Releasing Phosphorus from Waste Activated Sludge

Wisconsin Wastewater Operators Association
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Is Your Engineer an Extrovert?

Outline of Presentation

- Why do we care about phosphorus release?
  - Environmental concerns
  - Operating concerns
- Solutions MMSD examined and researched
- Direction MMSD is moving
- How can these lessons applied to other facilities?

Why do we care about this?

- Biological phosphorus removal increased phosphorus in WAS/biosolids.
- Several changes resulting from implementing EBPR:
  - Effluent phosphorus discharge decreased (+).
  - Increased struvite / vivianite formation potential (-).
  - More phosphorus applied to land via biosolids (-).
- High-quality reserves of phosphorus rapidly depleting.
- Sustainability has received an increased emphasis:
  - Recovery & reuse of materials.
  - Reduce use of excess nutrients in agriculture.

Phosphorus before EBPR

$$PI = PE + PB$$

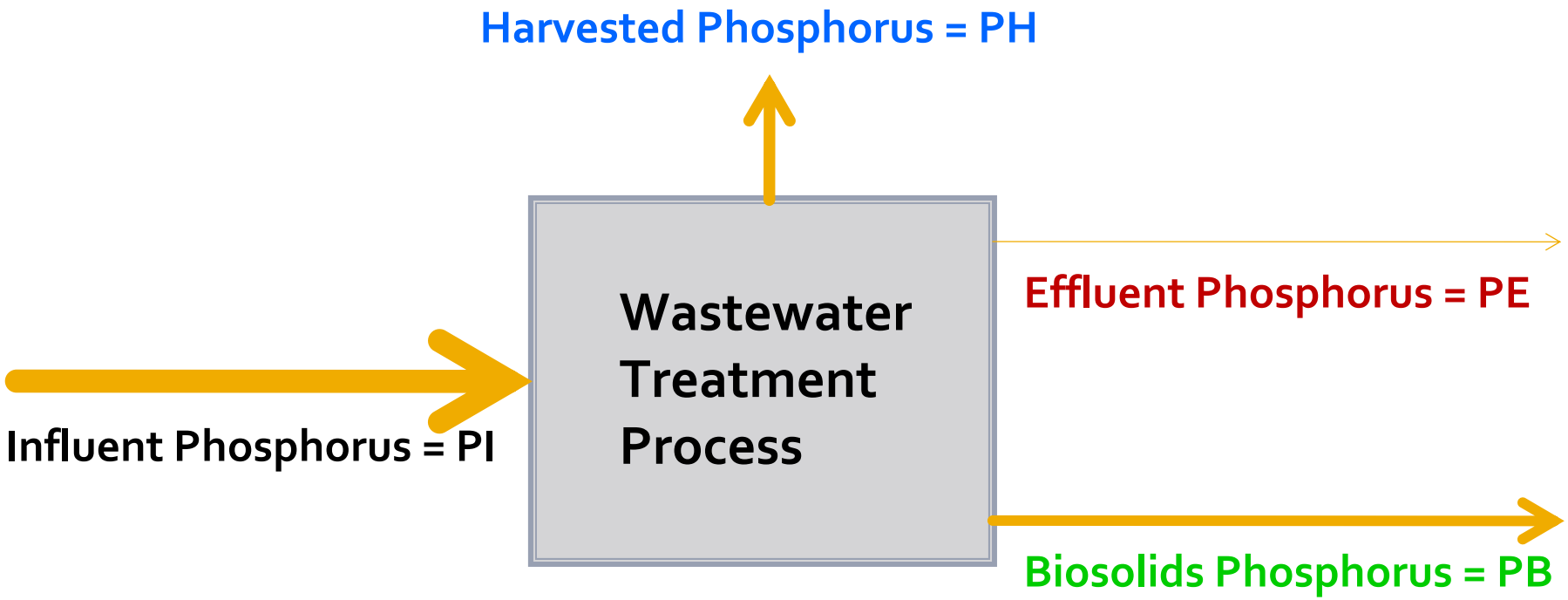
$$100 = 40 + 60$$

Phosphorus after EBPR

$$PI = PE + PB$$

$$100 = 5 + 95$$

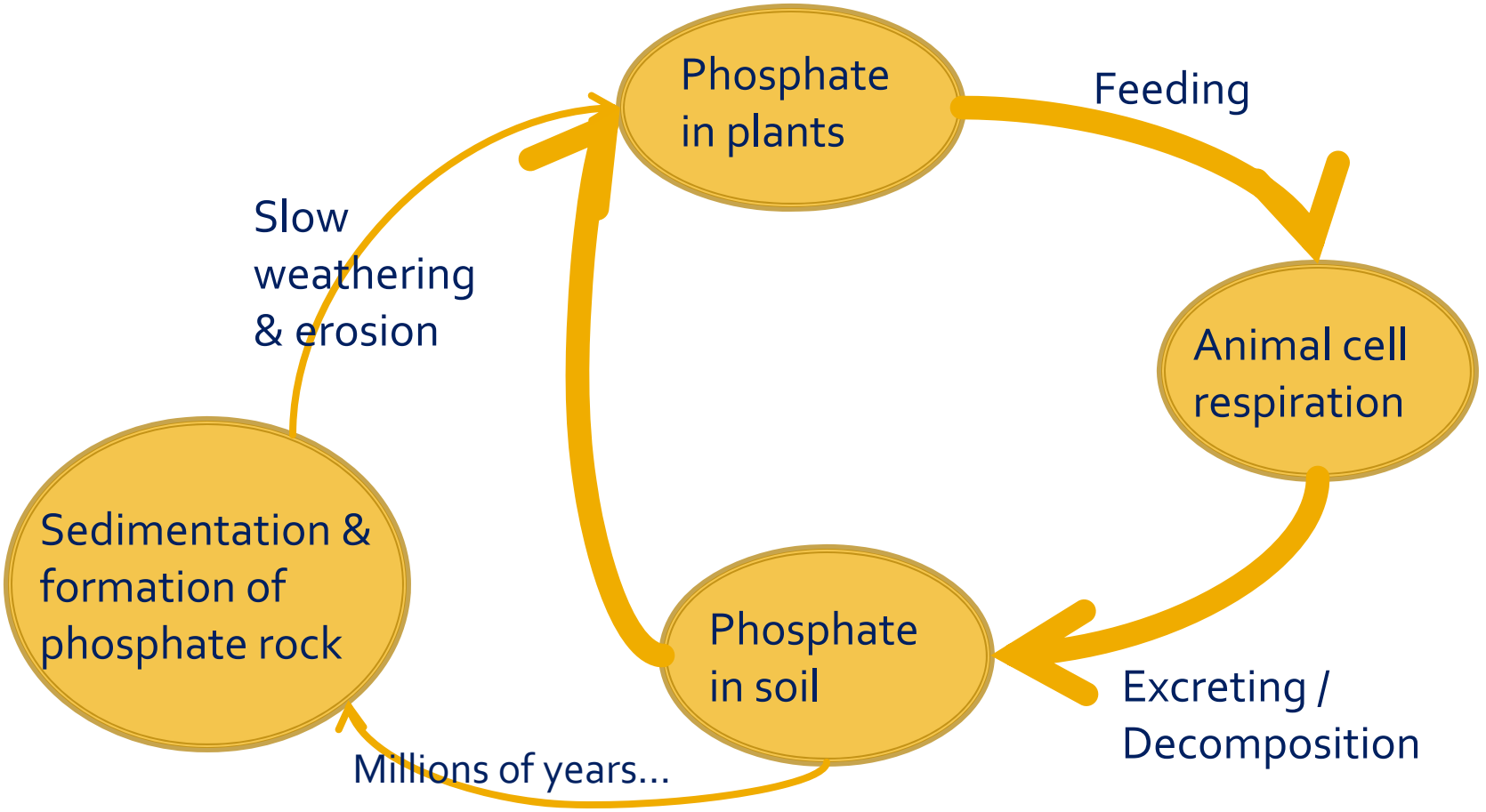
…and after EBPR & harvesting



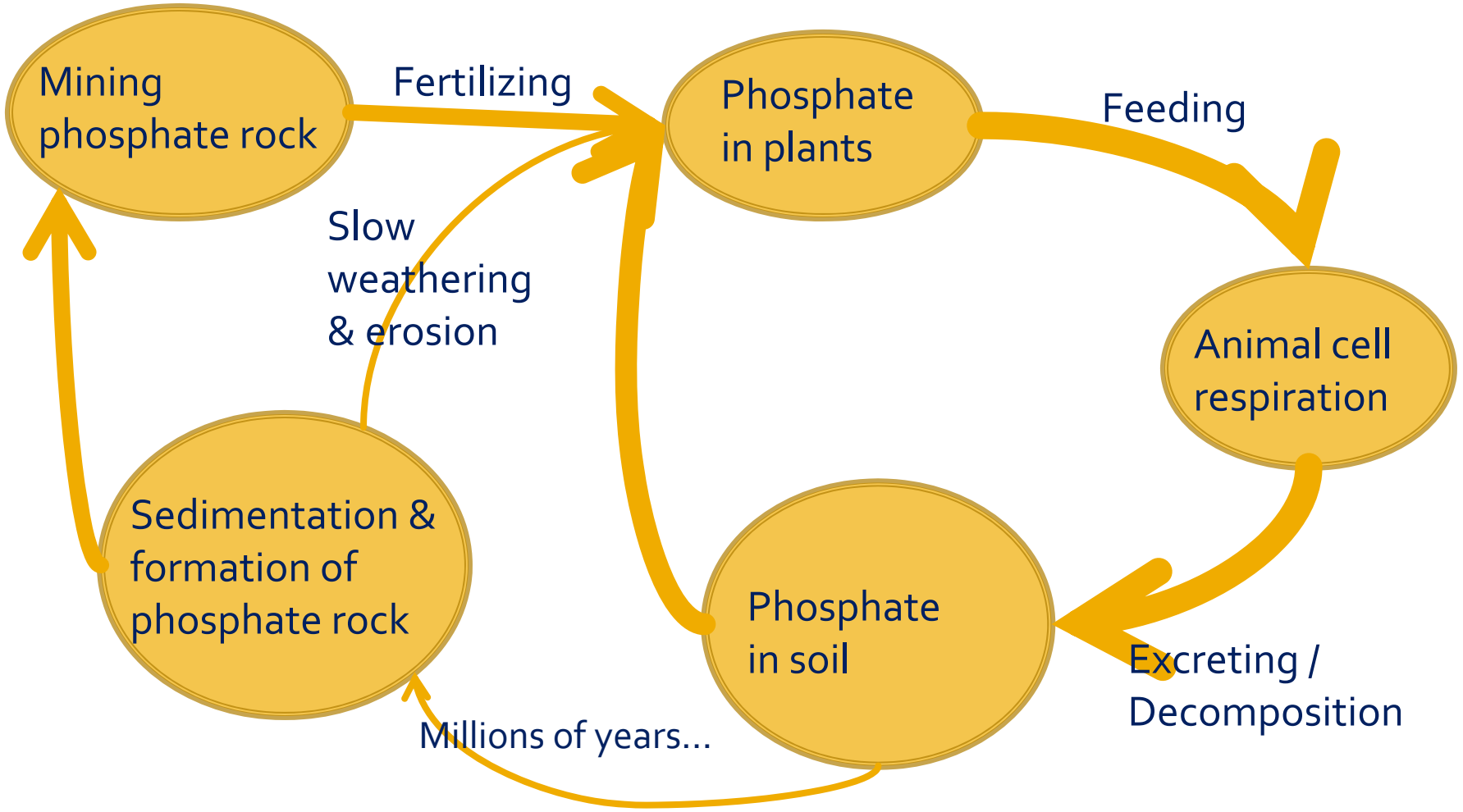
$$PI = PE + PB + PH$$

$$100 = 5 + 45 + 50$$

"Natural" phosphorus cycle



"Altered" phosphorus cycle

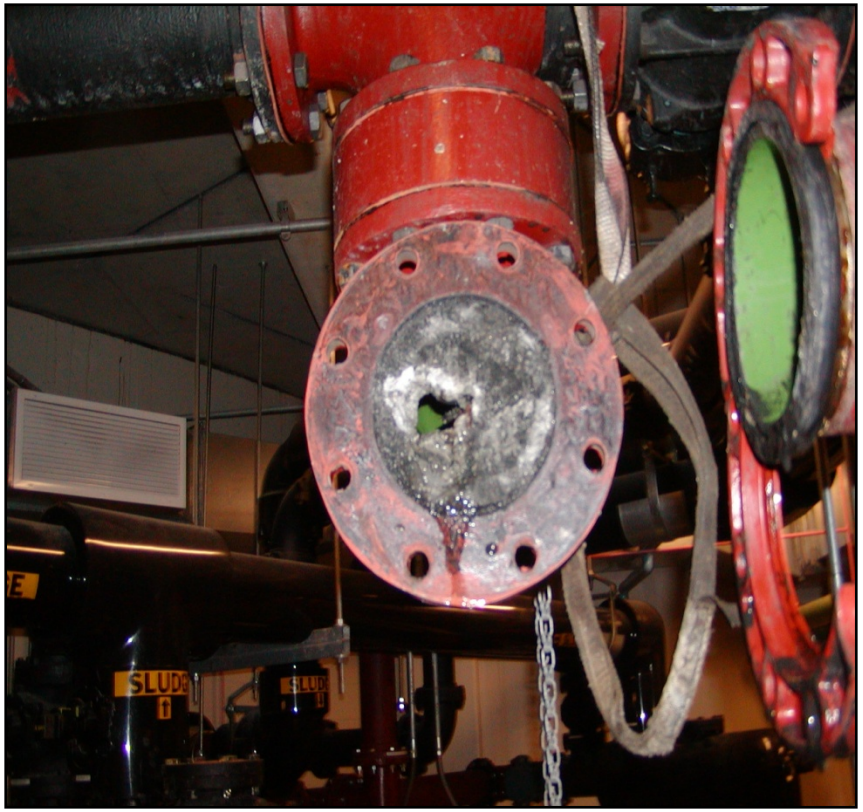


What is Struvite?

