

An Experimental Study of Effect of Recirculation on Leachate Characteristicsthrough Landfill Biofilter

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Abstract

As the water moves through the deposited waste mass of the sanitary landfill which is often drawn; it takes along the soluble constituents from the deposited mass which is undergoing deposition partly aerobically and partly anaerobically. The leachate contains in addition to the easily soluble constituents the products of decomposition of raw MSW also. Thus the various pollutants contained in leachate contribute a large amount of COD, BOD, Hardness and also some heavy metals. Various researches have carried out extensive studies on the mechanism of transport of such pollution by the leachate and the variation in the concentration of the pollutants has been extensively reported. As per MSW rules only such leachate which satisfies specific standards can be disposed off on the land or in receiving water. The raw leachate has hence to be treated to bring the pollutants within acceptable limits. The high cost of conventional treatment has lead to consideration of unconventional methods.

Hence it is worthwhile to identify treatment facilities and method for the management of leachate which has negative impacts on the environment and human health. The present paper aims to carry out experimental investigation of leachate treatment through landfill biofilter and also the effect of recirculation of leachate and type of soil used as filter media on leachate characteristics.

Keywords: Landfill biofilter, leachate recirculation, leachate treatment, liner system, Sanitary landfill.

Introduction

What is Leachate?

Leachate is defined as water that has percolated through the wastes (rainwater or groundwater

seepage), a source of soil and groundwater contamination. Leachate varies in composition regarding the age of landfill and the type of waste that it contains. Leachate usually contains both dissolved and suspended material. The Municipal Solid Waste (MSW) in 90% of the towns and cities in India is disposed off in an uncontrolled manner on land. The Municipal Solid Waste (Management & Handling) Rules, 2000 have stipulated that the non-biodegradable portion of solid waste should be disposed off only in properly designed sanitary landfills. Out of the rain water falling on the landfill a part flows on the surface as surface runoff, another part is evaporated and lost to the atmosphere through evapotranspiration from the surface of landfill and from the vegetation growing over it. The remaining part enters the landfill and percolates down. As the infiltrating water moves down it fills the voids in the deposited mass till the landfill mass reaches its field capacity. Field capacity is the moisture content of solid waste after gravity drainage is complete. Any additional quantity of water cannot therefore be absorbed and is released as leachate (Thorvat, *et. al*, 2010; Thorvat, *et. al*, 2014). This leachate then moves down and is collected by the under drainage system of the sanitary landfill and taken out where it has to be properly treated before its disposal either in receiving water or on land.

Generation of Leachate

Leachate is primarily generated from precipitation and then is principally influenced by climatic conditions such as annual precipitation, runoff, infiltration, evaporation, transpiration, freezing; mean ambient temperature, waste composition, waste density, initial moisture content, and depth of the landfill." All of these are taken into consideration in the "water balancing" equation, to figure the amount of water available for leachate production. Generally little or no leachate will be

produced until the landfill is finished and becomes saturated. The decomposition of solid waste, which produces leachate, is separated into three different phases that are: aerobic, anaerobic, and biological (Thorvat, and Chavan, 2013; Thorvat, and Joshi, 2013)). These will all be discussed in more detail in the following sections.

Annual precipitation data is rarely an accurate measure of water because of its variability both seasonally and geographically. Runoff and infiltration are most often modeled to determine their role. A good part of the water which is deposited on the land surface is taken away by runoff before it has a chance to penetrate the soil. The amount of water lost to runoff is a function of the soil type, topography, and vegetation present. The landfill cover is full of flaws that increase the infiltration of precipitation, and decrease the runoff, compared to normal untouched land. This must be taken into account when figuring the amount of water expected.

Evaporation losses must also be figured into the water balancing equation. The water lost to evaporation will also be a function of the hydraulic conductivity of the soil, the vegetation, and environmental conditions present. The evaporation of excess unwanted water is a great asset to a landfill that has an abundant supply of water, and is encouraged by the designers. The losses from evaporation can be fairly accurately estimated or measured.

