Effect of Leachate containments on Clay liners

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Abstract. Clayey soil is made up of extremely tiny clay particles that can be employed as a binding material and have a higher retention of water compared to other soils. A hydraulic barrier to fluid flow can be obtained by a clay liner. Clay liners serve a purpose in liner systems to regulate leachate release from the waste or in covering systems to reduce water infiltration. Long-term low hydraulic conductivity constitutes a demand for clay liners to accomplish these objectives. Clay liners were barriers designed to cover landfills and dispose of low and intermediate-level waste. Clay sample of its index and engineering characteristics permeability will be examined in a laboratory. After adding Na, Cl (salts) and Mg, Cr, Zn, Pb (metals) at different percentages to the clay soil the Hydraulic conductivity and index characteristics are examined within lab conditions. The measured values of the sample's including before and after the addition of chemicals at different percentages 0, 2, 4, 6, and 8%, have been compared by the results of the present investigation.

1 Introduction

Landfills were managed effectively engineering facilities used in industrialised nations to manage toxic trash in a way that protects the environment. Landfills need to be designed, located, operated, and regulated by national government laws and regulations. One of the landfill's most important components, the liner, stops leachate from penetrating the subsoil. When a landfill liner is placed beneath a completed landfill, it needs to have certain characteristics, such as strength, permeability, and swelling behaviour. The design and material requirements of landfill liners were very important because they facilitate the handling and management of various waste types. Additionally, for the purpose to prevent contamination of groundwater, liner systems must be constructed in a cost-effective and environmentally responsible approach (Arunkumar et al., 2022; Arunvivek & Rameshkumar, 2019; Sankar & Ramadoss, 2023).

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Leachate is the result of water and water-soluble chemicals building up in the landfill when water flows through it. Either rainfall or the garbage particles may have provided this water.

Groundwater and soil contamination as well as environmental deterioration may happen from landfill leachate that seeps deeply into the earth. In ponds and landfills, earthen liners are commonly used to confine dangerous and poisonous chemicals. The durability of liners which come into connection with different wastes is closely monitored, and there is a demand for more affordable, higher-quality options. The choice of clay liners for application in hazardous liquid waste containment facilities is mostly influenced by their permeability and sensitivity to modifications with time or chemical exposure. Fine matrix with granular soil are common mixes observed in earthen liners. The worldwide practice of land filling for the disposal of municipal solid waste has emerged as a significant environmental issue, leading to degradation and contamination of the ecosystem. The X-ray diffraction analysis, performed by Sachan et al. (2007), indicated that the clay contains kaolinite, illite, and shapeless quartz particles. These particles have an impact on the clay's hydraulic conductivity and leachates, which increases permeability. By measuring the total dry weight of the soil at various percentages of fly ash (15 and 25%) and lime (0–7%), Zalihe Nalbantoglu et al. (2011) assessed the impact of these materials on the compressibility along with hydraulic properties of an expansive soil in Cyprus. Additional investigations were performed as well on soils that contained 15% fly ash plus 3% lime.

The hydraulic conductivity of 7 geosynthetic clay liners (GCLs) to leachates of synthetic coal combustion products (CCP) was assessed in the investigation. The chemical composition of the leachates reflects both the best and most serious situations found in CCP dumps. Geosynthetics along with landfill liner materials Rajiv Kumar et.al (2023) were employing to improve the geotechnical characteristics of these liners. Additionally examine the application of waste materials and microstructural analysis (SEM–EDX, XRD, FT–IR, etc.) for compacting particles while enhancing the strength and stability of soils. While bentonite-polymer composites having polymer loadings that varied from 0.5 to 12.7% have been observed in four of the GCLs, normal sodium bentonite had been identified in the GCLs. Compacted clay liners, which decrease the rate at which contamination migrates by condensation, are commonly used as hydraulic barriers beneath the leachate collection systems of MSW landfills. Thyagaraj et al. (2021) investigated the poor hydraulic conductivity and rapid molecular diffusion of these liners. The impact of desiccation and leachate infiltrating fractures over natural hydraulic conductivity has been examined by Anggraini et al. (2020). Ajitha et al. (2019) concluded that a low hydraulic conductivity of less than 1*10-7 cm/s is the most important criterion. As the amount of lead grows, permeability falls and shear strength increases. It has been determined that the Langmuir model is the most suitable for this inventive liner.
Yonli et al. (2022) conducted hydro-mechanical experiments on the two sampled materials to evaluate their sealing qualities as well as their capacity to deform and rupture characteristics, which are crucial for ensuring a bottom liner's longevity. For the purpose of figuring out how the hydro-mechanical properties of the clayey soils were altered, all of these experiments were initially conducted using distilled water and subsequently with leachates acting as interstitial fluids. Silt aggregation, compaction density, and subgrade water content were among the five different geosynthetic clay liner products that Kerry Rowe et al. (2019) investigated for hydration. Assuming the same subsoil that has enough cations to cause exchange of cations after hydration, GCLs that satisfy accepted standards for low hydraulic conductivity and swelling index undergo hydration into equilibrium.

