders the biological nitrification– denitrification process.

The leachate, which is discharged straight into water resources without any treatment, can pose a threat to the surrounding ecology, particularly in areas where landfills are located upstream of the water intake system. Landfill’s leachate is a type of wastewater that has major environmental consequences as a result of the high quantities of contaminants present in it.

Removal of these contaminants requires the use of cost-effective technology, and a range of strategies for dealing with wastewater treatment have been developed during the last few decades. Adsorption employing activated carbon or other adsorbents such as zeolite, activated alumina, or low-cost adsorbents such as limestone, rice husk ash, and peat is one of the physicochemical processes (Halim et al., 2010). Adsorption is currently thought to be a simple and effective technique for treating water and wastewater, as well as the success of the method is heavily reliant on the creation of an effective adsorbent.

2.2 Pulau Burung Sanitary Landfill (PBSL)

According to prior research titled "Current state of Pulau Burung Sanitary Landfill leachate treatment, Penang Malaysia" (Kamaruddin et al., 2016), the PSBL receives around 1,800 tonnes of municipal and non-hazardous industrial solid waste daily. The majority of the inbound Municipal Solid Waste is from Penang Island, with the remainder coming from the mainland. By adopting a controlled tipping process in 1991 (landfill age >10 years), this site was developed into a semi-aerobic sanitary landfill Level II. By adopting regulated tipping and leachate recirculation, it was upgraded to a sanitary landfill Level III in 2001 (Aziz et al., 2010).

The landfill system operates using a modified Fukuoka method, which allows ambient air to flow naturally into the waste body via the leachate collection pipes, improving waste stability and increasing leachate quality due to an increase in microorganism activity in the trash (Kamaruddin et al., 2016). Figure 2.1 shows the location of PBSL from google map and Figure 2.2 summarizes the availability of landfill leachate treatment.

