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Chemical Characteristics of Leachate Contaminated Lateritic Soil

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Abstract: Landfill leachate is generated from liquids existing in the waste as it enters a landfill or from rainwater that passes through the waste within the facility. Leachate can consist of many different organic and inorganic compounds that are typically either dissolved or suspended in the wastewater. High concentrations of chemical oxygen demand (COD) associated BOD, nitrogen, phenols, pesticides, solvents and heavy metals are common in these systems. Most of the MSW generated is disposed in low lying areas, which eventually become open dumps, located in the outskirts of the city. After few years of dumping, these waste dumping yards get filled up and need to be abandoned. Meantime with urban development and expansion, these areas (dumping yards) come under a zone with serious scarcity of vacant land. Therefore, this areas need to be reclaimed for other purposes. Behaviour of such land containing MSW and contaminated by leachate are still not well understood under various loading conditions and thus a gap exist for predicting the engineering behaviour of structures constructed of/width MSW fills. Large areas of land are currently being used for this study. A laboratory testing program was carried out to determine the properties of leachate contaminated soils. MSW samples and leachate contaminated soil samples are used in this study. Contaminated samples are prepared by mixing the soil with different concentration of contaminants by adding equivalent weight of molecular mass of contaminant in 1 liter of distilled water to get the particular concentration of normality (N). These contaminant solutions are then added to the soil samples at different concentrations (0.1 N through 1.0 N) and thoroughly mixed with it. The results show that the MSW samples and leachate contaminated specimen effects the chemical characteristics of the soil.

The pH measurements of soil contaminated with leachate contaminated and MSW samples indicated an increase in pH values. This is also accompanied by slight increase in the cation exchange capacity of the soil. The change in chemical characteristics of lateritic soil contributed due to addition of leachate may be detrimental to foundation concrete in real field conditions. The present work deals with an attempt to study the effect of leachate on the chemical characteristics of soil.

Keywords: Lateritic soils, Leachate, Contamination, Chemical characteristics, pH value, Cation exchange capacity.

I. INTRODUCTION

The problems associated with solid waste management are many. Effective management is possible only when we appreciate the problems associated with waste disposal (solid or liquid). Any negligence in waste management will simply lead to numerous environmental problems including health hazards (affects).

Interaction of moisture with municipal solid waste (MSW), leachate is produced which is a hazardous liquid produced in landfills. Inadequate disposal methods of municipal solid waste into the dump yards results in pollution of soil and groundwater systems. Lateritic soils constitute an important group of soils in the plain districts of Brahmaputra river basin of Assam, India. The study area is situated in the southern bank of the mighty river Brahmaputra (Latitude 26°45’21”N, Longitude 94°12’34”E) has extensive lateritic formations. The soils are considered to be a good foundation material. Due to high permeability of lateritic soils open dumping of municipal solid waste may lead to environmental problems. Large areas of land are currently used for open dumping purpose. At one of the dumping yard around 150MT of municipal solid waste is being dumped without shredding and segregation. Due to heavy rainfall (2400mm annually) during monsoon leachate from such landfills flows out without any hindrance into the adjacent areas resulting in contamination of soil and groundwater. Substantial releases of leachate (due to open dumping) might have occurred during the past few years and the

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lateritic soil at the dump yard revealed extensive contamination. Leachate contamination may lead to significant effect on the behaviour of soils. Past work [1], [2], [3],[4], [5], [7], [9] has shown that the index and engineering properties of soil contaminated with leachate lead to change due to chemical reactions between the soil mineral particles and the contaminant. In connection with any possible applications, knowledge of the behaviour of contaminated soil is required and hence the present investigation is carried out.

II. SCOPE OF THE PROBLEM

In the study area, lateritic soils are predominant and about 12-15 ha of load are currently used as dump yards from the past few years. Municipal solid waste is being dumped on such land without shredding and segregation. Lateritic soil at the disposal area revealed extensive contamination due to leachate. With such dumping activity in process, the geotechnical engineers are also concerned with the effect of leachate contamination on the properties of the soil. The present investigation was carried out keeping the above points in mind.

