Impact of Sludge Characteristics on Planted Drying Bed Performance

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Introduction
The sanitation MDGs ... a good thing with adverse effects

Increase in the rate of access to improved facilities:
- Sewer systems
- Semi-collective systems
- On-site systems

Increase of effluent production:
- Wastewater
- Faecal sludge

Treatment issues:
- No WWTP or FSTP
- WWTP or FSTP are obsolete
- High operating and maintenance costs
- No qualified staff

What to do ....
Make sanitation one of the major engines of economic development in MDGs context...!

Implement a sanitation chain

Infrastructure
Transport
Treatment

Develop low-cost treatment facilities

Lagoons
Unplanted beds
Planted drying beds,

Resources recovery

Energy
Nutrients
Proteins
Water

Financing Sanitation

Healthy Environment

Healthy
Human
Health

HEALTH CARE is a RIGHT Not a PRIVILEGE

FSM3
Planted drying beds one of the low-coast technologies for **Resource Recovery**....

... but specific operation guidelines are needed for to each climatic zone!
PDB : well managed and reliable technologies in developed countries

- Loading rate
- Loading frequency
- Effluents treated
- Macrophytes

→ high expertise
Design and operation of PDB... Sub-Saharan Africa lags behind

- PDB in experimental stage

- Sludge loading rate: 200 kg/m²/year (Kengne et al., 2008)
- Loading frequency: 1X/week (Kengne et al., 2008)
  - Can that be in the semiarid to arid climate zone?

- Types of effluents treated: FS (Kengne et al., 2008)
  - What is the behaviour of the bed relative to other types of effluents? ...design perspectives.

- Types of macrophytes: Echinochloa pyramidalis (Kengne et al., 2008)
  - Is it as much or more effective than macrophytes long time used in drying beds?
Objectives

Improve the purification performances, and biosolids qualities

SO1: batch frequency

SO2: type of macrophytes

SO3: type of incoming sludge

Today’s presentation
Methodology
Design and system operation in 6 steps

Establishment of the bed
- Barrels of 200 l:
  - Height: 90 cm  Ø: 50 cm

Plantation
- Echinochloa pyramidalis 9 feet/m²
- Watered with tap water

Acclimatization
- Watered with tap water (a)
- Watered with faecal sludge supernatant (b)
- Duration: 1 month

Load increase
- 50, 75, 100, 150 kg/m²/year
- Duration: 2 months

Operation at rated load
- 200 kg /m²/year
- Loads of FS-ST, FS-SST and WwS once/week
- Duration: 9 months

Maturation
- Duration: 3 months
- No load
Assessment dewatering capacities

- Hydraulic retention time
- Dryness of accumulated sludge
- Leachate release rate
- “Clogging” (ponding of water on surface)
Measuring morphological characteristics of the plants

- **Height and average diameter of plants**
  - In each bed, ten (10) plants are selected.
  - Plant height (in cm) was measured using a measuring tape.
  - Average diameter (in mm) was measured using an electronic caliper.

- **Plant density**
  - The bed is divided into four (04) equal parts.
  - The plants are counted in one part.
  - The number of plants per m² is obtained by multiplying the number of plant of one by 4 and dividing by the surface.
Monitoring of purification performances

- For each application, raw sludge and percolates from each bed unit were collected.

- Analyses were done for TS, TSS, TVS, COD, TKN, TP, NH4+, NO3- as outlined in Standard Methods (APHA et al., 2005).

- pH, Conductivity, Salinity, ORP and T° are measured directly by using multiline electrodes.

- Purification performances are calculated throughout this equation:

\[
\text{Purification performance (\%)} = \frac{(C_{\text{influent}} \cdot V_{\text{influent}}) - (C_{\text{effluent}} \cdot V_{\text{effluent}})}{(C_{\text{influent}} \cdot V_{\text{influent}})} \times 100
\]

with: C: concentration in mg/L and V: volume in litre.
Sampling and biosolid samples preparation (5 sampling points)

Hand auger → Sampling → Sample

3 sub-samples

Heavy metals

Ascaris eggs

Physicochemical parameters

Drying → Sieving → Sample
Analyses of the agronomic quality of biosolids (at LAMA-IRD)

