

Effect of Landfill Leachate on Engineering Properties of Test Soil

S. A. Nta, M. J. Ayotamuno, I. J. Udom

Abstract—The work presents result of laboratory analysis of the effects of landfill leachate on engineering properties of test soil. The soil used for the present study was a sandy loam soil and acidic in nature. It was collected at a depth of 0.9 m. The landfill leachate used was collected from a hole dug some meters away from dumped solid waste and analyzed to identify the pollutants and its effect on engineering properties of the test soil. The test soil applied with landfill leachate was collected at 0.25 and 0.50 m radial distances at a depth of 0.15, 0.30, 0.45 and 0.60 m from the point of application of leachate after 50 days were the application of the leachate end and 80 days from the start of the experiment for laboratory analysis. Engineering properties such as particle size distribution, specific gravity, optimum moisture content, maximum dry density, unconfined compressive strength, liquid limit, plastic limit and shrinkage limit were considered. The concentration of various chemicals at 0.25 and 0.50 radial distances and 0.15, 0.30, 0.45 and 0.6 m depth from the point of application of leachate were different. This study founds the effect of landfill leachate on the engineering properties of soil. It can be concluded that, the type of soil, chemical composition of the leachate, infiltration rate, aquifers, ground water table etc., will have a major role on the area of influence zone of the pollutants in a landfill.

Keywords—Engineering properties of test soil, landfill leachate, Municipal solid waste.

I. INTRODUCTION

MUNICIPAL solid waste comprises of household wastes and commercial wastes. There is a mistaken belief that municipal solid waste is reasonably safe and would not harmfully affect the environment. The most common waste disposal method which is eco-friendlier is landfill. Landfills are often subjected to generation of leachate. Landfill leachate is generated from liquids existing in the waste as it comes into a landfill or from rain water that passes through the waste within the facility. Leachate consists of water and water soluble compounds in the refuse that accumulate, as water moves through the landfill.

The contaminants present in the landfill leachate can be classified as hazardous chemicals, conventional contaminants and nonconventional contaminants. A material cannot be classified as a hazardous waste, until a chemical is leached from it in concentrations at least 100-times the drinking water standard [1]. Conventional contaminants may include

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parameters such as total dissolved solids, hardness, alkalinity and other chemicals. Non-conventional contaminants are mainly organic chemicals that are of important to public health and ground water users. Literature accounts indicate that on average 95% of the organic materials in landfill leachate are of unknown composition. Those organic materials have not been known and clearly their possible impacts on environment are unidentified [2].

The risks of leachate generation can be mitigated by properly designed and engineered landfill sites, such as sites that are constructed on geologically impermeable materials or sites that use impermeable liners made of geo-membranes or engineered clay. Landfill liners should properly function so that they prevent leachate from seeping through the bottom and contaminating the ground water. But in most of the cases, liners will not function properly and will lead to the spread of leachate to the soil beneath. This may tend to pollute the soil.

This study aims at identifying selected pollutants and its effect on engineering properties of the test soil.

II. MATERIALS AND METHODS

A. Soil

The soil used for the study was a sandy loam soil and acidic in nature. It was collected at a depth of 0.9 m. Analysis of the upper layers is relevant in understanding soil interactions with other environmental compartments and the pathways of pollutants between them [3]. The initial engineering properties of the representative sample of the soil was performed through the determination of particle size distribution, specific gravity, optimum moisture content, maximum dry density, unconfined compressive strength, liquid limit, plastic limit and shrinkage limit were determined.

B. Landfill Leachate

The leachate used in this experiment was collected from Uyo main refuse dump site. The leachate was collected from a hole dug some meters away from the dumped waste. The sample was then transported to the laboratory and kept in the refrigerator at 4 °C prior to using in the study. Selected physicochemical parameters in the leachate were analyzed in line with American Public Health Association [4] to know its chemical composition.

C. Test Set-up

A rectangular intermediate bulk container (IBC) test tank was used for the experiment. An overhead tank was provided to supply leachate to the soil through a PVC tap system where rate of flow can be controlled. From the overhead tank the

leachate is supplied through a PVC perforated pipe, from which it percolates to the soil.

