E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 03 No 01 2018

A Study On Influence Of Real Municipal Solid Waste Leachate On Properties Of Soils In Warangal, India

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Received: Jan 2, 2018. Revised : Feb 22, 2018, Accepted: Feb 26, 2018, Published: 1 March 2018
DOI: 10.24273/jgeet.2018.3.01.1047

Abstract

Warangal city generates three hundred tons of garbage daily which is dropped into the Rampur dump yard by Warangal Municipal Corporation (WMC). Dumping of wastes will lead to the formation of leachate which in turn will cause environmental issues like soil and ground water contamination. Chemical analysis of leachate indicates that calcium, chloride, sodium and magnesium are the major ions, along with organic content. This leads to contamination of soil as well as ground water bodies. In this study, authors have attempted to know the behavior of soil under the influence of leachate. Contaminated specimens were prepared and tested for Atterberg limits, shear strength, swell potential and hydraulic conductivity of inorganic clays, high plasticity, fat clays (CH) and sand-clay mixtures (SC) which are present in the dumping yard. Index properties, hydraulic conductivity and swell potential decreased with increase in leachate concentration. Unconfined compressive strength also showed an increase. The decrease in hydraulic conductivity indicated the clogging of pores. In a nutshell, the present work deals with the impact of leachate on the index and engineering properties of CH and red soil.

Keywords: Soil Contamination, Leachate, Atterberg limits, Unconfined Compressive Strength (UCS), Swell potential, Hydraulic Conductivity.

1. Introduction

Rapid industrialization, urbanization and the rise in community living standards have tremendously increased the generation of enormous quantity of municipal solid wastes (Pandey, 2011; Orhan, 2013). Municipal Solid Waste (MSW) is mostly a combination of domestic wastes such as plastic, electrical, battery wastes and industrial wastes which are more aggressive in nature and causes severe contamination to the soil and surrounding water bodies (Uppot and Stephenson, 1989; Khan and Pise, 1994; Soule and Burns, 2001). In order to prevent the adverse effects caused by the unscientific disposal of these wastes, the most common disposal methods employed are incineration, stabilization/ solidification and landfilling. Among all these methods, landfilling is considered to be a safe and economical method to contain the waste (Reddy et al., 2017). Any negligence in waste management will contribute to numerous environmental problems and may even affect living things. Also, soil-leachate interactions may alter the properties of soil (Ramakrishna et al., 2011; Khan et al., 1994). Leachate is a hazardous liquid produced in landfills when moisture interacts with Municipal Solid Waste (MSW) (Sabrina et al., 2013). The major environmental impacts related to landfill leachate are pollution of the surface and sub-surface water (Peter et al., 2013). Previous studies have shown that the soil properties were changed after interacting with leachate (Mesri and Olson, 1970; Sridharan and Venkatappa Rao, 1979; Sridharan et al., 1981; Sivapullaiah and Savitha, 1997; Sunil et al., 2006). Most of the studies were related to the influence of leachate on geotechnical properties such as Atterberg limits and strength properties, while the swelling behavior of the leachate contaminated soil was largely untouched. This paper mainly deals with the influence of MSW leachate on the swelling behavior of locally available soils (CH and SC: Inorganic clays, low to moderate plasticity).

2. Materials and methodology

2.1 Materials

The material used in this study was collected from NIT Warangal campus and MSW leachate was collected from Rampur open dump yard. The properties of NITW campus soils are presented in table 1 and the soils were classified as highly compressible clay (CH) and clayey sand (SC). The soils used in this study was collected from National Institute of Technology (NIT) Warangal (NITW) campus and MSW leachate was collected from

Rampur open dump yard in Warangal. The properties of NITW campus soils are presented in Table 1 and the soils were classified as CH and SC soil. The leachate, collected from the dump yard, was stored at 4°C to avoid microbial growth. The leachate composition is presented in Table 2.

