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Effect of Leachate on Index Properties of Soil

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Abstract: *Leachate produced in landfills during waste decomposition is a significant environmental hazard. This paper investigates how leachate alters the index properties of soil, which is commonly used as a barrier or cover layer in landfills. A lab-scale experiment simulating landfill conditions was conducted using a PVC pipe column packed with compacted soil. Leachate was applied daily for 21 days. Pre- and post-exposure testing included shrinkage limit, plastic limit, liquid limit, compaction characteristics, UCS, and specific gravity. The study revealed a consistent reduction in soil strength and plasticity, signaling degradation in its containment capability. These findings highlight the necessity of soil treatment and composite barrier systems for effective long-term waste isolation.*

Key Word: *Leachate, Landfill, Soil Index Properties, Clayey Soil, UCS, Atterberg Limits, Waste Management.*

I.INTRODUCTION

The disposal of solid waste in landfills is a common practice, especially in urban areas. During decomposition, solid waste generates leachate, a contaminated liquid that results from the percolation of water through waste materials. Leachate contains organic matter, heavy metals, salts, and other pollutants that can seep into surrounding soils, potentially reaching groundwater sources. [1]

To mitigate these risks, compacted soil liners are often placed at the bottom and sides of landfills to restrict leachate movement. [2] However, the interaction between soil and leachate can significantly alter the soil's physical and chemical properties. Over time, this degradation could compromise the effectiveness of landfill containment systems.

This study explores the effects of simulated leachate infiltration on the index properties of soil in a controlled laboratory environment.

Landfill leachate typically contains dissolved organic matter, ammonia, nitrate, chloride, and heavy metals. These contaminants interact with the mineral structure of clayey soils, influencing plasticity, permeability, and strength. [3]

- **Siddique and Husain (2010)** [4] documented significant strength reduction in clays due to leachate.
- **Khoury and Daniel (2007)** [3] noted variations in permeability in clay liners under different leachate compositions.
- **Al-Yousfi and Lancelot (2014) [1]** demonstrated increased porosity in leachate-affected soils.
- **Pradhan and Ghosh (2015)** [5] studied Indian soils and highlighted that montmorillonite-rich soils showed reduced Atterberg limits after leachate exposure.

These findings highlight the need for localized laboratory simulation studies to validate the behaviour of clayey soils under leachate attack.

II.MATERIALS AND METHODS

A PVC column (75 cm height, 11 cm diameter) was used to replicate landfill conditions. The soil was compacted in three uniform layers. Leachate was collected from Sakri landfill, Raipur. Based on rainfall data (1250 mm/year) [6], 216 ml of leachate was applied daily.

Tests conducted:

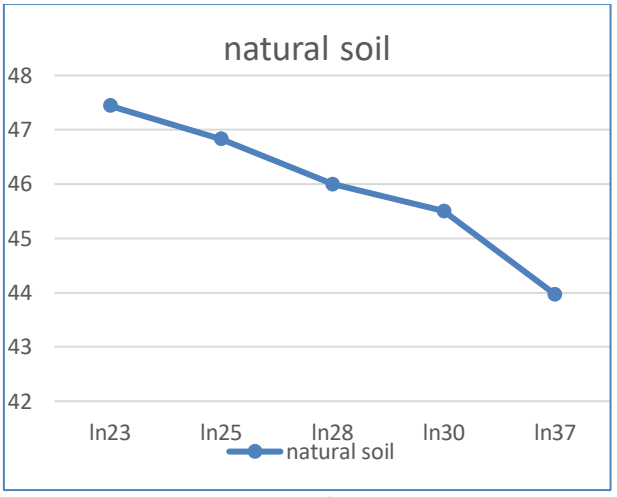
- Specific Gravity (IS: 2720 Part 3)[7]
- Liquid Limit, Plastic Limit, Shrinkage Limit (IS: 2720 Part 5 & 6)[8]
- Standard Proctor Test (IS: 2720 Part 7)[9]
- UCS (IS: 2720 Part 10)[10]

Soil samples were tested both before and after leachate infiltration.

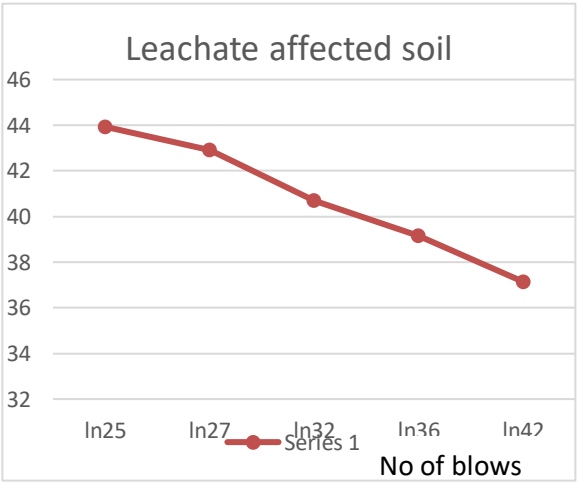
III.RESULTS & DISCUSSION

The following changes were observed after 21 days of leachate infiltration:

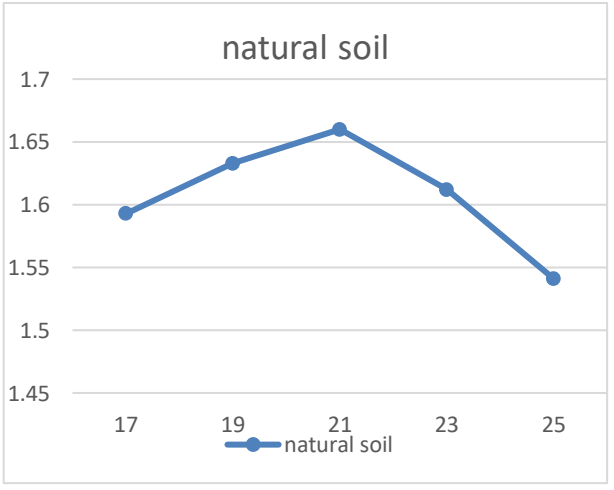
Property	Before Leachate	After Leachate	Change (%)
Shrinkage Limit	16.8%	13.2%	↓ 21.4%
Plastic Limit	25.53%	24.83%	↓ 2.82%
Liquid Limit	46.83%	43.93%	↓ 6.61%
Plasticity Index	25.53%	24.83%	↓ 2.82%
Optimum Moisture Content	21%	19.65%	↓ 6.88%
Maximum Dry Density (MDD)	1.66 g/cm³	1.607 g/cm³	↓ 3.30%
UCS	107 kPa	96 kPa	↓ 11.46%
Specific Gravity	2.40	2.37	↓ 1.25%



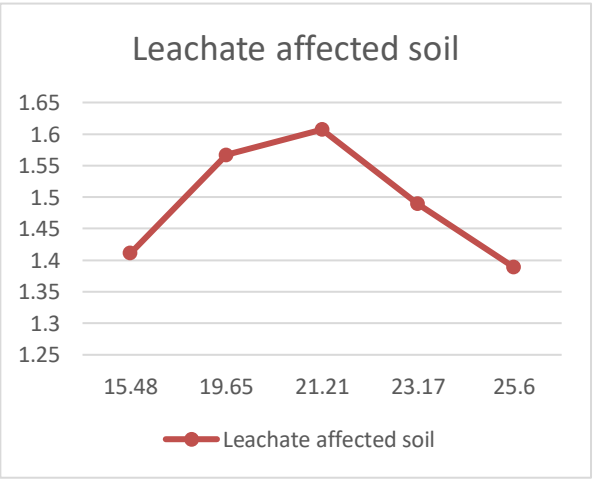
Liquid Limit of natural soil



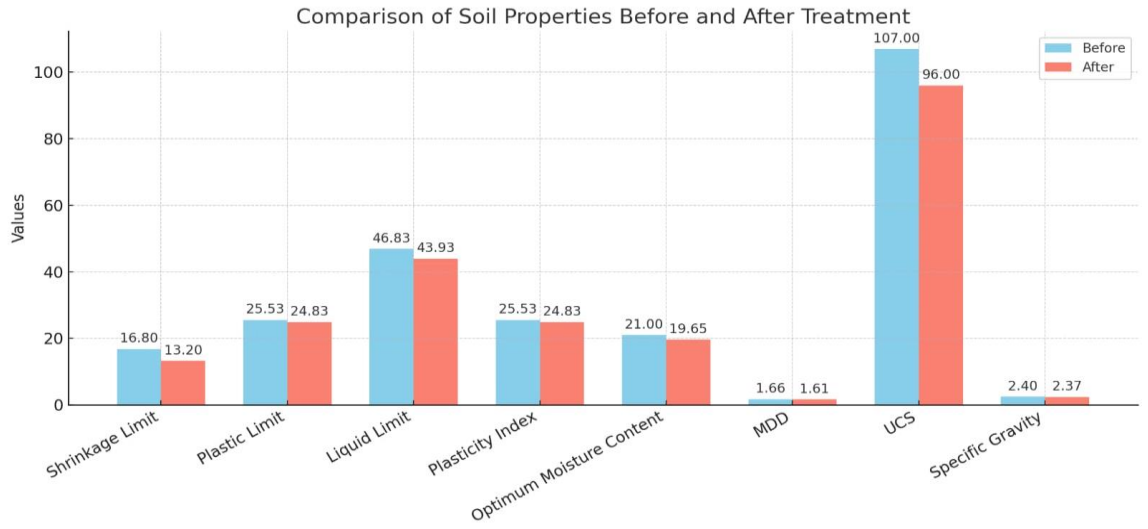
Liquid Limit of leachate affected soil



MDD vs Moisture content (in natural soil)



MDD vs Moisture content (in leachate affected soil)



The results show a consistent deterioration in the properties of soil after leachate exposure.

- **Shrinkage and Plastic Limits**: The reduction indicates that leachate disrupts water retention capacity, making the soil more brittle and less flexible.
- **Liquid Limit**: Lower LL reflects reduced shear strength due to chemical interactions in clay minerals.
- **Compaction**: Decreased MDD and OMC show that the soil structure weakens, becoming less dense and less resistant to water flow.
- **UCS**: The 29% drop in UCS suggests significant strength loss, affecting landfill stability.
- **Specific Gravity**: Slight decrease shows possible mineral dissolution or alteration due to leachate chemicals.

These changes pose serious risks in real-world scenarios, including leakage, cracking, and failure of containment systems.

IV.CONCLUSION

This research confirmed that even short-term exposure to landfill leachate causes notable degradation in soil index properties. The results indicate that:

- Soil becomes less plastic, weaker, and less compactable.
- Using untreated clayey soil in landfill construction could lead to liner failure.
- Protective strategies are essential to maintain environmental safety.

V.RECOMMENDATIONS

1. **Soil Stabilization** using lime, cement, or bentonite should be considered before using natural soil as a landfill liner.
2. **Composite Liners** combining soil with geosynthetic materials can improve containment.
3. **Efficient Leachate Collection** and drainage systems should be designed to prevent ponding and percolation.
4. **Periodic Testing** and long-term monitoring of soil behavior is crucial for safe landfill operation.
5. **Extended Research** involving different soil types, real field conditions, and longer infiltration periods is necessary.

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