Anaerobic Digestion Performance on a Sand Bedded Dairy Farm

5th AgSTAR National Conference
Green Bay, Wisconsin
April 28, 2010

Dana M Kirk
Michigan State University
Biosystems and Agricultural Engineering
Anaerobic Digestion Research and Education Center

Sand bedding benefits

- Sand advantages: animal health, cow comfort and milk production[1,2]
  - Increased milk production of 1.4 to 1.8 kg/cow/d[3]
  - Somatic cell count reductions 50,000 cells per mL[3]
  - Reduced lameness saving $82.50/cow4 (2001 dollars)[4]
  - $152/cow/yr (2004 dollars) benefit of sand[5]
- Sand usage averages 49 lb/cow/d (22 kg)[6]

1) Inglis et al. 2006., 2) Wedel. 2001., 3) Stone. 2003., 4) Cook. 2001.,
2) 5) Cook and Nordlund. 2004., 6) MWPS-18, 2000

Disadvantages of sand bedding[1,2]

- Sand laden dairy manure (SLDM) is abrasive
- SLDM is not pumpable or stackable
- Sand tends to settle, clogging pipes reducing volume
- Settled sand is difficult to resuspend often requiring physical excavation
- Sand is inorganic, no biogas potential

1) Inglis et al. 2006., 2) Karim et al. 2005a &b.

Sand manure separation

- Process steps[1]
  - Metering
  - Mixing (agitation and turbulence)
  - Sedimentation
  - Sediment (sand) removal
- System types
  - Mechanical
    - Counter current upflow and hydrocyclones
    - Capable of removing 80 to 90% of bedding sand[2]
  - Passive
    - Settling basins and sand lanes
    - Capable of removing 71 to 75% of bedding sand[3]

1) Wedel and Bickert. 1996., 2) Wedel and Bickert. 1998., 3) Fulhage. 2003.

Factors affecting biogas potential

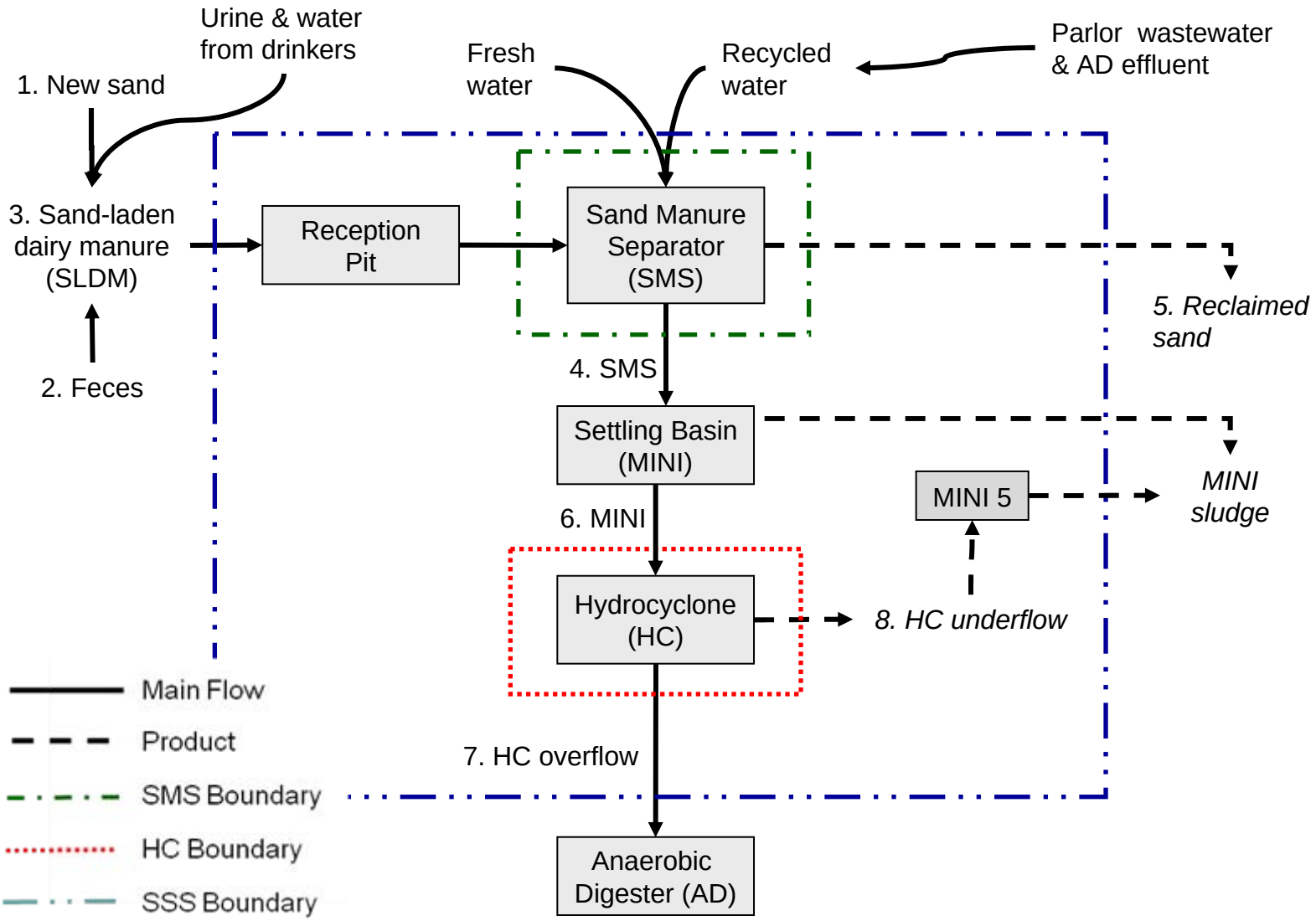
- Digester type/design
- Addition of dilution water
- Manure collection and conveyance
- Feedstock or blend of feedstock
- Bedding material and usage
- System management
- Organic conversion efficiency
- Biogas utilization

