Brown AND Caldwell

Northeast Residuals and Biosolids Conference 2016, Cromwell, Connecticut

Anaerobic Digestion- opportunities to optimize the process

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Acknowledgements

- Brown and Caldwell
  - Tom Chapman (Tucson), Steve Krugel (Seattle), John Willis (Atlanta), Perry Schafer (DC)
- Contributing Agencies
  - San Jose Water Pollution Control Plant
  - Southwest Water Pollution Control Plant, Philadelphia
  - South Treatment Plant, King County, WA
  - Port Angeles WWTP, WA
  - Vancouver WWTP, WA

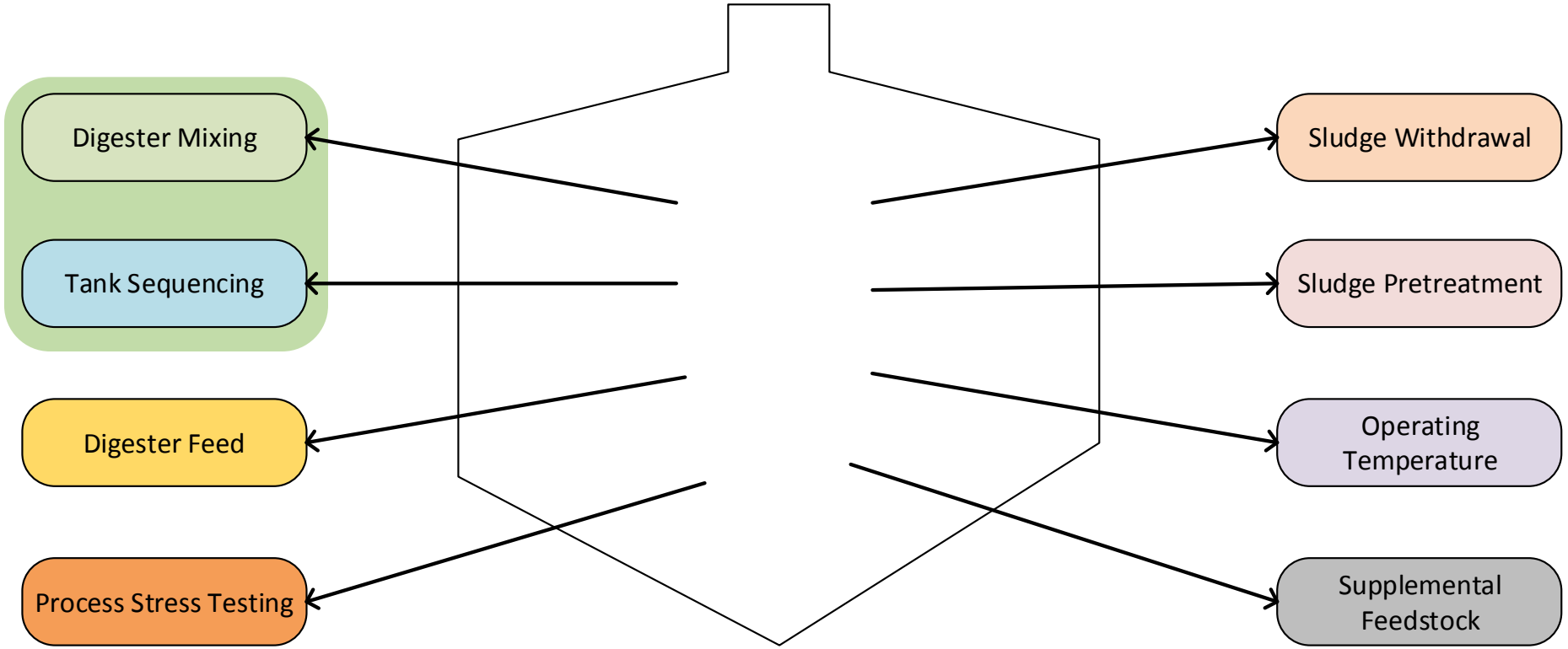
Why optimize your process?

- Improve process operations
  - VSr
  - Biogas production
  - Biosolids quality/stability (odors)
- Reduce sludge hauling
  - Fuel costs, hauling costs
- Increase energy
  - Heating during peak conditions
  - Power/fuel production
- Unlock capacity
  - Set yourself up for success
  - Maximize the value of infrastructure investments

Lulu Island, Vancouver, BC digesters lithium study showed 100% active volume in the digester

Gresham, OR FOG receiving station is used to enhance biogas production for renewable energy production.

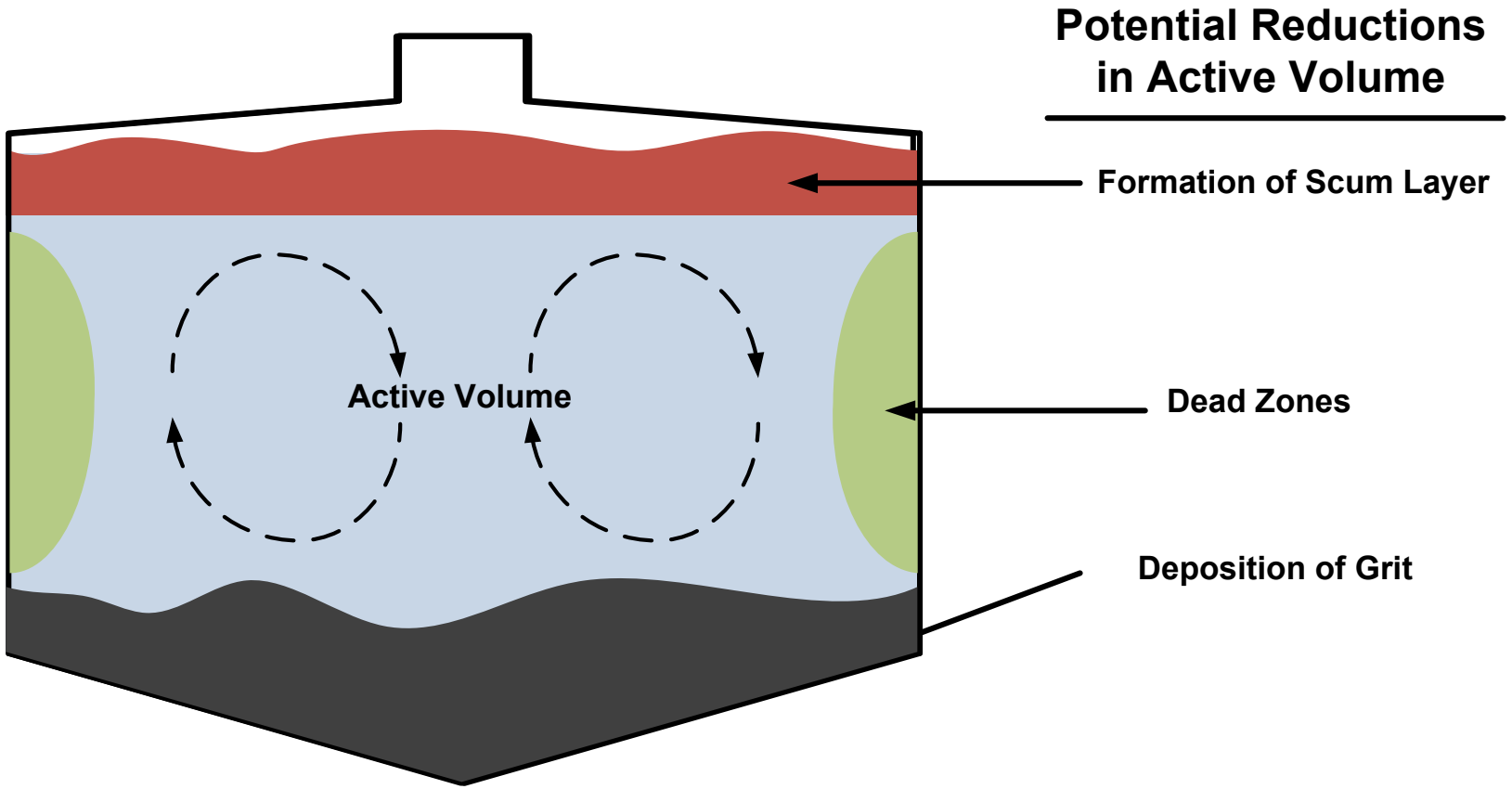
How do you want to optimize your digestion process?



Digester Mixing

Interior Annacis Island WWTP, Digesters Courtesy of Michael Stenstrom

Does digester mixing have a significant role?



