EFFECT OF SONICATION COMBINED WITH HYDROGEN PEROXIDE FOR SANITARY LANDFILL LEACHATE TREATMENT

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**A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Bachelor of Engineering (Hons.) Environmental Engineering**

**Faculty of Engineering and Green Technology
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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any others degree awards at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project entitled **"EFFECT OF SONICATION COMBINED WITH HYDROGEN PEROXIDE FOR SANITARY LANDFILL LEACHATE TREATMENT"** was prepared by **MARVIN SIA CHUN KEAT** has met the required standard for submission in partial fulfillment of the requirements for the award of Bachelor of Engineering (Hons) Environmental Engineering at Universiti Tunku Abdul Rahman.

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Specially dedicated to my beloved mother, father and brother

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ABSTRACT

Batu Gajah landfill site with the age of 40 years produced stabilized leachate which is highly contaminated and non-biodegradable. Batu Gajah leachate did not fulfil the discharge standard of Environmental Quality Regulations. Hence, treatment must be done before final discharged. Thus, this is study to measure characteristic of Batu Gajah leachate. Furthermore, it was also to investigate the effectiveness of ultrasonication on leachate as well as ultrasonication and hydrogen peroxide on the toxic leachate. It was found that through ultrasonication process, 50% amplitude is the optimum condition for ammoniacal nitrogen and 20% is the optimum condition for both suspended solid and BOD_5. Higher reaction time could increase removal efficiency for all 3 parameters. Besides, the leachate contained foreign object that interfere the COD testing procedure, hence, the foreign object should be determined and removed before proceeding for COD testing. High pH was able to remove ammoniacal nitrogen and suspended solid effectively. Low pH was able to remove BOD effectively. Ultrasonication did improve the removal efficiency for all pH value. H_2O_2 was found to be improving the efficiency of removing the three parameters and ammoniacal nitrogen was absent after the ultrasonication and 0.5 g/L of hydrogen peroxide addition process. With addition of H_2O_2 , COD was not able to be tested well as H_2O_2 is also an interfering agent for COD testing.

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LIST OF SYMBOLS / ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
MSW	Municipal Solid Waste
SBR	Sequencing Batch Reactor
SCOD	Soluble Chemical Oxygen Demand
SOP	Standard Operating Procedure
SWM	Solid Waste Management
SS	Suspended Solid
TCOD	Total Chemical Oxygen Demand
TDS	Total Dissolved Solid
TOC	Total Organic Compound
VOA	Volatile Organic Acid

^0C	Degree Celcius
g/L	Gram per Litre
mg/L	Milligram per Litre
nm	Nanometre
NTU	Nephelometric Turbidity Units

NH_3	Ammonia
NH_3-N	Ammoniacal nitrogen
CO_2	Carbon dioxide
Cl^-	Chloride ion
Cl_2	Chlorine
Cr^{3+}	Chromium (III) ion
$Cr_2O_7^{2-}$	Dichromate(VI) ion
H^+	Hydrogen ion
H_2O_2	Hydrogen peroxides
OH^-	Hydroxyl ion
CH_4	Methane
NO_3^-	Nitrate ion
O_2	Oxygen
O_3	Ozone
PtCo	Platinum Cobalt
TiO_2	Titanium dioxide
SO_4^{2-}	Sulphate ion
S^{2-}	Sulphide ion
H_2O	Water

CHAPTER 1

INTRODUCTION

1.1 Background

As the current technologies advance swiftly, rapid urbanisation also took place simultaneously. However, these caused a more revolutionary lifestyle and consumerism which leads to high and more toxic waste generation day by day. The accumulation of solid wastes became a consequence of life as we could see some historical event such as the Black Death: Bubonic Plague that took place in the 14th century due to poor public health, rubbish collection and etc. (BBC, n.d.).

Based on history records, landfills have been the most viable method for waste disposal. This method was a preferred solution due to its low operating cost and easy maintenance (Renou et al., 2008). The major drawback of this method is leachate. Leachate can be defined as liquid that passes through landfill and has extracted dissolved and suspended matter from it (Raghab et al., 2013).

Leachate generated from landfills is liquid that may contain concentrated organic matter and inorganic matter, with humic-type substances as well as ammonia nitrogen, heavy metals, chlorinated organic and inorganic salts (Li et al., 2009). Untreated leachate can permeate ground water or mix with surface waters and contribute to the pollution of soil, groundwater, and surface water. The potential dangers of landfill leachate have been confirmed and it is generally necessary to treat it so that it meets the standards for discharge into sewer or into natural waters. There are several options for leachate management that are being practiced. The key of leachate management is to eliminate any potential chances for the leachate to contaminate and pollute the aquifer through percolation. The available options are leachate recycling, leachate evaporation, leachate treatment and discharge to the nearest wastewater treatment plant.

Leachate features vary a lot due to waste composition found in different landfill, site age, climatic conditions and etc. The biological, physical and chemical treatments are the common treatment used to remove contaminants. The process to be selected will be determined by the contaminants to be removed.

Leachate treatment is connected with several parameters such as Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Sulphate (SO_4^{2-}), heavy metals and nonspecific toxic constituents. High COD values favours anaerobic treatments to take part as aerobic treatments are lavish. Basically, biological treatments mainly focus on removal of organics. Other physicochemical processes can be used to enhance the treatment process as different characteristic of leachate should be treated using different method to achieve optimum removal efficiency.

The applications of chemical processes are normally to remove and regulate leachate harmful chemical properties such as metal removal and ammonia removal. As for oxidation processes, organics could be removed as well and additional process like detoxification of certain inorganics (Tchobanoglous, 1993).

1.2 Problem Statement

Generally, characteristic of landfill leachate varies due to the different waste compositions, hydrological and climatic conditions and landfill age. Thus, it is important to determine the leachate properties as leachate can be treated efficiently with the correct adjustment of parameters such as types of landfilled waste, climatic conditions, landfill age and mode of operation (Zhang et al., 2013). Batu Gajah landfill was found to be more than 40 years, the main problem begins to arise as the leachate is becoming more and more concentrated. Leachate can be classified as hazardous and heavily polluted wastewater which consists of fragments of heavy metals, dissolved organic matter, ammoniacal nitrogen (NH_3-N) and inorganic salts. Untreated landfill could cause a heavy pollution to stream water quality as the pH, temperature, total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) and ammoniacal nitrogen (NH_3-N) (Maqbool et al., 2011). These are the factor that could affect the adaptability of aquatic life. Therefore, treatment should be done for the untreated leachate before discharging.

Besides, various methods were used for leachate treatment. However, due to the low biodegradability value of stabilized leachate, biological processes are normally inefficient in treating old landfill leachate. Therefore, physicochemical treatment process has been employed such as coagulation-flocculation, chemical precipitation, ammonium stripping, reverse osmosis, advance oxidation method and etc. Ultrasonication is one the advanced oxidation method which uses ultrasonic process to result in decrease in toxicity and biodegradable enhancement (Wang et al., 2008). Ultrasonic process is an effective treatment method to decompose the ammoniacal nitrogen in leachate.

Hydrogen peroxide was considered as an enhancement due to its oxidizing properties. Hydrogen peroxide was proven to be able to increase the efficiency of treatment process combining with other advance oxidation process (Tizaoui et al., 2006). Therefore, the combination of ultrasonication and hydrogen peroxide as advance oxidation process for leachate treatment was considered.

1.3 Objective of Study

1. To study the characteristics of landfill leachate generated from Batu Gajah landfill site, Perak.
2. To investigate the effect of ultrasonication time, pH and amplitude on landfill leachate treatment.
3. To evaluate the performance of ultrasonication process combined with hydrogen peroxide on leachate treatability.

CHAPTER 2

LITERATURE REVIEW

2.1 Municipal Solid Waste Management in Malaysia

Solid Waste Management (SWM) is slowly becoming one of the greatest trials throughout the world especially for those countries that are developing like Malaysia. This problem occurs when the rapid urbanisation took place that causes the industrialization which also causes the rapid growth of municipal solid waste production. As the problem continues, SWM in Malaysia uses the traditional landfill as it is preferable because of financial, social and technical factors. Besides, it also faces lots of technical challenge and problems with leachate recirculation and gas attraction in landfill (Samsudin & Don, 2013). Based on Department of Statistics Malaysia, Malaysia has a total population of 29.92 million with the average annual population growth rate of 1.4% (Department of Statistics Malaysia, 2015). Solid waste generation has drawn closed to a climacteric event. Based on Manaf et al. (2009), the annual waste generation had increased by 3% with several causes. For that reason, advance management of solid waste will only require small trouble since the level of waste generated is still manageable and mostly consists of organic materials. Currently, there are a few types of technologies used in Malaysia as waste management system. On 2006, it was reported that 5.5% are recyclables, 1.0% are sent for composting, 3.2% are managed by inert landfill and 59.4% are for other disposal sites. The sanitary landfill changes increased from 5% to 30.9% which causes percentage on other waste disposal methods (Tey et al., 2013). It was found that organic waste is present in Malaysia solid waste with a very high concentrated, thus, it constantly has high moisture content and with the bulk density of above 200 kg/m^3 (Manaf et al., 2009).

The responsibility of SWM in Malaysia falls on the local authority as stipulated in section 72 of the Local Government Act 1976. Under this act, any sort of public cleansing services of equitable and acceptable quality should be given to the communities within its jurisdiction. The local authorities had already spent 50% on the SWM and more than 50% just for waste collections. The government had to change the management structure consequently (Manaf et al., 2009). The waste collection were contracted to private companies such as Alam Flora Sdn Bhd, Idaman Bersih Sdn Bhd and Southern Waste Management Environment Sdn Bhd.

Malaysia government had emphasized to study and revise more of these main components which are waste management and sustainable development under 8th and 9th Malaysia Plan. Quick development that leads to country economic growth is one of the factors that affect the composition of solid waste as the change in lifestyle of people who are capable of producing even more waste but the income of residents does not determine the waste generation. For example, food and organic waste had the highest average weight percentage of component in SWM on a study conducted in Kuala Lumpur as shown in Table 2.1. Hence, a developing country like Malaysia should have a high efficiency on collection of waste and should be able to manage sthose waste collected with appropriate and sustainable method.

Table 2.1: Average composition weight percentage of components in MSW generated by various sources in Kuala Lumpur (Manaf et al., 2009)

Sources	Residential High Income (%)	Residential Medium Income (%)	Residential Low Income (%)	Commercial (%)	Institutional (%)
Food/organic	30.84	38.42	54.05	41.48	22.36
Mix paper	9.75	7.22	6.37	8.92	11.27
Newsprint	6.05	7.76	3.72	7.13	4.31
High grade paper	-	1.02	-	0.35	-
Corrugated paper	1.37	1.75	1.53	2.19	1.12
Plastic	26.21	20.04	11.66	17.18	19.50
Pampers	6.49	7.58	5.83	3.80	1.69
Textile	1.43	3.55	5.47	1.91	4.65
Rubber/leather	0.48	1.78	1.46	0.80	2.07
Wood	5.83	1.39	0.86	0.96	9.84
Yard	6.12	1.12	2.03	5.75	0.87
Glass	2.75	4.09	1.30	4.72	0.52
Ferrous	1.93	3.05	2.25	2.47	3.75
Non-ferrous	0.17	-	0.18	0.55	1.55
Alumnium	0.34	0.08	0.39	0.25	0.04
Batteries/hazards	0.22	0.18	-	0.29	0.06
Fine	-	0.71	2.26	-	0.39
Other organic	0.02	-	-	1.26	1.00
Other inorganic	-	0.27	0.25	-	8.05
Others	-	-	-	-	6.97
Total	100.00	100.00	100.00	100.00	100.00

The most common method of SWM practiced in Malaysia is landfilling. Landfill is the most preferred method in SWM due to its economic benefits. However, the existing landfills in Malaysia are filling up at a fast rate. Samsudin and Don (2013) reported that there are a total of 290 landfill sites in Malaysia with 176 still in operation and 114 have been closed. New appropriate sites for landfilling are becoming troublesome to be located as communities have the “Not my backyard syndrome”. Most of them would oppose any new landfill near their residence. Besides, landfill also causes several troubles such as facing the difficulties with leachate recirculation which causes water pollution and trouble with gas attraction in landfill. Therefore, these problems should be overcome with certain solutions such as leachate treatment, proper sanitary landfilling practices etc. Table 2.2 shows the distribution of landfill sites in Malaysia.

