

TREATMENT OF LANDFILL LEACHATE IN COAGULATION-
FLOCCULATION METHOD BY USING MICRO ZEOLITE AND MICRO SAND

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ABSTRACT

In this study, efficiency of coagulation-flocculation process was evaluated for leachate collected from Pasir Gudang sanitary landfill, Johor, Malaysia. The efficiency of coagulation-flocculation process using micro zeolite and micro sand of different sizes and combined with coagulants and coagulant aids were determined. In addition, the optimum rapid mixing time and speed, slow mixing time and speed, settling time of coagulants, settling time of coagulants with polymer, settling time with polymer and micro zeolite, settling time of coagulants with polymer and micro sand, pH, dose of coagulants, dose of coagulant aids and dose of micro zeolite and micro sand were determined. The efficiency of using polyaluminium chloride (PAC) as a coagulant in the coagulation-flocculation process to remove SS, colour, COD and ammoniacal nitrogen from semi-aerobic leachate as compared with alum and ferric chloride were also determined. PAC showed better removal efficiencies when compared with ferric chloride and alum. The doses of PAC, alum and ferric chloride were fixed at 2000 mg/L in the determination of the efficiency of micro zeolite and micro sand. The highest percentage of removal in SS, colour, COD and ammoniacal nitrogen were 96%, 95%, 58% and 35% for PAC, 89%, 92%, 46% and 26% for alum and 96%, 84%, 37% and 26% for ferric chloride. The leachate was also treated by adding coagulant aids, cationic polymer FO4290 SH and anionic polymer AN934 SH. Cationic polymer FO4290 SH achieved higher percentage of removal of SS, colour, COD and ammoniacal nitrogen compared with anionic polymer AN934 SH. The particle sizes of the micro zeolite and micro sand was divided into 6 categories which were 75µm-90 µm, 91 µm -106 µm, 107 µm -125 µm, 126 µm -150 µm, 151 µm -180 µm and 181 µm -212 µm. The micro zeolite was combined with the coagulant and coagulant aid. The process was repeated by using micro sand. Micro

zeolite combination with PAC and cationic polymer (PAC + cationic polymer + micro zeolite) was found to be more efficient in leachate treatment.



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ABSTRAK

Dalam kajian ini, kecekapan olahan pengumpulan-pengelompokan larut resapan yang diperoleh dari tapak pelupusan sanitari Pasir Gudang, Johor, Malaysia dinilai. Disamping itu, kecekapan olahan pengumpulan-pengelompokan mikro zeolit dan mikro pasir dalam saiz yang berbeza serta digabungkan dengan bahan penggumpal dan bahan bantu penggumpal turut dikaji. Namun demikian, kajian ini turut menentukan tempoh dan laju pengacauan cepat, penentuan tempoh dan laju pengacauan perlahan, penentuan masa penganapan bahan penggumpal, penentuan masa penganapan bahan penggumpal dengan polimer, penentuan masa penganapan bahan penggumpal dengan polimer dan mikro zeolite, penentuan masa penganapan optimum bahan penggumpal dengan polimer dan mikro pasir, pH, dos bahan penggumpal, dos bahan bantu penggumpal dan dos mikro zeolite dan mikro pasir yang optimum. Olahan pengumpulan-pengelompokan menentukan keberkesanan polialuminium klorida (PAC) sebagai bahan penggumpal dalam penyingkiran SS, warna, COD dan nitrogen ammonia dari larut lesapan semi-aerobik berbanding dengan ferik klorida dan alum. Penggunaan PAC menunjukkan kecekapan penyingkiran yang baik berbanding dengan ferik klorida dan alum. Dos PAC, alum dan ferik klorida telah ditetapkan pada 2000 mg /L untuk menentukan keberkesanan mikro zeolite dan mikro pasir. Peratusan penyingkiran yang tertinggi dalam SS, warna, COD dan nitrogen ammonia adalah 96%, 95%, 58% dan 35% untuk PAC, 89%, 92%, 46% dan 26% untuk alum dan 96%, 84%, 37 % dan 26% untuk ferik klorida. Larut resapan dirawat oleh bahan bantu penggumpal iaitu polimer kationik FO4290 SH dan polimer anionik AN934 SH. Polimer kationik FO4290 SH telah mencapai peratusan yang lebih tinggi dalam penyingkiran SS, warna, COD dan nitrogen ammonia berbanding dengan polimer anionik AN934 SH. Saiz zarah mikro zeolite dan mikro pasir telah dibahagikan kepada 6 kategori di mana adalah 75µm-90 µm, 91 µm -106 µm, 107 µm -125 µm, 126 µm -150 µm, 151 µm -180 µm dan 181 µm -212 µm . Mikro Zeolite adalah gabungan dengan bahan penggumpal dan bahan

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bantu penggumpal. Proses ini diulangi dengan menggunakan mikro pasir. Gabungan micro zeolite dengan PAC dan polimer kationik (PAC + polimer kationik + mikro zeolit) adalah yang paling cekap dalam rawatan larut resapan.



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LIST OF SYMBOLS AND ABBREVIATIONS

Alum	-	Aluminium Sulphate
BOD	-	Biochemical Oxygen Demand
CaCO ₃	-	Calcium Carbonate
COD	-	Chemical Oxygen Demand
FeCl ₃	-	Ferric Chloride
NH ₃ -N	-	Ammoniacal Nitrogen
NSWMD	-	National Solid Waste Management Department
PAC	-	Polyaluminium Chloride
PFS	-	Polyferric Sulfate
SBR	-	Sequencing Batch Reactor
SS	-	Suspended Solids
TOC	-	Total Organic Carbon
TP	-	Total Phosphorus
TSS	-	Total Suspended Solids
UASB	-	Up-flow Anaerobic Sludge Blanket
MHLG	-	Ministry of Housing and Local government
MPPG	-	Majils Perbandaran Pasir Gudang
MSW	-	Municipal Solid Waste



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CHAPTER 1

INTRODUCTION

1.1 Introduction

Solid waste generated in urban areas has been increasing year by year due to the rapid urbanization and diversity of lifestyles in Malaysia since the mid 1980s increasing waste management cost and securing final disposal landfills has become one of the most serious social issues in Malaysia. Responding to this emerging issue, the government of Malaysia in the 8th Malaysia Plan (2001-2005), has included waste minimization, promotion of reuse, developing a recycling oriented society and implementation of pilot project for recycling as some of its main policy goals. The 9th Malaysia Plan (2006-2010) further emphasized the continuation of reduce, reuse, recovery and recycling of waste as well as greater use of environmentally friendly products. In line with the basic policy framework articulated in the above plans, the Ministry of Housing and Local government (MHLG) has been conducting national programmes for the promotion of recycling and public awareness on 3Rs activities. Disposal and solid waste collection is an important issue in public health and it will affect a human life.

According the latest statistics department of statistics, Malaysia has a population of 28.9 million people in 2012 and is expected to rise to 29.8 million people in 2015. Malaysian produced 15000 -18000 tonnes of waste per day. Statistic show waste produced is increasing every year and total estimation of waste 7,772,402 tonnes per year in 2015 (10th Malaysia Plan 2011-2015).

Global environmental issue is a disposal of the growing quantities of solid waste, the waste generation rates are currently among the highest worldwide with the growth in population and the increase in per capita (Al-Yaqout et al. 2005). Continuing development of population and industrialization around the world has resulted in increasing production of municipal solid wastes (MSW). The major method of municipal solid waste (MSW) management is land filling work. It was one of the most important issues of a concern in landfill leachate and its potential for downgrading water resources systems (Sartaj et al. 2010).

In and around urban area pollution of natural water bodies is on the rise. As a result, wastewater irrigation is an increasingly common reality around most cities in the developing world. For reasons of technical capacity or economics, effective treatment may not be available for year to come; therefore, international guidelines to safeguard farmers and consumers must be practical and offer feasible risk management options (Bos et al. 2010).

Policies to control the unplanned reuse of wastewater where it is an ongoing practice are not only hard to implement but are even difficult to develop because governments are faced with the trade-off between public health protection and the ethical question of whether to prevent wastewater farmers from cultivating with the only source of water that is accessible to them. The WHO, to assist in this decision-making process, has in recent years been giving consideration both to the limitations faced by developing countries in providing sufficient wastewater treatment to meet water quality standards and the increasingly important livelihood dimension of wastewater use (Jimenez et al. 2010).

The wastes are cause by two types of pollution that is corresponding to the migration into the natural environment of leachate. Leachate is a source of soil and groundwater contamination and defined as water that has percolated through the wastes (rainwater or groundwater seepage). Biogas is a source of air pollution and it produced by the fermentation of organic matter. Nowadays, modern landfills are highly engineered facilities designed to minimize or dispose of the adverse impact of the waste on the surrounding environment. However, the generation of polluted leachate remains a destined consequence of the existing waste disposal practice and the future landfills (Abdulhussain et al.2009).

Leachate changed widely in quantity and in composition from one place to another. Treatment method highly dependent on leachate characteristics and tolerance of the method against changes in leachate quality such a variable nature along with other factors make the applicability. The leachate treatments are success depends also on the characteristics of the leachate and age of the landfill. Selection of a leachate treatment process depends on effluent discharge alternatives and limitations, treatment process residuals, permit requirements and cost-effectiveness of treatment .There are many factors affecting the quality of leachates such as age, precipitation, seasonal weather variation, waste type and composition.