Environmental Impacts

1. **Water pollution-** Surface and groundwater bodies can get contaminated by leachate and hazardous substances released from the dumpsite. Potable groundwater may become toxic.
2. **Soil pollution-** Toxic substances released into the soil are absorbed by surrounding vegetation and move into the food chain.
3. **Air pollution-** Open burning is the disposal behavior of municipal refuse, construction scraps, agricultural residues, etc., by uncontrolled combustion in an open yard or in barrels. These conditions result in incomplete combustion and release harmful air pollutants, such as fine particulates, PAHs, heavy metals, and dioxins. Open burning is common in urban and rural areas that have volume-rate disposal policies, which charge for disposal of household wastes based on the amount disposed.
4. **Dump fires-** when waste decomposes at dumpsites, methane is released; this gas is inflammable and can result in explosions or dump fires. The smoke from such fires contains toxic substances and is inhaled by the surrounding populace.

5. **Global warming-** Methane released from dumpsites is one of the main contributors to global warming.
6. **Source of disease-** Dumpsites breed flies, rodents, and pests which carry diseases into the surrounding population.
7. **Other impacts-** Foul smell, visual ugliness, bird menace which can be a hazard to aero planes.

Design Objectives of Landfill

1. Minimizing possibility of contamination of surface and ground water and control gaseous emissions.
2. Utilize excavated material as cover material.
3. Prevent rainwater from entering the landfill.
4. Accept the waste which falls under the concentration limit as stated.
5. Base liner and capping shall be a composite system comprising of clay layer and synthetic membrane as approved by SPCB.
6. A leachate collection and drainage system must be provided at base immediately above the liner to ensure that head of leachate will not exceed 300 mm during any season of the year.
7. To exclude rainwater, the landfill has a storm drainage system. Plastic drainage pipes and storm liners collect water from areas of the landfill and channel it to drainage ditches surrounding the landfill's base.

Treatment and Disposal

On-Site Treatment of Leachate

When discharge to a sewage system is not feasible, constructing treatment facilities on-site with the sole purpose of treating leachate may be necessary. These facilities will add to the cost of a new facility, but may be required to meet environmental standards.

Onsite treatment reduces high concentrations of COD and BOD. Retention times from 10 to 50 days can result in the removal of 90% of COD and ammonia. Nitrification of high concentrations of ammonia can be achieved by extended aeration and at increased temperatures. The addition of phosphoric acid may be required for microbial growth and inputs of sodium hydroxide for pH adjustment. The operating parameters vary, depending on the quality and nature of the leachate and extended trials are required to determine these for a specific leachate. Aerobic treatment results in a reasonable reduction in COD and ammonia and can be accomplished at quite high conductivity and chloride levels. However, the resulting effluents will still have a relative high COD and high conductivity, which is mainly related to chloride levels. Polishing of the leachate has included the

use of artificial reed beds and ozone treatment prior to discharge to a watercourse.

These methods have been applied widely to the on-site treatment of leachate from domestic waste sites, although waste sites that have accepted limited hazardous waste have also been successfully treated.

Off-Site Treatment of Leachate

This involves storage, pretreatment and transportation of leachate to offsite facilities not associated with the landfill. e.g. industrial effluent treatment facility etc. This will be feasible where offsite facilities are available at a reasonable distance and where pretreatment requirement for the Leachate are not very stringent.

Recirculation

Recirculation is another management technique for leachate. When leachate is recirculated through the waste pile, the decomposition process in the landfill speeds up, resulting in a shorter time for the landfill to stabilise. The technique, however, does not eliminate the leachate. Ultimately, the leachate will have to be treated by one of the other methods. Especially in cases where too much leachate is produced for storage thereof in evaporation ponds (Thorvat, and Chavan, 2016).

The objectives of recirculation are to:

1. Encourage early establishment and methanogenesis that is promoted by a high moisture content and the movement of moisture. It also promotes degradation of hazardous organic and other biodegradable waste.
2. Develop a more uniform quality of leachate in order to facilitate an easier operation of the landfill site.
3. Encourage leaching of solid industrial wastes.
4. Minimise dry zones in the waste that would remain undegraded for many years.
5. Take up absorptive capacity and reduce fluctuations in leachate flow rate.
6. Promote enhanced evaporative losses by surface spraying.
7. Provide temporary storage of short-lived peak flow rates.

The main advantage of recirculation of leachate for a landfill operator is the increase in the waste stabilization rate and the considerable decrease in leachate volume that can be obtained.