Swetha (2023) studied the enhancement of compressive strength and, as a result, shear strength. The results have been compared and recorded for 0, 7, 14, and 28 days for unconfined compressive strength (UCS). Compacted clay was subjected to permeability tests in a controlled environment to investigate the influence of desiccation cracking, hydraulic anisotropy, test specimen diameter, and storage duration. The hydraulic conductivities determined using the compaction-mold, consolidation-cell, and flexible-wall permeameters remained nearly the same by Boston et.al (1985). To evaluate the MDD and accompanying for lateritic soil-lime combinations affect their permeability in terms of lime content, curing time, and compactive effort from the investigation of Osinubi et.al (1998). Uncured specimens (standard Proctor) showed a maximum permeability at 4% lime content, while as the lime content grew, the permeability dropped.

With absence of naturally occurring impermeable soils, Ameta et al. (2008) concentrated on the permeability of compacted bentonite and sand combinations employed to form fluid barriers. Krishna et al. (2021) conducted a series of assessments, including plastic restriction, liquid limit, free swell index, unconfined compressive test (UCC), and California bearing ratio (CBR), which revealed that the soil sample lacked strength in shear, bearing, and plasticity. As a result, the researchers repeated those experiments using varying percentages of fly ash in place of the soil sample. A model pavement subgrade with the stabilised soil characteristics is designed by Vivek Kumar et.al (2021), and an economic analysis is done for the designed pavement subgrade. With expansive soils like black cotton soil, subgrade soil stabilisation is an important step in the pavement construction process. In this study,
Atterberg's limits, Optimum Moisture Content (OMC), and percentage of coal ash added by weight are included, which directly affect the CBR value.

Flexible concrete pavements with a bituminous layer constitute a majority of Indian roads, regardless of the design thickness of the pavements. A flexible pavement having bituminous covering was previously the norm in India due to the country's cement shortage. Because of its wonderful feature of gradually strengthening and improving with increased traffic, this flexible pavement is chosen over cement concrete roads by Kamalaraju et.al (2020) investigation. Using enrollment maps generated with GIS technology that suited the purpose, Katteri watershed produced a number of thematic guides. With the majority of large-scale studies being unfeasible in the field, a lab model of a landslip zone was used to study landslip movement at different slopes and levels of precipitation. The study conducted by Swaminathen et al. (2023) indicates that landslides are more likely to occur on steeper inclines with deeper soil, and that precipitation is the main cause of these events.

2 Materials and Methods

2.1 Soil and Chemicals

The soil used in this study is naturally Block cotton soil collected from Warangal city, of Telangana according to Indian standards (IS 2720, Part 1-1983)(6). The Leachate resembling the chemical composition of landfill leachate was prepared from salts and heavy metals solutions such as Na, Cl (salts) and Mg, Cr, Zn, Pb (metals). The list of heavy metals salts considering in this study and their corresponding Normality is taken as 2N from the initial tests.

