USDA-ARS Developed Technologies for Recovering Manure Phosphorus

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Summary

- Environmental issues – animal production
- Recoverable manure nutrients
- Phosphorus recovery from:
  - liquid swine manure
  - poultry litter
Pollution concerns because of excess soil N & P
Export or spatial transfer of nutrients with animal feed
Imbalance of N:P ratio in animal waste
Animal Manure – Excess P

Percent of Agronomic Crop and Forage Phosphorus Needs Supplied by Recoverable Plant Available Manure Phosphorus at the County Level in North Carolina

Barker & Zublena, 1995

<table>
<thead>
<tr>
<th>Crop</th>
<th>N:P ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bermudagrass</td>
<td>13.4:1</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>11.9:1</td>
</tr>
<tr>
<td>Corn</td>
<td>7.5:1</td>
</tr>
<tr>
<td>Cotton</td>
<td>6.2:1</td>
</tr>
<tr>
<td>Ryegrass</td>
<td>3.3:1</td>
</tr>
<tr>
<td>Liquid swine manure</td>
<td>3.2*</td>
</tr>
<tr>
<td>Poultry litter</td>
<td>2.1:1 to 2.6:1</td>
</tr>
</tbody>
</table>

Source: Edwards and Daniels, 1992; *Barker and Zublena, 1995
Livestock Manure Recycling of Excess P

Recovery
How much?

Transfer
How far?

Manure P Recycling

Utilization
Valuable byproducts?
Recoverable Manure P

How much?

- Quantity of the nutrient available for land application or utilization for other purposes
- Mass of nutrient per ton of manure remaining after nutrient losses during manure collection, transfer, storage, and treatment
- Total U.S. annual production of recoverable $P_2O_5 = 650$ M kg with 480 M kg in excess of on-farm needs
- Annual U.S. consumption $P_2O_5 = 1,680$ M kg (PPI, 2002)
- Recovery of manure P could substitute about 25% of annual U.S. consumption of P

Source: USDA-ERS (Kellog et al. 2000)
Manure Transfer
How Far?

Source: Keplinger and Hauck, 2006

Global Use of Fertilizers

• World fertilizer prices soar:
  merge of food and fuel economies

Utilization

Valuable byproducts?

- Compost
- Phosphates
- Organic soil amendments
Nutrients Recovered from Swine Manure

- Compost – N & P
- Phosphate
USDA-ARS Wastewater Treatment System
Phosphorus Removal and Recovery
from Liquid Swine Manure

FIG. 1

INFLUENT WITH AMMONIA PHOSPHORUS ALKALINITY → NITRIFICATION BIOREACTOR → PHOSPHORUS SEPARATION REACTOR

LIME OR CA/MG HYDROXIDE DISPENSER

EFFLUENT WITH NITRATE

PHOSPHATE PRECIPITATE

Wastewater Treatment System
U.S. Patent 6,893,567 B1
Enhanced Phosphorus Removal from Swine Manure Using New Process

P removed from liquid (mg/L)

Calcium hydroxide rates (Moles / mol P)

New Process
Conventional

1 5 10

Calcium hydroxide rates (Moles / mol P)
Environmentally Superior Technology (EST)  
State of North Carolina

- Permitable by government authority
- Technically, operationally and economically feasible

- Meets these environmental performance standards:
  - Eliminate discharge to surface and groundwater
  - Substantially eliminate ammonia emissions
  - Substantially eliminate odor emissions beyond farm boundaries
  - Substantially eliminate pathogens
  - Substantially eliminate nutrient and heavy metal contamination of soil and water.
EST – 1st generation, Super Soils USA System

New manure treatment system developed to replace hog lagoons in North Carolina. NC Attorney General – Smithfield Foods/PSF Agreement

Goshen Ridge Farm, Duplin Co., NC
4,360-finishing pig production unit
Raw Manure Treated: 39 m³/day

Wastewater Treatment System
US Patent # 6,893,567
Vanotti, Szogi and Hunt
Calcium Phosphate Solid-liquid Separation Module Nitrification Denitrification Module Phosphorus Removal Module

Swine Houses Separated solids

70% TP Mass Removed w/Solids Compost

25% TP Mass Removed from Liquid Stream

95% TP Removed from Farm

EST On-Farm Treatment System

Effluent

Calcium Phosphate
<table>
<thead>
<tr>
<th></th>
<th>INFLUENT (mg/L)</th>
<th>EFFLUENT (mg/L)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003-2004</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Suspended Solids</strong></td>
<td>11,051</td>
<td>264</td>
<td>98</td>
</tr>
<tr>
<td><strong>Volatile solids</strong></td>
<td>8,035</td>
<td>85</td>
<td>99</td>
</tr>
<tr>
<td><strong>TKN</strong></td>
<td>1,584</td>
<td>23</td>
<td>99</td>
</tr>
<tr>
<td><strong>TAN</strong></td>
<td>872</td>
<td>11</td>
<td>99</td>
</tr>
<tr>
<td><strong>COD</strong></td>
<td>16,138</td>
<td>445</td>
<td>97</td>
</tr>
<tr>
<td><strong>BOD</strong></td>
<td>3,132</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td><strong>TP</strong></td>
<td>576</td>
<td>29</td>
<td>95</td>
</tr>
<tr>
<td><strong>Cu</strong></td>
<td>26.8</td>
<td>0.36</td>
<td>99</td>
</tr>
<tr>
<td><strong>Zn</strong></td>
<td>26.3</td>
<td>0.25</td>
<td>99</td>
</tr>
</tbody>
</table>
Separated Solids
Manure solids processed into plant growth media
Step 3: Phosphorus Removal