Mixing Objectives

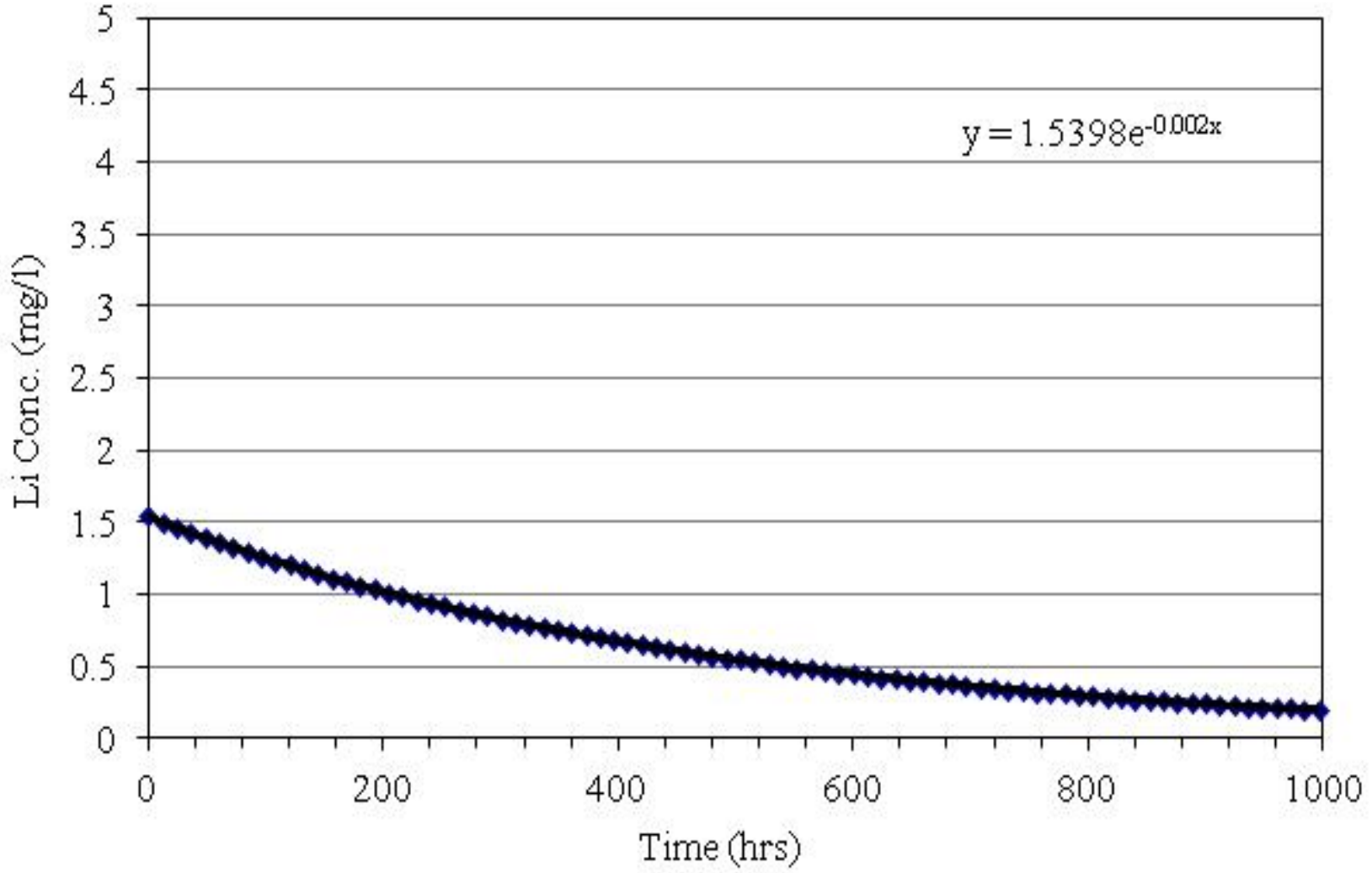
- Maintain process conditions
  - Maintain high active volume by eliminating dead zones
  - Uniform heat distribution
  - Dispersal of influent solids for maximum contact with microorganisms
  - Dilution of digestion inhibitors, such as toxic materials or unfavorable pH or temperature of feed material
- Improved separation of digester gas from digester liquid
- Maintenance considerations
  - Keep grit in suspension

How mixing effectiveness impacts high rate digestion

Ideal Mixing	Poor Mixing
Sludge Specific Gravity Max. active volume, HRT, largest VE extent	Reduced active volume, HRT, expanded sludge lower VE extent
Process Implications Max. VSr, HRT, biogas production, max OLR, no stratification	Reduced VSr, HRT, biogas production, reduced effective OLR, reduced process stability, stratification
Biosolids Production Reduced solids production, improved product stability	Increased solids production, decreased stability (odor)
O&M Higher power costs, larger or more equipment, reduced grit and debris accumulation	Lower power costs, smaller or fewer equipment, increased grit and debris accumulation

Lithium chloride washout studies can give good insight into the inner workings of digestion

Design Active Volume : 2 million gallons



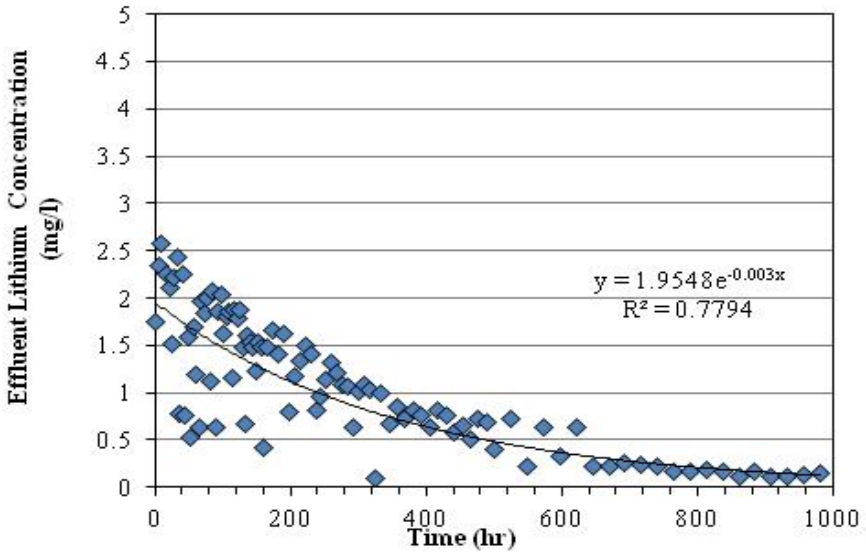
How well does a digester mimic a CSTR?

- Looked at mixing at the SWWPCP
  - Conducted a lithium dye tracer study
  - Tracer study steps
    1. Cease feeding
    2. Inject dye
    3. Wait 24 hours, with mixing on
    4. Restart feeding, commence digester effluent analysis
    5. Sample for 42 days

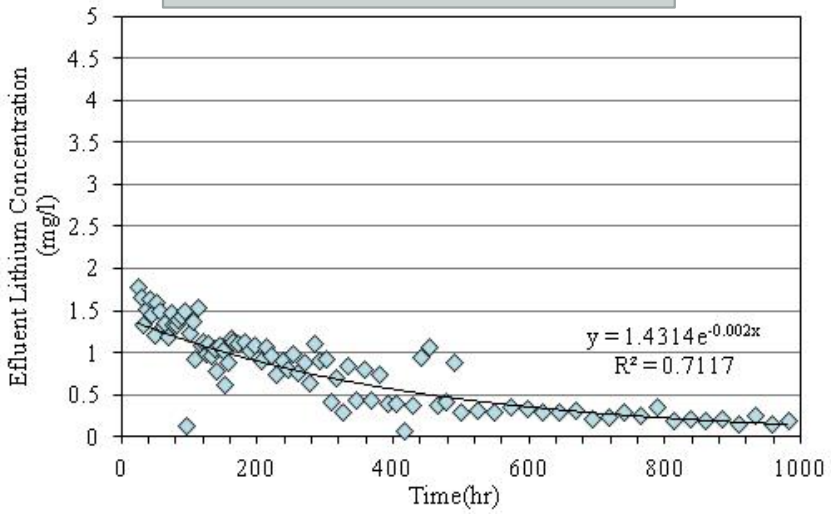
Southwest digesters

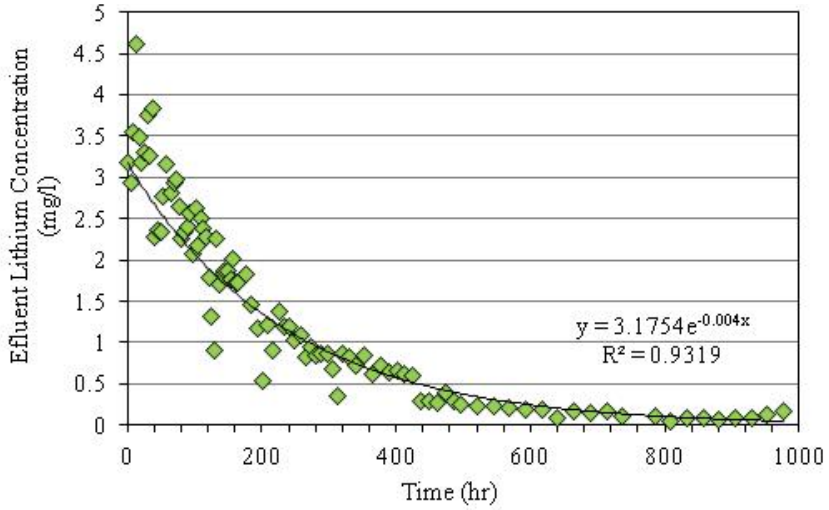
Northeast digesters

3 digesters at the same plant show varying wash out curves



largest active volume





Digester 11-
"Best" agreement between theoretical lithium concentration in full active volume at initial sampling rate.

