Critical assessment on treatment and remediation of municipal solid waste leachate

A.Sathyapriya * and G.Senthil Raj **

***Abstract* -** The**e**general concept behind this dissertation work is municipal solid waste management. Solid wastes and its composites affect the environment in several ways. And the major problems to be considered are the generation of leachate from solid waste dumping sites, which affects the ground water aquifers. Leachate from municipal solid waste is a major source of organic waste. And when this reaches the ground water table, it imparts adverse effects on the water stream. Today groundwater is the only water source in many areas in India as well as in many other countries. The leachate from the solid waste on the surface of the ground enters the soil and reaches the groundwater table, therebyaffecting it and preventing it for further use.

In this study, leachate is generated in lab and in an In-situ solid waste leachate pond and the characteristics study on its quantity of generation related to different conditions such as temperature, rainfall, etc, would be found out. The quantity of leachate generated from a landfill during variation in intensity of rainfall is also assessed by adding water artificially in different quantities to the municipal solid waste. The physical and chemical characteristics of leachate would be analyzed. Relating to these parameters, the method of treatment of leachate would be adopted. The treatment is adopted such that it must be economical and easy to be implemented in field. After treatment, the leachate would be subjected to disposal.

***Keywords*:**Leachate, Municipal solid waste, Landfill, Aquifers

I.INTRODUCTION

Landfilling is one of the predominant methods used for the management of Solidwaste. The degradation process of municipal solid waste (MSW) in a landfill is a long-term event. During MSW degradation, landfill gases are generated, the landfill surface settles and leachate concentrations are slowly and gradually attenuated. Leachate concentrations may therefore exceed permissible levels over a long period of time. Table 1shows the concentrations of MSW landfill leachate compared to Sewage and Groundwater concentration. When this highly concentrated leachate enters the nearer water bodies produces grave effect to the environment. Hence, leachate is one of the most important issues in the management of a landfill (Rovers and Farquhar, 1995).

* Assistant Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry – 605107, India, Email: priya.haridesh@gmail.com

** Assistant Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry – 605107, India, Email : gsenthilraj87@gmail.com@gmail.com

TABLE. I

TYPICAL CHEMICAL CONCENTRATIONS IN YOUNG LANDFILL LEACHATE

Parameter	Leachate concentrations (mg/l)	Typical sewage concentrations (mg/l)	Typical groundwater concentrations (mg/l)
COD	20,000-40,000	350	20
BOD5	10,000-20,000	250	0
TOC	9,000-15,000	100	5
VFA (as acidic)	9,000-25,000	50	0
NH3-N	1,000-2,000	10	0
Org-N	500-1,000	10	0
No3-N	0	0	5

A major constraint for the successful treatment of landfill leachates is the difficulty in identifying and quantifying their typical composition characteristics. If leachate treatment plants were designed to handle the average leachate quality only, they would occasionally be overloaded in practice, due to high pollutant peaks during certain time periods. Therefore, the leachate treatment plant has to be designed taking into consideration the maximum concentration of pollutants Žworst-case scenario. Hence detailed information about the seasonal variability of landfill leachate properties is essential for the design of an effective treatment system. Biological methods are typically applied for treatment of young leachates (e.g., from landfills of less than 1–2 years age), characterized by high 5-day biochemical oxygen demand (BOD5)/chemical oxygen demand (COD) ratios (>0.6) and high concentrations of low molecular weight organics. However, such methods are not effective for treatment of mature leachate (e.g., from landfills of more than 5–10 years age), due to their low BOD5/COD ratios (<0.3) and high fraction of high molecular weight, refractory organics. Hence, several physicochemical processes have been studied or used for pretreatment or full treatment of mature leachate. Among potential physicochemical technologies for leachate treatment, the Fenton process has been extensively studied in recent years and analyses indicate Fenton process to be one of the most cost-effective alternatives for this application. Therefore the objective of the study is to study the seasonal variation of simulated and In-Situ Municipal Solid Waste landfill leachate and treating it using an advanced oxidation process such as Fenton Process.

A. Scope and objectives

In the present study laboratory scale reactor and In-situ landfill leachate pit were used to simulate controlled landfill environment.

The objectives of this present study included the following,

1. To assess the quality and quantity of leachate generated both from laboratory scale reactor and In-situ MSW landfill.
2. To determine the Breakthrough time.
3. To treat the Municipal Solid Waste landfill leachate using an advanced oxidation process (Fenton reagent)

II. Leachate generation from a landfill

Leachate is produced when moisture enters the refuse in a landfill, extracts contaminants into the liquid phase, and produces moisture content sufficiently high to initiate liquid flow. Generally, as more water through the solid waste, more pollutants are leached. It is therefore important to review the methods that can beused to estimate the amount of leachate generated at a Municipal Solidwaste Landfill site (Tchobanoglous et al. (1993).