1.2 Problem statement

Leachate is generated when water is absorbed into the solid waste disposal site that contains bacteria, chemical pollutants, organic pollutants and non-organic, heavy metals, dissolved and colloidal solids and a variety of pathogens potentially contaminate groundwater and surface water (Tzoupanos & Zouboulis, 2010). Leachate quality are different and these differences are caused by several factors such as composition and depth of solid waste, availability of moisture and oxygen content, design and operational of the landfill and life expectancy of the solid waste. Leachate resulting from the decomposition of solid waste contain concentrations of COD, BOD, ammonia nitrogen and heavy metals such as zinc, copper, cadmium, lead, nickel, chromium and mercury are higher (Maleki et al, 2009).

Leachate would penetrate into the ground if poorly manage and treated, especially landfill that have a layer of permeable soil or landfill without sheeting layer or failure of the sheeting layer. Groundwater pollution is a major problem that exists in a sanitary landfill and is identified as a major problem in many countries in the world. According to a study found that 71.4 % by local authorities facing a serious ground water pollution, while 57.2% dealing with the problem of leachate management (Nasir et al,1999).

Leachate from landfill frequently exceeds standard for drinking water and surface water, often for several decades. The leachate has the frequently significant potential to pollute groundwater and surface water. The most common pathway for

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leachate to the environment is from the bottom of the landfill through the unsaturated soil layers to the groundwater, then by groundwater through hydraulic connections to surface water. However, pollution may also result from the discharge of leachate through treatment plants or by direct discharge of untreated leachates. The main factors influencing the pollution potential from leachate are the concentration and flux of the leachate. The landfill sitting such as the hydro geological setting and the degree of protection provided and the basic quality, volume, sensitivity of the receiving groundwater and surface water (Ghafari et al., 2009).

The primary components in leachate from landfill that constitute a significant pollution potential are dissolved organic matter and inorganic salts. Trace elements in leachate are limited and generally do not constitute to groundwater pollution problem due to strong attenuation. Where groundwater is used (as drinking water or for irrigation) downstream from the landfill, leachate has great potential to pollute the environment. Where groundwater is not used or is not usable downstream, the leachate's pollution potential (if not diluted to ambient concentrations) is transferred to where the groundwater is hydraulically connected to the receiving surface water (Li et al., 2009).

Landfill leachates are an important potential contamination source of ground and surface waters. The water are not properly collected, treated and safely disposed, causing extensive contamination of streams, creeks and water wells (Li et al 2010). The effluents are difficult to deal with and biological processes are totally inefficient for the toxic nature of stabilized leachates. Hence, physical-chemical stages are required as alternative technology. Coagulation-flocculation process is widely used in wastewater treatment plants because of implementation and operation simplicity (Rivas et al, 2004).

Ballasted flocculation units function through the addition of a coagulant, such as PAC, alum and ferric chloride; a cationic polymer and a ballast material such as micro zeolite and micro sand or chemically enhanced sludge. When coupled with chemical addition, this ballast material has been shown to be effective in coagulation-flocculation. The process used at stages of leachate treatment. It was high rate secondary clarification and final polishing for the removal of suspended solid (SS), colour, COD and ammoniacal nitrogen (NH_3N). The process operates with micro

zeolite and micro sand which enhances particle formation and acts as ballast to aid in rapid settlement of coagulated material (Semerjian & Ayoub, 2003).

The micro sand or micro zeolite ballasted flocculating process is a combination of coagulant and coagulant aids. The micro sand or micro zeolite enhances flocculation and acts as ballast, resulting is a unique with settling characteristics. The relatively high concentration of micro sand or micro zeolite in the mixing basin minimizes the impact of sudden variations in the leachate quality. Micro sand and micro zeolite ballasted settling is a high rate coagulation, flocculation and sedimentation process that uses micro sand and micro zeolite as a seed for particle formation. The micro sand and micro zeolite provides a surface area that enhances flocculation and acts as a ballast or weight. The resulting particle settles quickly, allowing for compact clarifier designs with high overflow rates and short detention times. Hence, it is extremely important monitoring, control, and maintain leachate quality and treated it by ballast material (Demirbas, 2011).

1.3 Significant of study

Landfills are treated as dirty and undesirable by the neighbouring residents who tend to be more concerned about the environmental aspects and on land development aspects. Thus, it is necessary to plan and design the landfill system which can prevent and minimise further contamination and pollution to surrounding environment. The landfill can also be considered as a treatment facility whereby the solid waste undergoes a process of decomposition and stabilisation. The biological, physical and chemical changes occurring in the waste layers play an important role in the treatment process. Leachate from the sanitary landfill site may be harmful and contaminate the water sources if it was discharged without treatment. Adequate and effective leachate treatment system must be provided with sufficient treatment and retention capacity to handle the leachate quantity, suitable treatment facilities should be provided in order to prevent and minimise further contamination and pollution to surrounding environment (Zhao et al., 2000)

The harmful liquid that collects at the bottom of a landfill is known as leachate. Leachate can also include the moisture content initially contained in the waste, as well

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as infiltrating groundwater. The generated leachate can cause significant environmental damage, becoming a major pollution hazard when it comes into contact with the surrounding soil, ground or surface waters. This leachate often contains a high concentration of organic matter and inorganic ions, including ammoniacal nitrogen and heavy metals. Therefore, in order to avoid environmental damage, landfill leachate must be collected and appropriately treated before being discharged into any water body (Oh et al., 2007).

Coagulation was used to remove suspended solids (SS), chemical oxygen demand (COD), colour and ammoniacal nitrogen (NH_3N) from the leachate. The coagulation is widely used in wastewater treatment and the operating cost is low (Wang et al., 2008). The coagulation was the process whereby destabilization of a given suspension or solution is affected. That is, the function of coagulation is to overcome the factors that promote the stability of a given system. Flocculation was the process whereby destabilized particles formed as a result of destabilization, are induced to come together, make contact, and thereby form larger agglomerates. (Semerjian et al., 2001).

1.4 Objective

The main objective of this research was to determine the efficiency of leachate treatment using coagulation-flocculation. This research examined the effectiveness of PAC, aluminium sulphate (alum) and ferric chloride as well as the use of synthetic polymers (cationic and anionic) and the use of micro sand and micro zeolite on removal of suspended solid (SS), COD, colour, and ammoniacal nitrogen (NH_3N). To achieve these objectives, the study through several stages include the following objectives:

1. To determine the effectiveness of PAC, alum and ferric chloride as a coagulant for use in leachate treatment.
2. To determine the difference in the removal efficiency of Polyaluminium Chloride (PAC), aluminium sulphate (alum) and ferric chloride as coagulant in removing ammonical nitrogen, COD, colour and suspended solids from

leachate, in the presence of coagulant aids (cationic polymer and anionic polymer).

3. To determine the effectiveness of using PAC, alum and ferric chloride as coagulant in removing ammonical nitrogen, COD, colour and suspended solids (SS) from leachate, in the presence of coagulant aids (cationic polymer and anionic polymer) with the micro sand and micro zeolite.

1.5 Scope of study

This study focuses on the process of coagulation-flocculation as a treatment process for leachate generated from Pasir Gudang sanitary landfill. This was obtained by conducting jar test in the laboratory using the three types of inorganic coagulant that is PAC, aluminium sulphate (alum) and ferric chloride as the use of cationic polymer FO4290 SH and anionic polymer AN934 SH. The effectiveness use of these coagulant substances studied on the removal of four parameters of the highest pollutant in leachate disposal that is chemical oxygen demand (COD), suspended solid (SS), colour and ammoniacal nitrogen (NH_3N). The effectiveness of using PAC, alum and ferric chloride as coagulant in removing ammonical nitrogen, COD, colour and suspended solids from leachate, in the presence of micro sand, micro zeolite and cationic polymer and anionic polymer. Pasir Gudang sanitary landfill had been chosen as the location for this study. To achieve the objective, this study focused on the effect of pH, coagulant dosage, coagulant aids dosage, micro zeolite dosage, micro sand dosage, specified mixing speed (rapid mixing and slow mixing), specified mixing time (rapid mixing time and slow mixing time) and settling time (settling time with polymer and settling time without polymer). This was the particle size of the optimum settling time (with polymer and without polymers), pH optimum and coagulant dosage optimum. Finally, it was determine the effectiveness of using micro zeolite and micro sand combined with coagulant and coagulant aids.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Landfill is the most common method use to dispose solid waste. It is an engineered method for disposing solid waste on land in a manner that minimizes environmental hazards and nuisances. Land filling operation involve compaction of solid waste in layers at properly selected site, thereby allowing waste to decompose under controlled condition until it eventually transform into relatively inert, stabilization and extraction of pollutants from a landfills depend upon these factors: composition of the wastes, degree of compaction, amount of moisture presence, presence of inhibiting materials, rate of water movement, and temperature (Zouboulis et al., 2008). The main environmental problem at landfills site are the infiltration of leachate and its subsequent contamination of the surrounding land and aquifers. Improvements in landfill engineering aim to reduce the leachate production, collection and treatment prior to discharge. Therefore, there is a need to develop reliable and sustainable options to manage leachate generation and treatment effectively (Sartaj et al., 2010).

Leachate production starts at the early stages of the landfill and continue several decades even after closure of landfill. It is generated mainly by the infiltrated water, which passes through the solid waste fill and facilitates transfer of contaminants from solid phase to liquid phase (Parkes et al., 2007). Due to the inhomogeneous nature of the waste and because of the differing compaction densities, water percolates through and appears as leachate at the base of the site. Depend on the geographical and geological nature of a landfill site, leachate may seep into the ground and possibly enter groundwater sources. Thus it can be major cause of groundwater pollution (Umar et al.2010).