Figure 2.1: Google Map's Image of PBSL

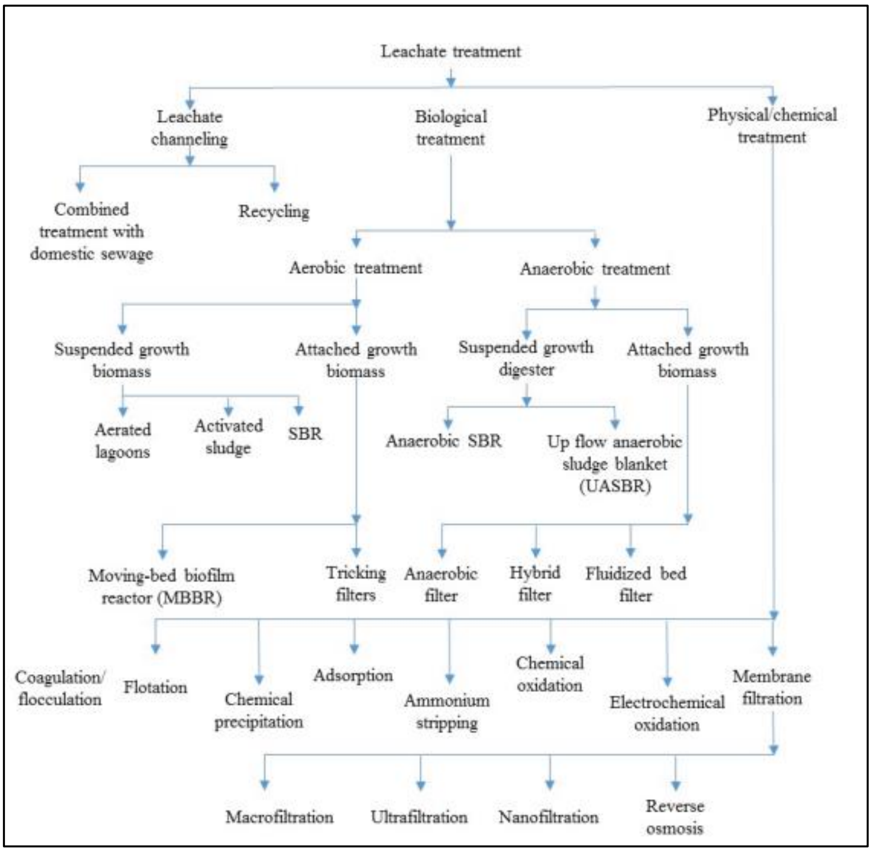

Figure 2.2: Landfill Leachate Treatment

2.2.1 Pulau Burung Sanitary Landfill Leachate Characteristic

Pulau Burung Sanitary Landfill has been operated more than 20 years since 1980s, hence the leachate that produce by the landfill is categorized as old leachate which normally in the methanogenic phase. COD, total organic carbon (TOC), BOD_5, BOD_5/COD ratio, pH, suspended material, turbidity, ammonia, Total Kjeldahl Nitrogen (TKN), bacterial count, and heavy metals content are all characteristics of landfill leachate. However, BOD_5 is the most commonly utilized measure of organic pollution indication or role as an indicator to assess whether or not the leachate is polluted. The Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulation 2009 (PU(A) 433) must be followed for determining the acceptable discharge limit for leachate. Second Schedule (Regulation 13) by Malaysia's Department of Environment prior to discharge into waterways. Table 2.1 below shows the PBSL leachate characteristic.

Table 2.1: PBSL Leachate Characteristic (Kamaruddin et al., 2016) Comparison with Industrial Effluent Regulation 2009 Limits, Standard B*

No.	Parameter	Average values	Standard B*
1.	BOD_5 (mg/L)	243	50
2.	COD (mg/L)	2345	100
3.	BOD_5/COD	0.124	0.5
4.	Nitrate-N (mg/L)	5233	-
5.	Nitrite-N (mg/L)	49	-
6.	Total phosphorus (mg/L)	17	-
7.	Orto-Phosphorus (mg/L)	159	-
8.	Phenols (mg/L)	6.7	1
9.	Total nitrogen (mg/L)	1200	-
10.	Ammonia-N (mg/L)	1568	50
11.	pH	8.28	5.5-9.0
12.	Color (Pt-Co)	3347	-
13.	Turbidity (mg/L)	180	-
14.	Total solids (mg/L)	9925	-
15.	Suspended solids (mg/L)	837	100
16.	Iron (mg/L. Fe)	3.4	5
17.	Zinc (mg/L. Zn)	0.5	2

The leachate can be classified as poor biodegradable leachate based on the data presented in Table 2.1, since the BOD_5/COD ratio was 0.124. The leachate was stable and difficult to decompose biologically, as indicated by the low BOD_5/COD ratio of 0.124 (Kamaruddin et al., 2016). As a result, physicochemical treatment approaches are especially advised for the treatment of stabilized leachate (Kurniawan et al., 2006).

2.2.2 Physico-chemical Treatment

The biological decomposition of the deposited wastes varies from a relatively brief initial period to a longer decomposition period, which has two separate sub-phases: acidic and methanogenic, as a landfill gets older. (Kamaruddin et al., 2016) mentioned that the pollutants concentrations in PBSL are low because the age of the landfill (>10 years). Because of PBSL has high pH (>8.2), low BOD_5 concentration, and low BOD_5/COD ratio of 0.124, its leachate created from unaerated landfills can be classified as conditions stabilized leachate (Kamaruddin et al., 2016). The high COD concentration in stabilized leachate implies the presence of humic and fulvic acids, which are difficult to degrade. Physico-chemical treatment techniques, such as adsorption, have recently been discovered to be particularly effective in eliminating refractory materials from stabilized leachate. PBSL used adsorption technology to treat their leachate, and research by a number of authors has shown that the adsorption process used by the landfill is effective.

2.3 Adsorption

Younger landfill leachates are usually easier to treat than older ones. Because it has been in operation for more than 20 years, PBSL is classified as old landfill leachate. As a landfill stabilizes over time, the biodegradable organic content of the leachate diminishes, reducing the effectiveness of the biological process and making physico-chemical methods such as adsorption one of the appropriate options.

Adsorption is an equilibrium separation process with significant potential in leachate treatment, and it is regarded as one of the most successful and promising ways for removing and reducing contaminants in leachate. For the treatment of landfill leachate, adsorbents having a wide surface area, a microporous structure, surface reactivity, and thermostability have been used. Table 2.2 shows the literature reviews on adsorption treatment of leachate and wastewater that were done by others studies.