Objectives of Present Study

1. To prepare a working model on bio-filter for treatment of leachate.

2. To carry out laboratory analysis for various parameters for black cotton soil.
3. To carry out laboratory analysis for various parameters for leachate coming out from the bottom of experimental setup.
4. To Re-circulate the leachate in order to lower down the leachate characteristics within permissible limits.
5. To study effects of Re-circulation and type of soil used on leachate characteristics.

Methodology of Present Study

1. To prepare a working model and experimental setup for treatment of leachate.
2. To carry out various experimental analysis such as pH, specific gravity, liquid limit, plastic limit, moisture content, silt, clay, fine sand, coarse sand, density etc.
3. To carry out laboratory analysis for various parameters such as Moisture content, pH, volatile substances, non volatile substances, calorific value.
4. To carry out laboratory analysis for various characteristics of raw leachate used in the study such as COD, BOD, pH, Total solids, Volatile solids, Dissolved solids, suspended solids, chlorides, Alkalinity, Total Hardness, Ca Hardness, Mg Hardness, sulphates, color.
5. To study the various effects such as reduction in organic loads, COD, BOD, Alkalinity and time consuming process for leachate disposal.

Study Area

The geographical area of Kolhapur district is about 7685 km², and the population of the district is about 35,15,413 of which Kolhapur city's population is about 5,79,281. The Kolhapur city is situated on latitude 16° 42' N and longitude 74° 14' E (Thorvat, *et al.*, 2012). Majority of the solid waste producing sources are present in Kolhapur city such as municipal solid waste (MSW), biomedical waste etc. Many private as well as Government agencies help in the collection, treatment and disposal of the solid waste. One of the enterprises named 'DAS' collects biomedical wastes from the clinics and hospitals situated in the Kolhapur city. The municipal solid waste generated in the city is collected and sent to the Zoom biofertilizers where it is treated further. The current information about the MSW production in the city is collected from Kolhapur Municipal Corporation (KMC) as well as by visiting the Zoom fertilizer project site. The overall information about solid waste generation, collection system and disposal methods is collected.

Total area covered for collection is 66.82 km. City is divided into 11 sanitary wards and collection is done separately. In Kolhapur city, everyday 165

MT of solid waste is generated at the rate of 375 gm/capita/day and the daily collection of all 165 MT of solid waste is done by various ways. Door to door collection of solid waste by 'Ghanta Gadi' is carried out from 06.00 am to 02.00 pm daily. At same places two separate bins are provided for biodegradable waste and non-biodegradable. The job of collection of solid waste is done by 1050 sweepers and 110 supportive staff. There are 937 RCC circular bins, 245 RCC rectangular bins, 22 dumpers, 20 RCC containers and 4 heaps provided for collection of solid waste from various wards. There are 22 collection vehicles containing 12 trucks, 6 tippers, 2 tractors, 2 dumper placers and 6 refuse collectors. Solid Waste collection from hotels and restaurants is done separately with nominal charges. Building construction waste is a major problem as these building debris are disposed indiscriminately on road or in garbage bins which amounts more to domestic solid waste. It has become difficult to separate it from biodegradable waste.

Experimental Setup

The experimental set up comprised of a 110 mm diameter 1.5 meter long PVC pipe column filled with 0.5 meter deep MSW layer obtained from the Kolhapur disposal site. A 0.15 meter thick layer of locally available black cotton soil was provided both at the top and bottom of the MSW column. The bottom soil layer was supported by a 0.05 meter thick layer of pebbles. The raw leachate was applied to the bioreactor at 175-525 L/m³ of MSW per day. The leachate coming out from the bottom was collected and analyzed for various parameters. The leachate was then again recirculated through

the bioreactor and the treated leachate was again analyzed for various parameters to evaluate the result of first recirculation. Similar recirculation was carried out for the second time and again for the third time and every time the samples collected from the bottom was analyzed for various parameters.

