MAKING SENSE OF MANURE TREATMENT TECHNOLOGY OPTIONS FOR LIVESTOCK FARMS

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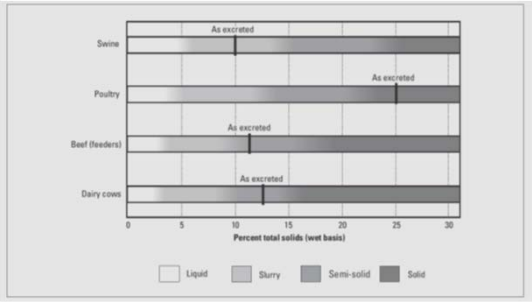
Nutrient Recovery Categories

- Coarse solid separation
- Fine solids separation
- Membrane separation
- Energy generation
- Fiber drying & bedding recovery
- Other technologies

Technology Selection Factors

- Manure characteristics
  - Moisture content
  - Nutrient content
  - Ash content / fixed solids
  - Grit / contamination
- Bedding
- Handling
  - Collection
  - Conveyance
- Target products

Manure Characteristics, excreted



MWPS – 18, Section 1, Manure Characteristics

Manure Characteristics, as managed

Beef Feedlot[1]	TS, % wb
High forage	46.7
High energy	47.9

Dairy[2]	TS, % wb
As excreted	14.3
Dry lot, daily scrape	21.9
Dry lot, weekly scrape	58.8
Freestall flush	1-3

Poultry[3]	TS, % wb
Broiler litter	78.5
Broiler cake	60.0
Turkey litter	73.5
Turkey cake	55.0

Swine[4]	TS, % wb
Fresh	9.2
Manure from building	2.0
Lagoon surface	0.37
Lagoon sludge	10.0

[1]*MWPS – 18, Section 1, Manure Characteristics*
[2]*http://www.manuremanagement.cornell.edu/Pages/General_Docs/Events/3.Dana.Kirk.pdf*
[3]*https://www.clemson.edu/extension/camm/manuals/poultry/pch3b_00.pdf*

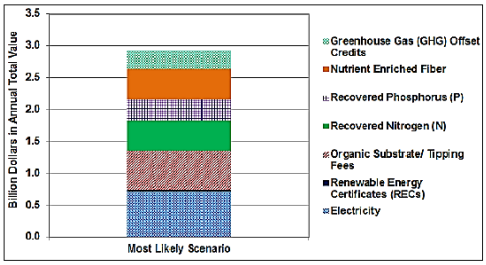
Manure Treatment >> Nutrient Recovery

Solid-Liquid Separation

Anaerobic Digestion

Dissolved Air Flotation

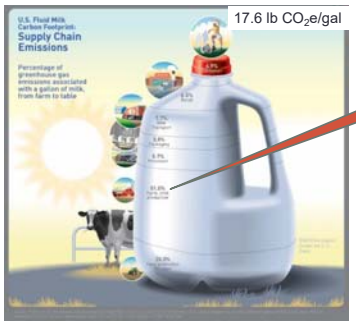
Potential Value of Dairy Manure



Dairies over 500 cows or 2,647 dairies nationwide

National market value for anaerobic digestion products. Report to Innovation Center for US Dairy, August 2013.

Carbon Footprint of Milk

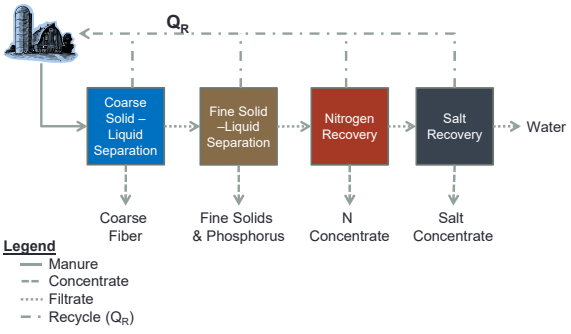


17.6 lb CO_2e/gal

51.5% at the farm

INNOVATION CENTER FOR U.S. DAIRY

Nutrient Recovery System



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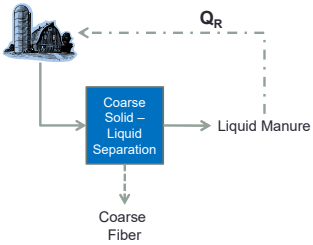
Nutrient Recovery System