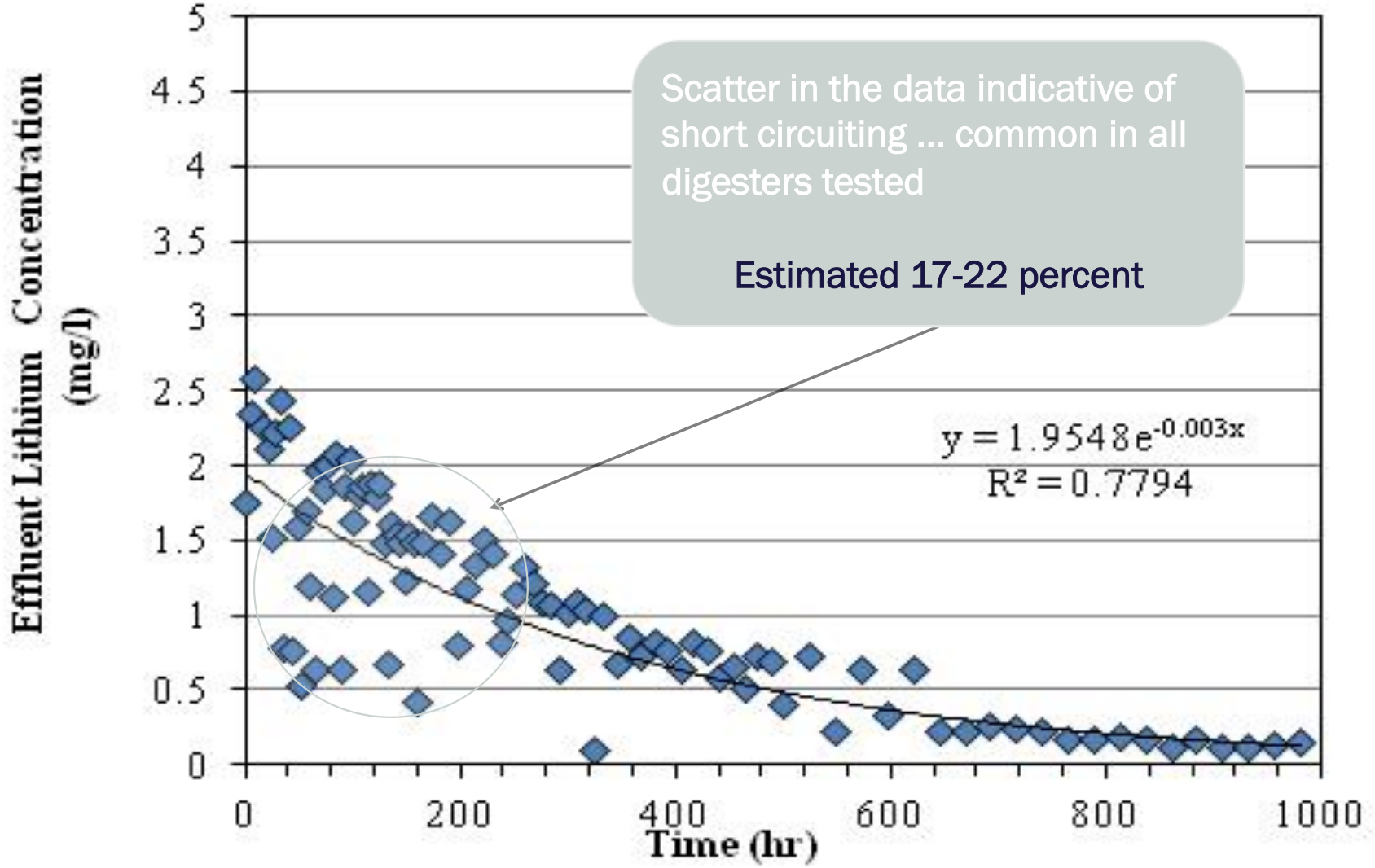
Digester 15-
Highest mixing intensity, lowest data scatter (**Highest R^2 value**)

Evaluating active volume

- *Method 1: washout coefficient approach*: This approach compares the inverse of the washout coefficient, which is defined as the active volume divided by the average flow. This approach assumes that there is no bypassing of the digester feed flow.
- *Method 2: bypass washout model*: This approach assumes that some fraction of the flow is not incorporated into the active volume but is bypassed.
- *Method 3: initial lithium concentration*: This method evaluates the concentrations of lithium in the digester at the commencement of digester feeding and compares them to the theoretical concentrations achieved at the design volume

	Estimated Active Volume (million gallons)		
Test Digester	Method 1	Method 2	Method 3
Digester 10	1.45	1.15	1.25
Digester 11	1.73	1.44	1.79
Digester 15	1.09	0.85	0.75

Estimated short circuiting at 17-22 percent



What could this mean in terms of process performance?

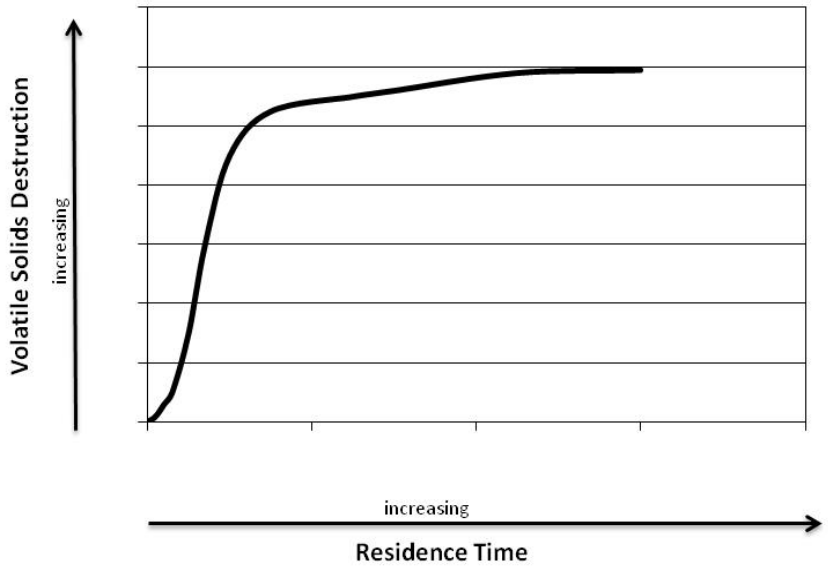
Assuming that short circuited solids do not degrade in the digester…

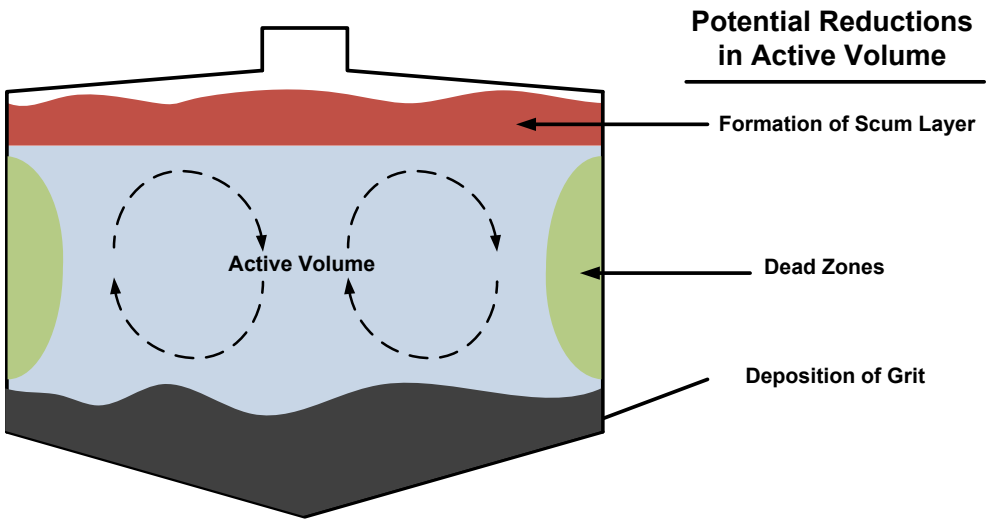
- Current condition
  - Volatile Solids Reduction: 48 percent
  - Biogas : 1,028,000 ft^3-biogas/day
  - Residual Solids: 156 tons per day
- Alleviate Short Circuiting
  - Volatile Solids Reduction: 62 percent
  - Biogas : 1,285,000 ft^3-biogas/day
  - Residuals Solids: 140 tons per day

Potential Benefits:
Daily Biogas Production: +25%
Digested Sludge Production: -13%

Draft tube mixer install, Dry Creek WWTP, Nashville TN

What can volatile solids destruction tell you about your digester?





Simple data analysis tools can provide a inexpensive means for looking at digester operating efficiency.

San Jose's digester system (at the time)

- City of San Jose WPCP
  - Operating 11 anaerobic digesters at time during the analysis period
  - Volume
    - two : 1.47 million gallon
    - nine : 2.47 million gallons
  - Mesophilic operation
  - Floor mounted gas mixers/shear fusers
  - Deciding what upgrades are needed as part of facilities planning effort
- How well is our system performing?
  - one measure is volatile solids destruction

Tuning heat exchanger at San Jose

Gas piping for digester mixing

Why does the same digester give you two different VSr numbers?

