# FARM DIGESTERS AND MANURE PHOSPHORUS MANAGEMENT

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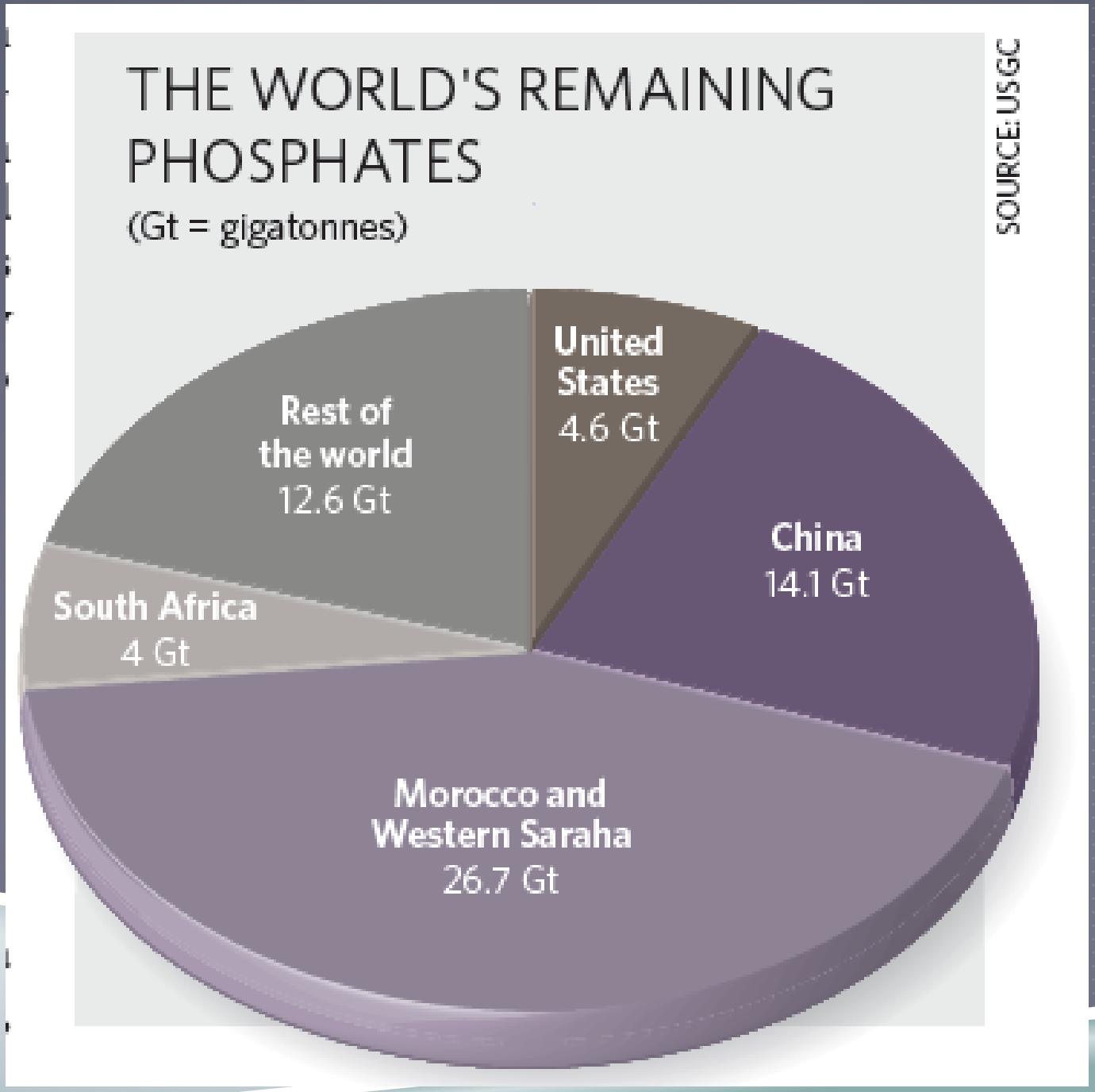
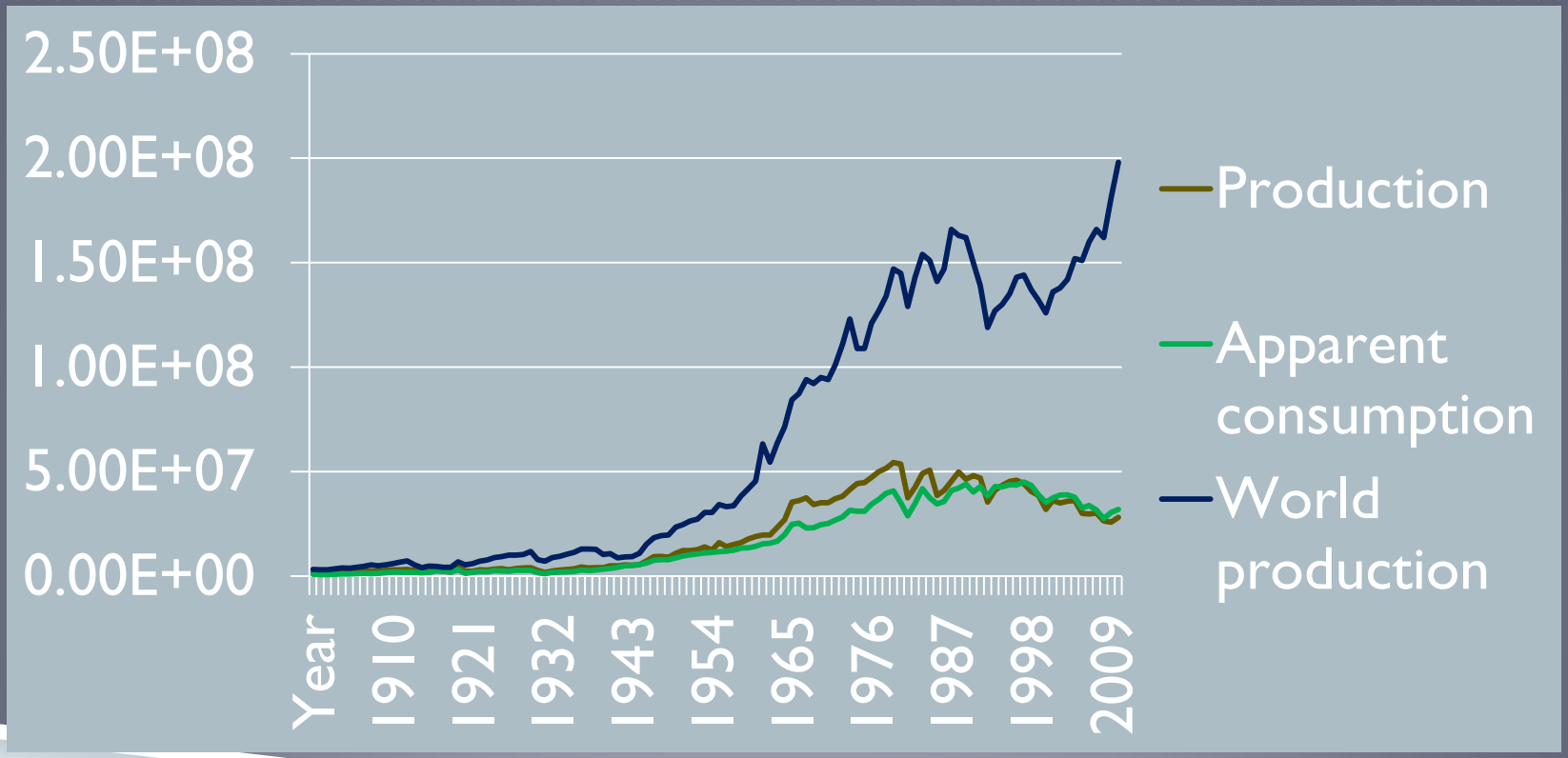
University of Wisconsin–Extension