- Chemically expressed: $(NH_4)MgPO_4 \bullet 6(H_2O)$
- Basically equal molar ratios of ammonia, magnesium, and phosphate
- Typical anaerobic digestion results in ammonia and phosphate in abundance
- Hard water in mid-west typically provides the third ingredient—magnesium
- When pH is raised the ingredients form a precipitate called struvite

Struvite in various forms

Operationally, struvite is a problem



Harvesting struvite has appeal

- Primary reasons for interest in harvesting:
  1. Reduce biosolids phosphorus content
  2. Recovery of an increasingly valuable, marketable material
- Harvesting typically done *after* anaerobic digestion.
- If we can release phosphorus *prior to* digestion, then reduction of soluble phosphorus in the anaerobic digester is a probable added benefit
- Can this be achieved?

Ways to trigger WAS P-release

- Combine primary sludge and WAS
- Add internal VFA source
  - Acid sludge addition
  - ATAD sludge?
- Add a chemical (external) VFA source
  - Acetate?
  - Propionic?
- Additives that contain no measurable VFA (readily biodegradable carbon, or "RBC")

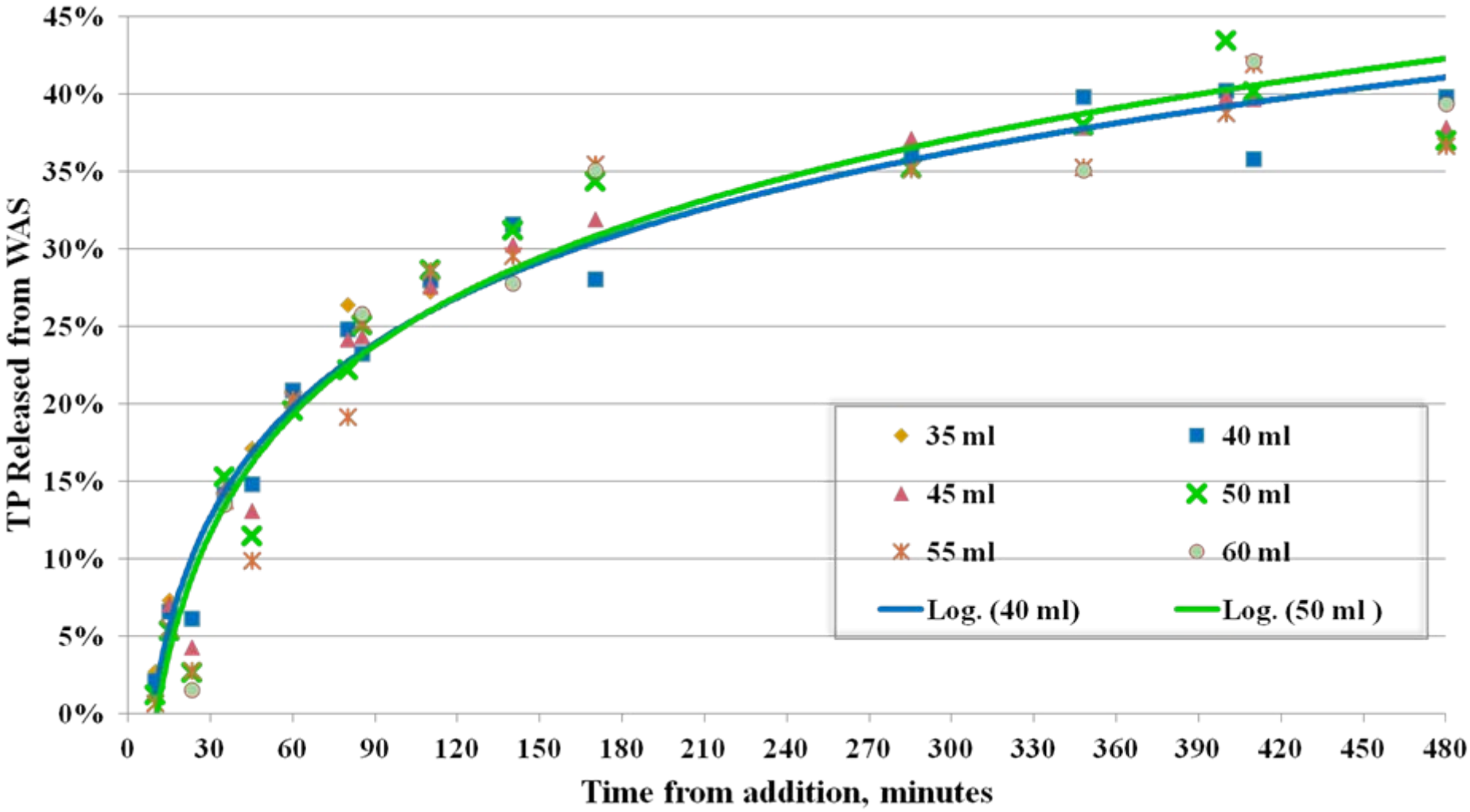
WAS & Primary co-thickening

- Research sponsored by MMSD and conducted by UW-Madison (2000 to present) demonstrated efficacy in multiple studies
  - Chaparro 2002
  - Condliff 2003
  - Corrado 2009
- Research determined this method to be reasonably effective and reliable
- Downside is added liquid volume (dilutes feed, more equip.)

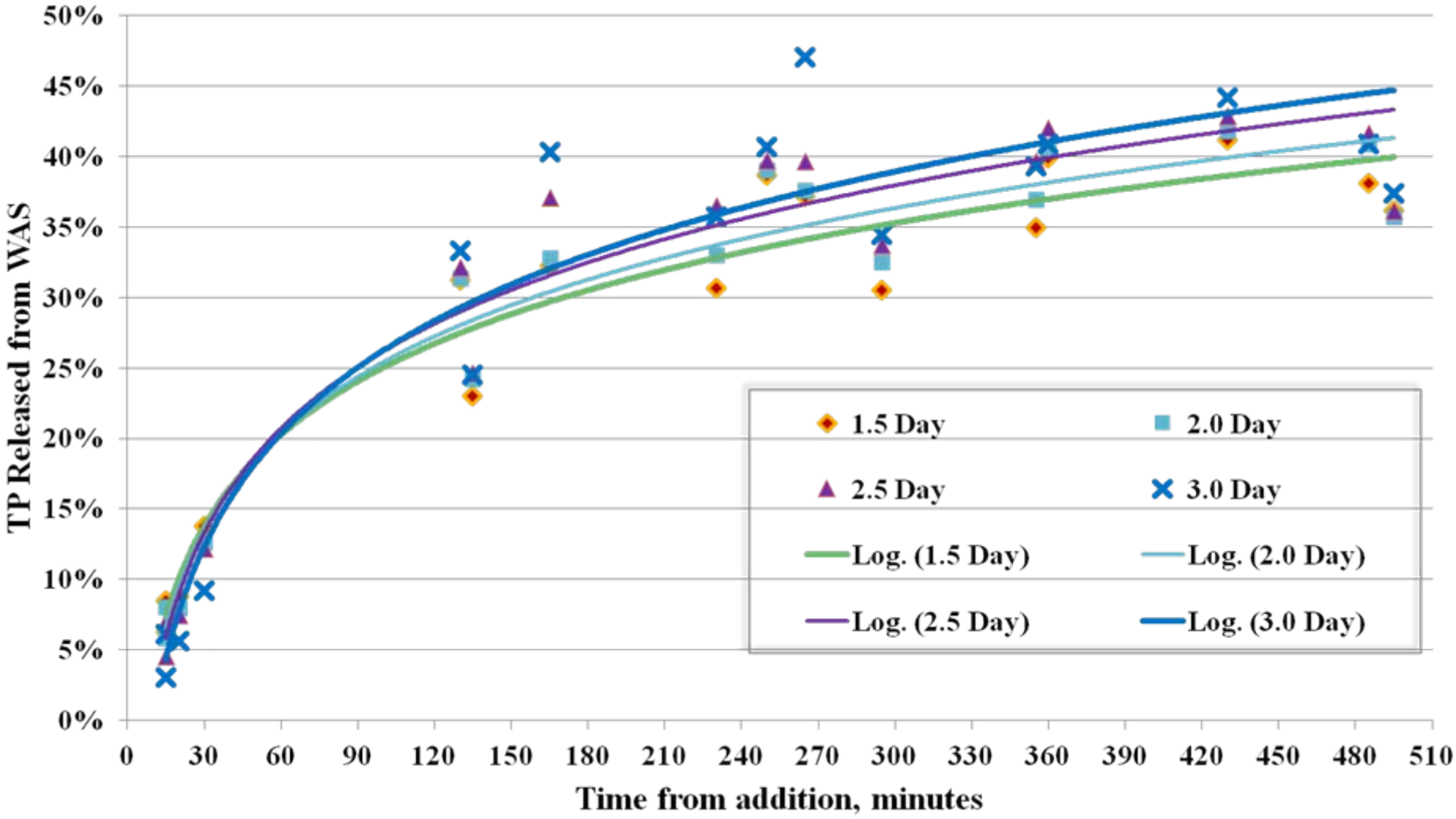
Adding internal VFA source

- 11th Addition plans selected acid-phase digestion
- Seemed a "natural fit" for VFA source.
- Demonstrated acid sludge works, optimal ratio shown lower than "textbook"
- Efficiency shown same or greater than co-thickening
- Greater phosphorus concentration achieved due to lower liquid volume
- Result of greater concentration is better efficiency in harvesting

