Using AMD Solids for Managing Phosphate in Manure

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Chesapeake Bay Dead Zone

Low to no dissolved oxygen in the Bay and tidal rivers every summer
Chesapeake Bay TMDL

- EPA sets pollution diet to meet states’ Bay clean water standards
- Caps on nitrogen, phosphorus and sediment loads for all 6 Bay watershed states and DC
- States set load caps for point and non-point sources
- Final TMDL published by EPA in Dec 2010
- States are required to develop plans to achieve TMDL caps and implement load-reduction actions
TMDL has caps for sediment, nitrogen, and phosphorus

This project deals only with phosphorus (P)
# Existing and Proposed P Loadings

<table>
<thead>
<tr>
<th>State</th>
<th>2008 P load</th>
<th>EPA Target</th>
<th>P removal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/yr P</td>
<td>lb/yr P</td>
<td>lb/yr P</td>
</tr>
<tr>
<td>PA</td>
<td>3,990,000</td>
<td>3,160,000</td>
<td>830,000</td>
</tr>
<tr>
<td>DC</td>
<td>140,000</td>
<td>130,000</td>
<td>10,000</td>
</tr>
<tr>
<td>DE</td>
<td>340,000</td>
<td>280,000</td>
<td>60,000</td>
</tr>
<tr>
<td>MD</td>
<td>3,100,000</td>
<td>3,040,000</td>
<td>60,000</td>
</tr>
<tr>
<td>NY</td>
<td>830,000</td>
<td>560,000</td>
<td>270,000</td>
</tr>
<tr>
<td>VA</td>
<td>7,180,000</td>
<td>7,050,000</td>
<td>130,000</td>
</tr>
<tr>
<td>WV</td>
<td>700,000</td>
<td>620,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Total</td>
<td>16,280,000</td>
<td>14,840,000</td>
<td>1,440,000</td>
</tr>
</tbody>
</table>
# 2006 loads and planned reductions, PA

## Susquehanna River Basin

<table>
<thead>
<tr>
<th>Source Type</th>
<th>2006 P (lb/yr P)</th>
<th>Target (lb/yr P)</th>
<th>Change (lb/yr P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1,765,000</td>
<td>1,024,000</td>
<td>741,000</td>
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<tr>
<td>Point Source</td>
<td>737,000</td>
<td>675,000</td>
<td>62,000</td>
</tr>
<tr>
<td>Urban</td>
<td>187,000</td>
<td>110,000</td>
<td>78,000</td>
</tr>
<tr>
<td>Mixed Open</td>
<td>268,000</td>
<td>313,000</td>
<td>-45,000</td>
</tr>
<tr>
<td>Forest</td>
<td>108,000</td>
<td>111,000</td>
<td>-4,000</td>
</tr>
<tr>
<td>All Sources</td>
<td>3,106,000</td>
<td>2,282,000</td>
<td>824,000</td>
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</tbody>
</table>
P primer

• Primary source of P from agriculture is land applied manure (dairy and swine)
• P is present in many forms in manure, all are measured by Total P analyses
• Not all P is environmentally mobile
  – Water Extractable Phosphorus (WEP) is a measure of soluble P and correlates with environmental mobility
P Control BMPs

- Apply less manure
- Change timing of application
- Change method of application
- Modify connection between field and stream so connectivity is lessened
P Control BMPs

- Apply less manure
- Change timing of application
- Change method of application
- Modify connection between field and stream so connectivity is lessened
- P chemistry is assumed fixed: no practices that change P chemistry and lessen environmental mobility
Mine Drainage Solids primer

- Clean passive solids are predominantly Fe and Al oxide minerals with lesser amounts of Si, Ca, and S
  - Phosphate readily sorbs to Fe and Al oxides
- Lime treatment solids are predominantly Ca minerals with lesser amounts of Fe, Al, and Mg
  - Phosphate reacts with Ca to form CaPO$_4$ (apatite)
P removal isotherms

- Brandy Camp
- Wilson
- Farmington

removed P, mgP/kg MDR

equilibrium P (mg/L)

- 0
- 5,000
- 10,000
- 15,000
- 20,000
- 25,000
- 30,000
- 35,000
- 40,000
- 45,000

20,000

10,000

5,000

0

0

20

40

60

equilibrium P, mg/L

removed P, mg P/kg MDR

Brandy Camp
Wilson
Farmington
Marchand A
Marchand E
Effect of MDR on WEP in manures

- Two manures: dairy and swine
- Four MDRs
  - Farm: passive acid clean (90% Fe solids)
  - Wilson: passive alkaline muddy (75% Fe solids)
  - Marchand: passive alkaline clean (90% Fe solids)
  - Brandy: lime (30% Fe and Al solids)
- Add variable amounts of MDR to 500 mL of manure; measure WEP
- Assess whether there is a dose-effect relationship
Dairy