- $pH_{\text{water}}$ and $pH_{\text{KCl}}$: suspension 1/2.5 (w/v) sample and, respectively deionized water and KCl (1M)
- Conductivity: suspension 1/5 (w/v) (sample/deionized water)
- CEC and exchangeable cations: respectively by colorimetric and atomic absorption spectrophotometry after extraction with ammonium acetate (1N)
- Organic carbon: Walkey Black method (1934)
- The inorganic nitrogen: colorimetric after extraction with a solution of KCl 1N
- The C/N: elementary auto-analyzer by gas chromatography
- TP: colorimetric after hot aqua regia attack
- $PO_4^{3-}$: Olson / Dabin method
Results and discussions
FS-STT and WWS are over 10 times more concentrated than the FS-ST.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>FS-ST</th>
<th>FT-STT</th>
<th>WwS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS</td>
<td>(mg/L)</td>
<td>6533.9 (3123.7)</td>
<td>72599.6 (13792.7)</td>
<td>37690.7 (10391.1)</td>
</tr>
<tr>
<td>TVS</td>
<td>(%)</td>
<td>51.5 (4.6)</td>
<td>53.7 (3.5)</td>
<td>53.6 (3.5)</td>
</tr>
<tr>
<td>TSS</td>
<td>(mg/L)</td>
<td>5613.8 (2557.6)</td>
<td>71643.0 (13667.7)</td>
<td>36390.9 (11075.4)</td>
</tr>
<tr>
<td>COD</td>
<td>(mg/L)</td>
<td>6922.3 (2884.4)</td>
<td>74263.3 (14611.5)</td>
<td>38725.3 (11056.4)</td>
</tr>
<tr>
<td>TNK</td>
<td>(mg/L)</td>
<td>240.4 (100.5)</td>
<td>1985.4 (382.4)</td>
<td>956.2 (372.5)</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>(mg/L)</td>
<td>122.6 (32.3)</td>
<td>321.0 (114.4)</td>
<td>208.3 (58.0)</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>(mg/L)</td>
<td>(82.8) (15.6)</td>
<td>238.5 (87.4)</td>
<td>276.6 (171.6)</td>
</tr>
<tr>
<td>TP</td>
<td>(mg/L)</td>
<td>58.0 (5.3)</td>
<td>634.5 (384.0)</td>
<td>205.7 (66.2)</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>(mg/L)</td>
<td>336 (6.1)</td>
<td>49.0 (11.0)</td>
<td>34.0 (14.5)</td>
</tr>
<tr>
<td>Conductivity</td>
<td>(µS/m)</td>
<td>1693.3 (281.7)</td>
<td>3189.6 (932.9)</td>
<td>5370.1 (1172.7)</td>
</tr>
<tr>
<td>Salinity</td>
<td>(g/L)</td>
<td>1.2 (0.3)</td>
<td>1.6 (0.5)</td>
<td>2.7 (0.7)</td>
</tr>
</tbody>
</table>

On average 115.52 litres of FS-ST against 10.40 litres for FS-STT and 20.03 litres for WwS corresponding respectively to 59 cm/m²; 5 cm/m² and 10 cm/m² of sludge height.
Best dewatering capacities in beds treating FS-STT and WWS after each feeding

High concentration of sludges lead to load loads that result in:

- Low volume of leachates recovered
- Low clogging percentages
- High dryness that can influence plants development
Development problems of plants in beds fed with FS-STT and WwS during the dry season
High pollutants removal rates ... but leachate characteristics above Senegalese standards

- No differences in the removal rates of TS, TSS, COD -> physical retention is the main removal process
- Low mineral removal in beds treating FS-ST
- Leachate concentrations higher than Senegalese standards
- Leachates from beds treating FS-STT and WwS are higher concentrated
- Significant differences in TS, COD and NO3-

<table>
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<tr>
<th>Parameters</th>
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<th>WwS</th>
<th>Senegalese standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS</td>
<td>(mg/L)</td>
<td>400.6 (1836.1)a</td>
<td>4096.6 (2484.2)b</td>
<td>4424.6 (1591.2)b</td>
<td>-</td>
</tr>
<tr>
<td>TVS</td>
<td>(%)</td>
<td>36.7 (5.2)a</td>
<td>40.7 (8.2)a</td>
<td>42.1 (7.4)a</td>
<td>-</td>
</tr>
<tr>
<td>TSS</td>
<td>(mg/L)</td>
<td>242.6 (109.5)a</td>
<td>247.7 (91)a</td>
<td>219.6 (41)a</td>
<td>50</td>
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<tr>
<td>CDO</td>
<td>(mg/L)</td>
<td>326.9 (179.7)a</td>
<td>723.1 (297.8)b</td>
<td>591.1 (143.6)b</td>
<td>200-100</td>
</tr>
<tr>
<td>TKN</td>
<td>(mg/L)</td>
<td>106.3 (37.2)a</td>
<td>142.4 (35.9)a</td>
<td>129.7 (80.1)a</td>
<td>30</td>
</tr>
<tr>
<td>NH4⁺</td>
<td>(mg/L)</td>
<td>63.4 (20.5)a</td>
<td>64.3 (21.4)a</td>
<td>50.2 (31.6)a</td>
<td>-</td>
</tr>
<tr>
<td>NO3⁻</td>
<td>(mg/L)</td>
<td>37.2 (15.2)a</td>
<td>92.2 (78.7)b</td>
<td>90.4 (49.1)b</td>
<td>-</td>
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<tr>
<td>TP</td>
<td>(mg/L)</td>
<td>16.1 (3.9)a</td>
<td>12.8 (12.8)a</td>
<td>18.3 (12.1)a</td>
<td>10</td>
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<tr>
<td>PO4³⁻</td>
<td>(mg/L)</td>
<td>5.7 (2.9)a</td>
<td>4.9 (1.7)a</td>
<td>5.2 (2.8)a</td>
<td>-</td>
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</table>
### Mature biosolids whatever the nature of the sludge