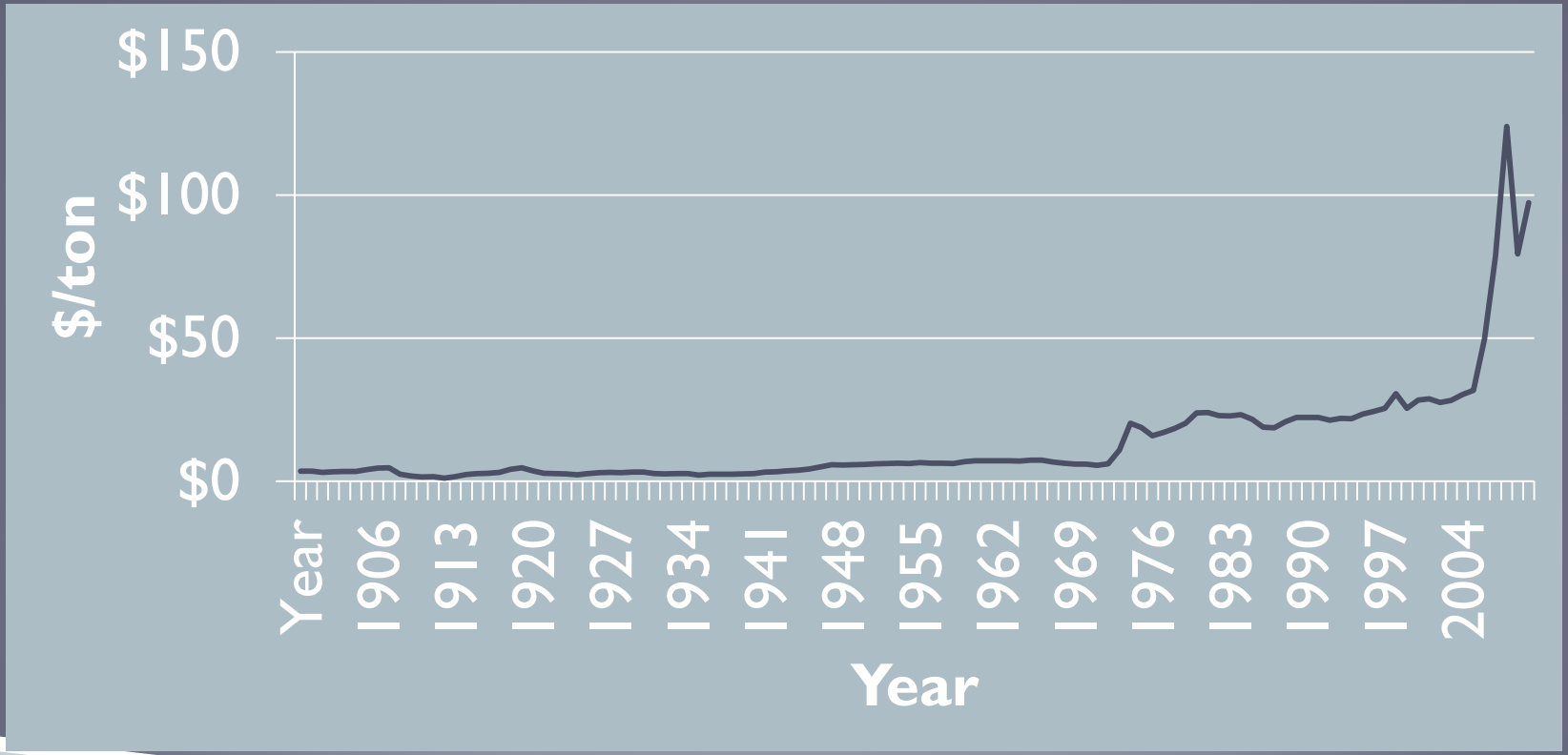

Gilbert, 2009. Nature.