Acid sludge addition



Acid sludge addition



Optimized acid sludge addition

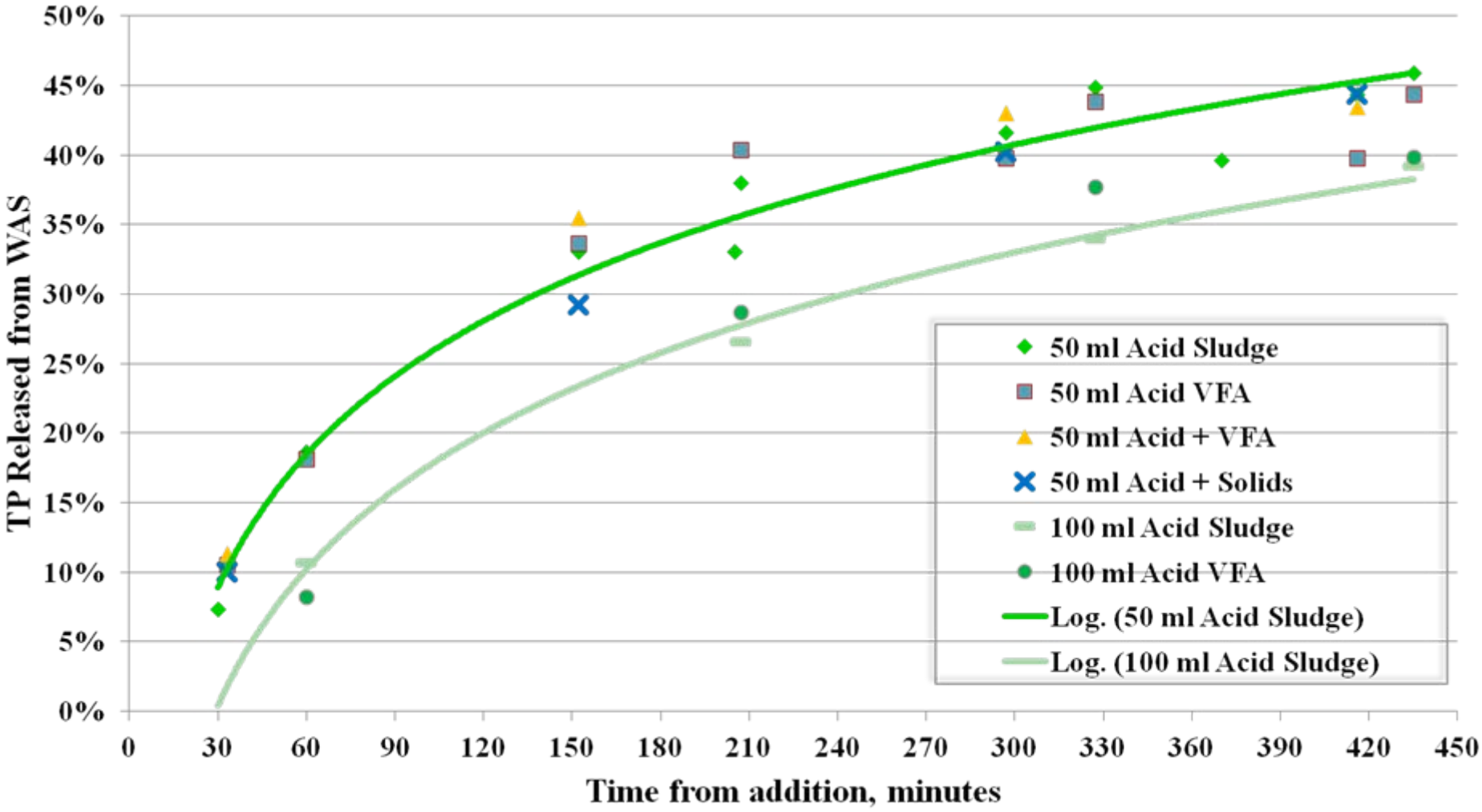
- Acid sludge:WAS ratio optimized at ~ 5% by volume (assumes ~5,000 mg/L VFA as acetic)
  - Inhibition experienced at higher doses
  - Reasonably independent of temperature & acid sludge age
- MMSD testing demonstrated VFA level key
- ATAD sludge reportedly behaved similarly in Salmon Arm (BC) pilot study (2008)[1]
- Merits of small "acid sludge generator"? Further research needed to evaluate feasibility

