Soil Pollution near a Municipal Solid Waste Disposal Site in India

Sruti Pillai, Anju Eizbath Peter, Sunil B.M., and Shrihari S.

Abstract--The Municipal Solid Waste disposal site for the city of Thrissur, in Kerala, India, has become an overflowing landfill because of the indiscriminate dumping of solid waste at the site. Gas and leachate generation are inevitable consequences of practice of solid waste disposal in landfills. The migration of gas and leachate away from the landfill boundaries present serious environmental concerns which include, and are not limited to, fires and explosions, vegetation damage, unpleasant odour, landfill settlement, ground water pollution, soil pollution and global warming. Leachate and soil samples were collected from this landfill-site and its adjacent area to study the possible impact of leachate percolation on soil quality. Concentration of various physicochemical parameters and engineering properties were determined in soil samples. Conductivity and compaction characteristics of soil were studied. The study indicated that leachate can modify the soil properties and significantly alter the behaviour of soil. Effect of leachate on physicochemical and geo-engineering properties of soil were estimated by treating it with synthetic leachate. There is a general deterioration in soil properties which is attributed to the chemistry of leachate and of soil

Keywords--Municipal Solid Waste, Leachate, Landfill, Geo-engineering.

I. Introduction

HUMAN beings produce a large quantity of wastes in various forms, often making our environment filthy and unhealthy. Although the Municipal Solid Wastes (Management and Handling) Rules 2000 of India [1] makes it obligatory for all urban local bodies to upgrade their waste collection, transportation, and processing/disposal systems, very few urban local bodies have made any substantial progress in this regard. Design and implementation of Sustainable Municipal Solid Waste Management Systems (SMSWS) is a real challenge for developing countries. This is particularly so in places with very high urbanization rates and very low public awareness.

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II. Literature Review

Solid waste is used to describe non-liquid waste material arising from domestic, trade, commercial & public services. It comprises of countless different materials. Dust, Food wastes, packaging in form of paper, metal, plastics or glass, discarded clothing, garden wastes, pathological waste, hazardous waste & radioactive waste [2]. The properties of Solid waste produced differs in different countries. The organic matter in solid waste in developing countries is much higher than that in the waste in developed countries [3]. But the waste characteristics change slightly with respect to different geographical regions and seasons, however, the influence of seasonal variation is insignificant [4].The organic content of this waste can be converted easily to biomanure and other useful products. Studies have been done on Anaerobic digestion [5], Biomethanation [6],[7] and composting [8] as suitable methods.

The most common method of waste disposal in India is dumping on land, because it is the cheapest method of waste disposal. However, this requires large area and proper drainage. The land disposal of municipal and industrial solid waste is potential cause of groundwater contamination. Unscientifically managed dumping yards are prone to groundwater contamination because of leachate production. Leachate is the liquid that seeps from solid wastes or other medium and have extracts with dissolved or suspended materials from it [9]. The volume of leachate depends principally on the area of the landfill, the meteorological and hydro-geological factors and effectiveness of capping. It is essential that the volume of leachate generated be kept to a minimum and also ensure that the ingress of groundwater and surface water is minimized and controlled. The volume of leachate generated is therefore expected to be very high in humid regions with high rainfall, or high run off and shallow water table [10].

Leachate from the solid waste dump has a significant effect on the chemical properties as well as the geotechnical properties of the soil. Leachate can modify the soil properties and significantly alter the behaviour of soil [11]-[15]. Addition of a chemical may affect the behavior of soil. Ramakrishne gowda et al [16] studied the effect of interaction of shedi soil containing alkali on various geotechnical properties such as

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the index properties, compaction characteristics, volume change behavior, strength characteristics and hydraulic conductivity. It was seen that though the plasticity index of soil decreases and optimum moisture content increases with increasing concentration of alkali content in the fluid, the shear strength of soil decreases essentially due to decrease in the cohesion of the soil particles.

III. Materials And Methods

A. Study Area

The study area is located about 5 km north of Thrissur city (10°30′49″N, 76°11'9"E), in Kerala state, India. The volume of waste being dumped at the dump yard was 55 tonnes/day in 2011. The waste dumped at this site includes domestic waste, e.g. kitchen waste; paper, plastic, glass, cardboard, cloths. Construction and demolition waste consisting of sand, bricks and concrete block are also dumped. Further waste from the poultry market, fish market, slaughterhouse, dairy farm and non-infectious hospital waste is also dumped. The site is a non-engineered low lying open dump, a huge heap of waste up to a height of 12-20 m. The waste is dumped irregularly without segregation, except the rag pickers who rummage through the garbage and help in segregating it.

