# 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

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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

phases, firstly soluble organic matter produced due to aerobic decomposition or acetogenic phase and secondly methane and carbon dioxide produce due to anaerobic decomposition or methanogenic phase.

TABLE I PERFORMANCE DATA OF LANDFILL SITE

Parameter	Year	Month											
Temperature		1	2	3	4	5	6	7		9	10	- 11	12
High	1	9	10.5	18.2	25	27.5	31.8	30.5	29.9	29.1	27.2	15	10
	2	18	7.3	12.9 16	28 17	24.9 33	34.6 33	35.5 34	34	32	26.1 22	19.1 16	4.4 12
	4	11	4	15	25	29	34	34	35	32	32	15	3
	5	15	6	11.7	23	24.1	30.4	30.0	29.4	29.7	24.4	17.4	6.1
LOW	2	-24.2	-15	-14.2	0	-0.4	22.1	12.4	13	6.4	-0.3	-13.3	-15.2
	3	-13	-11	-10	4	3	8	13 12	13	5	_	-2	-10
	- 4	-17	-20 -18 2	-22	-7	31	90	12 12 9	11	5 8.1	.21	.96	-11 -12.4
Precipitation	1	50.6	22.5	63.2	62.4	98.8	67.5	121.1	60	25.70	35	61	96.6
	2	71.70 45.6	69.90	38.30	98.30	14.90	32.50	18.50	139.40	244.30 74.2	46.30	104.80 70.3	60.10
	4	45.6	45.5 45.5	56.9 56.9	64.0 64.0	66.0 66.0	68.9 68.9	76.6 76.6	84.2	74.2	67.0 67.0	70.3	65.5 65.5
	5	45.6	45.5	56.9	64.0	66.0	68.9	76.6	84.2	74.2	67.0	70.3	65.5
BOD/COD ratio	1 2	0.07	0.08	0.10	0.09	0.07	0.06	0.07	0.06	0.07	0.13	0.19	0.15
	3	0.23	0.11	0.14	0.09	0.13	0.09	0.12	80.0	0.21	0.09	0.09	0.13
	- 4	0.55	0.12 0.12	0.49	0.8	0.28	0.14	0.06	0.09	0.14	0.08	0.1	0.11
Performance Data Alkalinity	,	2700	2700	1600	2900	3400	2500	3200	3200	3100	3500	3500	2500
Ananny	2	2400 1200	2700	3100	3100	3400	3300	4700	3300	2700	0	0	0
	3	1200 1700	2000 1600	1500 1400	2300 2200	2400 3100	2400 3100	2000 3400	2300	740	1900 3900	2150	1600
	5	2800	3200	2500	2200	2400	2420	1900	3800 1200	2900 1260	1300	3400 980	1570
Ammonia	1	230	270	140	240	330	270	300	330	300	290	320	250
	2	200 120	200 212	180	200	340 270	300	450 190	370 220	290	190	190	160
	4	140	150	110	200	230	310	320	440	230	380	310	210
BOD	5	360	330	280	210	220	215	299	125	119	92	85 90	148
300	2	120	170	38 1080	120	140	53 67	50 75	59	78	0	0	0
	3	120 1800	78 50	74 430	59 2500	110 200	59 114	67 60	58 135	120 125	59 100	50 92	74
	5	545	140	224	118	810	62	60	4	270	100	92	97
COD	1	480	690	410	640	1000	990	800	1000	1000	1300	490	850
	2 3	150 540	1200 730	1840 540	550 680	990 840	830 720	1230 580	970 730	780 570	660	610	570
	4	3300	450	890 1100	3160	720	850	1000	1500	890	1260	1000	910
Calcium	5	2500	1200	1100	628	1680	580	590 187	470	700	370 210	290	450
Calcium	2	240	253	641	411	392	275	307	132	155	0	0	0
	3	268	195		152	89	117	148		261	132	20.8	139
	5	433 1020	144 128	177 135	286 148	225 270	154 162	110 138	130 263	146 213	125 154	120 127	112 165
Chloride	1	580	290	440	640	960	760	833	929	879	886	765	685
	2	627 505	678 573	719 449	632	978 681	800 668	1160 515	630	761	584	0 569	390
	4	454	360	310	665	759	811	1040	1350	886	1220	990	806
	5	834 6900	990 7900	687	620	868 7600	814 7100	720 6590	438 7310	421 7620	419 8690	386	548
Conductivity	2	5520	5640	33200	33200	49300	8420	12100	10600	8740	0	0	0
	3	4150	5650	4090	5470	5760	5370	5070	5640	3160	5020	5310	4110