III. Mechanismsof leachate formation

A generalized pattern of leachate formation is presented in Fig. I. The components shown include the following steps:

1. Precipitation (P) falls on the landfill and some of it becomes runoff (RO).
2. Some of P infiltrates (I) the surface (uncovered refuse, intermediate cover, or final cover).
3. Some of I evaporates (E) from the surface and (or) transpires (T) through the vegetative cover if it exists.
4. Some of I may make up a deficiency in soil moisture storage (S) (the difference between field capacity (FC) and the existing moisture content (MC)).
5. The remainder of I, after E, T, and S have been satisfied, moves downward forming percolate (PERC) arid eventually leachate (L) as it reaches the base of the landfill.
6. PERC may be augmented by infiltration of groundwater (G). The procedure used to analyze these processes is referred to as a water balance (WB), various forms ofwhich are commonly used for the simulation of surface water hydrology. The algebraic statement of this form of water balance is

$$PERC = P - RO - ET - AS + G$$

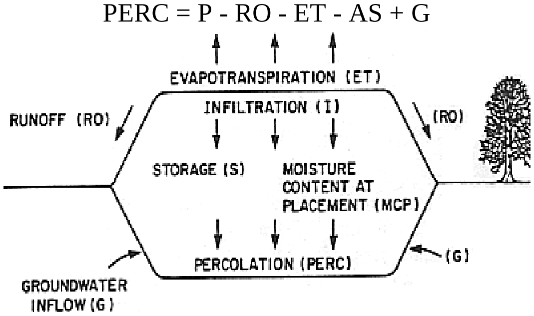

Fig1.Generalized pattern of leachate formation

While the above equation is conceptually correct and comprehensive, accurate predictions of leachate flow are difficult to achieve because of the uncertainties associated with estimating the various terms. Most formulae and methods in use are empirical. Some of the data base required is stochastic in nature (temperature, heat index, precipitation, wind, vegetative growth). Other data are poorly defined (runoff coefficients, refuse arid cover density and compaction, moisture storage capacities).

IV. Leachate generation based on rainfall pattern

The rainfall pattern of adjacent events decisively determines the water balance of a landfill. Being aware of this fact the available rainfall data have been evaluated and rainfall periods of 1-5 day's duration determined. For the fundamental step of determining the leachate generationor flow-rates to the treatment system the HELP model deems to be suitable.

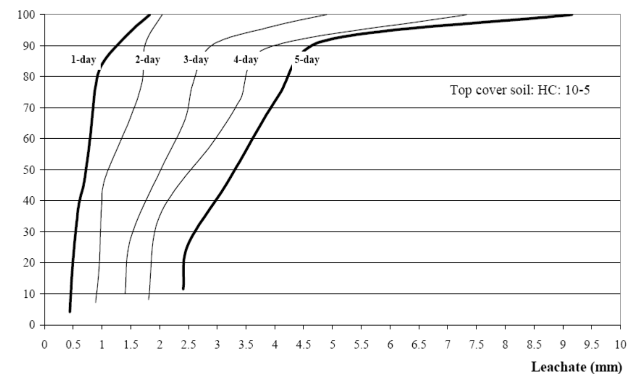

Fig 2. Leachate generation rates for covered system (IDF curves)

Rainfall events of 1-day, 2-days, and 5-days show the most frequent occurrence. The effect on the leachate generation is evident however; the double- and triple-fold increase shows only a moderate total amount (Figure II). For an almost covered system the contribution over a long lasting rain event is of minor significance. In contrary to these findings an open system generates much more leachate even if the field capacity is high. An uncertainty lies in the permeability of the waste itself. Provided a common permeability of 10-3 is given the leachate generation will increase by a factor of 5 - 10.

