Use of clay minerals for reducing sewage sludge's microbial load and nitrogen losses

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Introduction

Land application of sewage sludge

- Improves soil fertility (N, P, organic mater, micronutrients)
- Reduces dependence on chemical fertilizers
- Enriches the global goal of sustainability

Most common methods:

- N losses (NH$_3$) during stabilization period

Retention could possibly be achieved with certain clay minerals due to:

- Structure
- Strong colloidal properties
- Volume increase
Objectives

The ability of clay minerals to:

- Reduce sludge’s microbial load indicators
- Retain sludge’s N during the stabilization process

In comparison to:

- Untreated
- Limed sludge
### Materials and Methods

#### Certain properties of the clay minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>pH (1:10 H₂O)</th>
<th>CEC (cmolₖg⁻¹)</th>
<th>Mineral</th>
<th>pH (1:10 H₂O)</th>
<th>CEC (cmolₖg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite low grade (B1)</td>
<td>7.9</td>
<td>102</td>
<td>Saponite (S)</td>
<td>8.6</td>
<td>60.9</td>
</tr>
<tr>
<td>Bentonite high grade (B2)</td>
<td>9.5</td>
<td>96.5</td>
<td>Attapulgite (A)</td>
<td>8.3</td>
<td>71.3</td>
</tr>
<tr>
<td>Bentonite low grade treated with Na₂CO₃ (B3)</td>
<td>10.5</td>
<td>97.4</td>
<td>Mixed clay of saponite-attapulgite (SA)</td>
<td>8.5</td>
<td>80.0</td>
</tr>
<tr>
<td>Bentonite high grade treated with Na₂CO₃ (B4)</td>
<td>10.1</td>
<td>96.5</td>
<td>Thermally modified attapulgite (ThA)</td>
<td>7.6</td>
<td>81.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Zeolite (Z)</td>
<td>8.9</td>
<td>159</td>
</tr>
</tbody>
</table>
Certain properties of the dewatered sewage sludge

<table>
<thead>
<tr>
<th>Total coliform (MPN g⁻¹)</th>
<th>E. coli (MPN g⁻¹)</th>
<th>Enterococcus (MPN g⁻¹)</th>
<th>Salmonella spp. (per 25 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5 ( \times 10^4 )</td>
<td>2.9 ( \times 10^4 )</td>
<td>3.4 ( \times 10^4 )</td>
<td>Detectable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pH (1:5 H₂O)</th>
<th>Dry matter (g kg⁻¹)</th>
<th>LOI (g kg⁻¹)</th>
<th>NO₃-N (mg kg⁻¹)</th>
<th>NH₄-N (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>162</td>
<td>656</td>
<td>66.5</td>
<td>715</td>
</tr>
</tbody>
</table>

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Treatments
- 9 minerals
- Ca(OH)$_2$ (RG) rates 0 (control), 10, 20 and 30%

Experiment
- Plastic pots
- Equilibration period 70 days
- 2 samplings (35 and 70 days)
- Experimental design CRD, 3 replications
- ANOVA for each parameter, within each sampling (10 materials x 4 rates) & LSD test $p \leq 0.05$
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Results and discussion

Sludge’s microbial indicators

↓ Reduction trend after 35 and 70 days

Reduction of the fecal indicators (in logarithmic scale) and salmonella spp. of the 30% treatments in respect to the dewatered sewage sludge

<table>
<thead>
<tr>
<th>Microbial load</th>
<th>Material</th>
<th>B1</th>
<th>B2</th>
<th>A</th>
<th>SA</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. coliform</td>
<td></td>
<td>1.8</td>
<td>1.1</td>
<td>2.4</td>
<td>2.8</td>
<td>2.5</td>
</tr>
<tr>
<td>E. coli</td>
<td></td>
<td>2.0</td>
<td>1.0</td>
<td>2.1</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Enterococcus</td>
<td></td>
<td>1.4</td>
<td>1.3</td>
<td>0.7</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td></td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

- The fecal indicators were ND in all treatments of Ca(OH)$_2$

80-100%
Moisture
↓ Reduced in all treatments (7-14%)
↓ Significantly lowest in Ca(OH)$_2$ treatments (5-8%)

pH
• Similar results in both samplings
↓ Control treatments’ pH decreased to acidic levels (6.3-6.6)
↑ All materials increased significantly pH
  • B1, B2, S, A, SA, ThA, Z: slightly acidic to slightly alkaline range (6.7-7.2)
  • B3, B4: alkaline to strongly alkaline range (7.5-8.8)
  • RG10: strongly alkaline range (12.2-12.6)
Organic matter
- Almost similar results in both samplings
- Decreased with the addition of all materials
- No proportional decrease to the increase of the addition rate

Organic matter (as LOI %) of 30 % treatments, after 70 days of equilibration

<table>
<thead>
<tr>
<th>Rate</th>
<th>Material</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 %</td>
<td></td>
<td>20.9mn</td>
<td>20.7mn</td>
<td>20.6mn</td>
<td>20.3mn</td>
<td>28.7ij</td>
</tr>
<tr>
<td>30 %</td>
<td>A</td>
<td>27.8jkl</td>
<td>23.9k1m</td>
<td>23.5lm</td>
<td>24.2k1m</td>
<td>1.60</td>
</tr>
</tbody>
</table>

Highest OM content

Lowest OM content
NO₃-N

- At 30% rate:
  - Significantly lowest concentration of each material

NO₃-N (mg kg⁻¹) of all treatments at 30 % rate, after 70 days of equilibration

<table>
<thead>
<tr>
<th>Rate</th>
<th>Material</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 %</td>
<td></td>
<td>925lmn</td>
<td>802mno</td>
<td>166r</td>
<td>145r</td>
<td>776no</td>
</tr>
<tr>
<td>30 %</td>
<td>A</td>
<td>1417cd</td>
<td>861mno</td>
<td>842mno</td>
<td>975klm</td>
<td>496q</td>
</tr>
</tbody>
</table>

- Within each rate lowest concentration: B3, B4, RG

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**NH₄-N**

- Highest concentration: Z
- Lowest concentration: RG
- At 30% the rest minerals had similar content

**C/N ratio**

- Increase with the increase of rate (except Z)
- Ranged at low levels (5.3-8.4) even the control (6.8-7.0)
Conclusions

- Natural bentonite
- Attapulgite
- Mixed clay of saponite-attapulgite
- Zeolite

Promising materials for sewage sludge sanitation

- They preserve more sludge’s N
- Economic materials found in Greece

- Could be an alternative way to treat sludge
Thank you for your attention