2.2 Methodology

2.2.1 Index properties

Numerous factors, notably mechanical characteristics like compressive index, have an impact on the liquid limit. According to definitions, it happens when the soil's moisture content continues to act like a liquid and flows. The settlement analysis will serve from the significance of the compression index. The natural moisture content of soft soil has been estimated to be around the liquid limit. If the amount of moisture remains lower than the liquid limit, the soil is regarded as hard. Casagrande's liquid limit in Fig 2, gives a percentage of the weight of the oven-dried soil that represents the percentage of moisture of the soil during the period of transition between the liquid and plastic consistency stages.

The earth starts behaving as a plastic material at the plastic limit. When a plastic material is moulded to a specific shape, that shape remains intact. format. If the percentage of moisture is less than the plastic limit, the material is either solid or non-plastic. Soil starts becoming like a plastic material once it achieves a specific moisture content. As a percentage of the weight of the soil dried in an oven, the level of consistency at the border of a soil's plastic limit across the plastic and semisolid stages is calculated and showed in Fig 3. As per IS: 2720, soil dissolves when rolled into a thread (3 mm) in diameter and placed on a ground glass plate or other adequate surface.
The tests to determine index properties of soil were done using IS 2720.1985 (Part V) (6). They were done in soil treated with 0%, 2%, 4%, 6%, and 8% Na, Cl (salts) and Mg, Cr, Zn, Pb (metals) to understand the variation in properties of untreated as well as treated soil.

2.2.2 Compaction tests

When the typical compaction test forces air out of the pores between the soil grains, the soil densifies. Compaction happens when dirt is compressed by large machinery. The soil levels used for backfilling or filling a space were called lifts. The state of the natural material being covered will affect how well the initial fill layers compact under the weight of the earth fill over time, which may cause settlement cracks in the fill or in any supporting structures. The maximum dry unit weight and optimal moisture can be significantly influenced by the kind of soil, which includes characteristics like particle size distributions, soil grain shape, specific gravity of soil particles, and the amount of clay minerals present.

The permeability of soil is determined employing the falling head and constant head methods. By allowing the head to sink as water enters the sample, the falling head method lowers the test pressure. This method is generally only applicable to fine-grained soils, such
as clay. Before the flow measurements, the soil sample has been submerged and a specific volume of de-aired water is added to the standpipes. Once the water in the standpipe reaches a predetermined lower limit, the test is initiated by allowing the water to continue flowing through the specimen. The time-stamped amount of time that the water in the standpipe requires to fall from the uppermost level.

The tests to determine the optimum moisture content and maximum dry density were done using both standard proctor compactive effort and to IS 2720.1980 (Part VII) (6). The same is repeated for soil treated with 0,2,4,6, and 8% Na, Cl (salts) and Mg,Cr,Zn,Pb (metals).

Fig 4. Compaction by Standard Proctor Test (SPT)

2.2.3 Hydraulic conductivity testing

Hydraulic conductivity testing was done using consolidometer apparatus and falling head method was used, according to IS 2720.1986 (Part XVII) (6). The permeant used was water and value of coefficient of permeability was recorded once it reached a constant value after complete saturation. The same is repeated for soil treated with 0,2,4,6, and 8% Na, Cl (salts) and Mg,Cr,Zn,Pb (metals).

Fig 4. Falling Head Permeability Test setup

2.2.4 Preparation of Heavy Metals, salts solution

For example, taking Normality for Magnesium,

Normality(N) : Equivalent mass(M) / Total volume of solution(V)
Taking $N=2$, $M=24.31g$, $V=1$ litre

$1N=24.31/1000$

Using algebra and remembering that $N$ is eq/L:

$M = 1 \text{ eq/L} \times 1 \text{ L} \times 24.13g/\text{eq}$

Therefore $m=24.13g$

To make a $1N$ solution, $24.13$ grams of Mg dissolved in $1L$. Likewise, for a $2 \text{ N}$ solution of Mg, multiply by a factor of 2. Mass is equals to $48.26\text{ grams}$.