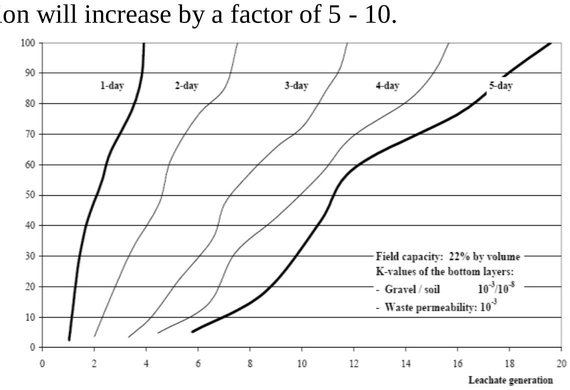

Fig 3. Leachate generation rates for open systems (IDF curves)

V. Methods and Material

The major component of the solid waste in Puducherry is organic matter that constitutes around 40%. The other components present in the waste stream include soil matter, metals, plastics, papers etc. The rag pickers collect most of the valuable recyclables to be sold to the junk dealers. The major non-compostable or non-recyclable residues in the waste stream are plastic carry bags and disposable teacups that have less or almost no value for recycling.

TABLE II
CHEMICAL COMPOSITION OF SOLID WASTE IN PONDICHERRY

S.No	Chemical Components	Value
1	Moisture Content, % mass	37.30
2	Organic carbon, % mass	38.49
3	Calorific value, kJ/ kg	2415.80
4	Nitrogen content, % mass	0.78
5	Phosphorous, mg/ kg	128.00
6	Potassium, mg/ kg	54.00
7	Copper, mg/ Kg	2.00
8	Zinc, mg/ kg	75.00
9	C / N ratio	37.2 to 49.3

The major chemical component of the solid waste in Pondicherry is the organic carbon that constitutes around 38.49%. The other components present in the waste stream include Nitrogen, Phosphorus, Potassium, Copper, Zinc, etc.

VI. Parameters Used for the Study

The conventional parameters that were analyzed in this study were as follows:

- Chemical Oxygen Demand (COD),
- Biological Oxygen Demand (BOD_5),
- Sulphate (SO_4),
- Chlorides (Cl),
- Total Solids (TS),
- Total Suspended solids (TSS),
- Total Dissolved solids (TDS),
- Total Volatile solids(TVS)
- pH
- Electrical conductivity

These parameters were chosen because sufficient data were available for each one at a majority of the landfill sites. The levels of chloride show no difference between degradation phases. Like the toxic and organic parameters.

VII. Results and Discussion

Presented in this chapter are the results of statistical and graphical analyses directed at the characterization of MSW landfill leachate. Tests were designed to identify trends in the data and to determine the effects of climate and waste characteristics on leachate quality

TABLE III
DETERMINATION OF LEACHATE PRODUCTION FOR LAB SCALE

S. No	% Dilution of Solid waste	Quantity of water added (ml)	Quantity of water Collected (ml)	Duration of leachate collection (min)	Q (ml/min)
1	100	2168.5			
2	10	217	38	6	6.333
3	20	433.7	89	12	7.417
4	30	650.5	226	20	11.3
5	40	867.4	655	50	13.1
6	50	1084.2	870	55	15.82
7	60	1301	1148	68	16.88
8	70	1518	1302	75	17.36
9	80	1735	1442	80	18.03
10	90	1951.7	1740	93	18.49
11	100	2168.5	1850	96	19.27
12	110	2385.4	2072	108	19.19
13	120	2602.2	2325	120	19.38
14	130	2819.2	2465	125	19.72
15	140	3035.9	2760	137	20.15
16	150	3252.8	2972	148	20.08
17	160	3469.6	3185	154	20.68
18	170	3686.5	3405	162	21.02
19	**180**	**3903.3**	**3756**	**175**	**21.46**

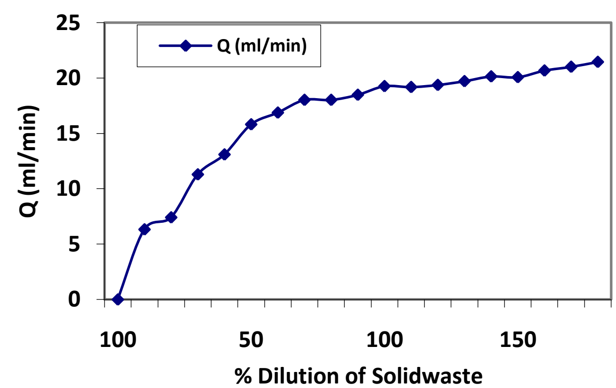

Fig 4 Leachate productions for Lab scale

A.Leachate characterization and statistical evaluation of results

It has been demonstrated that large variations in leachate quality exist for different percentage dilution of Solid waste. Physio-chemical characteristics of leachates collected from Lab scale reactor and In-situ leachate pit for different percentage dilution of Solidwaste are summarized in Table I and II.