Table 2.2: Distribution of landfill sites in Malaysia (Samsudin and Don, 2013)

States	Landfills in Operation	Landfills Have Been Closed
Johor	15	21
Kedah	10	5
Kelantan	13	4
Melaka	2	5
Negeri Sembilan	8	10
Pahang	19	13
Perak	18	11
Perlis	1	1
Pulau Pinang	2	1
Sabah	21	1
Sarawak	49	12
Selangor	8	12
Terengganu	9	11
Federal Territories	1	7
Total	176	114
	290	

2.2 Landfill

Landfill is a physical facility that is prepared for disposal of solid waste besides construction waste, leaves and miscellaneous waste. Construction waste or debris are not advisable to be placed in landfill due to its large size and would be expensive to deposit it in landfill. Landfilling is considered to be the ultimate waste disposal method that can handle all materials in waste streams (Badgie et al., 2012). Solid waste disposed in landfill will be subjected to a series of physical, chemical and biological degradation processes. Diversity promotes stability however it is strongly influenced by environmental conditions. These processes will normally have liquid and gas emission.

During the stabilization process, five phases are involved. Each phase will produce different characteristics of leachate and gases at different rate due to microbial activity.

1st Phase - Initial Adjustment

In this phase, initial placement of solid waste and accumulation of moisture within landfill. The accumulation will take a time period for sufficient moisture to develop and support active microbial environment. Preliminary changes in environmental components are needed to create favourable conditions for biochemical decomposition (Guo, 2014).

2nd Phase – Transition

This phase begins when field capacity exceeded with moisture content and leachate is formed. The media of landfill will transform from aerobic to anaerobic condition creating a reducing condition where electrons from oxygen molecules (O_2) will shift to nitrate ion (NO_3^-) and sulphate ion (SO_4^{2-}) by displacing O_2 to carbon dioxide (CO_2). Hence, O_2 trapped within landfill media will be depleted. Concentration of chemical oxygen demand (COD) and volatile organic acids (VOA) can be detected at the end of the phase (Guo, 2014).

3rd Phase – Acid Formation

The phase continues with continuation of hydrolysis of solid waste and microbial conversion processes. Produces intermediate VOA at high concentration and decreases the pH of media. As the pH decreases, mobilization is possible for metal species. Thus, it leads to high growth of acidogenic bacteria. Bacteria will cause rapid consumption of substrate and nutrient (Guo, 2014).

4th Phase – Methane Fermentation

Immediate acids produced will be consumed by methanogenic bacteria which will convert to methane (CH_4) and CO_2. SO_4^{2-} and NO_3^- is then reduced to S^{2-} and NH_3. The pH value will then be regulated to a higher value by bicarbonate buffering. Heavy metals are removed by complexation and precipitation (Guo, 2014).

5th Phase – Maturation Phase

This is the final state of landfill stabilization, nutrient and limiting substrate to react. Biological activity will shifts to relative present state but inactive. Gas production and leachate concentration will decrease although the slow degradation still occurs (Guo, 2014).

However, these must be accompanied by a good design of landfill site. A landfill site should be able to decrease or prevent any sorts of risk to human health and environment. It is fundamental for the designer to embrace the methods, guidelines, standards and standard operating procedures while designing the system for good efficiency and safe landfill site.

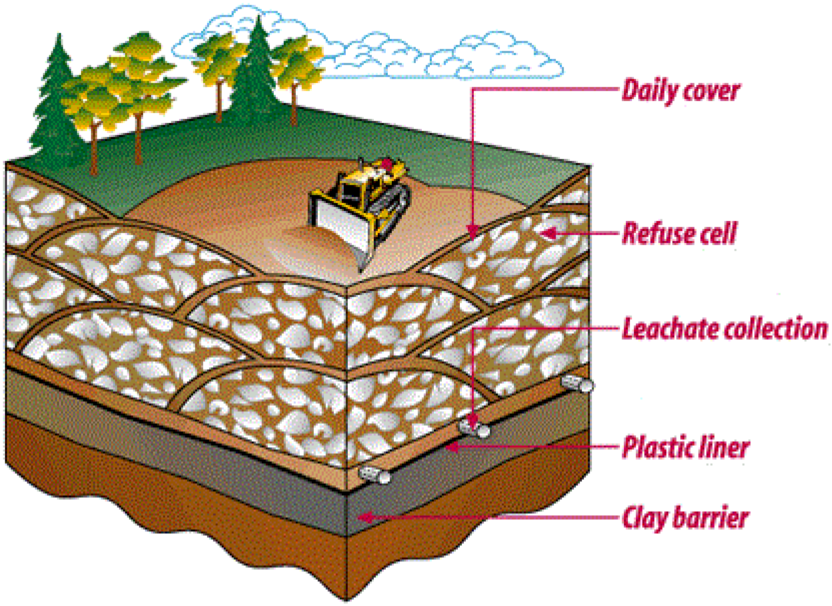

Figure 2.1: Cross section for composition of a modern active landfill design (BRA, 2011)

Based on Figure 2.1, all the landfill refuses are allowed to left expose to air overnight; therefore daily cover is used to reduce odour emission from working surface (Hurst et al, 2005). A layer of refuse contains many refuse cells. Refuse cells are compacted solid waste surrounded by soil by daily cover. When the cell has reached its capacity, the cell will be compacted and closed and the waste will continue to fill into another cell. Next, the leachate collection system that exists within the modern landfill design is to drain the leachate with perforated pipes with a layer of sand. Plastic liner or the geosynthetic layer acts as a primary layer of protection against leakage of leachate to prevent soil and groundwater contamination. Lastly, the clay barrier is the secondary barrier for leakage prevention. At some landfill, a few other components are added to enhance the monitoring of landfill such as landfill gas monitoring probe, groundwater monitoring wells, gas collection pipes etc.

2.3 Landfill Leachate

Landfill leachate is a highly contaminated wastewater which can be formed through the infiltration of precipitation such as rainfall through the landfill waste. As the rainwater percolates through the landfill, it interacts with the organic waste, contaminants and nutrients. Hence, landfill leachate contains high toxicity property. The composition of leachate may contain heavy metals, organic and inorganic components which make the treatment process to be a great problem. However, treatment of leachate is still necessary as the properties pose a great threat to water bodies such as groundwater.

There are many different factors that could influence the characteristics and composition of leachate such as climate condition, landfill age, types of solid waste and moisture content. Age of landfill is normally the prime factor of leachate characterization. The biological decomposition of wastes will takes longer with the aid of acid formation phase and methane formation phase as the age of landfill increases (Bashir et al., 2009).According to Kulikowska & Klimiuk (2008), age of landfill shows an obvious effect on leachate composition especially on organics and ammonia concentrations. Despite having high pH value, low COD concentrations, low heavy metals presence and low BOD_5/COD ratio of leachate, the landfill leachates that are mature are considered to be in methanogenic. Young leachates are normally more acidic in nature due to the presence of volatile fatty acids. In other words, the older leachate is less polluted than the young one as it had went through several phases of stabilization.

Although young leachate seems to be more polluted in Table 2.3, however stabilized leachate is harder to degrade as it had already reached stabilized condition.

Table 2.3: Characterization of different types of landfill leachate at different stage (Kurniawan et al., 2006)

Type of Leachate	Young	Intermediate	Stabilized
Age of landfill (years)	<1	1-5	>5
pH	<6.5	6.5-7.5	>7.5
BOD/COD	0.5-1.0	0.1-0.5	<0.1
COD (g/L)	>15	3-15	<3
Ammoniacal Nitrogen (mg/L)	<400	N/A	>400
TOC/COD	<0.3	0.3-0.5	>0.5
Kjehdal Nitrogen (mg/L)	0.1-2	N/A	N/A
Heavy Metals (mg/L)	>2	<2	<2

2.4 Leachate Treatment Technology

In the past, many different types of method were used to treat the high toxicity leachate to a lesser toxic substance. Some of the wastewater treatment technologies were utilized for treating leachate which is found to be effective such as biological treatment and physicochemical treatment. (Bashir et al., 2009).

2.4.1 Biological Treatment

Biological treatment is commonly used for removal of organics and nitrogenous matter of leachate which contributes the high concentrations of BOD value. It is well utilized as a leachate treatment due to its accessibility, profitable and creditability. Biodegradation will be carried out in this treatment with the usage of microorganisms which could decompose organic compounds to carbon dioxide and sludge and biogas as well with both aerobic and anaerobic processes taking place. However, the effectiveness of this process could be limited with the presence of some contrary substances or factors such as humic acids and fulvic acids (Renou et al., 2008). According to Agdag and Sponza (2005), concentrated leachate streams are best treated using anaerobic process method, reason being the advantage of economic method in terms of operating costs, generation of biogas product and pathogen-free solid residue that were produced could be used as cover material. Several anaerobic processes that are frequently used in the treatment industry are normally high rate with good efficient such as anaerobic sludge blanket reactor, anaerobic filter, digester and sequencing batch reactor (SBR). Aerobic treatment dampened partially the biodegradability of organic pollutant and ammoniacal nitrogen nitrification. The common methods of aerobic process would be aerated lagoons, activated sludge processes and SBR. Biological treatment was proven to be able to treat young leachate efficiently but as the age of leachate increases, the biodegradability decreases and hence became not suitable for continuation of treatment using this method (Sivan & Latha, 2013).

2.4.2 Physicochemical Treatment

Physicochemical processes involve both physical treatment process and chemical treatment process. Redox or reduction and oxidation of the leachate can take place with physical processes such as floatation, coagulation/ flocculation, adsorption and etc. These processes normally act as an addition for the treatment process (pre-treatment or last purification) (Renou et al., 2008). Since biological treatment is not sufficient and efficient in treating stabilized landfill leacahte, physciochemical treatment is employed to treat mature leachate (Sivan & Latha, 2013). There are several types of physicochemical treatment that are widely used in the treatment industry. The types of physicochemical treatment are summarized in Table 2.4.

Table 2.4: Types of physicochemical treatment that are common in the treatment industry (Kurniawan et al., 2006, Roodbari et al., 2012)

Type of Treatment	Advantage	Drawbacks
Coagulation-flocculation	Suitable for removal of heavy metals and non-biodegradable organic compounds	Expensive due to operational cost, chemical consumption, sensitivity process employed to pH value and generation of sludge
Chemical precipitation	Suitable for removal of ammonical nitrogen, heavy metals and non-biodegradable organic compounds	High dose of precipitant is needed to operate, sensitivity process employed to pH value, sludge generation and disposal.
Ammonium stripping	High ammoniacal nitrogen efficiency	Release of ammonia gas as effluent, therefore further treatment of gas is required thus increase the operational cost.
Reverse osmosis	Has a high rejection rate (98%-99%) for organic and inorganic contaminants, suitable for removal of heavy metals, suspended/colloidal particles and dissolved particles.	Low retention of small molecules that passes through the membrane, membrane fouling and high energy usage.
Ultrasonication	Suitable for removal of organic matters	High energetic cost.

2.4.2.1 Ultrasonication

Ultrasonication is a process whereby a liquid sample is being enhanced with ultrasonic waves resulting in a turbulence created within the media. The liquid media will be disturbed by the sound waves propagation causing the amendment in high pressure and low pressure cycles. Ultrasonication has been proven to be a great use in removal of organic compounds from wastewater using degradation. Formation of bubbles and sudden collapse of gas and vapour bubbles also known as acoustic cavitation process could result in sonochemical effect taking place.

Mechanism of cavitation occurs when it exceeds intensity threshold. Cavitation of bubbles will oscillate to positive pressure and collapse while ultrasound propagates (Mehrdadi et al., 2011). Collapse of cavitation bubbles in aqueous solution will affect the wastewater by high mechanical shear stress and radical reaction (Bohdziewicz et al., 2005).

It was found that ultrasonication could remove NH_3-N with pyrolytic decomposition. Pyrolytic decomposition is one of the methods for acoustic cavitation to take place. The other process could else causes acoustic cavitation is redox by generation of H^+ and OH^- which are radical ions. Based on a study by Roodbari et al. (2012), the ultrasonication acts well with these optimum parameters conditions at pH 10, 110 kW, 60 kHz and 5 mg/L of titanium dioxide (TiO_2), in which acts TiO_2 as a catalyst in the experiment.

According to Wang et al. (2008), COD removal efficiency could be improved with increment of power input to the ultrasonication process. According to the sonochemistry theory, as the intensity of ultrasound attains or transcends the cavity threshold, the bubble will formed easily and cavities will collapse violently. Therefore, increasing the power input will increase the energy of cavitation, quantity of cavitation bubbles and menacing the threshold limit of cavitation. In other words, it is a beneficial effect that generation of hydroxyl radicals contributed to pollutant degradation (Garbellini, 2012). The major drawback for this method is the operating cost of ultrasonication. However, it is expected to reduce the cost by using ultrasonication as the time would be the determinant factor for the cost but for long term running would save the capital cost.

