

A COMPARATIVE PERSPECTIVE OF US AND UK THINKING ON E COLI REACTIVATION IN DIGESTION AND DEWATERING

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Presentation Outline

- UK and US rules in Pathogens
- History of Reactivation/Regrowth in US
- WERF Projects
- Correlation to odors
- UK Situation
- Conclusions

US and UK regulations

- *The USEPA regulations are mandatory*
- *USEPA 503.15 The Class A pathogen requirements on 503.32 (a) or the Class B pathogen requirements in 503.32 (b) shall be met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site*

US and UK regulations

- *The Safe Sludge Matrix is a voluntary agreement between the UK water industry ADAS and the British Retail Consortium in order to ensure the highest possible food safety and gives retailers and the food industry unquestionable confidence that the use of biosolids on agricultural land is not only completely safe but also fully sustainable.*
- *Gives “clear guidance on the minimum acceptable level of treatment of any sewage sludge (often referred to as biosolids) based product which may be applied to that crop or rotation.*

Timeline of the reactivation and regrowth issue

- 2000 - A WWTP in North Carolina (digested product) converted to HS centrifuges
- Immediately, odors increased, and testing of indicator organisms showed orders of magnitude increases
- Generator felt compelled to stop land application, began landfilling
- Restarted land application with supplemental liming, odor was still an issue

Background: Reactivation and regrowth of FCs

- Several utilities and papers have recently reported an increased presence of fecal coliform and/or *E. coli* organisms in digested and dewatered cakes:

Iranpour et al., 2003 (thermophilic)

Erdal et al., 2003 (mesophilic)

Qi et al., 2004 (mesophilic)