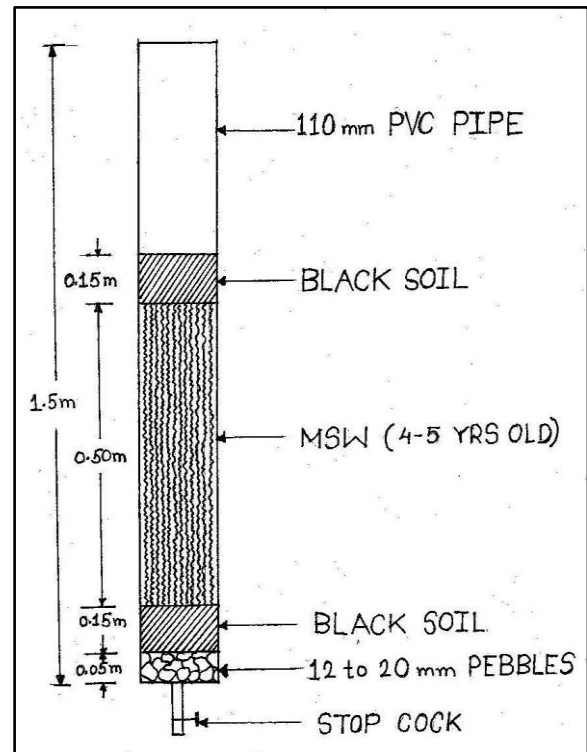


Figure 1: Experimental setup of landfill biofilter

Table 1: Source and quantity of municipal solid waste in Kolhapur city

Sr. No.	Description	Quantity	Unit
1	Area covered for collection of MSW	66.82	km ²
2	No. of households covered	90000	No.s
3	Total MSW generation	165	MT/day
4	Quantity of domestic MSW	105	MT/day
5	Quantity of commercial MSW	15	MT/day
6	Quantity of industrial (non-toxic and non-hazardous) waste	10	MT/day
7	Quantity of waste from markets	25	MT/day
8	Quantity of waste from hotels and restaurants	10	MT/day
9	Household (Urban)	40	MT/day
10	Slums	15	MT/day
11	Street sweeping	20	MT/day
12	Shops & commercial establishments	15	MT/day
13	Markets	20	MT/day
14	Hotels, restaurants, eating houses	10	MT/day
15	Gardens, parks, fairs	10	MT/day
16	Slaughter houses	5	MT/day
17	Building sites (debris, earth, etc.)	10	MT/day
18	C/N ratio	25	%

Laboratory Analysis and Results

Table 2: Readings for sample 1: (Period: 4 days)

Parameters	Raw leachate	1 st circulation	2 nd Recirculation	3 rd Recirculation
pH	6.9	7.01	7.12	7.18
Alkalinity(mg/l)	930	780	695	620
COD(mg/l)	2800	1984.8	1640	1470
Chlorides(mg/l)	1980	1460	1220	1140
Hardness(mg/l)	2600	1760	1340	1280

Table 3: Incremental increase in removal for sample 1

Parameters	% Removal after 1 st circulation	% Removal after 2 nd recirculation	Incremental increase after 2 nd recirculation	% Removal after 3 rd recirculation	Incremental increase after 3 rd recirculation
Alkalinity(mg/l)	16.12	25.26	9.14	33.33	8.07
Chlorides(mg/l)	26.26	38.38	12.12	42.42	4.04
Hardness(mg/l)	32.30	48.46	16.16	50.76	2.30
COD(mg/l)	29.11	41.42	12.31	47.5	6.08