Solid-Liquid Separation (Coarse)

- Why
  - Pipe clogging
  - Sludge accumulation
  - Storage crusting
  - Easier application
- Solids use
  - Bedding
  - Soil amendment
  - Compost

Coarse Solid Separation

Slope Screen
Sloped wedge-wire screens that diluted manure is pumped over to remove the course solids, often followed by screw presses or rollers to remove additional water.

Screw Press
A wedge-wire screen cylinder that manure is forced through by an auger to force out the water, back pressure is maintained on the material in the cylinder by means of a gate or gates at the discharge of the cylinder.

Rotary Drum Screen
Rotating drums of wedge wire or screen that manure is pumped through to remove the liquid, often followed by screw presses or rollers to remove additional water.

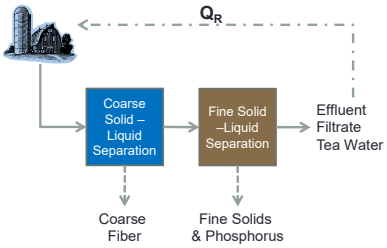
Images provided by Newtrient, LLC

Coarse Solid-Liquid Separation Approaches in the U.S.

Technology	Performance		OPEX ($/1000gal)	CAPEX ($/1000gal/yr)
	TN	TP		
Primary & Secondary Mechanical Screens	15 – 30%	15 – 25%	$0.68 – 0.82	$4.4 – 5

Frear, C. 2013. Review of Nutrient Recovery Technologies
Based on dairy manure applications, assume 7,3000 gal/cow/yr

Nutrient Recovery System



Fine Solid-Liquid Separation

- Why
  - Phosphorus limited
  - Reduced truck traffic or cost
  - Field distance
  - Desire to irrigate
  - Nutrient market opportunity
- Solids use
  - Soil amendment & fertilizer
  - Compost

Fine Solids Separation / Dewatering

Polymer or Coagulant Flocculation
Introduction of select chemicals to induce small suspended particles to bind together into larger particles or flocs so that they can either float or sink, leading to separation and removal.

Moving Disc Press
A cylinder made up of many vertically arranged plates that manure is forced through by an auger to force out the water; back-pressure is maintained on the material in the cylinder by means of a gate or gates at the discharge of the cylinder, may or may not be assisted by polymers or coagulants also used for dewatering following other fine solids separation systems.

Belt Filter Press
A long screen in the form of a belt with rollers that allows for separation of fine solids usually used with polymers or coagulants also used for dewatering following other fine solids separation systems.

Plate Presses
Fine screens attached to a series of plates that are pressurized by the inflow of dilute waste usually used with polymers or coagulants. also used for dewatering following other fine solids separation systems.

Images provided by Newtrient, LLC

Fine Solids Separation / Dewatering

Centrifuge
Physical separation of fine particles by centrifugal force may or may not be assisted by polymers or coagulants, also used for dewatering following other fine solids separation systems.

Vibrating Screen
Fine screens that are vibrated at a high frequency to assist in dewatering fine solids usually used with polymers or coagulant.

Dissolved Air Floatation(DAF)
Physical and chemical removal of fine solids by floating with very fine air bubbles assisted by polymers or coagulants.

Incline Screen
Similar to slope screens but with finer screens usually used with polymers or coagulants.

Struvite Crystallization
A process whereby existing soluble forms of phosphorus in the wastewater are induced to crystallize as a struvite crystal which is a combination of ammonia, magnesium and phosphorus, producing a dry, high phosphorus content, slow-release, pelletized fertilizer.