	5	4710 7730	3630 8690	3430 6430	6070 5850	6290 7050	7130 6230	8160 5450	11300 3750	7700 3730	10200 3900	8750 3090	6140 4500
DOC	1	1200	190	150	200	380	340	298	320	322	400	280	336
	3	300 148	287 126	510	320 195	600 277	480 193	825 158	645 152	185	220	160	160
	4	900	120	300	780	280	240	249	410	260	380	300	215
Hardness	5	515 828	350 901	270 762	170 882	600 869	132 914	195	120	98	112 1100	89 920	140
THE SECOND	2	1070	1140	2110	1530	869 1580	914 1300	1560	840	880	0	0	0
	3	1070	730 770	610 870	740	660 1200	650 1000	780 930	740	1050	780 860	300	610
	5	3720	960	980	890	1230	880	740	1020	860	730	520	750
Iron	1	11	25	5.1	3.4	4.5	3.8	4.9	4.86	9.6	2.45	2.57	2.27
	3	3.37 4.31	3.12 3.37	2.67	2.88 7.1	4.12	5.17	6.76 4.3	3.9	4.36 13.6	5.2	0.67	4.5
	4	14.9	4.6	5.3	17.7	5.7	3.5	2.3 2.1	6	14.1	18.6	4.4	2.3
Magnesium	5	241 110	2.4 140	82	3.3 93	10	2.2 114	132	36.9 71.2	3.6 91.1	1.9	121	3 104
	2	113	122 84.2	125 77.5	122	146 107	149	194 101	125	120	0	0	0
	3	97.6 144	84.2	77.5	88	107	86	101	95	98	57	59.4	64
	5	280	154	137	127	130	116	97	88	79	83	18.4	82
Nitrate	1	<0.5 <0.3	<0.5 <0.3	0.51 <1	<0.3 <0.5	-d	<0.3 <0.5	<0.5	<0.3 <1	4	<0.3	<0.5	<0.3 0
	3	<0.5	<1	4	<0.5	-2	<2	-2	<2	0.1	<2	<1	<2
	4	<0.5	<1	-1	-2	-2	<2	-2	<2	-2	<2	-2	<2
Nitrite	1	- 4	<0.5	0.45	<0.3	4	<1	40.5	- 4	- 4	- 41	4	<1 ×1
	2	-0.5	<0.5	4	<0.5 <0.5	- 4	- 4	- 4	-4	<1 -0.1	0	0	0
	4	<0.5	<1	- 41	-2	-2	-2	-2	<2	-0.1	<2	-2	-2
41	5	-2	-2	-2	-2	-2	<2	-2	-2	-2	<2	2	-2
pH	2	6.9 7.13	6.9	7.0	6.9 7.23	6.97	6.95	6.9 7.59	7.1	6.99	7.03	6.96	7.17
	3	7.66	7.12	7.42	7.21	6.93	7.08	7.07	7.24	6.88	7.25	8.35	7.05
	5	6.99 7.06	7.13 7.47	6.7 7.47	7.32 7.47	7.27	7.33 7.38	7.35 7.48	7.24	7.08	7.74 6.82	7.53 7.78	7.29 7.52
Phenois	i	16	25	9	10	4	25	64	12	83	203	150	203
	2	195 48	178	945	247 142	228 310	135 264	292 271	203	208	87	170	316
l	4	428 321	185	431 271	528	204 554	9	76 116	94	212 220	19 100	193	160 208
Phasphorus	5	321 1.2	271	271 0.15	261 1.4	554 1.5	141	116	12 4	220 1.8	100	89 2.2	208
. maganasa	2	1.4	1.6	2.2	3.1	4.4	4.6	4	3	40	0	0	0
	3	1.40	1.90	0.80	4.40	4.00	1.80	1.10	1.40	3.00	1.00	0.80	1.20
	5	1.3	1.7	1.7	2	2.3	23	1.7 700	1.4	0.8	0.8 923	0.6	1.4
Sodium	1	590	890 660	440 609	540	860 951	833 769	700	520	582	923	788	631
	3	632 416	483	428	773 453	696	545	1360 524	569	708 273	380	1020	310
	- 4	532	425	311	590	662	811	920	1240	979	1151	974	530
Sulphate	5	888 31	515 260	515 130	550 60	800 25	640 9.1	550 <10	380 43	332 120	230 23	305 17	378 29
	2	11	23	<20	60	<20	<10	-20	<20	<20	0	0	0
	3	485	90	102 66	41 90	<40 <40	<40 <40	<40	59	427	114	22	<40
	5	485 408 111	<40	<40	46	<40 57	<40	<40 <40	117	277	<40 <40	90	<40 51 111
Total Kjeldahl Nitrogen	1	240	580	170	290	390	300	300	430	320	300	360	520
rerogen	3	260 120	250 275	220 300	300 300	480 355	400 280	610 265	700 272	110	350	220	320
l	4	175 430	164	157	309	320	368	372	607 140	335 120	520	410	270
Total Surprended	5	430	340 70	340 27	290 8	340 22	350 16.3	240 11	140	120 25	98 15	99 11	200
Total Suspended Solid	2	43	12	27 44	35	480	16.3 16	29	18	14	0	0	0
l	3	35	18	20	83	44	30	19	14	190	31	4	25
L	5	140	120	120	22	340	24	24	74 1000	56	41	95	30
												-	

