LEACHATE QUALITY OF OLD LANDFILL COMPARTMENT AT BENCHAM LANDFILL, IPOH

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CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JULY 2009

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by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JULY 2009

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

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July 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NORHAZIRAH BINTI AB GHANI @ RANI

ABSTRACT

Leachate control is an important part of landfill operation. Leachate is the result of available as water percolation through solid waste. Without a proper control leachate can contaminated the groundwater and hazardous to surrounding area. This report presents the results of investigation on the quality of leachate produced at the old landfill compartment at Bercham Landfill site. The studies involve field investigation, samplings, sample analyses and result analyses. The field investigation was conducted to examine the site conditions and method of operations of the landfill. The assessment of physical, chemical and biological parameters have been done in laboratories tests. The results of the assessment will be useful for the future treatment of leachate in order to overcome the problem of leachate contamination from the landfill. Leachate sample was assessed in term of physical, chemical and biological such as pH, colour, turbidity, COD, TOC, BOD_5, Nitrate, Phosphorus, Ammonia and total suspended solid (TSS). Based on the value for COD and TOC, the sample was treated by using the batch experiment on activated carbon adsorption. Results from the adsorption experiement were analysed using Freundlinch Isotherm and Langmuir Isotherm to obtain the linear graph of adsorption onto activated carbon. From the graph, the Freundlinch Isotherm give a good fit of linear graph with correlation coefficient (R^2) values for COD and TOC are 0.927 and 0.946 respectively. Based on Langmuir Isotherm graph the correlation coefficient (R^2) values for COD and TOC are 0.968 and 0.061 respectively. So, the best isotherm as indicator for adsorption onto activated carbon is Freundlinch Isotherm.

ACKNOWLEDGEMENT

In the name of Allah the Most Merciful.

First of all, I would like to express my utmost gratitude to my supervisor, AP. Dr. Nasiman Bin Sapari, for his expertise, guidance, attention, suggestions, support and concern throughout the project execution and completion period.

I would like to thank the Environmental Engineering Laboratory personal and technicians, Mr. Khairul Anuar and Mr. Zaaba for their assistance, guidance and thrust in the handling of equipment during the project experimental work.

My appreciation goes to Ir. Mustafa Al Bashree, engineer from Ipoh Municipality Council and Mr, Faizal the site supervisor at Bercham landfill, for their patience and generosity during my visit to the landfill to get the leachate sample for the research project.

My gratitude also goes to my friends that have been providing support and tolerance throughout the development of my project.

My special thanks go to my beloved mother; Ms. Hamidah Binti Jaafar, and my siblings. Thank you for your everlasting support and confidence in me.

Last but not least, my appreciation goes to the individuals or groups that have assisted me in any possible way to complete the project successfully.

Thank you.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

This study is intended to assess the leachate quality from an old landfill compartment at Bercham Landfill site. Leachate is produced by precipitation percolating through the solid waste in a landfill. The percolating water become contaminated with pollutants once it is in contact with the decomposed waste. The contaminated water has the composition which depends on some factors such as the waste composition, site hydrology, the availability of moisture and oxygen, design and operation of the fill and its stage. When water percolates through solid wastes that are undergoing decomposition, both biological materials and chemical constituents are leached into solution.

This old landfill area is about 8.90 hectares and was an open dumping solid waste disposal ground. The landfill is located near the Sg. Choh stream thus potentially affecting the water quality of the stream. The leachate produced from this old landfill needs to be investigated using physical, chemical and biological monitoring parameters. Some of the parameters that will be examined are BOD_5, TOC (Total Organic Carbon), COD (Chemical Oxygen Demand), TSS (Total Suspended Solids), pH, Ammonia nitrogen, total phosphorus, nitrate, color and turbidity.

1.2 PROBLEM STATEMENT

The total amount of solid waste generated from domestic and commercial activities in Ipoh, in 1978 was 181, 300 kg per day which later rose to 243, 800 kg per day in 1983. Studies done by Ipoh City Council at that time estimated that with rapid increase of the population in Ipoh and the development by the year 2000, solid waste disposal will rise to 490, 940 kg per day. The open dumping sites did not have the minimum requirements for pollution control. There are some problems indentified from the leachateflow which can be summarized as follows:

i) Contaminations of water sources

The leachate produced by the old landfill may contaminate the nearest river and the groundwater in the area. The contaminated water sources could be a potential risk and danger to local user and to natural environment.

ii) The quality of leachate

The quality of leachate is highly influenced the leachate treatment which dependent on various factors including waste composition and operational procedures.

iii) Improperly designed landfill

The improperly designed landfill may increase the risk of water contamination because the leachate may percolate through soils and causing pollution to receiving waters

1.3 OBJECTIVES OF STUDY

There are three main objectives of this project:

1. To investigate the quality of leachate produced at the old landfill at Bercham.
2. To assess the leachate quality using physical, chemical and biological parameters.
3. To examine the treatability of the leachate by carbon adsorption.

1.4 SCOPE OF STUDY

This study focused on the quality of leachate produced at Bercham Landfill and to be completed within one year timeframe or two semesters of studies. The scope for the first phase of the project includes examination of leachate quality, leachate parameters, samplings the leachate and testing the leachate with some parameters. Phase 2 will involve the analyses, data interpretations and examine the treatability of the leachate by carbon adsorption.

CHAPTER 2

LITERATURE REVIEW

2.1 LANDFILL

The sanitary landfill plays a most important role in the framework of solid waste disposal and will remain an integral part of the new strategies based on integrated solid waste management.

Sanitary landfill is the most common method of ultimate disposal of solid wastes. It is an engineered method of disposing solid wastes on land in a manner that minimizes environmental hazards and nuisances.

Davis and Cornwell (1991) listed 15 basic factors that should be considered during the site selection process. These are:

1) Public opposition
2) Proximity of major roadway
3) Speed limits
4) Load limits of roadway
5) Bridge capacities
6) Underpass limitations
7) Traffic patterns and congestion
8) Average haul distance or haul time
9) Detours

10) Hydrology

11) Availability of cover material

12) Climate (for example, floods, mud slides, snow)

13) Zoning requirement

14) Buffer areas around the site

15) Historic buildings, endangered species, wetlands, and other environmental factors

Davis and Cornwell (1991) also listed other sitting requirements such as site not less than (1) 30 m from streams, (2) 160 m from drinking water wells, (3) 65 m from houses, school and parks, and (4) 3,000m from airport runways.

A soil with a low permeability is needed to prevent the passage of water into the fill and the loss of leachate from the landfill (Pfeffer, 1992). According to the Resource Recovery and Conservation Act required that landfill will be prohibited from accepting bulk and noncontainerized liquids, and containers holding free liquids unless these liquids are household or septic wastes. Also, recirculation of leachate or landfill gas condensate will be prohibited unless the landfill has the proper leachate collection and liner system to prevent the release of liquids. According Bodzek et al. (1994), the major threats of landfills are related to leachate discharged into the environment. A badly designed or managed landfill can be the source of groundwater and soil pollution because of seep leachate.

2.2 LEACHATE

Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials. In most landfills leachate is composed of the liquid that has entered the landfill from external source, such as surface drainage, rainfall, groundwater, and water from underground springs and the liquid produced from the decomposition of the wastes, if any (Tchobanoglous, 1993).

According Bodzek et al. (1994), the composition and amount of leachate depend on many factors, among others:

1) Quality of wastes and its crumbling
2) Techniques of landfilling and degree of waste compaction
3) Age of landfill
4) Biochemical and physical processes of waste decomposition
5) Moisture and absorption capacity of wastes
6) Precipitation, humidity, and evapotranspiration rate
7) Topography of landfill site
8) Lining system
9) Hydrologeology
10) Vegetation

Reinhart and Grosh (1997), also discussed that the characteristics of the leachate produced are highly variable, depending on the composition of the solid waste, precipitation rate, site hydrology, compaction, cover design, waste age, sampling procedures, and interaction of leachate with the environment, and landfill design and operation.

Monika and Andrzej (2008) have shown that high leachate production in relation to the quality of rainfall and its high variation in time. The average quantities of rainfall (QR) and leachate (QL) for each month are presented in Figure 2.

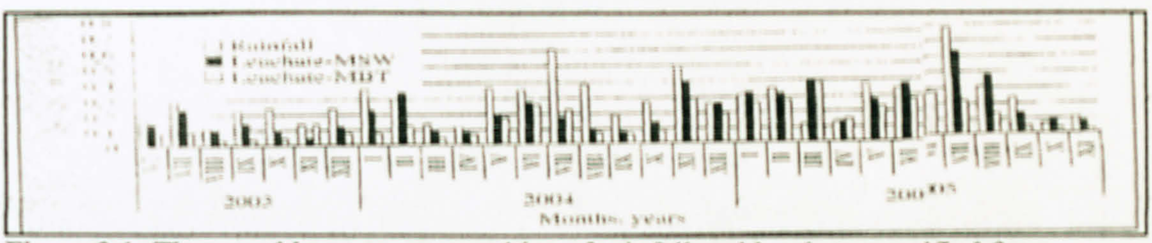


Figure 2.1: The monthly average quantities of rainfall and leachate specified for MSW (Municipal Solid Waste) and MBT (Mechanical Biological Treatment) (Monika and Andrzej, 2008)

The climate for the Perak state is heavy rainfall and warm temperatures appears to produce dilute leachate and it is hard to maintain the leachate concentrations. Bodzek et al. (1994) discussed that the precipitation and climate have the strongest influence on leachate generation, causing the amount to vary during the year. Absorption capacity of wastes is another factor affecting leachate production.