B.pH

The pH of the leachate varied widely within the range of 6.75 – 8.3 in Lab scale reactor and 6.9 – 8.23 in In-situ leachate pit. The near neutral pH of leachate samples is also reasonably consistent with the literature

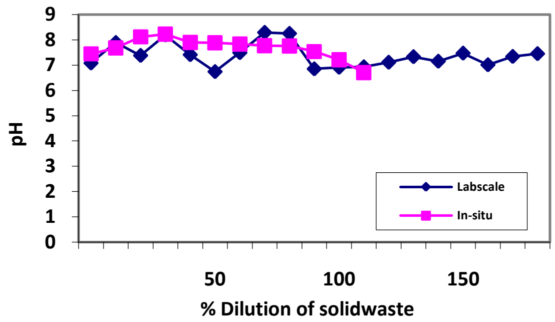

Fig 5 Variation of pH for different % dilution of solid waste

C.Solids and Conductivity

The cumulative leaching of total solids during the study period is depicted in Figure7.

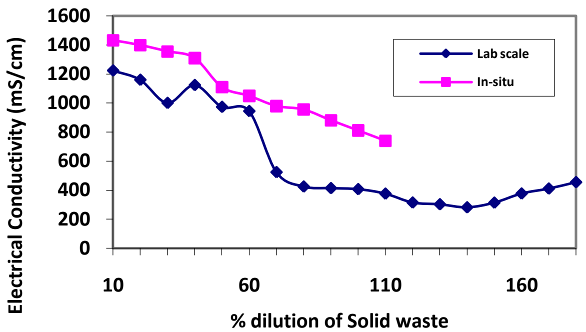

Fig 6. Variation of EC for different % dilution of solid waste

The leaching of solids varied widely between 590 – 950 mg/l in lab scale reactor and 1260 – 2550 mg/l in Field. The electrical conductivity of the leachate from lab scale and field varied widely between 283 - 1332 mS/cm and 741 – 1463 mS/cm, respectively.

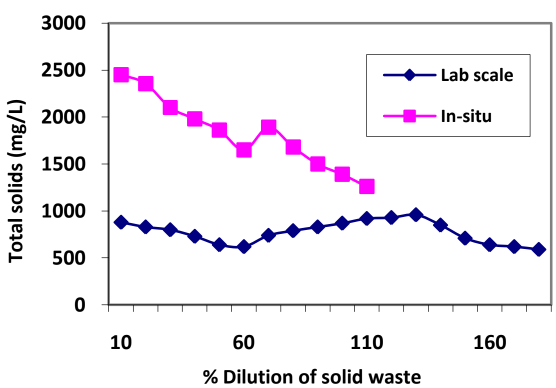

Fig 7.Variation of TS for different % dilution of solid waste

D.Chemicaloxygen demand

The gross parameter of COD may vary from approximately 1050 - 3348mg/l for field leachate samples, down to 66.67 – 1600 mg/l for Lab scale. The high values of leachate conductivity reflect the large content of soluble inorganics. Other organic or inorganic contaminants also follow the trend of decreasing concentrations with increasing leachate quantity.

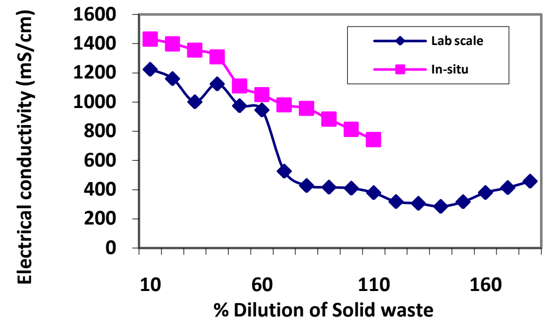

Fig 8. Variation of COD for different % dilution of solid waste

***E.**Chloride*

Chloride as shown in figure 4.8 is generally considered to be a very mobile and non-interacting anion and is considered to be a very conservative anion that is only attenuated during dilution. The chloride concentration varied from 47.86 – 381.8 mg/l for lab scale reactor and 298.43 – 594.25 mg/l for In-situ leachate pit. The cumulative load of chloride leached out from lab and field were around 11.077 kg. Chloride release is not controlled by factors such as pH.