III. EXPERIMENTAL INVESTIGATION

The studies of MSW samples and soil contaminated leachate have been done on the basis of the result obtained in an extensive experimental program. Representative lateritic soil samples from two sites are selected in study area to study the effect of leachate contamination on the chemical characteristics of lateritic soil. Hence in the present investigation synthetic leachate with a chemical composition most representative of the real leachate is prepared in the laboratory.

A. Preparation of sample

In the study area, it is very difficult to obtain real leachate from the landfills .The leachate used in the present study was simulated in the laboratory. To select a representative leachate produced in landfills, a database is prepared from published literature [1],[3],[5]

IV. METHODOLOGY

MSW samples from the two sites are obtained from bore holes upto a depth of 15m. (Bore Hole-1: Cremation ground landfill, Bore Hole-2: Daily market place landfill)The soils are air dried and kept for 7 days for maturation and passed through 425 mm sieve before using the same for laboratory test. About 300 gm of soil samples is taken for each test and after addition of contaminants the samples are placed in air tight packets and kept for 7 days for maturing. After 7 days packets are opened and test are conducted.

TABLE 1.
CHEMICAL CHARACTERISTICS OF THE MSW SAMPLES FROM BORE HOLE-1 AND BORE HOLE-2

Bore Hole	pH of soil 25˚c	EC of soil solution (µs/cm)	CEC (meg/100gm)	$CaCO_3$ (%)	OM of soil (%)	SO_4 $x10^{-3}$ (%)	Fe_2O_3 (%)	SiO_2 (%)	Al_2O_3 (%)
1	4.80	30	8.10	2.76	0.53	5	7.2	71	42.9
2	5.38	38	7.86	3.08	0.40	3	8.0	73	36.7

EC- Electrical conductance; CEC- Cation exchange capacity $CaCO_3$-Calcium carbonate; OM- Organic matter; SO_4-Soluble sulphate; Fe_2O_3- Iron content; SiO_2- Silica; Al_2O_3- Alumina content

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A. Chemical characteristics

The chemicals properties of the soils determined included pH of soil, electrical conductance of the soil solution, cation exchange capacity, organic matters total soluble sulphates, iron content silica etc. The results of chemical characteristics of uncontaminated lateritic soil are presented in Table 1.

V. RESULTS AND DISCUSSION

Effects of the municipal solid wastes (MSW) samples and leachate contaminated soil samples on chemical characteristics of lateritic in subsequent sections.

A. Effects of leachate on soil pH

pH determination of soil is important as excessive acidity or alkalinity can be detrimental. It is reported in literature [4],[8] that under high rainfall conditions cation especially Ca^{2+} leach, while under low rainfall conditions Ca^{2+} and other cations are not easily leached.

The results of pH of two MSW samples indicate that the soil is acidic. The experimental data indicates that the pH value of clean lateritic soil samples varies from 4.80 to 5.38. The acidic nature of the soil is mainly due to two reasons. First leaching of appreciable amounts of exchangeable bases from the soils due to high precipitation (2400 mm annually). Second, decomposition of organic matter, leads to the formation of organic and inorganic acid (e.g. Carbonic acid – H_2CO_3) which renders the soil acidic.

The experimental data of soil pH as a function of leachate added is presented in Fig. 1. It is observed from Fig. 1 that the pH of lateritic soil increases with leachate concentration. The probable reason for this behaviour may be due to high concentration of monovalent and divalent cation contained in the leachate. The concentration of each constituent of leachate is presented in Table 2. The leachate also contained chloride and sulphate anions. As a result of negative charge developed by the clay particles, ions are absorbed on the surface. Any process that encourages presence of high levels of exchangeable base such as calcium, magnesium, potassium and sodium will reduce acidity and increase alkalinity. Hence pH of the lateritic soil in Fig. 1 increases as the leachate concentration increase.

