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Study Of Carbonaceous And Nitrogenous Pollutants In Leachate Of A Sanitary Landfill Site

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Abstract. The characteristics of leachate from a mature landfill site were investigated over a period of six years to provide useful information for the design and management of landfill leachate. Data analysis revealed that low carbonaceous and nitrogenous pollutants can be achieved with proper groundwater and surface water management and also recirculation of leachate to control stabilization of decomposition in the waste layers.

Keywords: carbonaceous pollutants; nitrogenous pollutants; landfill leachate and decomposition

1. Introduction

Leachate is typically generated from a landfill deposited with waste contain wide spectrum of composition of pollutant both dissolved and suspended. As precipitation percolating through the landfill, water once in contact becomes contaminated however is assisted by decomposition of bacteria and fungi present in turn release by products of decomposition and rapidly consume any available oxygen. This biodegradation process utilize major portion of organic matter contained in the waste. This rapid decomposition cause temperature to rise and pH to fall which many metal ions normally relatively insoluble at neutral pH become dissolved.

Under normal condition of aerobic stage follow by anaerobic stage, carbonaceous organic removal is essentially completed and residue carbonaceous matters that are non-biodegradable which change the composition producing a wide range of other matters include complex mixture of organic acids, alcohols, simple sugar, carbon dioxide and other.

As carbonaceous concentration in leachate decreases ammonia nitrogen concentration increases resulting from the hydrolysis and fermentation of nitrogen containing fraction of biodegradable matters. This is followed by nitrification of ammonia nitrogen when a significant portion of non-ammonia nitrogen is readily converted usually measured as nitrogen concentration such as TKN.

The environmental risk posed due to leachate generation can be mitigated by properly designed and engineered landfill site such as lying of impermeable liners made of geotextiles or engineered clays that reduce the release of pollutants in order to meet sustainability requirement. Landfill configuration and leachate quality generation have been reported in numerous technical reports [1]-[4].

The purpose of this paper is to study the characteristic of carbonaceous and nitrogenous pollutant contain in leachate of a sanitary landfill site taking into consideration of operating condition such as climatic condition.

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2. Material and Method

The leachate data used in this study was obtained from the performance results of a landfill site at Toronto over a period of 6 (six) years spread from 2004 to 2009. The leachate composition was typical of a mature landfill. The landfill is deposited with wastes of solid, non-hazardous, industrial, commercial and institutional waste from municipalities and business.

The carbonaceous organic matters were evaluated in terms of BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand) and DOC (Dissolved Organic Carbon). The nitrogenous organic matters were evaluated in terms of TKN (Total Kjeldahl Nitrogen), ammonia, nitrite and nitrate.

Other inorganic matters such as calcium, chloride, iron, magnesium, sodium sulfate and xenobiotic organic compounds such as phenols were also evaluated.

Characteristic of both carbonaceous and nitrogenous content are analyzed in term of maximum and minimum value with mean (χ) and standard deviation (σ) obtained over the period of six years taking into consideration of influential factors such as climatic conditions.

3. Results and Discussion

Several technical studies have been reported on leachate quality but most are varied within range due to different magnitude of consideration taken [5]-[8]. This variability in leachate quality has caused the prediction of leachate quality over function of time difficult.

In this study, landfill that is designed with an engineered hydraulic trap as shown in Figure 1 to contain and collect leachate to minimize groundwater impact. It is also equipped with surface water management. Leachate recirculation is practiced with the intention to control waste decomposition thus make the prediction of leachate quality more readily. This is particularly important to ensure moisture movement through the waste layer especially to stimulate effect on methanogenesis.

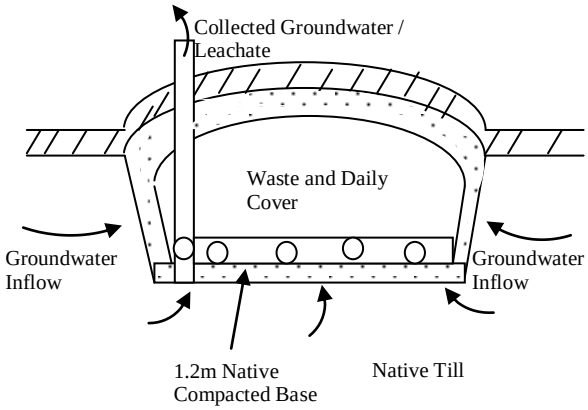

Figure 1 Landfill with Hydraulic Trap

Over the six years period of analysis, the climate of moderate rainfall ranging from 25.7 to 244.3 mm as depicted in Figure 2 tend to produce relatively low pollution levels compared to most reported values in leachate of other landfill. It is thus suggested that moisture content due to relatively moderate precipitation appear to have adverse impact to leachate quality. The moisture serves also as a good reactant in the hydrolysis reaction in landfill.