D. Experimental Procedure

The experiment was conducted in the developed laboratory set-up to study the percolating process. Test soil was air dried for 28 days and filled in the IBC test tank. The compacted and uncompacted bulk densities of the soils were 13.8 and 12.3 kN/m³, respectively. At the center of the tank, above the filled soil, a circular pit of 60 mm diameter and 50 mm depth was prepared. This pit resembles the solid waste dumping place. A circular PVC pipe of 60 mm diameter and 400 mm length was placed at this pit. Perforations were made on the portion of the PVC 50 mm where it is having contact with the soil. Leachate was transferred to the soil through this perforated container. Perforations facilitate the uniform passage of the leachate to surrounding soil. The entire leachate (4.76 liters, approximately 5 liters) was transferred to the soil from the overhead leachate tank to the perforated PVC pipe at a constant rate so as to achieve 50% saturation in 50 days (Fig. 1).

At the start of the experiment, uncontaminated water was first allowed through the tank to ensure steady state conditions before landfill leachate was introduced. This allows for the establishment of a proper outflow condition at the port so that a constant velocity is maintained. A discharge velocity of about 1.157×10^{-6} l/sec was used in the experiment. The leachate contaminated soils were collected from the positions corresponding to 0.25 and 0.50 m radial distances from the point of application of leachate. The samples were collected after 50 days were application of leachate end, 80 days from the commencement of experiment.

To collect samples at different depths, PVC pipe of 14 mm diameter and 0.7 m long was introduced at the center radial distances to enable the collection of the sample at the required depth. Eight samples were collected at different depths. That is, 0.15, 0.30, 0.45 and 0.60 m at 0.25 and 0.50 m radial distances and analyzed for engineering properties. Fig. 2 represents samples collection at different depth. This was carried out after 50 days were the application of the leachate end and 80 days from the commencement of the experiment.



Fig. 1 Laboratory Test Set-up

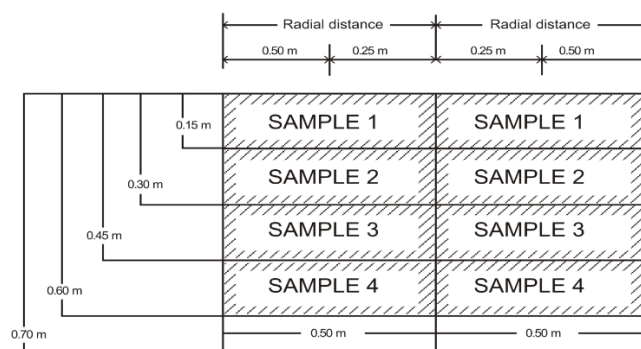


Fig. 2 Samples at Different Depths

E. Geotechnical Analysis of Samples

Geotechnical engineering properties of the selected soils were determined in the laboratory in line with current Bureau of Indian Specifications [5]. Parameters such as particle size distribution, specific gravity, optimum moisture content, maximum dry density, unconfined compressive strength, liquid limit, plastic limit and shrinkage limit were determined.

III. RESULTS AND DISCUSSION

A. Physicochemical Composition of Landfill Leachate

The physicochemical composition of landfill leachate used in the experiment is presented in Table I.

TABLE I
 MEAN PHYSICO-CHEMICAL COMPOSITION OF LANDFILL LEACHATE

Parameters	Leachate
pH	8.51
E.C (μ s/cm)	4463
Lead (mg/l)	0.31
Cadmium (mg/l)	0.06
Nickel (mg/l)	0.35
Copper (mg/l)	8.67

B. Effect of Landfill Leachate on Engineering Properties of Test Soil

Tables II and III show the results from the experiment after 50 and 80 days from were application of the leachate end and from the commencement of the experiment collected at 0.25 and 0.50 m radial distance at a depth of 0.15, 0.30, 0.45 and 0.60 m from the point of application of leachate. There are slight variations in 50 days, 80 days and the initial engineering properties of the test soil. This may be due to influence of chemical composition of landfill leachate used for the experiment. As the landfill leachate is a contaminated liquid emanating from the dumped wastes. In order to generalize the effect of the leachate on the engineering properties of the test soil, variation of the engineering properties was plotted graphically with respect to depth.

1. Particle Size Distribution

Fig. 3 shows that the contaminated test soil has more percentage of clay content than uncontaminated control soil at 50 days. As the maturity period increases (that is, after 80 days), percentage of clay decreases. For silt particles, the test

soil has lower percentage of silt at 50 days except at 0.15 m depth and at a 0.5 m radial distance that recorded 5.4% same as the uncontaminated control soil. As the maturity period

increases, that is 80 days, silt particles increase with decrease in soil depth.