Mass Balance Equation

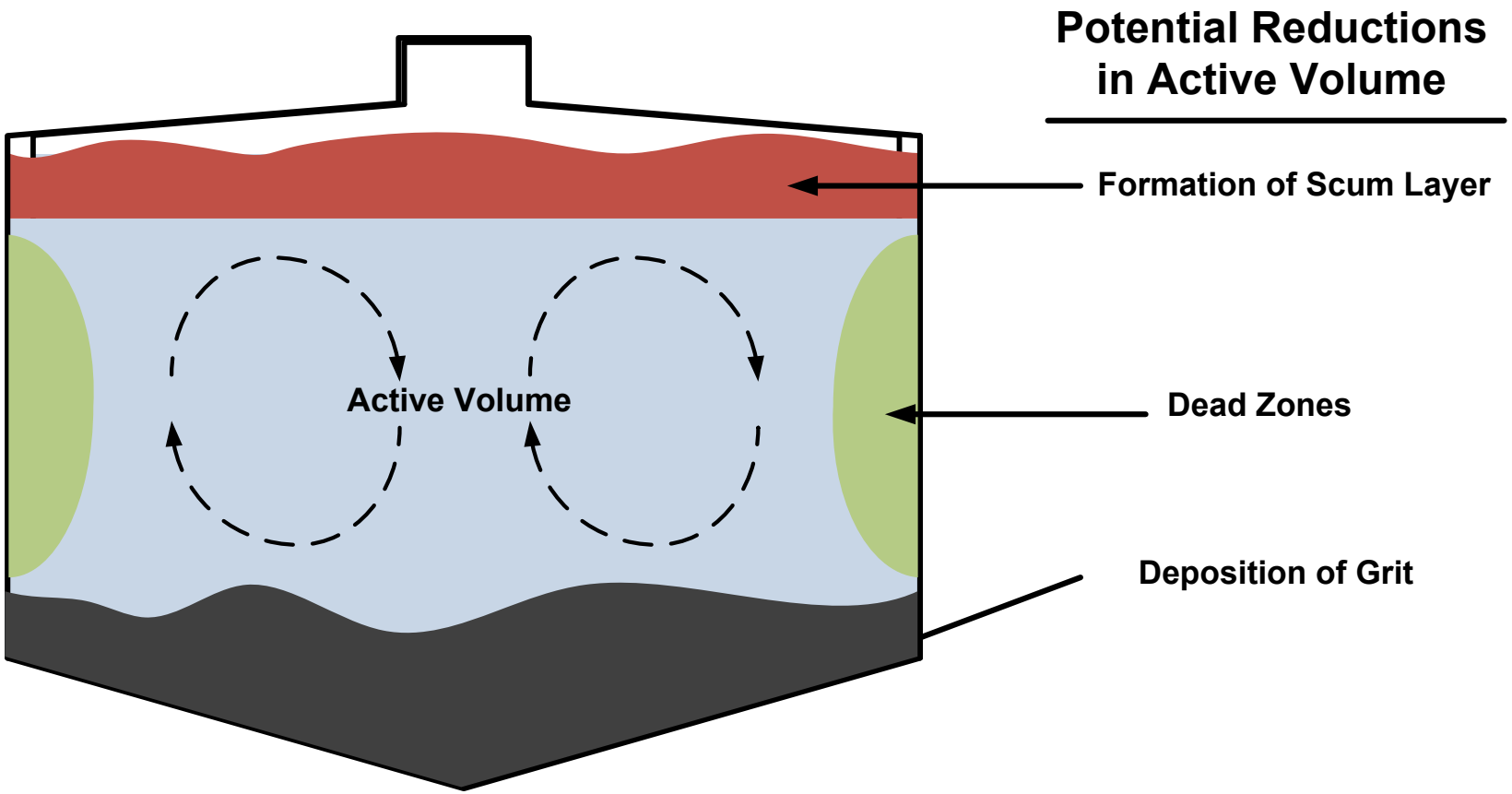
$$VSd = \frac{X_{VSRaw} - X_{VSDig}}{X_{VSRaw}} * 100$$

Van Kleeck Equation

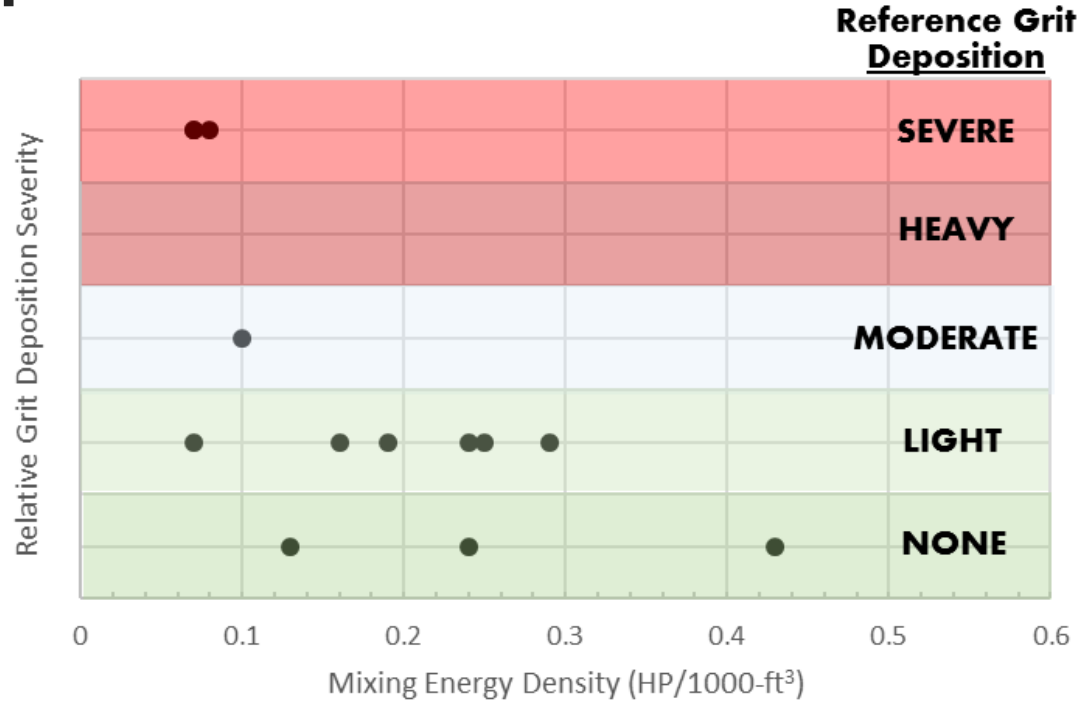
$$VSd = \frac{VF_{Raw} - VF_{Dig}}{VF_{Raw} - (VF_{Raw} * VF_{Dig})} * 100$$

Data Set	Mass Balance	Van Kleeck
2005 to 2007	56	47
7/9/2009 - 10/31/2009	59.8	44.8

What could be impacting the volatile solids measurement- Mixing?