Table 2.5: Performance of screening experiment using ultrasonication method (Pham et al., n.d.)

Run	Pre-treatment parameters			Pre-treated sludge characteristic	
	Amp (%)	Time (min)	TS (g/L)	SCOD/ TCOD	Total solids reduction
1	20	20	23	74	31.3
2	40	20	23	76	32.6
3	20	60	23	77	32.6
4	40	60	23	79	36.5
5	20	20	44	64	34.8
6	40	20	44	68	33.2
7	20	60	44	67	32.5
8	40	60	44	72	33.4
9	30	40	33	70	35.8
10	30	40	33	70	34.8
11	30	40	33	70	33.3
Control	X	x	23	38	27.4
Control	X	x	33	34	27.9
Control	X	x	44	33	26.1

2.5 Addition of Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) acts an additive towards oxidation process due to its high reactivity that produces radical OH^- in which is known as non-selective oxidants. Besides, Tizaoui et al. (2007) reported that H_2O_2 was proven to be able to enhance the treatment process of landfill leachate when combined with ozone (O_3) as compared to O_3 alone or H_2O_2 alone.

CHAPTER 3

METHODOLOGY

3.1 Research Flow Chart

The research procedures were summarized in Figure 3.1

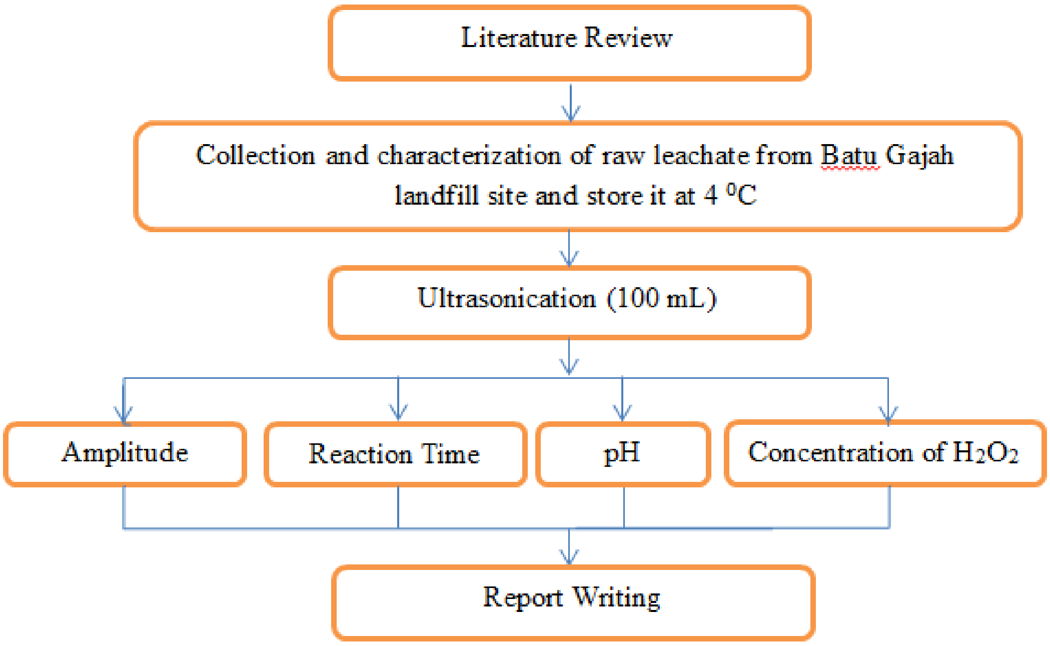

Figure 3.1: Flow chart of research

3.2 Site Location

The selected location for leachate sample collection was Batu Gajah landfill site which is located nearby Kampung Baharu, Batu Gajah, Perak. The distance between the landfill site and UTAR is approximately 22.8 km away from UTAR Perak Campus.

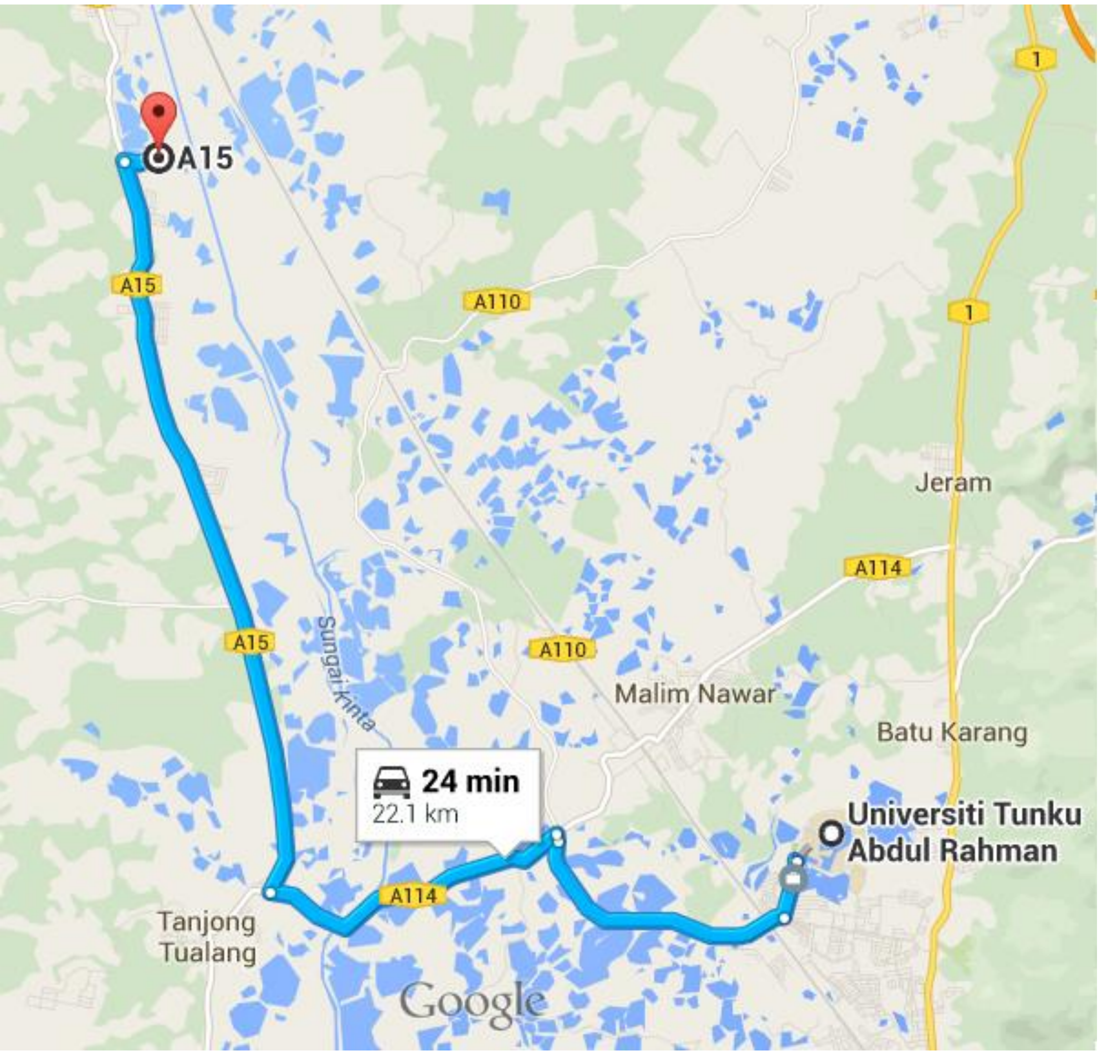

Figure 3.2: The path from UTAR, Perak Campus to Batu Gajah landfill site (Google Map)

Batu Gajah landfill mainly consists of all sorts of municipal waste collected from Batu Gajah, Mambang Diawang, Kampar, Malim Nawar, Jeram, Kuala Dipang, Gopeng, Kopisan, Lawan Kuda, Tronoh Mines and southern part of Sungai Siput back before the Sahom landfill operates. However, the old sampling site was already closed, therefore most of the waste were collected now were sent to Sahom landfill and currently only the sanitary landfill part is under operation. The amount of waste used to store at Batu Gajah landfill site exceeds 1000 tonnes per day (MHLG, 2012).

Figure 3.3: Batu Gajah landfill site

3.3 Leachate Collection and Characterization

Leachate samples were collected using a 5.5 L bottle at the leachate collection point before the leachate pond. Samples collected at this point were raw leachate and have not gone through the initial sedimentation process and aeration. The samples collected were stored under 4 ^{0}C from May, 2015 to August, 2015 to prevent biodegradation process.

Figure 3.4: Leachate sample collection point

3.4 Characteristic of Leachate

The characteristic of leachate such as BOD_5, COD, colour, NH_3-N, suspended solid and pH will be measured using the standard methods (APHA, 2005).

3.4.1 Biochemical Oxygen Demand (BOD_5)

In this experiment, BOD_5 was measured using Standard Method Section 5210B. A specific amount of leachate will be poured into the BOD bottle based on the expected BOD range value. Blank sample was prepared as well using deionized water to monitor the condition of BOD process throughout the 5 days. Dissolved oxygen (DO) was measured using a DO meter before and after 5 days of the placing of BOD bottles into and from the BOD incubator. No air bubbles were allowed in the BOD bottles in the entire process. BOD_5 was then calculated using the following equation:

$$BOD_5 = \frac{DO_5 - DO_0}{Decimal\ fraction} \tag{3.1}$$

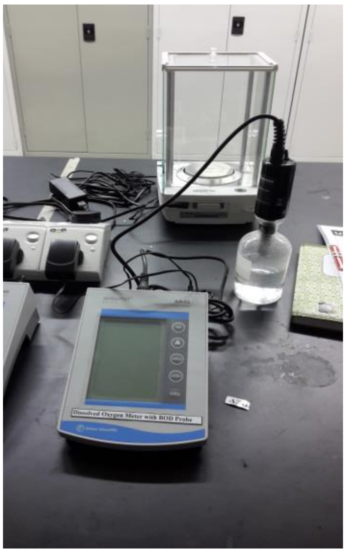

Figure 3.5: DO meter
(Fisher Scientific, acumet AB40)

Figure 3.6: BOD incubator
(VELP Scientifica, FOC 225E)

3.4.2 Chemical Oxygen Demand (COD)

Closed Reflux Method was used to measure to COD value of leachate sample. The COD reagent was prepared using silver sulphate solution and potassium dichromate solution. COD was measured using Hach Method Programme 435 with wavelength of 620 nm. COD digester block, model DRB 200 was preheated to 150 ^{0}C. After placing the COD vials into COD digester block, the leachate samples and blank sample were left for 2 hours. All the vials were removed from the digester block and left to cool for 30 minutes. UV-Vis-Spectrophotometer, DR 6000 was used to measure the COD values.

Figure 3.7: COD reactor block (Hach, DRB 200, USA)

Figure 3.8: UV-Vis-Spectrophotometer (Hach, DR 6000, USA)

3.4.3 Ammoniacal Nitrogen (NH_3-N)

NH_3-N can be measured with various methods such as distillation and titration, nesslerization and standard phenate method. Standard phenate method was selected to measure with wavelength of 640 nm. The standard operating procedure (SOP) for this method is adding the diluted sample with phenol solution and sodium nitroprusside with the presence of oxidizing solution. The colour of the samples and blank were allowed to settle before UV-Vis-Spectrophotometer was used to measure the NH_3-N concentration values.

3.4.4 Suspended Solid (SS)

Suspended solid can be measured with various methods such as gravimetric method and photometric method. Photometric method was selected to measure with wavelength of 810 nm. The standard operating procedure (SOP) for this method is pouring the blank and sample into sample cell and measure using UV-Vis-Spectrophotometer.

3.4.5 pH

In this set of experiment, pH were varied. Effect of different pH level on the removal efficiency in leachate was investigated in order to provide optimum condition. Next, the experiment design was carried out by using different pH level which includes 3, 5, 7, 9 and 11 respectively. Each sample was duplicated. Thus, the optimum pH level can be determined. pH was measured using pH meter.

3.5 Ultrasonication Process

The ultrasonication process began after conducting the characterization of leachate. The initial temperature was measured. Then, 100 mL of leachate was poured into a 250 mL beaker and placed in the ultrasonic homogenizer for ultrasonication. The characterization of leachate was conducted and temperature was measured again after the ultrasonication process. The effects of the process were then compared with the initial data. The process was repeated until the optimum variables were found. Figure 3.9 shows the schematic diagram of the process.

