BEHAVIOUR OF LEAD ON CLAYEY SOIL

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Abstract— a study was performed to determine the index properties, unconfined compressive strength, compressibility and permeability characteristics of the lead contaminated soil. Lead added to the natural soil in different concentrations such as 500ppm, 1000ppm and 2000ppm. Contamination is carried out by saturating the soil sample in Lead nitrate solutions for varying contamination periods such as 7, 14 and 28 days. UCS tests were conducted on these samples. The results showed pronounced changes in the index properties of the lead contaminated soil and gain in strength varies linearly till 1000ppm and after reaching the point, the strength starts to decline. Enhanced compressibility and permeability characteristics were observed for the lead contaminated soil. Correlations for unconfined strength as functions of contamination period and contamination concentration was established and discussed.

I. INTRODUCTION

Soil is getting contaminated by various pollutants because of different natural and human activities such as agriculture, industrial activities, unorganized dumping of wastes and other urban activities. This poses a significant threat to human and even to ecological systems. All this has led to several alterations in the natural soil thus resulting in wide scale contamination of this precious resource. Mining, manufacturing, and the use of synthetic products (e.g. pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Heavy metals also occur naturally, but rarely at toxic levels. Potentially contaminated soils may occur at old landfill sites (particularly those that accepted industrial wastes), old orchards that used insecticides containing arsenic as an active ingredient, fields that had past applications of waste water or municipal sludge, areas in or around mining waste piles and tailings, industrial areas where chemicals may have been dumped on the ground, or in areas downwind from industrial sites.

Industrial emissions of contaminant to the atmosphere which is finally deposited on soil or dumping of industrial wastes on disposal land may cause the problem in the environment beyond the limit. Generally topsoil layer contain largest amount of pollutants. The contaminant concentration in soil mainly depends on the adsorption properties of soil matter. The adsorption properties are largely determined by organic matter in soil and heavy metals concentration in soil directly or indirectly depends on the soil organic matter. Variation of organic matter may be the predominant cause of variation in environmental concentration in soil. Heavy metals accumulation in soil can be studied by different statistical method. Generally organic matter contains different types of functional groups such as phenolic group (-OH) which are capable of complexion metals. Organic matter may influence the concentration of heavy metals in soil by different processes such as release of heavy metals containing organic matter into the soil, extraction of heavy metals complexes by organic matter in the soil forming organic etc. Environmental factors such as land use, temperature, rainfall etc. can artificially change organic matter content as well heavy metals concentration in soil. The solubility of heavy-metal ions in soil was mainly influenced by many factors such pH, conductivity.

A. *Sources of Soil Pollution*

1) Seepage from a landfill
2) Discharge of industrial waste into the soil
3) Percolation of contaminated water into the soil
4) Rupture of underground storage tanks
5) Excess application of pesticides, herbicides or fertilizer
6) Solid waste seepage

The most common chemicals involved in causing soil pollution are:

1) Petroleum hydrocarbons
2) Heavy metals
3) Pesticides
4) Solvents

II. LITERATURE REVIEW

Lu et al (2010) studied the distribution characteristics of heavy metals (cadmium (Cd), lead (Pb) and zinc (Zn)) in the natural soil profiles around the Hulu Dao Zinc Plant (HZP), an old industrial base in Northeast China, were analyzed. The pollutant source was identified using 210Pb isotope technique to evaluate the geochemical characteristics of lead and the historical production records of HZP. The results indicated: dust precipitation from HZP was the primary source of the pollutants. The average deposition rates of Cd, Pb and Zn were 0.33, 1.75, and 30.97 g/m2 year, respectively at 1 km away after HZP, and 0.0048, 0.035, and 0.20 g/m2 year, respectively at 10km away after HZP.