3 Experimental Investigation

The index properties of soil is summarised in Table 1. From the test results, it was identified that the soil can be classified as clay of intermediate plasticity (CI) according to Unified Soil Classification system. The soil contains 30% sand, 23% silt and 39% clay particles. The variation in Liquid limit, Plastic limit, Plasticity Index and free swelling index is also provided. Chemical properties of MSW leachate values provided in Table 2.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel (%)</td>
<td>8</td>
</tr>
<tr>
<td>Sand(%)</td>
<td>23</td>
</tr>
<tr>
<td>Silt(%)</td>
<td>39</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>30</td>
</tr>
<tr>
<td>Liquid limit (%)</td>
<td>45</td>
</tr>
<tr>
<td>Plastic limit (%)</td>
<td>24</td>
</tr>
<tr>
<td>Plasticity index (%)</td>
<td>18.87</td>
</tr>
<tr>
<td>Free Swelling Index (%)</td>
<td>76</td>
</tr>
<tr>
<td>Optimum moisture content</td>
<td>17</td>
</tr>
<tr>
<td>Maximum dry density (g/cc)</td>
<td>1.84</td>
</tr>
<tr>
<td>Permeability(cm/sec)</td>
<td>$4.5\times10^{-6}$</td>
</tr>
</tbody>
</table>

Table 1. Properties of Clayey soil

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological oxygen demand</td>
<td>0.60</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>940</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>8.10</td>
</tr>
<tr>
<td>Total hardness</td>
<td>181</td>
</tr>
<tr>
<td>pH</td>
<td>8.7</td>
</tr>
<tr>
<td>Chloride</td>
<td>12.7</td>
</tr>
<tr>
<td>Lead</td>
<td>0.2118</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.2099</td>
</tr>
<tr>
<td>Sodium</td>
<td>200</td>
</tr>
<tr>
<td>Potassium</td>
<td>540</td>
</tr>
<tr>
<td>Sulphate</td>
<td>1.21</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.0012</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.60</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.3852</td>
</tr>
</tbody>
</table>

Table 2. Chemical characteristics of MSW leachate
4 Result and Discussion

The graph of experimental investigation carried out in different stages. In this experiments prepared soil mix with various Salts such as Chlorine, Sodium and Heavy metals such as Magnesium, Zinc, Lead with a defined percentages to test the soil properties such as Liquid limit, plastic limit, Standard compaction and Permeability. Below are the test results of the clay soil.

Table 3. Description of Soil composition of Salts and Heavy metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Chlorine (Cl)</th>
<th>Sodium (Na)</th>
<th>Chromium (Cr)</th>
<th>Magnesium (Mg)</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td>Soil+0% Cl</td>
<td>Soil+0% Na</td>
<td>Soil+0%Cr</td>
<td>Soil+0% Mg</td>
<td>Soil+0% Zn</td>
<td>Soil+0% Pb</td>
</tr>
<tr>
<td>S1</td>
<td>Soil+2% Cl</td>
<td>Soil+2% Na</td>
<td>Soil+2% Cr</td>
<td>Soil+2% Mg</td>
<td>Soil+2% Zn</td>
<td>Soil+2% Pb</td>
</tr>
<tr>
<td>S2</td>
<td>Soil+4% Cl</td>
<td>Soil+4% Na</td>
<td>Soil+4% Cr</td>
<td>Soil+4% Mg</td>
<td>Soil+4% Zn</td>
<td>Soil+4% Pb</td>
</tr>
<tr>
<td>S3</td>
<td>Soil+6% Cl</td>
<td>Soil+6% Na</td>
<td>Soil+6% Cr</td>
<td>Soil+6% Mg</td>
<td>Soil+6% Zn</td>
<td>Soil+6% Pb</td>
</tr>
<tr>
<td>S4</td>
<td>Soil+8% Cl</td>
<td>Soil+8% Na</td>
<td>Soil+8% Cr</td>
<td>Soil+8% Mg</td>
<td>Soil+8% Zn</td>
<td>Soil+8% Pb</td>
</tr>
</tbody>
</table>