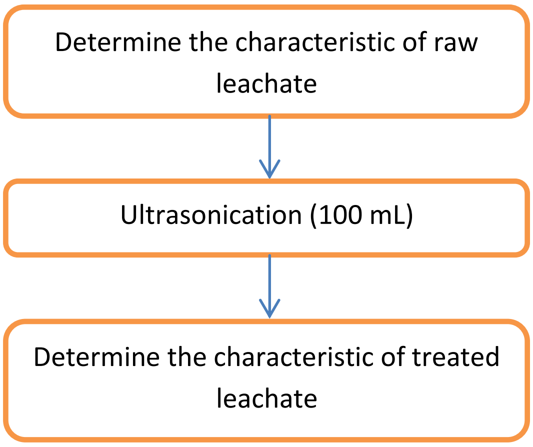

Figure 3.9: Flow chart of ultrasonication

Figure 3.10: Ultrasonic homogenizer

3.6 Experimental Procedures

Experimental procedures were prepared for determining the range of the leachate variables. The procedures were divided into 4 stages.

In first stage, the reaction time was fixed to be 30 or 40 minutes and amplitude was varied between the ranges of 20% to 50%. This range was previously found by Yap

(2014) that high amplitude with 40 minutes reaction time achieved optimal removal efficiency for NH_3-N and low amplitude with 40 minutes reaction time achieved highest energy efficiency. After determining the optimal amplitude, the reaction time was then varied from 5 minutes to 120 minutes.

In the second stage, the pH were being altered to pH 3, 5, 7, 9 and 11 to observe the effect of pH of leachate treatment using ultrasonication process with 30% amplitude at various time while the 3rd stage would be changing the pH of leachate but no ultrasonication process takes place to compare the removal efficiency.

In the final stage, the optimum concentration of hydrogen peroxide (H_2O_2) was determined by fixing the amplitude and reaction time. Up to 12 g/L of H_2O_2 was added into leachate to determine the removal efficiency of COD and NH_3-N (Tizaoui, 2007).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Characteristic of Raw Leachate of Batu Gajah Landfill

The raw leachate collected from the Batu Gajah landfill site is expected to change with time. Basic common physical and chemical properties of leachate measured at the time of the collection. The parameters measured were pH, concentration of ammoniacal nitrogen (NH_3-N), Total Chemical Oxygen Demand (TCOD), Soluble Chemical Oxygen Demand (SCOD), concentration of suspended solid (SS), colour at 465 nm, 5-days biochemical oxygen demand (BOD_5) and lastly the turbidity of leachate. The values were displayed in Table 4.1.

Table 4.1: Characteristic of raw leachate before treatment

Parameter	**Unit**	**Value (Range)**	**Value (Average)**
Temperature	^{0}C	24.0 - 26.3	25.2
pH	-	8.50 - 9.53	9.01
Ammoniacal Nitrogen	mg/L	320 - 340	330.00
TCOD	mg/L	557.00 - 565.00	561.00
SCOD	mg/L	548.00 - 554.00	551.00
Suspended Solid	mg/L	105.00 - 113.00	109.00

Colour	PtCo	1058.00 – 1080.00	1069.00
BOD_5	mg/L	127.00 - 136.00	131.00
Turbidity	NTU	98.4 - 101.0	99.7

The study was to document the analytical design to improve the quality of leachate. pH, ammoniacal nitrogen, suspended solids, biochemical oxygen demand and chemical oxygen demand were studied for the treatment and integrated treatment process. Leachate collected was amber in appearance and alkali.

4.2 Effects of Reaction Time and Amplitude

For the first stage of the experiment, the experiments were carried out in a way that the amplitude and reaction time were used as manipulating variables. The concentration for every parameter were recorded and removal efficiencies were determined.

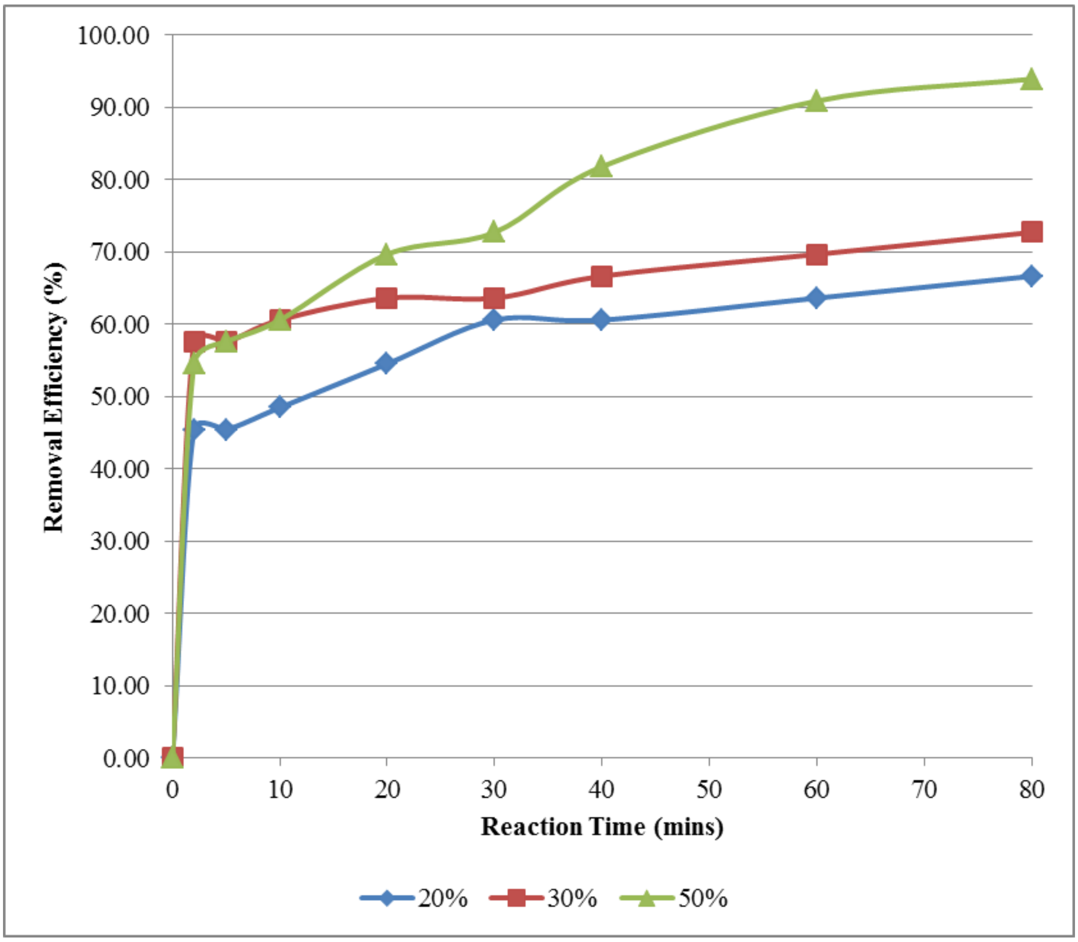

Figure 4.1: Removal efficiency of ammoniacal nitrogen at different amplitude and different reaction time

According to Figure 4.1, as the reaction time increases, the concentration of ammoniacal nitrogen decreases from the initial concentration of 330 mg/L to a low point of 20 mg/L. The concentration curves showed that concentration ammoniacal nitrogen was successfully removed in the ultrasonication process at all amplitude. The removal efficiency attained a high percentage of 93.94%. This determined that ammoniacal nitrogen is best being removed with 50% amplitude at 80 minutes.

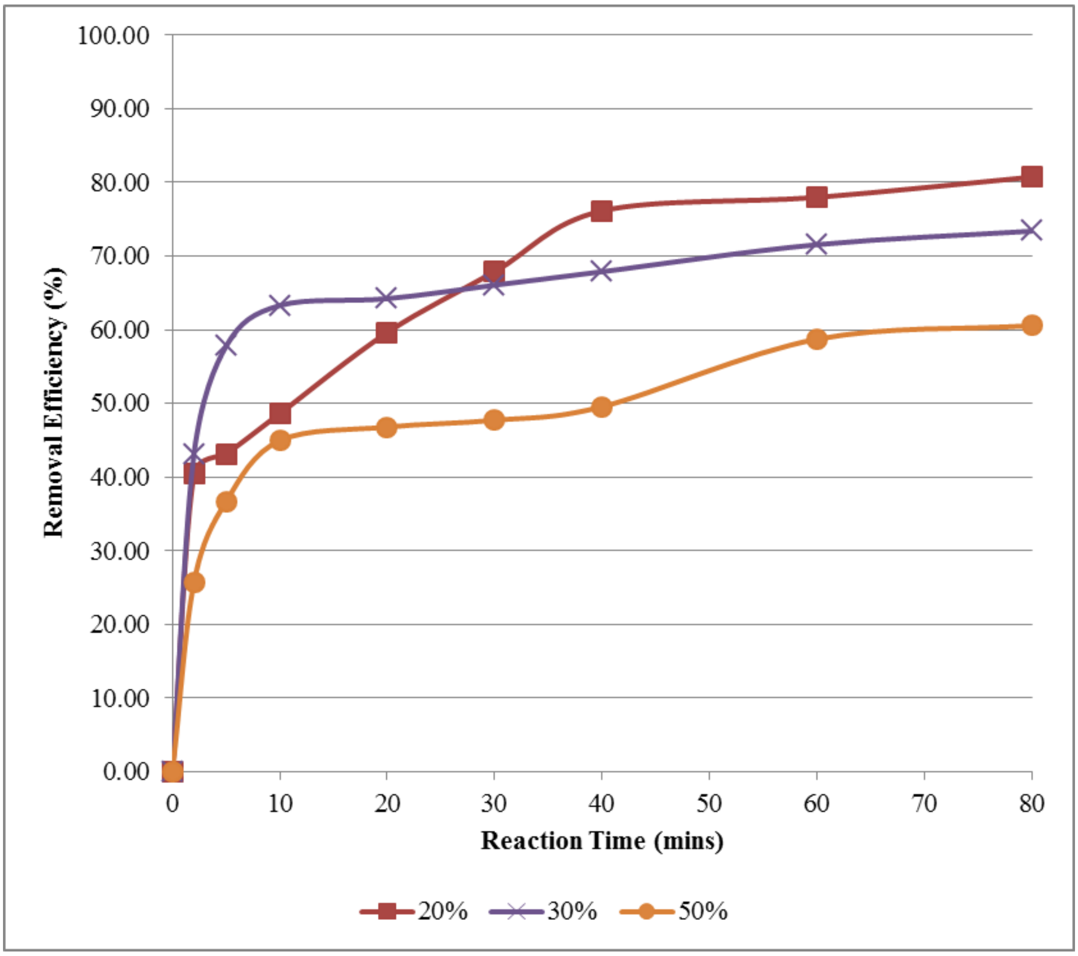

Figure 4.2: Removal efficiency of suspended solid at different amplitude and different reaction time

According to Figure 4.2, as the reaction time increases, the concentration of suspended solid was decreased significantly from 109 mg/L to as low as 21 mg/L. The concentration curves also showed that concentration of suspended solid was successfully removed in the ultrasonication process at all amplitude. The removal efficiency attained a high percentage of 80.74%. This determined that suspended solid is best being removed with 20% amplitude at 80 minutes.