THE WORLD'S REMAINING PHOSPHATES
(Gt = gigatonnes)
SOURCE: USGC
United States
4.6 Gt
China
14.1 Gt
Morocco and Western Saraha
26.7 Gt
South Africa
4 Gt
Rest of the world
12.6 Gt

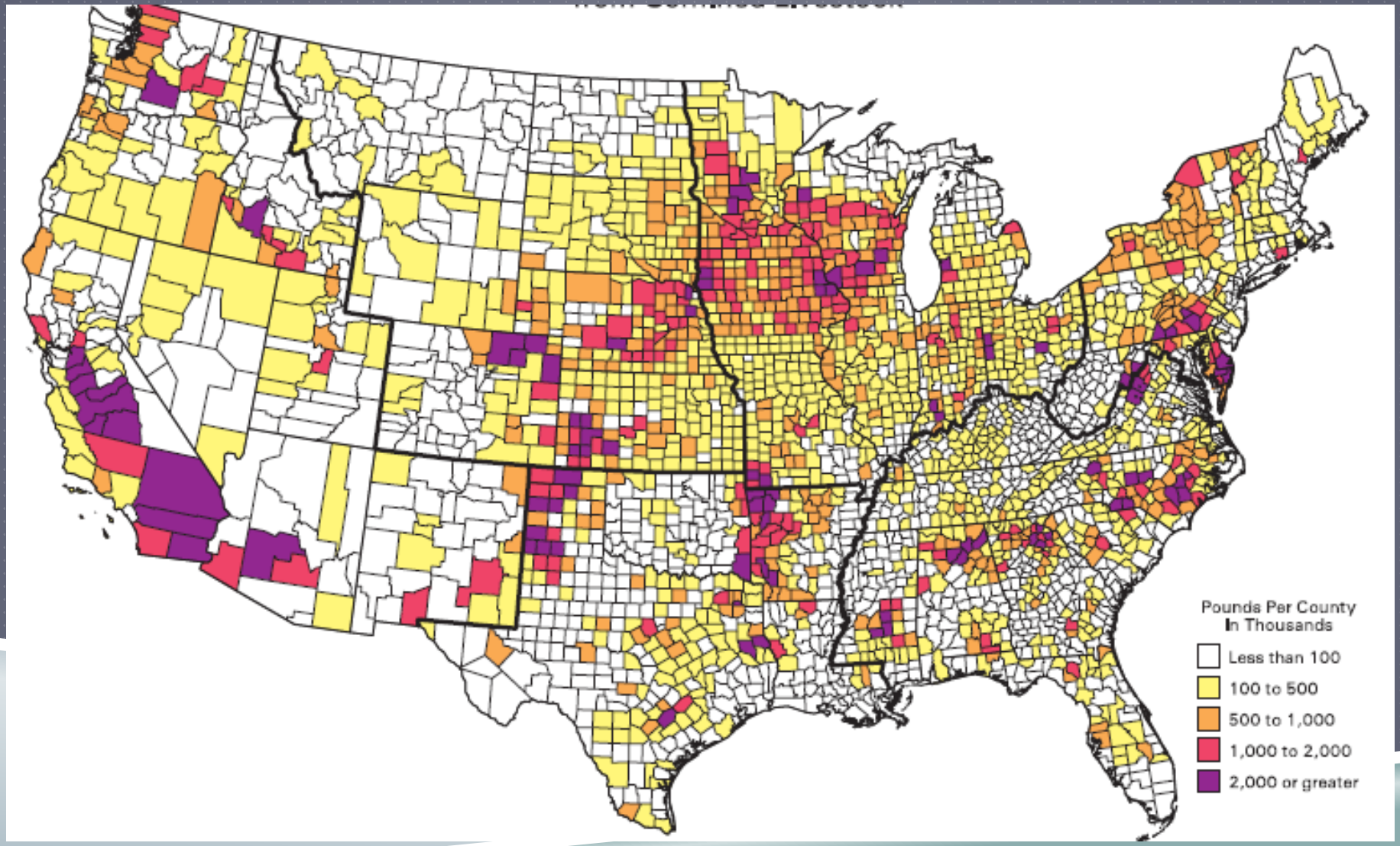
# PHOSPHORUS PRODUCTION



# PRICE OF PHOSPHORUS



# 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 $P_2O_5$ 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

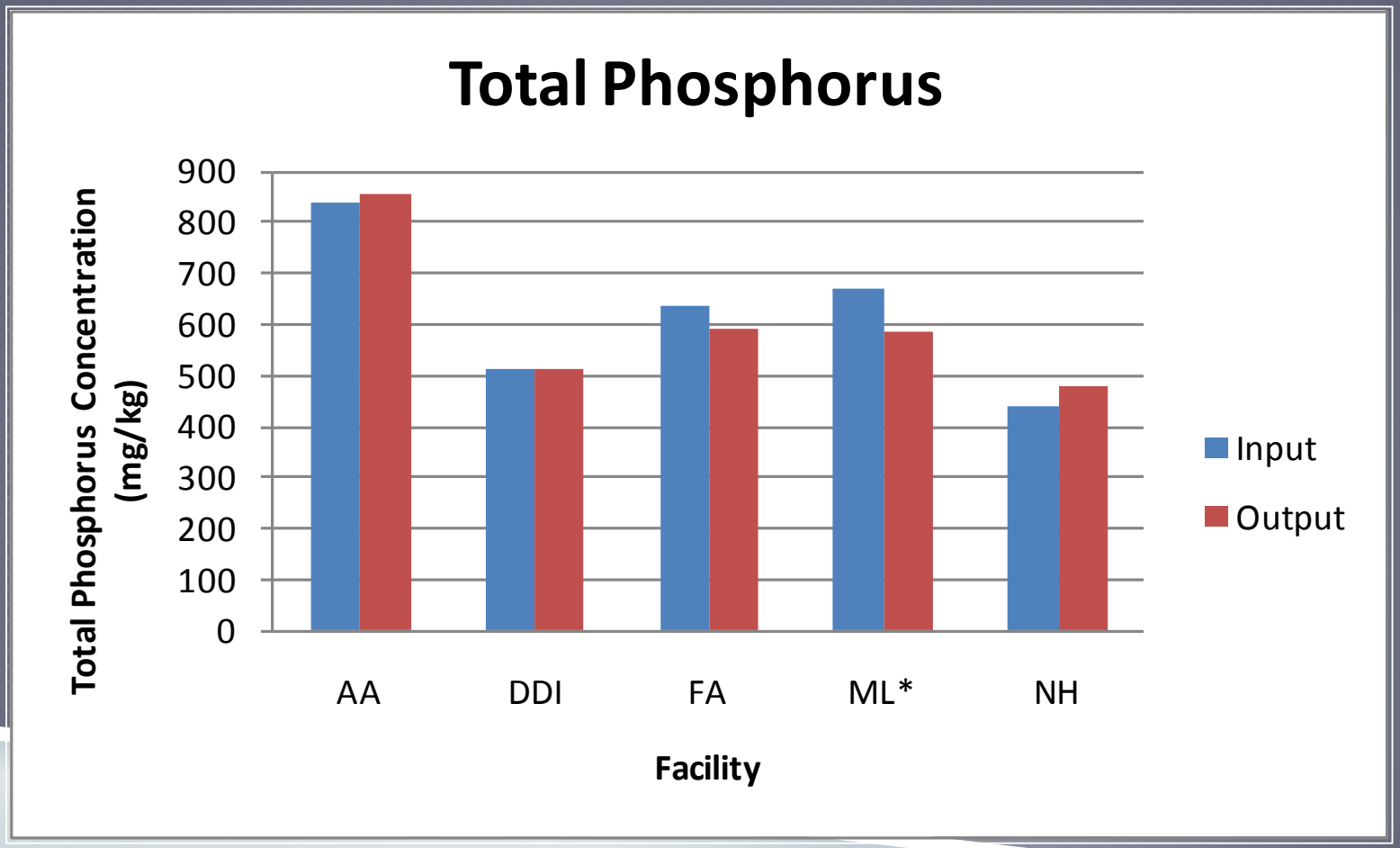
