

Characterization of Acetogenic and Methanogenic Leachates Generated from a Sanitary Landfill Site

Aik Heng Lee, Hamid Nikraz, Yung Tse Hung

Abstract—Decomposition processes take place in landfill generate leachates that can be categorized mainly of acetogenic and methanogenic in nature. BOD:COD ratio computed in this study for a landfill site over a 3 years duration revealed as a good indicator to identify acetogenic leachate from methanogenic leachate. Correlation relationships to predict pollutant level taking into consideration of climatic condition are derived.

Keywords—Acetogenic Leachate, Methanogenic Leachate, BOD:COD Ratio.

I. INTRODUCTION

LANDFILLS are major sources of groundwater and land contamination that can cause adverse impacts to the environment. Perforation of pollutants due to waste disposal which passes through as leachate if not properly handled will diffuse through the landfills and contaminate soils and groundwater if left unchecked. The constituents of leachate can be categorized into four types namely organic matter, inorganic matter, heavy metal and xenobiotic organic compounds [1].

The extent of contamination from the leachate depends on the type of control measures used in landfill. Nevertheless, pollutants in the leachate of different composition have different impacts on the environment. Even under controlled conditions such as those of a well planned and well managed landfill, leachate may percolate or penetrate through natural ground and may still contaminate groundwater and ultimate contaminate fresh water supplies over time. The environmental impact is most significant particularly those landfills without integration of engineering controls such as liners and leachate collection system.

The content of leachate generated from most landfill is subject to several factors such as climatic condition, infiltration and waste type. As leachate percolates through waste strata layers that undergo various decomposition high amounts of both organic matter and inorganic matters are found to be higher than those in groundwater [2]-[3].

Both temperature and water content in landfill will affect the rate of waste decomposition which is usually lower in dry

weather condition. Dissolved organic matter in leachate consists of various organic and inorganic constituents. Higher organic matter is anticipated in acetogenic phase whereas inorganic matter is lower in methanogenic phase due to lower dissolved organic matter and higher pH [4]-[8].

Leachate content generated from waste landfill can be broadly categorized as organic matters, inorganic matter, xenobiotic organic compounds and other compounds due to various conditions such as weather, infiltration, gravity drainage and groundwater inflow. The strength of leachate is depend on decomposition processes comprising of biological and chemical reactions which vary from pH and high concentration of biodegradable organic pollutant in early methanogenic phase to high pH and lower concentration of biodegradable organic content in later methanogenic phase.

The purpose of this paper is to study the impact of temperature and precipitation on landfill performance that yield various pollutant removal experiencing both acetogenic and methanogenic phases.

II. MATERIALS AND METHOD

Performance data from a landfill site in Toronto, Canada was evaluated over a period of 3 years to assess the range of pollutant in the leachate. The performance data is depicted in Table 1.

The dissolved organic matters were evaluated in terms of BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand) and DOC (Dissolved Organic Carbon). The inorganic matters such as ammonia, calcium, chloride, iron, magnesium, sodium and sulfate of the landfill leachate were evaluated and xenobiotic organic compounds such as phenols were also evaluated. Statistical study using regression analysis to establish correlation relationship to evaluate pollutants from landfill that are leached out from this traditional waste landfill using clay liner taking into consideration of basic properties and factors influencing landfill performance include climatic conditions such as temperature and precipitation and also the organic content of leachate in terms of BOD:COD ratio.

III. RESULTS AND DISCUSSIONS

As water passes through waste strata layer in landfill it triggers and activates decomposition due to present of microorganisms. The decomposition can be defined in two

Aik Heng Lee is Senior R & D Director with the Institute Alam Sekitar Malaysia (E-mail: lah@yesenviro.com).

Hamid Nikraz is Professor and Head of Civil Engineering Department, Curtin University of Technology (E-mail: H.Nikraz@curtin.edu.au).

Yung Tze Hung is Professor of Civil Engineering Department, Cleveland State University (E-mail: yungtzehung@gmail.com).

acidic and high ammonia concentration. Such aggressive nature of leachate prompts dissolution of other components in wastes resulting in high concentration of iron, magnesium, zinc and calcium.