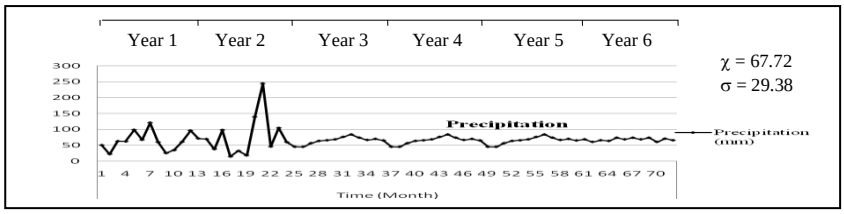

Figure 2 Precipitation Over The Study period

Generally, leachate is generated due to precipitation percolating through the waste layers deposited and became contaminated within the landfill where a series of reaction physically, chemically and biologically are taken place. The mechanism of these reactions however reduce the complexity of leachate eventually remove from the landfill.

The wide range of composition found in the leachate is mainly attributed to the decomposition of carbonaceous material by acetogenic bacteria converting insoluble to soluble organic matter and methanogenic bacteria converting soluble organic matter to methane and carbon dioxide. Like most mature landfill site, the organic matter removal is essentially completed which is characterized by relatively low values of BOD, COD and DOC. As depicted in Table 1 and Figure 3, minimum value of BOD, COD and DOC of 31, 150 and 54 mg/l with mean values of 250.4, 986.2 and 320.8 mg/l respectively were achieved. Peak values of BOD, COD and DOC of 2600, 3430 and 1340 mg/l were however observed due to hydraulic instability. The low concentration of carbonaceous organic matter, especially in term of BOD and COD, is likely caused by the effect of dilution. Another effect is also likely due to stimulation of methanogenesis as can be supported by the increase pH value throughout the period.

TABLE 1

Carbonaceous Pollutant Concentration In The Leachate

Parameter	Maximum value	Minimum Value	Mean	Standard Deviation
BOD (mg/l)	2600	31.0	250.4	503.8
COD (mg/l)	3430	150.0	986.2	833.8
DOC (mg/l)	1340	54.0	320.8	243.1
BOD/COD Ratio	0.8	0.06	0.19	0.17
pH	8.35	6.57	7.22	0.29