Table 1. Properties of soil

Parameters	BC soil	Red Earth
Gravel (%)	4	8
Sand (%)	26	51
Silt (%)	30	8
Clay (%)	40	33
Classification	CH	SC
Specific Gravity	2.6	2.67
Liquid Limit (%)	62	58
Plastic Limit (%)	26	24
Plasticity Index (%)	36	34
MDD (g/cc)	1.55	1.59
OMC (%)	24.7	23
FSI (%)	40	30

MDD: Maximum Dry Density,
OMC: Optimum Moisture Content and
FSI: Free Swell Index

Table 2. Chemical composition of landfill leachate

Parameter	Concentration (mg/l)	Method
COD	50800	Open reflux
BOD	28000	Winkler's
EC	13.62	Conductivity Meter
TDS	30000	TDS Meter
TSS	85450	Filtration
TA	11820	Phenolphthalein
TH	112350	EDTA Titration
Chloride	500	Ion Chromatography
Sulphate	72	
Sodium	368	
Potassium	17	
Calcium	876	
Magnesium	318	Ion Chromatography
Manganese	67	
Ammonium	48	
Mercury	3	
Zinc	37	
Iron	67	
Cobalt	38	
Lead	0.7	
pH	7	pH Meter

COD: Chemical Oxygen Demand
BOD: Biological Oxygen Demand
EC: Electrical Conductivity (mi Mhor /cm)
TDS: Total Dissolved solids
TSS: Total Suspended solids
TA: Total Alkalinity
TH: Total Hardness

3. Results and Discussions

3.1 Atterberg Limits

Variation of Atterberg limits for two soil samples (CH and SC) mixed with various percentages of leachate are shown in Figs 2 and 3. The Liquid Limit for uncontaminated CH soil was observed as 62% (Fig 2).

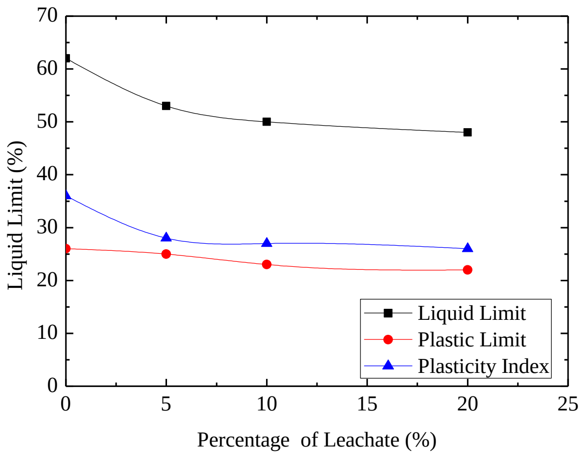


Fig. 2 Variation of Atterberg Limits

Fig. 2 shows that there is a considerable decrease in the liquid limit and plasticity index of the soil after interaction with 5% percentage of leachate. The results indicate that there is no significant differences between the liquid limit and the plasticity index with the increase in the percentage of leachate.
The Liquid Limit for uncontaminated SC soil was found as 58% (Fig. 3).

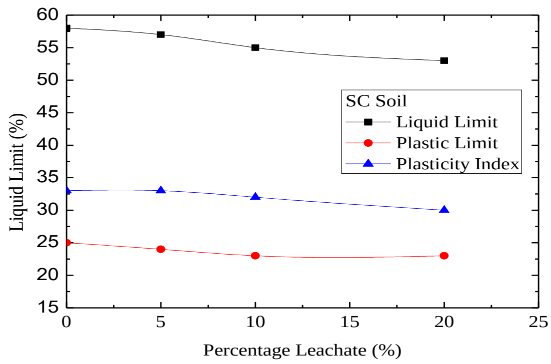


Fig. 3 Variations of Atterberg Limits

After mixing the leachate contaminant to the soil at various percentages (0%, 5%, 10% and 20%) by weight of soil, it was observed that the Liquid Limit showed a decrease with an increase in the concentration of leachate and the variation of these Atterberg limits were slightly less when compared to the CH soil sample. This decrease in the Atterberg limits are due to the predominant influence of the increased electrolyte concentration and organic chemicals present in the leachate on the diffuse double layer thickness of soil. The reduction in the diffuse double layer thickness of soil caused due to the increased electrolyte concentration and the reduction in the inter-particle cohesive nature due to the adsorption of the organic chemicals on the clay particles led to the decrease in the Atterberg Limits (Mathew and Rao, 1997; Eric et al., 2005).

3.2 Unconfined Compressive Strength

The variation of unconfined compressive strength (UCS) in Fig. 4 shows value for the two soil samples (CH type and SC type) mixed with various proportions of leachate. It was observed that the uncontaminated CH soil has a UCS value of 1.7 kg/cm^2. After mixing the leachate with the soil at various percentages (0%, 5%, 10% and 20%) by weight of soil with a curing period of 3 days, it was observed that there is a slight increase in UCS with increase in percentage of leachate. For uncontaminated SC soil, the unconfined compressive strength (UCS) was observed as 1.66 kg/cm^2.