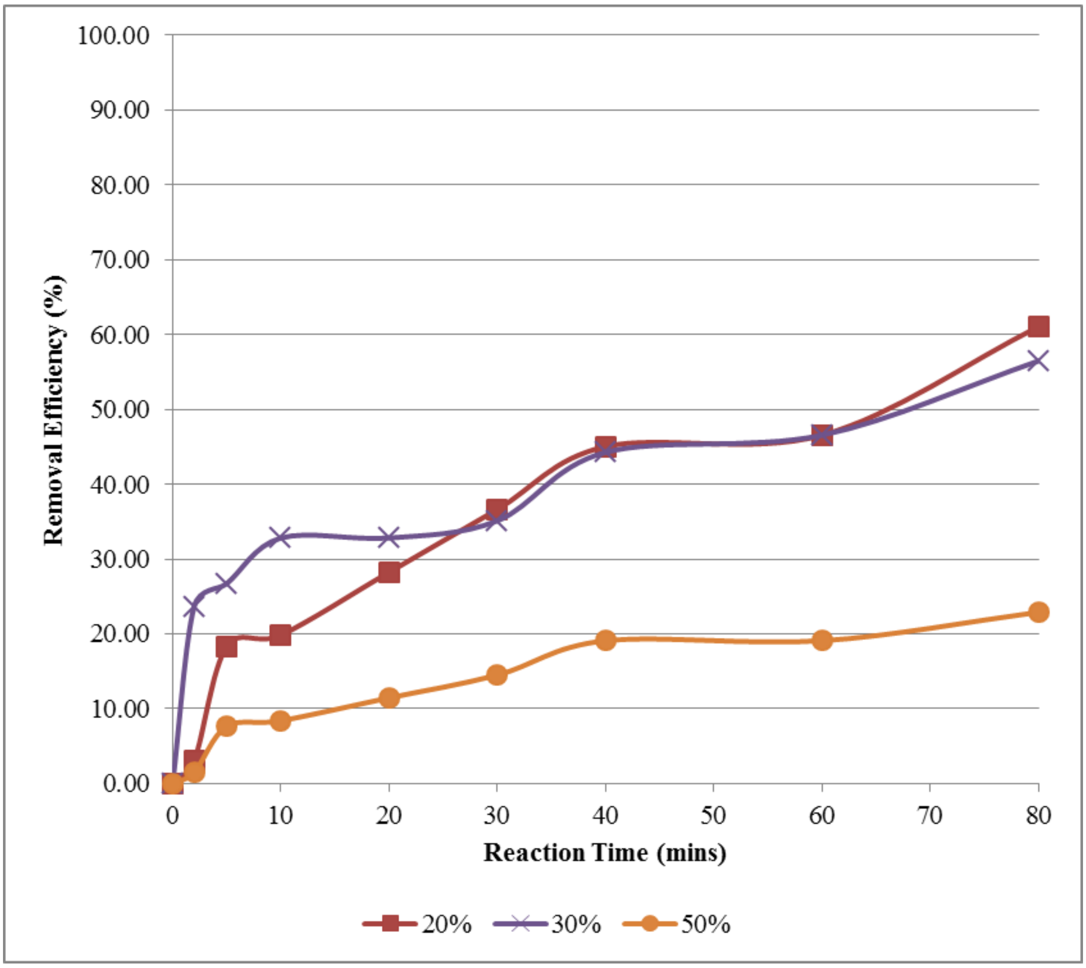

Figure 4.3: Removal efficiency of BOD_5 at different amplitude and different reaction time

According to Figure 4.3, as the reaction time increases, the concentration of BOD_5 decreased significantly from 131 mg/L to as low as 51 mg/L. The concentration curves also showed that concentration of BOD_5 was successfully removed in the ultrasonication process at all amplitude. The removal efficiency attained percentage of 61.07%. This determined that BOD_5 is best being removed with 20% amplitude at 80 minutes.

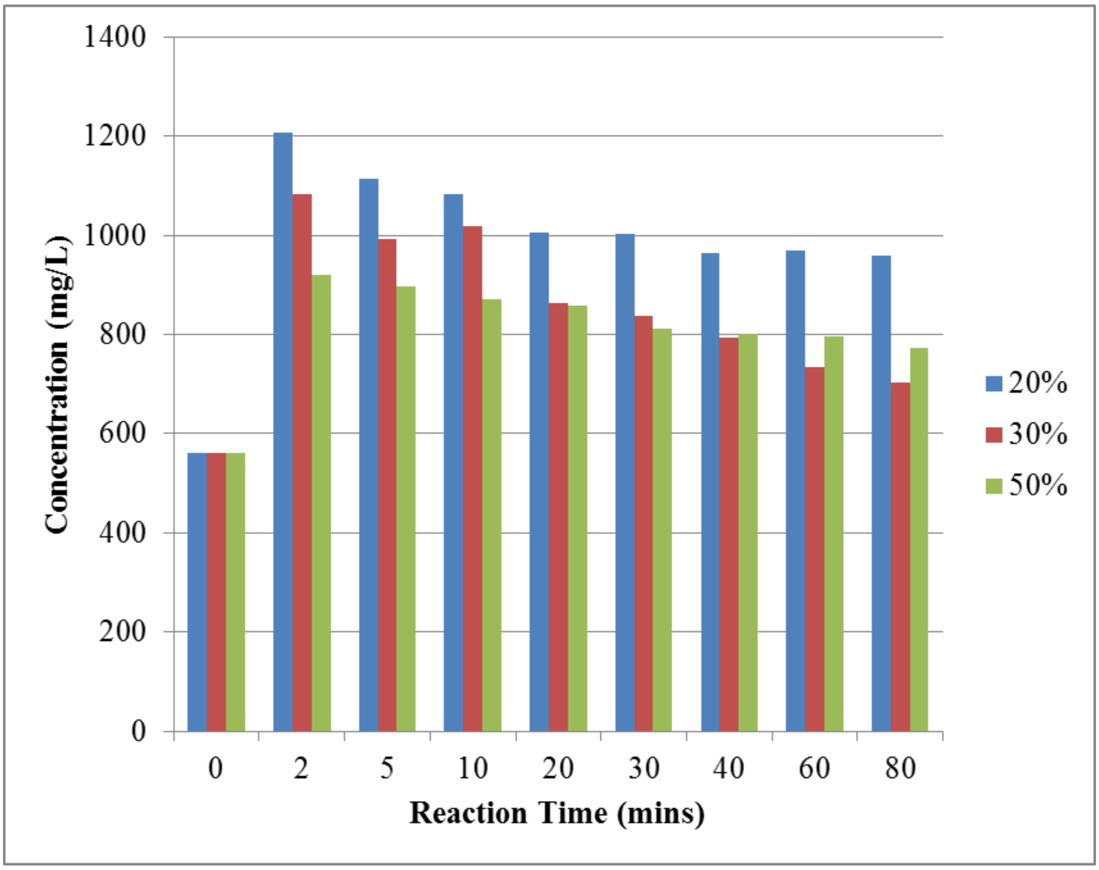

Figure 4.4: Concentration COD against reaction time at different amplitude

Based on Figure 4.4, the concentration curves showed that the Chemical Oxygen Demand (COD) increased after ultrasonication process. However, the curves showed that the trend of COD decreases as the reaction time increases. This could be due to the presence of interfering substances in leachate sample. It was found that chloride ions would be the main problem of the reaction. The reaction equation will be shown as below:

$$6\ Cl^- + Cr_2O_7^{2-} + 14\ H^+ \rightarrow 3\ Cl_2 + 3\ Cr^{3+} + 7\ H_2O \qquad (4.1)$$

The interference such as chloride should be removed in the leachate before proceeding to COD testing as it interfered the reading.

4.3 Effects of pH and Reaction Time

The next stage of the experiment was preceded with series of experiments by selecting amplitude with certain time to determine the optimum pH for removal efficiency for several parameters. The initial concentrations for each parameter were altered as well at different pH.

Based on Figure 4.5, the concentration curves shows that ultrasonication process could decrease the concentration of ammoniacal nitrogen efficiently at 5 minutes. On the other hand, concentration of ammoniacal nitrogen continued decrease as time increases but at acidic pH of pH 3 and pH 5 the concentrations dropped lesser compared to alkali pH which are pH 7, pH 9 and pH 11. The initial concentration for raw leachate before treatment was 330 mg/L and the highest removal efficiency is at pH 11 which is 93.94% which left the concentration of ammoniacal nitrogen left only 20 mg/L and lowest removal efficiency would be pH 3 which is 39.39%. As pH increases, ammoniacal nitrogen became more toxic but at the same time also became ammonia which is un-ionized (Wurts, 2003). More un-ionized ammoniacal nitrogen tends to become ionized forming ammonium ion and easier to be removed compared to the low pH with saturated ionized ammoniacal nitrogen which would be removed first before able to remove the un-ionized ammoniacal nitrogen.

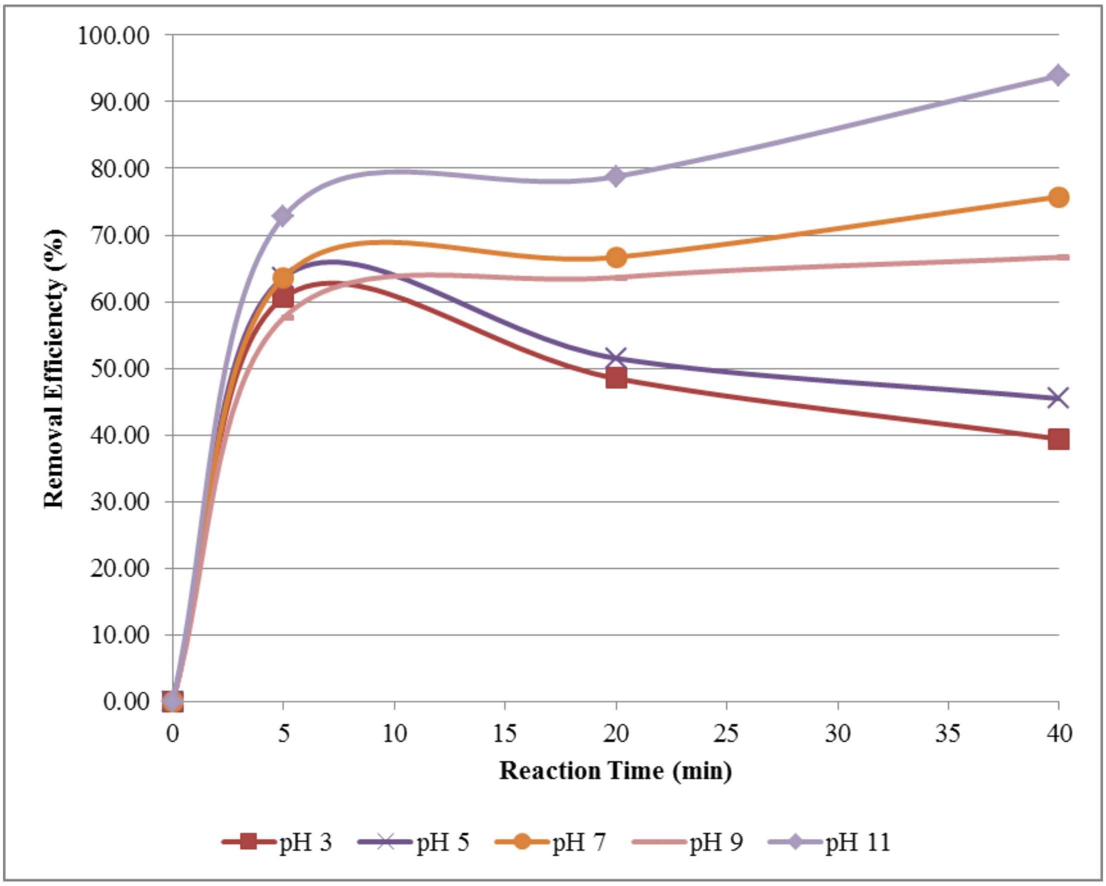

Figure 4.5: Removal efficiency of ammoniacal nitrogen at different pH against reaction time at 30% amplitude

The concentration of suspended solid successful decreased at pH ranging from pH 3 to pH 11. However, as the time increases, the concentration of suspended solid dropped from 109 mg/L to 19 mg/L at the end of 40 minutes ultrasonication at 30% amplitude for pH 7 and pH 11 hence showing the highest removal efficiency of approximately 82%.. As for the lowest removal efficiency, pH 3 failed to removed much concentration as other pH. It had a removal efficiency of 66.30% with removal concentration from 109 mg/L to 40 mg/L at the end of 40 minutes with 30% amplitude ultrasonication as shown in Figure 4.6. Water hardness could be related with suspended solid removal as shown. Hardwater tends to able to react well with ultrasonication process.

