MANURE PHOSPHORUS MANAGEMENT: PROCESSING TECHNOLOGIES AND EFFICIENCY

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THE DISAPPEARING NUTRIENT

THE WORLD'S REMAINING PHOSPHATES

(Gt = gigatonnes)

Rest of the world
12.6 Gt

South Africa
4 Gt

United States
4.6 Gt

China
14.1 Gt

Morocco and Western Sahara
26.7 Gt

SOURCE: USGC
PHOSPHORUS PRODUCTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td></td>
</tr>
<tr>
<td>1932</td>
<td></td>
</tr>
<tr>
<td>1943</td>
<td></td>
</tr>
<tr>
<td>1954</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
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</table>
ESTIMATED MANURE PHOSPHORUS PRODUCTION FROM CONFINED LIVESTOCK
WHY MANURE?

- 95% of phosphate rock mined in the US was used to make fertilizers and animal supplements
- Debate on reserves and estimated supply
- Increasing demand as population grows
- Significant amount is more difficult to extract than current sources
- US to see significant drop in production in 25 years
- Recovery and recycling have great potential
- Initial interest in wastewater treatment plant recovery
- 5 times more phosphorus in livestock waste than human waste
- Livestock population greater than 10 times the human population
WISCONSIN MANURE

- 1.26 million dairy cows (NASS 2010)
- Over 8 billion gallons of manure annually
- ~7 pounds $\text{P}_2\text{O}_5$ per 1,000 gallons of manure
- Many agricultural sources with potential for environmental impact
- Need for solutions which make economic sense
- Potential benefits to agricultural operations, environment, economics, and the public
P SUSTAINABILITY

- Reuse = limit purchase of P
- Reduce losses to environment
- Meet regulatory requirements
PHOSPHORUS REMOVAL MECHANISMS

- Phosphorus does not disappear
- Chemical removal
  - Aluminum sulfate, aluminum chloride
  - Ferric chloride, ferric sulfate
  - Lime
- Physical
  - Separation
- Biological
SOLID LIQUID SEPARATION

- Can produce multiple products of various strengths of phosphorus
- Must examine entire manure handling system to see benefits
- Numerous technologies
  - Screw press
  - Centrifuge
  - Settling basins
- Varying cost and complexity
SOLIDS SETTLING & PHOSPHORUS

- Dependent upon influent solids concentration
- Dependent upon particle size (smaller particles are more difficult to separate)
Removal of approximately 28% TP in settling basins with no addition (initial TS of ~4%)
SOLID LIQUID SEPARATION

Midwest Plan Service, 2001
SEPARATOR - SCREW PRESS
SEPARATOR - CENTRIFUGE

Centrifuge - Dane County Digester; Clear Horizons
SEPARATOR - BEDDING RECOVERY UNIT
PHOSPHORUS

Screw Press w/ Digester
Screw Press w/o Digester

Liquid %
Solid %
## N-P-K

<table>
<thead>
<tr>
<th>Concentration</th>
<th>N (g/kg)</th>
<th>P$_2$O$_5$ (g/kg)</th>
<th>K$_2$O (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>50</td>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>Liquid</td>
<td>101</td>
<td>27</td>
<td>75</td>
</tr>
<tr>
<td>Solid</td>
<td>15</td>
<td>14</td>
<td>8</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Ratio</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Liquid</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Solid</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
### Screens