Bodzek et al. (1994) stated that the amount of leachate generated in municipal landfill can be calculated with the following water balance equation:-

$$LP = P - (R + \Delta U + ET + \Delta U_W) \quad (1)$$

Where LP= leachate production, P = precipitation, R = surface runoff, ΔU = changes in soil moisture storage, ET = evaporation from soil/evapotranspiration from a vegetated surface, and ΔU_w = changes in moisture content in wastes.

$$Q = P - R - E \ (mm/m^2) \quad (2)$$

Where Q = amount of leachate, P = mean height of annual precipitation calculated on landfill surface unit, R = surface runoff from landfill surface unit, and E = evaporation as a part of rainfall calculated on landfill surface unit.

There are some parameters used to characterize leachate which are typical by using physical, chemical and biological monitoring parameters.

Table 2.1 : Leachate Sample Parameters Source: (Tchobanoglous, 1993)

Physical	Organic constituents	Inorganics Constituents	Biological
Appearance pH Oxidation-reduction potential Conductivity Color Turbidity Temperature Odor	Organic chemicals Phenols Chemical oxygen demand (COD) Total Organic Carbon (TOC) Volatile acids Tannins, lignins Organic-N Ether soluble (oil and grease) Methylene blue active substance (MBAS) Organicfunctional groups as required Chlorinated hydrocarbons	Suspended solid (SS) Total dissolved solid (TDS) Volatile Suspended Solids(VSS) Volatile Dissolve Solids (VDS) Chloride Sulfate Phosphate Alkalinity and acidity Nitrate- N and Nitrite-N Ammonia- N Sodium Potassium Calcium Magnesium Hardness Heavy metals Arsenic Cyanide Fluoride Selenium	Biochemical Oxygen Demand(BOD) Coliform bacteria (total fecal, fecal streptococci) Standard plate court

(Pohland, 1989) also discussed leachate parameters which according to the value reached, indicate the degree of stabilization reached by the landfill.

Table 2.2: Leachate Indicator Parameters (Pohland, 1989)

Parameter identify	Utility for phase description
Physical	
pH[a]	Acid-base/stabilization phase indicator
ORP[a]	Oxidation-reduction/ stabilization phase indicator
Conductivity	Ionic strength/ activity indicator
Temperature	Reaction indicator
Chemical	
COD[a], TOC, TVA[a]	Substrate indicators
TKN[a], NH3-N[a], PO4-P[a]	Nutrients indicators
SO_4/S[a], NO_3/NH_3	Stabilization phase indicators
TS, choride	Dilution/mobility indicator
Total alkaline earth metals	Buffer capacity indicator
Heavy metals	Toxicity / environmental effects indicators
Biological	
BOD_5	Substrate/biodegradability
Total/ faecal coliforms	Health effect indicators
Faecal streptococci	Health effect indicators
Viruses	Health effect indicators
Pure/enrichment cultures	Stabilization phase indicators

[a] Parameters frequently used for evaluation

2.3 DECOMPOSITION OF LANDFILLED ORGANIC WASTE

Leachate composition has been studied in numerous components. It is because leachate is the main concern in sanitary landfill management in last twenty year. It is known that leachate from sanitary landfill is the source of groundwater contaminations. Variations in leachate composition are depending on the chemical, physical and biological factors.

2.3.1 Biochemical Process In Sanitary Landfill

There are three categories mechanisms which regulated mass transfer from wastes to leaching water which are:

a) Hydrolysis of solid waste and biological degradation

b) Solubilization of soluble salts contained in the waste

c) Dragging of particular matter

2.3.1.1 Aerobic Degradation Phases

According Barber (1979) in initial stage (stage 1), the organic wastes decompose aerobically. The production of carbon dioxide (CO2), water, nitrates and sulphates, typical catabolites of all aerobic processes from degradation of amino acids. The aerobic degradation happened due to the high oxygen demand of waste relative to the limited quantity of oxygen present inside the landfill. The waste temperature also rises due to the exothermicity of biological oxicidation.

Christensen and Kjeldsen (1989) also discussed that the refractory organic carbon remained in the landfilled wastes, aerobic phase will appear second time in the upper layer of the landfill. In this stage (Phase V) the rate of production methane is low. Thus the air will start diffusing from atmosphere, make rise to the aerobic zones for methane formation.

2.3.1.2 Anaerobic Degradation Phases

Christensen and Kjeldsen (1989) discussed that there are three different phases anaerobic decomposition of waste. The acid fermentation which is Phase II caused decrease in pH, high concentrations of volatile acids and considerable concentration of inorganic ions. The decrease in pH is caused by the high production of volatile fatty acids and the high partial pressure of CO_2.

Stegmann and Spendlin (1989) discussed that in second phase (Phase III) slow growth of methanogenic bacteria is started. This growth may affect an excess of organic volatile acids which are toxic to methanogenic bacteria. The methane concentration in the gas increases, carbon dioxide and volatile fatty acids decreased.

In third stage (Phase IV) anaerobic degradation is characterized by methanogenic fermentation. The pH range ranges from 6 to 8. The composition of leachate almost neutral pH values, volatile acids in low concentration, and total dissolved solids whilst present of biogass which is methane.

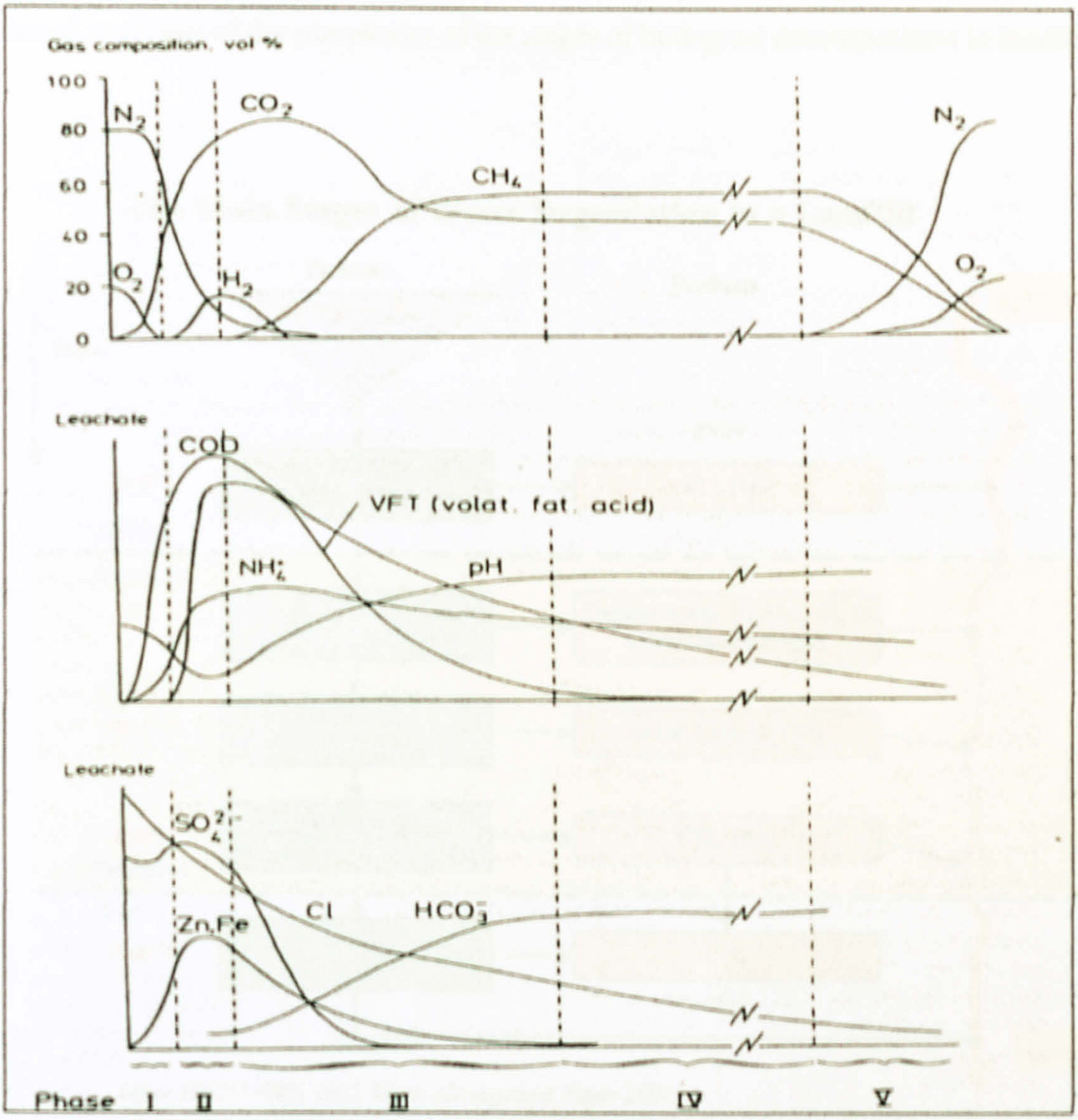


Figure 2.2: Illustration of developments in leachate and gas in a landfill cell (Christensen & Kjeldsen, 1989)

The process of the leachate composition can be seen in. The diagram below provided a broad overview of the complexity of the stages of biological decomposition in landfill.