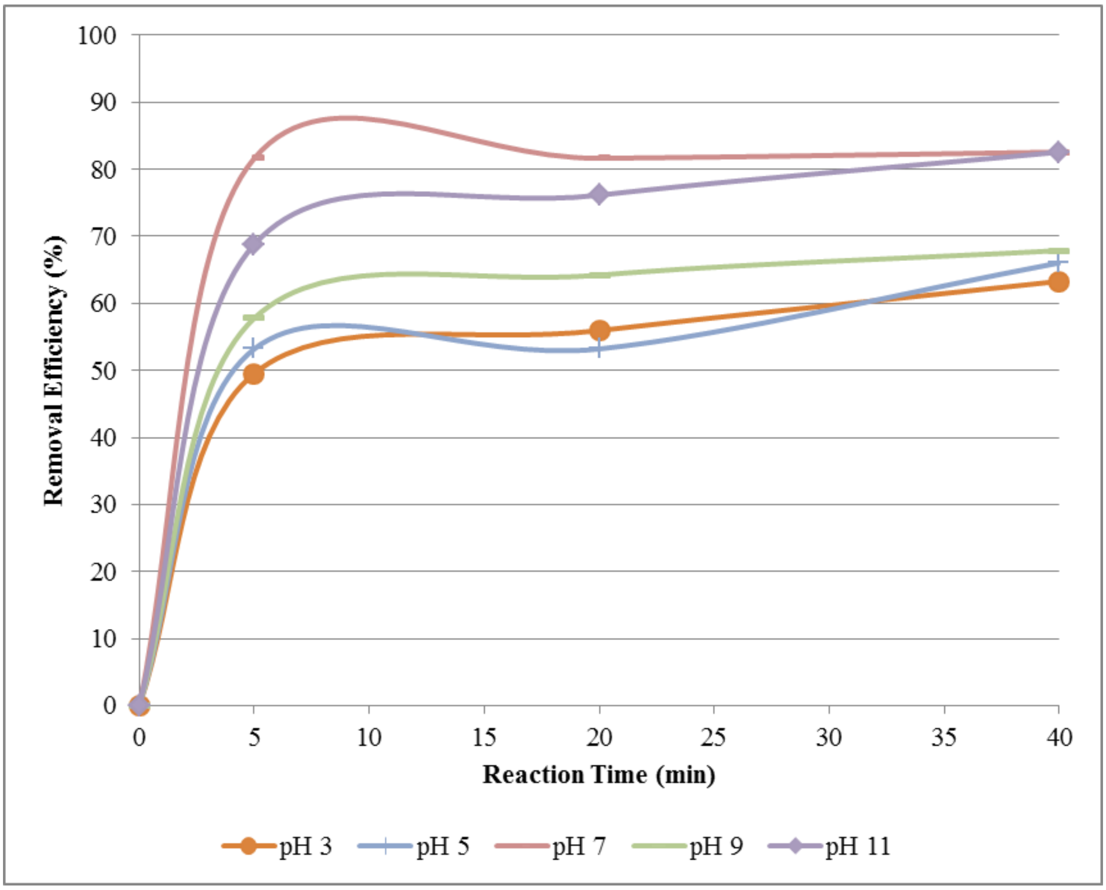

Figure 4.6: Removal efficiency of suspended solid at different pH against reaction time at 30% amplitude

Based on Figure 4.7, all BOD_5 concentration successfully decreased upon the initiation of ultrasonication at pH ranging from 3 to 11. pH 3 had the best removal efficiency as shown in the figure. The concentration declined from 131 mg/L to 18 mg/L with removal efficiency as high as 86.26%. The trend could not be observed as the BOD_5 removal do not had a direct relationship with acidity or alkalinity. On the other hand, at pH 9 BOD_5 value had the lowest drop in concentration which was from 131 mg/L to 73 mg/L with removal efficiency of 44.27%.

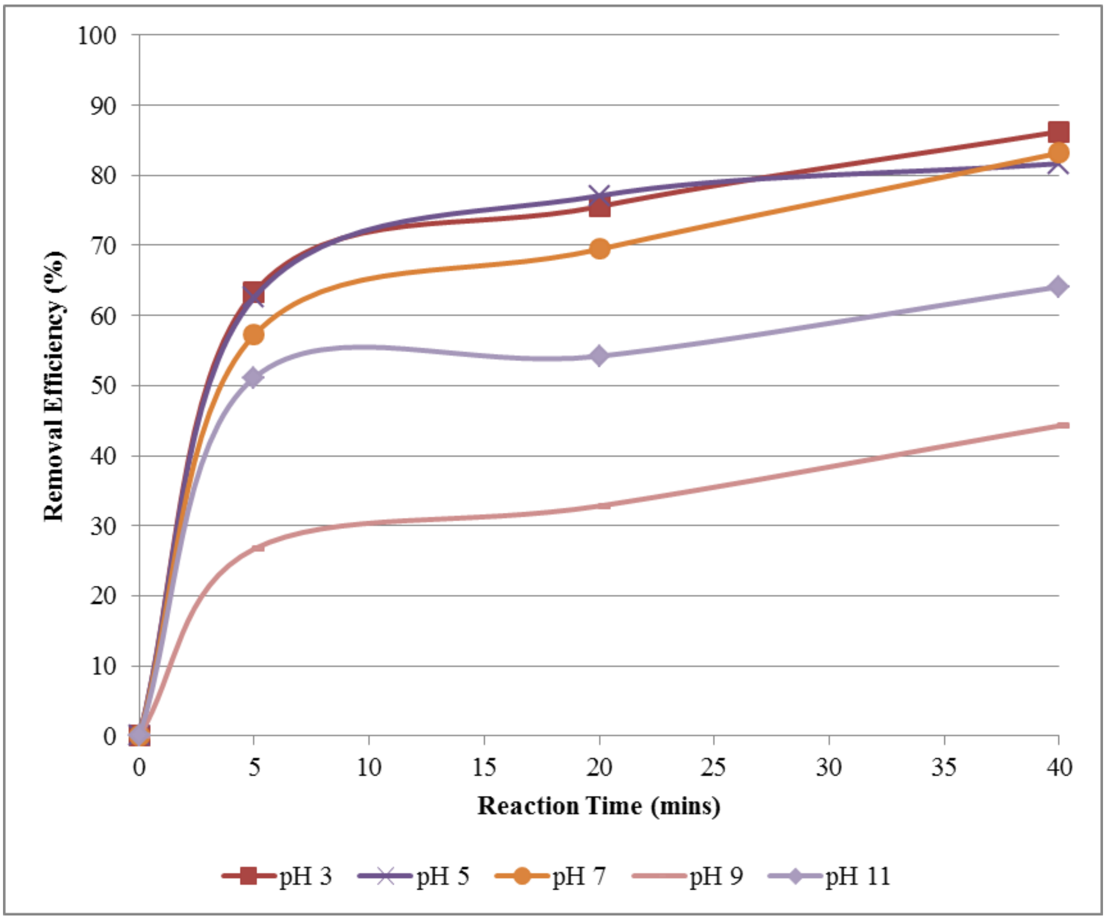

Figure 4.7: Removal efficiency of BOD_5 at different pH against reaction time at 30% amplitude

According Figure 4.8, the trend showed that the initial concentration of COD increased in acidic pH value and decreased in alkaline pH. The figure also suggested that even in different pH, the trend had the similar traits as Figure 4.4. Concentration of COD increases after ultrasonication process except for pH 5 which showed a small decline from 721 mg/L to 713 mg/L. Besides, concentration still decreased as the reaction time increases.

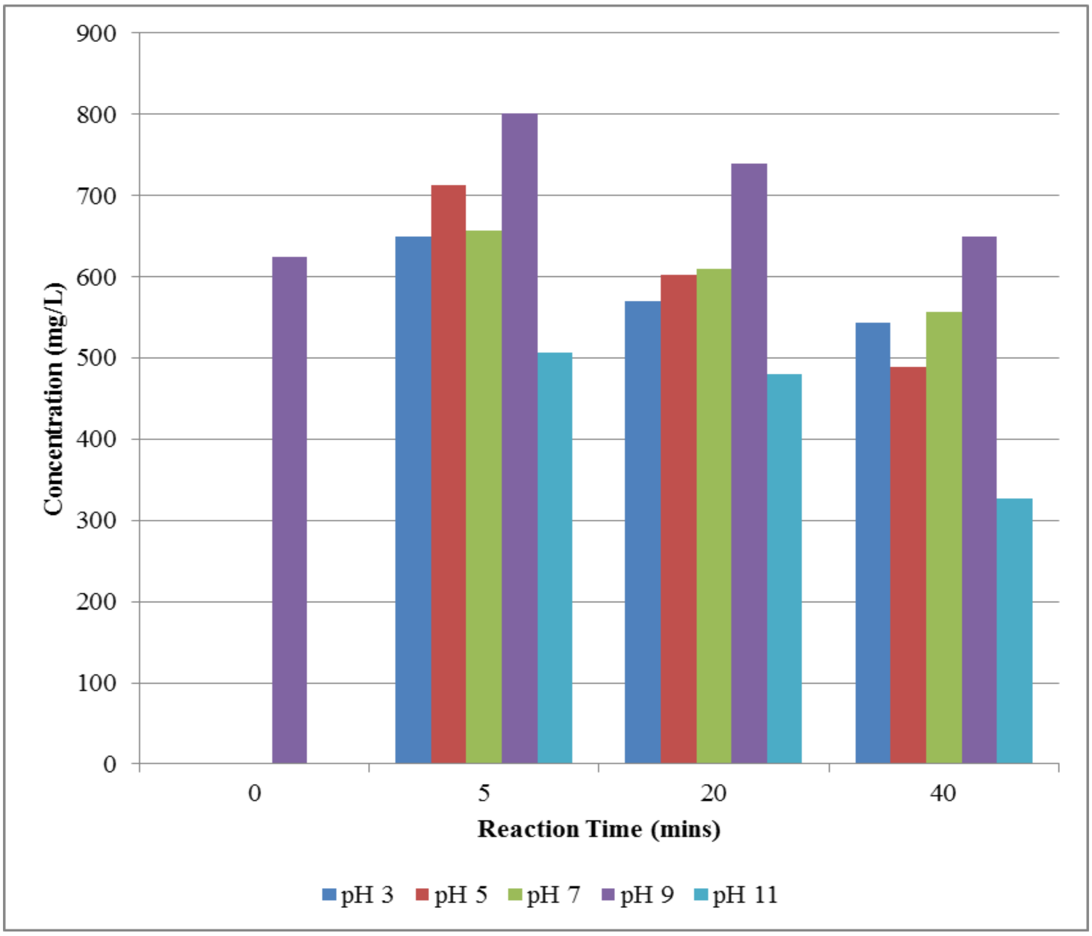

Figure 4.8: COD concentration against reaction time at different pH

4.4 Effects of pH Without Ultrasonication

A few test experiments on the effects on the leachate properties by altering the pH values without running the ultrasonication process were ran. This was ran to compare the difference with ultrasonication process. All the runs were set to have a reaction time of 40 minutes.

As shown in Figure 4.9: The removal efficiency trend for ammoniacal nitrogen increases as the leachate pH is more alkaline. The concentration of ammoniacal nitrogen remains the same for low pH which is 330 mg/L but with pH starting from 9 the concentration began to drop to 300 mg/L to 220 mg/L hence explaining the removal efficiency. However, suspended solid has little difference in removal efficiencies though it has the range of 58% to 65%. The concentration for suspended solid dropped as pH increased from the initial concentration to 45 mg/L till 39 mg/L which decline in a small scale. Lastly, BOD_5 value showed a trend of declining removal efficiency as the pH increases from 43.51% to 24.42%. There was a small increased in removal efficiency at pH 11 compared to pH 9 which was 25.96%. As summary, ammoniacal nitrogen was not removed below pH 9 and had higher efficiency as pH increases, suspended solid showed an average removal along the pH increment of around 60% removal rate and BOD_5 removal efficiency decreases as pH increases.