Song Jie et al. (2008) were studied the availability and profile characteristics of arsenic (As), 2 cadmium (Cd), lead (Pb) and zinc (Zn) in contaminated soils from the Pb/Zn mining and smelting areas in Human Province of China, and the risks of these metals were also assessed. The results show that the concentrations of As, Cd, Pb and Zn in soil samples are higher than the Permissible levels of Soil Quality of China. The mobility of metals in soil profiles is mainly characterized by the low pH and organic matter content of soil. The major part of As, Cd, Pb and Zn is restricted to the upper soils and the contamination of these metals in soils is significantly influenced by the long-term Pb/Zn mining and smelting activities. Based on the results from the sequential extraction, the fraction of Cd in the soil profiles is predominantly existed in the acid-extractable form and the large amount of Pb is closely associated with reducible fraction. Finally it is found that the availability of Cd and Pb is predominantly higher than that of as and Zn in the soil profiles.

Resmi et al. (2011) found that the clay liners are subjected to leaching of various chemicals and hazardous wastes since they are widely used as barriers to arrest the migration of pollutants. Migration of heavy metals through the liner material may lead to changes in the soil properties and this, in turn, may affect the performance of liners. In this paper, the change in index and engineering properties of clayey soil due to migration of lead is presented. Pronounced changes in soil properties are noticed when the soil is contaminated with high concentrations of lead. The effect of lead contamination on the index and engineering properties of two types of clayey soil was studied by conducting a series of tests in the laboratory. Tests were conducted for soils contaminated with different concentrations of lead. From the results, it is concluded that various engineering properties of soil are getting affected by adsorption of lead. As the concentration of the $Pb(NO_3)_2$ solution increases, the amount of lead (Pb) adsorbed also increases. Adsorption of lead in clayey soils causes displacement of H+ ions and results in flocculation, decrease in strength and an increase in the coefficient of permeability. As Fig 2.3 indicates the contamination of clayey soils with lead causes reduction in liquid limit and plastic limit values. Shrinkage limit is also getting decreased, but there is no appreciable reduction.

III. OBJECTIVE

The objectives of the study are to carry out a comprehensive laboratory study on contaminated soil with varying concentrations of lead, saturated for different curing periods and also to bring out the effect of lead contamination on engineering and index properties of soil.

IV. MATERIALS USED

Soil sample was collected from the site & it is brought to the laboratory. The soil was mixed thoroughly, stored in poly-ethylene bags and kept in containers without any moisture loss. The soil samples so collected were tested for basic index properties as per IS 2720: 1991. The results are presented in Table 1. As per IS 1498-1970, the soils is classified as CH (clay with high plasticity) respectively. In this investigation, lead nitrate $Pb(NO_3)_2$ salt of analytical reagent grade was used for preparing lead solution used for artificially contaminating the soil. The soil was artificially contaminated with lead nitrate $Pb(NO_3)_2$ solutions of concentrations 500 ppm, 1000 ppm and 2000 ppm.

Properties	**Value**
Specific gravity, Gs	2.64
Clay	55%
Silt	30%
Sand	15%
Liquid limit, WL	74%
Plastic limit, WP	31%
Plasticity index, Ip	43%
Shrinkage Limit	13%
Unified Soil Classification	CH
Compaction test results	
Optimum moisture content, OMC	23.6%
Maximum Dry Density, γd,max	1.28 g/cc
Unconfined compressive strength (kPa)	96

Table.1: Properties of soil

A. PREPARATION OF SAMPLES

In order to obtain the effect of lead contamination on the index properties of soil, the liquid limit, plastic limit, shrinkage limit tests are conducted by adding lead nitrate solutions of 500ppm, 1000ppm & 2000ppm instead of water. The effect of lead contamination on the strength of the soil is obtained by conducting unconfined compressive strength (UCS) test. The specimens for UCS are prepared at the maximum dry unit weight and optimum moisture content of uncontaminated soil. To attain the required moisture content the lead nitrate solutions of required concentration are added to the pre – weighed soil instead of water. Then the soil sample is mixed thoroughly to get uniform distribution of lead nitrate solution. This soil sample is compacted statically in a cylindrical mold to achieve the required dry unit weight. Thus prepared soil samples are immediately subjected to unconfined compressive strength test. The above tests were carried out as per Indian Standards.