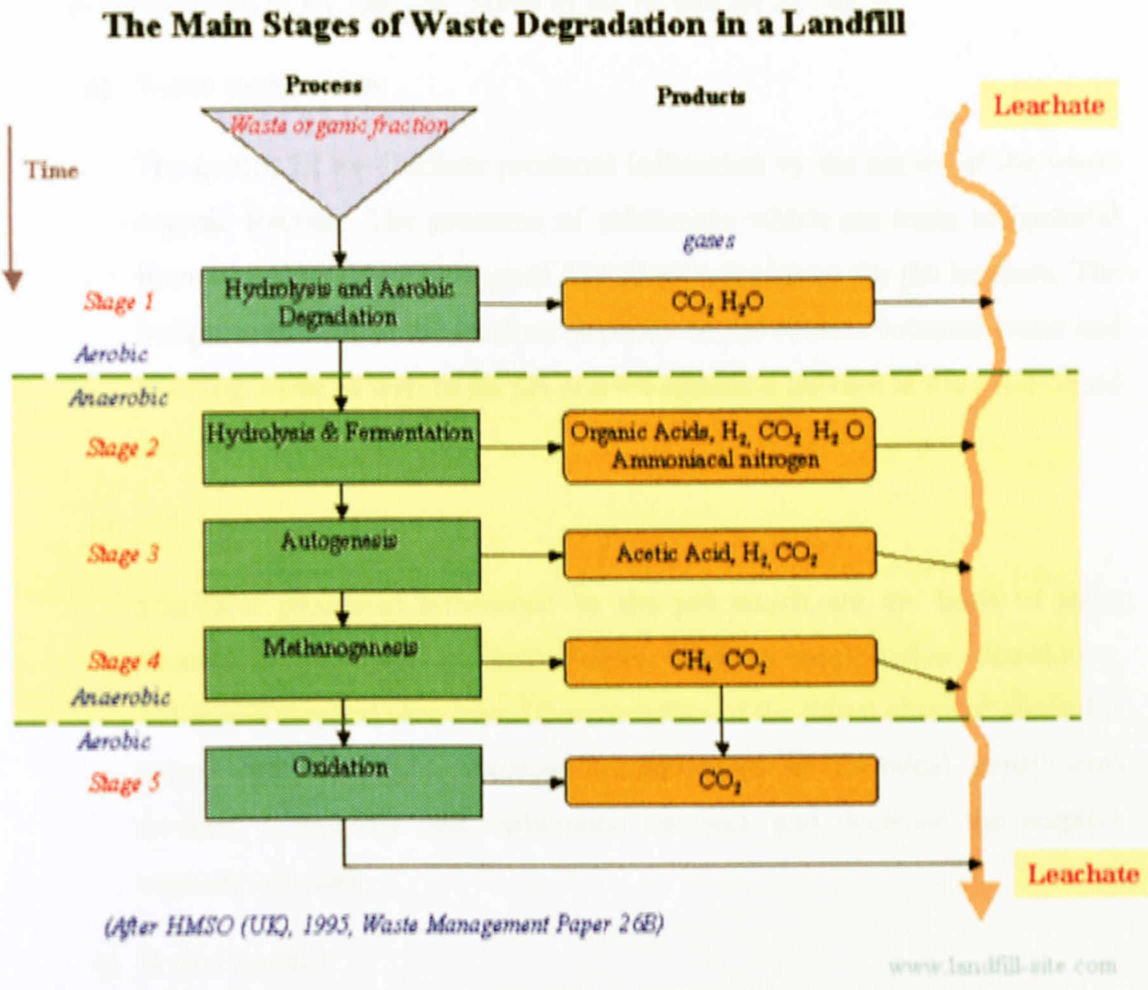


Figure 2.3: The main stages of waste degradation in a landfill

(http://www.landfill-site.com/html/waste_decomposition.html)

2.3.2 CHEMICAL COMPOSITION OF LEACHATE

2.3.2.1 Factors Affecting Leachate Composition

According Andreottola and Cannas 1992, there are some factors which effected the chemical composition of the leachate. Some of the factors are as follow:

a) Waste composition

The quality of the leachate produced influenced by the nature of the waste organic fraction. The presence of substances which are toxic to bacterial flora may slow down biological degradation processes for the leachate. The inorganic content of the leachate depends on the contact between waste and leaching water as well as on pH and the chemical balance at the solid-liquid interface.

b) pH

Chemical processed influenced by the pH which are the basis of mass transfer in the waste leachate system, such as precipitation, dissolution, redox and sorption reactions. Characteristics of the initial phase of anaerobic degradation of waste, increase solubilization of chemical constituents (oxides, hydroxides and carbonated species), and decrease the sorptive capacity of waste.

c) Redox landfill

Reducing condition, which are corresponding to second and third phases of anaerobic degradation, influenced solubility of nutrients and metals in leachate.

d) Landfill age

Landfill age result in variation of leachate composition and in quantity of pollutants removed from waste. Leachate characteristic governed by the type of waste stabilization process can be determined but landfill age is important.

2.4 VARIATION IN LEACHATE COMPOSITION

Composition of leachate depends on the age of landfill and the time of sampling. If the sampling is collected during the acid phase of decomposition, the value for pH will be low and the value for concentrations of BOD5, TOC, COD, nutrients, and heavy metals will be high. The pH of leachate is not only depending on the concentrations of the acid present, but the partial pressure of the CO_2 in the landfill gas that is in contact with the leachate is also important.

The biodegradability of the leachate varies with the time. By checking the BOD5/COD ratio, the changes in the biodegradability of the leachate can be monitored. In matured landfill, the BOD5/COD ratio is often in the range of 0.05 to 0.2. The ratio drops because leachate from mature landfills typically contains humic and fulvic acids, which are not readily biodegradable (Tchobanoglos, 1993)

According Reinhart and Grosh (1997), because of the variability in leachate quality, prediction of leachate characteristics as a function of time has been quite difficult. General trends in quality are possible, however these ranges are still large and prediction of the point in time at which each phase begins and ends is not possible as of yet.

As a result in variation of the leachate, the treatment systems will have different design for the new landfill and the mature landfill. The problem arises when analytical result interpretation is complicated because the leachate comes from the solid waste of different ages. Lu et al. (1984) develop a relationship between landfill age and various constituents in leachate. The data of BOD, COD, TOC, total alkalinity, calcium, potassium, sodium, sulfate and chloride are shown in Figure

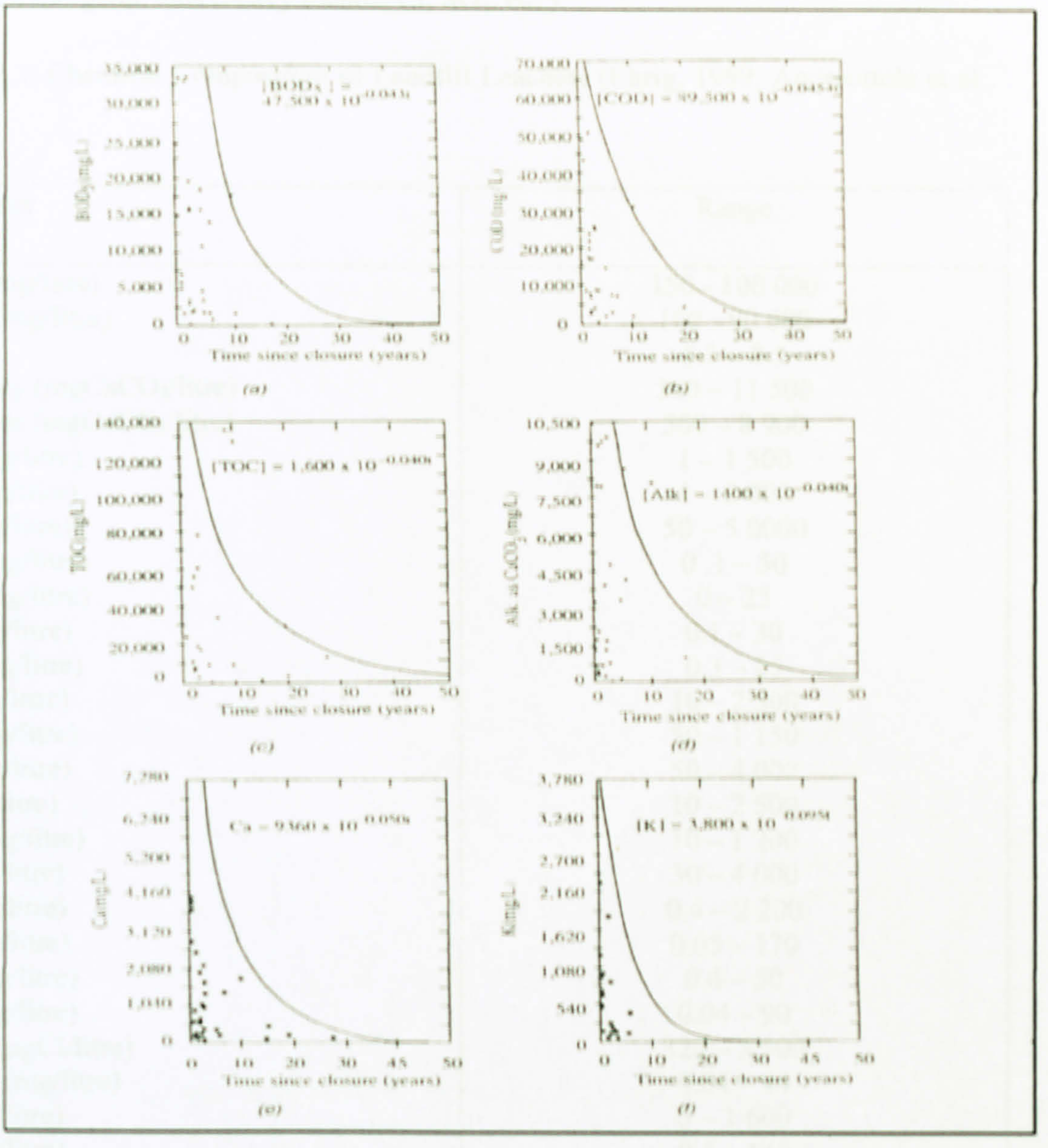


Figure 2.4: Relationship between landfill age and leachate composition: a) BOD, b)COD, c) TOC, d) alkalinity, e) calcium and f) potassium (Lu et al. 1984)