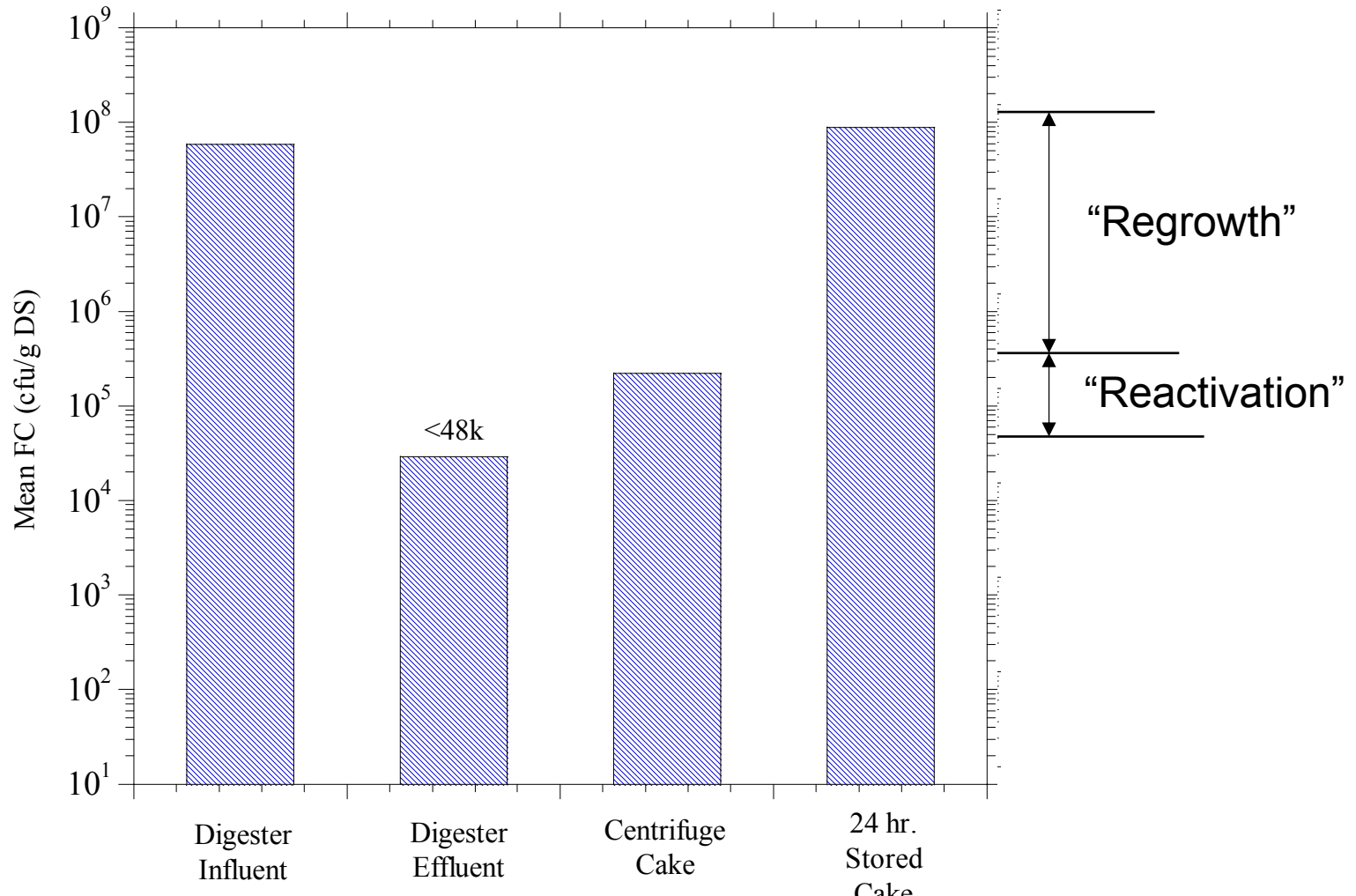
Monteleone et al., 2004

Cheung et al., 2003

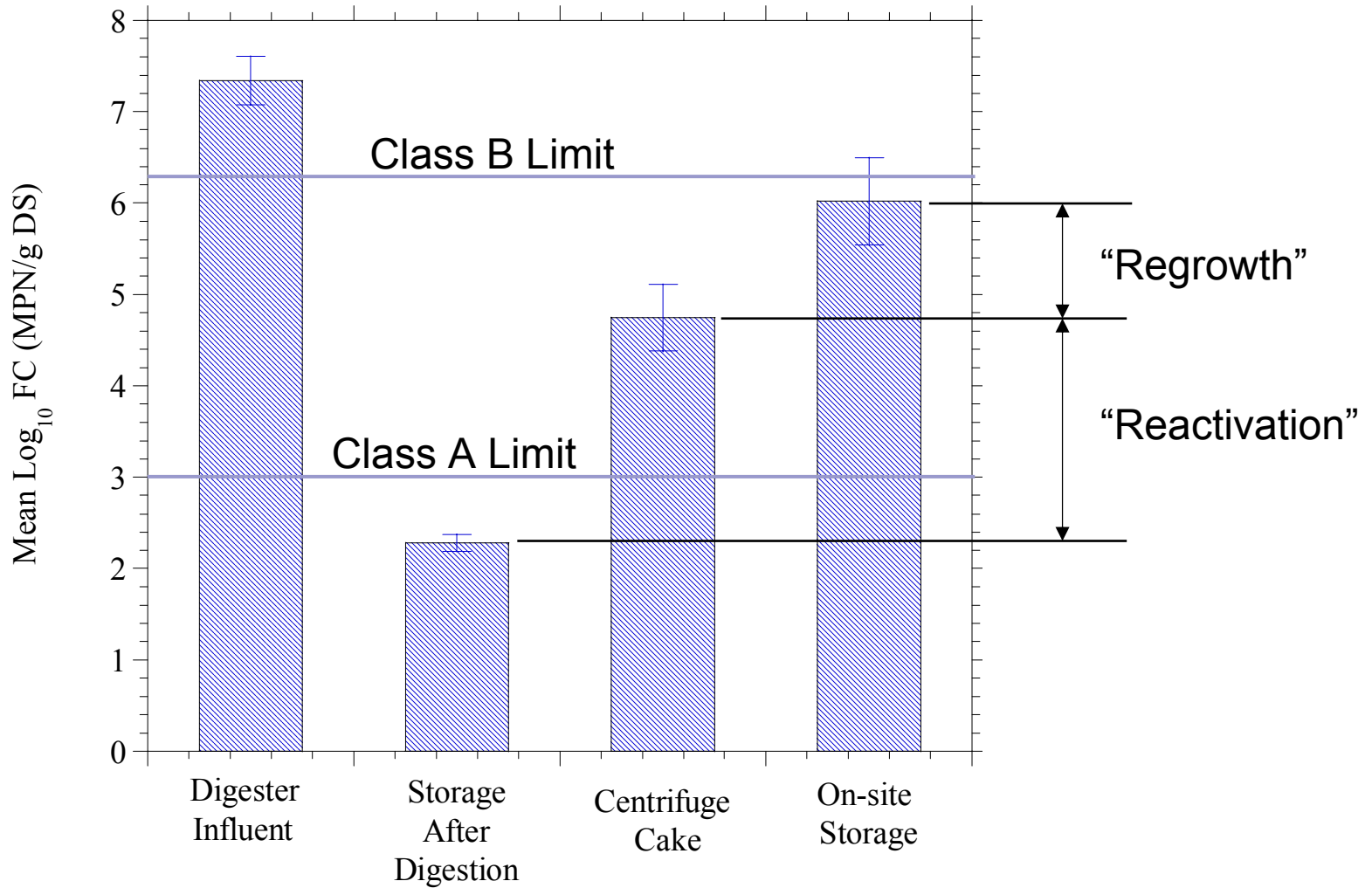
WERF Project - 04-CTS-3T

Reactivation/Regrowth

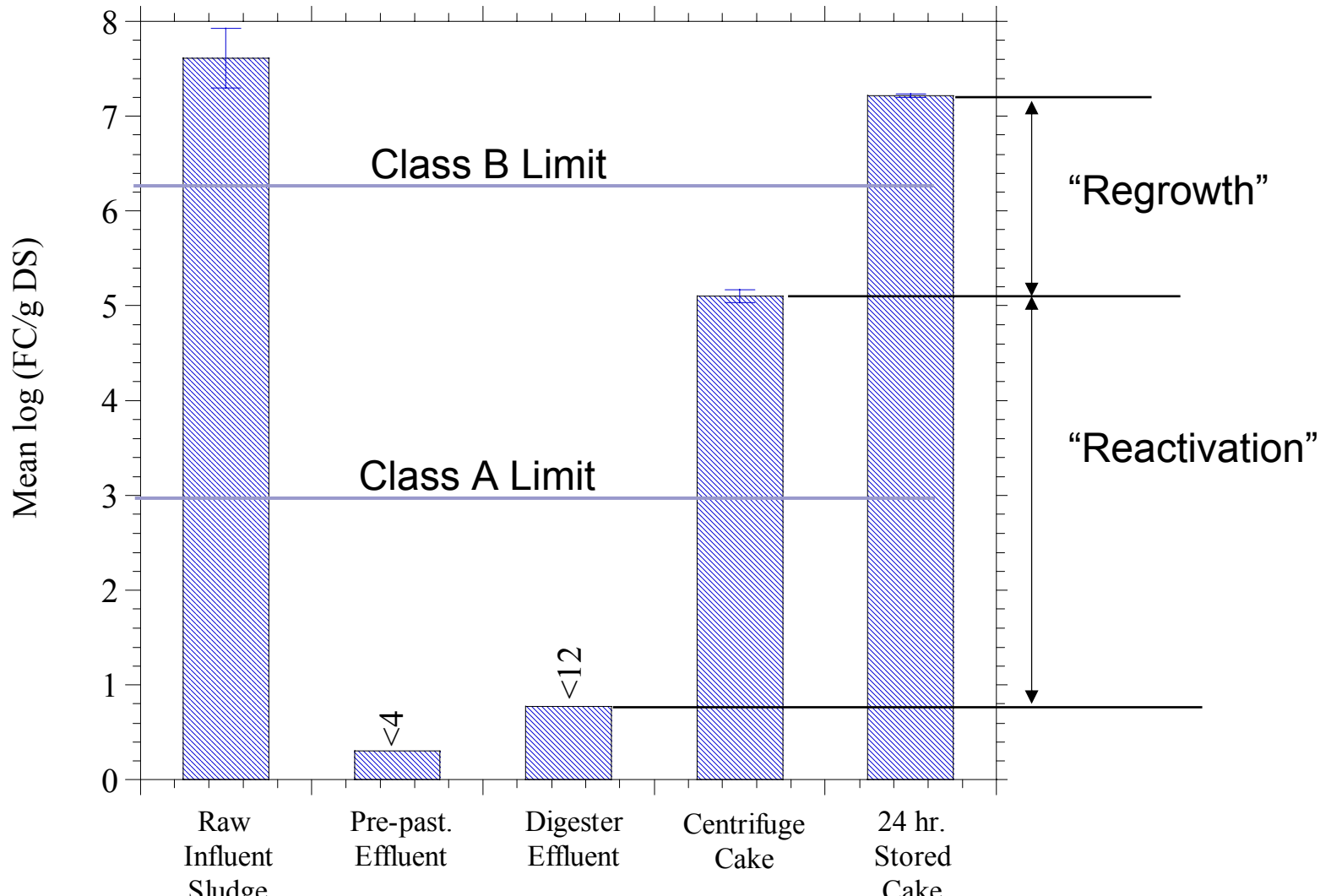
Class B – Mesophilic Digestion



Reactivation/Regrowth – Thermophilic Digestion Process



Reactivation/Regrowth Class A – Pre-pasteurization with Mesophilic Digestion



VBNC Hypothesis:

- During digestion, microbes (such as *E. coli*, *Salmonella*) enter a viable but non-culturable (VBNC) state
- Cells are still viable and present but are not enumerated by standard culturing methods (SCMs)
- Dewatering creates conditions that result in cells becoming culturable (reactivation or resuscitation via a released autoinducer)
- Conditions in the cake (substrate, competition) supports rapid growth (regrowth)

Reactivation of VBNC bacteria not without precedent

- *Helicobacter pylori* in VBNC state in most water supplies
- In most of our systems
- Autoinducer in some people revives the bacteria and causes ulcers

Research Objectives

Phase I

Demonstrate that FCs and *E. coli* can:

1. enter the VBNC state during digestion;
and
2. be reactivated or resuscitated from the VBNC state during centrifuge dewatering

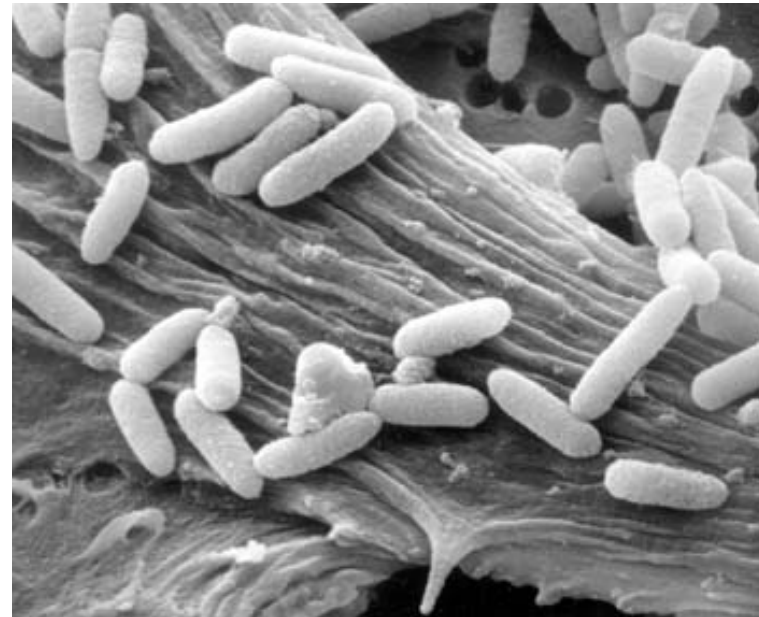
Research Approach

Used molecular techniques to quantify bacteria in VBNC state:

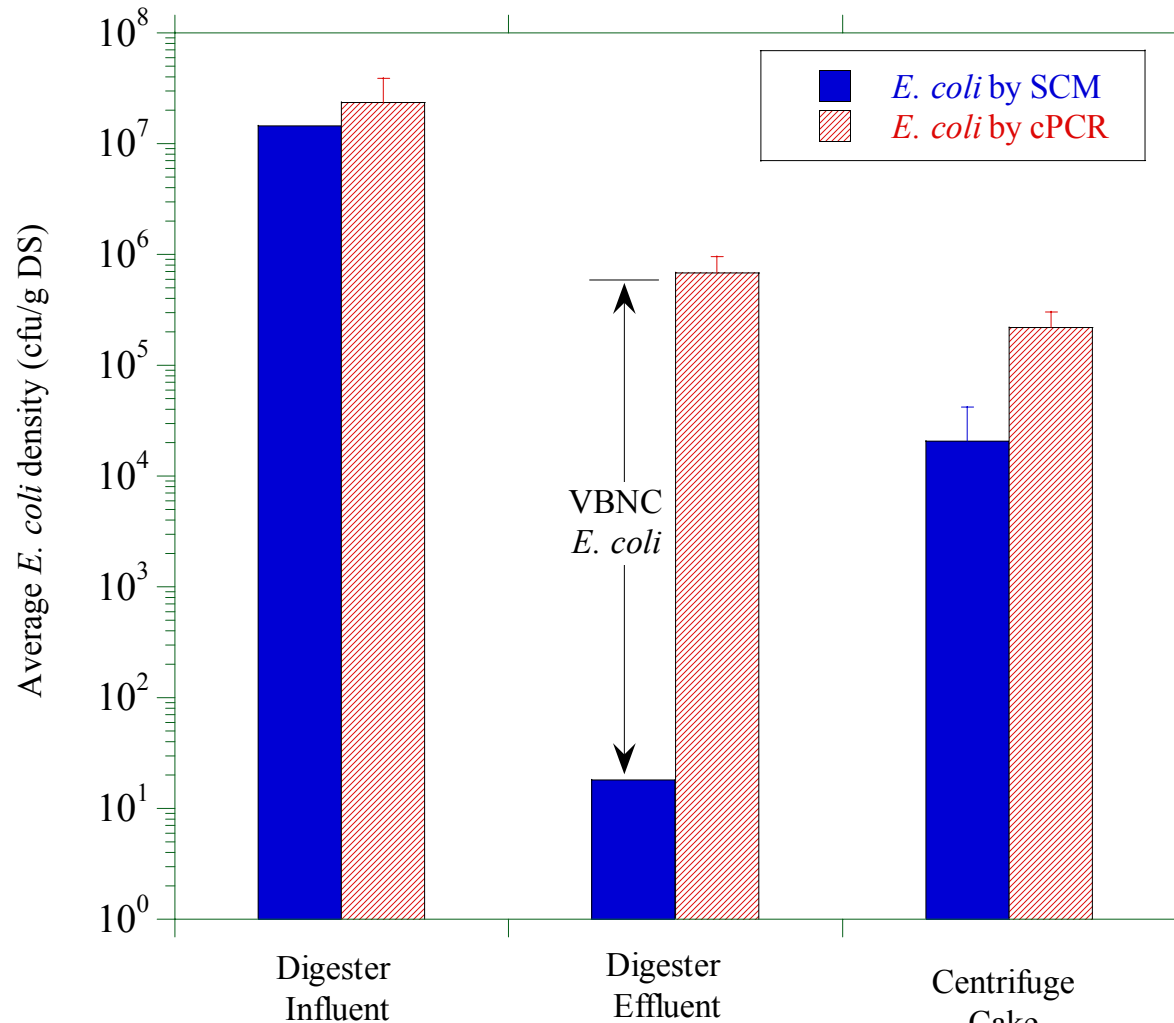
Phase I - cPCR

E. coli chosen as target:

1. One of the FCs,
2. Typically about 50% of FCs
3. Shown to enter VBNC state
4. A lot of information available

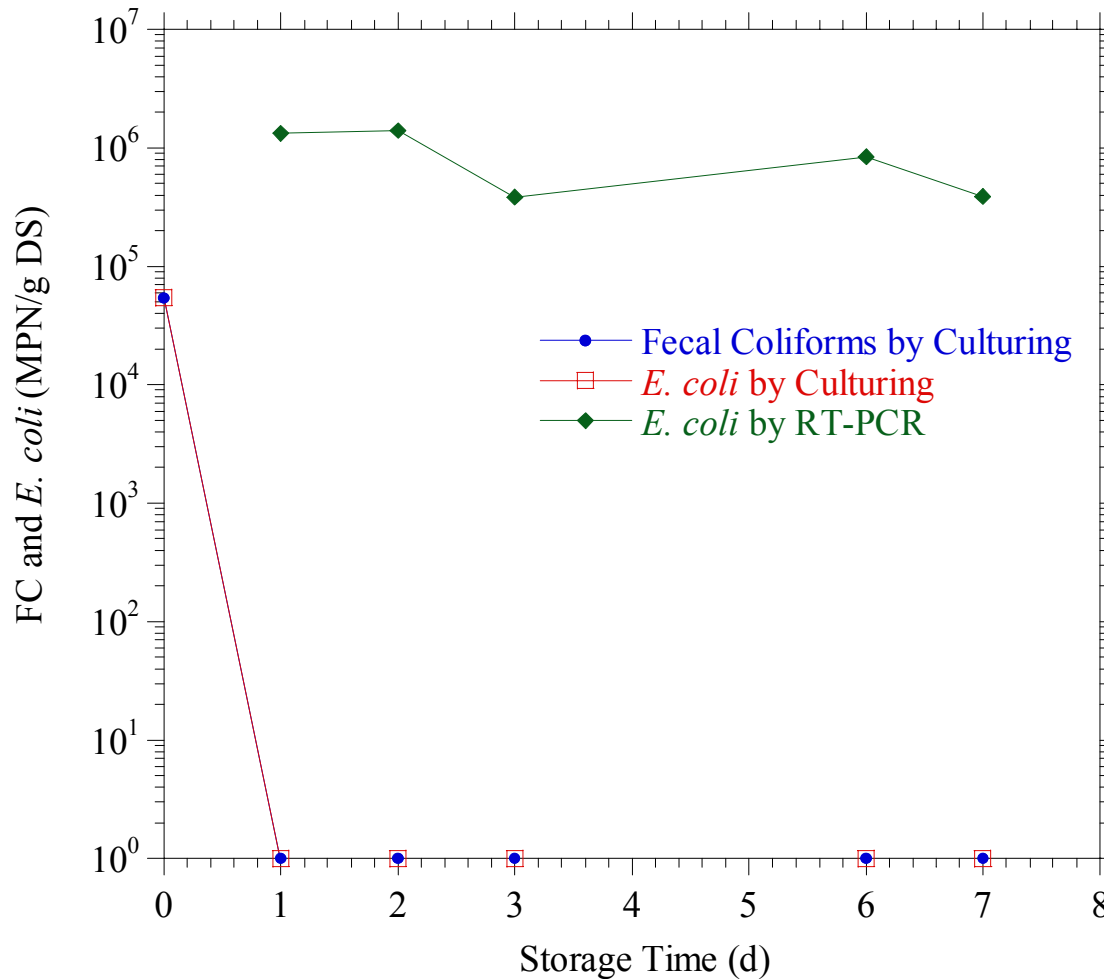


Standard culturing method vs. PCR



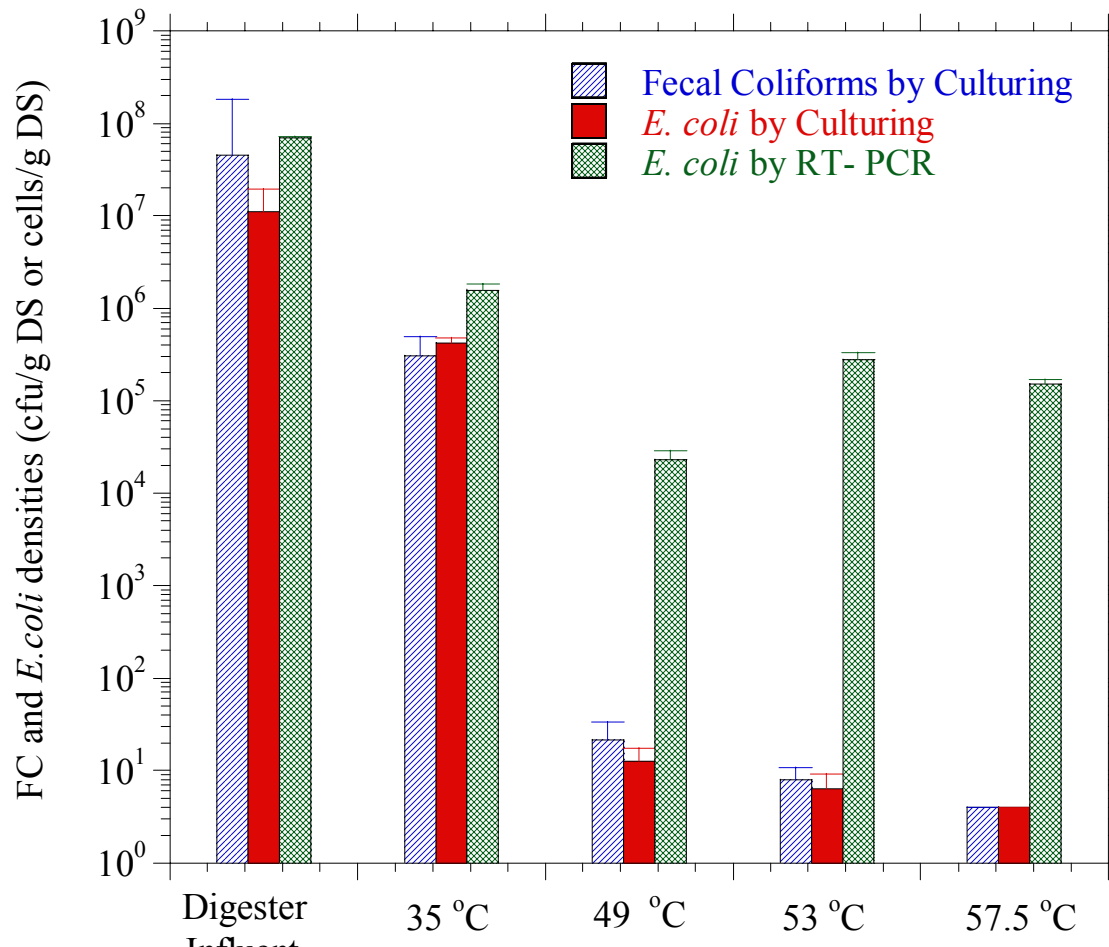
Batch Digestion Lab Studies

Effect of Time at 55 C



Bucknell
Reactors

CSTR Lab Studies Effect of Temperature (15 day SRT)