TABLE II
EXPERIMENT RESULTS AFTER 50 DAYS

	0.25 m Radial Distance				0.50m Radial Distance				Control
	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	
Depth (m)	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	
Clay (%)	10.8	12.8	12.8	12.8	10.5	10.8	10.8	12.8	10.0
Silt (%)	3.4	1.4	1.4	1.4	5.4	3.4	3.4	1.4	5.4
Specific gravity	2.4	2.6	2.8	2.8	2.5	2.7	2.7	2.9	3.2
Optimum moisture content	16	19	20	27	12	16	18	18	10
Maximum dry density	1.50	1.44	1.47	1.48	1.45	1.45	1.48	1.48	1.63
Unconfined compressive strength	110	111	114	118	108	115	118	119	101
Liquid limit	35	36	38	39	34	35	39	30	32
Plastic limit	15	15	14	14	14	15	16	15	13
shrinkage	20	22	21	20	19	20	20	22	17

TABLE III
EXPERIMENT RESULTS AFTER 80 DAYS

	0.25 m Radial Distance				0.50m Radial Distance				Control
	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	
Depth (m)	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	
Clay (%)	6	5	7	6	5	6	7	7	10.0
Silt (%)	13.8	13	9	13	12	11.5	9.2	10	5.4
Specific gravity	2.10	2.30	2.40	2.70	2.40	2.60	2.70	2.90	3.2
Optimum moisture content	10	14	16	20	15	16	16	19	10
Maximum dry density	1.62	1.51	1.54	1.50	1.57	1.54	1.56	1.59	1.63
Unconfined compressive strength	128	135	140	160	129	130	145	150	101
Liquid limit	30	35	34	33	32	37	39	31	32
Plastic limit	12	17	16	15	14	17	18	15	13
shrinkage	19	24	18	20	17	20	21	23	17

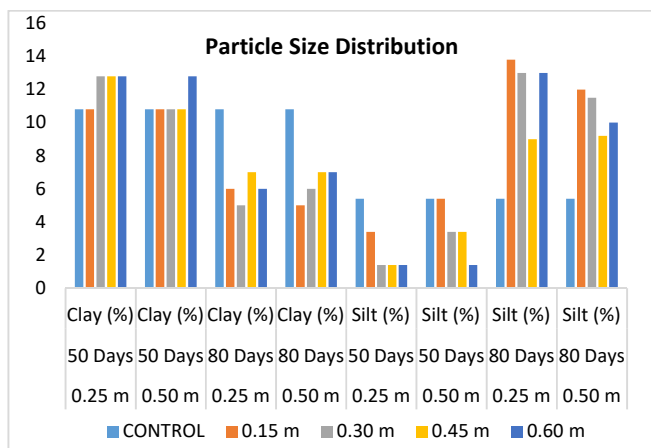


Fig. 3 Variation of Particle Size Distribution of Test Soil after 50 and 80 Days with Depth

The results of this study show that the clay particles are increased due to the influence of chemical composition in the landfill leachate. Variation in the particle size of the soil can be described by chemical weathering. Chemical weathering is the transformation of primary minerals into secondary materials. Secondary materials function as the basic building blocks of the small particles with the soil. As the result, new materials may be synthesized.

According to [6], clay grain content in heavily polluted soil samples is higher than that of light polluted soil. When a soil

mass is influenced by pollutants, the colloids in the soil, such as organic and inorganic composite colloids and soluble salts, get dissolved and it results in the weakening of strong link between soil grains. Thus most of the soil grains will disperse easily and clay grain content will get increased in heavily polluted soil [7].

2. Specific Gravity

The result of the specific gravity of test soil contaminated with landfill leachate along with control soil is presented in Fig. 4. The results show that the difference between the values of the specific gravity of the test soil at corresponding depths after 50 days was slightly higher compared to those after 80 days at corresponding depths. The values of the specific gravity of the contaminated test soils were generally lower than those obtained for the uncontaminated soil.

3. Compaction Characteristics

Results of the compaction characteristics of contaminated test soil are presented in Figs. 5 and 6. The result shows variation on Maximum Dry Density (MDD). They were lower than that of uncontaminated control soil. Optimum Moisture Content (OMC) was observed to increase with increased in depth over that of uncontaminated control soil. This result conforms with the results of the particle size distribution, which indicates greater percentages of fine fractions in the contaminated test soil. Since fine particles within soil have more affinity for water, and from the classical theory of soil

mechanics, the higher the OMC, the lower the MDD.