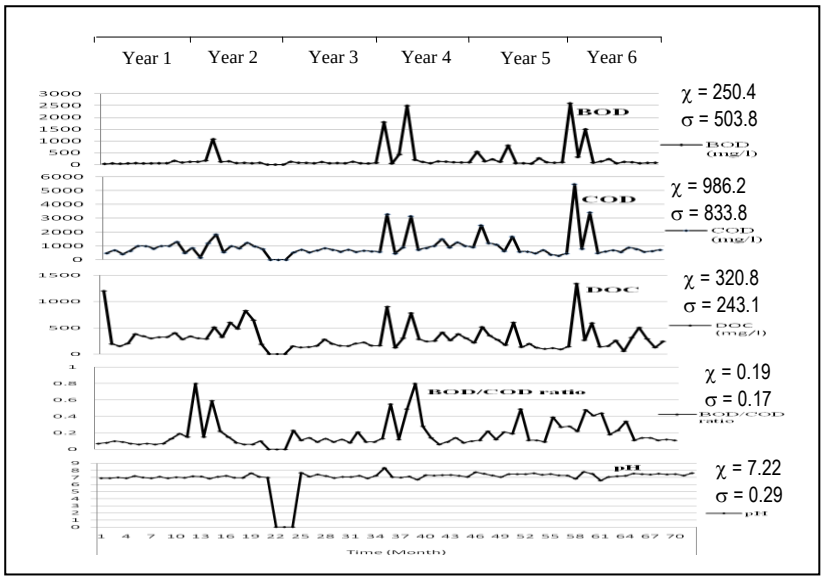

Figure 3 Carbonaceous Pollutant Concentration In The Leachate

It is also observed that low BOD/COD ratios of mostly less than 0.1 were achieved as depicted. The BOD/COD ratio is found to be most reliable and useful to relate the organic matter composition in leachate. Typical range of BOD/COD ratios of 0.02 to 0.80 is reported with averages of 0.58 and 0.06 for acetogenic and methanogenic respectively [6]. Over the study period, BOD/COD ratios in the range of 0.06-0.8 are observed. The results reflects that low biodegradability of the organic matter in the leachate is attained as BOD is a measurement for biological content thus BOD/COD ratio is an indicator of biologically degradable organic matter to total organic matter. It is anticipated that low BOD/COD ratio in leachate made subsequent biological treatment not effective.

As the organic concentration decreases in the leachate, ammonia nitrogen concentration increases caused high activity of nitrification in the waste bed especially in the mature landfill. It is also reported that ammonia nitrogen in the range of 50-2200 mg/l with average of 740 mg/l can be found in leachate composition [6].

Table 2 depicts the low value of nitrogenous matter in term of ammonia, nitrite and TKN of 46, 0.3, 0.3 and 98 mg/l with mean values of 238.8, 1.462, 1.394 and 313.4 mg/l respectively however with peak values of 450, 2, 2 and 700 mg/l.

TABLE 2

Nitrogenous Pollutant Concentration In The Leachate

Parameter	Maximum value	Minimum Value	Mean	Standard Deviation
Ammonia (mg/l)	450	46.0	238.8	82.0
Nitrite (mg/l)	2	0.3	1.462	0.629
Nitrate (mg/l)	2	0.3	1.394	0.707
TKN (mg/l)	700	98.0	313.4	121.9

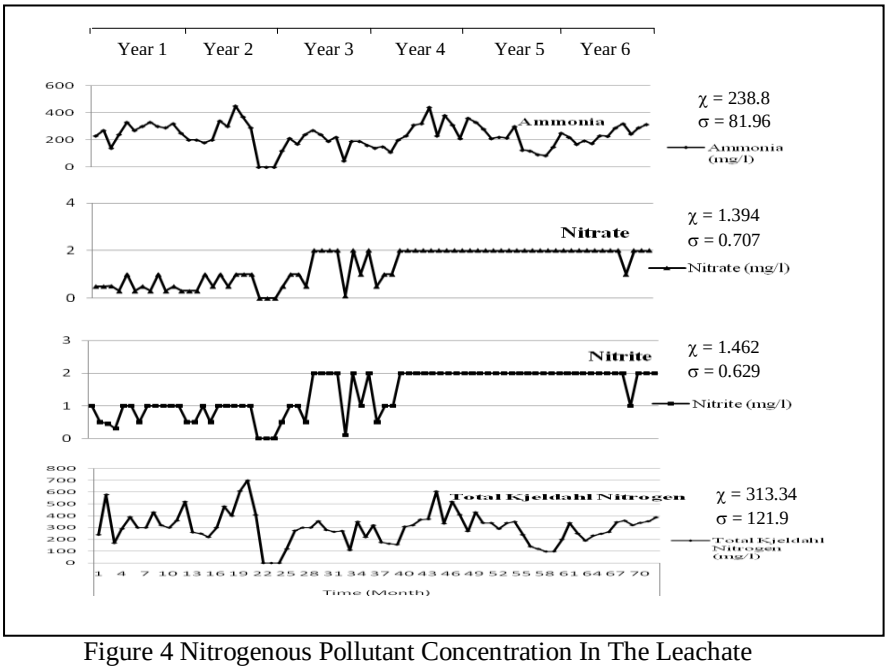

Figure 4 Nitrogenous Pollutant Concentration In The Leachate

Due to diffusion effect through some unbroken matter in the waste layer, ammonia nitrogen is anticipated to be occurred at higher concentration as compared to carbonaceous concentration such as COD that demand large amount of oxygen.

