Best Practices for Landfill Stabilization
Based on Experiences in East Delhi

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East Delhi

- Population: 3.95 million (2011)
- Area: 125 sq. km.
- Density: 31,600/sq. km.
- Waste Generation: 2,100 TPD
- CCAC Waste Initiative participating city
Ghazipur Landfill

- Area: 70 acres
- Open: 1984
- Planned site life: 25 years
- Height: 55-60 m (2017)
- Daily disposal: 1,800 – 2,000 MT
- Short-lived climate pollutants:
  - Methane from open dumpsite
  - Black carbon from fires
Slope Failure

- Slope failure on September 1, 2017 resulted in 2 fatalities
- Slope ratio was estimated to be approximately 1:1.9
- 45 m wide at the crest, extended 50 m down the slope, approximately 3 m deep, and represented a waste volume of about 7,000 m$^3$
- Causes:
  - High moisture (preceded by heavy rains)
  - Steep slopes
  - Improper operations and management
  - Surface and subsurface fires adding to instability
Post Slope Failure

• East Delhi Municipal Corporation:
  o Temporarily stopped disposal at Ghazipur landfill
  o Began clean up
  o Started moving waste to create benches
  o Sought technical assistance from the CCAC Waste Initiative

• U.S. Environmental Protection Agency:
  o provided technical expertise to conduct an analysis and identify best practices to reduce the risk of future slope failures and fires at Ghazipur
## Steep slopes at Ghazipur Landfill

<table>
<thead>
<tr>
<th>Location</th>
<th>Area (Upper/Lower)</th>
<th>Slope Ratio (Vertical:Horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southeast Slope</td>
<td>Upper slope</td>
<td>1:1.5 – 1:2.2</td>
</tr>
<tr>
<td></td>
<td>Lower slope</td>
<td>1:1.6 – 1:2.7</td>
</tr>
<tr>
<td>North Slope</td>
<td>Upper slope</td>
<td>1:1.3 – 1:1.9</td>
</tr>
<tr>
<td></td>
<td>Lower slope</td>
<td>1:2.3 – 1:3.8</td>
</tr>
<tr>
<td>Southwest Slope</td>
<td>--</td>
<td>1:1 – 1:1.6</td>
</tr>
<tr>
<td>Closed Area (North side)</td>
<td>Plateau area</td>
<td>5 percent</td>
</tr>
<tr>
<td>Northwest Slope</td>
<td>--</td>
<td>Shallow, well-benched, includes access road</td>
</tr>
</tbody>
</table>

Ideally slopes should be no steeper than 1:3 with benches of at least 5 m width for every 10-15 m of vertical distance down the side slope.
Slope Failure Indicators

- Cracks or non-uniform settlements
- Bulges in lower portions of the slope
- Aerial images comparison for lateral or vertical movement
- Leachate breakouts or seepage
- Perched or surface ponding in waste
- Potential surface infiltration & poor stormwater management
- Distressed vegetation
Best Practices for Slope Stabilization

- Form terraces or benches
- Cease placing waste at the top
- Grade all flat waste surfaces to slopes of at least 5% to promote positive surface runoff
- Apply a soil cover on side slopes of at least 0.3 m
- Improve waste compaction
- Monitor liquid levels
- Regularly inspect for tension cracks, deformation or rapid settlement
Potential Causes of Fires at Ghazipur site

• Surface fires:
  o Off-site source - “HOT” loads
  o Equipment
  o Smoking
  o Waste-salvagers

• Subsurface fires
  o Microbial activity producing heat
  o Plenty of fuel in waste mass
  o Air infiltration in waste mass
Best Practices for Fighting Fires

• Smother with soil
• Have a soil stockpile nearby
• Use foams and suppressants
• Avoid water, especially near slopes
• Train landfill operators
• Train local fire department(s)
East Delhi Current Actions and Considerations

• Decentralize waste management
• Continue to address slope issues
• Mine waste at landfill and use inert material for highway embankment
• Consider a vertical retaining structure
• Improve operations
Thank you! Questions?

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