Not keeping inert solids in suspension can impact volatile fraction measurements

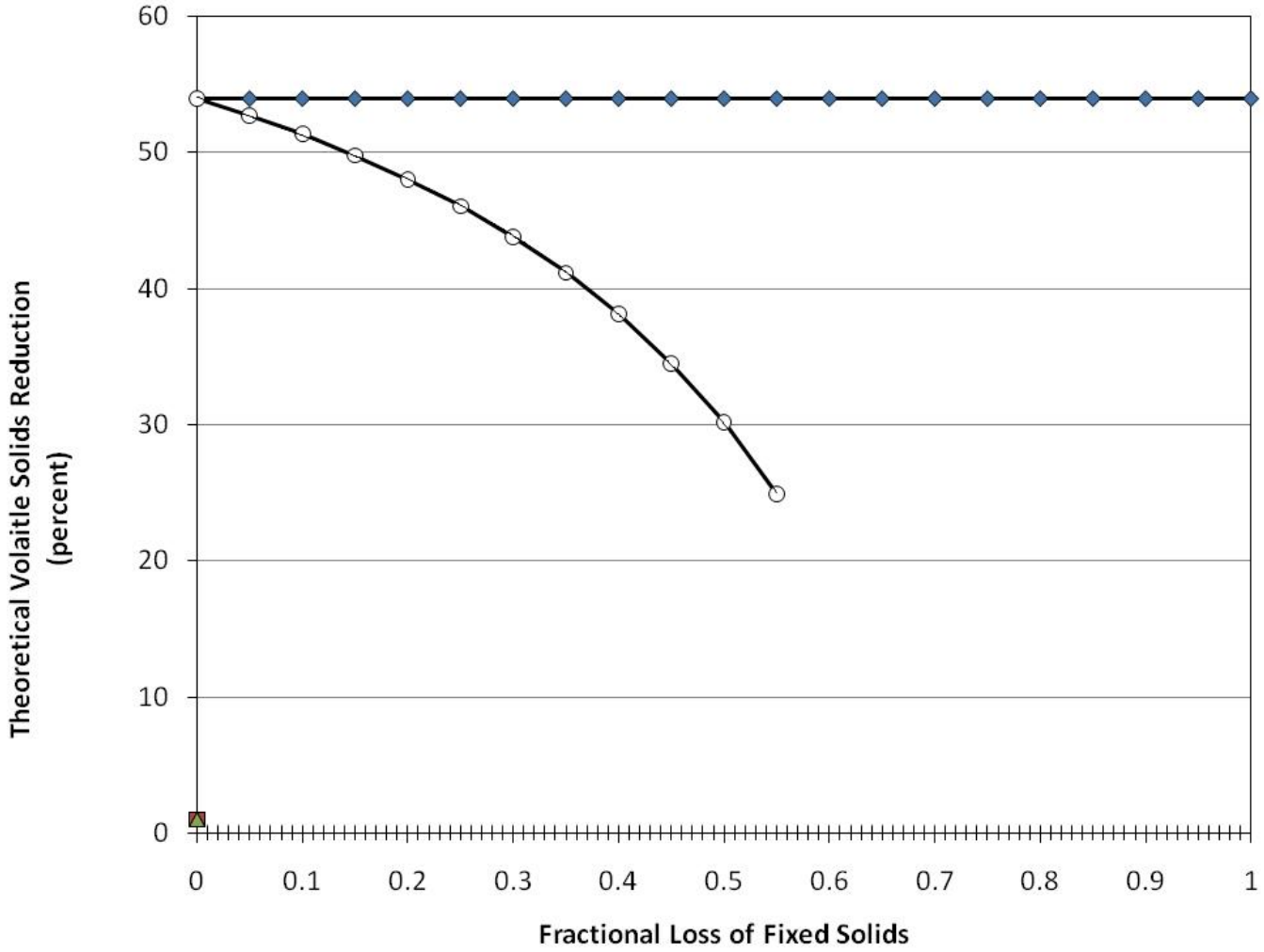


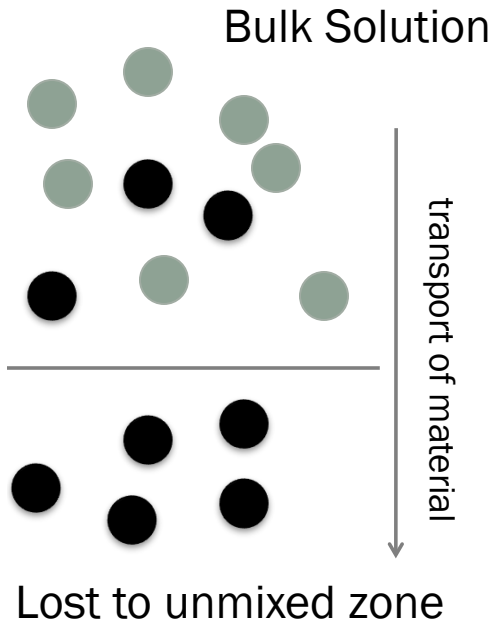
$$VSd = \frac{VF_{Raw} - VF_{Dig}}{VF_{Raw} - (VF_{Raw} * VF_{Dig})} * 100$$

$$VF = \frac{VS}{VS+IS}$$

- Brown and Caldwell Internal Research
  - Evaluation of digesters reporting grit deposition relative to mixing intensity/energy density
  - 11 plants, 15 total operating condition assumptions
  - No survey of plant upstream grit treatment

Initial model- fixed solids and volatile solids act discretely

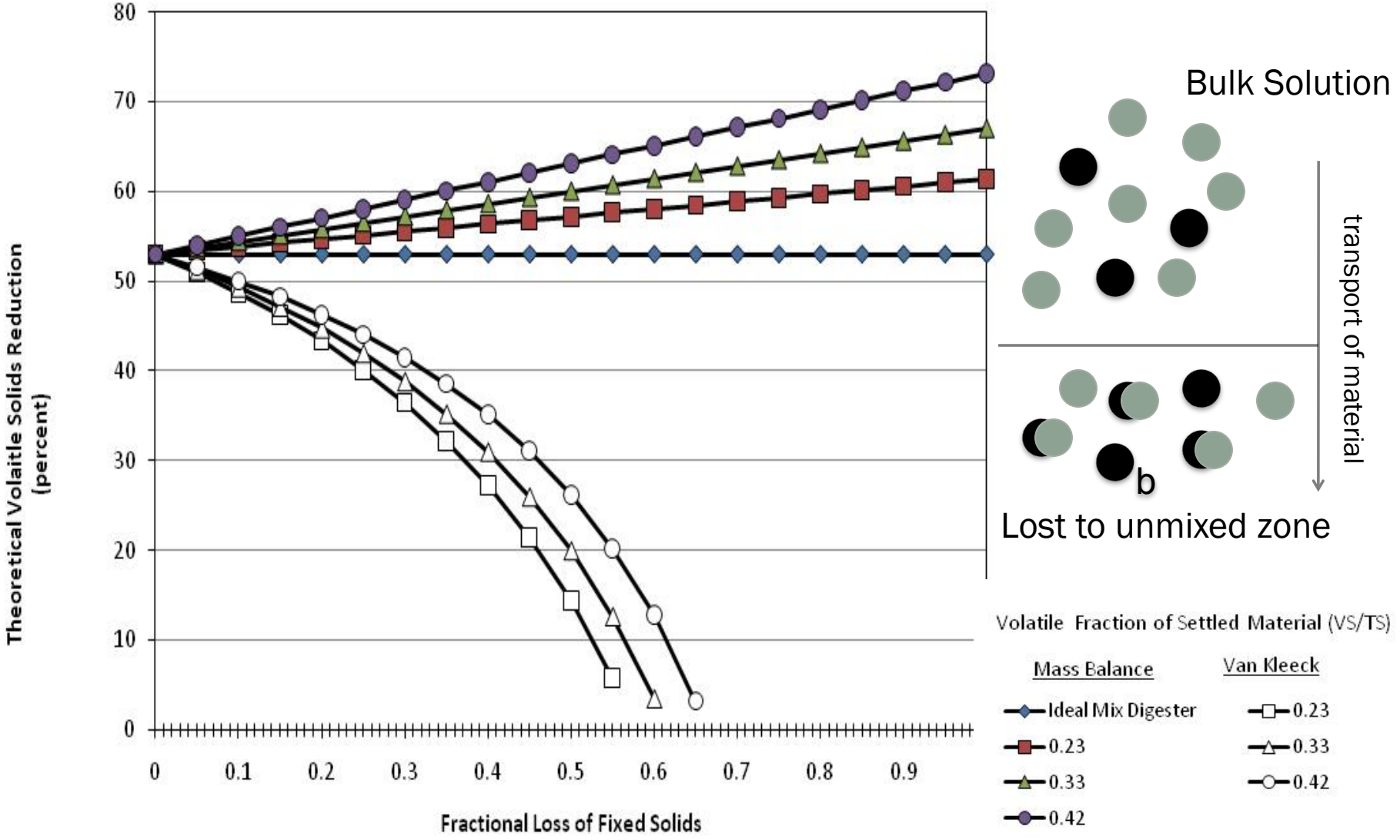




Mass Balance (Inerts Only)

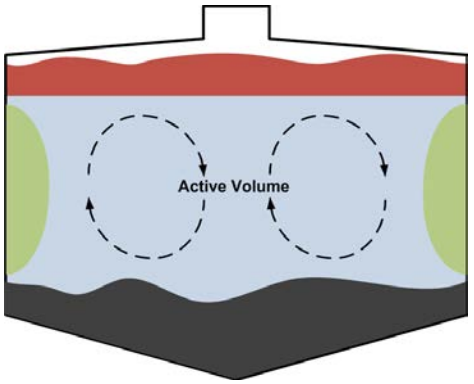
Van Kleeck (Inerts Only)