2.2 Management of sanitary landfill system

Landfill methods are considered as the most economical and environmentally acceptable way of disposing of solid wastes throughout the world. Even with the implementation of waste in landfill will still remain as an important component of an integrated solid waste management strategy. In engineering terms, a sanitary landfill is also sometimes identified as a bioreactor due to the presence of anaerobic activities in the wastes. As such, landfilling sites need the incoming waste stream to be monitored, as well as placement and compaction of the waste, and installation of landfill environmental monitoring and control facilities. Gas vent and leachate collection pipes are important features of a modern landfill (Demirbas, 2011).

The main aim of a sanitary landfill is to use it for a longer time for disposal of solid waste with less negative effect to the ecosystem. If the sanitary landfill is design for energy extraction, the landfill gas can be used as a source of energy. Moreover, in some countries, reclamation of land is done especially where land is limited (Agamuthu, 1999). Although the sanitary landfill have a lot of benefits but they also have some disadvantages. Landfills require usable land which should be located near several cities. Unfortunately land is in short supply and sometimes expensive. Secondly, sanitary landfill can pollute ground water with toxic waste like pesticides. Another disadvantage is that they produce methane gas which causes air pollution. Finally, it may cause loss of resources which may become extinct (Chiras, 2001). The landfill should be allocated far away from water resources such as stream, lakes and aquifers in order to reduce the problems of water pollution. There must be several monitoring wells around the landfill to monitor the movement of pollutants. There should also be a special drainage system which can help to reduce the flow over from the landfill surface. Thus, the amount of water that penetrates it will be reduced. Typically, impermeable clay cap located at the top of landfill can prevent the infiltration of water through the landfill.

2.3 Overview of municipal solid waste landfill

A landfill is any form of waste disposal land, ranging from an uncontrolled rubbish dump to a full containment site engineered with high standard to protect the

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environment. There are several types of landfills with or without engineering measures which are shown in the Table 2.1.

The landfill is the most economical for solid waste disposal that minimizes adverse environmental effects, associated risks and inconveniences, thereby allowing the waste to decompose under controlled condition until it eventually transforms into a relatively inert and stabilized material. Most landfills can be operated satisfactorily for at least some period in their lifetime and absence of any significant negative environmental impact makes this method cheap and effective in preventing pollution by leachate discharges (Joseph, 2002).

Table 2.1: Types of landfill (Joseph, 2002)

Type	Engineering measures	Leachate management	Landfill gas management	Operation measures
Open dumps	None	Unrestricted release of contaminants	None	Few mostly scavenging
Controlled dump	None	Unrestricted release of contaminants	None	Recording and placement of waste with compaction
Engineered landfill	Infrastructure and placing of liner	Containment and some level of leachate management	Passive ventilation or flaring	Registration and placement of waste with compaction and daily use of soil cover
Sanitary landfill	Proper siting and infrastructure : liner and leachate collection	Containment and leachate treatment (biological and physic-chemical)	Flaring	Registration and placement of waste with compaction and daily use of soil cover, and final top cover
Controlled contaminant release landfill	Proper siting and infrastructure with low permeable liner; low permeable final top cover	Controlled release of leachate based on assessment and proper siting and treatment	Flaring or passive ventilation through top cover	Registration and placement of waste with compaction and daily use of soil cover, and final top cover

Table 2.1 (continued)

Landfill bioreactor	Proper siting and infrastructure with liner and leachate recirculation system	Controlled leachate recirculation for enhanced degradation and stabilization of waste and leachate	Landfill gas recovery	Registration and placement with compaction, daily cover, closure, mining and material recovery
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2.4 Landfill in Malaysia

In Malaysia, there are about 296 landfills all over the countries and 130 of these landfills are no longer in operation. The 166 landfills which are in operation are either dumpsites or controlled tipping areas and only seven of the operating landfills are classified as sanitary landfills. At present, almost all landfills are owned by the federal government. They are operated by the concession companies or the local authorities themselves. In the southern part of peninsular Malaysia, most landfills are operated by Southern waste Management Sdn Bhd, a concession company appointed by the government to handle privatization of solid waste management whereas in the central region there is mixture of operator between Alam Flora Sdn Bhd and local authorities (Agamuthu, 1999).

A landfill within particular local authorities is meant for the disposal of solid waste from that area. There are few occasions when a couple of local authorities shared a landfill, but solid waste from one state does not cross over to be disposed in a landfill in another state. Under the federalization of solid waste management under act 672, the department of national solid waste management decides on location, type and size of landfills and the coverage area of each landfill. The building of new landfills, alteration and closure need an approval from the department and the operator of landfill will also be required to apply for license. Disposal of solid waste will be allowed only at landfills designated by the department (Aziz et al., 2008).

The federalization of solid waste management will enable disposal of solid waste to be carried out across state borders. Under this approach, regional landfills complete with centralized treatment plant will be build. In this regard, several local

authorities either from same states or from neighboring states and situated near the border may shared the same sanitary landfill. This approach is to capitalize on the short distances between the sources of waste and the landfill and thus keep the cost of transportation low (Lee et al., 2011).

The constrained faced in the closure of non-sanitary landfills are the difficulties in finding suitable sites for new landfills. As a result, existing landfills continue to be used and temporary measures are taken to upgrade these landfills so as to mitigate further environmental degradation especially leachate problem. Since the time taken to plan and build a new landfill is approximately 2.5 years, non-sanitary landfills identified to be closed will be upgraded and continue to be used at the most another three years. However, in the future, sanitary landfills which are safely closed can be utilized as recreational areas as well as green lungs (National Solid Waste Management Department).

Table 2.2: Numbers of Solid waste Disposal Sites in Malaysia (National Solid Waste Management Department, NSWMD)

State	Operational landfills	Non-operational landfills
Perlis	1	1
Kedah	9	6
Pulau Pinang	2	1
Perak	17	12
Pahang	16	16
Selangor	8	14
Federal Territory Putrajaya	0	0
Federal Territory Kuala Lumpur	0	7
Negeri Sembilan	7	11
Melaka	2	5
Johor	14	23
Kelantan	13	6
Terengganu	8	12

Table 2.2 (continued)

Peninsular Malaysia	97	114
Federal Territory Labuan	1	0
Sabah	19	2
Sarawak	49	14
Total	166	130
OVERALL TOTAL		296

2.5 Sanitary landfills

There are four critical elements in a sanitary landfill: a bottom line, a leachate collection system, a cover, and the natural hydro geologic setting. The natural setting can be selected to minimize the possibility of wastes escaping to groundwater beneath a landfill. Three other elements must be engineered. Each of these elements is critical to success. In pursuance to a better management of solid waste disposal, there are two levels of sanitary landfill that are being built by the department (Cotman & Gotvajn., 2010). Sanitary landfill level 3 is complete with retaining structure; clearly defined cells, surface water drainage, and daily soil cover together with liner system, leachate collection and recirculation system. The leachate is collected through a series of collection pipes and reticulated back to the waste layer so that it may be reprocessed and further decompose to improve leachate quality. Recirculation will also promote faster evaporation and thus reduce the quantity of the effluent. The level 4 sanitary landfill is an improvement of the level 3 landfill with leachate treatment facilities (Cook & Fritz., 2002).

Sanitary landfill is one the popular means to address the disposal of the solid waste particularly in developing countries in comparison with incinerators. Although, it is much cheaper, it is faced with land constraint and continuous management for 20-30 years throughout its active operating time. After it is no longer in operation; post closure management has to be in place to address any environmental pollution that may arise. Nevertheless, sanitary landfill ensures that solid waste is to be disposed off in an environment friendly manner. Leachate is contained and treated by the treatment plant and the incidence of vector borne diseases is addressed. In addition, sanitary

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landfill is a potential source of renewable energy where the methane gas can be harness into providing electricity (Al – Abdali et al., 2008, Al – Yaqout et al., 2005).

2.6 Leachate

The harmful liquid that collects at the bottom of a landfill is known as leachate. The generation of leachate is a result of uncontrolled runoff, and percolation of precipitation and irrigation water into the landfill (Cook & Fritz et al., 2002). Leachate can also include the moisture content initially contained in the waste, as well as infiltrating groundwater. Leachate contains a variety of chemical constituents derived from the solubility of the materials deposited in the landfill and from the products of the chemical and biochemical reactions occurring within the landfill under the anaerobic conditions (Mor et al., 2006).

The generated leachate can cause significant environmental damage, becoming a major pollution hazard when it comes into contact with the surrounding soil, ground, or surface waters. One such problem is caused by infiltrating rainwater and the subsequent movement of liquid or leachate out of the fill into the surrounding soil. This leachate often contains a high concentration of organic matter and inorganic ions, including ammoniacal nitrogen and heavy metals. Therefore, in order to avoid environmental damage, landfill leachate must be collected and appropriately treated before being discharged into any water body (Parkes et al., 2007).

2.7 Composition and characteristics of leachate

Leachate tends to percolate downward through solid waste, continuing to extract dissolved or suspended materials. In most landfills, leachate seeps through the landfill from external sources, such as surface drainage, rainfall, groundwater, and water from underground springs, as well as from the liquid produced from the decomposition of the waste. Many factors influence the production and composition of leachate. One of the major factors is the climate of the landfill. For example, where the climate is prone to higher levels of precipitation, there will be more water entering the landfill and therefore more leachate generated.