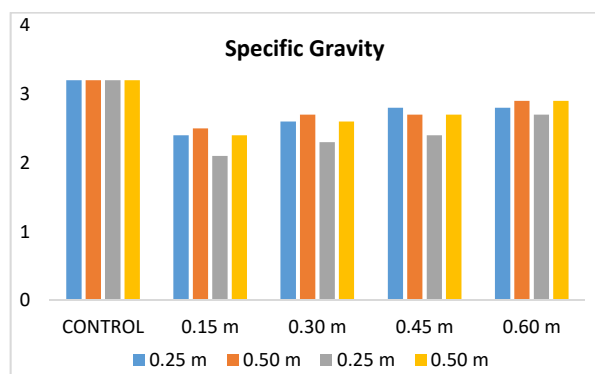


Fig. 4 Variation of Specific Gravity of Test Soil after 50 and 80 Days with Depth

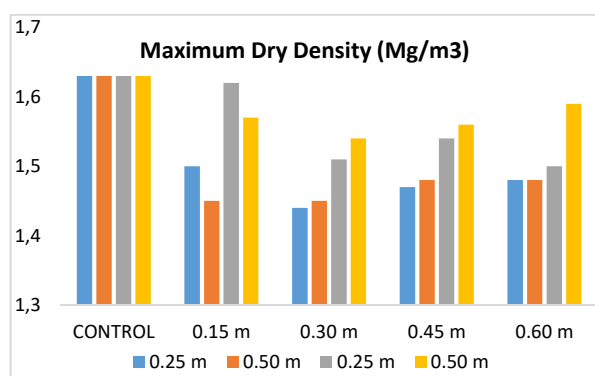


Fig. 5 Variation of MDD of Test Soil after 50 and 80 Days with Depth

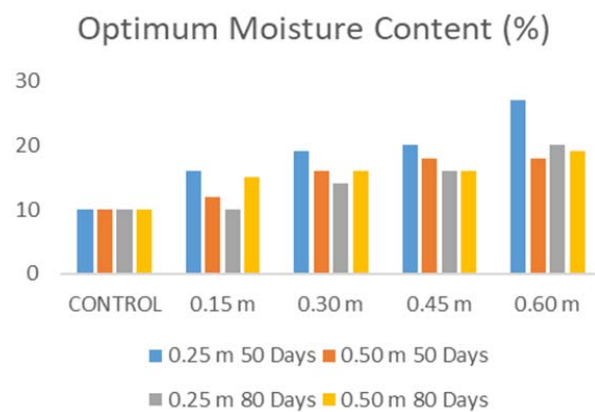


Fig. 6 Variation of OMC of Test Soil after 50 and 80 Days with Depth

4. Unconfined Compressive Strength

Unconfined compressive strength of treated test soil was observed to be increased due to increase in depth of contaminated test soil. It shows a slight increasing trend towards maturity period, that is, after 80 days. Increase in unconfined compressive strength of contaminated test soil with increase in depth may be attributed to the change in the thickness of diffuse double layer.

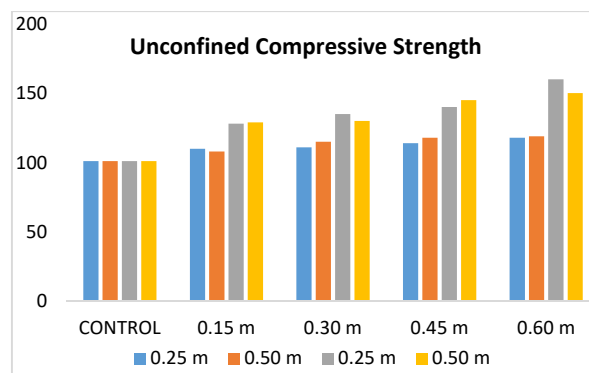


Fig. 7 Variation of Unconfined Compressive Strength of Test Soil after 50 and 80 Days with Depth

5. Atterberg Limits

Figs. 8-10 show the variation in Atterberg limits of test soil as the landfill leachate and contact period changes. Landfill causes an increase in liquid limit on contaminated test soil with increase in depth after 50 days. As maturity period increases, the liquid limit decreases. Thus it is proved that landfill leachate as well as maturity period has major influence on the liquid limit of treated test soil, showing a slight increase with low concentration and ageing and gradually reduces below that of untreated control soil.