<table>
<thead>
<tr>
<th>Screen size[^b] (mm)</th>
<th>Amount retained (g/L)</th>
<th>Fraction of TSS (%)</th>
<th>Amount retained (g/L)</th>
<th>Fraction of VSS (%)</th>
<th>Amount retained (mg/L)</th>
<th>Fraction of TKN (%)</th>
<th>Amount retained (mg/L)</th>
<th>Fraction of TP (%)</th>
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</thead>
<tbody>
<tr>
<td>3.360</td>
<td>0.74</td>
<td>6.4</td>
<td>0.38</td>
<td>6.7</td>
<td>43.13</td>
<td>7.6</td>
<td>10.57</td>
<td>6.8</td>
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<tr>
<td>2.000</td>
<td>2.76</td>
<td>23.9</td>
<td>0.94</td>
<td>16.6</td>
<td>43.85</td>
<td>7.7</td>
<td>8.16</td>
<td>5.7</td>
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<tr>
<td>1.588</td>
<td>3.24</td>
<td>28.1</td>
<td>1.78</td>
<td>31.4</td>
<td>33.04</td>
<td>5.8</td>
<td>8.86</td>
<td>6.0</td>
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<tr>
<td>1.000</td>
<td>3.78</td>
<td>32.8</td>
<td>1.60</td>
<td>28.3</td>
<td>66.11</td>
<td>11.6</td>
<td>16.66</td>
<td>11.4</td>
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<tr>
<td>0.794</td>
<td>3.18</td>
<td>27.6</td>
<td>2.18</td>
<td>38.5</td>
<td>66.12</td>
<td>11.6</td>
<td>16.67</td>
<td>12.1</td>
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<tr>
<td>0.590</td>
<td>3.98</td>
<td>34.5</td>
<td>2.48</td>
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<td>77.93</td>
<td>13.7</td>
<td>16.96</td>
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<td>0.500</td>
<td>3.92</td>
<td>34.0</td>
<td>1.54</td>
<td>27.2</td>
<td>59.81</td>
<td>10.5</td>
<td>15.16</td>
<td>11.0</td>
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<td>0.297</td>
<td>4.22</td>
<td>36.6</td>
<td>1.90</td>
<td>33.6</td>
<td>60.68</td>
<td>10.6</td>
<td>15.43</td>
<td>11.1</td>
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<tr>
<td>0.250</td>
<td>4.82</td>
<td>41.8</td>
<td>2.14</td>
<td>37.8</td>
<td>78.26</td>
<td>13.7</td>
<td>23.26</td>
<td>16.7</td>
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</tbody>
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## Screens with Polymers

<table>
<thead>
<tr>
<th>Polymer rate (mg/L)</th>
<th>TSS</th>
<th>VSS</th>
<th>TKN</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>64.9</td>
<td>64.3</td>
<td>18.9</td>
<td>19.6</td>
</tr>
<tr>
<td>60</td>
<td>71.6</td>
<td>73.8</td>
<td>37.1</td>
<td>34.4</td>
</tr>
<tr>
<td>120</td>
<td>75.9</td>
<td>74.2</td>
<td>35.8</td>
<td>33.8</td>
</tr>
<tr>
<td>180</td>
<td>82.8</td>
<td>79.8</td>
<td>48.1</td>
<td>44.4</td>
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<tr>
<td>240</td>
<td>86.8</td>
<td>83.5</td>
<td>55.9</td>
<td>52.0</td>
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<tr>
<td>300</td>
<td>90.0</td>
<td>87.6</td>
<td>63.9</td>
<td>58.9</td>
</tr>
<tr>
<td>360</td>
<td>92.7</td>
<td>92.4</td>
<td>65.0</td>
<td>57.8</td>
</tr>
<tr>
<td>420</td>
<td>94.9</td>
<td>92.9</td>
<td>74.0</td>
<td>66.4</td>
</tr>
<tr>
<td>480</td>
<td>95.0</td>
<td>93.0</td>
<td>73.1</td>
<td>64.9</td>
</tr>
</tbody>
</table>

Removal efficiency [a] (%)

PAM
Dissolved Air Flotation

- Air is dissolved in the waste water stream and injected at bottom of unit.
- Fine solids are carried or “floated” to surface.
- Chemical addition of polymers and flocculent is needed for optimum efficiency.
CHEMICAL PRECIPITATION

