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Variation of Hydraulic Conductivity of Montmorillonite Rich Clay upon Zinc Contamination

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Abstract -*Zinc is released into environment from both natural and anthropogenic sources. The primary sources are related to mining and metallurgic operations involving zinc. Most important sources of zinc come from discharges of slags, wastes, and coal fly ash. Zinc does not volatilize from soil, but remains adsorbed to soil. This paper deals with the change in behaviour of montmorillonite rich bentonite clay liner in the presence of zinc. The increase in permeability is undesirable as it lead to consequent leaching to ground water. It can further bioconcentrate in aquatic organisms.*

Key Words: **Bentonite, Hydraulic conductivity, Leaching, Liner, Zinc Contamination**

1. INTRODUCTION

Industrialization brought forth with it the associated problems. The industrial activities generated large quantities of wastes. Part of these waste exist in different physical forms such as solids, liquids, and gases which turn as pollutants in due course. Based on the safety level, these wastes can be hazardous or non-hazardous. Wastes can be controlled by different options such as waste reduction at source, resource recovery through separation and recycling, resources recovery through waste processing, waste transformation and environmentally sustainable disposal on land [1].

Despite all efforts, to minimize waste, and to neutralize it, the requirement for storage or disposal still exists. The most frequently used disposal option for solid waste in the landfill because of its low cost and efficiency. The landfill plays a vital role in the whole waste treatment or disposal process.

The basic philosophy of all engineered landfills should revolve around environmental protection through proper containment and controlled release, physical compatibility of the final landform to the surroundings, longevity for the design period, appropriateness to the type of waste and cost effectiveness. The main components of an engineered landfill are a liner system at the base and sides of the landfill which prevent migration of leachate or gas to the surrounding soil, a leachate collection facility which collects and extracts the leachate from within and from the base of land fill and then treats the leachate, a gas control facility which collects and extracts gas from within and from the top of the landfill, a final cover system which enhances surface drainage intercepts infiltrating water and supports surface vegetation. The final cover system can comprise of multiple layers of soils.

Environmental protection Agency (EPA) has laid down norms for the selection of suitable standard liner materials. With regard to the long term satisfactory performance of landfills, the liners covers play a very vital role. The most common land fill liner materials are clayey soils of low permeability, since they satisfy the EPA standards.

Clayey soils pose numerous problems to geotechnical engineers because of their high compressibility and poor shear strength. Desiccation is the continuous process of pore water loss from a soil exposed to a warm environment. In response to drying, soil water volume decreases and in consequence the soil shrinks. If shrinkage is restrained, soils can crack during desiccation as and when the tensile stresses that develop within the soil exceed the tensile strength of soil [2].

Zinc is an element commonly found in the Earth's crust. It is released to the environment from both natural sources and anthropogenic sources; however, releases from anthropogenic sources are greater than those from natural sources. The primary anthropogenic sources of zinc in the environment (air, water, soil) are related to mining and metallurgic operations involving zinc and use of commercial products containing zinc. Worldwide, releases to soil are probably the greatest source of zinc in the environment.

Most important sources of anthropogenic zinc in soil come from discharges of smelter slags and wastes, mine tailings, coal and bottom fly ash, and the use of commercial products such as fertilizers and wood preservatives that contain zinc [3].

Zinc does not volatilize from soil. Although zinc usually remains adsorbed to soil, leaching has been reported at waste disposal sites. Zinc does not volatilize from soil but is deposited primarily in sediments through adsorption and precipitation. Severe zinc contamination tends to be confined to areas near emission sources. It is therefore unlikely that the zinc found in the contaminated soil would pose a health risk if ingested.

1.1 Literature Review

Brutsaert (1987) studied about suitability of marine clays as hazardous waste site liners. He found that Larger the mineral content, greater potential shrinking and swelling, higher plasticity limit, higher cation exchange capacity (CEC), lower hydraulic conductivity.

Albrecht and Benson (2001) studied about effect of desiccation on compacted natural clays. They found that lowest volumetric shrinkage strains are there near optimum water content. Volumetric shrinkage strain was observed to increase with clay content. Most severe cracking will be at point of highest volumetric shrinkage strain.

Kaya and Durukan (2003) studied about utilization of bentonite-embedded zeolite as clay liner.It was found that zeolite due to its high adsorption capacity result in a thinner liner and reduction of contamination migration.

Miller (2004) studied about suitability of fiber reinforcement for waste containment soil liners.The permeability was reported to be restored to approximately 90%, for a fiber content of 0.8%.

He et al.(2015) studied about influence of salt concentration on volume shrinkage and water retention characteristics of compacted GMZ bentonite. They found that the chemistry of pore water plays an important role on its behaviour during the drying process.

Hassanikhah et al. (2018) conducted bench-scale study of behaviour of zinc contamination in clayey soil. They found that the bench scale box is an useful method for observing moisture content changes with depth as a function of time during soil drying.

Zhang et al. (2018) conducted research on effects of tension crack on stability of bentonite-water slurry trenches in clay Bentonite-water slurry trenches are utilised not only in underground excavations, but also in geo-environmental protections. Slurry trench can be used to prevent leaks and spills of the contaminant from landfills. They presented a procedure for evaluation of the impact of possible tension crack on stability of slurry trench in clay. The procedure is based on variational limiting equilibrium approach to slope stability.