This table below shows the chemical composition of landfill leachate. The table shows the mains indicators of organic pollution (COD, BOD,TOC), microbiological population and main inorganic ions (heavy metals, Cl, SO_4, etc.).

Table 2.3: Chemical Composition of Landfill Leachate (Ehrig, 1989; Andreottola et al., 1990)

Parameter	Range
COD (mg/litre)	150 - 100 000
BOD_5 (mg/litre)	100 - 90 000
pH	5.3 – 8.5
Akalinity ($mgCaCO_3$/litre)	300 – 11 500
Hardness ($mgCaCO_3$/litre)	500 – 8 900
NH_4(mg/litre)	1 – 1 500
N_{org}(mg/litre)	1 – 2 000
N_{tot}(mg/litre)	50 – 5 0000
NO_3 (mg/litre)	0 .1 – 50
NO_2 (mg/litre)	0 – 25
P_{tot} (mg/litre)	0.1 – 30
PO_4 (mg/litre)	0.3 – 25
Ca (mg/litre)	10 – 2 500
Mg (mg/litre)	50 – 1 150
Na (mg/litre)	50 – 4 000
K (mg/litre)	10 – 2 500
SO_4 (mg/litre)	10 – 1 200
Cl (mg/litre)	30 – 4 000
Fe (mg/litre)	0.4 – 2 200
Zn (mg/litre)	0.05 – 170
Mn (mg/litre)	0.4 – 50
CN (mg/litre)	0.04 – 90
AOX[a] (µgCl/litre)	320 – 3 500
Phenol (mg/litre)	0.04 – 44
As (µg/litre)	5 – 1 600
Cd (µg/litre)	0.5 – 140
Co (µg/litre)	4 – 950
Ni (µg/litre)	20 – 2 050
Pb (µg/litre)	8 – 1020
Cr (µg/litre)	30 – 1 600
Cu (µg/litre)	4 – 1 400
Hg (µg/litre)	0.2 - 50

[a] Adsorbable organic halogen

According to Millot and Courant (1992) studied two leachate samples from different landfill which are Villeparisis and Val Saint Germain located near Paris. Two leachates were sampled in the retention basins which receive the leachates collected by the drainage systems. The results of chemical analysis of these leachates are presented in Table 2.4.

Table 2.4: Analysis of the Leachates at the Val Saint Germain Landfill and the Villeparisis Landfill

Parameters	Val Saint Germaint	Villeparisis
pH	6.8	7.2
Conductivity	12 000	25 000
COD	20 000	5 600
BOD	8 500	2 100
TOC	6 600	1 900
TKN	1 300	950
N.NH4	1 180	910
N.NOX	0.1	0.1
P.tot	1.2	1.0
Chloride	1 800	4 900
Acetic acid	3 950	1 280
Propionic acid	2 600	780
Butyric acid	2 950	860
Valeric acid	1 850	360
Iron	530	72
Zinc	22	8
Manganese	25	6

All parameters in mg/litre except pH (pH unit) ad conductivity (µS/cm).

He added that the results indicated a high organic load with BOD/COD ratio of about 0.4. The high biodegradable organic content may be explained by the high concentration of fatty acids which represents a theoretical TOC of about 85% of the measured TOC. The Total Kjeldahl Nitrogen content is high for the two leachates and is mainly represented by ammonia nitrogen. The heavy metal content consists primarily of iron.

2.5 LEACHATE COMPOSITION

Studied and researched have been done by various universities and institutions such as Indian Institute of Technology Delhi and University of Antwerp, Belgium. Based on the results of the leachate taken from Gazipur Landfill site, the leachate has significant impact on groundwater quality near the area of site. The groundwater quality will be better when the sample taken from the deeper and further from the pollution source. (Mor, et al., 2003)

The paper report also done by Faculty of Urban Construction and Environmental Engineering, Chongqing University, China, the results of a laboratory scale investigation aimed at evaluating the effectiveness of mature municipal landfill leachate treatment by a biological stage. The monitored samples taken from the Chan Sheng bridge landfill site in Chongqing City, China has its concentrations of COD, BOD5 and NH3-N about 1650, 75 and 1 100 mgL^{-1} respectively (Tengrui et al., 2007)

Basically, three phases of decomposition are distinguished for domestic landfills occurring within twenty years, as shown in Table 5.

Table 2.5: Leachate Classification (Tengrui et al., 2007)

Leachate type	Young	Intermediate	Stabilized
Landfill age yr	<5	5-10	>10
pH	<6.5	7	>7.5
COD gL^{-1}	>20	13-15	<2
BOD/COD	>0.3	0.1-0.3	<0.1
TOC/COD	0.3	-	0.4
Organic matter	70 -90 % VFA	20-30 % VFA	HMW
Nitrogen	100 – 2000 mgL-1		
Metal gL^{-1}	TKN 2	<2	<2

According Bodzek et al. (1994), when landfill is less than 3-5 years old, there are many organic compounds in the leachate that result from the first acidogenic phase of anaerobic waste decomposition. In this case, both COD (Chemical Oxygen Demand)

and BOD_5 reach very high concentrations and pH is low due to the considerable amounts of volatile fatty acids produced in this phase.The BOD5/COD ratio reaches values possibly higher than 0.7, due to high biodegradability of organic compounds contained in such a leachate. With the biodegradation process it is noted that the above mentioned parameters habe undergone changes.

The typical composition of the three landfill leachate at ages 1, 5 and 16 years are provided in Table 2.6 by Chian and DeWalle 1976 and 1977a. Keenan et al. (1983) worked also can be refer in Table 7 provided the average composition of leachate collected each year over a period of four years. However Tchobanoglous et al. (1993), in Table 8 based on the results of many studies, developed leachate characteristics data for 2 and 10 year old landfills.

Table 2.6: Composition of Ladfill Leachate (Chian and DeWalle 1976, 1977a)

	Age of Landfill		
Parameters	1 Year	5 Year	12 Year
BOD	7 500 – 28 000	4 000	80
COD	10 000 – 40 000	8 000	400
pH	5.2 – 6.4	6.3	
TDS	10 000 – 14 000	6 794	1 200
TSS	100 – 700		
Specific	600 – 9 000	-	
Conductance	800 – 4 000	5 810	2 250
Alkalinity (CaCO3)	3 500 – 5 000	2 200	540
Hardness	25 – 35	12	8
Total P	23 – 33	-	
Ortho P	56 – 482		
NH4-N	0.2 – 0.8	0.5	1.6
Nitrate	900 – 1 700	308	109
Calcium	600 – 800	1 330	70
Chloride	450 – 500	810	34
Sodium	295 – 310	610	39
Potassium	400 – 650	2	2
Sulfate	75 – 125	0.06	0.06
Manganese	160 – 250	450	90
Magnesium	210 – 325	6.3	0.6
Iron	10 – 30	0.4	0.1
Zinc	-	<0.5	<0.5
Copper	-	<0.05	<0.05
Cadmium	-	0.5	1.0
Lead			

Table 2.7: Landfill Leachate Characteristics over Four Year Period (Keenan et al., 1983)

Item	Year 1	Year 2	Year 3	Overall
BOD	4 460	13 000	11 359	10 907
COD	11 210	20 032	21 836	18 533
TSS	1 994	549	1 730	1 044
Dissolved	11 190	14 154	13 181	13 029
Solids	7.1	6.6	7.3	6.9
pH	5 6885	5 620	4 830	5 404
Alkalinity	5 116	4 986	3 135	4 652
(CaCO3)	651	894	725	818
Hardness	652	454	250	453
(CaCO3)	2.8	2.6	3.0	2.7
Calcium	1 966	724	883	1 001
Magnesium	1 660	760	611	984
Phosphate	114	683	428	462
Ammonia-N	4 816	4 395	3 101	4 240
Kjedahl-N	1 177	1 386	1 457	1 354
Sulfate	969	950	968	961
Chloride	0.04	0.09	0.10	0.09
Sodium	0.16	0.43	0.22	0.28
Potassium	0.44	0.39	0.32	0.39
Cadmium	245	378	176	312
Chromium	0.53	1.98	1.27	1.55
Copper	0.52	0.81	0.45	0.67
Iron	8.70	31	11	21
Nickel	0.007	0.005	0.011	0.007
Lead				
Zinc				
Mercury				

