Clean compost: pollution control: during composting of livestock and poultry manure

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1. The source, characteristic livestock manure
2. The concept, principle and influence factors of composting
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Huge quantities of solid waste was produced every day, How to deal with them, testing our wisdom and ability
Livestock Farming Status in China

•2018/6/21
Livestock Farming Status in China

Source: China Statistical Yearbook (based on slaughter)

*2018/6/21*
Livestock Farming Status in China

With rapid development of the livestock industry, the production of manure increased year by year.

Fig. Amounts (a) of livestock manure in China during 1978 to 2011, and cropland load of manures in 2011 (b)

Source: Zhu et al., 2014.
## Nutrient And Pollutant Contents in Livestock Manure

### A. The nutrient contents in livestock manure

<table>
<thead>
<tr>
<th>Category</th>
<th>N(%)</th>
<th>P$_2$O$_5$(%)</th>
<th>K$_2$O(%)</th>
<th>Cu(mg/kg)</th>
<th>Zn(mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig Manure</td>
<td>0.2~5.19</td>
<td>0.39~9.05</td>
<td>0.94~6.65</td>
<td>12.1~1742</td>
<td>40.5~2287</td>
</tr>
<tr>
<td>Cattle Manure</td>
<td>0.32~4.13</td>
<td>0.22~8.74</td>
<td>0.20~3.75</td>
<td>8.9~437.2</td>
<td>31.3~634.7</td>
</tr>
<tr>
<td>Chicken Manure</td>
<td>0.60~4.85</td>
<td>0.39~6.75</td>
<td>0.59~4.63</td>
<td>16.8~736.5</td>
<td>38.8~1017</td>
</tr>
<tr>
<td>Sheep Manure</td>
<td>0.25~3.08</td>
<td>0.35~2.72</td>
<td>0.89~3.00</td>
<td>13.1~47.9</td>
<td>30.2~161.1</td>
</tr>
</tbody>
</table>

Source (Li et al., 2009)
## B. Heavy metals contents in livestock manure

<table>
<thead>
<tr>
<th>Category</th>
<th>Cd</th>
<th>Pb</th>
<th>Cr</th>
<th>As</th>
<th>Hg</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig Manure</td>
<td>0.06~2.75</td>
<td>0.71~16.02</td>
<td>0.20~116.20</td>
<td>0.54~88.97</td>
<td>0~0.13</td>
<td>4.03~20.45</td>
</tr>
<tr>
<td>Chicken Manure</td>
<td>0.04~1.48</td>
<td>0.92~26.94</td>
<td>0.60~42.75</td>
<td>0.57~66.99</td>
<td>0~0.12</td>
<td>7.44~15.08</td>
</tr>
<tr>
<td>Cattle Manure</td>
<td>0.10~1.67</td>
<td>2.11~23.61</td>
<td>0.05~29.04</td>
<td>0.42~5.95</td>
<td>0~0.11</td>
<td>3.73~19.15</td>
</tr>
</tbody>
</table>

Unit: (mg/kg)

Source (Jia et al., 2016)
C. Antibiotic contents in pig and chicken manure

<table>
<thead>
<tr>
<th>Parameter (mg/kg)</th>
<th>Tetracycline TTC</th>
<th>Oxytetracycline OTC</th>
<th>Aureomycin CTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig Manure</td>
<td>0.4~78.57</td>
<td>0~524.4</td>
<td>0~124.8</td>
</tr>
<tr>
<td>Chicken manure</td>
<td>0~14.56</td>
<td>0~23.43</td>
<td>0~121.78</td>
</tr>
</tbody>
</table>

Source (Wang et al., 2013)
Environmental Pollutions of Livestock Manure/ Solid waste

Air pollution
(Obnoxious gases)

Water contamination
(Eutrophication)

Soil pollution
(Heavy metals, resistance gens)

Food safety
(Heavy metals)

Causing bacterial disease

Pathogens

Heavy metals

Antibiotic and resistance gene
Environmental pollution of municipal solid waste

Municipal solid waste

Enter into

Water
Eutrophication
Aquatic organisms (plastic, toxic elements)

Enter into

Soil
Destroy soil structure (plastic, rubber)
Soil pollution (organic pollutant, heavy metals)

Enter into

Air
Air pollution (dust, dioxin, odor)
Acid rain (nitric oxide)