- More effective for dissolved phosphorus
- Requires regular additions, large doses for manure
- Can be costly
- Can pose issues in soils
- Typically require polymer additions for application
- Significant amount of sludge production
CHEMICAL & POLYMER P SEPARATION

- Significant additions of chemical and polymer
- 80-90% TP removal
- Dairy manure at 0.87% & 1.5% TS
- Chemical additions alone cost $0.01
BIOLOGICAL ADDITION

- Phosphorus uptake by microorganisms
- L4DB® microbial treatment used for study in Texas
- Found some decreases in TP but not dissolved reactive phosphorus
- Reduction of ~50%

S. Rahman & S. Mukhtar, Texas A&M University
ANAEROBIC DIGESTION

- No phosphorus removal!
COMPOSTING

- Volume reductions = increase in P concentration
- Reduction in soluble P
## EFFICIENCY COMPARISON

<table>
<thead>
<tr>
<th>Technology</th>
<th>Initial TS (%)</th>
<th>TP Removal (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settling Basin</td>
<td>~4</td>
<td>28</td>
</tr>
<tr>
<td>Screw Press</td>
<td>variable</td>
<td>15-24</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>variable</td>
<td>60</td>
</tr>
<tr>
<td>Dewatering using Geotextiles</td>
<td>0.71</td>
<td>46</td>
</tr>
<tr>
<td>Inclined Plane</td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>Screens</td>
<td>0.4-3.2</td>
<td>&lt;17</td>
</tr>
<tr>
<td>Screens with Polymers</td>
<td>0.4-3.2</td>
<td>34-65</td>
</tr>
<tr>
<td>Chemical Precip</td>
<td>0.87-1.5</td>
<td>80-90</td>
</tr>
</tbody>
</table>
SOLIDS SEPARATION – SYSTEM PERFORMANCE

• Key issues
  ▶ Separator efficiency
    – Solids capture rate rates range from less than 5% to higher than 70%
    – Can be increased significantly with the use of polymer

  WHY IS THIS IMPORTANT? – Determines the amount of solids that will be recovered

  ▶ Solids content of recovered solids
    – Studies range from approximately 12% to 40% or higher

  WHY IS THIS IMPORTANT? – Characteristics of solids are critical to value-added opportunities

SOLIDS SEPARATION – SYSTEM PERFORMANCE (CONT.)

• Screens
  ▶ Perform better with low solids manures
    – Avoids clogging of screens
    – Less moisture will be found in the solids
    – Balancing act between screen size and separator efficiency

• Presses
  ▶ Higher separator efficiency and solids content
    – Little data available on performance
    – Often used following screens

WHAT IS THE “RIGHT” SEPARATION SYSTEM

- Depends on the objectives of the facility
  - Capture as many solids as possible – high separator efficiency
  - High solids content product – separation efficiency may be lower and more solids will end up in the lagoons
- Cost can be a factor
  - The most expensive separator may not be best to meet the objectives
  - The least expensive separator may not be best to meet the objectives

COSTS

- Separation systems are highly variable on cost to implement
- Really it all comes down to end use!
- If you are land applying, the cost of these systems has to primarily be from savings in application
  - How far away are your fields that are not P limited?
- When markets begin to develop for solids this may change
- Possible to sell solids as bedding, compost, etc.
CONCLUSIONS

- Efficiency of phosphorus sequestration is highly dependent upon initial concentration and solids removal.
- No P disappears, it always ends up somewhere but where is it that you want it to be?
- Must integrate the system through land application.
- Pay attention to the costs associated with your system.
- Make sure you are aware of removal data that a potential company may give you, even that done at a non-biased source. THESE SYSTEMS ARE EXTREMELY VARIABLE.
MANAGE YOUR SYSTEM!

- If you are not experiencing the removal you may want you need to examine where the issues may exist
- Companies commonly try to get your system to operate with little maintenance issues not necessarily removal performance
FUTURE…

- Developing some tools to evaluate your system
- What is up ahead?
THANK YOU!

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