1. Kelly, H.G., et al; Wastewater Resource Extraction, *Water Environment & Technology*, Dec 2010, **22** (12), 50-52

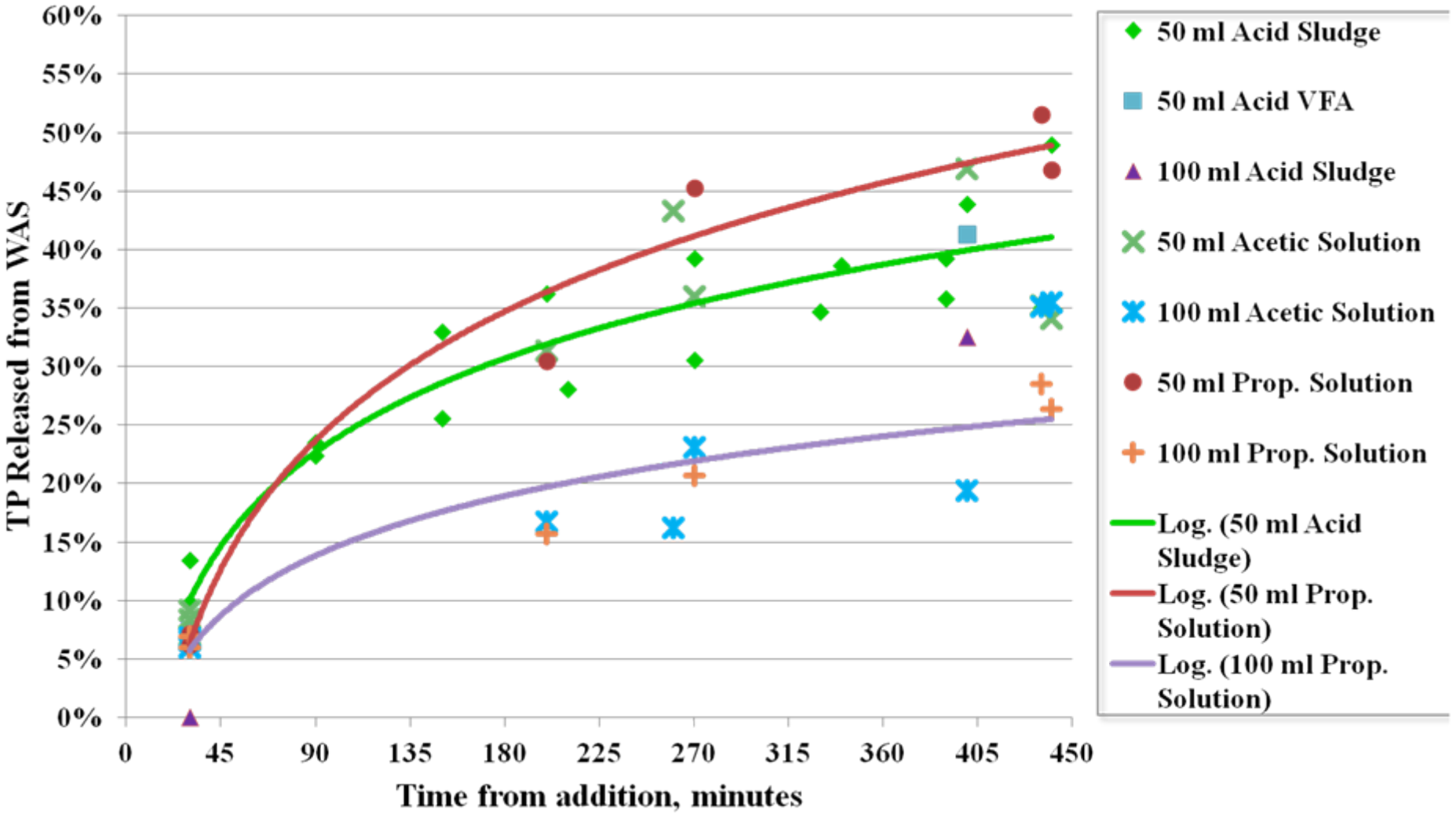
VFA from chemical source

- Chemical VFA from external source exhibited same behavior, confirmed VFA as key
  - Filtered acid sludge
  - Acetic acid
  - Propionic acid
- Similar release rates and inhibition points
- Propionic appeared slightly more sensitive, potentially more effective?
- VFA addition from chemical source appears viable with respect to performance. Cost? TBD.