The composition of leachate is important in determining its potential effects on the quality of nearby surface water and groundwater. Contaminants carried in leachate are dependent on solid waste composition and on the simultaneously occurring physical, chemical and biological activities within the landfill. The quantity of contaminants in leachate from a completed landfill can be decreased with time, but it will take several years to stabilize. Landfill more than 10 years old was in the methanogenic phase and the leachate was produced as stabilized leachate (Bashir et al., 2011).

Table 2.3: Composition of leachate from landfill (Tchobanoglous et al., 1993)

Constituent*	Range	Typical
BOD (5-day Biochemical Oxygen Demand)	2000-30,000	10,000
TOC (Total Organic Carbon)	1500-20,000	6000
COD (Chemical Oxygen Demand)	3000-45,000	18,000
TSS (Total Suspended Solids)	200-1000	500
Organic Nitrogen	10-600	200
Ammoniacal Nitrogen	10-800	200
Nitrate	5-40	25
Total Phosphorus	1-70	30
Ortho Phosphorus	1-50	20
Alkalinity as CaCO ₃	1000-10,000	3000
pH	5.3-8.05	6
Total hardness as CaCO ₃	300-10,000	3500
Calcium	200-3000	1000
Magnesium	50-1500	250
Potassium	200-2000	300
Sodium	200-2000	500
Chloride	100-3000	500
Sulfate	100-1500	300
Total Iron	50-600	60

*All in mg/L units except pH

2.8 Factor affecting leachate quality

The composition of leachate is influenced by various factors such as solid waste composition and age of landfill. These factors interlinked with one another have potential to influence the leachate quality, thereby producing an integrated effect on its quality.

2.8.1 Solid waste composition

The leachate quality is significantly affected by the composition of refuse. The nature of the waste organic fraction influences considerably the degradation of waste in the landfill and also the quality of the leachate produced. In particular, the presence of substances which are toxic to bacterial flora may slow down or inhibit biological degradation processes with consequences for the leachate. The organic content of the leachate depends on the contact between waste and leaching water and the chemical balance at the solid liquid interface. In particular, the majority of metals are released from the waste mass under acid conditions. The organic content leached is as a result of hydrolysis and degradation of higher molecular weight organic compounds by the microorganisms present in the waste (Durmusoglu et al., 2006).

2.8.2 Age of landfill

Variations in leachate composition and in quantity of pollutants removed from waste are often attributed to landfill age, defined as time measured from the deposition of waste or time measured from the first appearance of leachate. Landfill age obviously plays an important role in the determination of leachate characteristics governed by the types of waste stabilization processes. It should be underlined that variations in composition of leachate do not depend exclusively on landfill age but on the degree of waste stabilization and volume of water which infiltrates into the landfill. The pollutant load in leachate generally reaches maximum values during the first years of operation of a landfill (2-3 years) and then gradually decreases over following years. This trend is generally applicable to organic pollution i.e. COD, BOD, total organic

carbon (TOC), microbiological population and to main inorganic ions i.e heavy metals, chloride and sulphate (Jamali et al., 2009).

2.9 Environmental pollution due to leachate

The dilution of leachate is faster in surface water than in groundwater, but the contaminants may also spread over larger areas much faster. As well as becoming diluted, biodegradable matter in surface water decomposes, leading to oxygen depletion. Some organic substances in leachate may be toxic to aquatic organisms (Chen et al., 1996)

The major concern about organic matter from leachate in surface water was the ecological effects. Some components (inorganic trace elements) also have cumulative effects on aquatic organisms. The inorganic component of concern in leachate is ammonia. Ammonia is toxic to fish and other aquatic organisms and may generate eutrophication. During nitrification of ammonia in surface water, oxygen depletion will occur and may affect the aquatic ecosystem. For freshwater courses, discharge of leachate with high salt concentration may alter the salinity and thereby affect the aquatic ecosystem (Guo et al., 2010).

2.10 Leachate treatment

The leachate treatment processes have different effectiveness depending on the leachate from landfill of different ages. Leachate can be treated by three main methods that is physical, chemical and biological treatment. Treatment can be alone or combination of two or three of the above methods. Air stripping, adsorption are major physical leachate treatment methods, while the other methods such as coagulation-flocculation, chemical precipitation, chemical and electrochemical oxidation methods are the common chemical methods used for the landfill leachate treatment. This combination method is most popularly used to achieve excellent leachate treatment efficiency (Sartaj et al., 2010; Basher, et al., 2009).

2.10.1 Biological treatment

The most common practice for leachate treatment worldwide is biological treatment. Biological systems can be divided in anaerobic and aerobic treatment processes. Both can be realized by using different plant concepts. A combination of aerobic, anaerobic and anoxic processes is the main processes used for biological treatment. Biological treatment of landfill leachate usually results in low treatment efficiencies because of high chemical oxygen demand (COD), high ammonium nitrogen content and also presence of toxic compounds such as heavy metals (Primo et al., 2008).

2.10.1.1 Aerobic biological treatment processes

High ammonia concentrations and phosphorus deficiency in leachate hamper the efficiency of biological treatment. A general consensus among researcher is that high nitrogen levels are also hazardous to receiving waters and need to be removed prior to discharge. This is generally carried out through physical-chemical processes in the stabilized leachate. Conventional aerobic systems consist of either attached or suspended growth systems. The advantages and disadvantages of each system is case specific. Suspended growth systems range from aerated lagoons, activated sludge and SBR while attached growth processes include trickling filters and rotating biological contractors. Trickling filters are generally not used for leachate treatment when the leachate contains high concentration of organic matter, because of the large sludge production, which result in clogging of the filters (Lin & Chang., 2000). The most common aerobic biological treatment methods are aerated lagoons and activated sludge plants

Doyle et al., (2001) conducted a study of high rate nitrification in SBR on a mature leachate obtained from a domestic landfill. The leachate possessed high ammonia content with an average concentration of 880 mg/L, while the average BOD₅ and COD concentration were 600 and 1100 mg/L respectively.

Uygun et al., (2004) has been investigated in biological treatment of landfill leachate usually results in low nutrient removals because of high chemical oxygen demand (COD) and high ammonium content. Experiments were carried out the operations with a total cycle time of 21 h at a constant sludge age of 10 days. The

SBR resulting in 75% COD, 44% $\text{NH}_3\text{-N}$ and 44% $\text{PO}_4\text{-P}$ removals after 21 hours of operation.

Maehlum (1995) has been used on site anaerobic-aerobic lagoons and constructed wetlands for biological treatment of landfill leachate. Overall N, P and Fe removals obtained in this system were above 70% for diluted leachate.

Orupold et al., (2000) studied the feasibility of lagooning to treat phenolic compounds as well as organic matter. Abatement of 55-64% of COD and 80-88% of phenol was achieved. However, as stricter requirements are imposed, lagooning may not be a completely satisfactory treatment option for leachate in spite of its lower costs.

Hoilijoki et al., (2000) investigated nitrification of anaerobically pre-treated municipal landfill leachate in lab-scale activated sludge reactor, at different temperatures (5-10°C) and with the addition of plastic carrier material. Aerobic post-treatment produced effluent with 150-500 mg COD L⁻¹, less than 7 mg BOD L⁻¹ and on an average, less than 13 mg $\text{NH}_4^+\text{-NL}^{-1}$. Addition of PAC to activated sludge reactors enhanced nitrification efficiency on biological treatment of landfill leachate.

Trickling filters has been investigated by Martienssen and Schops for the biological nitrogen lowering from municipal landfill leachate. Above 90% nitrification of leachate was achieved in laboratory and on-site pilot aerobic crushed brick filters with loading rates between 100 and 130 mg $\text{NH}_4^+\text{-N L}^{-1}\text{ day}^{-1}$ at 25°C and 50 mg $\text{NH}_4^+\text{-N L}^{-1}\text{ day}^{-1}$ even at temperatures as low as 5-10°C respectively.

Moving-bed biofilm reactor (MBBR) process is based on the use of suspended porous polymeric carriers, kept in continuous movement in the aeration tank, while the active biomass grows as a biofilm on the surfaces of them. Welander et al., (1998) reported nearly 90% nitrogen removal while the COD was around 20%.

2.10.1.2 Anaerobic biological treatment

Anaerobic biological treatment uses microorganisms, which grow in the absence of dissolved oxygen and convert organic material to carbon dioxide, methane and other metabolic products. An anaerobic digestion treatment of leachates allows ending the process initiated in the tip, being thus particularly suitable for dealing with high strength organic effluents, such as leachate streams from young tips. The most

common aerobic biological treatment methods are up-flow anaerobic sludge blanket (UASB) reactors, up-flow anaerobic filter or anaerobic digester (Motta et al., 2007).

The main advantages of anaerobic treatment over aerobic treatment are:

1. Lower energy requirement as no oxygen is required and thus reduces the operational cost.
2. Low sludge production as only about 10-15% of organics is transformed into biomass.
3. Biogas production (85-90%) favors the energy balance with a low nutrient requirement making it appropriate for treating leachate.
4. Anaerobic microorganisms seldom reach endogenous phase, important for the treatment of leachate with variable volume and strength.
5. Elimination of odor problems.
6. Anaerobic sludge is highly mineralized than aerobic sludge, which increases its value as fertilizer if toxic metals are removed.

Up-flow anaerobic sludge blanket (UASB) process is a modern anaerobic treatment that can have high treatment efficiency and a short hydraulic retention time. The process temperatures reported have generally been 20-35°C for anaerobic treatment with UASB reactors. In these conditions, the average performance of COD decrease efficiency was always higher than 70% at ambient temperature (20-23°C) and 80% at 35°C. Up to 92% COD decreases were obtained by Kennedy & Lentz (2000) at low and intermediate organic loading rates (between 6 and 19.7 g COD L⁻¹ day⁻¹).