B. Sampling and Analytical methods

Since the landfill site was not equipped with a leachate collector, the leachate collected at the base of the landfill was sampled randomly from three different locations and were mixed prior to its analysis.

After the sampling, the leachate sample was immediately transferred to the lab and stored in cold room (4^{o}C). The analysis was done as per the standard methods [17]. Various physico-chemical parameters examined in leachate sample included, pH, electrical conductivity (EC), total dissolved solids (TDS), Total suspended solids(TSS)chemical oxygen demand (COD), biological oxygen demand (BOD), total alkalinity (TA), total hardness (TH), calcium , magnesium , sodium , potassium ,chloride , Sulphates and Nitrates. The results of the analysis were compared with standards prescribed in Municipal waste Municipal Solid Wastes (Management and Handling) Rules [1].

A synthetic leachate was used instead of natural leachate in the study. The synthetic leachate was simulated to have a composition similar to the leachate that was collected between August and October 2011.

C. Sampling of soil

Soil samples were collected from the dumpsite, by removing the surface debris and subsurface soil dug to a depth of about 30cm and 1m with a hand auger. 30 Kg of soil sample was taken into the sterile containers and labelled. The soil samples were carried to NITK Surathkal laboratory and analysed for soil chemical properties, soil consistency limits and other properties.

The soil samples were analysed for various chemical characteristics and for soil consistency limits such as liquid limit, plastic limit, shrinkage limit, plasticity index, specific gravity and hydraulic conductivity of soil in the laboratory.

Table 1
Chemical Composition Of Synthetic Msw Leachate

Sodium Chloride (NaCl)	749.33 mg/L
Sodium Hydrogen carbonate ($NaHCO_3$)	1349.69 mg/L
Sodium Nitrate ($NaNO_3$)	141.93 mg/L
Potassium Hydrogen carbonate ($KHCO_3$)	3475.26 mg/L
Ammonium Hydrogen Carbonate (NH_4HCO_3)	145.509 mg/l
Ammonium sulphate $(NH_4)_2SO_4$	27.65 mg/L
Magnesium Sulfate ($MgSO_4.6\ H_2O$)	3289.61 mg/L
Calcium Chloride dehydrate purified ($CaCl_2.2\ H_2O$)	1161.46 mg/L
Ferrous chloride tetrahydrate ($FeCl_2.4\ H_2O$)	14.89 mg/L
Dextrose	4000 mg/L
Bioreactor Effluent	5 ml

D. Preparation of soil sample for soil chemical analysis

The collected soil sample was air dried for two days, crushed with a wooden mallet and passed through 2.36 mm sieve (425 micron sieve for estimation of pH). 260 g of soil was taken and was treated with 15%, 20% and 25% synthetic leachate, mixed thoroughly and kept for 48 hours. The supernatant was then filtered and used for soil chemical analysis.

E. Preparation of soil sample for soil properties

For the determination of soil properties the soil sample was air dried in laboratory and sieved through 425 micron IS sieve for determination of consistency limits. The soil sample was air dried in oven at 110^{O}C and sieved through 4.75 mm standard sieve for determination of UCC strength. The maximum dry density and optimum moisture content values were established for uncontaminated soil. To vary the degree of contamination the dry soil samples were mixed with 15%, 18%, 20% and 25% leachate by weight of dry soil. A light compaction and hydraulic conductivity tests were carried out on soil samples after 48 hours of contamination. To study the hydraulic characteristics of soils after contamination with leachate the soil specimens were compacted to corresponding standard Proctor maximum dry density using standard Proctor optimum moisture content.

VI. Results And Discussion

A. Physico-chemical analysis of leachate samples

The average characteristics of the leachate sample collected from the Lalur dumping site is presented in Table 2. The relatively high values of EC and TDS indicate the presence of inorganic materials in the samples.

B. Physico-chemical analysis of Soil Sample

The leachate generated at bottom of landfill carries numerous contaminants to the soil surface and to adjacent areas. During percolation of leachate through the soil, leachate undergoes various processes such as physicochemical decomposition process, ion exchange reactions, chemical alterations, oxidation, hydrolysis etc. These reactions alter the soil original properties. The variation in soil chemical properties with varying concentration of leachate is presented below.