In this active decomposing waste layer of landfill, pH falls and non-conservative constituents in leachate such as metal ions which are relatively insoluble at neutral pH can become dissolved in the leachate except conservative constituents like chloride, sulfate and other residue of decomposition. These values are depicted in Table 3 and Figure 5. The results also reveal that with decrease in organic matter in the leachate, more non-biodegradable residues are released in the leachate.

TABLE 3

Other Pollutant Concentration In The Leachate

Parameter	Maximum value	Minimum Value	Mean	Standard Deviation
Calcium (mg/l)	1020	20.8	224.6	146.2
Chloride (mg/l)	1350	243.0	687.7	217.3
Iron (mg/l)	241	0.67	9.348	28.91
Magnesium (mg/l)	280	18.4	115.2	36.58
Sodium (mg/l)	1360	230.0	633.3	231.6
Sulfate (mg/l)	485	9.1	81.75	111.4
Phenol (mg/l)	945	1.0	220.9	200.3

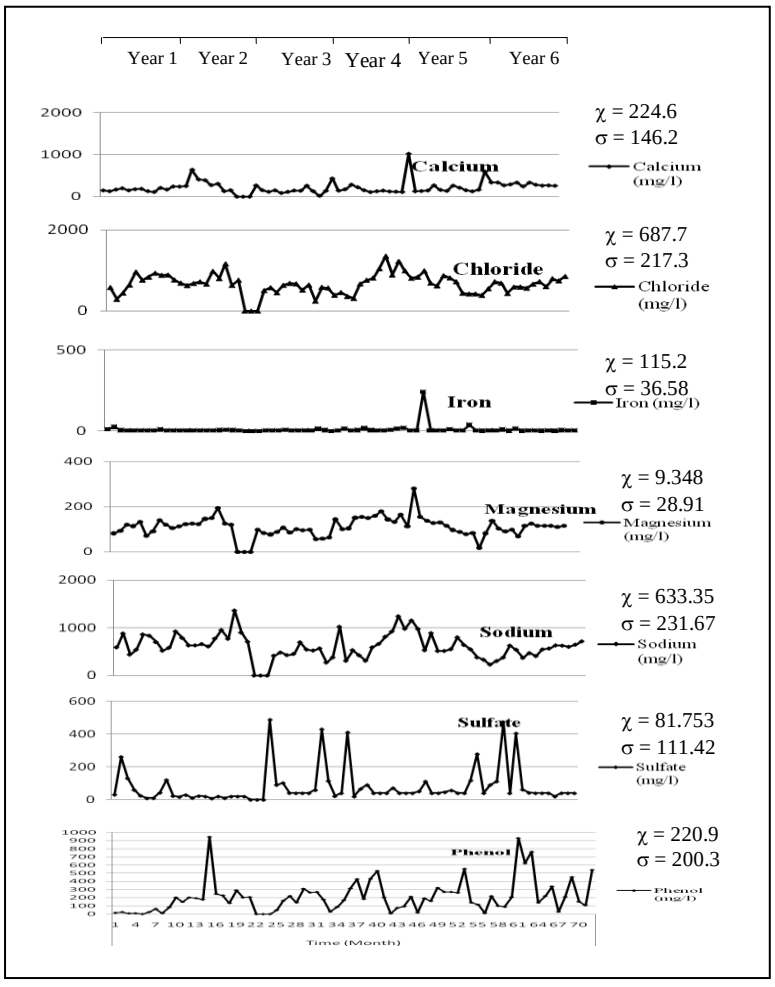

Figure 5 Other Pollutant Concentration In The Leachate

In general, mixed leachates from a mature landfill are anticipated to undertake various stages of decomposition particularly change from early acetogenic condition where high organic strength leachate are generated to later methanogenic stage where these organic matters are actively converted to landfill gas. It is

also inferred that the recirculation of leachate at the landfill is likely put decomposition of waste under better control thus made leachate characteristics more predictable.

4. Conclusion

It is concluded that study on a well control landfill site can provide useful information for the design and management of landfill leachate that made prediction more realistic for future trends. Moisture is also attributed as the most significant factor to ensure waste stabilization. Proper operational control to ensure water balance by leachate recirculation couple with climatic precipitation is important consideration for landfill to produce good leachate quality.

5. Acknowledgements

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