Table 2.2: Literatures Reviews on Adsorption Treatment of Leachate/Wastewater

Study	Sample	Summary	References
Treatment of Mature Landfill Leachate Using Hybrid Processes of Hydrogen Peroxide and Adsorption in An Activated Carbon Fixed Bed Column	Leachate	This study examined at the treatment of mature landfill leachate using H_2O_2 oxidation along with adsorption in a fixed bed column of granular activated carbon (GAC). The leachate biodegradability was increased by 116 percent by the combined H_2O_2 and GAC adsorption. The integrated treatment achieved a COD removal rate of 97% in the first two hours of operation, surpassing the rates of the H_2O_2 process (29.9%) and adsorption process (85.4%) alone.	(Eljaiek-Urzola et al., 2018)

Overview of Biologically Digested Leachate Treatment Using Adsorption	Leachate	Adsorption is commonly applied to remove organics and metals in leachate and adsorption is often applied in leachate treatment as it enhances removal of refractory organic compounds.	(Azreen & Zahrim, 2018)
Treatment from Abandoned Mine Landfill Leachates. Adsorption Technology	Leachate	Mining and industrial activities discharge heavy metals into the environment. This pollution has become a global problem due to their toxicity. Furthermore, as these elements are not biodegradable, they tend to accumulate in living organisms. The adsorption method has become one of the preferred processes for removing heavy metals from water as it has been found to be the most efficient and economical technique due to its fast removal rate and minimum pre-treatment of samples.	(Ayala & Fernández, 2019)
Treatment of Landfill Leachate by Integrated Sequence Of Air Stripping, Coagulation–Flocculation and Adsorption	Leachate	Adsorption were largely applied to treat stabilized landfill leachate. Adsorption is also largely effective to remove heavy metals from liquid medium. In this study, it was discovered that at the ideal pH 7 condition, adsorbent dose of 0.6 g/L of chitosan beads, and contact time of 66.4 min using adsorption treatment, approximately 56.1 percent of COD and 89.2 percent of Hg removal were observed.	(De et al., 2019)
Adsorption Technique for Pollutants Removal; Current New Trends and Future Challenges	Wastewater	Adsorption process is a promising method for the removal organic and inorganic pollutants for wastewater. The largest adsorption capacity for heavy metals from literature was 2840.9 mg/g for sweet lemon peel biochar (Citrus limetta) for the removal of Pb^{+2} by using activated carbon (AC) as the adsorbent.	(El-Baz et al., 2020)

Adsorption and Coagulation in Wastewater Treatment	Wastewater	Efficient wastewater treatment is the basic need of the present society and could be a solution for protecting the environment. Adsorption and coagulation are wastewater effective treatment methods with a simple design and lower processing cost used by industry. Adsorption could be used to remove and recover heavy metals in wastewater, even at a low concentration. Therefore, adsorption is a practical and simple process to apply in wastewater treatment compared with other methods.	(Sukmana et al., 2021)

2.4 Zeolite

Combinations of organic and inorganic pollutants found in landfill leachate need the use of adsorbents capable of removing a wide range of contaminants, including organic and inorganic species. Zeolite is a natural ion exchanger that is commonly used to remove ammonia and other inorganic contaminants from leachate or other wastes because it is a cost effective and uncomplicated approaches adsorbent type.

Adsorption and ion exchange are the two main properties of zeolites. These two properties are due to reactive surfaces, which are caused by the presence of Al^{3+} on adsorption sites where a Si^{4+} ion resides, and the crystalline system of micropores. These properties enable the zeolite to be used in a variety of applications. Zeolites are essentially nontoxic and pose no risk to the environment (Rashed & Palanisamy, 2018). Many studies have been conducted in recent years to investigate the efficiency of zeolite as an adsorbent resin in the ion exchange process. Because of its three-dimensional structure, zeolite is considered an efficient ion-exchange material capable of removing ammonia-nitrogen from wastewater (Kasmuri et al., 2018). Aside from that, the presence of monovalent and divalent cations in the zeolite structure increases the zeolite's effectiveness for ion exchange in the contact solution (Kasmuri et al., 2018). A few factors must be considered while estimating the capability of zeolite in ion exchange in this batch investigation. They are the pH of the solutirasoulion and the zeolite dosage. These factors must be considered in order to attain a high removal efficiency. There are two different types of zeolite: natural zeolite and synthetic zeolite. The types of zeolites, along with their sources and properties, are displayed in Table 2.3 below. Table 2.4 shows the literature reviews on the use of zeolite in the treatment of water by other studies.