Burning
The Disadvantage of Traditional Composting

• The emission of greenhouse gas
  \[ CH_4, N_2O \]

• The Nitrogen loss
  \[ NH_3, N_2O \]

• High mobility of heavy metals
  \[ Cu, Zn, Cd, Pb, As \]

• Low degree of humification
  \[ Humus, Humic acid, fulvic acid \]
Composting is one of the possible opportunities for Solid Waste management.
Major Problems in Solid Waste Composting

- **Thermo acidophilic stage**
  - Reduced pH
  - Acidic odour
  - Microbial inhibition
  - Reduced composting efficiency
  - Huge quantity of GHGs emission

- **Controlling the acidity**
  - Improves the composting
  - Prevents acidic odour
  - Requires alkaline substances

- **However, increased pH results**
  - Ammonia/ nitrous oxide emission
  - Reduce the N content of compost
  - Increase the salinity

- **Resulting in**
  - Compost product with low nutrient content, especially N
  - Higher EC content that affects the soil application in high quantities
Improving the Composting Process and Quality of Compost

◆ Optimizing the physical-chemical parameter

Adjust C/N, moisture content, aeration rate

◆ Adding various kinds of additives

Microbial additive, mineral additive, chemical additive

◆ Improve composting pattern

Windrow composting, trough composting, fermentation cylinder
**Aims of this study**

**Formulation of novel feedstock mixture**

To evaluate heterogeneity of additives amendment for total organic carbon loss mitigation through CO$_2$ and CH$_4$ emission and nitrogen conservation by N$_2$O and NH$_4$ reduction

To study the relationship between the mechanisms involved in the total gaseous emission, carbon, nitrogen losses and humification of the composting mixtures.

**The end product quality improvement**
Methodology

1. Formulation of starting mixture

2. Mixing of additives: Zeolite, Lime, biochar and Ca-bentonite

3. Monitored the gaseous emission, temperature, pH, moisture, EC, C/N ratio, NH$_4^+$-N, during 0, 3, 7, 10, 14, 21, 28, 42 and 56 days of the composting period.

4. Compost maturity was evaluated and compared with HKORC/TMECC compost quality standard.
Collection of Sewage sludge and mixing with bulking agents
Flow diagram of composter
Dewatered fresh sewage sludge (DFSS) or sewage sludge (SS) and wheat straw mixed 1:1 ratio on dry weight basis, while additives added on SS dry weight basis; Day 0: 50-60% moisture content Bulk density of the compost mass in the reactor was determined to estimate the compost weight in the reactor; Continuous thermophilic (55 °C)
### Initial properties of mixing ratio

<table>
<thead>
<tr>
<th>Parameters</th>
<th>DFSS</th>
<th>WS</th>
<th>Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (%)</td>
<td>81.24±1.85</td>
<td>10.43±0.20</td>
<td>56.23±1.45</td>
</tr>
<tr>
<td>pH (solid:water = 1:5)</td>
<td>7.27±0.04</td>
<td>4.93±0.14</td>
<td>8.12± 0.05</td>
</tr>
<tr>
<td>EC (mS cm⁻¹)</td>
<td>5.10±0.16</td>
<td>0.71±0.03</td>
<td>3.05± 0.03</td>
</tr>
<tr>
<td>(Solid: water = 1:5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total organic matter (%)</td>
<td>79.28±2.18</td>
<td>97.86±2.74</td>
<td>93.63± 2.78</td>
</tr>
<tr>
<td>Total organic carbon (%)</td>
<td>41.38±2.40</td>
<td>62.30±2.41</td>
<td>44.89± 1.02</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen (%)</td>
<td>2.81±0.15</td>
<td>0.80±0.03</td>
<td>1.78± 0.05</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>14.72± 0.05</td>
<td>77.90±0.25</td>
<td>25.21± 0.12</td>
</tr>
</tbody>
</table>

DFSS (dewatered fresh sewage sludge or biosolids) and WS (wheat straw)
# Initial properties of additives