1) USDA NRCS. 2007. 2) Cornell Pro Dairy Manure Management Program.

Green Meadow Farms (GMF) farm summary

- Livestock
  - 2,900 milk cows on sand
  - 300 dry cows on sand and bedded pack
- Manure management system
  - Manure collection: scrape
  - Manure conveyance: auger/pump
  - Treatment:
    - Mechanical sand separation (3 levels)
    - Anaerobic digestion
    - Phosphorus separation
  - Storage: synthetic/clay lined storages
  - Disposal: land application

GMF process flow diagram



Green Meadow Farms Anaerobic Digester

- 3 tank complete mix
- Capacity of 2.7 million gallons
- 22 to 26 day HRT
- CAT 3516 engine-generator
- Heating
  - Hot water to sludge
  - Sludge to sludge
  - In wall & floor heat
- Prop style mixers

GMF system evaluation

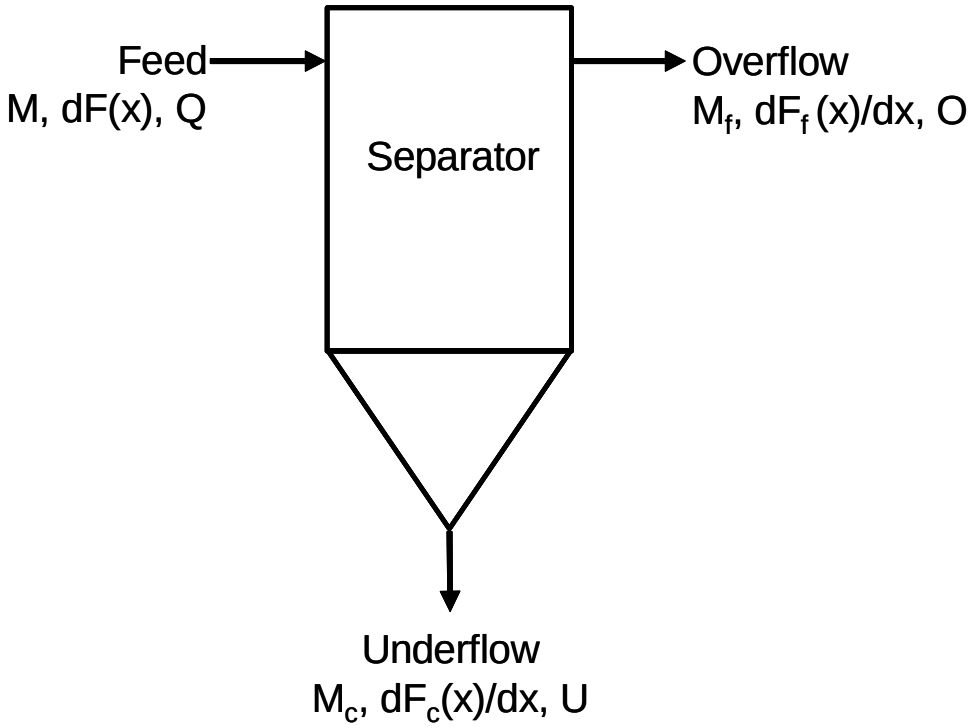
- Sand removal efficiency
- Change in sand composition
- Loss of volatile solids

Assumptions & data collection challenges

- Assumptions
  - No storage in the sand separation system units
  - Fixed solids contribution primarily from sand
  - Industry standards used when data collection not possible
- Challenges
  - System complexity
  - Access to sample locations (safety)
  - Operations

Determination of sand separation efficiency

Mass balance theory[1]



1) Svarovsky. 1990.