At 20% leachate, the increase in strength was 7% compared with uncontaminated CH soil, whereas the increase is only 4% for SC soil. This increase in UCS is due to the electrolyte concentration in the MSW leachate which results in particle aggregation to a flocculated structure, thereby leading to an increase in the UCS of the soil (Mitchell and Soga, 2005).

3.3 Hydraulic Conductivity

The hydraulic conductivity (k) test on the soil samples were conducted by using variable head permeameter (IS 2720 Part – 17 and Roque and Didier, 2006). The hydraulic conductivity (k) of CH soil and SC soil samples were found as 6.8 × 10^{-7} cm/sec and 1.7 × 10^{-4} cm/sec, respectively after permeating the soil sample with water and 3.2 × 10^{-7} cm/sec and 3.4 × 10^{-5} cm/sec, respectively after leachate permeation. The percent reduction of hydraulic conductivity for CH and SC soil samples were observed as 52% and 80% respectively. The reduction of hydraulic conductivity for CH and SC soils after interacting with leachate is 52 and 80 percentage respectively.

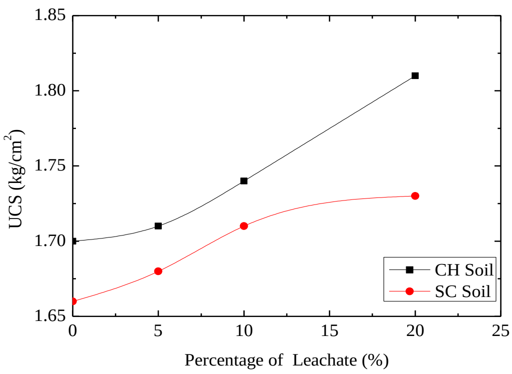


Fig. 4 UCS after interaction with MSW leachate

The reduction in hydraulic conductivity is mainly due to the presence of suspended particles and biological activity (small bacteria) obstructing the flow of leachate through the voids of the soil. Table 3 shows that the reduction in hydraulic conductivity is more in SC soil when compared to CH soil. This is due to the formation of more bacterial activity and suspended particles getting accumulated in the bigger void spaces of SC soil.

Table 3 Variation of hydraulic conductivity for CH and SC soil types with water and leachate.

Soil type	Hydraulic Conductivity (k = cm/sec)		Percentage Reduction in hydraulic conductivity
	Water	Leachate	
CH	6.8 × 10^{-7}	3.2 × 10^{-7}	52
SC	1.7 × 10^{-4}	3.4 × 10^{-5}	80

3.4 Swelling Potential

The swelling potential tests for the two soil types with water and leachate were conducted in the Teflon made consolidation cell and the variation of the swelling potential of the soils are shown in Table 4.

Table 4. Variation of swelling potential for two soil types with water and leachate.

Soil type	Swelling potential (%)		Decrease in swelling potential
	Water	Leachate	
CH	22	13	9
SC	9.7	6	3.7

It was observed that the decrease in swelling potential for CH soil was about 9% more than SC soil which was about 3.7%. From the results of swelling potential, it is observed that the swelling potential depends on clay content and minerals present in the soil. Thus, the CH soil is found to be more reactive with leachate than SC soil.

From Fig 5, it is clear that the percentage swelling for CH soil with water is 22%, whereas swelling potential with Leachate is reduced to 13%. The decrease in the percentage swell is due to changes in the diffuse double layer repulsive forces caused by the presence of organic chemicals and also due to the smaller dielectric constant of leachate (Foreman and Daniel, 1986; Murat and Mustafa 2009).

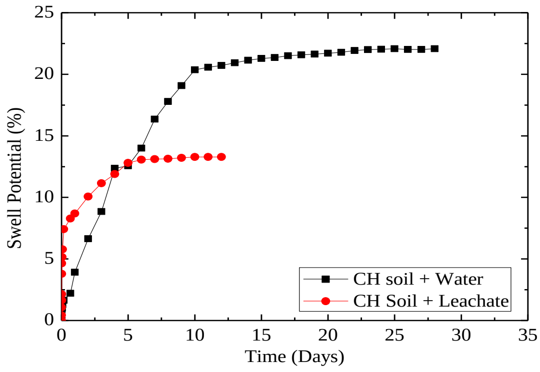


Fig. 5 Variations of swelling potential with water and leachate in CH soil

Also, it was observed that as the percentage of leachate concentration in the soil increased, the plasticity of the soil was reduced simultaneously. Since swelling is a function of plasticity, the swelling potential is reduced.