Parameters	Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature	High	1	9	10.9	12.4	25	27.1	11.8	30.1	29.9	29.1	27.7	16	45
		2	18	7	12.4	38	29.9	18.8	30.1	31	30	27.7	16	45
		3	0.4	6	16	38	30.9	18.8	30.1	31	30	27.7	16	45
		4	11	7	15	26	29	18	31	30	29	12	15	45
Low	1	21	19	30.1	7	2	4.8	11.4	9.3	14.5	0.7	4.8	24	2
	2	25.9	16	12.4	7	2	2.4	22.7	12.1	11	4.8	0.7	11.9	16
	3	12	35	22	11	26	4	7	12	11	0.1	0	4	11
	4	15	18.2	22.5	11.5	14	31	5	15	11.5	0.1	0.1	5.4	14.4
Precipitation	1	50.4	22.9	43.2	62.4	96.8	47.1	121.1	46	20	30	41	96.4	1
	2	21.0	49.6	38	38	36.39	14.9	12.58	119.26	24	44.26	104.88	48.19	2
	3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	4	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6
BIOIODI rate	1	0.037	0.038	0.10	0.02	0.07	0.034	0.03	0.03	0.037	0.11	0.13	0.19	0.39
	2	0.00	0.10	0.10	0.10	0.22	0.11	0.00	0.10	0.00	0.10	0.09	0.09	0.13
	3	0.11	0.11	0.11	0.11	0.09	0.11	0.11	0.09	0.11	0.09	0.11	0.09	0.11
	4	0.050	0.11	0.49	0.18	0.28	0.11	0.11	0.10	0.00	0.11	0.09	0.11	0.11
5	0.22	0.12	0.1	0.11	0.04	0.10	0.11	0.10	0.09	0.09	0.07	0.06	0.12	
Performance Rate	Ability	1	2700	2700	1600	2000	2000	2000	2000	2000	2000	2000	2000	2000
	2	2400	2300	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700
	3	2400	2300	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700
	4	2400	2300	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700
Ammonia	1	2200	2200	2200	2200	2200	2200	2420	1900	1200	1200	1200	980	1500
	2	220	220	140	220	220	220	220	220	120	120	120	220	220
	3	200	200	200	200	200	200	200	200	200	200	200	200	200
	4	160	160	160	160	160	160	160	160	160	160	160	160	160
BIO	1	360	330	280	270	220	270	269	125	119	92	80	148	148
	2	160	160	160	160	160	160	160	160	160	160	160	160	160
	3	120	110	100	130	140	41	51	99	18	0	0	0	16
	4	120	120	120	120	120	120	120	120	120	120	120	120	120
CDO	1	548	188	224	118	89	42	80	45	700	1000	1000	88	100
	2	680	680	680	680	680	680	680	680	1000	1000	1000	680	680
	3	180	180	180	180	180	180	180	180	180	180	180	180	180
	4	150	150	150	150	150	150	150	150	150	150	150	150	150
Calcium	1	2600	1200	1100	628	1680								

On the other hand, microorganisms in methanogenic phase that can remove soluble organic matter are gradually established due to absence of oxygen. The decomposition in this phase thrives to convert soluble organic matter to methane and carbon dioxide thus release as landfill gas. Methanogenic leachate generated is typically characterized by low BOD value and low ratio of BOD:COD with high concentration of ammonical nitrogen and inorganic matters such as iron, sodium, potassium, sulphate and chloride due to active dissolution.

BOD:COD ratio is thus defined as an indicator for degradation of organic matter that differentiate the acetogenic phase from methanogenic phase in landfill which trickling leachate. Figure 1 depicts the ratio of BOD:COD spread over the 3 years in the landfill studied.



The ratio of BOD:COD computed for the landfill exhibited that more than 90% of time leachate in the landfill experienced methanogenic phase.

The results of leachate generated containing low ratio of BOD:COD indicate that the decomposition is stabilized and is biological active and is dynamically in equilibrium.

It is reported that the intensity of decomposition is significantly affected by various external forces such as climatic conditions in terms of environmental temperature and precipitation [9].