More realistic scenario: volatile and fixed solids exit the bulk solution

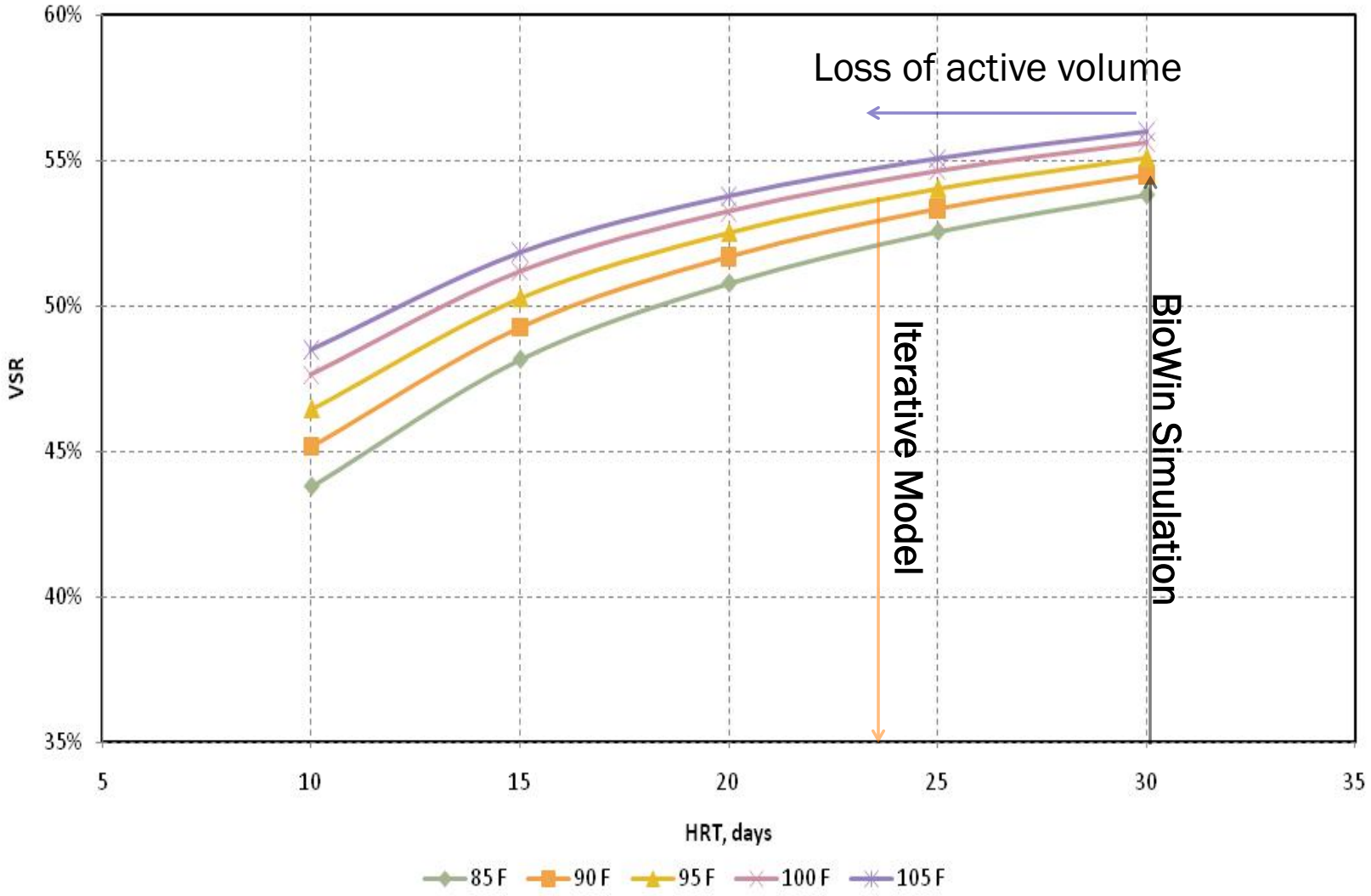


Observations from this analysis.

- Volatile solids destruction measures work well only with complete mix systems
  - Mass balance: over estimates with loss of material
  - Van Kleeck: under estimates with loss of material
- Implications
  - A method to evaluate operating conditions
    - mixing efficiency
    - process performance evaluation
    - active volume- true capacity



Process simulator compared with iterative results suggest a reduction in system active volume

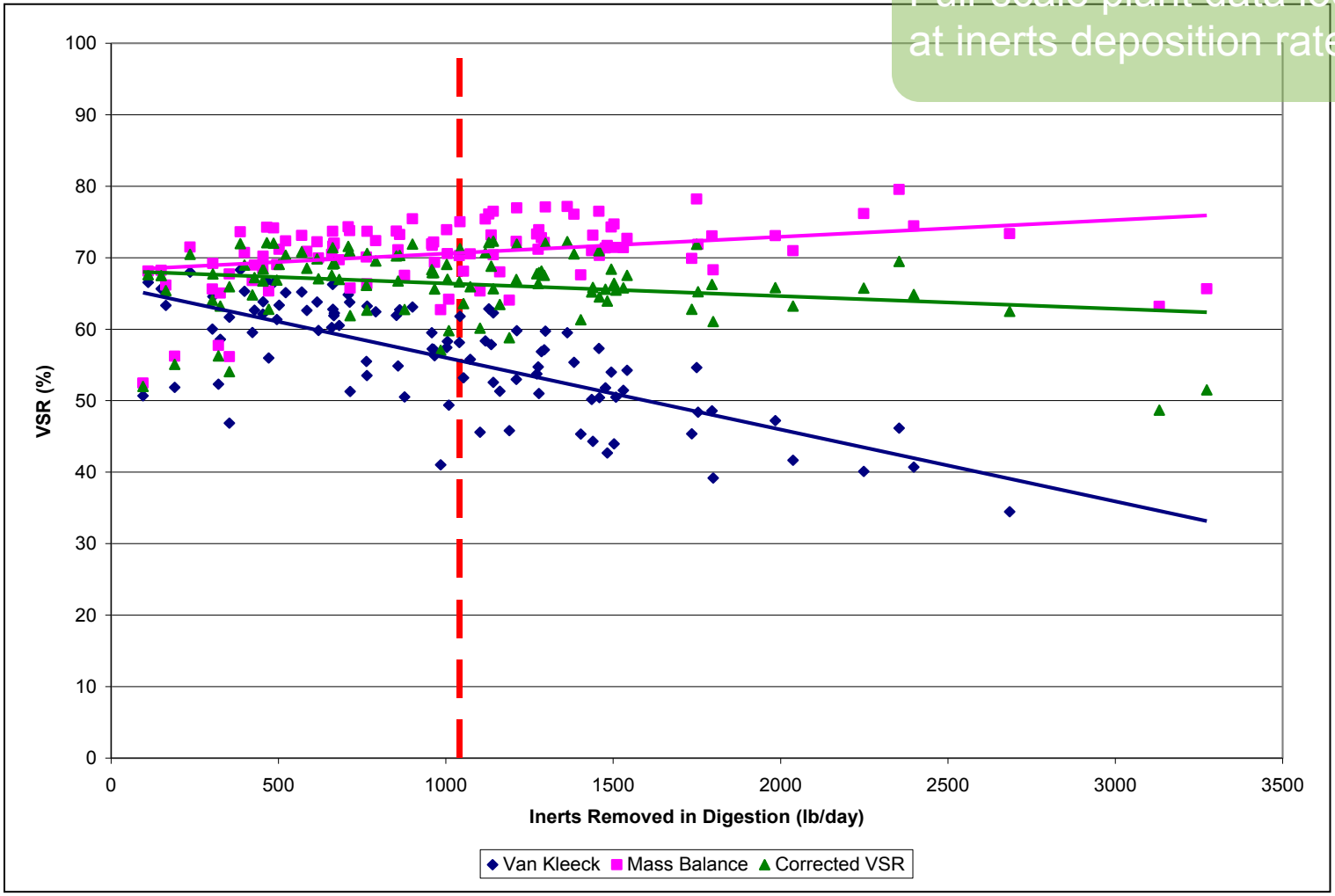


Results for San Jose and future uses….

- Using this approach it was estimated that the City had lost about 17.5 percent of the systems active volume.
  - 17.5 % = ~5.1 million gallons of capacity
- Justified need for enhanced mixing.
- Gives measure of capacity conditions.
  - HRT
  - organic loading rate
- Potential benefits
  - digester cleaning
  - self evaluation of system
  - Verification of improvements
- Is the model and approach universally applicable?
  - maybe with further development

Full-scale operating data from Vancouver, WA WWTP

Full-scale plant data looking at inerts deposition rate



Understanding how close to ideal can save you money in disposal costs and lost energy

We want to be on this side!

Ideal Mixing		Poor Mixing
Sludge Specific Gravity Max. active volume, HRT, largest VE extent	→	Reduced active volume, HRT, expanded sludge lower VE extent
Process Implications Max. VSr, HRT, biogas production, max OLR, no stratification	→	Reduced VSr, HRT, biogas production, reduced effective OLR, reduced process stability, stratification
Biosolids Production Reduced solids production, improved product stability	→	Increased solids production, decreased stability (odor)
O&M Higher power costs, larger or more equipment, reduced grit and debris accumulation	→	Lower power costs, smaller or fewer equipment, increased grit and debris accumulation

Process Enhancement: Series Digestion

South Treatment Plant, King County, WA

Can you make your digester run better?