# PHOSPHORUS REMOVAL MECHANISMS

- Chemical removal
  - Aluminum sulfate, aluminum chloride
  - Ferric chloride, ferric sulfate
  - Lime
- Physical
  - Separation
- Biological

# ANAEROBIC DIGESTION

- No phosphorus removal!

# NUTRIENTS & ANAEROBIC DIGESTION



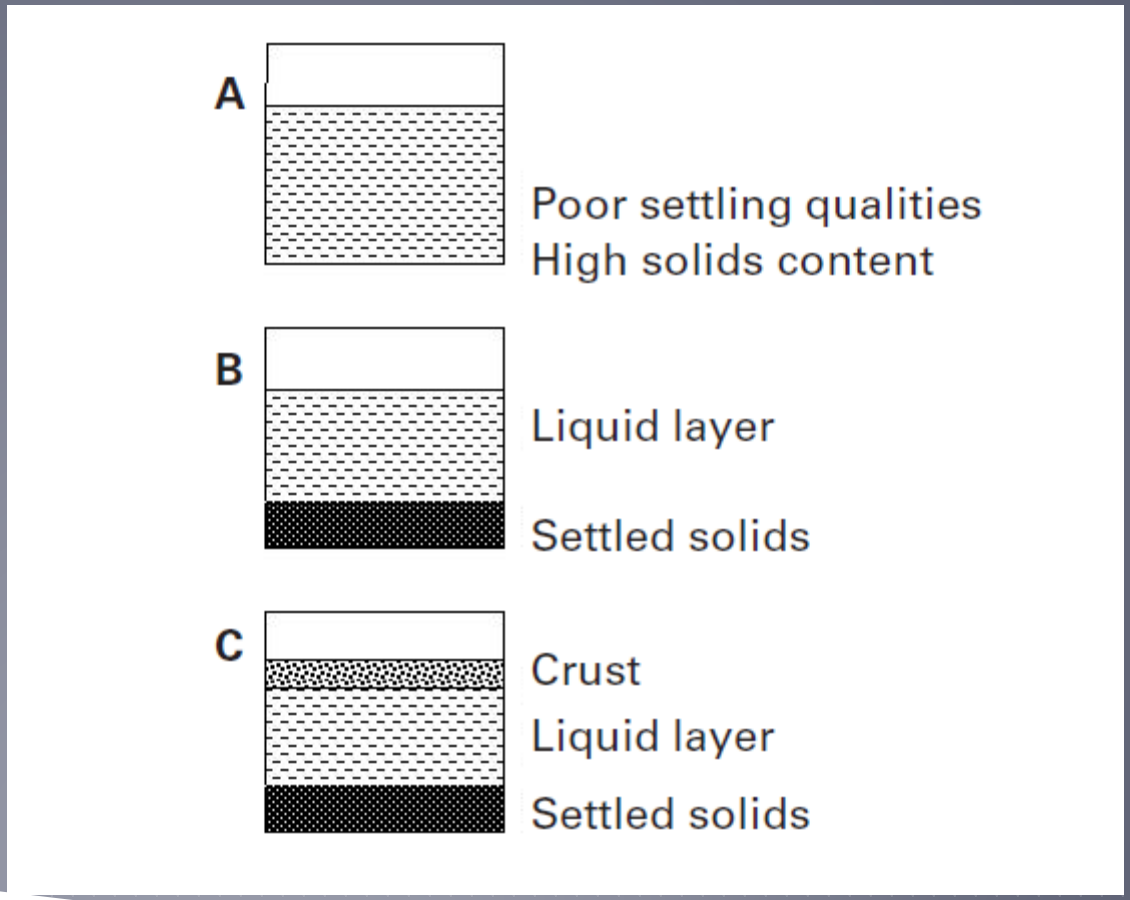

Wright, et al. 2004. Preliminary Comparison of Five Anaerobic Digestion Systems on Dairy Farms in New York State

