Lactic Acid Fermentation, Urea and Lime: Promising Faecal Sludge Sanitizing Methods for Emergency Situations

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Background

Problem Statement
When refugee or IDP camps are located in densely populated or sensitive areas (flood prone, rocky terrain, high water table), to prevent disease and safeguard public health, there is a need to sanitize the generated faecal sludge/wastewater before discharge. Current treatment options are limited and there is a need to investigate simple sanitation processes that could be easily implemented in an emergency setting.

Emergency Sanitation Criteria
1. Safety
2. Sanitation
3. Robustness
4. Deployment
Experimental Set up

**Pit Latrine**

*Bangwe Market Pit Latrine*
Users per day: 50-100 people
Sludge age: 2 weeks - 1 month
## Faecal Sludge Characteristics

### Household Pit Latrines Sludge

- **Sludge Age**: 1-7 years
- **pH**: 7.3-7.6
- **Total Solids (TS) (%)**: 6-9
- **Volatile Solids (as % of TS)**: 45-55
- **E. Coli (CFU/100ml)**: $3 \times 10^6$
- **Amount of Solid Rubbish**: 60 - 120 L

### Market Pit Latrines Sludge

- **Sludge Age**: 1-4 weeks
- **pH**: 6.0-7.4
- **Total Solids (TS) (%)**: 4-15
- **Volatile Solids (as % of TS)**: 60-70
- **E. Coli (CFU/100ml)**: 2-7 $\times 10^6$
- **Amount of Solid Rubbish**: 10 - 40 L
Lactic Acid Fermentation

Method

1. Prepare Pre-culture Inoculum
2. Fill Drums with Sludge
3. Chemical Addition
   - 10%w/w Pre-culture
   - 10% w/w molasses
4. Mix 3 minutes
5. Seal Container
6. Collect Samples
   - 0d, 2d, 4d, 7d, 9d

Control

Reactor 1
- 10% Molasses
- 10% w/w pre-culture

Reactor 2
- 10% Molasses
- 10% w/w pre-culture

Reactor 3
- 10% Molasses
- 10% w/w pre-culture
# Lactic Acid Fermentation

## Results

<table>
<thead>
<tr>
<th>Lactic Acid Field Trials (Faecal Sludge Volume: 25L)</th>
<th>LATR: 10% Molasses, 10% LAB pre-culture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time (day)</strong></td>
<td><strong>Lactic Acid Conc (mg/L)</strong></td>
</tr>
<tr>
<td>0</td>
<td>62</td>
</tr>
<tr>
<td>48</td>
<td>72</td>
</tr>
<tr>
<td>96</td>
<td>75</td>
</tr>
<tr>
<td>168</td>
<td>77</td>
</tr>
<tr>
<td>216</td>
<td>68</td>
</tr>
</tbody>
</table>

![Graph showing Lactic Acid Concentration (mg/L) vs Treatment Time (hours) with pH, pH - control, E. coli Count LOG10(CFU/100ml) - Control, E. coli Count LOG10(CFU/100ml) - Reactor, Lactic Acid - Control mg/L, Lactic Acid - Reactor mg/L.](chart.png)
Lactic Acid Fermentation

Economics

Chemical Costs: €32/m³

Pre-culture
Lactic Acid concentration 16,000 mg/L

Chemical Costs: €2/m³

Treated Sludge
Lactic Acid concentration 47,000 mg/L

2g glucose per kg sludge

Molasses
Pre-culture

Molasses
Urea Treatment

• Experimental Set up
  1. Fill drums with 25kg sludge
  2. Add Urea
  3. Mix
  4. Monitor and Sample
Urea Treatment

• Results: E. coli

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>pH</th>
<th>pH Nitrogen NH3-N (mg N/L)</th>
<th>NH3-N (mg N/L)</th>
<th>E.coli (CFU/100ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7.43</td>
<td>7.7</td>
<td>77</td>
<td>9 x 10^5</td>
</tr>
<tr>
<td>48</td>
<td>7.03</td>
<td>9.03</td>
<td>22</td>
<td>4.9 x 10^3</td>
</tr>
<tr>
<td>96</td>
<td>7.11</td>
<td>9.13</td>
<td>19</td>
<td>6.3 x 10^3</td>
</tr>
<tr>
<td>144</td>
<td>6.94</td>
<td>9.19</td>
<td>10</td>
<td>7.6 x 10^3</td>
</tr>
<tr>
<td>168</td>
<td>7.28</td>
<td>9.22</td>
<td>20</td>
<td>8.3 x 10^3</td>
</tr>
</tbody>
</table>