Correlation relationship of leachate concentration to temperature is evaluated in terms of physical properties of pH, alkalinity, hardness, conductivity and total suspended solid; dissolved organic matters of BOD, COD and DOC; inorganic matters of sulphate, chloride, ammonia, calcium, magnesium, sodium, iron, nitrate, nitrite and Total Kjeldahl Nitrogen and xenobiotic organic compounds of phenols.

From the data evaluation as depicted in Figures 2 to 5, all physical properties ($r>0.118$) except hardness ($r=0.004$), all inorganic matters ($r>0.100$) except iron ($r=0.071$) and xenobiotic organic compounds of phenols ($r=0.200$) depict there is some degree of significance of correlation relationship of leachate to temperature in the environment. This can be explained by the active decomposition rate in the

waste due to high temperature that facilitates both biological and chemical reaction inside the mass.

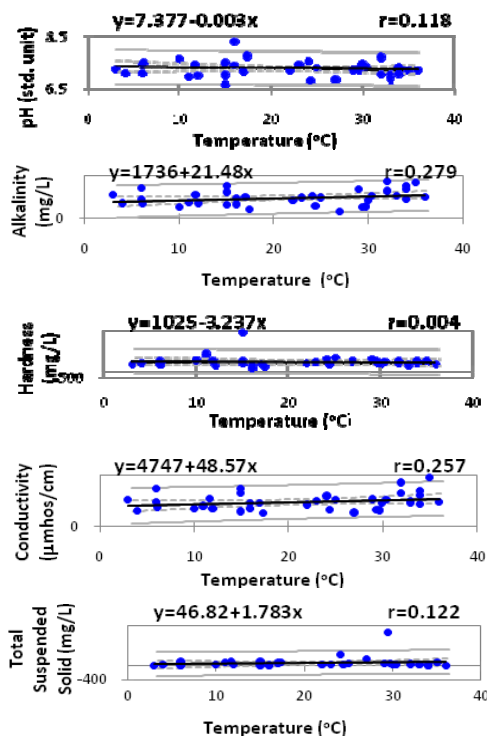


Fig. 2 Physical Properties of Leachate Versus Temperature

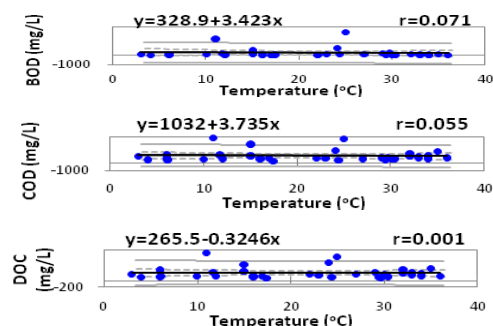


Fig. 3 Dissolved Organic Matters of Leachate Versus Temperature

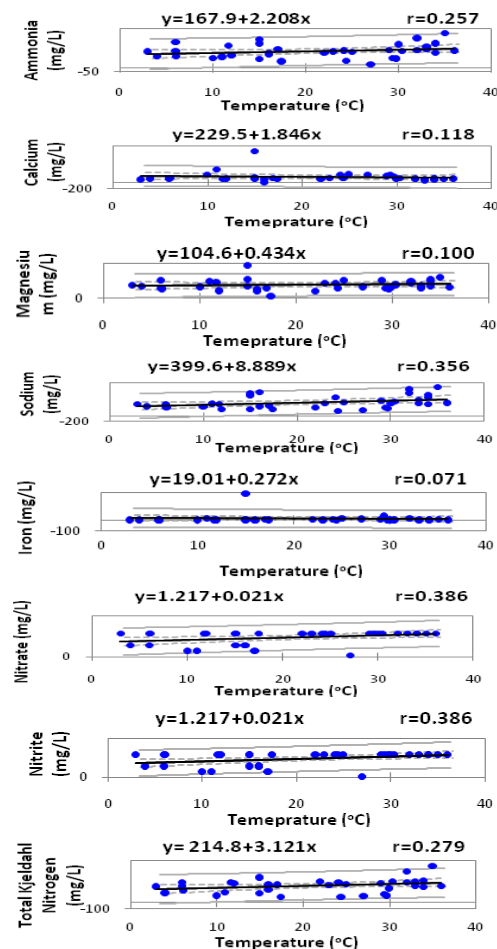
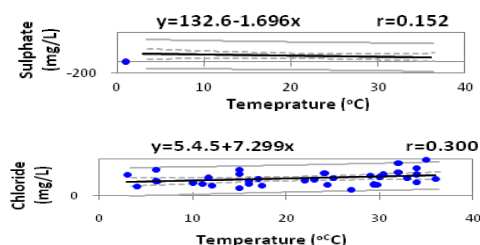