Anaerobic filter is a high rate system that gathers the advantages of other anaerobic systems and that minimizes the disadvantages. Henry et al., (1987) demonstrated that anaerobic filter could reduce the COD by 90%, at loading rates varying from 1.26 to 1.45 kg COD m⁻³ day⁻¹, and this for different ages of landfill. Total biogas production ranged between 400 and 500 L gas kg⁻¹ COD destroyed and methane content between 75 and 85%.

Hybrid bed filter consists on an up-flow sludge blanket at the bottom and an anaerobic filter on top. Enhanced performance of such a process results from

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maximization of the biomass concentration in the reactor. Newdwell and Reynolds et al., (1996) reported steady state COD removal efficiencies of 81-97% under methanogenic digestion, depending upon organic loading rate. One drawback of hybrid reactor, as well as anaerobic filter, is the added cost of the support media.

2.10.2 Physical – chemical treatment

a. Air stripping

Air and liquid are contacted in countercurrent flow in stripper tower. The ammonia, other gases and volatile organics are removed. It has been found that the best method for removing a high concentration of $\text{NH}_3\text{-N}$ in wastewater treatment technologies is air stripping. The leachate usually contains high levels of ammonium and nitrogen, and both of them can be eliminated by using the air stripping method (Marttinen et al., 2002). This method is efficient at a high pH value because Marttinen et al., (2002) confirmed that about 89% ammonia was reduced at pH 11 within 24 hour retention time. However, this method has a disadvantages which is emission of NH_3 into the air which can cause air pollution if ammonia.

b. Coagulation

Colloidal particles are destabilized by rapid dispersion of chemicals. Organics, suspended solids, phosphorus, some metals and turbidity are removed. Alum, iron salts and polymers are commonly used coagulation chemicals. Coagulation is the first step destabilizes the particle's charges. Coagulants have an opposite charge to those of suspended solids. The coagulants are used in the leachate in order to defuse the negative charges on dispersed solids which are not settled like color producing organic substances and clay. When the charge is neutralized, the small particle which are suspended particles are neutralized because the coagulant is not enough and needs more coagulant to be added (Ayoub et al., 2001). The next step after coagulation is flocculation which occurs in the moving particles that are not fixed into large flocs so that



it can settle very fast. Coagulation further reduced suspended solids and neutralized pH.

c. Ion exchange

This treatment is capable of effectively removing the traces of metal impurities to meet the increasingly strict discharge standards in developed countries. The leachate should first be subjected to a biological treatment prior to ion exchange. The application of ion exchange is not commonly employed for the treatment of landfill leachate because it is expensive due to high operational cost (Abbas et al., 2009).

d. Flotation

Flotation has found extensive use in wastewater treatment. Flotation has been employed to separate heavy metal from a liquid phase using bubble attachment, originated in mineral processing. Dissolved air flotation (DAF), ion flotation and precipitation flotation are the main flotation processes for the removal of metal ions from solution. Flotation have several advantages over the more conventional method, such as high metal selectivity, high removal efficiency, high overflow rates, low detention periods, low operating cost and production of more concentrated sludge (Rubio et al., 2002). The disadvantages involve high initial capital cost, high maintenance and operation cost.

e. Chemical precipitation

Chemical precipitation is widely used as pre-treatment in order to remove high strength of ammonium nitrogen ($\text{NH}_4^+\text{-N}$). Li et al., (1999) confirmed that the performance of a conventional activated sludge process could be significantly affected by a high concentration of $\text{NH}_4^+\text{-N}$. the COD removal declined from 95 to 79%, when the $\text{NH}_4^+\text{-N}$ concentration in wastewater increased from 50 to 800 mg L^{-1} .

f. Reverse osmosis (RO)

RO is another alternative physic-chemical treatment for stabilized leachate. RO can be used for the removal of heavy metals, suspended/colloidal materials and dissolved solids from landfill leachate. The treatment of young leachate from the Chung Nam landfill (South Korea) was carried out using an RO system. About 96-97% removal of COD and $\text{NH}_3\text{-N}$ was achieved with initial concentration of 1500 and 1400 mg/L respectively. The results suggest that RO greatly enhanced treatment efficiency by removing non-biodegradable organic compounds from landfill leachate (Ahn et al., 2002).

Table 2.4: Summary of the physic-chemical treatments for stabilized landfill leachate

No	Type of treatment	Target of removal	Remarks	References
1	Coagulation-flocculation	Heavy metals and suspended solids	High sludge production and subsequent disposal may be a problem	O'Melia, C.R et al., 1999
2	Chemical precipitation	Heavy metals and $\text{NH}_3\text{-N}$	Requires further disposal due to sludge generation	Chareerntanyarak, L (1999)
3	Ammonium stripping	Ammoniacal nitrogen	Requires other equipments for air pollution control	Ali, M.A.B et al., 2004
4	Microfiltration	Suspended solids	Used after metal precipitation	Visvanathan, C et al., 1994
5	Ultrafiltration	High molecular weight compounds	Costly and limited applicability due to membrane fouling	Saffaj, N et al., 2004,
6	Nanofiltration	Sulphate salts and hardness ions, like Ca(II) and Mg(II)	Costly and requires lower pressure than reverse osmosis	Alborzfar, M et al., 1998
7	Reverse osmosis	Organic and inorganic compounds	Costly and extensive pre-treatment is required prior to RO	Cornellison, E.R et al., (2001)

Table 2.4 (continued)

8	Activated carbon adsorption	Organic compounds	Carbon fouling can be a problem and GAC adsorption is costly	Kargi, F et al., (2003)
9	Ion exchange	Dissolved compounds, cations/anions	Used as a polishing step after biological treatments and treatment cost is high	Fettig, J et al., (1999)

2.11 Coagulation-flocculation

Coagulation-flocculation is widely used for wastewater treatment. This treatment is efficient to operate. It has many factors that can influence the efficiency, such as the type and dosage of coagulant/flocculants, pH, mixing speed and time and retention time. The optimization of these factors may influence the efficiency (Wang et al., 2007). Coagulation-flocculation is destabilizing the colloidal suspension of the particles with coagulants and then causing the particles to agglomerate with flocculants. After that, it will accelerate separation and thereby clarify the effluents (Gnandi et al., 2005). Coagulation-flocculation treatments are done by adding coagulant and coagulant aids. Polyaluminum chloride (PAC), ferric chloride and aluminium sulphate (alum) are commonly used as coagulant. Furthermore, polymer is used as coagulant aid. Coagulation-flocculation process is usually used for treating fresh leachate and it is applied as a pretreatment before biological treatment. It is used to remove heavy metal and non-biodegradable organic compounds from landfill leachate (Tatsi et al., 2003).

Coagulation-flocculation studies are carried out in usual jar test equipment. The jar test has been the typical technique used in wastewater and drinking water industry to improve the addition of coagulant and flocculants (Galvez et al., 2005). The speed and duration of mixing are significant factors in both the first and second steps. For example if the mixing strength is too high, it could be a reason to split up the aggregated floc. The other important factor is the duration of settlement (Choi et al., 2006).

REFERENCES

Abbas, A.A, Guo, J.S, Liu, Z.P, Pan, Y.Y. & Al-Rekabi, W.S. (2009). Review on landfill leachate treatments. *American Journal of Applied Sciences*, 6(4), pp. 672-684.

Aboulhassan, M.A, Souabi, S, Yaacoubi, A. & Baudu, M. (2006). Improvement of paint effluents coagulation using natural and synthetic coagulant aids. *Journal of Hazardous Materials*, B138, pp. 40-45.

Abdulhussain, A.A, Guo, J.S, Liu, Z.P, Pan, Y.Y. & Al-Rekabi, W.S.(2009). Review on landfill leachate treatments. *American Journal of Applied Sciences* 6(4), pp. 672-684.

Achak, M, Mandi, L. & Ouazzani, N. (2009). Removal of organic pollutants and nutrients from olive mill wastewater by a sand filter. *Journal of Environmental Management*, 90, pp. 2771 – 2779.

Aguilar, M.I, Saez, J, Llorens, M, Soler, A. & Ortuno, J.F. (2003). Microscopic observation of particle reduction in slaughterhouse wastewater by coagulation-flocculation using ferric sulphate as coagulant and different coagulant aids. *Water Research*, 37, pp. 2233-2241.

Agamuthu, P. (1999). Characterization of municipal solid waste and leachate from selected landfills in Malaysia. *Malaysia Journal of Science*, 18, pp. 99 – 103.

Ahn, W.Y, Kang, M.S, Yim, S.K. & Choi, K.H. (2002). Advanced landfill leachate treatment using an integrated membrane process, *Desalination*, 149, pp. 109-114.

Alborzfar, M, Jonson, G. & Gron, C. (1998). Removal of natural organic matter from two types of humic groundwater by nanofiltration, *Water Res*, 32, pp. 2983-2994.

Ali, M.A.B, Rakib, M, Laborie, S, Viers, P.H. & Durand, G. (2004). Coupling of bipolar membrane electro dialysis and ammonia stripping for direct treatment of wastewater containing ammonium nitrate. *J. Membr.Sci*, 244, pp. 89-96.