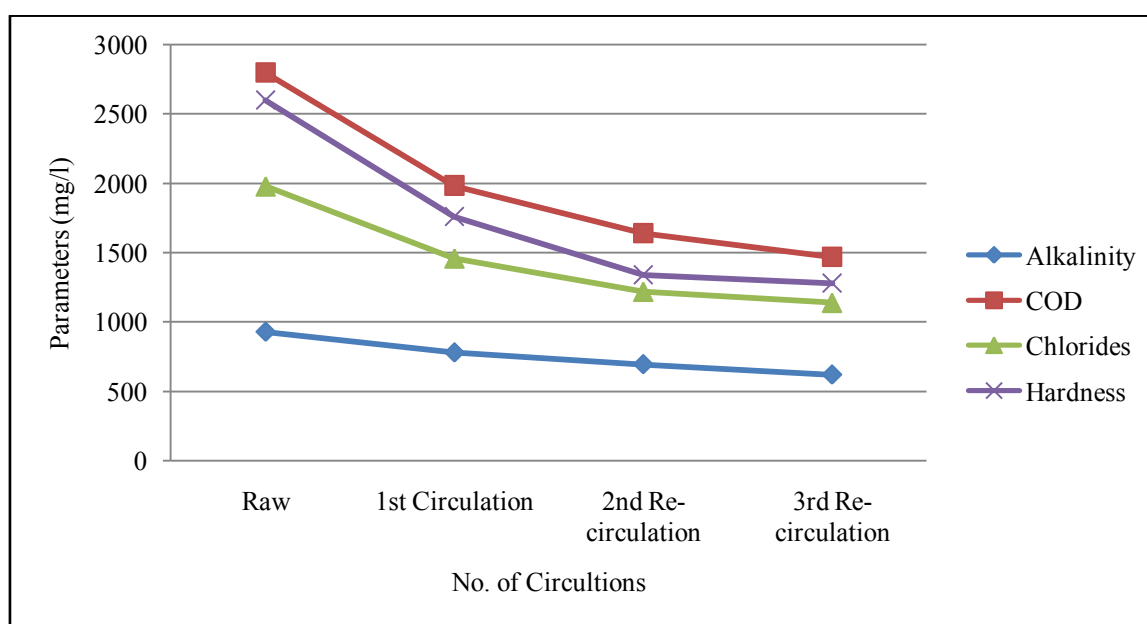


Figure 2: Results of recirculation (4 days period)

Table 4: Readings for sample 2: (Period: 6 days)

Parameters	Raw leachate	1 st circulation	2 nd Recirculation	3 rd recirculation
pH	6.79	6.95	7.02	7.24
Alkalinity(mg/l)	1100	920	850	790
COD(mg/l)	3040	2180	1660	1340
Chlorides(mg/l)	2101.6	1775	1292.2	1079.2
Hardness(mg/l)	3800	1960	1370	1350

Table 5: Incremental increase in removal for sample 2

Parameters	% Removal after 1 st circulation	% Removal after 2 nd recirculation	Incremental increase after 2 nd recirculation	% Removal after 3 rd recirculation	Incremental increase after 3 rd recirculation
Alkalinity(mg/l)	16.36	22.72	6.36	41.81	19.09
Chlorides(mg/l)	15.54	38.51	15.52	48.64	0.53
Hardness(mg/l)	48.42	63.94	22.97	64.47	10.13
COD(mg/l)	28.28	45.39	17.11	55.92	10.53

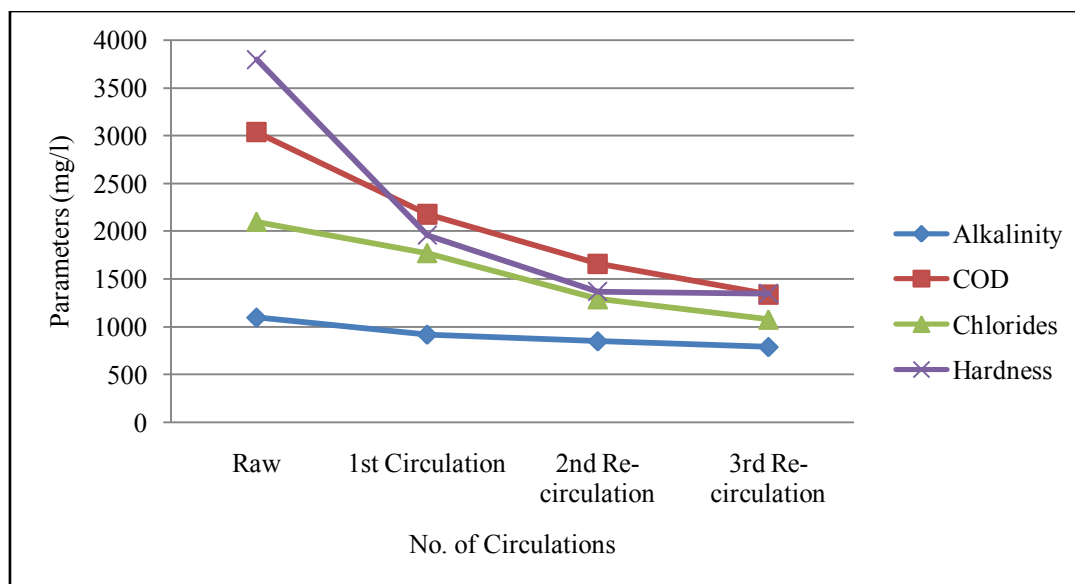


Figure 3: Results of recirculation (6 day period)