Images provided by Newtrient, LLC

Advance Treatment of Dairy Manure

Parameters	Chemical & Belt Press Input (mg/L)	Chemical & Belt Press Effluent (mg/L)		UF Effluent (mg/L)
Total Solids	4.2%	0.4%		0.7%
Total Nitrogen	1,740	634		1,354
Ammonia (NH_4-N)	864	552		1,294
Phosphorus (P_2O_5)	684	2		39
Potassium (K_2O)	1,356	924		1,393

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Fine Solids Products

Fine Solid-Liquid Separation Approaches in the U.S.

Technology	Performance		OPEX ($/1000gal)	CAPEX ($/1000gal/yr)
	TN	TP		
Sequential Screening + Advance Non-Chemical	24 – 30%	50-65%	$3.4 – 6.8	$8 – 19
Sequential Screening + Advance Chemical	45 – 55%	75 – 90%	$3.4 – 10.3	$18 – 21
Struvite Crystallization	30%	75%	$12.3 – 15.1	$14 – 21

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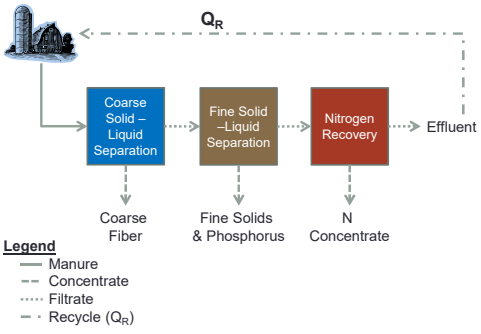
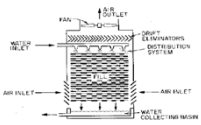
Based on dairy manure applications, assume 7,3000 gal/cow/yr

Nutrient Recovery System



Nitrogen Recovery

- Why
  - Application restrictions
  - Desire to irrigate
  - Nutrient market opportunity
- Technology
  - Air stripping
    - Temp, pH & ammonia concentration sensitive
  - Biological conversion
- Product use
  - Nitrogen gas or fertilizer
  - Low nutrient water



USEPA, 2000

http://nnspo.com/p1/Nitrification.htm

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Nitrogen Recovery

Nitrification/Denitrification
Both traditional and modified methods to convert ammonia nitrogen biologically to non-reactive nitrogen gas that can be released to the atmosphere. Various organisms and degrees of aerobic and anaerobic contact allow for the conversion.

Ammonia Stripping
Various approaches, including air, steam, carbon dioxide, membrane, etc. that use temperature, pressure, and chemicals to preferentially adjust the pH and therefore the form of the ammonia away from soluble ionic ammonia to free, gaseous ammonia. The gaseous ammonia is then collected and often converted to a more stable ammonia-salt form using contact various acids, i.e. sulfuric acid to ammonium sulfate fertilizer.

Images provided by Newtrient, LLC

Nitrogen Recovery Approach in the U.S.

Technology	Performance		OPEX ($/1000gal)	CAPEX ($/1000gal/yr)
	TN	TP		
Ammonia Stripping	65 – 85%	85 – 90%	$14 – 26	$60 – 90

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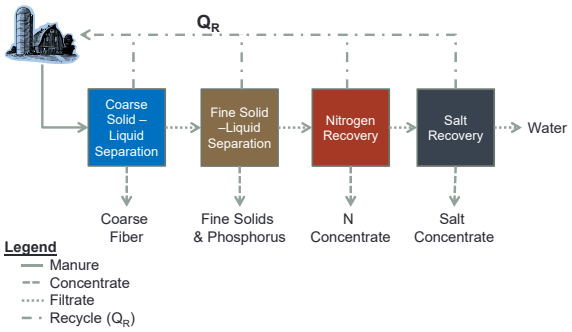
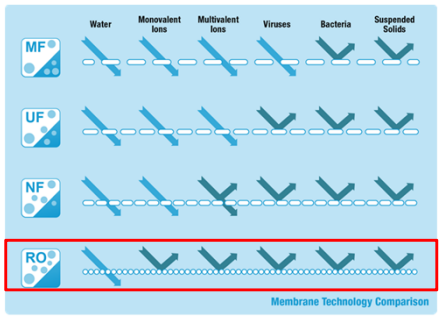
Nutrient Recovery System