Al-Abdali, S. N. (2008). *Physic-Chemical Treatment of Bukit Tagar Sanitary Landfill Leachate Using P-Floc775 and Ferric Chloride*. University Malaya: Master's Thesis

Al-Yaqout, A.F, Hamoda, M.F. & Zafar, M. (2005). Characteristics of wastes, leachate, and gas at landfills operated in arid climate. *Practice Periodical of Hazardous, Toxic and Radioactive Waste Management*, pp. 97 – 102.

Amokrane, A, Comel, C. & Veron, J. (1997). Landfill leachates pretreatment by coagulation-flocculation. *Water Res*, 31, pp. 2775.

APHA, AWWA, WEF (2005) *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association, Washington. 21st Edition.

Amuda, O.S. & Alade, A. (2006). Coagulation/flocculation process in the treatment of abattoir wastewater. *Desalination*, 196, pp. 22-31.

Avezzu, F. (1992). Combination of wet oxidation and activated sludge treatment, in: T.H Christensen, R. Cossu, R. Stegmann (Eds), *Landfilling of waste Leachate*, Elsevier, Amsterdam, pp. 333-352.

Aygun, A. & Yilmaz, T. (2010). Improvement of coagulation-flocculation process for treatment of detergent wastewater using coagulant aids. *International Journal of Chemical and Environment Engineering*, 1(2), pp. 97-101.

Ayoub, G. M, Semerjian, L, Acra, A, El – Fadel, M. & Koopman, B. (2001). Heavy metal removal by coagulation with seawater liquid bittern. *J. Environ. Eng*, 127, pp 196 – 202.

Aziz, H. A, Adlan, M. N. & Ariffin, K. S. (2008). Heavy metal (Cd, Pb, Zn, Ni, Cu and Cr (III)) removal from water in Malaysia: Post treatment by high quality limestone. *Bioresource Technology*, 99, pp. 1578 – 1583.

Aziz, H.A. & Smith, P.G. (1996). Removal of Manganese from water using crushed dolomite filtration technique. *Water Research*. 30, 20, pp 489-258.

Baeza, A, Fernandez, M, Herranz, M, Legarda, F, Micro, C. & Salas, A. (2004). Elimination of man- made radionuclides from natural waters by applying a standard coagulation-flocculation process. *Journal of Radionalytical and Nuclear Chemistry*, 260, 2, pp 321-326.

Baeza, A, Fernandez, M, Herranz, M, Legarda, F, Micro, C. & Salas, A. (2006). Removing uranium and radium from a natural water. *Water, Air and Soil Pollution*, 173, pp. 57-69.

Baker, H.M, Massadeh, A.M. & Younes, H.A. (2009). Natural Jordanian zeolite: removal of heavy metal ions from water samples using column and batch methods. *Environ Monit Assess*, 157, pp. 319-330.

Basher, Isa, M.H, Kutty, S.R.M, Awang, Z. & Aziz, H.A, Mohajeri, S and Farooqi, I.H.(2009). Landfill leachate treatment by electrochemical oxidation. *Waste Management*, 29, pp. 2534-2541.

Bashir, M. J. K, Aziz, H. A. & Yusoff, M. S. (2011). New sequential treatment for mature landfill leachate by cationic/anionic and anionic/cationic processes: Optimization and comparative study. *Journal of Hazardous Materials*, 186, pp. 92 – 102.

Bruch, I, Fritsche, J, Banninger, D, Alewell, U, Sendelov, M, Hurlimann, H, Hasselbach, R. & Alewell, C. (2011). Improving the treatment efficiency of constructed wetland with zeolite-containing filter sands. *Bioresource Technology*, 102, pp. 937 – 941.

Burgess, R.M, Perron, M.M, Cantwell, M.G, Ho, K.T, Serbst, J.R. & Pelletier, M.C. (2004). Use of zeolite for removing ammonia and ammonia caused toxicity in Marine toxicity identification evaluations. *Arch. Environ. Contam. Toxicol*, 47, pp. 440-447.

Casey, T. J. (1997). *Unit Treatment Processes in Water and Wastewater Engineering*. John Wiley & Sons, Chichester, England.

Charerntanyarak, L. (1999). Heavy metals removal by chemical coagulation and precipitation. *Water Sci. Technol*, 39, pp. 135-138.

Chen, P.H. (1996). Assessment of leachates from sanitary landfills: impact of age, rainfall, and treatment. *Environment International*, 22(2), pp. 225-237.

Choi, K.J, Kim, S.G, Kim, C.W. & Park, J.K. (2006). Removal efficiencies of endocrine disrupting chemicals by coagulation/flocculation, ozonation, powdered/granular activated carbon adsorption, and chlorination. *Korean J. Chem. Eng*, 23(3), pp. 399-408.

Chutia, P, Kato, S, Kojima, T. & Satokawa, S. (2009). Adsorption of As(V) on surfactant-modified natural zeolites. *Journal of Hazardous Materials*, 162, pp. 204 – 211.

Cook, A.M. & Fritz, S.J. (2002). Environmental impact of acid leachate derived from coal-storage piles upon groundwater. *Water, Air, and Soil Pollution*, 135, pp. 371 – 388.

Cornellison, E.R, Sijbers, P, Berkmortel, H, Koning, J, Wit, A.D, Nil, F.D. & Impe, J.F. (2001). Reuse of leachate wastewater using MEMBIOR technology and reverse osmosis. *Membr. Technol*, 136, pp. 6-9.

Cotman, M. & Gotvajn, A.Z. (2010). Comparison of different physic-chemical methods for the removal of toxicants from landfill leachate. *Journal of Hazardous Materials*, 178, pp. 298 – 305.

Daud, Z. (2008). *Olahan Larut Lesapan Semi-Aerobik Tapak Pelupusan Sanitari Pulau Burung Menggunakan Gabungan Kaedah Penggumpalan-Pengelompokan Dan Penurasan*. Universiti Sains Malaysia: Ph.D. Thesis

Demirbas, A. (2011). Waste management, waste resource facilities and waste conversion processes. *Energy Conversion and Management*, 52, pp. 1280 – 1287.

Durmusoglu, E. & Yilmaz, C. (2006). Evaluation and temporal variation of raw and pre-treated leachate quality from an active solid waste landfill. *Water, Air and Soil Pollution*, 171, pp. 359-382.

Environmental Quality 1974, Environmental Quality (Control of pollution from solid waste transfer station and landfill), Ministry of Natural Resources and Environment, Malaysia.

Fettig, J. (1999). Removal of humic substances by adsorption/ion exchange. *Water Sci. Technol*, 40, pp. 171-182.

Foo, K.Y. & Hameed, B.H. (2009). An overview leachate treatment via activated carbon adsorption. *Journal of Hazardous Materials*, 171, pp. 54-60.

Fu, F. L. & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environment Management*, 92, pp. 407 – 418.

Gan, C.H, Elmolla, E. S. & Chaudhuri, M. (2009). Physicochemical Pretreatment of Landfill Leachate. *2nd International Conference on Engineering Technology*. pp. 1-5.

Ghafari, S, Aziz, H.A. & Bashir, M.J.K. (2010). The use of poly-aluminium chloride and alum for the treatment of partially stabilized leachate: A comparative study. *Desalination*, 257, pp. 110-116.

Ghafari, S, Aziz, H.A, Isa, M.H. & Zinatizadeh, A.A. (2009), Application of response surface methodology (RSM) to optimize coagulation-flocculation treatment of leachate using poly-aluminium chloride (PAC) and alum. *Journal of Hazardous Materials*, 163, pp. 650-656.

Gnandi, K, Tchangbedji, G, Killi, K, Baba, G. & Salim, O. (2005). Processing of phosphate mine tailings by coagulation flocculation to reduce marine pollution in Togo: laboratory tests. *Mine Water and the Environment*, 24, pp. 215 – 221.

Golob, V, Vinder, A. & Simonic, M. (2005). Efficiency of the coagulation/flocculation method for the treatment of dyebath effluents. *Dyes and Pigments*, 67, pp. 93-97.

Gone, D. L, Seidel, J. L, Batiot, C, Bamory, Kamagate, Ligban, R. & Biemi, J. (2009). Using fluorescence spectroscopy EEM to evaluate the efficiency of organic matter removal during coagulation-flocculation of a tropical surface water (agbo reservoir). *Journal of Hazardous Materials*, 172, pp. 693-699.

Govind, N, Andzelm, J, Reindel, K. & Fitzgerald, G. (2002). Zeolite-catalyzed hydrocarbon formation from methanol: density functional simulations. *International Journal Molecular Sciences*, 3, pp. 423 – 434.

Guo, J.S, Abbas, A.A, Chen, Y.P, Liu, Z.P, Fang, F. & Chen, P. (2010). Treatment of landfill leachate using a combined stripping, fenton, SBR, and coagulation process. *Journal of Hazardous Materials*, 178, pp. 699-705.

Gupta, S. K. & Singh, G. (2007). Assessment of the efficiency and economic viability of various methods of treatment of sanitary landfill leachate. *Environ Monit Assess*, 135, pp. 107 – 117.

Gurses, A, Yalcin, M. & Dogar, C. (2003). Removal of remazol red by using Al (III) as coagulant-flocculant: effect of some variables on settling velocity. *Water, Air and Soil Pollution*, 146, pp. 297 – 318.

Haydar, S. & Aziz, J.A. (2009). Coagulation-flocculation studies of tannery wastewater using combination of alum with cationic and anionic polymers. *Journal of Hazardous Materials*, 168, pp. 1035-1040.

Henry, J.G, Prasad, D. & Young, H. (1987). Removal of organics from leachates by anaerobic filter. *Water Res*, 21, pp. 1395-1399.