V. RESULTS & DISCUSSION

The dominating mechanism governing the adsorption of metals in a porous medium is the affinity of the soil for the positively charged metal. The adsorption mechanism is usually ion exchange, whereby naturally abundant cautions such as those among Group I and II, including H^+, Na^+, K^+, Ca^{2+}, Mg^{2+} etc, which adsorb onto the negatively charged clay surface, are exchanged with heavy metals like lead. Hence clay liners used for containment of heavy metal such as lead, show natural attenuation of the metal by adsorption. Results obtained by adsorption study show the suitability of clay as a barrier material for arresting the migration of heavy metals such as lead.

A. ENGINEERING PROPERTIES

1) Tests on Consistency Limits

The results of various tests on consistency limits are presented in Figs. 1a-c. It can be seen that clayey soil with lead appreciably reduces the liquid limit and the plastic limit. This may be considered as typical behavior of clays as the liquid limit of these soils varies directly with the thickness of the diffuse double layer surrounding the clay particles (Mitchell, 1993). Reduction in the liquid limit may be due to reduction in the thickness of the diffuse double layer. Shrinkage limit is found to increase in contamination with lead. Results obtained indicate that when the soil is contaminated with high concentrations of lead, the diffuse double layer thickness decreases resulting in reduction in liquid limit, plastic limit and shrinkage limit. Index Properties of the lead contaminated soil is listed in Table.2

Concentration of lead (ppm)	LL (%)	PL (%)	PI (%)	SL (%)
0	74	43	31	13
500	65	28	37	12
1000	67	29	38	15
2000	64	28	36	13

Table.2: Index Properties of contaminated soil

2) Effect of Unconfined Compressive Strength on clayey soil

Unconfined compressive strength (UCS) tests were carried out using contaminated and uncontaminated soil specimens. The water content was maintained at 24%. Three tests were carried out and an average value of compressive strength was reported. The variation between the results of each test was ±3%. Typical stress strain curves obtained for the two soils are presented in Fig. The peak values from the stress strain curves were taken and reported as the values of UCS. It can be seen that the unconfined compressive strength values increase with increase in the level of contamination of these soils. The test results are summarized in Table.3. Strength decreases at higher concentration was expected because more Pb was available for sorption on soil with the increase in application. However, the percentage of Pb sorbed on soils decreased.

Concentration of lead	Unconfined Compressive Strength (kPa) for 28 days contamination
0 ppm	96
500 ppm	170
1000 ppm	240
2000 ppm	205

Table. 3: UCS test results

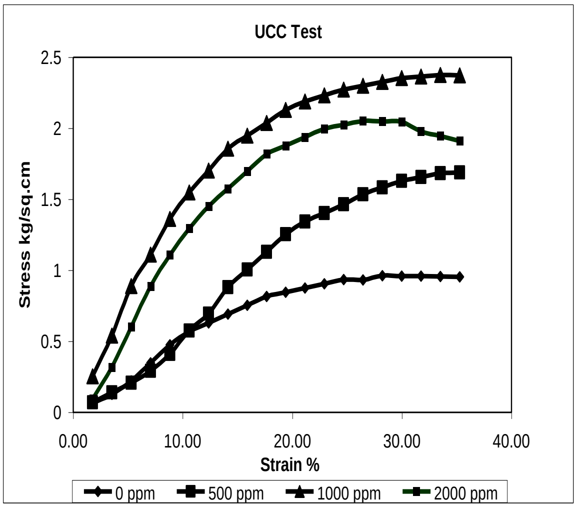

Fig. 1: Variation of strength on addition of lead

This was also expected because the availability of the binding sites decreased with the increase in concentration. According to Mohamed et al (1992) at low concentration, clay particles tend to disperse due to the full development of the diffuse double layer, therefore clay particle surfaces in contact with the solution at the maximum. The sorption increases until a certain points where the sorption becomes constant. This phenomenon is due to the sorption capacity of soil is higher at lower concentration, resulting more Pb is adsorbed. This also indicates that the sites for adsorption on this soil are still available at lower concentration. When the sorption sites become saturated with Pb, the sorption decreases with further increasing of Pb in the solution.