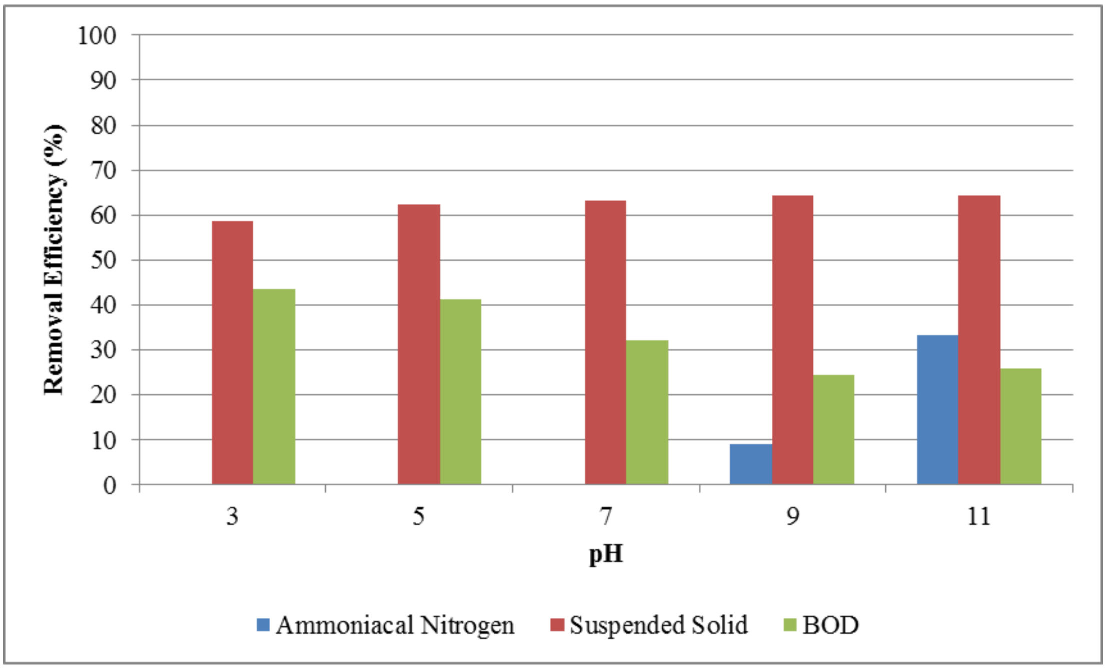

Figure 4.9: Removal efficiency of parameters at different pH over 40 minutes retention time without ultrasonication

As shown in Figure 4.10, pH 3 had a slightly lower COD value than pH 5 but as for the rest as the pH increases, COD value decreases. A relationship between COD value and suspended solid removal can be observed here as COD value decreased, the suspended solid removal rate increased as the inorganic

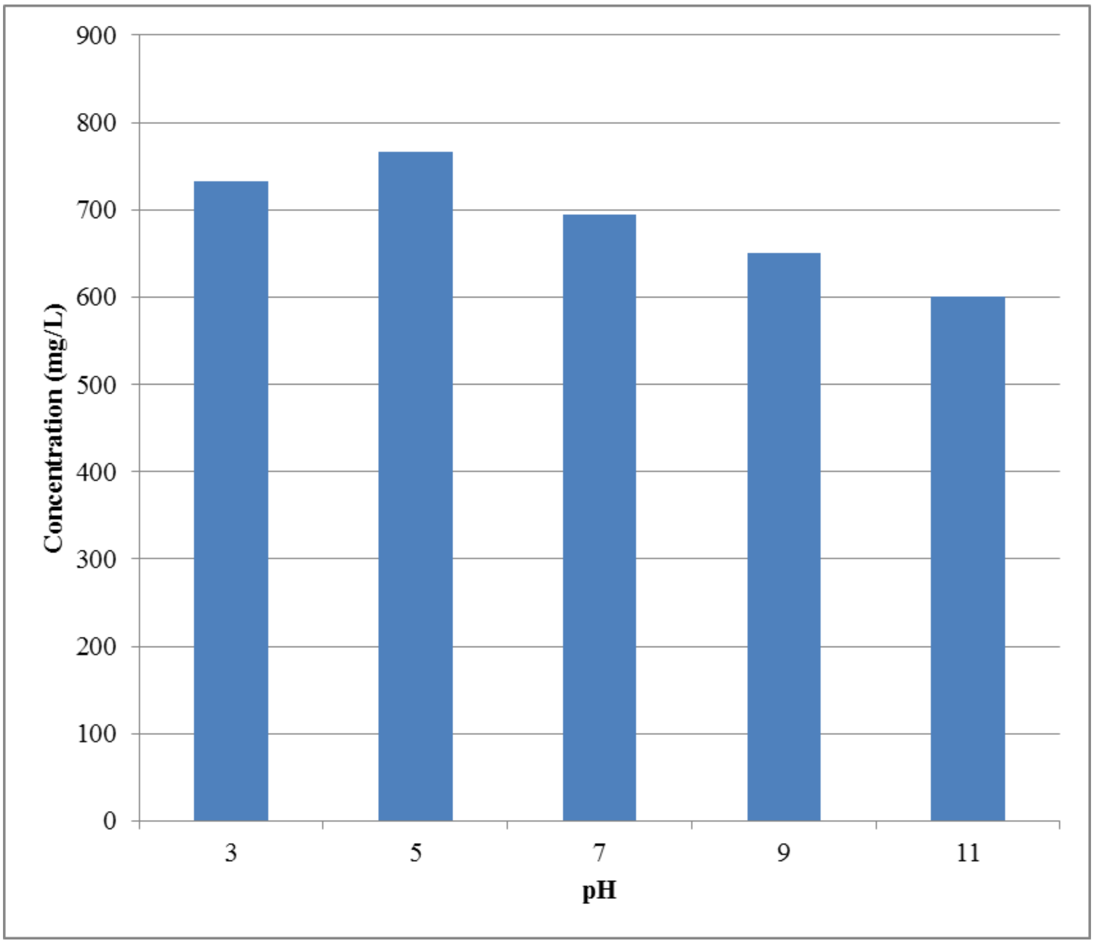

Figure 4.10: COD value at different pH over 40 minutes retention time without ultrasonication

4.5 Effects of Concentration of Hydrogen Peroxide (H_2O_2)

Lastly, several tests were run to determine the optimum concentration of hydrogen peroxide to be added into the process. This was done to observe the removal efficiency and to compare with the process without the addition of hydrogen peroxide.

Figure 4.11 showed that ammoniacal nitrogen can be removed completely from upon addition of 1 g/L of H_2O_2 into the leachate before the ultrasonication process took place compared to the one without H_2O_2 only had removal efficiency of 91%. The figure also showed that suspended solid had higher removal efficiency with addition than without adding H_2O_2. Lastly, H_2O_2 showed a significant change in BOD_5

concentration. As the dosage of H_2O_2 increases, the BOD removal rate also increases from 53.44% to 76.34%. The BOD value dropped from initial value of 131 mg/L to 31 mg/L.

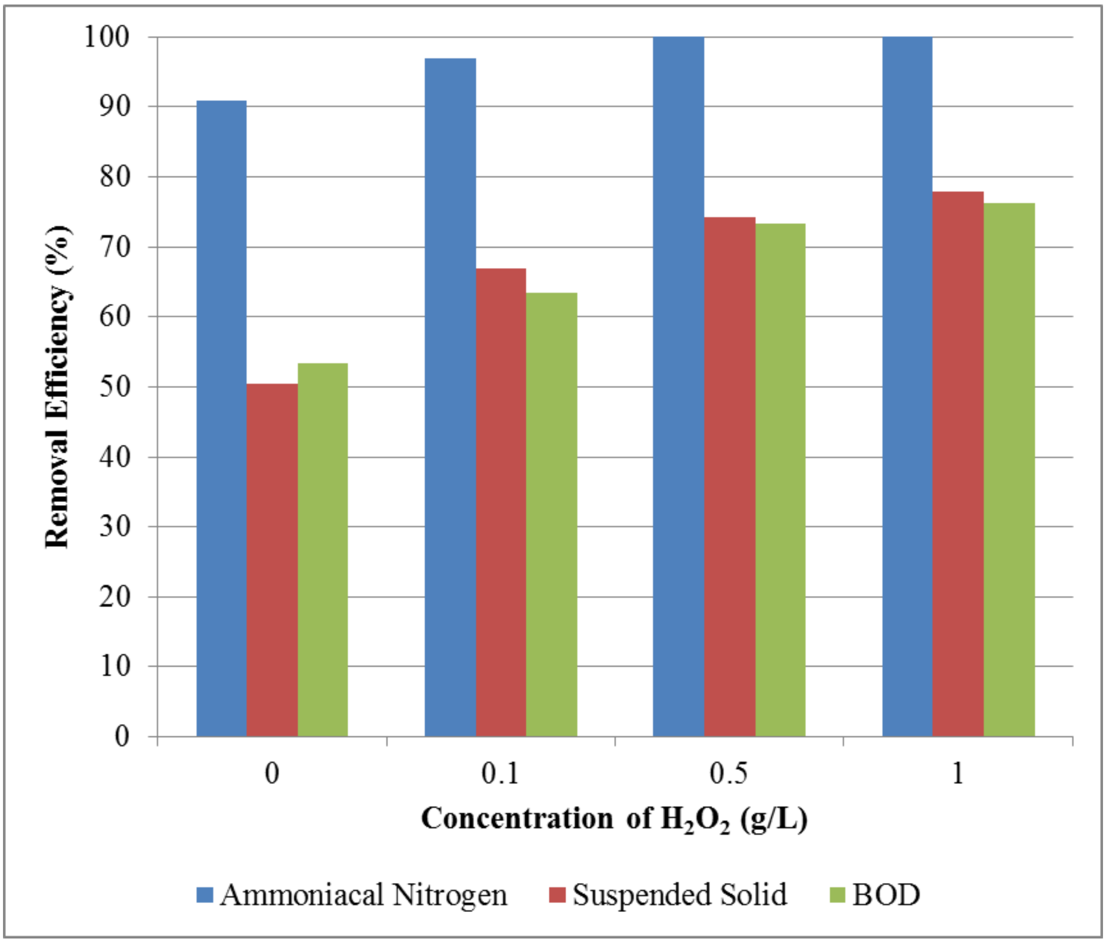

Figure 4.11: Effects of concentration of H_2O_2 on removal efficiency of parameters

Figure 4.12 showed that after adding H_2O_2, COD value increases as the dosage of H_2O_2 increases. Therefore, it shows that H_2O_2 is not suitable to use as a COD removal agent. This could be due to H_2O_2 is an inhibiting agent for COD reaction. According to Talinli and Anderson (1992), H_2O_2 is found to be forming a multiplex structure with one of the compound of COD reagent, potassium dichromate (VI). The concentrations of COD in wastewater samples were found to be different even with the absence of organic substances. Hence, this proved that H_2O_2 is an interfering agent for standard COD test.

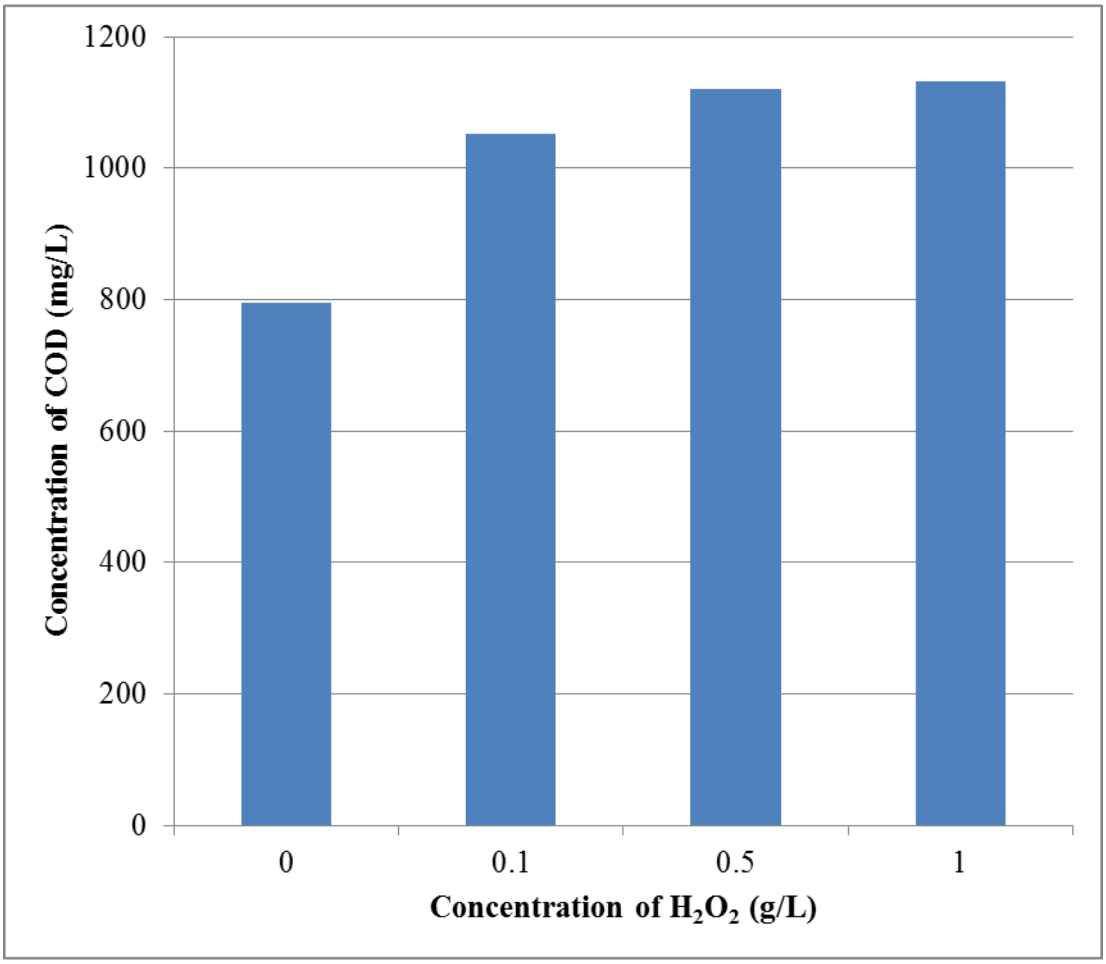

Figure 4.12: Effects of concentration of H_2O_2 on COD concentration.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In a nutshell, the characteristic of landfill leachate generated from Batu Gajah landfill site was studied and the average temperature of the leachate was 25.2 ^{0}C with alkali properties of pH 9.01. Average amount of 330 mg/L of ammoniacal nitrogen was contained within the leachate. The average TCOD values and SCOD values of landfill leachate were 561 mg/L and 551 mg/L respectively. The suspended solids contained within the leachate were approximately 109 mg/L. The colour of the leachate was amber with the value of 1069 PtCo. The 5-days BOD value of the leachate was measured to be 131 mg/L averagely. The leachate was cloudy in nature containing lots of impurities with turbidity value of 99.7 NTU.