Fig. 4 Inorganic Matters of Leachate Versus Temperature

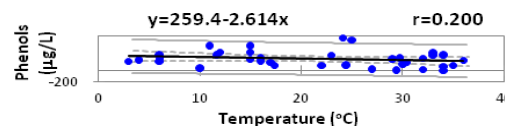


Fig. 5 Xenobiotic Organic Compounds of Leachate Versus Temperature

Figures 6 to 9 depict the correlation relationship of leachate concentration to precipitation. Results illustrate that all physical properties ($r > 0.114$) except pH ($r = 0.077$); all dissolved organic matters ($r > 0.257$); all inorganic matters ($r > 0.118$) except ammonia ($r = 0.077$) and xenobiotic organic compound of phenol ($r = 0.339$) are relatively quite correlated to precipitation as excessive precipitation is likely to slow down decomposition rate in the waste environment which leachate is percolated through.

BOD:COD ratio is also evaluated to established the correlation relationship to leachate concentration obtained from the landfill. Figures 10 to 13 depict the correlation relationship of leachate concentration to BOD:COD ratio.

Results reveals that all physical properties ($r > 0.146$) except total suspended solid ($r = 0.045$); dissolved organic matters ($r > 0.633$); inorganic matter ($r > 0.118$) except iron ($r = 0.063$) and xenobiotic organic compound ($r = 0.688$) are correlated significantly to BOD:COD ratio computed for the leachate concentration obtained for the landfill in this study.