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>FS-ST</th>
<th>FS-STT</th>
<th>WwS</th>
<th>Mature biosolids</th>
<th>References</th>
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<tbody>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>pH$_{\text{water}}$</td>
<td>-</td>
<td>6.54</td>
<td>6.45</td>
<td>6.46</td>
<td>6.58</td>
<td>Kengne et al. (2009)a</td>
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<tr>
<td>pH$_{\text{KCl}}$</td>
<td>-</td>
<td>6.40</td>
<td>6.41</td>
<td>6.36</td>
<td>5.28</td>
<td>Kengne et al. (2009)a</td>
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<tr>
<td>Salinity</td>
<td>%</td>
<td>0.87</td>
<td>1.73</td>
<td>1.60</td>
<td>0.10</td>
<td>Kengne et al. (2009)a</td>
</tr>
<tr>
<td><strong>Stability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NH$_4^+$/NO$_3^-$</td>
<td>-</td>
<td>0.46</td>
<td>0.50</td>
<td>0.33</td>
<td>&lt; 1</td>
<td>Ko et al. (2008)</td>
</tr>
<tr>
<td>C/N</td>
<td>-</td>
<td>9.01</td>
<td>9.05</td>
<td>10.05</td>
<td>&lt; 12</td>
<td>Bernal et al. (1998)</td>
</tr>
<tr>
<td>CEC</td>
<td>meq%</td>
<td>44.44</td>
<td>36.77</td>
<td>39.50</td>
<td>&gt; 60</td>
<td>Harada and Inoko (1980)</td>
</tr>
<tr>
<td><strong>Nutrients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total N</td>
<td>%</td>
<td>2.80</td>
<td>2.59</td>
<td>2.35</td>
<td>2.00</td>
<td>Kengne et al. (2009)a</td>
</tr>
<tr>
<td>NO$_3^-$</td>
<td>%</td>
<td>0.04</td>
<td>0.12</td>
<td>0.07</td>
<td></td>
<td></td>
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<tr>
<td>NH$_4^+$</td>
<td>%</td>
<td>0.02</td>
<td>0.05</td>
<td>0.02</td>
<td>0.04</td>
<td>Bernal et al. (2009)</td>
</tr>
<tr>
<td>Total P</td>
<td>%</td>
<td>1.09</td>
<td>0.92</td>
<td>1.08</td>
<td>2.3</td>
<td>Kengne et al. (2009)a</td>
</tr>
<tr>
<td>PO$_4^{3-}$</td>
<td>%</td>
<td>0.25</td>
<td>0.19</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total K</td>
<td>%</td>
<td>0.52</td>
<td>0.81</td>
<td>0.50</td>
<td>0.03</td>
<td>Kengne et al. (2009)a</td>
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<tr>
<td>Mg</td>
<td>%</td>
<td>0.47</td>
<td>0.62</td>
<td>0.12</td>
<td>0.14</td>
<td>Kengne et al. (2009)a</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td>ppm</td>
<td>38</td>
<td>58.17</td>
<td>36.83</td>
<td>100</td>
<td>E.U.C (1986)</td>
</tr>
<tr>
<td>Zn</td>
<td>ppm</td>
<td>113.33</td>
<td>142.50</td>
<td>110.5</td>
<td>2500-4000</td>
<td>E.U.C (1986)</td>
</tr>
</tbody>
</table>
Three months of maturation are not sufficient to sanitize biosolids

<table>
<thead>
<tr>
<th>Types of Sludge</th>
<th>Dryness (% TS)</th>
<th>Temperature (°C)</th>
<th>Fertile</th>
<th>Infertile</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS-ST</td>
<td>80,6</td>
<td>29±0,21</td>
<td>12,6</td>
<td>66,7</td>
<td>87,3</td>
</tr>
<tr>
<td>FS-STT</td>
<td>78,4</td>
<td>30±0,91</td>
<td>36,7</td>
<td>172,8</td>
<td>209,5</td>
</tr>
<tr>
<td>WwS</td>
<td>75,6</td>
<td>29±0,83</td>
<td>8,5</td>
<td>40,6</td>
<td>49,1</td>
</tr>
</tbody>
</table>

Number of *Ascaris eggs* (number of eggs/g TS)
Conclusion
Based on these results, faecal sludge from septic tanks should undergo settling prior to loading on planted drying beds to reduce clogging.

However, an increased feeding frequency should then be used to improve plant growth and fodder quality.

Based on Senegalese standards, leachate should undergo a polishing step prior to discharge or use in irrigation.

Planted drying beds are capable to transform any type of sludge into mature composts.

Dried sludge should undergo longer periods of maturation for reduction of *Ascaris* eggs,

But following three months resting could potentially be safe for uses other than food crops.