Table 4. Liquid Limits (%) for Clayey Sample with Salts and Metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cl</th>
<th>Na</th>
<th>Cr</th>
<th>Mg</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>47</td>
<td>44.25</td>
<td>47.56</td>
<td>43</td>
<td>43.6</td>
<td>44</td>
</tr>
<tr>
<td>S2</td>
<td>51</td>
<td>43</td>
<td>48.89</td>
<td>40</td>
<td>41.26</td>
<td>42.67</td>
</tr>
<tr>
<td>S3</td>
<td>56</td>
<td>42.86</td>
<td>49</td>
<td>39</td>
<td>40</td>
<td>40.5</td>
</tr>
<tr>
<td>S4</td>
<td>58</td>
<td>41</td>
<td>52</td>
<td>36</td>
<td>37</td>
<td>38.89</td>
</tr>
</tbody>
</table>

Table 5. Plastic Limits (%) for Clayey Sample with Salts and Metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cl</th>
<th>Na</th>
<th>Cr</th>
<th>Mg</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Limit (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>27</td>
<td>26.5</td>
<td>25</td>
<td>28</td>
<td>25.29</td>
<td>26</td>
</tr>
<tr>
<td>S2</td>
<td>29</td>
<td>27.89</td>
<td>24.39</td>
<td>30.41</td>
<td>23</td>
<td>25.04</td>
</tr>
<tr>
<td>S3</td>
<td>32</td>
<td>28.6</td>
<td>22.64</td>
<td>32</td>
<td>22.56</td>
<td>24</td>
</tr>
<tr>
<td>S4</td>
<td>33</td>
<td>29</td>
<td>21.87</td>
<td>33</td>
<td>20.3</td>
<td>22</td>
</tr>
<tr>
<td>Plasticity Index (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>20</td>
<td>17.75</td>
<td>22.56</td>
<td>17.86</td>
<td>18.31</td>
<td>18</td>
</tr>
<tr>
<td>S2</td>
<td>22</td>
<td>15.11</td>
<td>24.5</td>
<td>16.62</td>
<td>18.26</td>
<td>17.63</td>
</tr>
<tr>
<td>S3</td>
<td>24</td>
<td>14.26</td>
<td>26.36</td>
<td>15.9</td>
<td>17.44</td>
<td>16.5</td>
</tr>
<tr>
<td>S4</td>
<td>25</td>
<td>12</td>
<td>30.13</td>
<td>13.05</td>
<td>16.7</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Table 6. Optimum Moisture Content (%) for Clayey Sample with Salts and Metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cl</th>
<th>Na</th>
<th>Cr</th>
<th>Mg</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>17</td>
<td>17.23</td>
<td>15.43</td>
<td>16.95</td>
<td>15.04</td>
<td>15.6</td>
</tr>
<tr>
<td>S2</td>
<td>18.5</td>
<td>17.6</td>
<td>14.27</td>
<td>17.1</td>
<td>14.07</td>
<td>14</td>
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</table>
Table 7. Maximum Dry Density for Clayey Sample with Salts and Metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cl</th>
<th>Na</th>
<th>Cr</th>
<th>Mg</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1.96</td>
<td>1.98</td>
<td>1.9</td>
<td>2.0</td>
<td>1.76</td>
<td>1.89</td>
</tr>
<tr>
<td>S2</td>
<td>2.0</td>
<td>2.46</td>
<td>1.98</td>
<td>2.56</td>
<td>1.65</td>
<td>1.92</td>
</tr>
<tr>
<td>S3</td>
<td>2.5</td>
<td>2.8</td>
<td>2.06</td>
<td>2.98</td>
<td>1.58</td>
<td>1.976</td>
</tr>
<tr>
<td>S4</td>
<td>2.76</td>
<td>3.2</td>
<td>2.18</td>
<td>3.1</td>
<td>1.46</td>
<td>2.024</td>
</tr>
</tbody>
</table>