Besides It was observed that different amplitude is required for different pollutants removal, however as the reaction time increases, the removal efficiency of pollutants increases. It was found that the optimum amplitude for treating ammoniacal nitrogen was 50% without buffering the leachate as it has the removal efficiency up to 93% at 80 minutes of reaction time. However, when it was buffered to pH 11, 30% amplitude would be sufficient to treat ammoniacal nitrogen with removal efficiency up to 93% as well but with shorter time. Figure 4.9 also tells that without ultrasonication process, the removal efficiency would decline severely. But with the addition of H_2O_2, the removal efficiency for ammoniacal nitrogen achieved 100% with just 0.5 g/L of H_2O_2 added into the leachate before ultrasonication process began. As for suspended solid, the optimum amplitude for removal would be

20% as it reaches removal efficiency of approximately 80% at the end of 80 minutes reaction time. The removal efficiency of suspended solid spiked up to 82% when it was buffered to alkali with shorter time. Ultrasonication process boosted up the removal efficiency from average value of 60% to 82% as compared to Figure 4.9 and Figure 4.6. The suspended solid performed not as well with the addition of H_2O_2 as just ultrasonication alone even with high concentration added still only achieves 77% removal efficiency which is lower. For BOD_5, it is best seen in removal with the optimum amplitude of 20% for 80 minutes with the removal efficiency of 60%. COD value increases after ultrasonication process this could be due to the presence of interfering substances such as chloride. Therefore, the optimum amplitude for ammoniacal nitrogen removal would be higher with longer reaction time and addition of H_2O_2 would definitely increase the efficiency. The optimum condition for suspended solid removal would be in alkali property and longer time. Lastly. BOD_5 optimum condition would be 20% amplitude with high reaction time. H_2O_2 was proven to be able to increase efficiency of ammoniacal nitrogen, suspended solid and BOD but not for COD as H_2O_2 is an interfering agent for COD testing.

5.2 Recommendation for Future Research

Although the removal efficiency could be good for certain parameters but it is recommended that the treatment achieves leachate discharge quality according Environmental Quality Regulations 2009 (APPENDIX E). Therefore, as long as it fulfils the discharge standard, they would be no point increasing the efficiency as it would only increase the cost.

- To achieve the discharge quality standards, addition of H_2O_2 in the middle of ultrasonication process is recommended shortly after successfully removed suspended solid and BOD_5.
- It is recommended that interfering compound should be tested and removed before proceed to treatment process such as chloride should be removed to prevent interference to COD test by using mercuric sulphate (HgSO4) (Dobbs & Williams, 1963).

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APPENDICES

APPENDIX A: Raw Leachate Characteristic

Parameter	**Unit**	**1**	**2**	**3**	**Range**
Temperature	^0C	24	25.6	26.3	24.0 - 26.3
pH	-	8.5	8.64	9.53	8.50 - 9.53
Ammoniacal Nitrogen	mg/L	330	340	320	320-340
TCOD	mg/L	561	557	565	557.00 - 565.00
SCOD	mg/L	551	548	554	548.00 - 554.00
Suspended Solid	mg/L	109	105	113	105 - 113
Colour	PtCo	1058	1058	1080	1058 - 1080
BOD_5	mg/L	131	136	127	127.00 - 136.00
Turbidity	NTU	98.4	99.1	101	98.4 - 101.0

APPENDIX B: Treatment Variable using Amplitude and Reaction Time

Treatment Concentration at 20% Amplitude

Time (mins)	0	2	5	10	20	30	40	60	80
pH	7.68	8.25	8.15	8.17	8.10	8.12	8.61	8.63	8.63
Ammoniacal Nitrogen (mg/L)	330	180	180	170	150	130	130	120	110
COD (mg/L)	561	1208	1114	1084	1006	1002	964	970	960
Suspended Solid (mg/L)	109	65	62	56	44	35	26	24	21
Colour (PtCo)	1058	1104	1066	1056	1066	1080	1068	1098	1078
BOD_5 (mg/L)	131.00	127.00	107.00	105.00	94.00	83.00	72.00	70.00	51.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	45.45	45.45	48.48	54.55	60.61	60.61	63.64	66.67
Suspended Solid Removal Efficiency (%)	-	40.37	43.12	48.62	59.63	67.89	76.15	77.98	80.73
BOD Removal Efficiency (%)	-	3.05	18.32	19.85	28.24	36.64	45.04	46.56	61.07

Treatment Concentration at 30% Amplitude

Time (mins)	0	2	5	10	20	30	40	60	80
pH	7.68	8.18	8.23	8.45	8.53	8.61	8.63	8.80	8.36
Ammoniacal Nitrogen (mg/L)	330	140	140	130	120	120	110	100	90
TCOD (mg/L)	561	1082	992	1019	863	837	794	734	704
Suspended Solid (mg/L)	109	62	46	40	39	37	35	31	29
Colour (PtCo)	1058	1219	1067	1135	1124	1397	1210	1228	1208
BOD_5 (mg/L)	131.00	100.00	96.00	88.00	88.00	85.00	73.00	70.00	57.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	57.58	57.58	60.61	63.64	63.64	66.67	69.70	72.73
Suspended Solid Removal Efficiency (%)	-	43.12	57.80	63.30	64.22	66.06	67.89	71.56	73.39
BOD Removal Efficiency (%)	-	23.66	26.72	32.82	32.82	35.11	44.27	46.56	56.49

Treatment Concentration at 50% Amplitude

Time (mins)	0	2	5	10	20	30	40	60	80
pH	7.68	8.08	8.21	8.52	8.84	8.75	8.75	8.73	8.92
Ammoniacal Nitrogen (mg/L)	330	150	140	130	100	90	60	30	20
COD (mg/L)	561	919	898	872	857	811	802	795	774
Suspended Solid (mg/L)	109	81	69	60	58	57	55	45	43
Colour (PtCo)	1058	1166	1178	1468	1482	1748	1782	1740	1819
BOD_5 (mg/L)	131.00	129.00	121.00	120.00	116.00	112.00	106.00	106.00	101.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	54.55	57.58	60.61	69.70	72.73	81.82	90.91	93.94
Suspended Solid Removal Efficiency (%)	-	25.69	36.70	44.95	46.79	47.71	49.54	58.72	60.55
BOD Removal Efficiency (%)	-	1.53	7.63	8.40	11.45	14.50	19.08	19.08	22.90

APPENDIX B: Treatment Variable using pH and Reaction Time

Treatment Concentration at pH 3 with 30% Amplitude

Time (mins)	0	5	20	40
Ammoniacal Nitrogen (mg/L)	330	130	170	200
COD (mg/L)	624	650	570	544
Suspended Solid (mg/L)	109	55	48	40
Colour (PtCo)	1058	1109	900	1364
BOD_5 (mg/L)	131.00	48.00	32.00	18.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	60.61	48.48	39.39
Suspended Solid Removal Efficiency (%)	-	49.54	55.96	63.30
BOD Removal Efficiency (%)	-	63.36	75.57	86.26

Treatment Concentration at pH 5 with 30% Amplitude

Time (mins)	0	5	20	40
Ammoniacal Nitrogen (mg/L)	330	120	160	180
COD (mg/L)	624	713	603	489
Suspended Solid (mg/L)	109	51	51	37
Colour (PtCo)	1058	1096	1099	1271
BOD_5 (mg/L)	131.00	49.00	30.00	24.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	63.64	51.52	45.45
Suspended Solid Removal Efficiency (%)	-	53.21	53.21	66.06
BOD Removal Efficiency (%)	-	62.60	77.10	81.68

Treatment Concentration at pH 7 with 30% Amplitude

Time (mins)	0	5	20	40
Ammoniacal Nitrogen (mg/L)	330	120	110	80
COD (mg/L)	624	657	610	557
Suspended Solid (mg/L)	109	20	20	19
Colour (PtCo)	1058	921	94	1052
BOD_5 (mg/L)	131.00	56.00	40.00	22.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	63.64	66.67	75.76
Suspended Solid Removal Efficiency (%)	-	81.65	81.65	82.57
BOD Removal Efficiency (%)	-	57.25	69.47	83.21

Treatment Concentration at pH 9 with 30% Amplitude

Time (mins)	0	5	20	40
Ammoniacal Nitrogen (mg/L)	330	140	120	110
COD (mg/L)	624	801	740	650
Suspended Solid (mg/L)	109	46	39	35
Colour (PtCo)	1058	1067	1124	1210
BOD_5 (mg/L)	131.00	96.00	88.00	73.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	57.58	63.64	66.67
Suspended Solid Removal Efficiency (%)	-	57.80	64.22	67.89
BOD Removal Efficiency (%)	-	26.72	32.82	44.27

Treatment Concentration at pH 11 with 30% Amplitude

Time (mins)	0	5	20	40
Ammoniacal Nitrogen (mg/L)	330	90	70	20
COD (mg/L)	624	507	480	327
Suspended Solid (mg/L)	109	34	26	19
Colour (PtCo)	1058	823	529	1037
BOD (mg/L)	131.00	64.00	60.00	47.00
Ammoniacal Nitrogen Removal Efficiency (%)	-	72.73	78.79	93.94
Suspended Solid Removal Efficiency (%)	-	68.81	76.15	82.57
BOD Removal Efficiency (%)	-	51.15	54.20	64.12

APPENDIX C: Treatment Variable using pH without ultrasonication

pH	3	5	7	9	11
Ammoniacal Nitrogen (mg/L)	330	330	330	300	220
COD (mg/L)	733	766	694	650	600
Suspended Solid (mg/L)	45	41	40	39	39
Colour (PtCo)	759	739	909	928	959
BOD (mg/L)	74	77	89	99	97
Ammoniacal Nitrogen Removal Efficiency (%)	0.00	0.00	0.00	9.09	33.33
Suspended Solid Removal Efficiency (%)	58.72	62.39	63.30	64.22	64.22
BOD Removal Efficiency (%)	43.51	41.22	32.06	24.43	25.95

APPENDIX D: Treatment Variable with H_2O_2 as additive

Concentration of H_2O_2	0	0.1	0.5	1
Ammoniacal Nitrogen (mg/L)	30	10	0	0
COD (mg/L)	795	1052	1121	1132
Suspended Solid (mg/L)	54	36	28	24
Colour (PtCo)	1672	1259	1121	499
BOD_5 (mg/L)	61	48	35	31
Ammoniacal Nitrogen Removal Efficiency (%)	90.91	96.97	100	100
Suspended Solid Removal Efficiency (%)	50.46	66.97	74.31	77.98
BOD Removal Efficiency (%)	53.44	63.36	73.28	76.34

APPENDIX E: Environmental of Quality Regulations 2009 (Control of Pollution from Solid Waste Transfer Station and Landfill), Malaysia Environmental Quality Act 1974

Parameter	**Unit**	**Standard**
Temperature	^{0}C	40
pH value	-	6.0 - 9.0
BOD_5 at 20^{0}C	mg/L	20
COD	mg/L	400
Suspended Solid	mg/L	50
Ammoniacal Nitrogen	mg/L	5
Mercury	mg/L	0.005
Cadmium	mg/L	0.01
Chromium, Hexavalent	mg/L	0.05
Chromium, Trivalent	mg/L	0.20
Arsenic	mg/L	0.05
Cyanide	mg/L	0.05
Lead	mg/L	0.10
Copper	mg/L	0.20
Manganese	mg/L	0.20
Nickel	mg/L	0.20
Tin	mg/L	0.20
Zinc	mg/L	2.0
Boron	mg/L	1.0
Iron	mg/L	0.001
Silver	mg/L	0.10
Selenium	mg/L	0.02
Barium	mg/L	1.0
Fluoride	mg/L	2.0
Formaldehyde	mg/L	1.0
Phenol	mg/L	0.001
Sulphide	mg/L	0.50
Oil and Grease	mg/L	5.0
Colour	PtCo	100