Table 6: Readings for sample 3: (Period: 12 days)

Parameters	Raw leachate	1 st circulation	2 nd Recirculation	3 rd recirculation
pH	6.09	6.26	6.81	7.02
Alkalinity(mg/l)	1760	1050	830	760
COD(mg/l)	3240	2360	1980	1790
Chlorides(mg/l)	2430	1775	923	810
Hardness(mg/l)	4050	2650	1830	1440

Table 7: Incremental increase in removal for sample 3

Parameters (mg/l)	% removal after 1 st circulation	% removal after 2 nd recirculation	Incremental increase after 2 nd recirculation	% removal after 3 rd recirculation	Incremental increase after 3 rd recirculation
Alkalinity(mg/l)	40.34	52.84	12.50	56.81	3.97
Chlorides(mg/l)	26.95	62.01	35.06	66.66	4.65
Hardness(mg/l)	34.56	56.81	22.25	64.44	7.63
COD(mg/l)	27.16	38.88	11.72	44.75	5.87

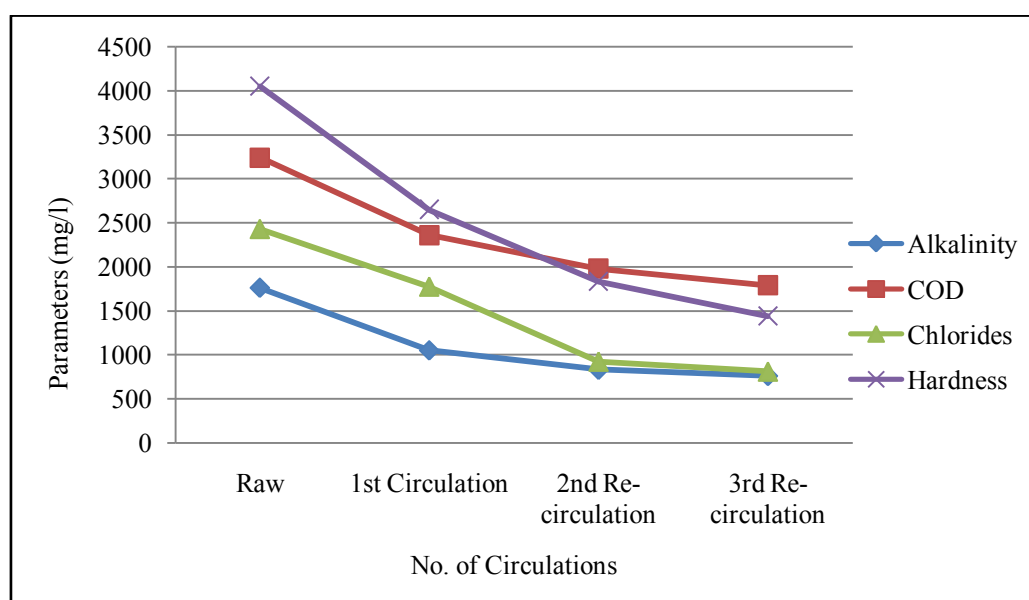


Figure 4: Results of recirculation (12 days period)

Conclusion

1. The percentage removals for 1st sample of 4 days period after third re-circulation were 33.33, 42.42, 50.76, and 47.50 for alkalinity, chloride, hardness and COD respectively.
2. The percentage removal for 2nd sample of 6 days period after third re-circulation was 41.81, 48.64, 64.47, and 55.92 for alkalinity, chloride, hardness and COD respectively.
3. The percentage removals for 3rd sample of 12 days period after third re-circulation were 56.81, 66.66, 64.44, and 44.75 for alkalinity, chloride, hardness and COD respectively.
4. The re-circulation of the leachate through a biofilter results in increased removal of the pollutants in the leachate.
5. It can be seen that the additional increase in the removal efficiency goes on decreasing during the successive recirculation.

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