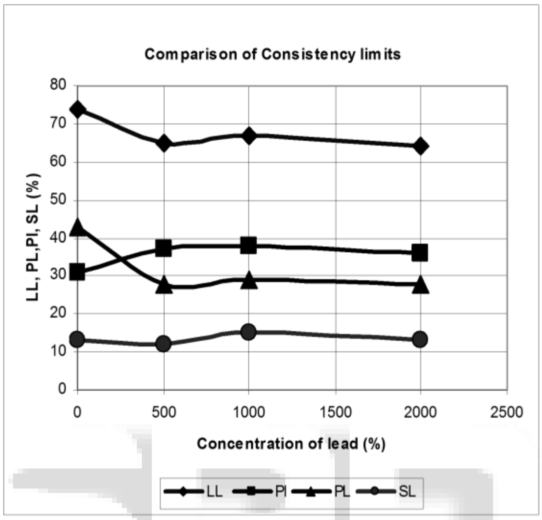

Fig. 2: Variation of index properties on addition of lead

3) Effect of Compressibility characteristics on clayey soil

The contaminated soil and uncontaminated soil samples were prepared in the consolidation ring at a density of 23.6kN/m^3. The samples were subjected to loading and unloading conditions. Load increment rate was maintained as unity during the tests. Each load increment was kept for a sufficiently long period (24 hours) so that consolidation is complete. Void ratio (e) corresponding to each load P was calculated. The results for rate of consolidation from the tests for various concentrations of lead were tabulated in Table. The coefficient of consolidation (C_v) indicates the combined effect of permeability and compressibility of the soil on the rate of volume change. Coefficient of consolidation (C_v) was determined by the method proposed by Taylor. The value shows that the coefficient of consolidation increases with increase in sorbed concentration of lead. Also it is observed that void ratio decreases with increase in concentration of lead in clayey soil. This may be due to the reduction in the double layer thickness.

Concentration of lead (ppm)	**Coefficient of consolidation, C_v (cm^2/s) * 10^{-4}**
0	0.901
500	1.121

1000	1.920
2000	1.650

Table. 4: Coefficient of Consolidation for the soil sample

4) *Effect of Permeability on clayey soil*

The coefficient of permeability was determined from the consolidation test using one dimensional consolidation theory. The coefficient of permeability, k corresponding to 100kPa was determined for both the uncontaminated soil and lead contaminated soil. The results obtained are summarized in Table. The coefficient of permeability of contaminated soil was found to be increasing with increase in the concentration of lead in the soil.

Concentration of lead (ppm)	**Coefficient of Permeability, k (cm/s) * 10^{-7}**
0	0.101
500	0.95
1000	0.452
2000	0.388

Table. 5: Coefficient of Permeability for the soil sample

5) *Effect of pH and Electrical conductivity*

In the present analysis, the pH and electrical conductivity of the contaminated soil sample and uncontaminated soil sample was tested. The test results are compared with virgin soil and it is found that both pH and electrical conductivity increased gradually. The results are tabulated in Table 6.