Virginia
Tech
Reactors

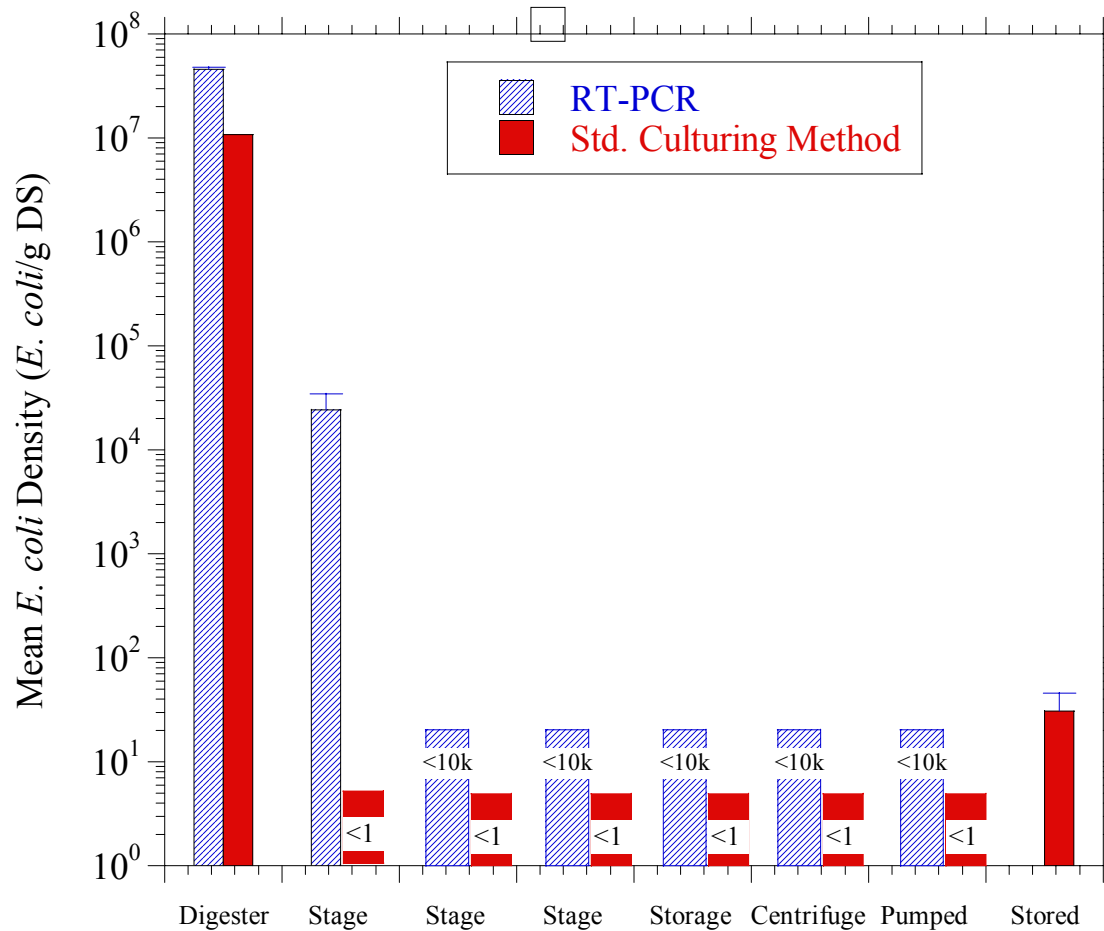
Phase I Summary

1. Bacteria can enter the VBNC state during digestion and be reactivated during centrifuge dewatering
2. Mesophilic can have zero to one order of magnitude difference,
3. Thermophilic several orders of magnitude difference.
4. Does not occur at all plants, data suggests it may be related to reactor configuration/hydraulics
5. Reactivation appears to be due to some inducer compound or change in environmental conditions
6. Additional research is needed to better understand this phenomena

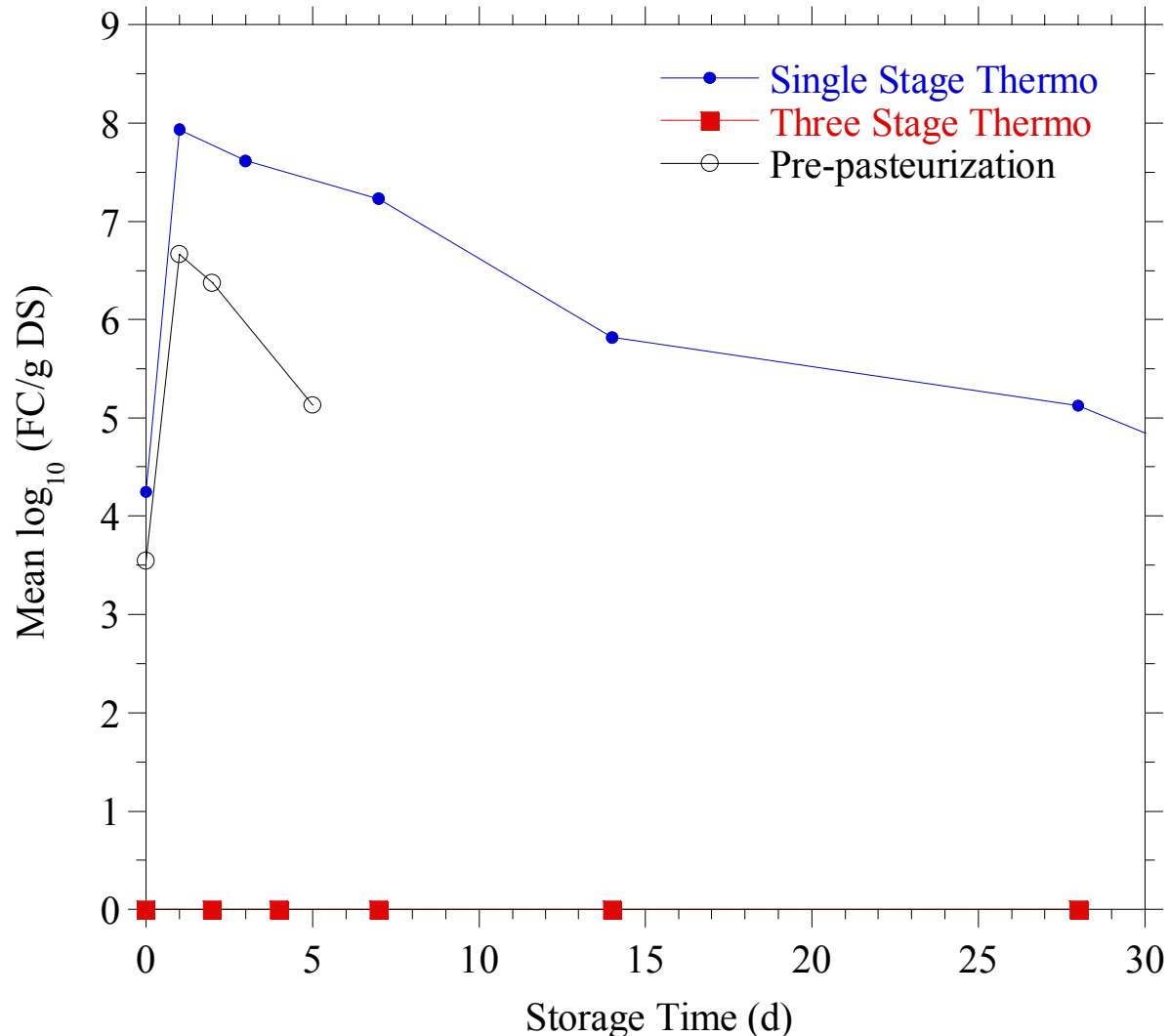
Phase II Research Objectives

1. Reactor hydraulics;
2. Time-temperature combinations;
3. Reactivation mechanisms, dewatering;
4. Potential for regrowth after reactivation;
5. Full-scale sampling - how prevalent is this?