Table 2.3: Type of Zeolite

Type of zeolite	Natural zeolite	Synthetic zeolite
Properties	Non-porous	Porous and possess get structure
Example	Analcime, Chabazite, Clinoptilolite, Erionite, Ferrierite, Heulandite, Laumontite, Mordenite, and Phillipsite	Zeolites A, X, Y, and Zms-5
Sources	Form from weathering, dissolution and reprecipitation in fine grained high silica igneous rocks. Mainly volcanic origin.	Form by using elevated temperature or pressure, natural raw materials, and/or synthetic silicates in a laboratory setting, hydrothermal processes can be attempted to imitate.

Picture	 Figure 2.3: Clinoptilolite zeolite	 Figure 2.4: Zms-5 zeolite

Table 2. 4: Literature Reviews on The Use of Zeolite in The Water Treatment

Study	Key Findings	References
Oily wastewater treatment by adsorption-MF hybrid process using PAC, natural zeolite powder and low-cost ceramic membranes	Mullite-zeolite membrane in adsorption microfiltration (MF), with addition of all powdered activated carbon (PAC) concentration (100–800 mg L^{-1}) permeation flux (PF) enhanced the process. This is because of hydrophilic nature of zeolite in membrane structure, weak fouling on membrane surface and crushing of membrane surface with PAC. Enhancement of PF and TOC rejection up to 99.9% was achieved by employing natural zeolite powder in in-line adsorption-MF hybrid process.	(Rasouli et al., 2017)
Preparation and application of modified zeolites as adsorbents in wastewater treatment	Natural zeolite is a useful adsorbent for wastewater treatment for removing cations. Natural zeolite is a kind of porous material with large specific surface area but limited adsorption capacity. Natural zeolite can not only reduce turbidity and chromaticity but also degrade ammonium, heavy metal cations and other cationic pollutants.	(Shi et al., 2017)

Using Zeolite in the Ion Exchange Treatment to Remove Ammonia-nitrogen, Manganese and Cadmium	According to the study, zeolite can remove ammonia-nitrogen and heavy metals from leachate by ion exchange process and it capable to replace advanced chemical wastewater treatment. Its porous structure offers excellent ammonia-nitrogen and heavy metal adsorption. This experiment showed that zeolite could remove 93% of ammonia-nitrogen and 83% cadmium from synthetic medium. Zeolite can remove 75% of ammonia-nitrogen and 86% cadmium from leachate.	(Kasmuri et al., 2018)
Adsorption and Ion Exchange Properties of Zeolites for Treatment of Polluted Water	Zeolites are the most important inorganic cation exchangers and adsorptive materials. It shows higher cation exchange selectivity, good resistance to temperature and ionizing radiations, and excellent compatibility with the environment. Therefore, zeolites are widely used in modern technologies as selective adsorbents, molecular sieves, and particularly as catalysts.	(Rashed & Palanisamy, 2018)
Intensification of supercritical water oxidation (ScWO) process for landfill leachate treatment through ion exchange with zeolite	Ion exchange using clinoptilolite provided high NH_3-N removal, thus eliminating the major disadvantage of the ScWO process in leachate treatment. The zeolite removed 81% total organic carbon (TOC), 90% NH_3-N, 98% color, 98% turbidity, 74% COD, 100% NO_2-N, and 98% NO_3-N from the leachate	(Scandelai et al., 2020)

2.5 Effect of pH Solution on the Efficiency of Adsorption Test

The sample pH values have a major impact on extraction efficiency because they alter the sorbent surface charge density, which in turn affects the interactions between the analyte and the adsorbent. In reality, the sorbent and analyte properties determine whether adsorption is favorable in acidic or basic solutions. Whereas magnetic nanoparticles could be partially dissolved in analyte solutions with pH less than 2, the effect of pH was studied from 2 to 9. The ionic or neutral form of zeolite in aqueous solution is affected by the pH of the solution, which might affect extraction efficiency.

A study titled "Study on Landfill Leachate Treatment by Corncob Derived Activated Carbon (CACC): A Kinetic and Isotherm Study" was conducted by (Laishram & Kumar, 2021) on the influence of pH solution on the efficiency of adsorption test and COD removal. In their study, the results proved that the pH of the solution can influence the COD removal by adsorption. The effect of pH was studied at pH levels ranging from 2 to 12 with a random CCAC dose of 10g/L. It was discovered that the maximum elimination of COD occurred at a pH of 2. COD removal at pH 12 was 28.75%, corresponding to 73.6 mg/g adsorption, with a maximum COD removal of 66.25% and 169.6 mg/g adsorption capacity at pH 2. Lower COD removal was achieved at basic pH because the CCAC's surface developed a negative charge that rejected the organic molecules in the leachate. (Laishram & Kumar, 2021). The summary of a few studies that were done to determine the optimum pH for the adsorption process used to treat water is shown in Table 2.5 below.