Horan, N. J, Gohar, H. & Hill, B. (1997). Application of a granular activated carbon-biological fluidized bed for the treatment of landfill leachates containing high concentration of ammonia. *Water Sci. Technol.*, 36, pp. 369-375.

Hoilijoki, T.H, Kettunen, R.H. & Rintala, J.A. (2000). Nitrification of anaerobically pretreated municipal landfill leachate at low temperature. *Water Res*, 34, pp. 1435-1446.

Huang, H.M, Xiao, X.M, Yan, B. & Yang, L.P. (2010). Ammonium removal from aqueous solutions by using natural Chinese (Chende) zeolite as adsorbent. *Journal of Hazardous Materials*, 175, pp. 247 – 252.

Jamali, H.A, Mahvi, A.H, Nabizadeh, R, Vaezi, F. & Omrani, G.A. (2009). Combination of coagulation-flocculation and ozonation process for treatment of partially stabilized landfill leachate of Tehran. *World Applied Sciences Journal* 5, *Special Issue for Environment*, pp. 9-15.

James, R. & Sampath, K. (1999). Effect of zeolite on the reduction of cadmium toxicity in water and a freshwater fish, *oreochromis mossambicus*. *Bull. Environ. Contam. Toxicol*, 62, pp. 222-229.

Joseph, K. (2002). Solid waste dump sites to sustainable landfills. *Environ Vision* 2002, B1, (3), pp. 1 -14.

Jung, J.Y, Pak, D, Shin, H.S, Chung, Y.C. & Lee, S.M. (1999). Ammonium exchange and bioregeneration of bio-flocculated zeolite in a sequencing batch reactor. *Biotechnology letter*, 21, pp. 289 – 292.

Kargi, F. & Pamukoglu, M.Y. (2003). Simultaneous adsorption and biological treatment of pre-treated landfill leachate by fed-batch operation. *Process Biochem*, 38, pp. 1413-1420.

Kargi, F. & Pamukoglu, M.Y. (2004). Adsorbent supplemented biological treatment of pre-treated landfill leachate by fed-batch operation. *Bioresour. Technol*, 94, pp. 285-291.

Kennedy, K.J. & Lentz, E.M. (2000). Treatment of landfill leachate using sequencing batch and continuous flow upflow anaerobic sludge blanket (UASB) reactors. *Water Res*, 34, pp. 3640-3656.

Khalili, M, Makizadeh, M. A. & Taghipour, B. (2005). Evaporitic zeolites in central Alborz, north of Iran. *Carbonates and Evaporites*, 20(1), pp. 34 – 41.

Kim, D, Ryu, H.D, Kim, M.S, Kim, J.Y. & Lee, S.I. (2007). Enhancing struvite precipitation potential for ammonia nitrogen removal in municipal landfill leachate. *Journal of Hazardous Materials*, 146, pp. 81 – 85.

Kurniawan, T.A, Lo, W.H. & Chan, G.Y.S. (2006). Physic-chemical treatments for removal of recalcitrant contaminants from landfill leachate. *Journal of Hazardous Materials*, B129, pp. 80-100.

Lee, W. & Westerhoff, P. (2006). Dissolved organic nitrogen removal during water treatment by aluminum sulphate and cationic polymer coagulation. *Water Research*, 40, pp. 3767-3774.

Lee, M.R. & Zawawi, D. (2011). Efficiency of coagulation-flocculation for the leachate treatment. *International of Sustainable Development*, 2, 10, pp. 85 – 90.

Lee, M.R, Zawawi, D. & Abdul, A.A.L. (2012). Treatment of leachate by Coagulation-Flocculation using different coagulants and polymer. *International Journal on Advanced Science, Engineering and Information Technology*, 2, 2, pp. 1-4.

Li, W, Hua, T, Zhou, Q.X, Zhang, S.G. & Li, F.X. (2010). Treatment of stabilized landfill leachate by the combined process of coagulation/flocculation and powder activated carbon adsorption. *Desalination* 264, pp. 56-62.

Li, H.S, Zhou, S.Q, Sun, Y.B, Feng, P. & Li, J.D. (2009). Advanced treatment of landfill leachate by a new combination process in a full-scale plant. *Journal of Hazardous Materials*, 172, pp. 408-415.

Li, X.Z, Zhao, Q.L. & Hao, X.D. (1999). Ammonium removal from landfill leachate by chemical precipitation. *Waste Manage*, 19, pp. 409-415.

Liang, Z, Wang, Y.X, Zhou, Y, Liu, H. & Wu, Z.B. (2009). Variables affecting melanoidins removal from molasses wastewater by coagulation/flocculation. *Separation and Purification Technology*, 68, pp. 382 – 389.

Lin, S.H. & Chang, C.C. (2000). Treatment of landfill leachate by combined electro-fenton oxidation and sequencing batch reactor method. *Wat. Res*, 34(17), pp. 4243-4249.

Lopez, A, Pagano, M, Volpe, A. & Pinto, A, C. (2004). Fenton's pretreatment of mature landfill leachate. *Chemosphere*, 54, pp. 1005 – 1010.

Maehlum, T. (1995). Treatment of landfill leachate in on-site lagoons and constructed wetlands. *Water Sci. Technol*, 32, pp. 129-135.

Makhtar, S.M.Z, Ibrahim, N. & Selimin, M.T. (2010). Removal of colour from landfill by solar photocatalytic. *Journal of Applied Sciences*, 10(21), pp. 2721-2724.

Maleki, A, Zazouli, M.A, Izanloo, H. & Rezaee, R. (2009). Composting plant leachate treatment by coagulation-flocculation process. *American-Eurasian J. Agric. & Environ. Sci*, 5(5), pp. 638-643.

Maranon, E, Castrillon, L, Nava, Y.F, Mendez, A.F. & Sanchez, A.F. (2008). Coagulation-flocculation as a pretreatment process at a landfill leachate nitrification plant. *Journal of Hazardous Materials*, 156, pp. 538-544.

Martienssen, M. & Schops, R. (1997). Biological treatment of leachate from solid waste landfill sites-alterations in the bacterial community during the denitrification process. *Water Res*, 31, pp. 1164-1170.

Martinen, S.K, Kettunen, R.H, Sormunen, K.M, Soimasuo, R.M. & Rintala, J.A. (2002). Screening of physical – chemical methods for removal of organic material, nitrogen and toxicity from low strength landfill leachates. *Chemosphere*, 46, pp. 851 – 858.

Md Sa'at, S.K. (2006). Subsurface Flow and Free Water Surface Flow Constructed Wetland with Magnetic Field for Leachate Treatment. Universiti Teknologi Malaysia: Master's Thesis

Mor, S, Ravindra, K, Dahiya, R.P. & Chandra, A. (2006). Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. *Environmental Monitoring and Assessment* (2006), 118, pp. 435-456.

Motta, E.J.L., Silva, E., Bustillos, A., Padron, H. & Luque, J. (2007). Combined anaerobic/aerobic secondary municipal wastewater treatment: pilot plant demonstration of the UASB/aerobic solids contact system. *Journal of Environmental Engineering*, 133(4), pp. 397-403.

Mukesh Kumar Choudhary (2005), *Landfill Leachate Treatment Using a Thermophilic Membrane Bioreactor*. Asian Institute of Technology: Master's Thesis

Nandy, T., Shastry, S., Pathe, P.P. & Kaul, S.N. (2003). Pre-Treatment of Currency printing Ink Wastewater through Coagulation-Flocculation Process. *Water, Air, and Soil Pollution*, 148, pp. 15-30.

National Solid Waste Management Department. (2011, Jan). *Summary of solid waste disposal sites*. Retrieved July, 2011, from NSWND website via GOV Access <http://www.kpkt.gov.my/jpspn/main.php?Content=sections&SectionID=59&IID=>

Neczaj, E., Okoniewska, E. & Kacprzak, M. (2005). Treatment of landfill leachate by sequencing batch reactor. *Desalination*, 185, pp. 357-362.

Nedwell, D.B. & Reynolds, P.J. (1996). Treatment of landfill leachate by methanogenic and sulphate-reducing digestion. *Water Res*, 30, pp. 21-28.

Oh, B.T., Lee, J.Y. & Yoon, J.Y. (2007). Removal of contaminants in leachate from landfill by waste steel scrap and converter slag. *Environ Geochem Health*, 29, pp. 331-336.

O'Meila, C.R., Becker, W.C. & Au, K.K. (1999). Removal of humic substances by coagulation. *Water Sci. Technol*, 40, pp. 47-54.

Ozkan, A. & Yekeler, M. (2004). Coagulation and flocculation characteristics of celestite with different inorganic salts and polymers. *Chemical Engineering and processing*, 43, pp. 873-879.

Papadopoulos, A, Fatta, D. & Loizidou. (1998). Treatment of stabilized landfill leachate by physic-chemical and bio-oxidation processes. *J. Environ. Sci. Health, A33*, pp. 651.

Park, S.Y, Bae, H. & Kim, C.W. (2008). Decision model for coagulant dosage using genetic programming and multivariate statistical analysis for coagulation/flocculation at water treatment process. *Korean J. Chem. Eng, 25, 6*, pp. 1372-1376.

Parkes, S. D, Jolley, D. F. & Wilson, S. R. (2007). Inorganic nitrogen transformation in the treatment of landfill leachate with a high ammonium load: A case study. *Environ Monit Assess, 124*, pp. 51 – 61.

Plattes, M, Bertrand, A, Schmitt, B, Sinner, J, Verstraeten, F. & Welfring, J. (2007). Removal of tungsten oxyanions from industrial wastewater by precipitation, coagulation and flocculation processes. *Journal of Hazardous Materials, 148*, pp. 613-615.