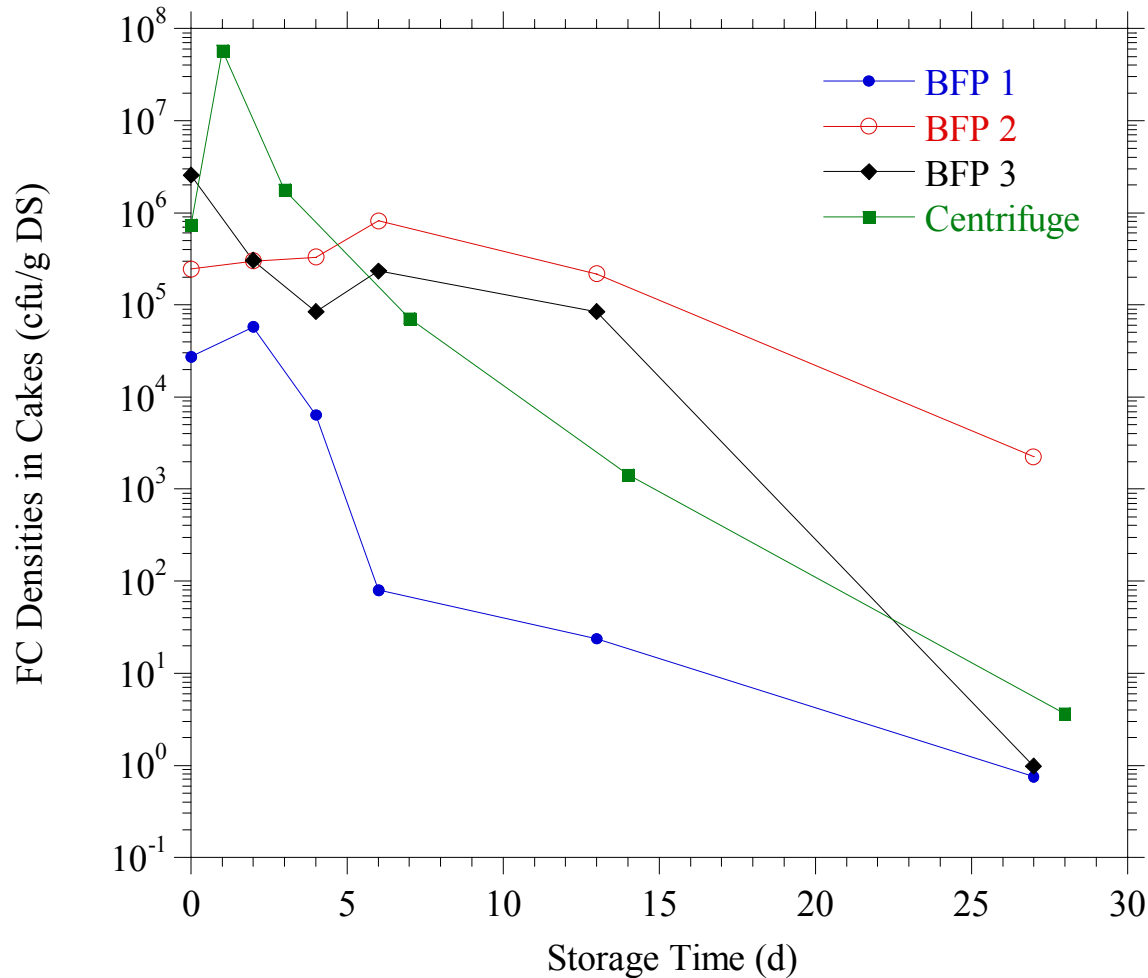
Phase II Results – Reactor Configuration Three Stage Thermophilic



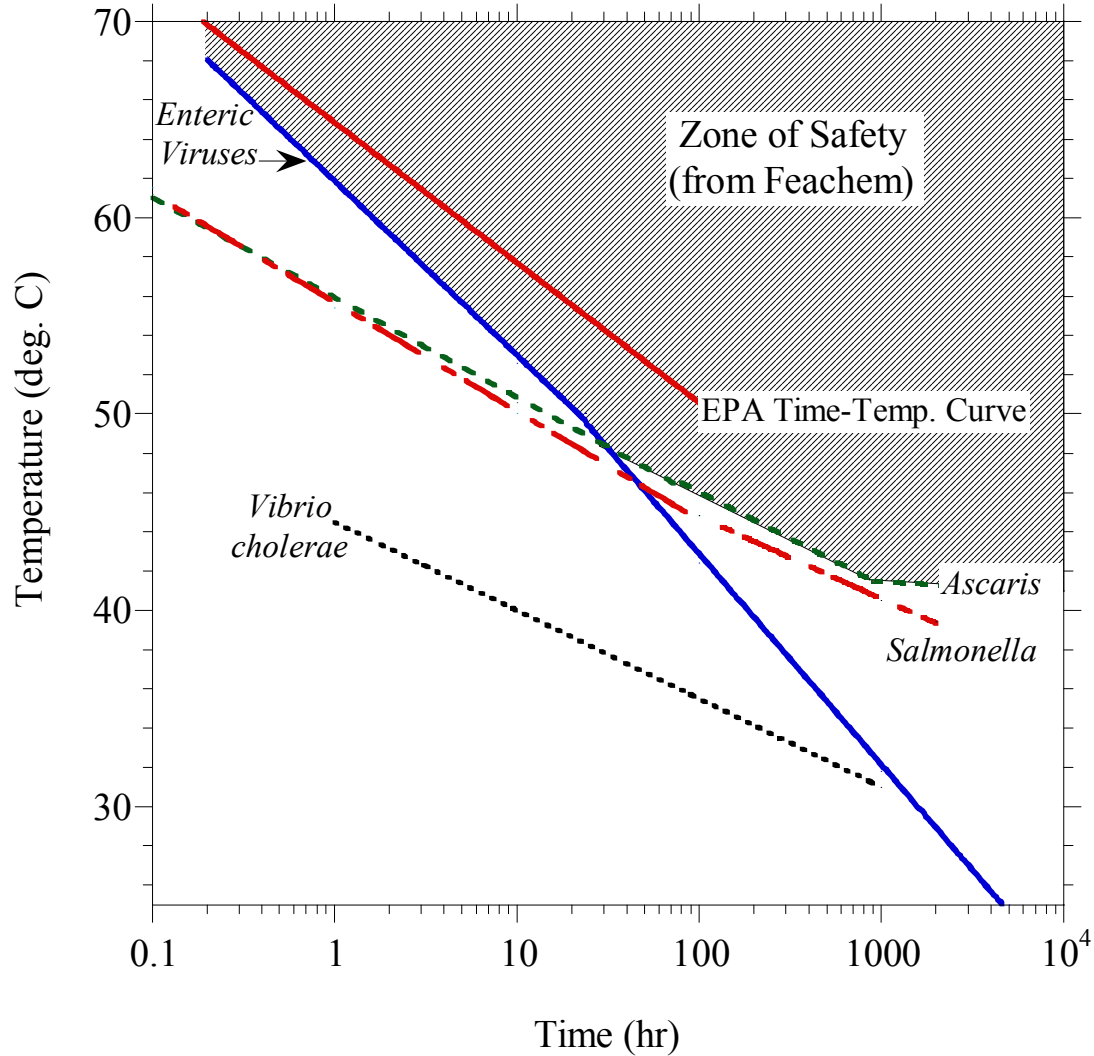
Regrowth for Thermophilic with Centrifuges