It was observed from Fig 6, that the swelling potential for SC soil with water is 9.7%, whereas percent swell with leachate is decreased to 6%. The changes in swelling in the soils might be due to changes in repulsive forces and the reduction in the plasticity of the soil. When compared to the SC soil, the CH soil shows more swelling and after interacting with leachate, the swelling of both SC and CH soils reduced significantly.

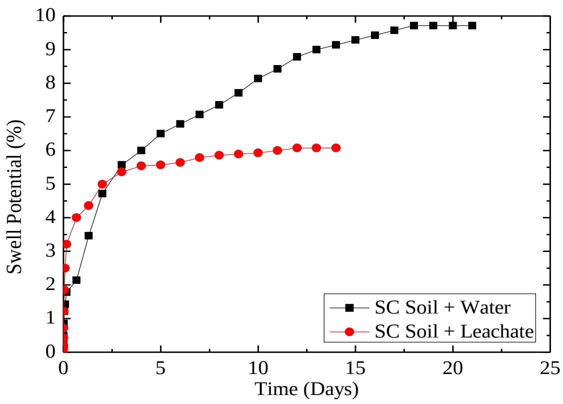
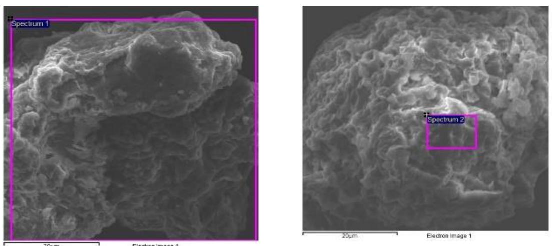


Fig. 6 Variations of swelling potential with water and leachate in SC soil

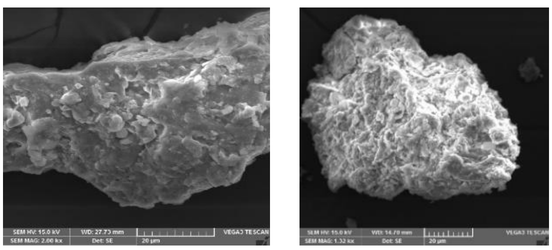
3.5 Scanning Electron Microscope (SEM)

The uncontaminated soil samples and samples contaminated with leachate were collected from the oedometer after completion of the swell tests. These collected samples were tested for morphological changes. The results are as shown in Fig. 7a and 7b.



Uncontaminated Soil Contaminated Soil

Fig. 7a SEM of CH soil



Uncontaminated Soil Contaminated Soil

Fig. 7b SEM of SC soil

The SEM images of the contaminated and uncontaminated soil samples of CH and SC soils show the changes in the morphology of the soil particle after interacting with the leachate. The morphology of both the soils are associated with the arcuate steps, imbricated blocks, fractured plates, meandering ridges and irregular depressions which indicate the aggregation of the soil particles. This leads to the decrease in the plasticity index and the swell potential and the increase in the Unconfined Compressive Strength (UCS) of the leachate contaminated soil when compared to uncontaminated soil.

4. Conclusions

From the above experimental study, it is concluded that the liquid limit and plasticity index decrease with an increase in the percentage of leachate. These changes are more for the CH soil sample than SC soil sample. The Unconfined Compressive Strength (UCS) also showed an increase with the presence of leachate for both CH and SC soil samples. The hydraulic conductivity of the soil after permeating with leachate decreased due to the blockage of pores by leachate and the hydraulic conductivity of CH soil is well within the range of USEPA specified liner material requirement (i.e. $< 1 \times 10^{-7}$ cm/sec). The swelling potential with water for CH soil was more than for SC soil. The decrease in swelling potential with leachate for CH soil was more than that for SC soil. From the above study, it is concluded that the landfill leachate was more reactive with CH soil than SC soil and it persisted its hydraulic conductivity after interaction with leachate.

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