Primo, O, Rivero, M.J. & Ortiz, I. (2008). Photo-fenton process as an efficient alternative to the treatment of landfill leachates. *Journal of Hazardous Materials, 153*, pp 834-842.

Rajec, P. & Domianova, K. (2008). Cesium exchange reaction on natural and modified clinoptilolite zeolites. *Journal of Radioanalytical and Nuclear Chemistry, 275(3)*, pp. 503 – 508.

Ramirez, I.M. & Velasquez, O. (2004). Removal of transformation of recalcitrant organic matter from stabilized saline landfill leachate by coagulation-ozonation coupling process. *Water Res, 38*, pp. 2359-2367.

Ratsak, C. H. & Verkuijden, J. (2006). Sludge reduction by predatory activity of aquatic oligochaetes in wastewater treatment plants: science or fiction? A review. *Hydrobiologia, 564*, pp. 197 – 211.

Renou, S, Givaudan, J.G, Poulain, S, Dirassouyan, F. & Moulin, P. (2008). Landfill leachate treatment: review and opportunity. *Journal of Hazardous Materials*, 150, pp 468-493.

Rivas, F.J, Beltran, F, Carvalho, F, Acedo, B. & Gimeno, O. (2004). Stabilized leachate: sequential coagulation-flocculation + chemical oxidation process. *Journal of Hazardous Materials B116*, pp. 95-102.

Rossini, M, Garrido, J.G. & Galluzzo, M. (1999). Optimization of the coagulation-flocculation treatment: influence of rapid mix parameters. *Water Res*, 3, pp. 1817-1826.

Saffaj, N, Loukil, H, Younssi, S.A, Albizane, A, Bouhria, M, Persin, M. & Larbot, A. (2004). Filtration of solution containing heavy metals and dyes by means of ultrafiltration membranes deposited on support made of Moroccan clay, *Desalination*, 168, pp. 301-306.

Sartaj, M, Ahmadifar, M. & Jashni, A.K. (2010). Assessment of in-situ aerobic treatment of municipal landfill leachate at laboratory scale, *Iranian Journal of Science & Technology, Transaction B, Engineering*, 34(B1), pp. 107-116.

Schwarzenbeck, N, Leonhard. & Wilderer, P, A. (2003). Treatment of landfill leachate –high tech or low tech. *Water Sci. Technol*, 48, pp. 277-281.

Semerjian, L. & Ayoub, G.M. (2003). High-pH-magnesium coagulation-flocculation in wastewater treatment. *Advances in Environmental Research*, 7, pp. 389-403.

Shah, R, Payne, M.C. & Gale, J.D. (1997). Acid-base catalysis in zeolites from first principles. *International Journal of Quantum Chemistry*, 61, pp. 393 – 398.

Silva, A.C, Dezotti, M. & Sant' Anna Jr, G.L. (2004). Treatment and Detoxification of a sanitary landfill leachate. *Chemosphere*, 55, pp. 207-214.

Song, L.Y, Zhao, Y.C, Sun, W.M. & Lou, Z.Y. (2009). Hydrophobic organic chemicals (HOCs) removal from biologically treated landfill leachate by powder-activated carbon (PAC), granular-activated carbon (GAC) and biomimetic fat cell (BFC). *Journal of Hazardous Materials*, 163, pp. 1084 – 1089.

Suarez, S, Lema, J.M. & Omil, F. (2009). Pre treatment of hospital wastewater by coagulation-flocculation and flotation. *Bioresource Technology*, 100, pp. 2138-2146.

Sun, T, Liu, L.L, Wang, L.L. & Zhang, Y.P. (2011). Preparation of a novel inorganic polymer coagulant from oil shale ash. *Journal of Hazardous Materials*, 185, pp. 1264-1272.

Tchobanoglous, G, Burton, Theisen, H. & Vigil, S. (1993). *Integrated solid waste management engineering principles and management issues*: Mc Graw Hill. pp. 14.34.

Thompson, D, Moore, R. & Hackworth, D. (2005). Ballasted sedimentation boots floc settling. *AWWA Opflow*, pp. 14 -17.

Torabian, A, Hassani, A.H. & Moshirvaziri, S. (2004). Physicochemical and biological treatability studies of urban solid waste leachate. *International Journal of Environmental Science & Technology*, 1(2), pp. 103-107.

Turan, N.G. & Ergun, O.N. (2009). Removal of Cu(II) from leachate using natural zeolite as a landfill liner material. *Journal of Hazardous Materials*, 167, pp. 696 – 700.

Tzoupanos, N.D. & Zouboulis, A.I. (2010). Characterization and application of novel coagulant reagent (polyaluminium silicate chloride) for the post treatment of landfill leachates. *Water Treatment Technologies for the Removal of High Toxicity Pollutants*, pp. 247-252.

Ulusoy, U. & Simsek, S. (2005). Lead removal by polyacrylamide-bentonite and zeolite composites: Effect of phytic acid immobilization. *Journal of Hazardous Materials*, B127, pp. 163 – 171.

Verma, S, Prasad, B. & Mishra, I.M. (2010). Pretreatment of petrochemical wastewater by coagulation and flocculation and the sludge characteristics. *Journal of Hazardous Materials*, 178, pp. 1055-1064.

Visvanathan, C, Muttaamara, S. & Babel, S. (1994). Treatment of landfill leachate using cross-flow microfiltration and ozonation. *Sep. Sci. Technol*, 29, pp. 315-332.

Wang, P, Lau, I, Fang, H. & Zhou, D. (2000). Landfill leachate treatment combined UASB and Fenton coagulation, *J. Environ. Sci. Health*, A35, pp. 1981.

Wang, X.J, Chen, S, Gu, X.Y. & Wang, K.Y. (2009). Pilot study on the advanced treatment of landfill leachate using a combined coagulation, fenton oxidation and biological aerated filter process. *Waste Management*, 29, pp 1354-1358

Welander, U, Henrysson, T. & Welander, T. (1998). Biological nitrogen removal from municipal landfill leachate in a pilot scale suspended carrier biofilm process. *Water Res*, 4, pp. 95-102.

Wei, Y.X, Li, Y.F. & Ye, Z.F. (2010). Enhancement of removal efficiency of ammonia nitrogen in sequencing batch reactor using natural zeolite. *Environ Earth Sci*, 60, pp. 1407-1413.

Welander, U. & Henrysson, T. (1998). Physical and chemical treatment of a nitrified leachate from a municipal landfill. *Environ. Technol*, 19, pp. 591.

Widiastuti, N, Wu, H.W, Ang, M. & Zhang, D.K. (2008). The potential application of natural zeolite for greywater treatment. *Desalination*, 218, pp. 271 – 280.

Wiszniewski, J, Robert, D, Surmacz-Gorska, J, Miksch, K. & Weber, J.V. (2006). Landfill leachate treatment methods: A review. *Environ Chem Lett*, 4, pp. 51-61.

Yang, H.Y, Cui, F.Y, Zhao, Q.L. & Ma, C. (2004). Study on coagulation property of metal-polysilicate coagulants in low turbidity water treatment. *Journal of Zhejiang University Science*, 5(6), pp. 721-726.

Yoo, H, Cho, S. & Ko, S. (2001). Modification of coagulation and Fenton oxidation processes for cost-effective leachate treatment. *J. Environ. Sci. Health*, A36, pp. 39.

Yoon, J, Cho, S, Cho, Y. & Kim, S. (1998). The characteristics of coagulation of Fenton reaction in the removal of landfill leachate organics. *Water Sci. Technol*, 38, pp. 209-214.

Young, J.C. & Edwards, F.G. (2003). Factors affecting ballasted flocculation reactions. *Water Environ. Res*, pp. 263 – 272.

Zahrim, A.Y, Tizaoui, C. & Hilal, N. (2011). Coagulation with polymers for nanofiltration pre-treatment of highly concentrated dyes: A review. *Desalination*, 266, pp. 1-16.

Zamora, R.M.R, Moreno, A.D, Velasquez, M.T.O. & Ramirez, I.M. (2000). Treatment of landfill leachates by comparing advanced oxidation and coagulation-flocculation processes coupled with activated carbon adsorption. *Water Sci. Technol*, 41, pp. 231-235.

Zemmouri, H, Drouiche, M, Sayeh, A, Lounici, H. & Mameri, N. (2012). Coagulation-flocculation test of keddera's water dam using chitosan and sulphate aluminium. *Procedia Engineering*, 33, pp. 254-260.

Zhao, Y.C, Liu, J.G, Huang R.H. & Gu, G.W. (2000). Long-term monitoring and prediction for leachate concentrations in shanghai refuse landfill. *Water, Air and Soil pollution*, 122, pp. 281-297.

Zhang, P.Y, Zhen, W, Zhang, G.M, Zeng, G.M, Zhang, H.Y, Li, J, Song, X.G. & Dong, J.H. (2008). Coagulation characteristics of polyaluminum chlorides PAC-Al30 on humic acid removal from water. *Separation and Purification Technology*, 63, pp. 642-647.

Zouboulis, A.I. & Petala, M. D. (2008). Performance of VSEP vibratory membrane filtration system during the treatment of landfill leachates. *Desalination*, 222, pp. 165 – 175.

Zouboulis, A, Jun, W. & Katsoyiannis. (2003). Removal of humic acids by flotation, *colloids surfaces A: Physicochem. Eng. Aspects*, 231, pp. 181-193.



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