Table 8. Permeability (10⁻⁷ cm/sec) for Clayey Sample with Salts and Metals

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cl</th>
<th>Na</th>
<th>Cr</th>
<th>Mg</th>
<th>Zinc</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>3.21</td>
<td>3.61</td>
<td>3</td>
<td>3.8</td>
<td>4.12</td>
<td>3.22</td>
</tr>
<tr>
<td>S2</td>
<td>2.93</td>
<td>2</td>
<td>2.1</td>
<td>2.7</td>
<td>3.5</td>
<td>2.6</td>
</tr>
<tr>
<td>S3</td>
<td>2.6</td>
<td>1.78</td>
<td>1.89</td>
<td>1.8</td>
<td>2.8</td>
<td>1.98</td>
</tr>
<tr>
<td>S4</td>
<td>1</td>
<td>1.1</td>
<td>1.5</td>
<td>1.1</td>
<td>1.6</td>
<td>1.86</td>
</tr>
</tbody>
</table>

Fig 8. Liquid Limits (%) for Clayey Sample with Salts and Metals

Fig 9. Plastic Limits (%) for Clayey Sample with Salts and Metals
The Liquid limit is the moisture level at which soil behaves to flow like water. The liquid limit and plastic limit of the soil alone was found to be 45%, 24%. Liquid limit increases as the chlorine percentage increases and decreases when magnesium or sodium percentages decreases as shown in Fig 8 and Fig 9. Liquid limit increases as the chromium percentage increases and decreases when Lead and Zinc percentages decreases shown in Table 4. Plastic limit of chlorine and magnesium are approximately same when compared to the values of sodium. The results of Lead, Zinc and Chromium are decreased as the chemical percentage increases. Plasticity index almost same behavior when chemicals react with soil as displayed in Fig 10 and Table 5.

The maximum dry density (Table 7) and optimum moisture content (Table 6) of untreated and treated with 0, 2, 4, 6, and 8% Na, Cl (salts) and Mg, Cr, Zn, Pb (metals) soil is obtained through standard method. As the percentage of chemical increases from 0% to 8%, it was observed that the maximum dry density increased from 1.8 g/cc for 0% chemical and the optimum moisture content decreased from 17% for 0% as shown in Fig 11 and Fig 12. As the percentage of chemical increases the variation in the OMC value is also rapidly increasing. The Magnesium percentage increases the MDD value has a minor change. That there is an increase in the MDD value as the percentage of Na, Cl, Cr, Zn, Pb increases. The results of the hydraulic conductivity for the various chemical percentages of 0, 2, 4, 6, and 8% Na, Cl (salts) and Mg, Cr, Zn, Pb (metals) treated with soil that can affect the hydraulic conductivity.

From the results, it can be observed that with 0% marble dust addition, a maximum value of \( k = 4.5 \times 10^{-6} \) cm/sec. The permeability of the soil after the addition of chemicals at a percentage of 2%, 4%, 6%, 8% is been decreased. Results of Permeability as displayed in Fig 13 and Table 8 after addition of Chlorine, Magnesium, Sodium with the fore mentioned graph describes that the soil permeability had been reached to a certain point after the chemicals percentage had been increased and shows similar results approximately.

### 5 Conclusions

Leachate high concentration of chemicals which is affected to soil properties. Locally available soil was treated with 0, 2, 4, 6, and 8% Na, Cl (salts) and Mg, Cr, Zn, Pb (metals) to evaluate the index properties and hydraulic conductivity. The results are obtained the following conclusions can be arrived upon.
For every 2% addition of 2N chlorine solution i.e., from 2% to 8% of chemical the liquid limit, plastic limit results are increased when increase in content of chlorine solution and on other side the optimum moisture content values were improved maximum dry density and permeability results were declined.

In case of zinc and lead solutions maximum dry density value is improved and the optimum moisture content values were decreased as of permeability values.

In case of magnesium and sodium solutions plastic limit value is improved compared to Liquid limit and the optimum moisture content values were improved as of permeability values.

In this observations for every 2% addition of 2N chromium solution i.e., from 2% to 8% of chemical the maximum dry density results are increased when increase in content of chlorine solution and on other side optimum moisture content and permeability results were declined.

Hydraulic conductivity of clayey soil was found to be 4.5*10^{-6} cm/sec which is not acceptable as per the relevant standards. Hence clayey soil was mixed with chemicals of 2N. Based on the Hydraulic conductivity (1x10^{-7} cm/sec), the clayey soil mixed with 8% salts satisfies the criteria for hydraulic conductivity.

References