Note: All values in mg/L except pH

Table 2.8: Typical Data on the Composition of Leachate from New and Mature Landfills (Tchobanoglous,et al. 1993)

Constituent	Value, mg/L[a]		
	New landfill (less than 2 years)		Mature landfill (greater than 10 years)
	Range[b]	Typical[c]	Range[b]
BOD5	2 000 – 30	10 000	100 – 200
TOC	000	6 000	80 – 160
COD	1 500 – 20	18 000	100 – 500
Total Suspended Solids	000	500	100 - 400
Organic nitrogen	3 000 – 60	200	80 – 120
Ammonia nitrogen	000	200	20 – 40
Nitrate	200 – 2 000	25	5 – 10
Total Phosphorus	10 -800	30	5 – 10
Ortho Phosphorus	10 -800	20	4 – 8
Alkalinity as CaCO3	5 – 40	3 000	200 – 1 000
pH	5 – 100	6	6.6 – 7.5
Total hardness as	4 – 80	3 500	200 – 500
CaCO3	1 000 – 10	1 000	100 – 400
Calcium	000	250	50 – 200
Magnesium	4.5 – 7.5	300	50 – 400
Potassium	300 – 10 000	500	100 – 200
Sodium	200 – 3 000	500	100 – 400
Chloride	50 – 1 500	300	20 – 50
Sulfate	200 – 1 000	60	20 - 200
Total iron	200 – 2 500		
	200 – 3 000		
	50 – 1 000		
	50 – 1 200		

[a] Except pH, which has no units

[b] Representative range of values. Higher maximum values have been reported in the literature for some of the constituents

[c] Typical values for new landfills will vary with the metabolic state of landfill

2.6 LEACHATE TREATMENT BY ACTIVATED CARBON ADSORPTION

According Song et. al (2009) , the wastewater treatment industry has identified that organic, inorganic and heavy metals compound emitted due to leachate seepage into the waterways as a risk to the natural environments. Thus, a wide range of new tertiary treatment has been abounded. Kurniawan and Uygur et. al mentioned the work has focused on the enhanced coagulation-flocculation, clarification and biological processes such as aerated lagoons, activated sludge, anaraerobic filters, stabilization ponds, upflow anaerobic sludge blanket as plausible circumstances for leachate treatment because of its realiability, simplicity, high-cost effectiveness, reduction of stabilization time and acceleration of biogass production.

Qasim et. al stated that a large variety of organic solutes, and a more limited number of inorganic solutes can be removed from aqueous waste stream by adsorption onto activated carbon. Activated carbon has a high adsorptive surface area (500-1500 m^2/g). It is used as powdered activated carbon (PAC) or as a granular activated carbon (GAC) bed.

According Foo et. al (2009) in most cases, activated carbon adsorption has revealed the prominence in removal an essential amount of organic compounds and ammonium nitrogen from the leachate samples.

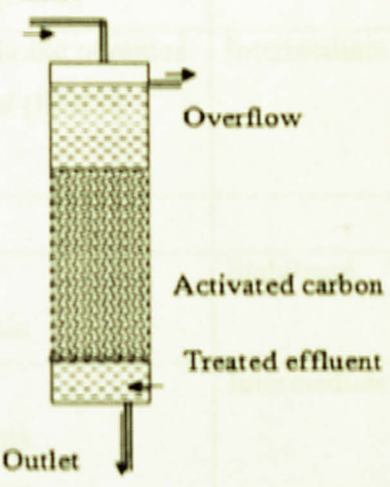


Figure 2.5: Experimental set up of activated carbon column of the leachate treatment

In Malaysia, Aziz et al. (2004) has carried out a comparative study for the removal of ammonium nitrogen using granular activated carbons and limestone in Burung Island landfill. Approxilamtely 40% of ammonium nitrogen with an initial concentration of 1909 mg/L was eliminated with 42 g/L of GAC while 19% removal was achieved using 56 g/L of limestone under the same concentration.

Table 2.9: List of researches for the landfill leachate treatment via activated carbon (Foo et. al, 2009)

Activated carbon type/ precursor	Adsorbate	Leachate type	Maximum adsorption capacity (mg/g)	Percentage removal (%)
Desotec	Adsorbate organic Halogen (AOXs) COD	Stabalized	0.59 268	
Norit SA 4	COD	Intermediate	-	38
Commercial PAC	COD Ammonia	Synthetic	-	87 16
DARCO	COD Dissolved organic carbon (DOC)	Stabilized	-	38 40
Commercial PAC	Hydrophobic organics chemical (HOCs) COD	Intermediate	-	89.2 24.6
Commercial GAC	HOC			73.4
GAC (type PHO 8/35 LBD)	COD Ammonia	Stabilized	165.46 53.58	60 95
Commercial PAC	COD Ammonia Phosphate	Intermediate	-	75 44 44

Oil Palm Shell	COD	Stabilized	1460	50
Norit 0.8	COD	Intermediate	0.253	68
Chemviro AQ40			0.258	55
Picacarb 1240			0.148	48
Commercial GAC	Benzene Trichloroethylene 1,2-dicholoroethane	Synthetic	0.23 0.54 0.48	-
Carbotech	COD	Intermediate	0.250	75
GAC 40	COD	Stabilized	38.12	-
Commercial PAC	COD Ammonia	Intermediate	-	49 16
Commercial PAC	COD	Stabilized	4300	38
Commercial PAC	DOC	Stabilized	50.00	-
CalgonFiltrasorb 400	COD	Stabilized	564	70
Commercial PAC	COD Ammonia Colour	Young	-	49 78 50
Rice Husk	COD Colour	Young	-	70 60
Norit 0.8	COD	Stabilized	88.80	90
Commercial PAC	COD	Stabilized	6.5	-

2.6.1 Adsorption of leachates on activated carbon

Rivas et al. (2005) stated that among tertiary treatments, adsorption onto activated carbon (AC) has been reported as one of the most effective methods to remove high molecular weight compound (present in stabilized leachates) from aqueous matrix. The investigation has been carried out using several isotherm equations to adequately correlate the experimental data.

2.6.2 Adsorption Theory

Rivals et. al (2005) has testing several isotherm models to find the best fit of the experimental data and also considered the additional information derived from the estimated parameter (i.e. sorption nature, energy calculations, surface heterogeneity, etc). Thus, the following models were adopted:

1) Freundlich isotherm (FR)

$$Q_e = K_f C_e^{1/n} \qquad (3)$$

2)Langmuir isotherm (LG)

$$Q_e = \frac{Q_m b C_e}{1 + bC_e} \qquad (4)$$

3) Redlich- Peterson isotherm (RD):

$$Q_e = \frac{a_R \beta_R C_e}{1+\beta_R C_e^{\gamma}} \qquad (5)$$

4) Temkin isotherm (TM)

$$Q_e = A(T) \ln [B_T C_e] \qquad (6)$$

5) Dubinin – Radushkevich isotherm (DR)

$$Qe = \Phi D \exp\{-\Psi D(\ln (1 + \frac{1}{Ce})^2\} \qquad (7)$$

6) Toth isotherm (TH) :

$$Q_e = \frac{\delta_T C_e}{(a + C_e)^{\lambda}} \qquad (8)$$

7) Sips isotherm (SP)

$$Q_e = \frac{Q_s\,(\omega_s C_e)^{\xi}}{1 + (\omega_S C_e)^{\xi}} \qquad (9)$$

According to Ho et al. (2002), each model differs in the thermodynamic or empirical base behind its determination and each one present its own set of advantages and inconveniences. From the equations, Qe and Ce stand for the values of the measured parameter (i.e. COD, TC or ansorbance) in the solid per mass unit of absorbent and the remaining concentration of the aforementioned parameters in the liquid after equilibrium condition are attained.