During acenogenic phase microorganisms convert insoluble organic compounds to acetic acid, carbon dioxide and hydrogen by acetogenic bacteria. Leachate generated in the phase typically are characterized by high BOD value, high BOD:COD ratio illustrating a high concentration of soluble organic matters that are biodegradable and pH value that is

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.

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 phrase 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.

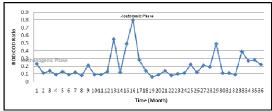


Fig. 1 Ratio of BOD:COD Over 3 Years Duration

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.

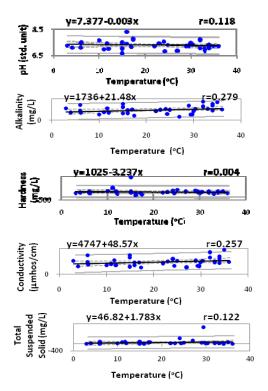


Fig. 2 Physical Properties of Leachate Versus Temperature

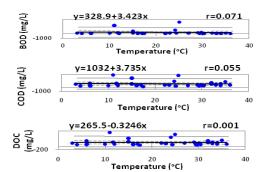
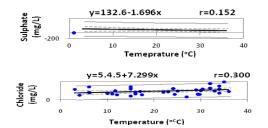


Fig. 3 Dissolved Organic Matters of Leachate Versus Temperature



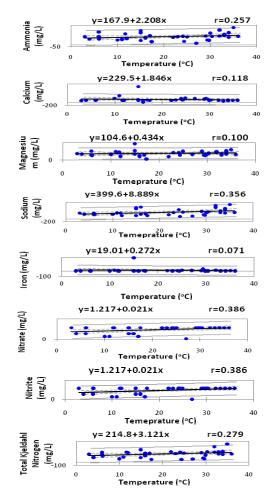


Fig. 4 Inorganic Matters of Leachate Versus Temperature

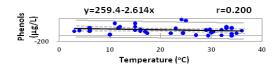


Fig. 5 Xenobiotic Organic Compounds of Leachate Versus Temperature

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.