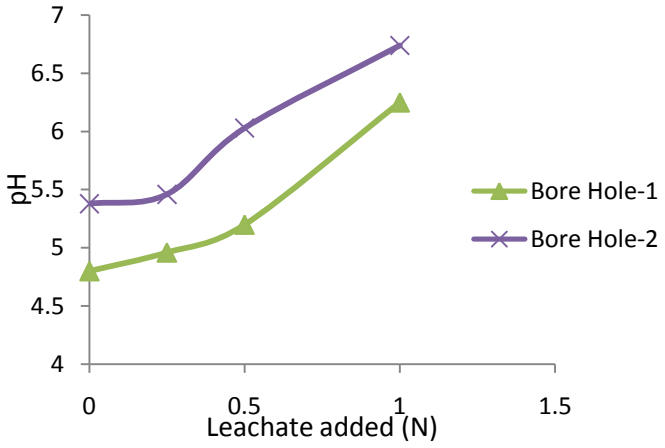

Fig. 1 Variation of Soil pH with Leachate Added (N)

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TABLE 2.

CHEMICAL COMPOSITION OF SYNTHETIC LEACHATE

Concentration (mg/l)						Other characteristics	
Cl^-	Mg^{2+}	Ca^{2+}	NH_4^+	TDS	COD	pH,25^{0}C	EC,25^{0}C ($\mu s/cm$)
1250	2200	752	730	12650	18300	7.3 - 8.5	16500

TDS –Total dissolved solids; COD- Chemical oxygen demand; EC- Electrical conductance

B. Effect of Leachate on cation exchange capacity of soil

Ion exchange is the most important of all processes occurring in the soil. The capacity of the soil to absorb and exchange ions varies greatly with the amount of clay. Exchange of ions takes place due to isomorphous substitution (i.e substitution of one element for another). Results of CEC determinations are plotted in fig.2. From the results, it can be seen that CEC has increased from an initial value of 6.28 meq/100gm to 12.46 meq/100gm. While the increase in cation exchange capacity of soil is interesting and some researchers [8], [10] attribute the following reason: It concludes that the increase in cation exchange capacity of soil is attributed due to rise in pH. The acquisition of extra negative charge with a rise in pH is mainly due to two reasons:

First, the development of negative charge is due to the dissociation of hydrogen of SiOH groups present at the edges of the tetrahedral layers, and the surface of the clay is left with the negative charge of the oxygen ions according to the reaction,

$$SiOH = SiO^- + H^+ \quad \ldots \quad \ldots \quad \ldots \quad \text{Eq (1)}$$

This type of negative charge is pH dependent charge. The amount of dissociation increases with increasing pH and results in an increase in the cation exchange capacity. Some researchers also reported the changes in CEC to be pH dependent, and this arises from exposed – SOH and AlOH sites [8]. Second, the non crystalline compounds formed contribute to CEC. At higher pH, silica and alumina present in the soil dissolve and form non crystalline compounds of silicates and aluminates. These non crystalline compounds acquire a negative charge and contribute to CEC. Although these charges are observed during experiments in the laboratory a different situation may arise in field. Toxic waste/leachate from landfills may seep into the surround soil to increase the pH of the soil.

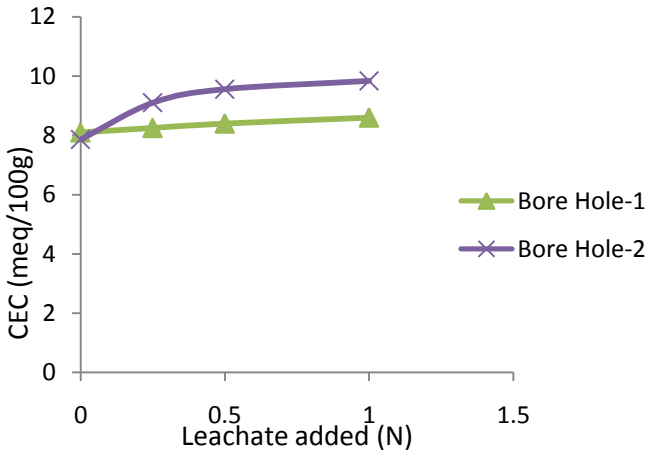

Fig. 2 Variation of Cation Exchange Capacity with Leachate Added (N)