Slejko and Frank (1985) give the relationship between q and C_e in the following graph in accordance with Freundlich and Langmuir models. The linear adsorption curve as figure 6 below:

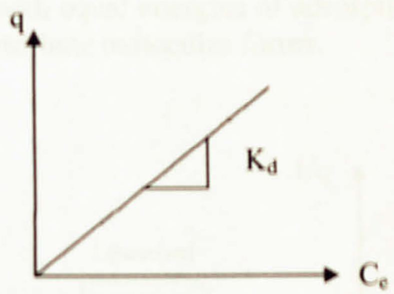
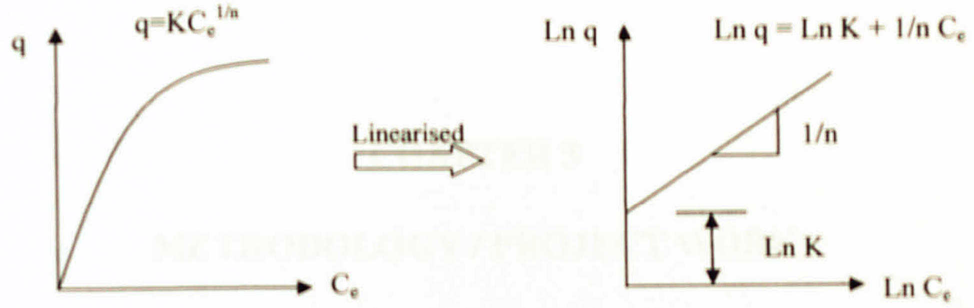


Figure 2.6 : Linear graph of adsorption

2.6.2.1 Freundlich Isotherm

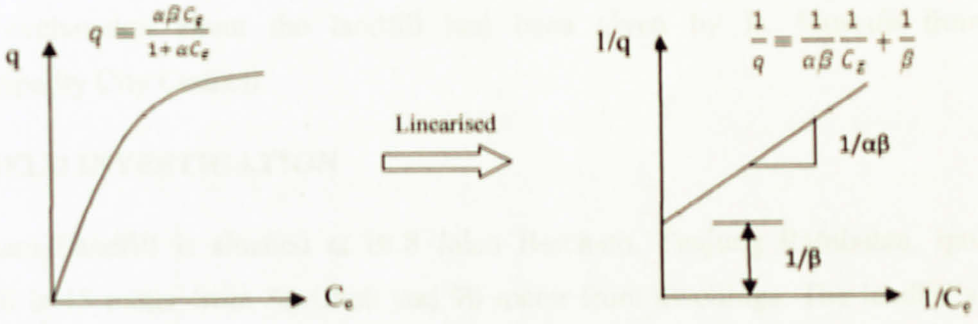
Walker and Weatherley (2000) assume that the adsorbate has a heterogeneous surface with adsorption sites that have different energies of adsorption and which are not always available. The equation can be described as follows:



Where ,
K = Freundlich constant
n = empirical constant related to adsorption capacity and intensity
q = the amount of solute adsorbed per unit weight of adsorbent at equilibrium (mg/kg)
C_e = residual liquid phase concentration at equilibrium (mg/L)

2.6.2.2 Langmuir Isotherm

Walker and Weatherley (2000) assumed that Langmuir isotherm is based on the adsorption on homogeneous surface, i.e., the surface consist of identical sites, equally available for adsorption and with equal energies of adsorption, and that the adsorbent is saturated after one layer of adsorbate molecules forms.



Where,
α = adsorption constant related to binding energy of the affinity parameter (l/mg)
β = maximum amount of solute that can be adsorp by granular activated carbon (mg/kg)
q = the amount of solute adsorbed per unit weight of adsorbent (mg/kg)
C_e = residual liquid phase concentration at equilibrium (mg/L)

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 RESEARCH AND INFORMATION GATHER

The research work has been done continuously for the whole year in order to have a better understanding of the project.

3.2 SITE VISIT

Site visit was made at Bercham Landfill, Ipoh on 4th February 2009 in order to know the location and place of the landfill. The site visit was accompanied by the engineer from Ipoh Municipality Council, Ir. Mustafa Al Bashree, the person who is responsible for this landfill.

During the site visit, the direction of leachate flows and ponds have been identified and brief explanation about the landfill had been given by Ir. Mustafa from Ipoh Municipality City Council.

3.3 FIELD INVESTIGATION

Bercham Landfill is situated at Bt.8 Jalan Bercham, Tanjung Rambutan, Ipoh. The landfill is 15 meter from Sg Choh and 90 meter from dwellings. The landfill's age is about 22 year old and it was originated from a mining lake. Field investigation was out to observe the landfill location and operations. At Bercham Landfill, there are two huge leachate pond located near new landfill. The leachate from new and old landfill flows to the leachate pond via earth drain.

3.4 INSTALLATION MONITORING WELL

Three monitoring well was installed on the top of the landfill. The monitoring well have different depth namely 6m , 9m and 12m. Leachate samples were collected from Bercham Landfill on 14 August 2009. Sample was collected, transported to the laboratory and stored at 4 °C.

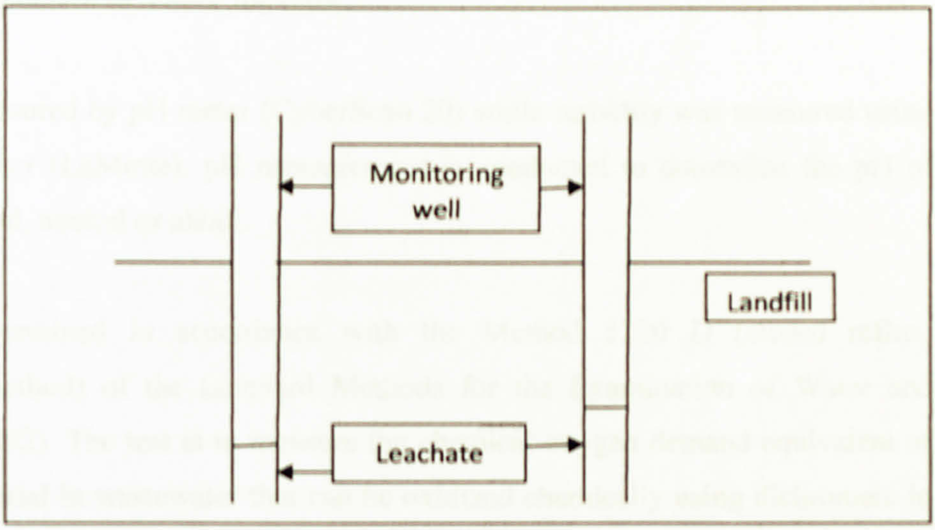


Figure 3.7: Monitoring well diagram

3.5 ANALYSIS OF SAMPLE

After sampling, leachate was analyzed for some tests according to the Standard Methods for the Examination of Water and Wastewater (1992). Leachate samples were removed from the refrigerator and were placed for about 2 hours at about 22°C for conditioning. Samples were thoroughly agitated for re-suspension of possible settling solids before any test was conducted. The physico-chemical parameters are carried out for the following test:-

a) BOD
b) COD
c) TOC
d) Nitrogen
e) pH

f) Turbidity
g) Color
h) Ammonia
i) Total Phosphorus

Samples were withdrawn using plastic syringe from the point located about 2 cm below the liquid level for the determination of color, COD, and turbidity. Analyses were undertaken in triplicates to reduce the error.

The pH was measured by pH meter (CyberScan 20) while turbidity was measured using 2020 Turbidimeter (LaMotte). pH measurement is conducted to determine the pH of sample either acid, neutral or alkali.

COD were determined in accordance with the Method 5220 D (closed reflux, colourimetric method) of the Standard Methods for the Examination of Water and Wasterwater (1992). The test is to measure the chemical oxygen demand equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution. Chemical Oxygen Demand (COD) is widely used to characterize the organic strength of wastewater and pollution of natural waters. It is the amount of oxygen that is required to oxidize an organic compound (biodegradable and non-biodegradable) to CO_2 and water under the influence of a strong oxidant ($K_2Cr_2O_7$) in an acid environment (Silver nitrate used as a catalyst). Compared to the BOD test, the major advantage of this test is that it requires a shorter time which is approximately 3 hours.

Colour measurements were reported as true colour (filtered using 0.45 μm filter paper) assayed at 455 nm using DR 2000 HACH spectrometer following Standard Method for the Examination of Water and Wastewater (1992), Method No. 2120C reported in Platinum-cobalt (PtCo), the unit of colour being produced by 1 mg platinum/l . This gives "true color" value.

Inorganic constitution which is ammonia was determined in accordance with the Method 8038 (Nessler Method) using DR 2000 HACH spectrophometer following Standard Methods for the Examination of Water and Wastewater (1992). The low-level ammonia nitrogen may be present in water naturally as a result of the biological decay of plant and animal matter. Ammonia concentrations are determined by direct Nesslerization. In some waters, calcium and magnesium concentrations can cause cloudiness of the reagent. Adding a few drops of mineral stabilizer solution will prevent this cloudiness. Results are expressed as ppm (mg/L) $NH_3 - N$.

Total Phosphorus in the sample was determined in accordance with the Method 8190 usind DR 2000 HACH spectrometer following Standard methods for the Examination of Water and Wastewater (1992). Total phosphorus is a measure of all the various forms of phosphorus that are found in a water sample. Phosphorus is an element that, in its different forms, stimulates the growth of aquatic plants and algae in water bodies.

3.6 ADSORPTION TEST

Adsorption batch experiment was conducted with 100ml landfill leachate in flask. Each flask was added with different predetermined amount of granular activate carbon (GAC). The amount of GAC used for this study varied from 0.2 g to 4.0 g. The initial concentration (C_o) from each of conical flask was determined. These sealed flasks were put in a shaker for 24 hours with the state of agitator 150 rpm. The samples were filtered to get COD and TOC concentration (C_e) in the supertants using the standard method for the examination of water and wastewater.

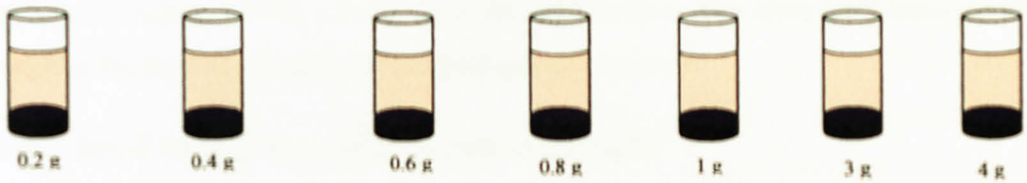


Figure 3.8 : Adsorption batch experiment for activated carbon

The results were presented in the table as follows and graph in linear curve will be plotted. The graphs will be analyzed using Freundlich and Langmuir Isotherm.