2. MATERIALS

2.1. Bentonite

Bentonite usually forms from weathering of volcanic ash, most often in the presence of water.Bentonite is absorbent aluminiumphyllosilicate clay consisting mostly of montmorillonite. For industrial purposes, two main classes of bentonite exist: sodium and calcium bentonite. Here we use sodium bentonite for the crack study. Sodium bentonite expands when wet, absorbing as much as several times its dry mass in water. Because of its excellent colloidal properties, it is often used in drilling mud for oil and gas wells and boreholes for geotechnical and environmental investigations. The property of swelling also makes sodium bentonite useful as a sealant, since it provides a self-sealing, low permeability barrier. It is used to line the base of landfills. Various surface modifications to sodium bentonite improve some rheological or sealing performance in geoenvironmental applications, for example, the addition of polymers. Fig. 1 shows the sodiumbentonite and Table 1 shows the properties of sodium bentonite.

Fig -1: Sodium Bentonite

Table -1: Initial Properties ofBentonite Clay

Properties	Value
Specific gravity (IS 2720 part3)	2.57
Liquid limit (IS 2720 part 5)	336%
Plastic limit (IS 2720 part 5)	47%
Shrinkage limit (IS 2720 part 6)	12.4%
Plasticity index (IS 2720 part 5)	289%
Optimum moisture content (IS 2720 part 7)	40%
Maximum dry density (IS 2720 part 7)	1.19 g/cc
Soil classification	CH
Free swell index (IS 2720 part 40)	120 %
UCS strength (IS 2720 part 10)	112.7 kN/m^2
Coefficient of permeability (IS 2720 part 17)	3.2x10^{-10} m/s

2.2. Zinc Acetate Dihydrate

In anhydrous zinc acetate the zinc is coordinated to four oxygen atoms to give a tetrahedral environment, these tetrahedral polyhedra are then interconnected by acetate ligands to give a range of polymeric structures. Most metal diacetates feature metals in octahedral coordination with bidentate acetate groups. In zinc acetate dihydrate the zinc is octahedral, wherein both acetate groups are bidentate.

3. METHODOLOGY

Tests conducted in the study was

•Falling Head Permeability test (IS: 2720 (Part 36)-1983)

The index properties of Bentonite were determined as per the respective IS Codes.

The Sodium bentonite clay is collected from English India pvt limited Kochi. Hydrometer analysis was used to obtain the particle size distribution of the samples in accordance with the standard specifications. For the particle size analysis clay contents are percentages of soil fractions smaller than 0.002mm.

The soil type obtained is CH type. Falling head permeability test were done to find its coefficient of permeability and was obtained as 3.2×10^{-10}m/s.

Plasticity characteristics were obtained as: liquid limit (w_L) is 336%, plastic limit (w_P) is 47%, shrinkage limit(w_S) is 12.4% and plasticity index (I_P) is 289%, compaction characteristics (OMC and MDD) and strength (UCS) of clayey soil, were determined in accordance with IS specifications.

Throughout the study zinc acetate solutions are prepared as standard solution. Weight of the solute (zinc acetate) for preparing various molar concentrations is calculated using the formula;

$$\text{Weight of solute} = \frac{\text{Molarity} \times \text{Molecular weight of solute} \times \text{volume of solvent}}{1000\text{ml}}$$

Molecular weight of solute = 219.49 g/mol

The bentonite clay samples which are contaminated with zinc of different molar concentrations (0 to 0.1M) were tested. The permeability of each mix were determined in accordance with IS specifications.

4. RESULTS AND DISCUSSIONS

4.1. Variation in permeability

The permeability was seen to be varied from 3.2×10^{-10}m/s to 5.3×10^{-10}m/s with varying concentrations of zinc in bentonite. With increasing zinc contamination, particle aggregation in a bentonite-water mixture produced larger channels. This will create more initial micro-cracks which will develop longer cracks and hence permeability also increases.This can cause negative effect if such soils are used as liners in landfill system.

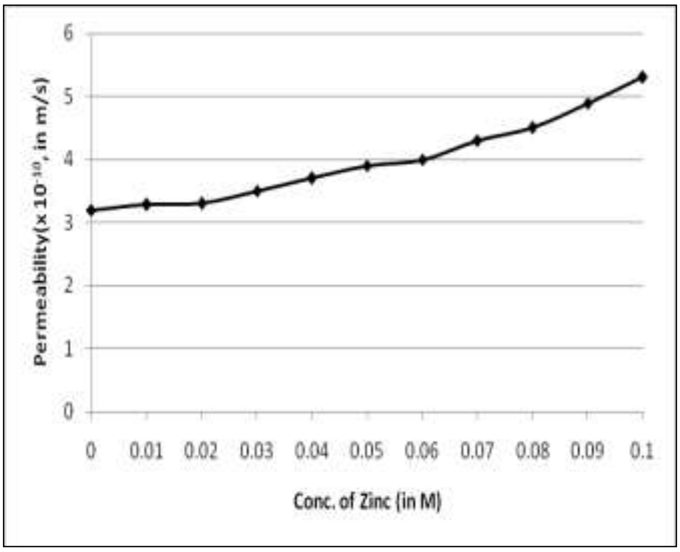

Chart -1: permeability v/s conc. of zinc

Table 2: variation in permeability

Concentration(M)	Permeability($\times10^{-10}$m/s)
0	3.2
0.01	3.28
0.02	3.3
0.03	3.5
0.04	3.7
0.05	3.9
0.06	4
0.07	4.3
0.08	4.5
0.09	4.89
0.1	5.3

5. CONCLUSIONS

- The hydraulic conductivity was seen to vary from 3.2×10^{-10} m/s to 5.3×10^{-10}m/s with varying concentrations of zinc.
- Increase in hydraulic conductivity can cause more leaching of contaminants.
- Zinc leaching out to water sources lead tobio concentration on aquatic organisms.

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