P Separation Module
Dewatering and bagging of calcium phosphate

P sludge production = 700 kg/year
Recovered P in sludge = 99.5%
4,360 Finishers Production Unit
2nd Generation EST
2nd Generation System: 5600-finishing pigs in North Carolina

- Solid-liquid Separation
- Homogenization tank
- Nitrification/denitr.
- Phosphorus and pathogens

Benefits of new technology have potential to pay for all the cost of treatment.

<table>
<thead>
<tr>
<th>benefits</th>
<th>Anaerobic Lagoon Technology</th>
<th>2nd Generation Superior Technology</th>
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<tr>
<td>Carbon Credits</td>
<td>0</td>
<td>32</td>
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<td>Productivity Enhancement</td>
<td>0</td>
<td>120</td>
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<tr>
<td>Treatment Cost</td>
<td>$ / 1000 lb SSLW / year</td>
<td>90</td>
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<td>120</td>
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Compost – Swine Manure Solids

Separated solids composted with cotton gin residue

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N</td>
<td>5.3</td>
</tr>
<tr>
<td>Total P</td>
<td>4.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>2.3</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.1</td>
</tr>
</tbody>
</table>
# Recovered Phosphates
## Chemical Composition

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{P}_2\text{O}_5$</td>
<td>24.4</td>
</tr>
<tr>
<td>Calcium</td>
<td>27.3</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.9</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.8</td>
</tr>
</tbody>
</table>

### SEM Image

*SEM X 1200*
Recovered P – Swine Manure Fertilizer Manufacture

Photos: ARS & IFDC

Final Product
Poultry Litter
Manure + Bedding Material
Nutrients Recovered from Poultry Litter
USDA-ARS Florence, SC

Washed Solids

• Process selectively extracts up to 80 percent of the phosphorus from poultry litter, but little of the nitrogen

• It produces two useful materials:
  - The washed solids, with a balanced N:P ratio for crop production
  - A "slow-release" phosphorus fertilizer

Recovered P

• ARS has granted an exclusive license to Renewable Organics LLC, of N.C., for the commercial development of the process
Poultry Litter
Phosphorus Removal and Recovery
Quick Wash (Chemical) Process

1. P extraction
   Acidic solution

2. P removal
   Alkaline pH

3. P precipitation
   enhancement

Liquid Effluent

U.S. Patent Office. Washington, DC.
Quick Wash

Selective Extraction of Phosphorus

A) Phosphorus

<table>
<thead>
<tr>
<th></th>
<th>Water (pH 8.1)</th>
<th>Acid (pH 4.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extracted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B) Nitrogen

<table>
<thead>
<tr>
<th></th>
<th>Water (pH 8.1)</th>
<th>Acid (pH 4.5)</th>
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<td></td>
</tr>
<tr>
<td>Extracted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N:P 1.8:1 5.8:1
Manure Wash Pilot Experiment
Quick Wash

Step 2
P removal
Lime addition
pH 9 - 10

Step 3
P enhancement
Flocculant addition
(PAM -)
Quick Wash
Products

Poultry litter after quick wash

P recovered from poultry litter
Phosphorus material recovered from poultry litter using the Quick Wash process

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g per 100 g</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.9</td>
</tr>
<tr>
<td>$P_2O_5$</td>
<td>13.5</td>
</tr>
<tr>
<td>Carbon</td>
<td>23.8</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>2.4</td>
</tr>
<tr>
<td>Calcium</td>
<td>13.4</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.0</td>
</tr>
<tr>
<td>Potassium</td>
<td>1.1</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Use of Recovered Phosphate as Fertilizer

• Green house tests using P recovered from: 1) pig manure (RPM), and 2) from poultry litter (RPL)
• Applied at 0, 20, 40, 80 and 160 mg/kg soil
• Commercial triple super phosphate (TSP) was used as fertilizer control

Plant: *Annual ryegrass*
Soil: *Uchee sand*
Amendment: Lime (pH ~6.5)
Air temperature: 25.5 – 32.0 °C
Biomass harvested at:
19, 34, and 47 d after planting
Effect of fertilizer material and P rate on ryegrass biomass

Biomass (g pot$^{-1}$) vs P Rate (mg P kg soil$^{-1}$)

LSD$_{0.05}$

- **Control**
- **RPM**, P recovered from pig manure;
- **RPL**, P from poultry litter;
- **TSP**, triple superphosphate.
Conclusions

• Nutrient recovery technologies offer the opportunity to resolve problems of excess application of manure phosphorus to land.

• N & P concentration in manure byproducts should be sufficiently high to allow long distance transportation.

• The aspect of P recovery and reuse is important for the global cycling of these nutrients (e.g.: energy savings and limited resource).


http://www.ars.usda.gov/main/site_main.htm?modecode=66-57-00-00