Table 2.5: Optimum pH Used for Water Treatment Process by Using Adsorption

Sample	pH	Efficiency (removal %)					References
		BOD_5	COD	Color	Heavy metal (Hg)	Heavy metal (Zn)	
Leachate	8	N/A	29.9	N/A	N/A	N/A	(Eljaiek-Urzola et al., 2018)
Leachate	6	N/A	N/A	N/A	N/A	90	(Ayala & Fernández, 2019)
Leachate	7	N/A	56.1	N/A	89.2	N/A	(De et al., 2019)
Leachate	7	96	86	93	N/A	N/A	(El Mrabet et al., 2020)
Leachate	2	N/A	88.75	N/A	N/A	N/A	(Laishram & Kumar, 2021)

2.6 Effect of Adsorbent Dosage on the Efficiency of Adsorption Test

One of the main criteria determining the removal or reduction of contaminants in leachate is the amount of adsorbent used. Adsorption increases with dosage due to an increase in surface area and the availability of more binding sites for the adsorption of ions (Ayala & Fernández, 2019). According to a study conducted by El Mrabet et al. (2020) titled "Low-cost biomass for the treatment of landfill leachate from Fez City: application of a combined coagulation–adsorption process", it stated that increasing the adsorbent dosage from 0.5 to 1 g L^{-1} results in the greatest reduction in COD which is 35%, which is due to the high availability of adsorption sites. Sumalatha et al. (2014) mentioned in his article which is "Removal of Indigo Carmine from Aqueous Solution by Using Activated Carbon" that the percentage removal of dye increases with increasing adsorbent dose, and this is due to an increase in the availability of active sites due to an increase in effective surface area caused by increasing adsorbent dose and conglomeration of adsorbent particles, particularly at higher adsorbent doses. Table 2.6 below shows the summary of a few studies that were done to determine the optimum dosage for the adsorption process used for leachate treatment.

Table 2.6: Optimum Adsorbent Dosage Used for Leachate Treatment by Using Adsorption

Adsorbent	Dosage (g L^{-1})	Efficiency (removal %)					References
		BOD_5	COD	Color	Heavy metal (Hg)	Heavy metal (Zn)	
Hydrogen Peroxide (H_2O_2)	5	N/A	29.9	N/A	N/A	N/A	(Eljaiek-Urzola et al., 2018)
Red Mud Activated with Acid Treatment	10	N/A	N/A	N/A	N/A	90	(Ayala & Fernández, 2019)
Chitosan Beads	0.6	N/A	56.1	N/A	89.2	N/A	(De et al., 2019)
Cupressus Sempervirens Cones	1	96	86	93	N/A	N/A	(El Mrabet et al., 2020)
Corncob activated carbon (CCAC)	16	N/A	88.75	N/A	N/A	N/A	(Laishram & Kumar, 2021)

2.7 Effect of Contact Time on the Efficiency of Adsorption Test

Despite of the other experimental parameters that have an effect on the kinetics of adsorption, the contact time plays a very important role in the adsorption system. Contact time is an important parameter since it might reflect an adsorbent's adsorption kinetics for a particular adsorbate concentration (Syafalni et al., 2015). According to a study conducted by Panda et al. (2017), its stated that the contact is an effective factor in adsorption process because contact time allows the diffusion and adhesion of adsorbate molecules to take place. Metal ion uptake occurred in two stages, with the first being rapid and the second being slow. When the number of available sites is much greater than the number of metal species to be adsorbed, the adsorption process appears to proceed quickly. The required contact time increased as the amount of metal adsorbed increased (Panda et al., 2017). Table 2.7 summarizes a few studies that were conducted to determine the contact time for the adsorption process used to treat leachate.

Table 2.7: Contact Time for Leachate Adsorption Treatment Process

Adsorbent	Contact time (hour)	Efficiency (removal %)					References
		BOD_5	COD	Color	Heavy metal (Hg)	Heavy metal (Zn)	
Mixed Granular	2	N/A	55	N/A	N/A	N/A	(Daud et al., 2018)
Red Mud Activated with Acid Treatment	24	N/A	N/A	N/A	N/A	90	(Ayala & Fernández, 2019)

Chitosan Beads	1	N/A	56.1	N/A	89.2	N/A	(De et al., 2019)
Cupressus Sempervirens Cones	8	96	86	93	N/A	N/A	(El Mrabet et al., 2020)
Corncob activated carbon (CCAC)	2	N/A	88.75	N/A	N/A	N/A	(Laishram & Kumar, 2021)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter details the procedure needed in gathering data and results for the treatment of PBSL leachate. Figure 3.1 shows the methodology used to achieve the study's objectives in a schematic flow chart. The study's overall procedures are divided into a few stages, as illustrated in a flow chart as figure below.