TABLE II
AVERAGE CHARACTERISTICS OF LEACHATE SAMPLES

Sl. No.	Parameters	Standards of disposal of treated leachate	Sample
1.	pH	5.5-9.0	6.8
2.	EC	Not specified	5.97 ms/cm
3.	COD	250 mg/L	1152 mg/L
4.	BOD	30 mg/L	80 mg/L
5.	TDS	2100 mg/L	2.56×10^6 mg/L
6.	Total Alkalinity	600 mg/L	2,915 mg/L
7.	Total Hardness	600 mg/L	700 mg/L
8.	Ca Hardness	500 mg/L	316.8 mg/L
9.	Mg Hardness	416 mg/L	393.2 mg/L
10.	Iron (Fe)	-	4.094 mg/L
11.	Sodium (Na)	200 mg/L	760 mg/L
12.	Potassium(K)	-	1,525 mg/L
13.	Sulphates	250 mg/L	20.63 mg/L
14.	Chlorides	250 mg/L	960 mg/L
15.	Nitrates	-	103.55 mg/L

The observed value of pH in the three soil samples with varying concentrations of leachate is presented in Fig. 1. The pH of control sample was slightly acidic. There was no change in pH due to addition of leachate. A decrease in pH as the concentration of leachate increased was observed.

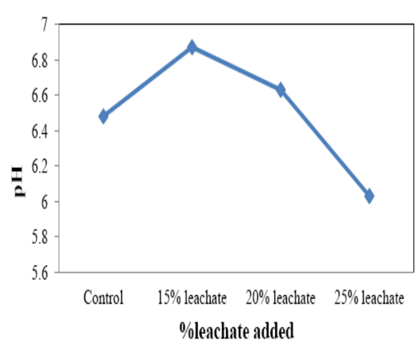

Fig. 1 Variation of pH in Soil with different concentration of leachate added

This may be due to the formation of organic acid as a byproduct of decaying organic matter. This can also be due to the acidic nature of the synthetic leachate itself.

Conductivity is a measure of ability of a material to transmit charges. The conductivity of the soil samples initially increased with increasing concentration of leachate, but was found to decrease for the sample with 25% leachate.

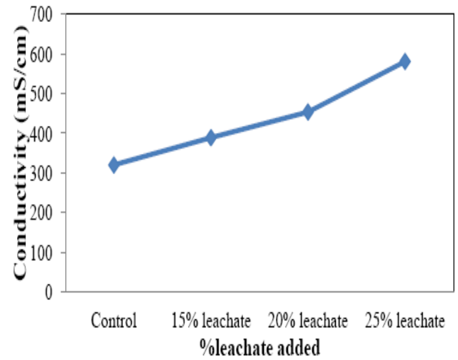

Fig. 2 Variation of Conductivity in Soil with concentration of leachate added

The increase in electrical conductivity may be possibly due to the increase in dissolved salts of sodium and magnesiumin soil due to application of leachate. The levels of Na^+, K^+,Ca^{+2},and Mg^{+2} present in the leachate were sufficiently high that they could effectively exchange some of the cations present in the soil during diffusion.

The observed values of hardness for the soil sample is shown in Fig.3. The hardness of the control sample was found to be much higher than the hardness of the polluted samples. There is a slight increase in the hardness of the soil sample,this may be attributed to the increasing calcium concentration in leachate.

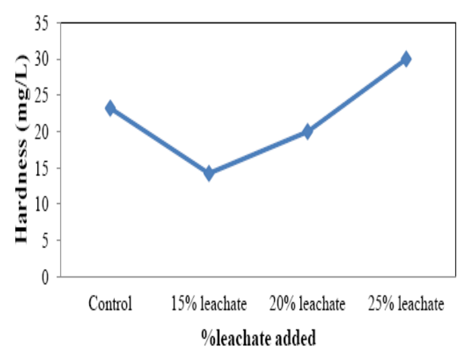

Fig.3Variation of hardness in Soil with concentration of leachate added

The variation in chloride concentration is shown in Fig 4. The concentration of chloride in control soil was found to be much less than that in polluted soil,as well as the polluted soil which was treated with leachate. But it was observed that the chloride concentration did not vary much with increasing concentration of synthetic leachate.

Sulphates in soil did not show any variation.(Fig.5).The concentration of ammonia is very high in the control soil as compared to the polluted soil. There is not much change in nitrate concentration even after addition of increasing concentration of synthetic leachate. Under anaerobic conditions the nitrates in the soil reduces when the microorganisms use up the oxygen present with nitrates. Here as the reaction happening is aerobic, there is no decrease in nitrate concentration. Contrary to that there is an increase in nitrates which may be due to increasing nitrate concentration in the leachate (Fig. 6). Again absence of oxygen prevents nitrification and denitrification and due to this the ammonia concentration is not affected by the reactions in soil.