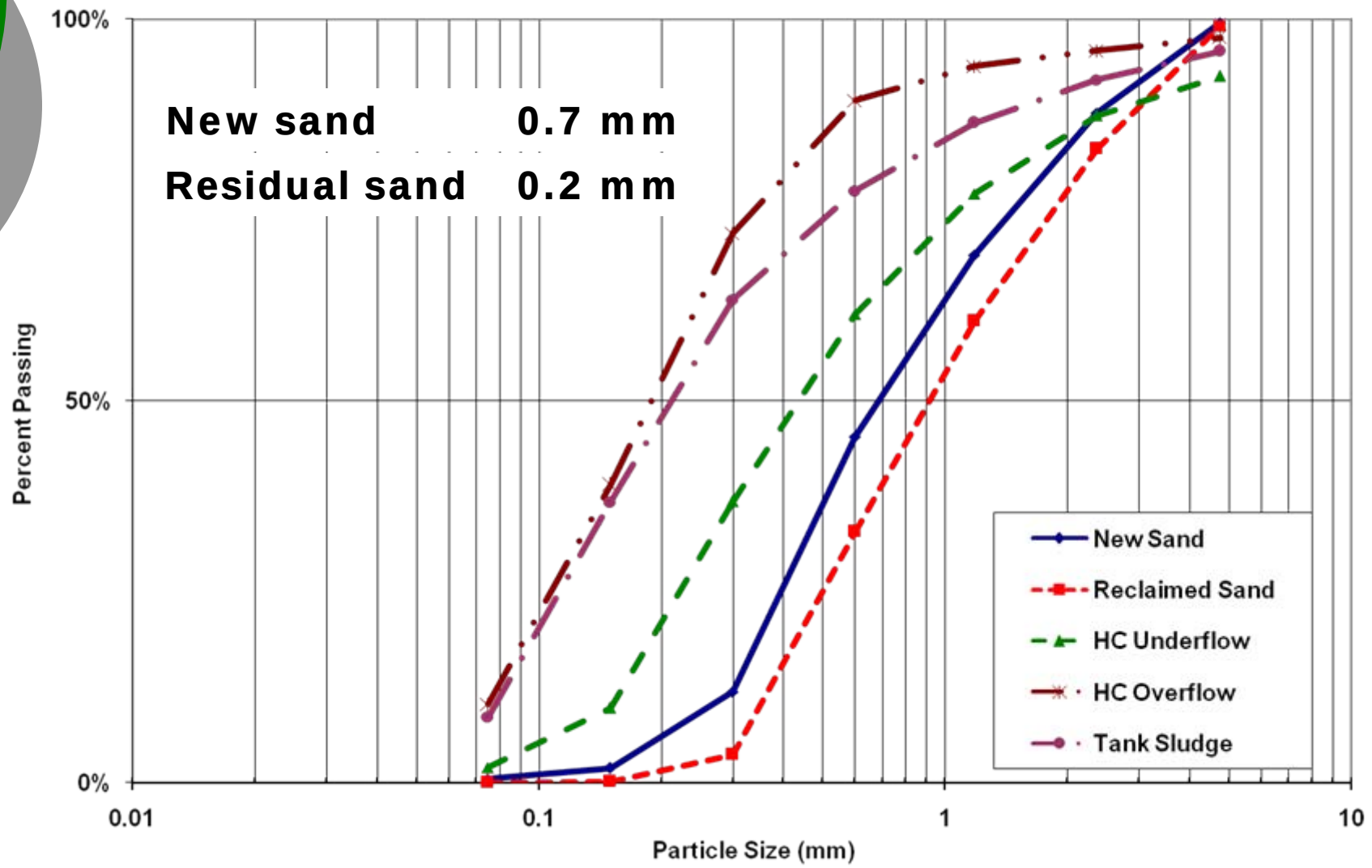
Sand removal efficiency

- Fixed solid (FS) analysis

Sample Location	Mean FS (%)	Standard Deviation (%)	Median (%)	Count
Feces	2.1	1.0	1.9	67
SLDM	20.0	9.7	21.6	67
SMS	2.2	1.1	2.0	53
MINI	1.5	0.4	1.4	70
HC Overflow	1.1	0.5	1.2	40

- Separation Efficiency
  - SMS 87% (83-90)
  - MINI 94% (92-95)
  - HC 97% (96-98)

Sand particle size distribution change



Volatile solid changes due to sand separation

- Volatile solid (VS) analysis

Sample Location	Mean VS (%)	Standard Deviation (%)	Median (%)	Count
Feces	12.6	1.7	12.5	68
SLDM	7.6	1.4	8.0	69
SMS	3.7	0.9	3.8	54
MINI	3.4	1.0	3.5	70
HC Overflow	3.0	1.1	3.2	40

Conclusions

- Manure from sand bedded dairy farms can be digested
- Successfully heating dilute feedstock
  - Frozen manure is a problem
  - Sludge to sludge heat recovery difficult/abandon
- Effective sand removal
  - 100% removal not achievable
  - Law of diminishing returns
- Reduction in residual sand particle size
  - Reduced settling & scour velocity
  - Conventional mixing sufficient
  - Field verification of minimal sand accumulation

Conclusions

- Volatile solids losses do occur
  - Volatile solids are removed with sand
  - System design & operation leading cause
    - System designed between 1998 & 2001
    - Maximum sand removal objective, sand quality a distant second
  - Electrical generation potential reduced by about 25% compared to theoretical whole manure

Conclusions

- System evaluation required to understand the dynamic of sand bedding and biogas production
  - Site specific conditions
    - Addition of dilution water
    - Sand particle size
    - Management objectives
  - Determination sand removal level necessary
  - System design can minimize VS losses
  - Biogas production model and verification
- Benefits of sand bedding for cow comfort exceed the potential loss of biogas potential

Questions?

Dana M Kirk
Biosystems Engineering
Michigan State University
Manager, ADREC
kirkdana@msu.edu
517.432.6530

"Turning waste into resources"
Anaerobic Digestion Research & Education Center
ADREC

MICHIGAN STATE UNIVERSITY

BAE
Department of Biosystems and Agricultural Engineering