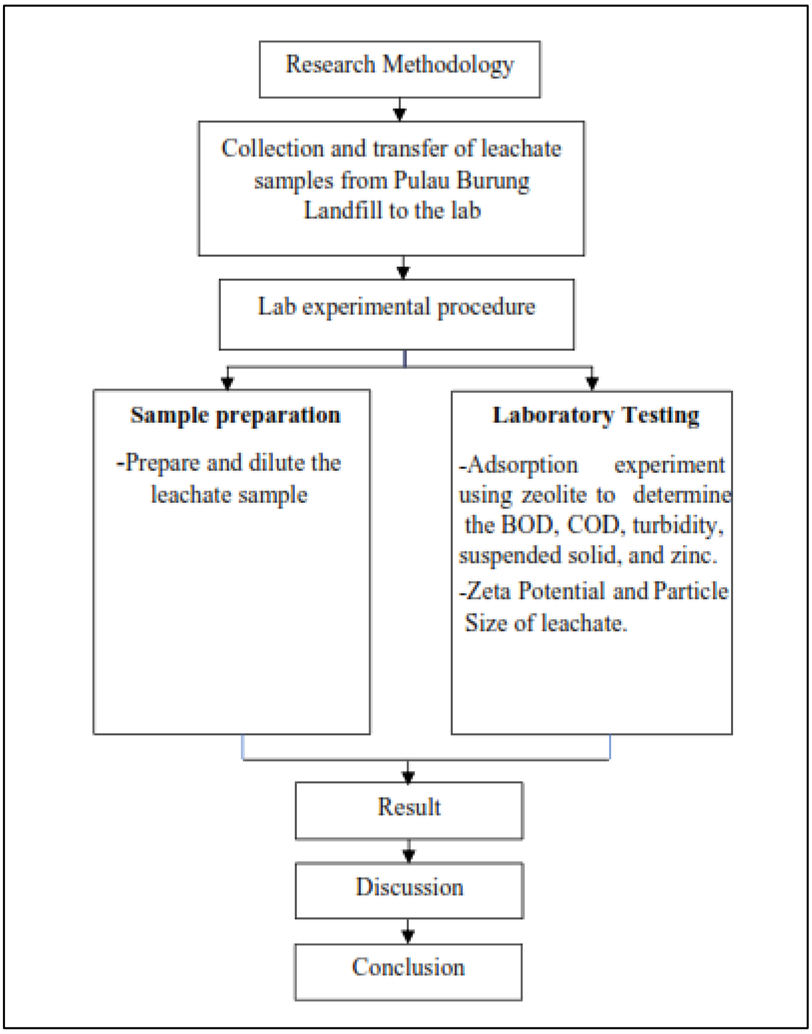

Figure 3.1: Summary of Research Methodology

As stated in the study scope, appropriate research and planning on the various leachate treatment options will be evaluated and considered first. The research will focus primarily on physical chemical treatments in order to accomplish the study's purpose. After obtaining appropriate data and information, a landfill leachate sample was retrieved from the Pulau Burung Sanitary Landfill. This sample was utilised in all subsequent studies.

The laboratory experiment began with the preparation of a sample of raw leachate. Following sample preparation, a preliminary evaluation of the landfill raw leachate sample was conducted in order to determine its parameters. BOD concentrations are only some of the parameters that will be determined on the raw leachate. The next stage of the laboratory experiment was to characterize the leachate successfully treated. Similarly, to the preliminary evaluation, all parameters which are turbidity, COD, suspended solid and zinc, except the BOD were determined at the last stage. Lastly, the leachate was analyzed after the adsorption process by determined the zeta potential of the leachate using Zeta Sizer

3.2 Materials and Equipments

Those are the list name and the functions of the materials and equipment used for this research.

Table 3.1: List of Materials and Equipment Used and Its Function

Materials / Equipment	Name / Serial Number	Functions
	Natural zeolite	As an adsorbent in adsorption process to treat the leachate.