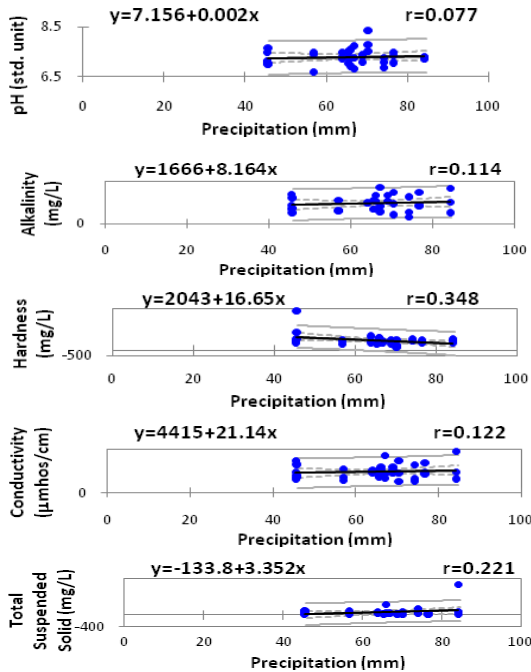


Fig. 6 Physical Properties of Leachate Versus Precipitation

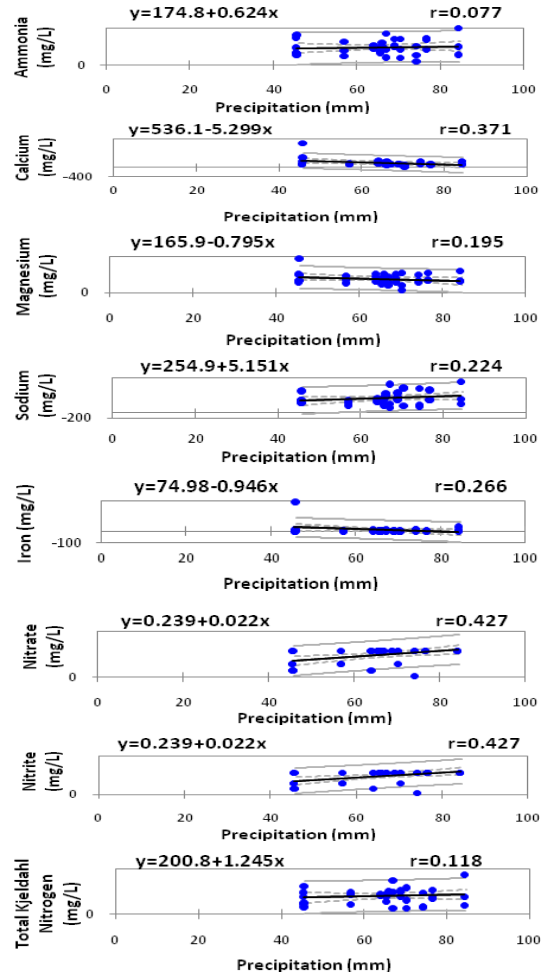


Fig. 8 Inorganic Matters of Leachate Versus Precipitation

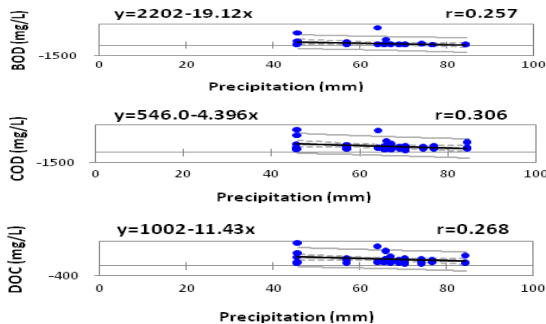


Fig. 7 Dissolved Organic Matters of Leachate Versus Precipitation

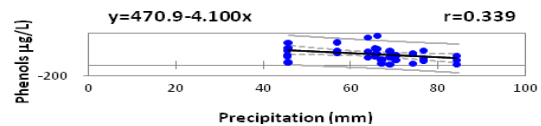
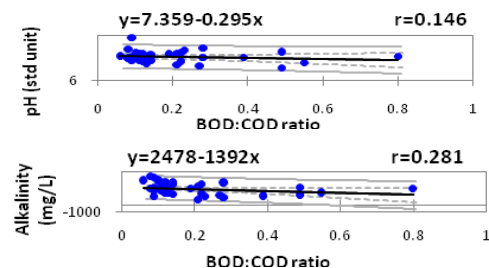
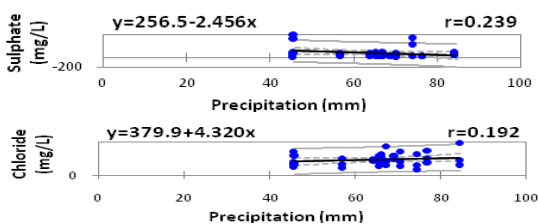