Soil	pH	Electrical Conductivity (mS/cm)
Uncontaminated	8.12	0.721
Contaminated	9.43	0.764

Table. 6: Test result of soil

VI. CONCLUSIONS

The effect of lead contamination on the index properties and engineering characteristics of clayey soil was studied by conducting a series of tests in the laboratory. Tests were conducted for soils contaminated with different concentrations of lead. From the results, it can be concluded that various engineering properties of soil are getting affected by adsorption of lead. As the concentration of the $Pb(NO_3)_2$ solution increases, the amount of lead (Pb) adsorbed also increases to certain extent. Since adsorption of lead in clayey soils causes flocculation and an increase in the strength characteristics of the soil. Pronounced changes in soil properties were noticed for clayey soils contaminated with higher concentrations of lead. The conclusions drawn from the current study are summarized below. Contamination of clayey soils with lead causes

1) Reduction in liquid limit and plastic limit values up to 19%
2) Increase in Shrinkage limit values up to 34%.
3) Strength of contaminated clayey soil increases to 150% as a result of contamination of soil with lead.
4) Enhanced pH and electrical conductivity values for higher concentration of lead.
5) Enhancement in compressibility and permeability characteristics.

REFERENCES

[1] Chirenje Tait., Ma L.Q., Reeves M., Szulczewski M., (2003) ‘Lead distribution in near- surface soils of two Florida cities: Gainesville and Miami’, Geoderma, vol. 119, pp. 113– 120.
[2] Christoforidis Achilleas., Stamatis Nikolaos., (2009) ‘Heavy metal contamination in street dust and roadside soil along the major national road in Kavala’s region’, Geoderma, vol.151, pp.257–263.
[3] Deka Jayashree., Sarma H. P., (2012) ‘Heavy metal contamination in soil in an industrial zone & its relation with some soil properties’, Archives of Applied Science Research vol. 4, pp. 831-836.
[4] Embrick L. Lura., Porter M. Halil., Pendergrass Alisha., Butcher J.David., (2005) ‘Characterization of lead and arsenic contamination, Haywood Country, NC’, Microchemical Journal vol.81, pp.117– 121.
[5] Hursthouse, Patkowska Markiewicz Julita., Przybyla Kij Hann, (2004) ‘the interaction of heavy metals with urban soils: sorption behaviour of Cd, Cu, Cr, Pb and Zn with a typical mixed brownfield deposit’, Environment International Journal vol.3, pp.513– 521.
[6] Jie Song., Zhao-hui Gou., Xi-yuan Xiao., MIAO Xu-feng Miao., Feng-yong Wang., (2010) ‘Availability and profile characteristics of arsenic, cadmium, lead and zinc in metal-contaminated soils’, Journal of Hazardous Materials vol. 182, pp. 743–748.
[7] Khan S., Khan M. A., Rehaman S., (2011) ‘Lead and Cadmium Contamination of Different Roadside Soils in Peshawar City, Pakistan’, Pedosphere vol. 21, pp.351–357.
[8] Lu C.A., Zhang J.F., Jiang H.M., Yang J.C., Zhang J.T., Wang J.Z., Shana H.X., (2010) ‘Assessment of soil contamination with Cd, Pb & Zn & source identification in the area around the Huludao zinc plant’, Journal of Hazardous Materials, vol. 182, pp. 743–748.
[9] Reshmi.G, Thampi G.Santhosh., Chandrakaran.S, (2011) ‘Impact of Lead Contamination on the Engineering Properties of Clayey Soil’, Journal of geological society of India, Vol.77, pp.42-46.
[10] Schwarz. K., Pickett T.A Steward Lathrop. G Richard., Weathers Kathleen, Pouyat V Richard., Cadenasso L Mary., (2012), ‘The effects of the urban built environment on the spatial distribution of lead in residential soils’, Environmental Pollution, vol.163 pp. 32-39.
[11] Siposa Pe´ter., Ne´metha Tibor., Mohaib Ilona., Istva´n Do´donyc., (2005) ‘Effect of soil composition on adsorption of lead as reflected by a study on a natural forest soil profile’, Geoderma, vol. 124, pp. 363–374.
[12] Zulfahmi A. R ., Ulfahmi., Wan Zuhairi .W. Y., Raihman .M. T., Sahibin A. R., Syakireen Nur A.R., Noorulakma.A., (2012) ‘Influence of Amang on Geotechnical Properties of Clay Soil’ Sains Malaysiana, vol.41, pp. 303–312.