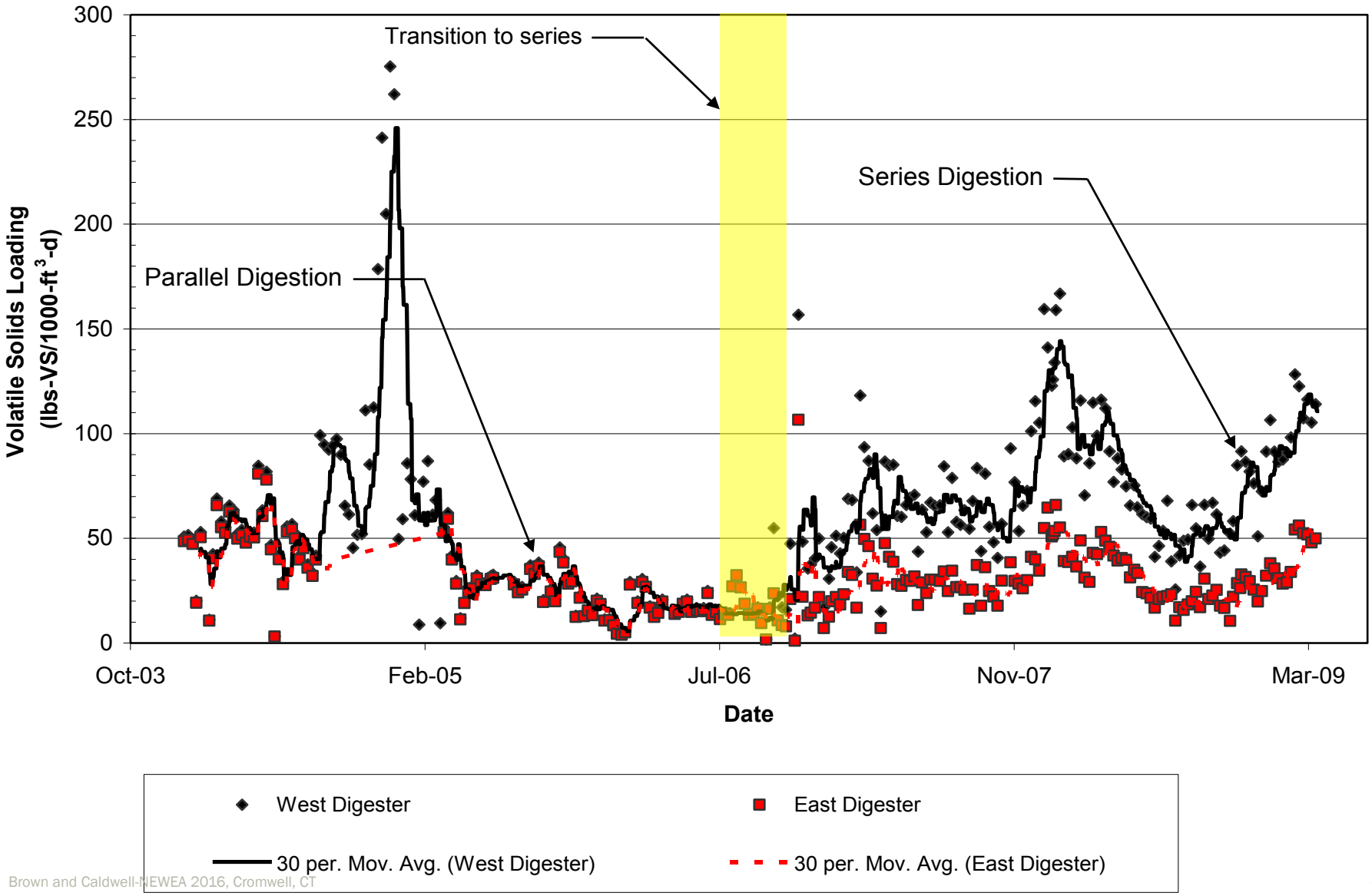
- Potential Approaches
  - Advanced digestion
  - Sludge disintegration
  - Co-digestion
  - Series-digestion
    - 2 case studies

- Application
  - During early years following construction/expansion.
  - When loadings don't materialize.
  - Design conditions don't match actual operating limits.

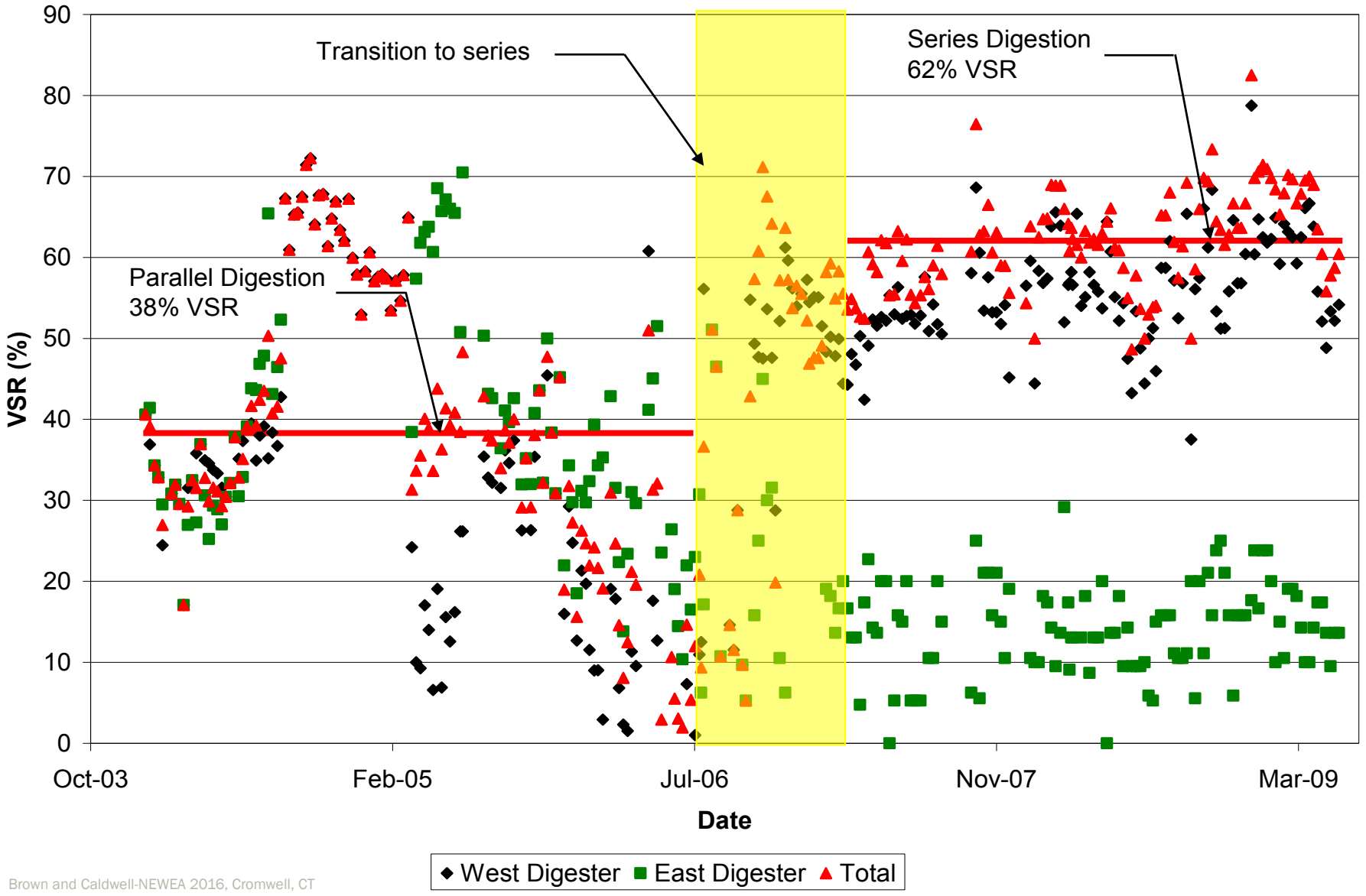
Port Angeles, WA

- Two digesters changed from parallel to series operation
  - Converted to series digestion after a process upset
- Improvement of performance with series digestion indicate process was under loaded