Economics: Chemical Cost 25kg Urea per m³ = € 20/m³
Lime Treatment

Experimental Set up

1. Fill drums with 25kg sludge
2. Add Lime to achieve target pH
3. Mix
4. Monitor and Sample

Control
Reactor 1 pH 9
Reactor 2 pH 10
Reactor 3 pH 11
Reactor 4 pH 12
## Lime Field Trials (Faecal sludge volume: 25L)

<table>
<thead>
<tr>
<th>Lime Field Trials (Faecal sludge volume: 25L)</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH 6 - 7</td>
<td>0%</td>
<td>3 - 9%</td>
<td>5 - 12%</td>
<td>7 - 17%</td>
</tr>
<tr>
<td>pH 9</td>
<td>3 x 10^6</td>
<td>2 x 10^5</td>
<td>Not Detected</td>
<td>Not Detected</td>
</tr>
<tr>
<td>pH 10</td>
<td>2 x 10^5</td>
<td>5 x 10^4</td>
<td>Not Detected</td>
<td>Not Detected</td>
</tr>
<tr>
<td>pH 11</td>
<td>1 x 10^6</td>
<td>Not Detected</td>
<td>Not Detected</td>
<td>Not Detected</td>
</tr>
<tr>
<td>pH 12</td>
<td>3 x 10^6</td>
<td>1 x 10^6</td>
<td>Not Detected</td>
<td>Not Detected</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment Time (hr)</th>
<th>E.coli (CFU/100ml)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4 x 10^6</td>
</tr>
<tr>
<td>1</td>
<td>3 x 10^6</td>
</tr>
<tr>
<td>2</td>
<td>4 x 10^6</td>
</tr>
<tr>
<td>5</td>
<td>3 x 10^6</td>
</tr>
</tbody>
</table>

Chemical Cost of Lime Treatment per m³ = € 12/m³
Summary

Faecal Sludge Treatment

<table>
<thead>
<tr>
<th>Technology</th>
<th>Biological Treatment</th>
<th>Bio-Chemical Treatment</th>
<th>Chemical Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitising Time</td>
<td>7 days</td>
<td>4 days</td>
<td>1 hour</td>
</tr>
<tr>
<td>End pH</td>
<td>pH 4</td>
<td>pH 9</td>
<td>pH 11</td>
</tr>
<tr>
<td>Chemical cost per m³ faecal sludge</td>
<td>€ 2/m³</td>
<td>€ 20 /m³</td>
<td>€ 12 /m³</td>
</tr>
</tbody>
</table>
## Conclusions

**Lactic Acid, Urea Treatment and Lime Treatment**
Faecal Sludge Treatment Processes that satisfy the *Emergency Sanitation Criteria*

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>The process can be conducted safely and adhere to the safety, health and environmental norms and standards during operation and maintenance;</td>
</tr>
<tr>
<td><strong>Sanitation</strong></td>
<td>The process is able to reduce <em>E.coli</em> to below detectable limits</td>
</tr>
<tr>
<td><strong>Robustness</strong></td>
<td>The process can treat both liquid and solid sludge. All three technologies could be undertaken in either an above ground tank or portable bladder and therefore could be effective under challenging physical conditions such as unstable soils, high water tables and flood-prone areas</td>
</tr>
<tr>
<td><strong>Deployment</strong></td>
<td>The process is simple and requires readily available material, and therefore have the potential for rapid deployment upon the event of an emergency.</td>
</tr>
</tbody>
</table>
Acknowledgements

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Lactic Acid Fermentation

Carbohydrates → Lactic Acid Bacteria

Metabolites (e.g. Lactic Acid)

Environmental pH

Lactic Acid Bacteria

Bacteriocins (Bactericidal proteins)

Lactobacillus casei Shirota
Urea Treatment

Urea Hydrolysis

Urea → Urease → NH₃ + CO₂

Ammonia gas (NH₃)

Minimize head space and ventilation

Toxic to pathogens

Emergency Sanitation Project
SPEEDKITS
WASTE
UNESCO-IHE
TU Delft
Hydrated Lime \([\text{Ca (OH} \text{)}_2]\)

**Sanitising Mechanisms**

- **Hostile alkaline environment**
  - Increasing pH through addition of \(\text{Ca(OH)}_2\)

- **Ammonia Toxicity**
  - Increased pH increases ammonia \((\text{NH}_3)\) concentration