Co (mg/L)	Ce (mg/L)	V (mL)	M (g)	q (mg/kg)	ln q	ln Ce	1/q	1/Ce

Absorbed amount (q) calculated using formula :

$$q = (C_O - C_e)\frac{V}{M}$$

The linearised of the Freundlich and Langmuir Isotherm as follow:

$$Ln\, q = Ln\, K + 1/n\, C_e$$

$$\frac{1}{q} = \frac{1}{\alpha\beta}\frac{1}{C_E} + \frac{1}{\beta}$$

All the constants and variables were determined and calculated step by steps to obtain the result.

CHAPTER 4

RESULT AND DISCUSSION

4.1 LEACHATE QUALITY

The results for leachate quality are shown in the table below. The tests have been carried out in terms of biological, physical and chemicals parameters.

Table 4.10 : Result for leachate quality at Bercham landfill

Tests	Results	Standard A	Standard B
pH	7.3 – 8.02	6.0 – 9.0	5.5 – 9.0
Colour (Pt. Co)	325 – 453	-	-
Turbidity	139 – 278	-	-
COD (mg/L COD)	2110 -3250	50	100
TOC (mg/L)	3224 – 4568	-	-
BOD_5 (mg/L)	190 – 473	20	50
Nitrate (mg/L NO_2^-)	15 – 17	-	-
Total Phosphorus(mg/L PO_4^{3-})	130 – 137	-	-
Ammonia (mg/L NH_3-N)	1575 – 1970	-	-
Total Suspended Solid (TSS)	0.007 – 0.036	50	100
TOC/COD	>1.52	-	-
BOD_5/COD	>0.09	-	-

From the table above, the pH of the leachate varied widely within the range of 7.30 – 8.02. Leachate is alkaline in nature, heavy rainfall may also influence in maintaining the concentration of the leachate. The near neutral pH of leachate sample is also reasonably consistent with the literature which suggests that natural buffered leachate pH.

Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The characteristics of the leachate collected in Bercham landfill site has been presented in Table 10 above.

The presence of average value of BOD_5 (190 - 473 mg/L) and COD (2110 – 3250 mg/L) indicates the high organic strength. Among the nitrogenous compound, ammonia nitrogen (1575 -1970 mg/L) was present in high cocncentration, this is probably due to the deamination of amino acids during the decomposition of organic compounds (Tatsi and Zouboulis, 2002). Moreover, the value for total phosphorus and nitrate are 130 – 137 mg/L and 15 – 17 mg/L respectively. The value is low and indicates neither nitrification occurred.

The value for TOC/COD is more than 1.52 and value for BOD_5/COD is more than 0.09. According to Tengrui et al, 2007 the value indicates that the leachate is in intermediate stage.

The physical parameter such as turbidity and color give the high value. The value for color is 325 – 453 Pt.Co and the value for turbidity is 139 – 278 ntu. The physical parameter indicates that the leachate is brown in color.

4.2 ADSORPTION BATCH EXPERIMENT

The results of COD and TOC from the experiment are shown in Table 11 and Table 12 below: The constant and unknown are calculated using the equations for Freundlich Isotherm and Langmuir Isotherm.

Co (mg/L)	Ce (mg/L)	V (mL)	M (g)	q (mg/kg)	ln q	ln Ce	1/q	1/Ce	% Removal
2270	1560	100	0.2	3.55E5	12.77987307	7.3524411	2.8E-6	6.4E-4	31.27
2270	1430	100	0.4	2.1E5	12.25486281	7.265429723	4.8E-6	7.0E-4	37.00
2270	1300	100	0.6	161667	11.99329188	7.170119543	6.2E-6	7.7E-4	42.70
2270	1270	100	0.8	12.5E3	11.73606902	7.146772179	8.0E-6	7.9E-4	44.05
2270	1130	100	1	11.4E3	11.64395373	7.029972912	8.8E-6	8.8E-4	50.20
2270	810	100	3	48667	10.79274961	6.697034248	2.05E-5	1.23E-3	64.30
2270	630	100	4	41000	10.62132735	6.445719819	2.44E-5	1.59E-3	72.24

Table 4.11: COD data for Freundlinch and Langmuir isotherm

Co (mg/L)	Ce (mg/L)	V (mL)	M (g)	q (mg/kg)	ln q	ln Ce	1/q	1/Ce	% Removal
3607	3245	100	0.2	181000	12.10625231	8.084870629	5.5E-6	3.1E-4	10
3607	3015	100	0.4	148000	11.90496755	8.011355109	6.8E-6	3.3E-4	16.4
3607	2902	100	0.6	117500	11.67419361	7.973155433	8.5E-6	3.4E-4	19.55
3607	2850	100	0.8	94625	11.45767699	7.955074273	1.06E-5	3.5E-4	21
3607	2734	100	1	87300	11.37710574	7.913521017	1.15E-5	3.7E-4	24.2
3607	2477	100	3	37667	10.53653081	7.814803429	2.65E-5	4.0E-4	31.33
3607	2227	100	4	34500	10.4487146	7.708410667	2.9E-5	4.5E-4	38.3

Table 4.12: TOC data for Freundlinch and Langmuir Isotherm

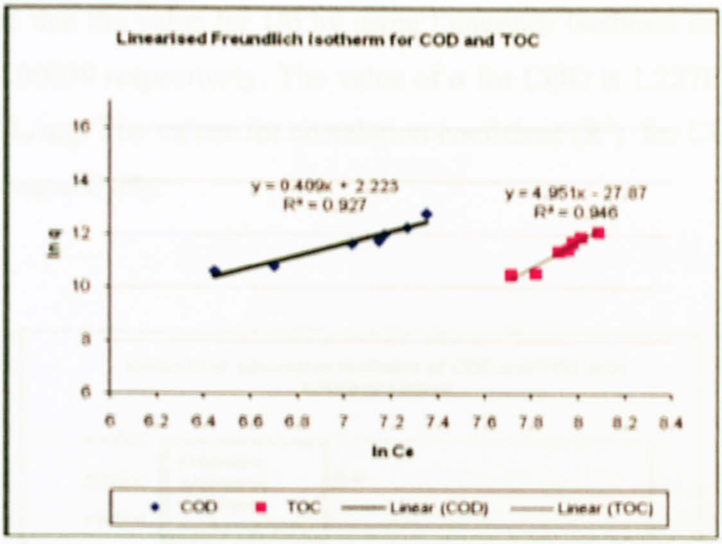


Figure 4.9 : Linearised Freundlinch Isotherm for COD and TOC

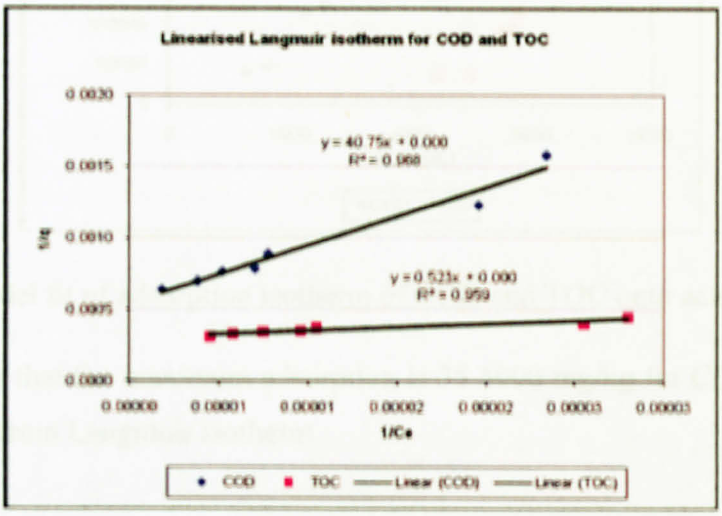


Figure 4.10 : Linearised Langmuir Isotherm for COD and TOC

Figure49 showed that the value of ln K for COD adsorption is 2.223 and -27.87 for TOC adsorption according Freundlich Isotherm. So, K are 9.234 mg/kg and 0.0078 mg/kg for COD and TOC respectively. However, the value for n which is empirical constant related to adsorption capacity and intensity for COD is 2.444 and for TOC is 0.202. The correlation coeficient (R^2)for COD and TOC are 0.927 and 0.946 respectively.

Figure 4.10 showed that the value for 1/β by using Langmuir Isotherm for COD and TOC are 0.0005 and 0.00039 respectively. The value of α for COD is 1.227E-5 L/mg and for TOC is 7.54E-4 L/mg. The values for correlation coeficient (R^2) for COD and TOC are 0.968 and 0.959 respectively.