# 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

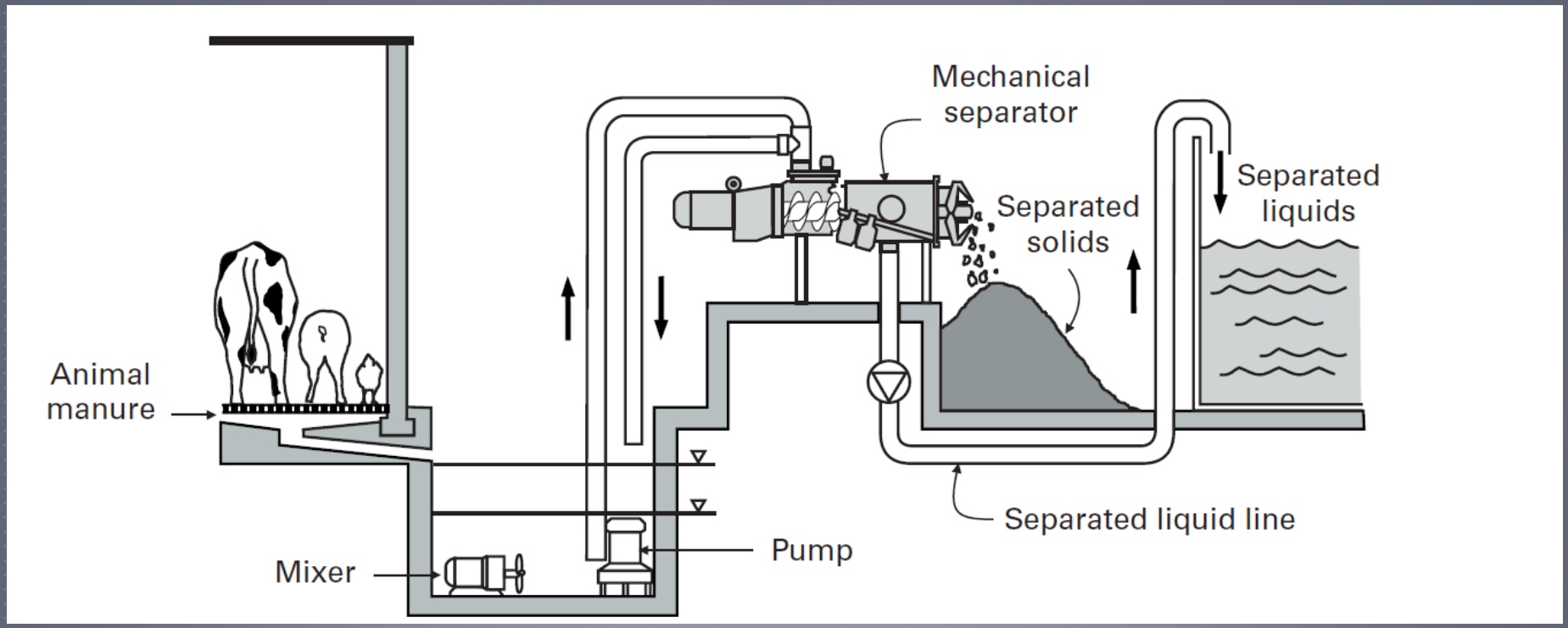
- Dependent upon influent solids concentration
- Dependent upon particle size (smaller particles are more difficult to separate)



# SETTLING BASINS/STORAGE

- Removal of approximately 28% TP in settling basins with no addition (initial TS of ~4%)