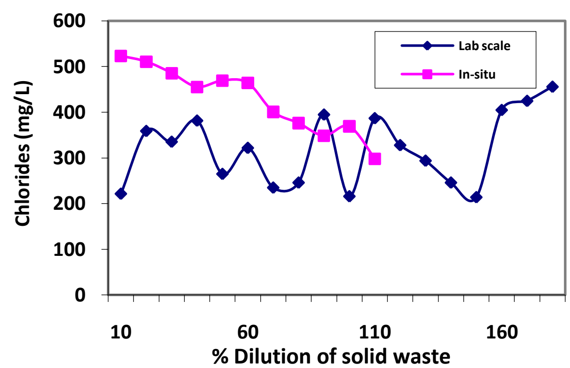

Fig 9. Variation of Chlorides for different % dilution of solid waste

F.Effect of reaction time

The results demonstrated that organic materials were rapidly degraded by Fenton's reagent. Most organic removal occurred in the first 20 min. After 20 min, the change of residual COD became insignificant. More foam was observed on the top layer of leachate as the oxidation proceeded. Based on the results, the reaction time for the Fenton's treatment with batch reactor was determined to be 30 min for further experiments.

G. Effect of H2O2/Fe(II) molar ratio

In Fenton process, iron and hydrogen peroxide are two major chemicals determining operation costs as well as efficacy. Determination of the favorable amount of the Fenton's reagent is highly important. In order to investigate the optimum H_2O_2/Fe(II) molar ratio, three different H_2O_2/Fe(II) molar ratios were tested with three different COD strengths.

TABLE IV
COD REMOVAL EFFICIENCY FOR DIFFERENT H2O2/FE(II) MOLAR RATIOS

Molar Ratio / **Influent COD**	**1**	**2**	**3**
940 mg/ L	42 %	62 %	65 %
1050 mg/ L	44 %	58 %	60 %
4800 mg/L	30 %	47 %	51 %

VI. Conclusions

Based on the experimental work carried out on Solid waste the following conclusions are drawn. A future scope of this study are also pointed out below
Major conclusions drawn from the research study are,

1. The systematic monitoring of the physico-chemical characteristics of leachate from lab scale reactor and field in simulated controlled dumps has revealed that the rainfall and the age of the waste has a significant effect on leachate generation and the characteristics.
2. During monsoon, rainwater percolated through the refuse beds and solubilized the constituents, producing a larger volume of dilute leachate, while during the dry summer the concentration of certain pollutants (Sulphate, Total solids and Chloride) were higher.
3. However, the characteristics of leachate are also affected by many site specific factors such as waste composition, moisture availability, and climate.
4. It takes almost 61 days for the landfill to become completely saturated.
5. The effects of major parameters on the Fenton process were evaluated using a batch reactor. It was proved that organic materials in leachate could be successfully removed by Fenton's reagent. Favorable operation conditions were thoroughly investigated. The oxidation of organic materials by Fenton's reagent was so fast that it was complete in 30 min with batch experiments.
6. The oxidation of organic materials in the leachate showed pH dependence and was most efficient in thepHrange of 3. A favorable H_2O_2/Fe(II) molar ratio was 2, and organic removal increased as dosage increased at the favorable H_2O_2/Fe(II) molar ratio.

References

[1 Akesson M,Nilsson P, (1997) Seasonal changes of leachate production and quality from test cells, Journal of environmental engineering , vol. 123, n^{o}9, pp. 892-900

[2] Akyurek,(1995.) "Trends in landfill leachate characteristics." Presented at the Eighteenth International Madison Waste Conference, Department of Engineering Professional Development, Madison.

[3] ASTM Method D-4874, (1995) Standard Test Method for Leaching Solid Waste in a Column Apparatus

[4] APHA (1995) Standard Methods for the Examination of Water and Wastewater, 19th edn. American Public Health Association, Washington, DC.

[5] Al-Yousfi, and Pohland, F.G. (1998) Strategies for Simulation, Design, and Management of Solid Wastes Disposal Sites as Landfill Bioreactors, Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 2(1), 13-21.

[6] AyrtonFigueiredo Martins (1998), Advanced oxidation processes applied to effluent streams from an agrochemical industry, Pure &Appl. Chern.,Vol. 70, No. 12, pp. 2271-2279.

[7] Baccini et al, (1987). Water and element balances of municipal solid waste landfills. Waste Manage. Res. 5,483-499.

[8] Bagchi, A. (1994) Design, construction and monitoring of landfills, John Wiley & Sons INC., chapter 3,

[9] Barbre C. and Marais P. J. (1984) Recirculation of leachate as a landfill management option: benefits and operational problems. Q. J. Eng. Geol. London 17, 9±29.

[10] Barlaz, R.K. Ham, and D.M. Schaefer, "Methane production from municipal refuse: A review of enhancement techniques and microbial dynamics," Critical Reviews in Environmental Control, 19(6): 557 (1990).