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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.

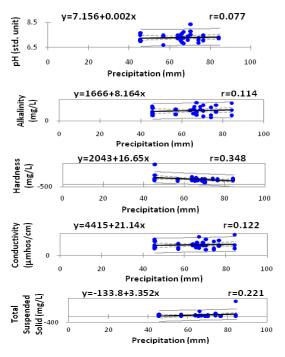


Fig. 6 Physical Properties of Leachate Versus Precipitation

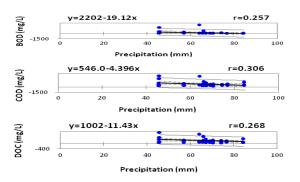
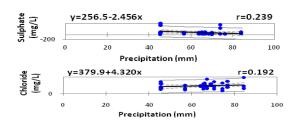


Fig. 7 Dissolved Organic Matters of Leachate Versus Precipitation



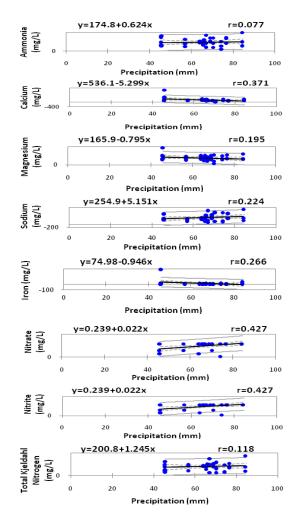


Fig. 8 Inorganic Matters of Leachate Versus Precipitation

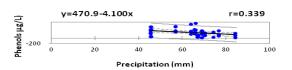
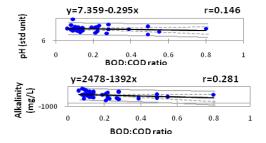


Fig. 9 Xenobiotic Organic Compounds of Leachate Versus Precipitation



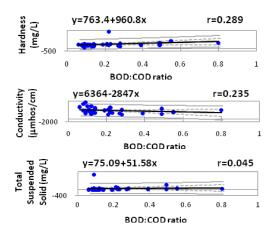


Fig. 10 Physical Properties of Leachate Versus BOD:COD Ratio

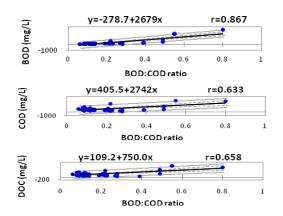
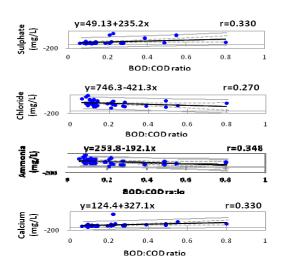


Fig. 11 Dissolved Organic Matters of Leachate Versus BOD:COD Ratio



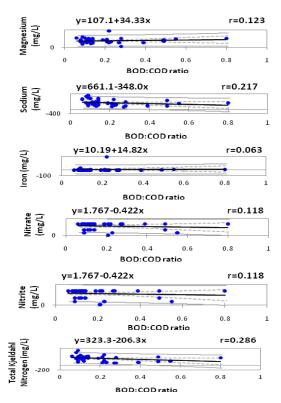


Fig. 12 Inorganic Matters of Leachate Versus BOD:COD Ratio

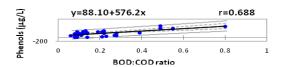


Fig. 13 Xenobiotic Organic Compounds of Leachate Versus BOD:COD Ratio

# 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 biodegradion 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 degradion 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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