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C. Effect of leachate on other chemical characteristics of soil

From Table 3 it is observed that electrical conductivity (EC), calcium, sulphate and iron content in the soil increases when leachate concentration increase. This is mainly due to leachate characteristics rather than the chemical characteristics of soil. As the leachate is simulated in the laboratory and prepared using chemicals with a chemical composition most representative of the real leachate. Depending upon the composition of real leachate chemicals like acetic acid, ammonium chloride, calcium chloride, sodium chloride, magnesium chloride, ferric chloride, sulphate are used in the preparation of synthetic leachate. The adsorption of chemical constituents of leachate on the clay surface influences the chemical characteristics of soil and it is due to leachate characteristics.

VI. CONCLUSIONS

An extensive laboratory testing program is carried out to study the effect of leachate contamination on the chemical characteristics of lateritic soils. The following conclusions are made based on the test results:

Chemical characteristics of soil increases with the increase in concentration of contaminants. The pH of soils is marginally increased due to leachate. The increase in cation exchange capacity of soil may also be attributed due to marginal increase in pH value of soil with leachate. The increase in electrical conductivity, calcium, sulphate and iron content is due to leachate characteristics. The change in chemical characteristics of lateritic soil may be detrimental to foundation concrete in real field conditions.

For example, the increase in pH of soil may influence the corrosion of reinforcement. Also the sulphate content of soil increases with increase in leachate concentration. This may have effect on the buried concrete leading to foundation problems. The preceding results present the short term effect of leachate contamination on the chemical characteristics of lateritic soils.

TABLE 3.

CHEMICAL CHARACTERISTICS OF LATERITIC SOIL AFTER CONTAMINATION WITH LEACHATE

Sl. No.	Parameter	Soil mixed with leachate with different concentrations (N)			
		0 N	0.25 N	0.5 N	1.0 N
1.	pH of soil, 25^{o}C	4.80	4.96	5.20	6.25
		5.38	5.46	6.03	6.74
2.	EC of soil solution,25^{o}C (μs/cm)	30	155	180	300
		38	170	200	320
3.	CEC (meq/100gm)	8.10	8.25	8.40	8.60
		7.86	9.10	9.56	9.84
4.	$CaCO_3$	2.76	3.05	3.78	4.32
		3.08	3.16	4.10	4.54
5.	SO_4 x 10^{-3}(%)	5	3.40	5.30	7.00
		3	6.20	15.00	65.0
6.	Fe_2O_3	7.2	7.5	8.5	9.2
		8.0	8.3	8.9	9.5

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APPENDIX A

METHODOLOGY AND REFERENCE USED IN DETERMINING CHEMICAL CHARACTERISTICS OF SOIL AND LEACHATE

Sl. No.	Parameter	Instrument used	Methodology	Reference
1	pH	ELICO make digital pH meter		
2	Cation exchange capacity(CEC) (meq/100gm)			Compendium of Indian Standards on Soil Engineering(part 1) p.243-246
3	Calcium Carbonate			Compendium of Indian Standards on Soil Engineering(part 1) p.252-252
4	Ammonia Nitrogen as NH_4N	LOVIBOND make spectrophotometer	Nesslerization	Standard methods p.356
5	Chloride as Cl^-		Argentometric method	Standard Methods p.4-67
6	Calcium as Ca^{2+}	SYSTRONICS make microprocessor based Flame photometer	Flame photometric method	
7	Magnesium as Mg^{2+}		Calculation method	Standard Methods p.3-83
8	Total dissolved solids	ELICO make microprocessor based Water analysis kit		
9	Chemical Oxygen demand	LOVIBOND make spectrophotometer and digester	Closed reflex colorimetric method	Standard Methods p.5-17

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BIOGRAPHY

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