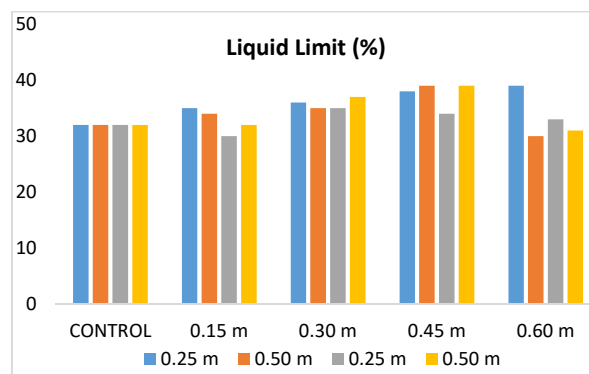


Fig. 8 Variation of Liquid Limit of Test Soil after 50 and 80 Days with Depth

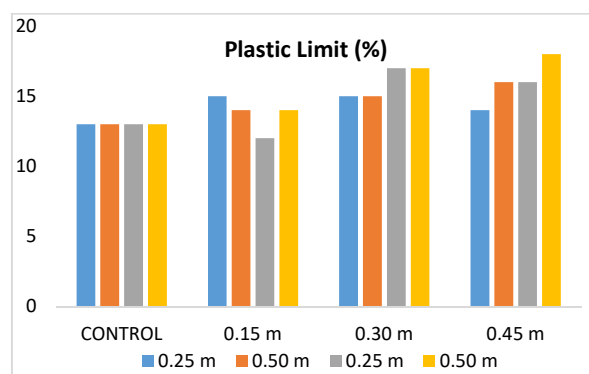


Fig. 9 Variation of Plastic Limit of Test Soil after 50 and 80 Days with Depth

Plastic limit of test soil is observed to be varied with

increase in depth and radial distances after 50 and 80 days.

Fig. 10 shows that, application landfill to the test soil causes variation in shrinkage limit. No substantial change is shown as ageing increases.

Variation in Atterberg limits may be attributed to the change in nature of pore water fluid. The alkaline nature of landfill leachate in the pores media tends to disintegrate the soil particles and causes increase specific area of soil.

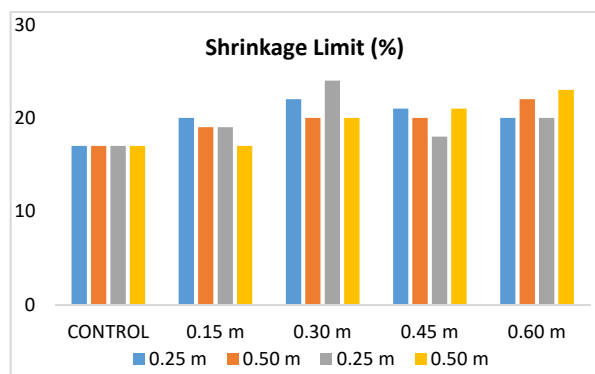


Fig. 10 Variation of Shrinkage Limit of Test Soil after 50 and 80 Days with Depth

IV. CONCLUSION

The aim of the research was to identify selected pollutant and its effect on engineering properties of test soil. Based on the results of the study, the following conclusions can be drawn:

- The landfill leachate is following a point source or leaky pattern of flow through a uniform dense, single soil layer. But it is understood from the literature that, number of layers, variation in density, presence of cracks and fissures, direction of ground water flow etc., will have major role in the flow direction and pattern of leachate through soil. Since the site conditions of each landfill are different, the flow pattern of leachate through landfill cannot be generalized.
- The composition of landfill leachate varies from landfill to landfill. The adsorption property of soil, mobility and solubility of chemicals etc., will influence the retention of the chemicals in soil.
- It is also proved that the composition of landfill leachate has a major influence on the engineering properties of soil. The chemical composition of the leachate may cause disintegration of soil grains and this may cause reduction in specific gravity and changes in Atterberg limits, as well as flocculation of soil grains.
- Percolation of leachate was the only source of water in the test soil during the test period. After stopping the leachate application, considerable change in chemical concentration is not observed. This proves that the chance for the mobility of chemicals through soil without pore water flow is less.

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