Phase II Results – Regrowth Impact of Dewatering



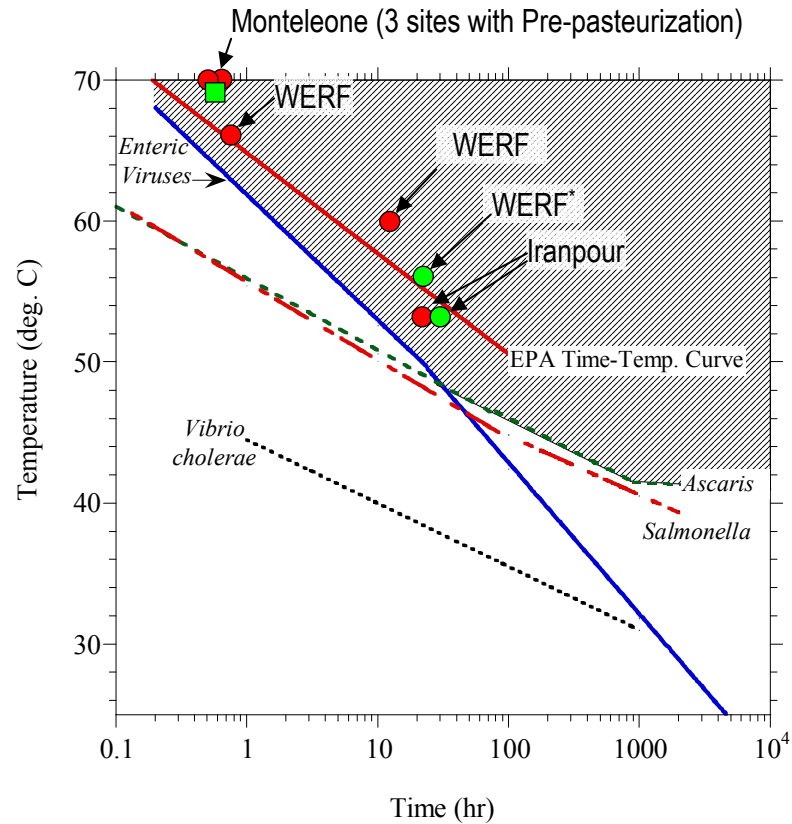
Class A Time Temp. Curve



Class A Reactivation and Regrowth

Legend

- Centrifuge dewatering with reactivation and/or regrowth
- Centrifuge dewatering without reactivation and/or regrowth
- Belt Filter Press dewatering without reactivation and/or regrowth