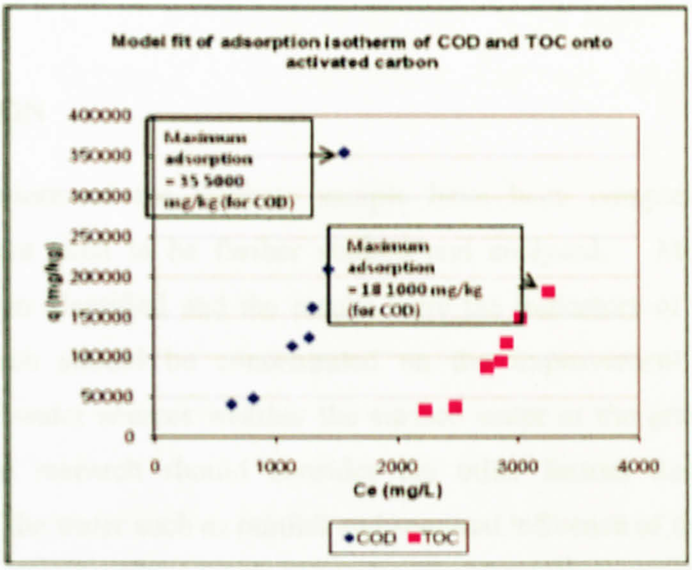


Figure 4.11: Model fit of adsorption isotherm of COD and TOC onto activated carbon

Figure 4.11 shows that the maximum adsorption is 35 5000 mg/kg for COD and 18 1000 mg/kg for TOC from Langmuir isotherm.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The characterizations of the leachate sample have been completed. The leachate proposed treatment need to be further studied and analysed. Methods of test the leachate have been identified and the results were the indicators of the quality of the leachate.. Research should be concentrated on the improvement of the effect of contamination of water sources weather the surface water or the groundwater sources. Besides that, the research should consider the other factors that may affect the contamination of the water such as rainfall and seasonal influence of the climate.

From the analyses, the presence of high value of COD indicates the high organic strength. The high values for ammonia nitrogen probably due to the deamination of amino acids during the decomposition of organic compound. According Tengrui et al (2007), the value indicates that the leachate is in intermediate stage when TOC/COD is more than 1.52 and BOD_5/COD is more than 0.09.

In this project the batch adsorption isotherm experiment by activated carbon has been done. The linearised Freundlinch isotherm showed a better fitting of the adsorption of organic compounds compared to Langmuir isotherm analysis with the correlation coefficient (R^2) 0.927 for COD and 0.946 for TOC. For future work, the treatment using activated carbon need to be done whether by column or by other means of treatment.

5.2 RECOMMENDATION

5.2.1 Provide impermeable liner and drainage system

Bercham landfill is non- engineered landfill. It is neither having any bottom liner nor any leachate collection and treatment system. Therefore, all leachate generated will finds its paths into the surrounding environment. The landfill should be provided with impermeable liner and drainage system at the base of the landfill in order to avoid leachate percolates into subsoil. All accumulated leachate at the base of the landfill can be collected for recycling or treatment.

5.2.2 Further study on the treatment should be carried out

The remedial measures should be considered by studying on the possible treatment for this landfill. In this project, the author has proposed the treatment by using activated carbon which is affordable and feasible to be used. In most cases, activated carbon adsorption has worked well in removing the essential organic compounds and ammonium nitrogen from the leachate samples.

5.2.3 Continuous monitoring is required

Continuous monitoring is required in order to evaluate the quality of the leachate precisely. It is also recommended that, the antecedent rainfall of Ipoh is evaluated to get the quantity of leachate produced at the landfill. The samples from nearest river Sg. Choh also need to be assessed in order to know the influenced of leachate contaminated to the water source

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APPENDIX A

GANTT CHART

GANTTCHART OF FINAL YEAR PROJECT II (JULY 2009)

NAME : NORHAZIRAH BINTI AB GHANI @ RANI
ID NO : C7485
PROJECT TITLE : LEACHATE QUALITY OF OLD COMPARTMENT AT BERCHAM, IPOH
SUPERVISOR : AP DR NASIMAN BIN SAPARI

JULY, AUGUST, AND SEPTEMBER

ACTIVITIES	MONTH	JULY															AUGUST																					SEPTEMBER								
	WEEK						1					2					3					4					5					6					7					8				
	DATE	13	14	15	16	17	20	21	22	23	24	27	28	29	30	31	3	4	5	6	7	10	11	12	13	14	17	18	19	20	21	24	25	26	27	28	31	1	2	3	4	7	8	9	10	11
Researches																																														
Site visit																																														
Data analysis																																														
Treatment																																														
Weekly meeting with supervisor																																														
Preparation for poster exhibition																																														
Poster Exhibition																																														
Submission of final report (softbound dissertation)																																														
Oral presentation																																														

SEPTEMBER, OCTOBER, NOVEMBER

ACTIVITIES	MONTH	SEPTEMBER													OCTOBER																						NOVEMBER				
	WEEK	9					10					11					12					13					14					15					16				
	DATE	14	15	16	17	18	21	22	23	24	25	28	29	30	1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27	28	29	30	2	3	4	5	6
Researches																																									
Site visit (sample collection)																																									
Data analysis																																									
Treatment																																									
Weekly meeting with supervisor																																									
Preparation for poster exhibition																																									
Poster Exhibition																																									
Submission of final report (softbound dissertation)																																									
Oral presentation																																									

APPENDIX B

LOCATION PLAN

APPENDIX C

CALCULATION

APPENDIX

BOD

	First Reading	Second Reading	Third Reading	Average Reading
Blank	8.34	8.32	8.30	
	8.14	8.15	8.05	
DO Blank	0.20	0.17	0.25	0.206
Sample	8.32	8.32	8.29	
	6.66	6.70	6.77	
DO Sample	1.66	1.62	1.52	1.6
Seed	8.31	8.32	8.31	
	8.27	8.16	8.12	
DO Seed	0.04	0.16	0.19	0.13

$$BOD_5 = \frac{(1.6 - 0.206 - 0.13) \times 10}{\frac{20}{300}} = 189.6 \text{ mg/L}$$

	First Reading	Second Reading	Third Reading	Average Reading
Blank	8.96	8.97	8.95	
	8.77	8.70	8.83	
DO Blank	0.19	0.27	0.12	0.19
Sample	8.88	8.85	8.83	
	7.44	7.66	7.53	
DO Sample	1.44	1.19	1.3	1.31
Seed	8.90	8.70	8.80	
	8.34	8.29	8.31	
DO Seed	0.56	0.41	0.49	0.49

$$BOD_5 = \frac{(1.31 - 0.49 - 0.19) \times 50}{\frac{20}{300}} = 473 \text{ mg/L}$$

BOD_5 = 190 – 473 mg/L

TOTAL SUSPENDED SOLID

Sample	Initial	Final	TSS	Dilution	Average
1	1.2653	1.2938	0.0285		
2	1.2697	1.3052	0.0355		0.028
3	1.2612	1.2817	0.0205		
1	1.2725	1.2782	0.0057		
2	1.3067	1.3124	0.0057		0.007
3	1.2843	1.294	0.0097		
1	1.2795	1.2834	0.0039	0.039	
2	1.3056	1.3107	0.0051	0.051	0.036
3	1.2858	1.2876	0.0018	0.018	
1	1.2785	1.279	0.0005	0.005	
2	1.304	1.3042	0.0002	0.002	0.009
3	1.2864	1.2884	0.002	0.02	

TSS = 0.007 – 0.036

TOC

Sample	Dilution	TC (ppm)	TIC(ppm)	TOC(ppm)		ppm	mg/L
1	1:50	33.885	18.279	15.606	780.3		
2	1:100	74.974	8.895	66.079	6607.9	3228	3224
3	1:150	22.769	7.466	15.303	2295.45		
1	1:50	81.918	20.037	61.881	3094.05		
2	1:100	38.686	11.63	27.056	2705.6	3038	3035
3	1:150	31.231	9.141	22.09	3313.5		
1	1:250	27.29	7.545	19.745	4936		
2	1:250	22.537	5.281	17.256	4314	4573	4568
3	1:250	23.267	5.388	17.879	4470		

TOC = 3224 – 4568 mg/L

COD

15/10/09	Reading	Dilution	
1	126	(1:25)	3150
2	128	(1:25)	3200
19/10/09			
1	211	(1:10)	2110
2	243	(1:10)	2430
13/10/09			
1	65	(1:50)	3250
2	87	(1:25)	2175
3	321	(1:10)	3210

COD = 2110 – 3250 mg/L

Nitrate

Sample	Reading	Dilution	
1	3.25	1:5	16.25
2	3.3	1:5	16.5
3	3.2	1:5	16
1	3.2	1:5	16
2	3.3	1:5	16.5
3	3.1	1:5	15.5
1	3.2	1:5	16
2	3.1	1:5	15.5
3	3.2	1:5	16

Nitrate = 15 – 17 mg/L

Ammonia nitrogen

Sample	Reading	Dilution	
1	1.94	1:1000	1940
2	1.97	1:1000	1970
3	1.99	1:1000	1990
1	1575		
2	1940		
3	1575		

Ammonia nitrogen = 1575 – 1970 mg/ L

pH

Sample	Reading
1	8.02
2	8
3	7.98
1	7.3
2	7.5
3	7.6

pH = 7.3- 8.02

Turbidity

Sample	Reading	Dilution	
1	7.23	1:25	180.75
2	11.1	1:25	277.5
3	6.52	1:25	163
1	2.92	1:50	146
2	5.72	1:50	286
3	2.78	1:50	139

Turbidity = 139 - 278

Color

Sample	Reading
1	453
2	325
3	354

Color = 325 - 453

Total Phosphorus

Sample	Reading	Dilution	
1	2.7	1:50	135
2	2.73	1:50	136.5
3	2.6	1:50	130

Total Phosphorus = 130 -137 mg/L