# SOLID LIQUID SEPARATION



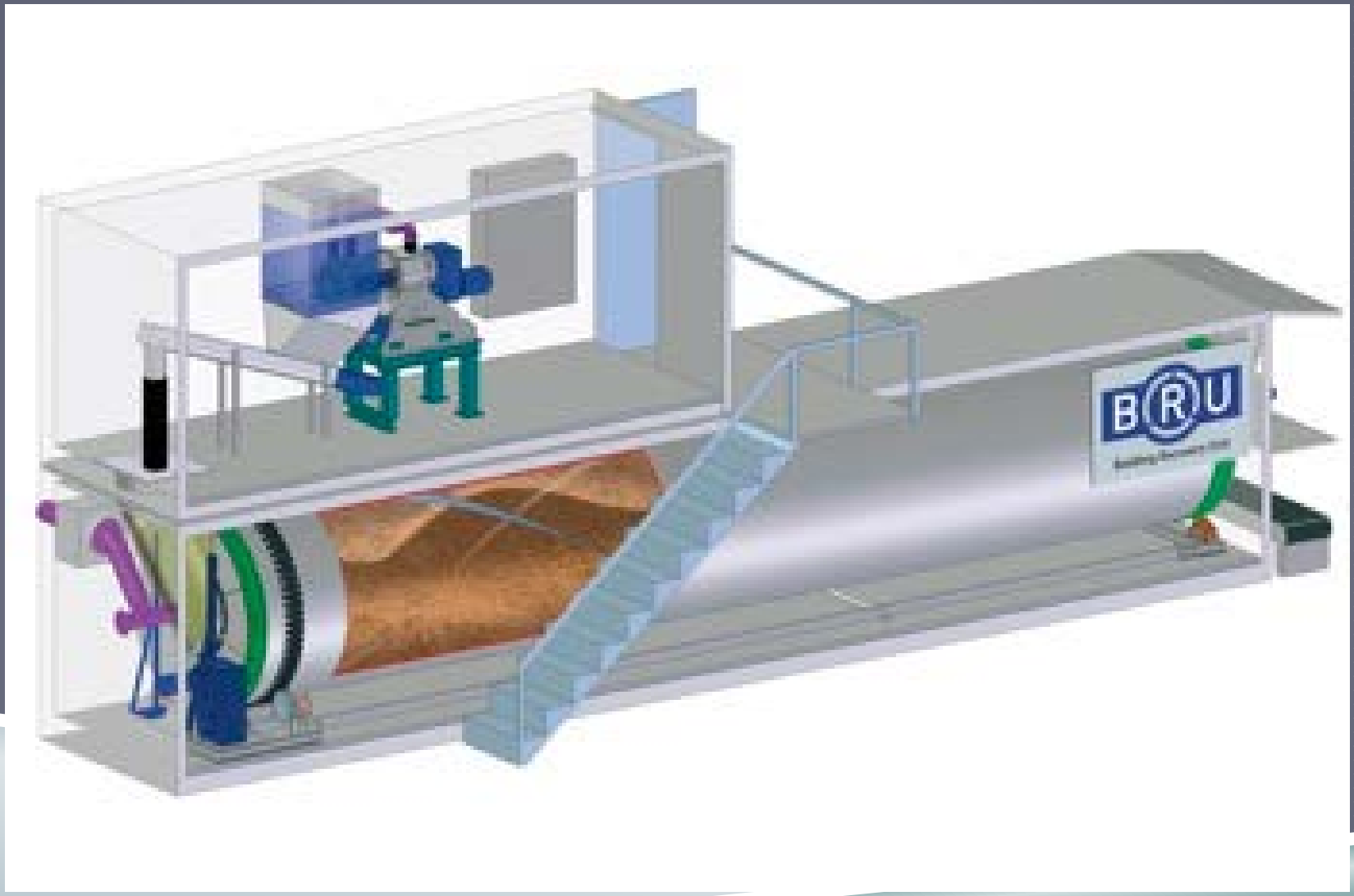

Midwest Plan Service, 2001

# SEPARATOR - SCREW PRESS

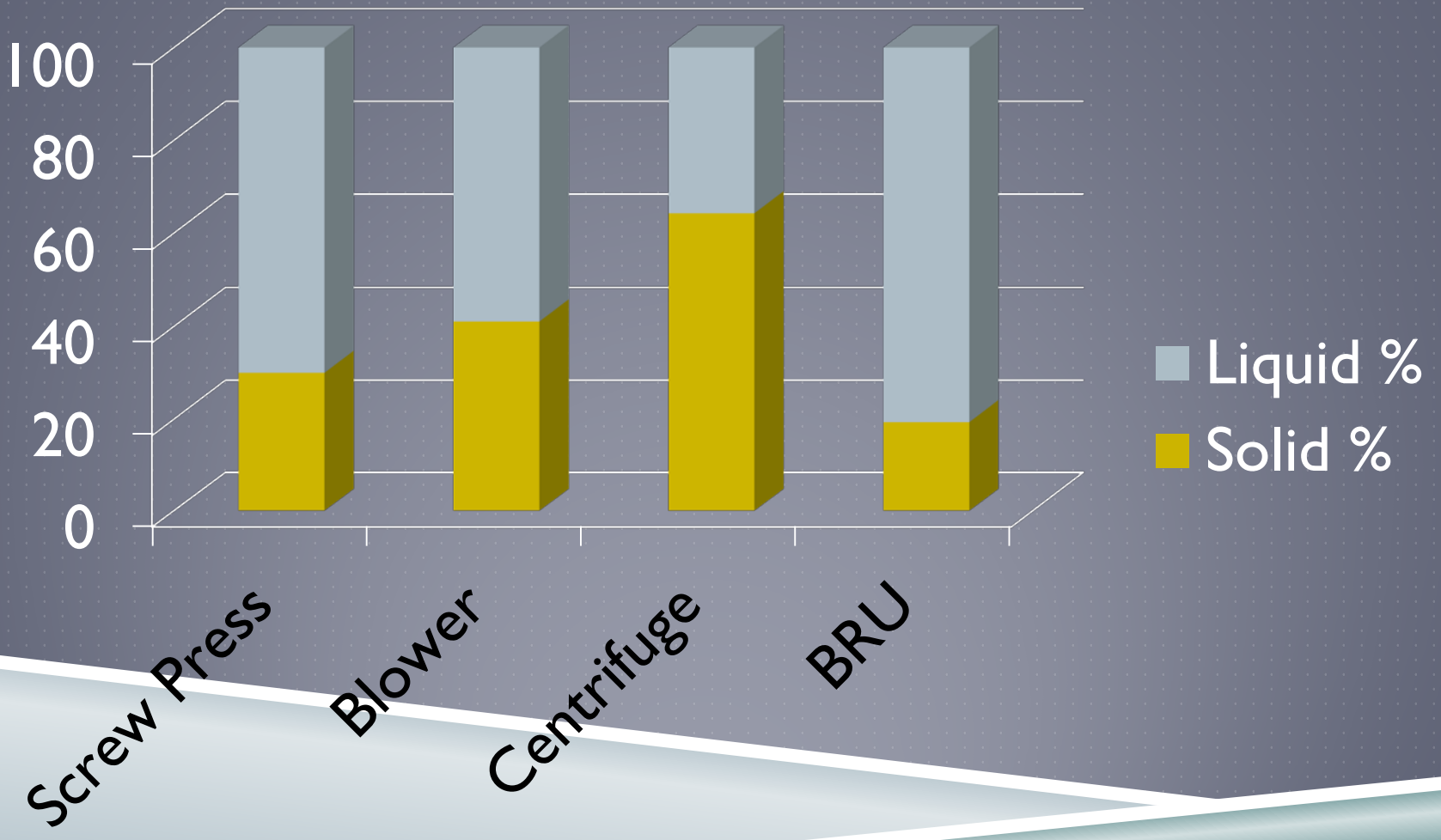
# SEPARATOR - CENTRIFUGE

Centrifuge - Dane County Digester; Clear Horizons

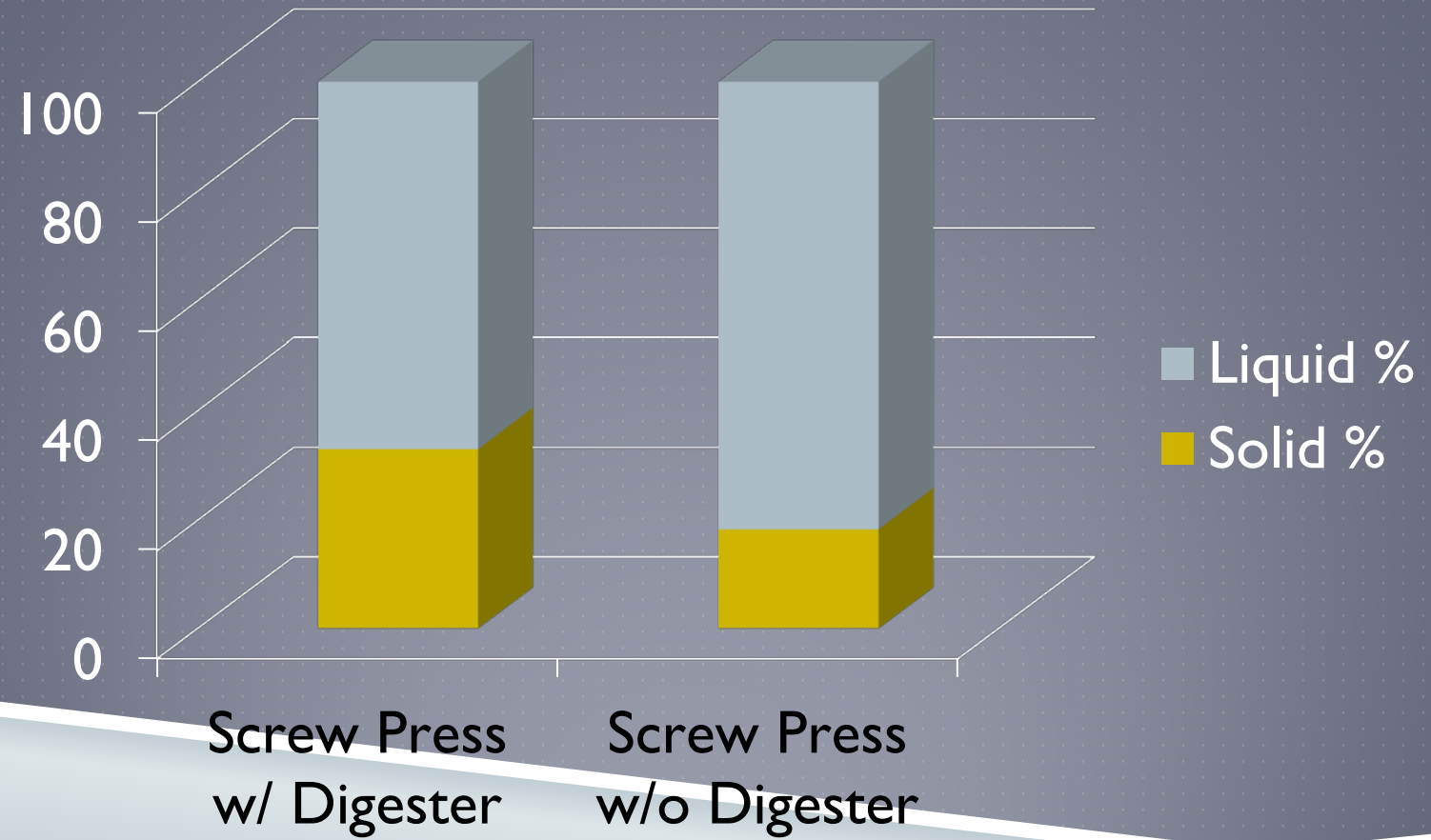
# SEPARATOR - BEDDING RECOVERY UNIT



# PHOSPHORUS


100
80
60
40
20
0
Screw Press
Blower
Centrifuge
BRU
Liquid %
Solid %

# PHOSPHORUS


100
80
60
40
20
0
Screw Press w/ Digester
Screw Press w/o Digester
Liquid %
Solid %

# N-P-K

| Concentration | N (g/kg) | $P_2O_5$ (g/kg) | $K_2O$ (g/kg) |
|---|---|---|---|
| Manure | 50 | 18 | 41 |
| Liquid | 101 | 27 | 75 |
| Solid | 15 | 14 | 8 |

| Ratio | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Manure | 3 | 1 | 2 |
| Liquid | 4 | 1 | 3 |
| Solid | 2 | 2 | 1 |

# SCREENS

| | TSS | | VSS | | TKN | | TP | |