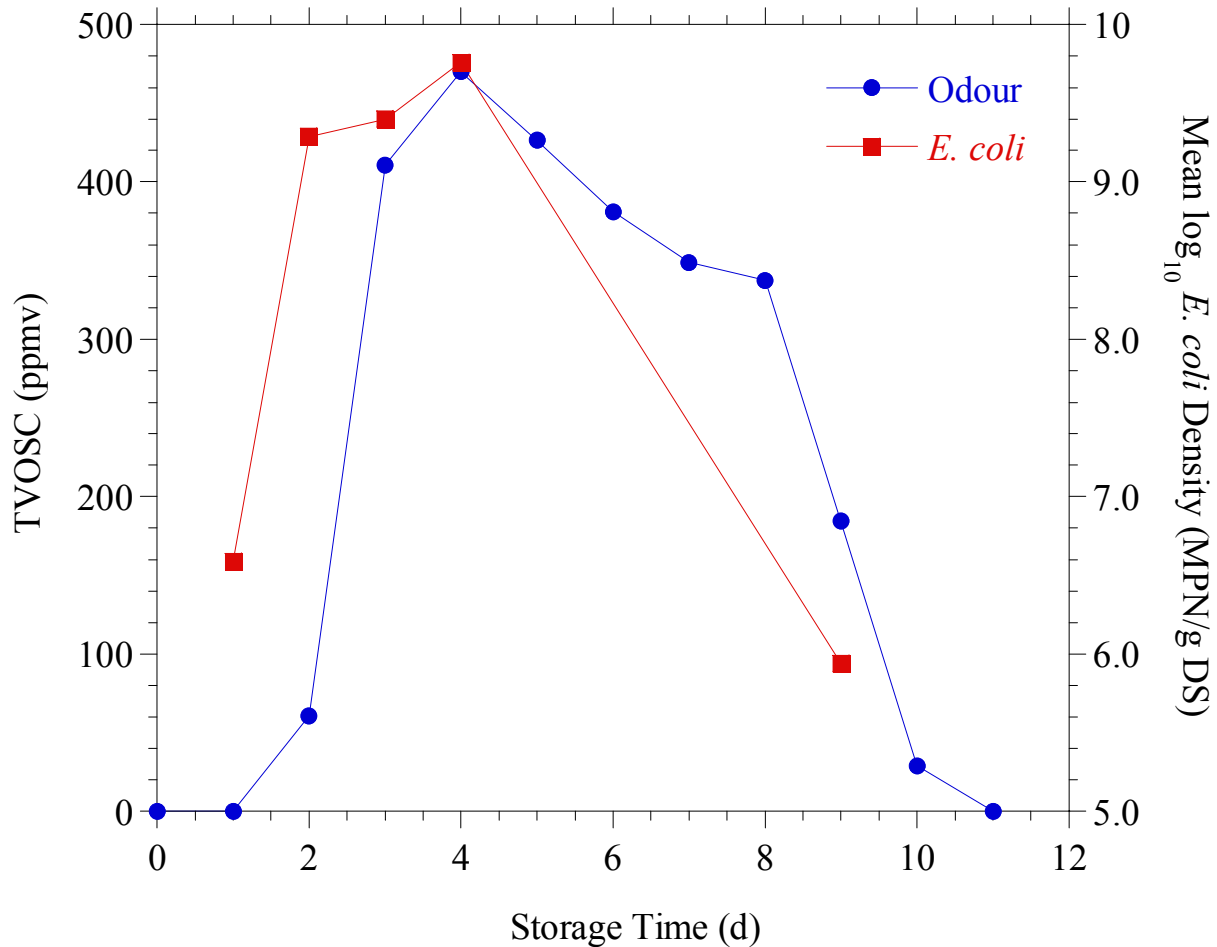
Summary of Phase II

1. Thermophilic CSTRs in series may be needed to destroy FCs and prevent reactivation.
2. Belt filter press does not seem to induce reactivation and regrowth
3. Increased mesophilic digester SRT reduces FCs
4. Batch digestion at 55 C does not appear to destroy *E. coli* as completely as SCM suggests

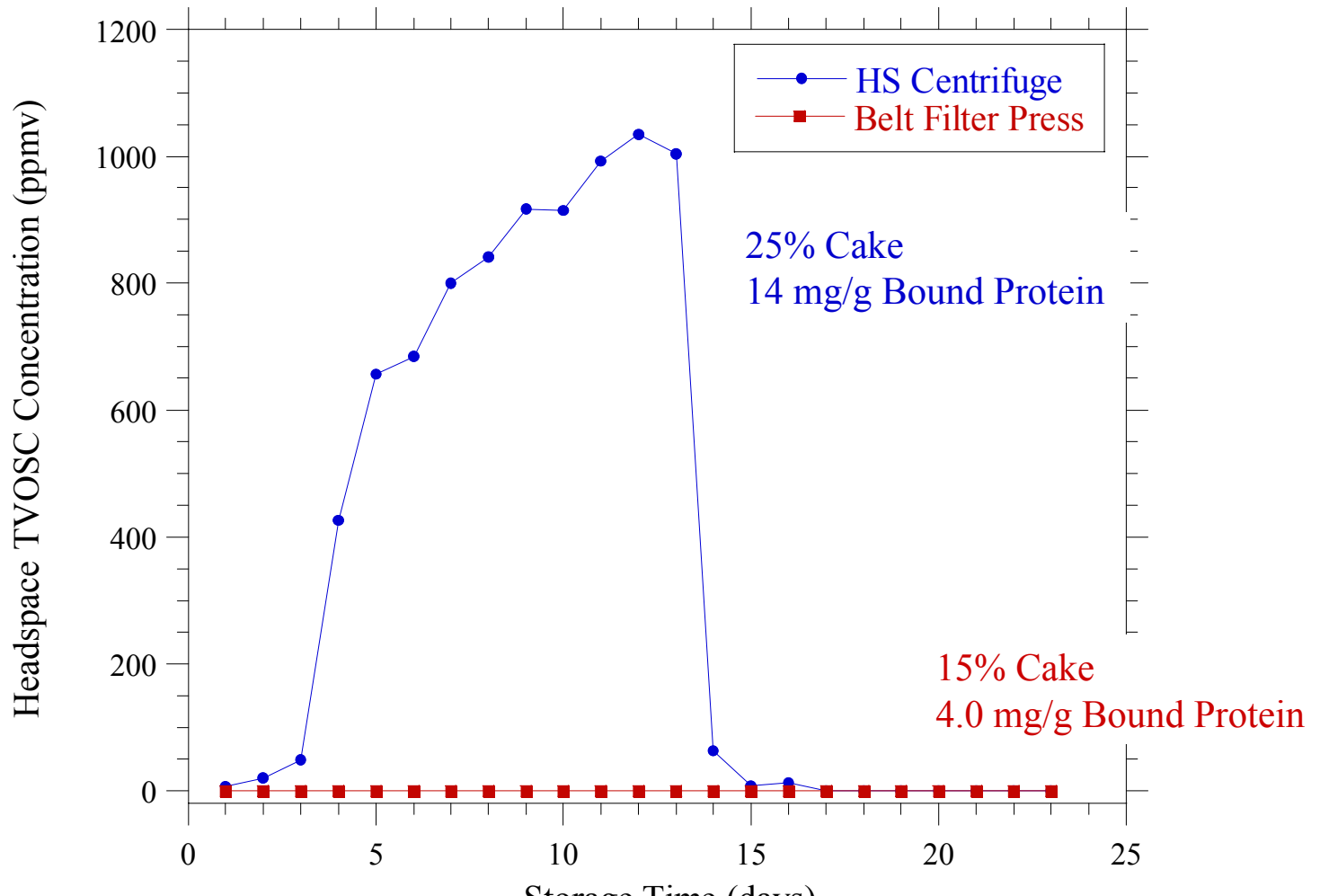
Reactivation/Regrowth Summary

■ <u>Other Literature and WERF Study</u>	<u>R&R</u>		
□ MAD + High Solids Centrifuges:	17/19		} 29/33
□ MAD + Low Solids Centrifuges:	5/5		
□ ATAD + Centrifuges		1/1	
□ Thermo or TPAD + Centrifuge:		3/5	
□ Pre-Past. + MAD + Centrifuge:		<u>3/3</u>	
□ MAD + Belt Filter Press:	1/7		} 2/10
□ MAD + Rotary Press:		1/2	
□ Pre-Past. + MAD + Belt Filter Press	<u>0/1</u>		

Link between odors and regrowth



Belt Filter Press vs. HS Centrifuge TVOSC Production Profiles



Preliminary summary of pathogen testing

- For Class A processes, reactivation/regrowth of *Salmonella* was not observed in all cases.
- For Class B mesophilic processes, regrowth of *Salmonella* was observed.
- Mixed results with other bacterial pathogens

Implications for Utilities

- Class B – Mesophilic Facilities,

Regrowth is the main issue

Regrowth also goes hand-in-hand with high odors

Mitigation measures needed to meet Class B FC limits

- Class A Thermophilic Facilities

Reactivation and regrowth are both a concern

UK Situation

- Reactivation reported at all Water Companies contacted
- This included high temperature (70C) and advanced digestion systems (up to 70C)
- Some confusion over Safe Sludge Matrix interpretation

Conclusion

- US is some way ahead on addressing this issue
- They have an open approach to it
- Presence/absence of reactivation should be part of HACCP in the UK
- UK research is required