Chemical Phosphorus Separation

Experiences from Michigan Dairy Farms

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Why consider phosphorus separation?

Background

- Chemical precipitation makes phosphorus insoluble
  - Algae need *soluble nutrients*
- Chemical coagulants used in water and wastewater treatment since 1970's
  - Driven by the Clean Water Act and the need for more complete nutrient removal

Waste strength: Dairy vs. Municipal

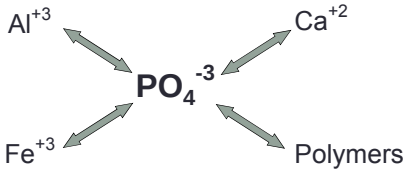
Parameter	Municipal Wastewater *(mg/L)*	Dairy Manure *(mg/L)*
Color	Grey to black	Brown to black
BOD5	250	15,000
COD	500	37,000
Total N	40	6,000
Total P	9	3,000
Total solids	300	95,000
Volatile solids	240	81,000

Phosphorus separation options

- Biological
  - Cycling of anaerobic and aerobic conditions
- Chemical precipitation
  - Addition of chemical compounds to bind soluble phosphorus
- Struvite formation (magnesium ammonium phosphate)
  - Crystallized growth containing phosphate, ammonium, and magnesium

Chemical phosphorus separation

- Chemical phosphorus removal is based on the principles of general chemistry



"OPPOSITE CHARGES ATTRACT"

Terminology

- Precipitation & coagulation
  - Change from a liquid to thickened, curdlike, insoluble state
  - Brought about by the addition of chemical coagulants
  - Charge neutralization brought about by interaction
    - Destabilization of colloids by the addition of coagulants
- Flocculation
  - Aggregation of small particles into larger particles
  - Interaction of destabilized particles to form dense flocs
    - Aided by the addition of polymers
    - Excessive mixing may breakdown floc
- Separation
  - Passive
  - Mechanically
    - Belt filter press or dissolved air floatation

Factors impacting chemical selection

- Influent phosphorus
- Desired phosphorus reduction
- Wastewater suspended solids
- Alkalinity
- Chemical cost
- Reliability of chemical supply
- Climatic conditions
- Sludge handling facilities
- Ultimate disposal method
- Compatibility with other treatment processes
- Changes in feed ration

Metcalf and Eddy, Wastewater Engineering Treatment, Disposal, and Reuse, 1991

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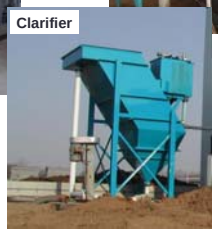
Equipment

- Rapid mix chamber with chemical injector
- Flocculation tank
- Separation devices
  - Belt filter press
  - Dissolved air floatation (DAF)
  - Clarifier
  - Screw press
  - Settling cell

Equipment



Experience from Michigan

- Three systems installed in early 2000's
  - Green Meadow Farms (2002)
    - Belt press
    - 3,300 cows (sand)
  - Maple Row Dairy Farm (2004)
    - Belt press
    - 2,500 cows and replacements (sand)
  - Bradford Dairy (2003)
    - Dissolved air floatation
    - 1,200 cows (organic bedding)
- Driven largely by regulatory uncertainty
  - NPDES permits new
  - Michigan Right to Farm law (GAAMP's)

Experience from Michigan

Reason for system adoption

- Green Meadow Farms
  - Existing irrigation system
  - Manure management labor
- Maple Row Dairy Farm
  - Concern over manure application
  - Wanted to install irrigation
    - Reduce manure transport
    - Improved crop yield
- Bradford Dairy
  - Proximity to the city of Sparta
  - Manure management labor

General phosphorus system goals

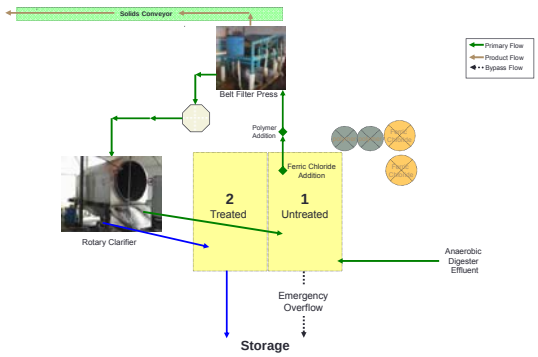
- Effluent characteristics
  - >90% soluble phosphorus reduction
  - >50% solids reduction
  - Low odor
- Separated solids - "cake"
  - >20% total solids
  - Concentration of phosphorus, organic nitrogen and solids
  - Compostable
- Chemical
  - Minimal usage
  - Cost effective

Experience from Michigan

System specifics

- Green Meadow Farms
  - Sand separation at the source
  - Pump to manure treatment center
  - Chemical cost ≈ $73/yr/cow (2003)
- Maple Row Dairy Farm
  - Vacuum manure from the barn alley, transport to manure treatment center
  - Entire manure processing system under one roof
- Bradford Dairy
  - Gravity flow to manure treatment center
  - Entire manure processing system under one roof
  - Chemical cost ≈ $50/yr/cow (2003)

Green Meadow Farms, Inc



Scrape Manure Collection

Mechanical & Passive Sand Separation

Anaerobic Digester

Chemical Phosphorus Separation System

Chemical Storage

Inline Ferric Mixing

Rapid Mix Floc Tank

Belt Press

Belt Press & Phosphorus Cake

Phosphorus Cake

Solid Manure Use & Export

Rotary Drum Thickener

Effluent Storage

Effluent Use

System products

Parameters	Input	Effluent	Solids	
	(lb/1,000 gal)	(lb/1000 gal)	(lb/ton)	(lb/1000 gal)
Total Solids	4.2%	0.4%	16.6%	16.6%
Total Nitrogen	14.5	5.3	10.9	45.5
Ammonia (NH_4-N)	7.2	4.6	1.70	7.1
Phosphorus (P_2O_5)	5.7	0.2	5.2	21.7
Potassium (K_2O)	11.3	7.7	2.8	11.7

Treatment costs (chemicals)

- Flow rate – 110,000 to 120,000 gpd

Chemical	Usage (lb/d)	Cost
Ferric chloride	16,000	$1,150
Organic polymer	230	$360
De-foamer	40	$30

- Approximate treatment cost per gallon $0.013
- MI application cost $0.01 to $0.032 per gallon

Technology challenges

- Capital investment
- Chemical cost
- Maintenance
- Engineering is of paramount concern
- System reliability
  - Step learning curve
  - Some redundancy needed
- Fate of bound phosphorus and chemical additives
  - Stability of phosphorus complex
  - Addition of metals to cropland

Benefits of chemical separation

- >90% reduction in soluble phosphorus
- Reduction in fresh water consumption
  - Less to dispose
- Marketable commodity
- Odor reduction
- Improved nutrient management
  - Time, form, rate, & placement

Conclusions

- Innovative technologies are here…
  - More research is needed
  - Experience will come from those who take the risk
- Wide range of options
  - Nutrient separation ranges from minimal to near 100%
  - Simple to intensive
  - Inexpensive to $$$$$$
- Anaerobic digestion is beneficial for pretreatment
  - Stabilized pH, temperature & flow
  - Seasonal changes do still occur

Questions

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