|---|---|---|---|---|---|---|---|---|
| Screen size[b] (mm) | Amount retained (g/L) | Fraction of TSS (%) | Amount retained (g/L) | Fraction of VSS (%) | Amount retained (mg/L) | Fraction of TKN (%) | Amount retained (mg/L) | Fraction of TP (%) |
| **3.360** | 0.74 | 6.4 | 0.38 | 6.7 | 43.13 | 7.6 | 10.57 | 6.8 |
| **2.000** | 2.76 | 23.9 | 0.94 | 16.6 | 43.85 | 7.7 | 8.16 | 5.7 |
| **1.588** | 3.24 | 28.1 | 1.78 | 31.4 | 33.04 | 5.8 | 8.86 | 6.0 |
| **1.000** | 3.78 | 32.8 | 1.60 | 28.3 | 66.11 | 11.6 | 16.66 | 11.4 |
| **0.794** | 3.18 | 27.6 | 2.18 | 38.5 | 66.12 | 11.6 | 16.67 | 12.1 |
| **0.590** | 3.98 | 34.5 | 2.48 | 43.8 | 77.93 | 13.7 | 16.96 | 12.3 |
| **0.500** | 3.92 | 34.0 | 1.54 | 27.2 | 59.81 | 10.5 | 15.16 | 11.0 |
| **0.297** | 4.22 | 36.6 | 1.90 | 33.6 | 60.68 | 10.6 | 15.43 | 11.1 |
| **0.250** | 4.82 | 41.8 | 2.14 | 37.8 | 78.26 | 13.7 | 23.26 | 16.7 |