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Biochar</th>
<th>Zeolite</th>
<th>Ca- bentonite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (%)</td>
<td>2.42±0.50</td>
<td>1.23±0.06</td>
<td>1.20±0.10</td>
</tr>
<tr>
<td>pH (solid:water = 1:5)</td>
<td>8.78±0.10</td>
<td>8.58±0.02</td>
<td>8.35±0.04</td>
</tr>
<tr>
<td>EC (mS cm⁻¹) (Solid: water = 1:5)</td>
<td>0.98 ±0.03</td>
<td>0.14±0.04</td>
<td>0.11±0.08</td>
</tr>
<tr>
<td>Total organic matter (%)</td>
<td>96.23±2.84</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total organic carbon (%)</td>
<td>67.75±1.78</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen (%)</td>
<td>0.58±0.02</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>116.81 ± 1.43</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>
Flow diagram of composting process

- Initial feed stock preparation
- Dewatered fresh sewage sludge
- Wheat straw (Mixed 1:1 dry weight basis)
- Biochar: Lower dosage (2%, 4%, 6%) and higher dosage (8%, 12% & 18%)
- Zeolite: 10%, 15% and 30%
- Ca-bentonite: 2%, 4% and 10%
- Mixing of raw materials
- Initial feed stock
- Formulated feed stock feeding in composter
- Composting without additives (Control)
- Composting with additives
Changes temperature and pH during composting

![Graph a](image)

![Graph b](image)

![Graph c](image)

![Graph d](image)
Changes temperature and pH during composting
Gaseous emission

- **CO₂ Evolution (g/day)**
- **CH₄ Emission (gCH₄/C/kg/day)**
- **N₂O Emission (gN₂O-N/kg/day)**
- **NH₃ N Emission (g/day)**

Composting time (days)
Gaseous emission

(a) CO₂-C evolution (g/day)

(b) CH₄ emission (gCH₄-C/kg/day)

(c) NH₃-N emission (g/day)

(d) N₂O-emission (gN₂O-N/kg/day)
Gaseous emission

(a) CO₂-C evolution (g/day) vs. Composting time (days)
(b) CH₄ emission (gCH₄-C/kg/day) vs. Composting time (days)
(c) NH₃-N emission (g/day) vs. Composting time (days)
(c) N₂O-emission (gN₂O-N/kg/day) vs. Composting time (days)
Pig manure composting/ Gaseous emission
Pig manure composting/ Gaseous emission

![Graphs showing emission trends over time](image)
16SRNA technology for microbial dynamics

(a) (b)
The relative abundance of the dominant bacterial taxonomic groups separated using total 16S rDNA gene sequences
Heat-map of species abundance is clustering; the genus classification position clustering (horizontal) and top 35 genera sample clustering (vertical clustering).

Different color means the different relative abundance of the genus in the all seven treatments (red means great abundance).
The relative abundance of each class based on 16S rDNA sequence analysis. The relative abundance is expressed in percentage and classification tree of complex samples.

Different color of circle fan means different sample; the size of the fan means the relative abundance of proportional size on classification level of samples; the numbers below the classification name stands for the average percentage of relative abundance on this classification level in all samples.

There were two numbers, the former one means the percentage of all species, the latter one means the percentage of selected species.
Total greenhouse emission (g/kg CO$_2$-eq. DM)

(a) and (b) show the comparison of total greenhouse emissions under different treatments.
Total greenhouse emission (g/kg CO$_2$-eq. DM)
Principal Component and Redundancy Analysis

(a) Principal Component Analysis

(b) Redundancy Analysis

- Parameters: DOC, AP, DON, TP, TNa, TKH, WS-Na, WS-K, Solid C/N ratio, TOC, GI, Soluble C/N ratio, PhE-N, EC, TOM, NH4-N, CH4, N2O, CO2, TN, TNa, TK, Nitrate, pH, AP, TP, DEA, DEA, TNa, TNa, TVFAB, TAPB, TAAB, TACB, TAB, AEA, XEA.
Conclusions

- Higher dosage of biochar and zeolite added treatments significantly reduced the NH₃, CH₄ and N₂O emission by 58.0-65.2%, 93.0-95.3% and 95.1-97.3% as compare to control treatments.

- Furthermore, it was estimated that the 30% zeolite and 12% biochar could reduce the length of the active phase and enhance the humification with significant reduction of total N loss and GHG emissions.

- In addition, the RDA and PCA analysis were also shows significant correlation between gaseous emission and nutrients transformation during the composting.

- Overall, the addition of 12% biochar for composting demonstrated to be a beneficial practice for the management of solids waste.
Questions?

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Thank You…