Fig. 9 Xenobiotic Organic Compounds of Leachate Versus Precipitation



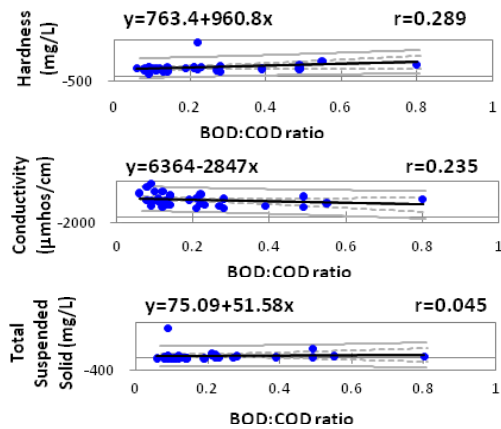


Fig. 10 Physical Properties of Leachate Versus BOD:COD Ratio

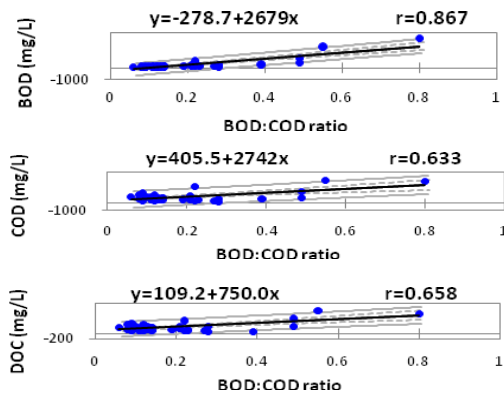


Fig. 11 Dissolved Organic Matters of Leachate Versus BOD:COD Ratio

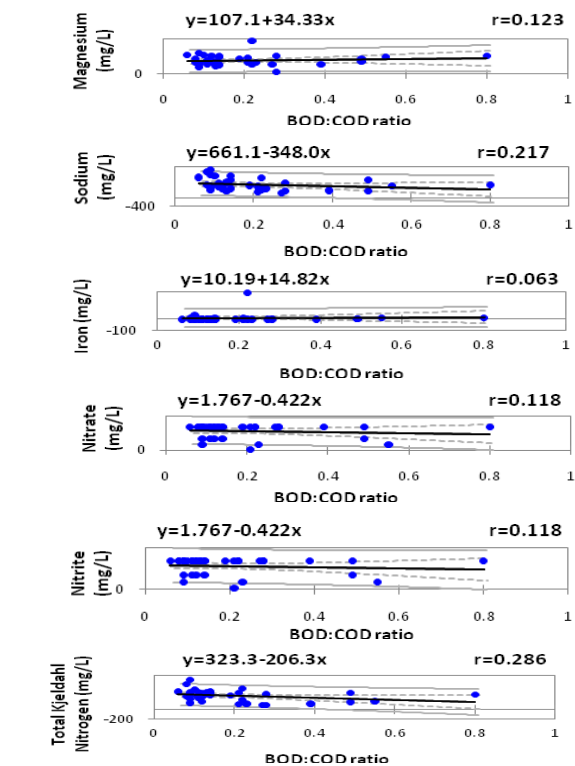
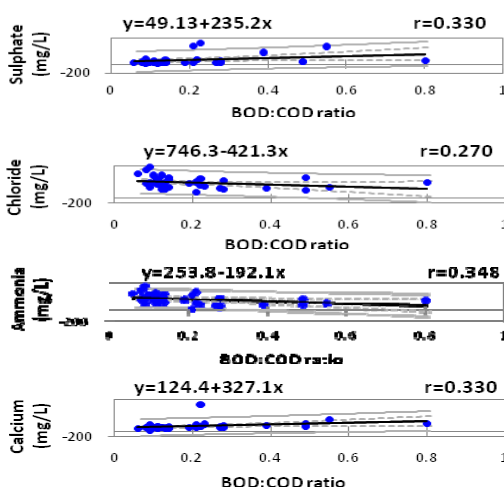


Fig. 12 Inorganic Matters of Leachate Versus BOD:COD Ratio

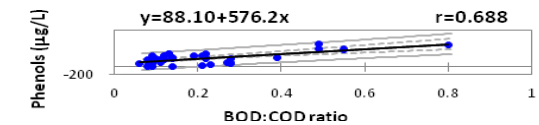


Fig. 13 Xenobiotic Organic Compounds of Leachate Versus BOD:COD Ratio

IV. CONCLUSION

The study concluded that in an actively decomposing waste landfill, leachate generated can be characterized as acetogenic and methanogenic and BOD:COD ratio of leachate is a good indicator to illustrate the degree of stabilization in landfill. The BOD:COD ratio of leachate computed indicate if sufficient biological and chemical decomposition as well as biodegradation are carried out under changing ambience conditions in the landfill body. It is referred that decreasing BOD:COD ratio is taken as an indicator of degradation of organic substrate due to decomposition.

Acetogenic leachates are typically characterized by its high BOD value and high BOD:COD ratio due to rapid hydrolysis of insoluble organic matters that make it readily degradable. On the other hands, methanogenic leachates are characterized by its relatively low BOD values and low ratios of BOD:COD due to the active dissolution of soluble organic matters present as well as inorganic matter, sulphate, chloride and calcium.

The study also reveals that the waste decomposition in landfill is influenced by climatic condition such as temperature and precipitation based on correlation relationship established. The intensity of decomposition is observed to be significantly affected by amount of precipitation and the temperature inside the landfill mass. Rises in temperature accelerate decomposition while precipitations slow down decomposition to anaerobic condition.

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