MDR, g/L

WEP, mg/kg solid

control
Brandy
Farm
MDR is neutral
Swine

MDR, g/L

WEP, mg/kg solid

Brandy
MDR is neutral
Cost Evaluation: Dairy

• 8 g/L dose of MDR will decrease WEP and PSC by 50%

• $200/ton (processed) plus $50/ton trucking and application = $250/ton applied
  – $8.33 / 1000 gallons manure
  – At 5,000 gal/acre = $42/acre
  – $25/milking cow per year
  – $0.01-0.02 / gallon milk

• Competitive with alternative BMPs
What’s Wrong with this Idea?

• Is the incorporation of MDR with manure tedious?
• Is MDR hazardous?
• Will MDR decrease plant availability of P and lessen crop yield?
<table>
<thead>
<tr>
<th>Element</th>
<th>units</th>
<th>503 limit</th>
<th>Brandy</th>
<th>Farm</th>
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<tbody>
<tr>
<td>Fe</td>
<td>%</td>
<td>None</td>
<td>13.1</td>
<td>50.0</td>
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<tr>
<td>Ca</td>
<td>%</td>
<td>None</td>
<td>19.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Si</td>
<td>%</td>
<td>None</td>
<td>2.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Al</td>
<td>%</td>
<td>None</td>
<td>2.0</td>
<td>0.4</td>
</tr>
<tr>
<td>S</td>
<td>%</td>
<td>None</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>As</td>
<td>ppm</td>
<td>75</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Cd</td>
<td>ppm</td>
<td>85</td>
<td>0.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Cr</td>
<td>ppm</td>
<td>3,000</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Cu</td>
<td>ppm</td>
<td>43,000</td>
<td>22</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Mo</td>
<td>ppm</td>
<td>75</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Ni</td>
<td>ppm</td>
<td>420</td>
<td>373</td>
<td>50</td>
</tr>
<tr>
<td>Pb</td>
<td>ppm</td>
<td>840</td>
<td>&lt;5</td>
<td>14</td>
</tr>
<tr>
<td>Se</td>
<td>ppm</td>
<td>100</td>
<td>&lt;3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Zn</td>
<td>ppm</td>
<td>7,500</td>
<td>434</td>
<td>40</td>
</tr>
<tr>
<td>Hg</td>
<td>ppm</td>
<td>57</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>
MDRs and EPA 503 limits

- Tested 13 MDRs
- Two exceeded As limit
- One exceeded Ni limit
- None exceeded Cd, Cr, Cu, Hg, Mo, Pb, Se and Zn
Corn growth: no signs of P deficiency

Control

Farmington MDR

Control

Brandycamp MDR
Greenhouse Test

- Dr. Rick Stehouwer, PSU Soil Scientist
- Grew ryegrass on P-deficient soil with two manure application rates and three MDR treatment rates
  - Manure increased plant growth
  - MDR did not affect plant growth
- Leached pots three times
  - MDR lessened leaching of P
Feasibility Calculation

• Large lime plant treating 6000 gpm, 60 mg/L Fe makes about 5,000 ton/yr dewatered sludge
  – Could treat 150 million gallons manure
  – About 300 mid-sized dairy farms
  – About 24,000 milking cows

• Amend the Susquehanna River the PA border
  – Estimate 30,000 ton/yr MDR
Conclusions

• Mine drainage solids can be used to lessen WEP in dairy and swine manure
  – the most effective solids were from a lime plant
• No evidence that solids inhibit crop growth
• Some MDRs contain high As and Ni – screening is necessity
• Cost is competitive with other BMPs
• If practice was accepted; huge demand for mine drainage solids is possible
removed
Effect of Brandy MDR on Swine P

[Graphs showing the relationship between WEP (mg/kg solid) and MDR (g/L) for Brandy.]
## Animals and P produced in the PA Susquehanna River watershed

<table>
<thead>
<tr>
<th></th>
<th># animals</th>
<th>lb P per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>541,000</td>
<td>21,634,000</td>
</tr>
<tr>
<td>Dairy</td>
<td>413,000</td>
<td>41,784,000</td>
</tr>
<tr>
<td>Swine</td>
<td>1,038,000</td>
<td>12,095,000</td>
</tr>
<tr>
<td>Layers</td>
<td>23,423,000</td>
<td>10,592,000</td>
</tr>
<tr>
<td>Broilers</td>
<td>19,481,000</td>
<td>4,833,000</td>
</tr>
<tr>
<td>Turkey</td>
<td>2,300,000</td>
<td>2,344,000</td>
</tr>
</tbody>
</table>