# SCREENS WITH POLYMERS

| Polymer rate (mg/L) | Removal efficiency [a] (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TSS | | VSS | | TKN | | TP | |
| | PAM | | | | | | | |
| 0 | 64.9 | (0.090) | 64.3 | (4.44) | 18.9 | (0.021) | 19.6 | (2.68) |
| 60 | 71.6 | (0.232) | 73.8 | (2.06) | 37.1 | (0.436) | 34.4 | (1.03) |
| 120 | 75.9 | (0.671) | 74.2 | (0.823) | 35.8 | (2.60) | 33.8 | (5.05) |
| 180 | 82.8 | (0.246) | 79.8 | (2.03) | 48.1 | (3.56) | 44.4 | (5.31) |
| 240 | 86.8 | (1.47) | 83.5 | (2.63) | 55.9 | (5.65) | 52.0 | (8.64) |
| 300 | 90.0 | (1.15) | 87.6 | (1.75) | 63.9 | (3.36) | 58.9 | (4.73) |
| 360 | 92.7 | (0.285) | 92.4 | (0.835) | 65.0 | (4.69) | 57.8 | (5.93) |
| 420 | 94.9 | (0.575) | 92.9 | (1.67) | 74.0 | (8.76) | 66.4 | (9.43) |
| 480 | 95.0 | (0.614) | 93.0 | (0.208) | 73.1 | (3.56) | 64.9 | (2.73) |

# DISSOLVED AIR FLOTATION

R. Sheffield

- 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

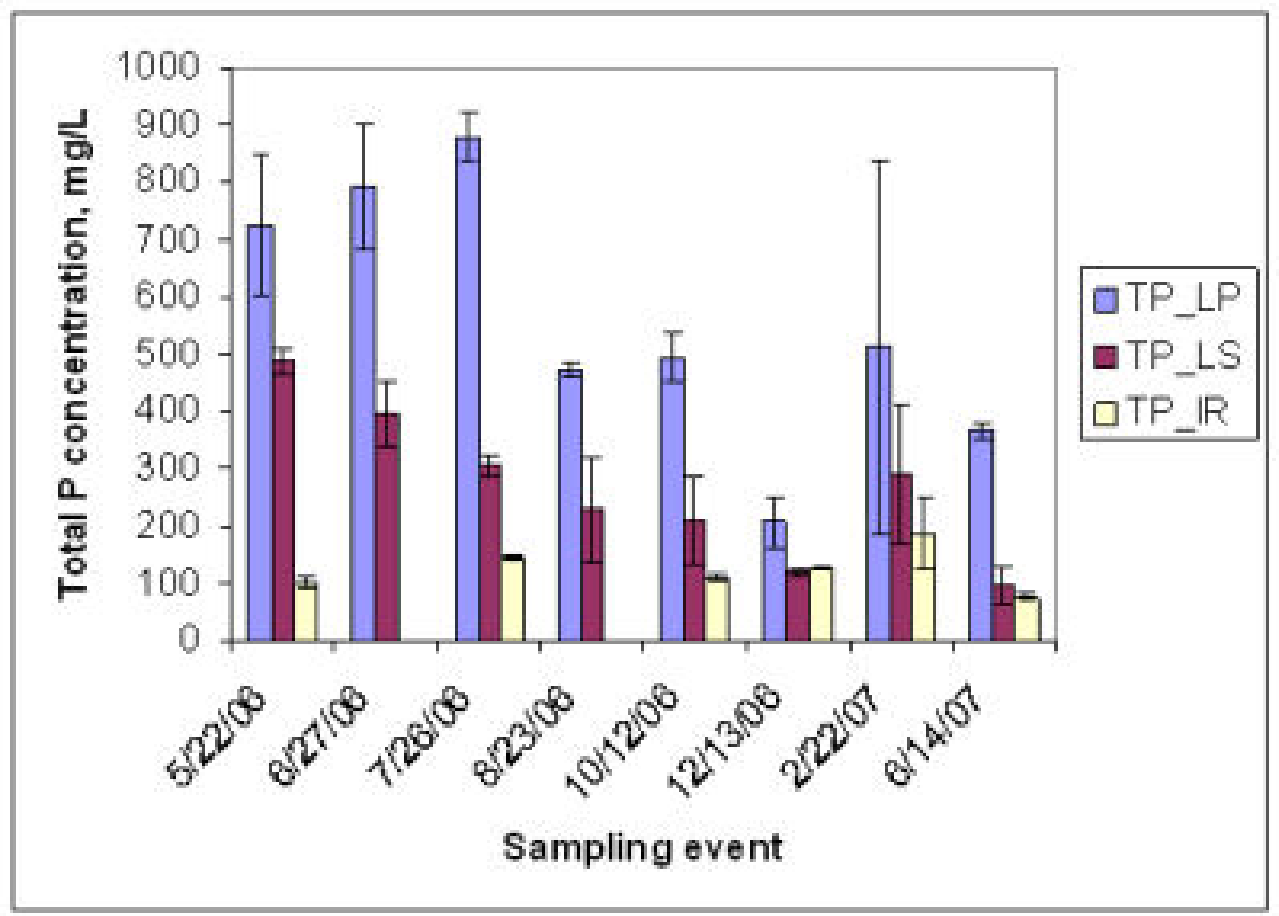
- More effective for dissolved phosphorus
- Requires regular additions, large doses for manure
- Can be costly
- Can pose issues in soils
- Typically require polymer additions for application
- Significant amount of sludge production

# 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

# EFFICIENCY COMPARISON

| Technology | Initial TS (%) | TP Removal (%) |
|---|---|---|
| Settling Basin | ~4 | 28 |
| Screw Press | variable | 15-24 |
| Centrifuge | variable | 60 |
| Dewatering using Geotextiles | 0.71 | 46 |
| Inclined Plane | | 53 |
| Screens | 0.4-3.2 | <17 |
| Screens with Polymers | 0.4-3.2 | 34-65 |
| Chemical Precipitation | 0.87-1.5 | 80-90 |

# 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.

# THANK YOU!

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