Batch Adsorption Test of Phenol on Soils

Mohd Raihan Taha

Dept. of Civil & Structural Engineering, and Institute for Environment & Development (LESTARI)

Universiti Kebangsaan Malaysia
Contents

- Introduction
- Batch Adsorption Test
- Adsorption Isotherms
- Test Materials
- Test Results
- Conclusion
Introduction: Malaysia
Introduction: Geology of Peninsular Malaysia

Legend:
- Granite residual soil
- Sedimentary residual soil
- Quaternary deposits

North-South Highway

Penang
Kuala Lumpur
Universiti Kebangsaan Malaysia
Singapore

Thailand
**Introduction: Sorption**

**Adsorption** = Sticking on the soil surface

**Absorption** = Penetrates into the soil particle
Introduction: Cross section of a landfill

- Geomembrane
- Waste to be placed in here

Soil/Clay liner = low hydraulic conductivity, good stability against chemicals/contaminant, high adsorption/attenuation characteristics, etc.
Batch Adsorption Test

Shake a mixture of known chemical concentration ($C_o$) and soil ($M$) between 18 to 24 hrs. Then final concentrations ($C_e$) were taken after 2 weeks of equilibration. Calculate the amount adsorbed ($q$) from the following formula:

$$q = (C_o - C_e) \frac{V}{M}$$
Adsorption Isotherms: Linear Adsorption Isotherm

\[ K_d = \text{Partition or distribution coefficient} \]

1-D Advective-Dispersive Model for Contaminant Transport in Soil

\[
R \frac{\partial C}{\partial t} = D_L \frac{\partial^2 C}{\partial x^2} - v_x \frac{\partial C}{\partial x}
\]

\[
R = \left( 1 + \frac{\rho}{n} K_d \right)
\]
Adsorption Isotherms: Freundlich Isotherm

\[ q = K C_e^{1/n} \]

\[ \ln q = \ln K + \frac{1}{n} C_e \]

K = Freundlich constant

n = empirical constant
Adsorption Isotherms: Langmuir Isotherm

\[ q = \frac{\alpha \beta C_e}{1 + \alpha C_e} \]

\[ \frac{1}{q} = \frac{1}{\alpha \beta C_e} + \frac{1}{\beta} \]

- \( \alpha \): adsorption constant related to the binding energy or the "affinity" parameter
- \( \beta \): maximum amount of solute that can be adsorbed by the soil
Test Materials: Grain Size Distribution

![Graph showing grain size distribution with markers for residual soil and kaolinite](image-url)
### Test Materials: Some Basic Soil Properties

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Granite residual soil</th>
<th>Kaolinite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>2.55</td>
<td>2.63</td>
</tr>
<tr>
<td>Natural moisture content (%)</td>
<td>31</td>
<td>-</td>
</tr>
<tr>
<td>Liquid limit (%)</td>
<td>76.3</td>
<td>74.2</td>
</tr>
<tr>
<td>Plastic Limit (%)</td>
<td>27.5</td>
<td>41.5</td>
</tr>
<tr>
<td>pH</td>
<td>4.6</td>
<td>5.16</td>
</tr>
<tr>
<td>Organic Carbon Content (%)</td>
<td>1.37</td>
<td>0.88</td>
</tr>
<tr>
<td>Cation exchange capacity, $CEC$, (mmol charge/100g)</td>
<td>8.96</td>
<td>9.91</td>
</tr>
<tr>
<td>% clay fraction (&lt;2 µm)</td>
<td>46</td>
<td>31</td>
</tr>
</tbody>
</table>
Test Materials: Phenol

Phenol is an organic compound widely used in industries such as in the manufacturing plastics, lubricants, paints, pharmaceuticals, herbicides, and resins. Chemically, phenol is a hazardous chemical and if absorbed through skin, inhaled, or swallowed may lead to serious injuries and/or fatalities. One of the major hazard of phenol is its ability to penetrate the skin rapidly. Therefore most phenolic compounds are priority pollutants. For example, the United States Environmental Protection Agency (USEPA) established the drinking water standard for phenol at 1 ppb or less (Acar et al. 1992). As such its disposal have been and still a major issue especially in many developing countries where waste management industries are still in its infancy.
Test Results: Linear Adsorption Isotherm

Phenol-Residual Soil

![Graph showing linear adsorption isotherm for phenol-residual soil series at low concentrations.](image)

\( K_d = 10.48 \text{ L/kg} \)

Observation: 1. Plot is linear; 2. The residual soil has greater adsorption capacity

Phenol-Kaolinite

![Graph showing linear adsorption isotherm for phenol-kaolinite series at low concentrations.](image)

\( K_d = 1.18 \text{ L/kg} \)

Figure 2 Linear adsorption isotherm for phenol-residual soil series at low concentrations.

Figure 3 Linear adsorption isotherm for phenol-kaolinite series at low concentrations.
Test Results: Freundlich & Langmuir Isotherms

Observation: The parameters further indicate that the residual soil has greater adsorption capacity compared to the commercial kaolinite.
Test Results: High Concentrations

Figure 6: A linear adsorption isotherm for phenol-soil interaction for all test results.

Observation: Use of linear $K_d$ is not justified
Test Results:
High Concentrations

Observation: A highly non-linear plot can be significantly linearised in Freundlich and Langmuir’s isotherm.

Figure 7 Linearized Freundlich adsorption isotherm for phenol-soil interaction for all test data.

Figure 8 Linearized Langmuir adsorption isotherm for phenol-soil interaction for all test data.
Test Results: High Concentrations

Maximum adsorption = 245 mg/kg (compare with 238.1 mg/kg from low range adsorption).

Maximum adsorption = 28 mg/kg (compare with 23 mg/kg from low range adsorption).

Observation: Low range prediction can be used to estimate maximum adsorption
Conclusion

1. Adsorption test is one of the tests that can be used to evaluate the potential of a soil for a clay liner material.

2. The granite residual soil adsorb greater amounts of phenol compared to the commercial kaolinite.

3. Tests at low concentration yields linear $K_d$ whereas at low concentrations did not.

4. Low concentration tests can be used to estimate maximum adsorption capacity of soil.
Thank You