Salt (Water) Recovery Technology



MF – mirco
UF – ultra
NF – nano
RO – reverse osmosis

http://www.kochmembrane.com/Learning-Center/Technologies.aspx

Salt Recovery – Membrane Systems

Membrane Systems

A series of membranes, either micro-filtration, ultra-filtration and/or reverse osmosis filtration can be used singly or in a combination to remove various sized contaminants within the wastewater, using high pressure flow through a membrane designed to selectively remove certain particle sizes. Membranes can be used in concert with digesters, ammonia removal systems to significantly remove solids, nutrients, and pathogens, incorporation of reverse osmosis can remove dissolved salts producing a clean water. Use always produces a reject stream composed of material not passing the membrane, thus not zero discharge. Membrane failure and high pressure/energy costs can be a concern.

Images provided by Newtrient, LLC

Clean Water Approach in the U.S.

Technology	Performance		OPEX ($/1000gal)	CAPEX ($/1000gal/yr)
	TN	TP		
Salt Recovery	85 – 95%	85 – 95%	$68–137	$200–250

Frear, C. 2013. Review of Nutrient Recovery Technologies
Based on dairy manure applications, assume 7,3000 gal/cow/yr

Energy Generation / Thermal Conversion

Pyrolysis
Use of moderate temperatures (approximately 400C or higher) in the absence of air to convert biomass solids into more energy-dense forms, producing combustible gases, liquids that can be further refined to liquid fuels and solid bio-chars.

Torrefaction
A lower temperature version of pyrolysis (approximately 200-370C) aimed at densifying the energy content of biomass solids, by producing primarily a bio-char or charcoal.

Gasification
High temperature, controlled combustion in presence of air (>800C) that completely converts solid biomass to gases, which can then be used for heat, power, and fuel.

Images provided by Newtrient, LLC

Energy Generation / Anaerobic Digesters

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Fiber Drying & Bedding Recovery

Drum Driers
A slightly inclined drum fed on high end with solids and counter-current flow of warm air starting on the lower end. With strategically placed lifters and rotation, effective air/solids mixing occurs for evaporation and drying of solids.

Belt Driers
A series of perforated steel plates which are chain driven to carry solids across a horizontal flow of warm air, inducing evaporation of moisture and drying of solids.

Composting Drums
Rotating drum with conveyed, separated manure solids rotating against hot air produced by biological organisms, leading to aerated, compost process during 1-3 day retention time.

Images provided by Newtrient, LLC

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Other Technologies

Vermifiltration
Higher organisms such as red worms within a media filter-bed can convert ammonia nitrogen to bound organic nitrogen in the worms/castings, non-reactive nitrogen gas as well as other forms, thus vastly reducing the ammonia content of the wastewater while making saleable worm/casting by-products.

Evaporative Systems
Beyond manure drying, as discussed above regarding manure solids, manure wastewater can be partially or completely dried by evaporating the liquid through a series of in-series cascading evaporative reactors. Energy inputs and balances can be a concern while treatment of volatiles in the evaporated liquid is also required.

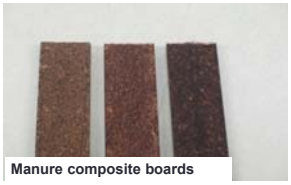
Images provided by Newtrient, LLC

Products & Markets

Products & Markets


Manure solids as bedding


Compost


Manure composite boards

Products & Markets

Products & Markets

http://www.fertikal.be/en/process-distribution

Where do we stand today

- Manure application costs inexpensive
- Social pressure extremely high
- Nutrient recovery technologies
  - Commercially viable technologies available
  - Capital and operational costs are high
  - Nutrients do not go away, still require management
- Manure storage practices
  - Planning for nutrient recovery products
  - Storage design standards may not apply to some products
- Resources and opportunities exist

Questions?

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