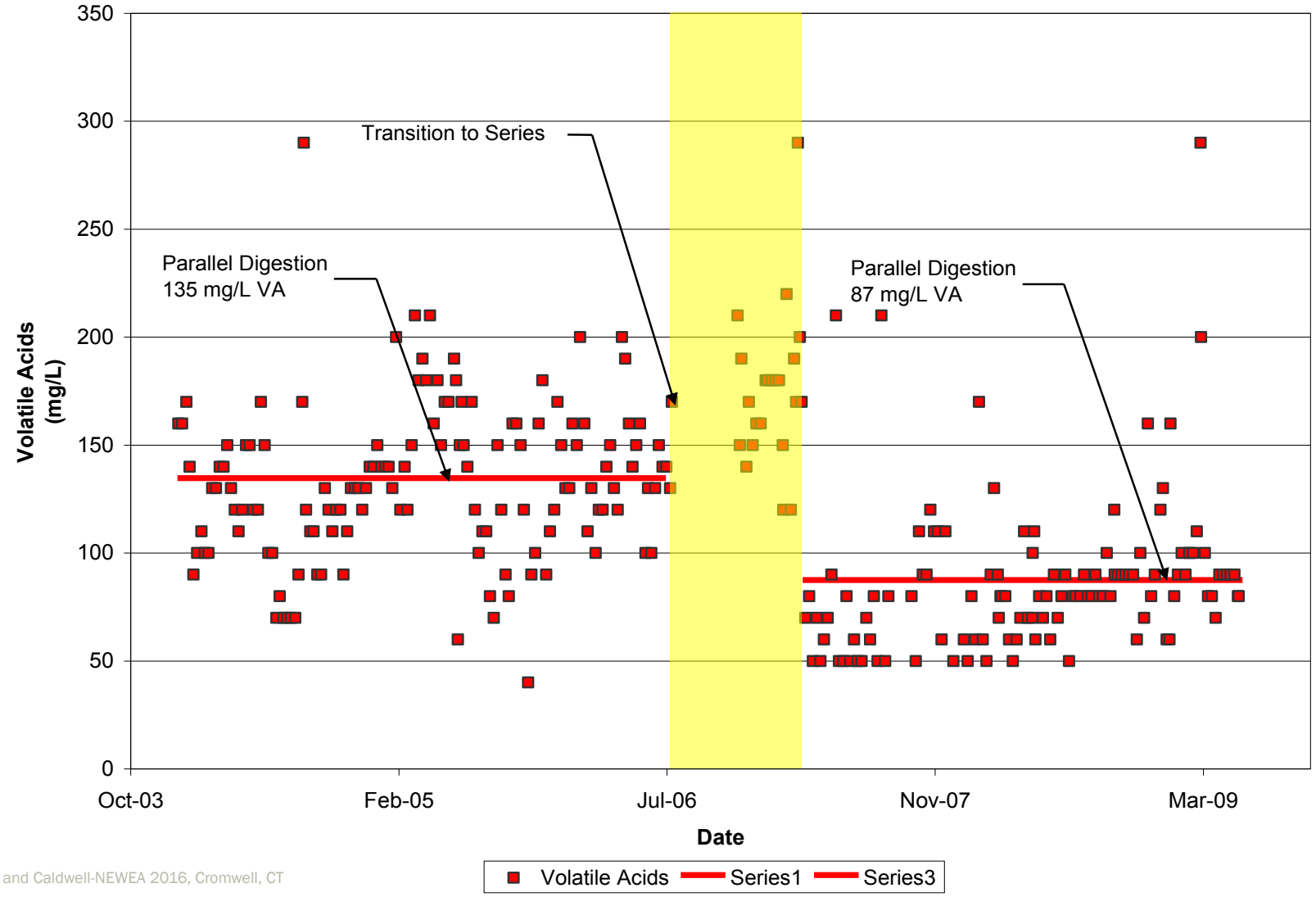
Doubled the load to the lead digester



Improvement in overall system VSr



Higher loading appeared to improve system health



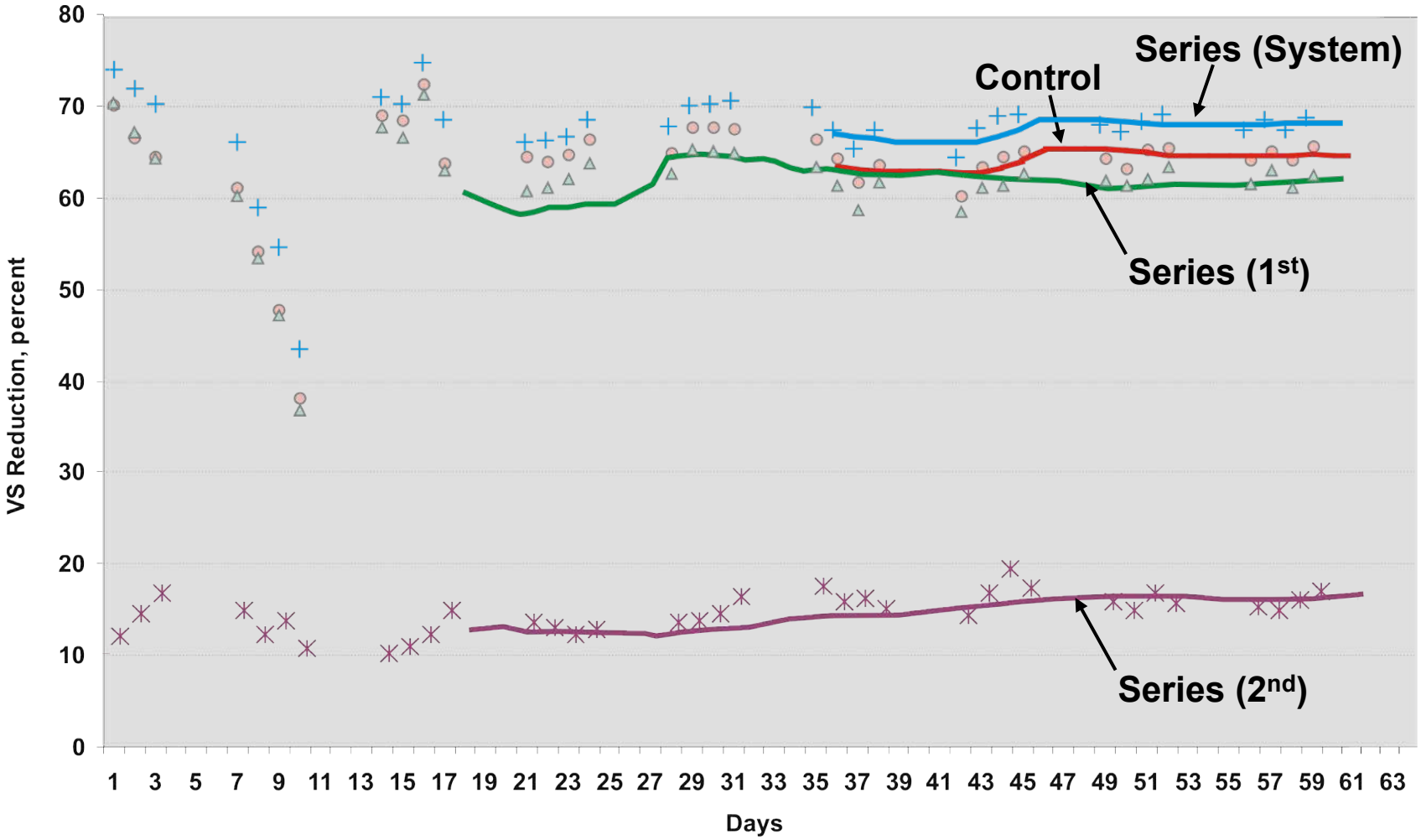
Series Digestion: Experimental Design

- Two Digesters in Series, 18.2 days HDT each
- Control Digester, 35.7 HDT
- Remaining Digester fed remainder of raw sludge
- Operational features
  - Continuous feed, different strategy for series digesters
  - Continuous heating
- Study period - 60 days

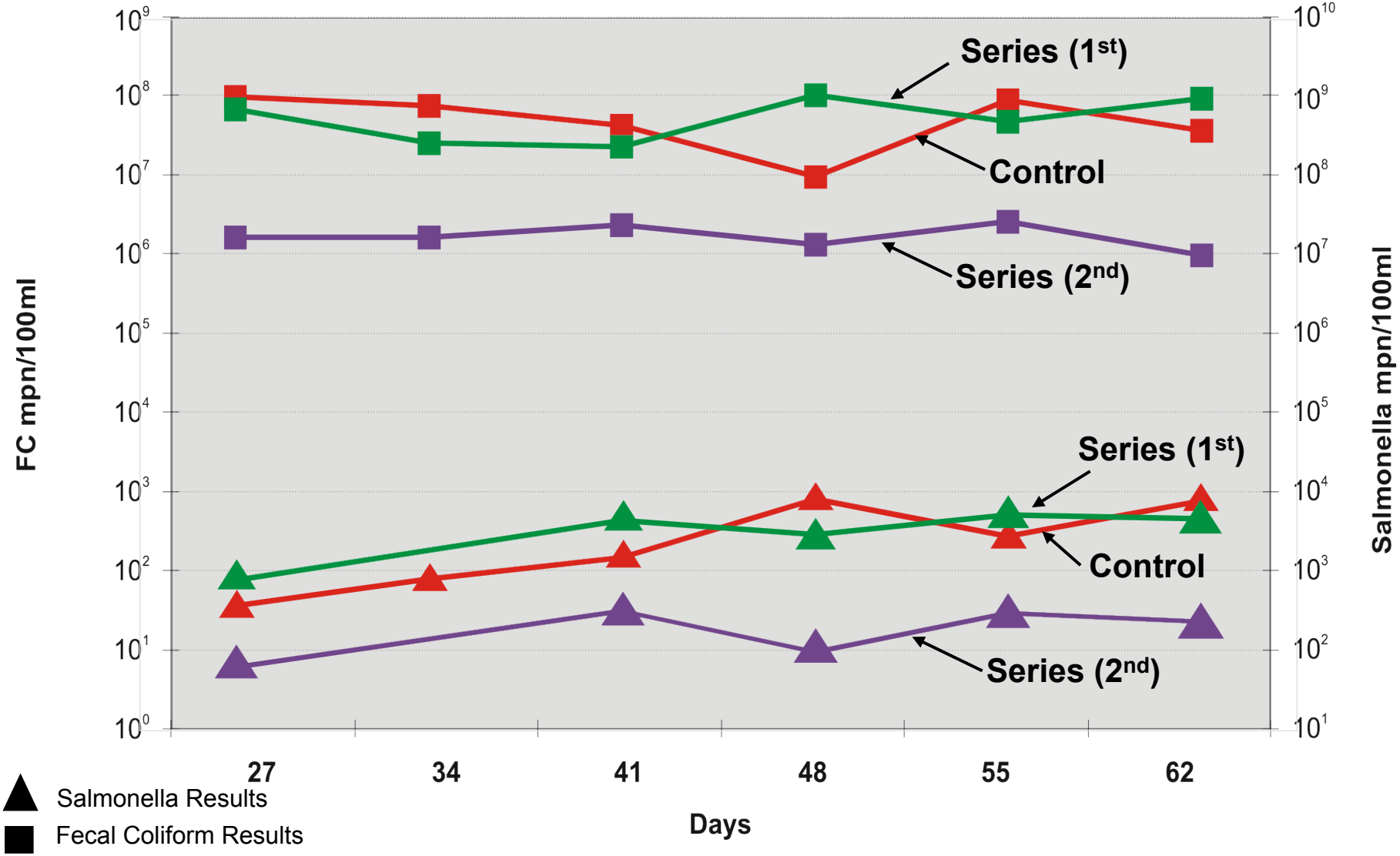
King County mesophilic anaerobic digesters mixed with a combination of pumps and gas spargers

King County upgrades the biogas for injection into the natural gas grid

Series Digestion Test Results: Volatile Solids Reduction



Series Digestion Test Results: Pathogen Reduction



Observations for series digestion

- This can a good means to enhance systems performance with limited to no capital investment
- Improved performance approximately an additional 5% point volatile solids destruction
- Increased biogas production
- Potential for enhanced fecal coliform and Salmonella reductions.
- Good strategy to more optimally utilize tankage when loading rates are within capacity limits.

QUESTIONS?

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