Fig. 4 Variation of Chlorides in Soil with concentration of leachate added

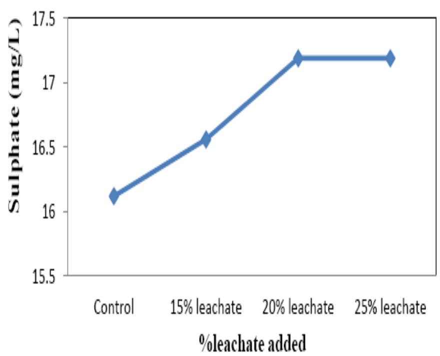

Fig. 5 Variation of sulphates in Soil with concentration of leachate added

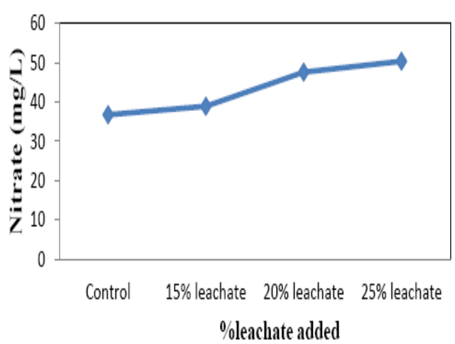

Fig.6 Variation of Nitrates in Soil with concentration of leachate added

C.Variation in soil properties

In conventional soil mechanics, it is assumed that Atterberg limits remain constant for a given soil, but these properties are subject to change when the pore fluid changes. The changes in Atterberg limits depend on intensity, duration, type of contaminant and type of interaction or reaction which happens in soil. In this study the variation in Atterberg limits and other properties of soil are studied with respect to increasing concentration of leachate. Distilled water is applied to soil as control measure.

The effect of leachate on liquid limit of soil is shown in Table 3. The liquid limit decreases with increasing leachate concentration. This may be due to the presence of salts in the leachate. It has been noticed that presence of calcium ion can decrease the liquid limit of soil. The physicochemical properties of soil indicate an increasing calcium concentration which may also be responsible for the reduction in liquid limit. The plastic limit of the soil sample showed an increasing trend upon addition of leachate. The variation in plastic limit may be due to the effect of increasing concentration of contaminants in the soil. There was a marked difference between the specific gravity of the soil under the dump and the control. The specific gravity of the soil sample which was treated with leachate was higher than that of the control sample. Soil with higher specific gravity usually contain organic matter and as such are very compressible.

Permeability tests were carried out on uncontaminated and contaminated soil samples to study the hydraulic conductivity compacted to standard Proctor maximum dry density in the permeability mould. The soil hydraulic conductivity decreased significantly when the permeating liquid which is the synthetic leachate contained microorganisms. The decrease of hydraulic conductivity was caused by reduction of the effective porosity due to pore clogging.

TABLE III
SOIL PROPERTIES IN CONTROL AND CONTAMINATED SOILS

Soil properties		Control	Sample + Leachate			
			15%	18%	20%	25%
Atterberg Limits	Liquid limit(%)	45	39	41	44	47
	Plastic limit(%)	19	17	18	19	20
	Plasticity Index(%)	26	22	23	25	27
	Shrinkage limit(%)	13.42	11.44	8.75	7.17	6.89
Specific Gravity		2.7	2.62	-	2.65	2.73
Dry density KN/m^3		18.8	18.01	-	17.4	17.3
Hydraulic Conductivity (x 10^{-6}) cm/sec		4.629	1.962			

V. CONCLUSIONS

The study evaluated the effect of solid waste dump on the engineering and some chemical properties of the underlying soil for the dumpsite at Lalur. The collected leachate sample from lalur was examined in laboratory and it was found that the physico chemical parameters of the leachate exceeded the specified standards for disposal into surface water bodies or sources. To determine the effect of this soil on leachate a synthetic leachate was prepared which was used to investigate the change in physico chemical properties, hydraulic conductivity, specific gravity and atterberg limits when it comes in contact with the leachate. Soil was contaminated with varying concentrations of leachate to vary the degree of contamination. Various chemical parameters in the soil showed different trends with increasing leachate concentrations. The specific gravity and plastic limit showed an increasing trend upon addition of leachate whereas the hydraulic conductivity and liquid limit decreased. Generally, solid waste dumps have some effect on the Engineering and chemical properties of soil. Not only does it reduces the overall soil strength and consequently its usefulness as a foundation material, it also can result in pollution of ground water sources due to percolation of toxic and hazardous chemical.

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