Chemical VFA addition



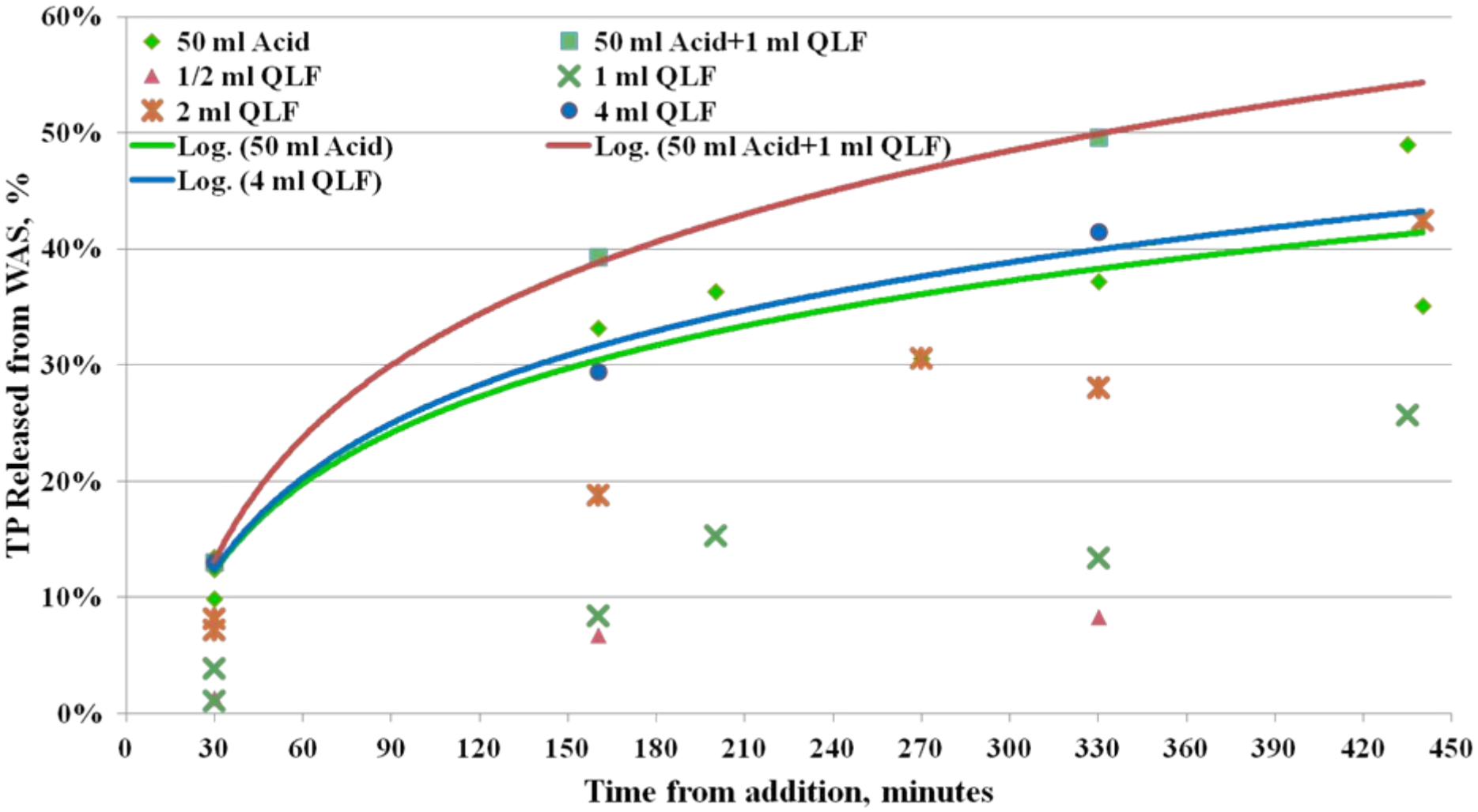
Chemical VFA addition



Non-VFA containing additives

- Tested sample of Quality Liquid Feeds (QLF)
- Detected no VFA; high BOD/CBOD content.
- Testing in lab showed:
  - 0.2% to 0.4% QLF alone = performance of 5% acid sludge (by volume).
  - 0.1% to 0.2% QLF added *with* acid sludge outperformed performance of either alone
- For facilities interested that lack anaerobic digestion or ATAD, may represent an option
- Other readily biodegradable carbon (RBC) sources may perform similar

Non-VFA additives



Summary of Testing

- WAS P-release requires VFA or other basic carbon source
- Adherence to "textbook" ratios resulted in early failures (look outside the "box")
- 2.5:1 to 4:1 found as ideal VFA:TP-released ratio for MMSD
  - Release at or over 35% WAS-TP at or under 5 hours
  - Inhibition observed at higher VFA doses
  - 250 mg (as acetic) VFA added per L WAS most effective
- Acetic acid solution almost identical performance

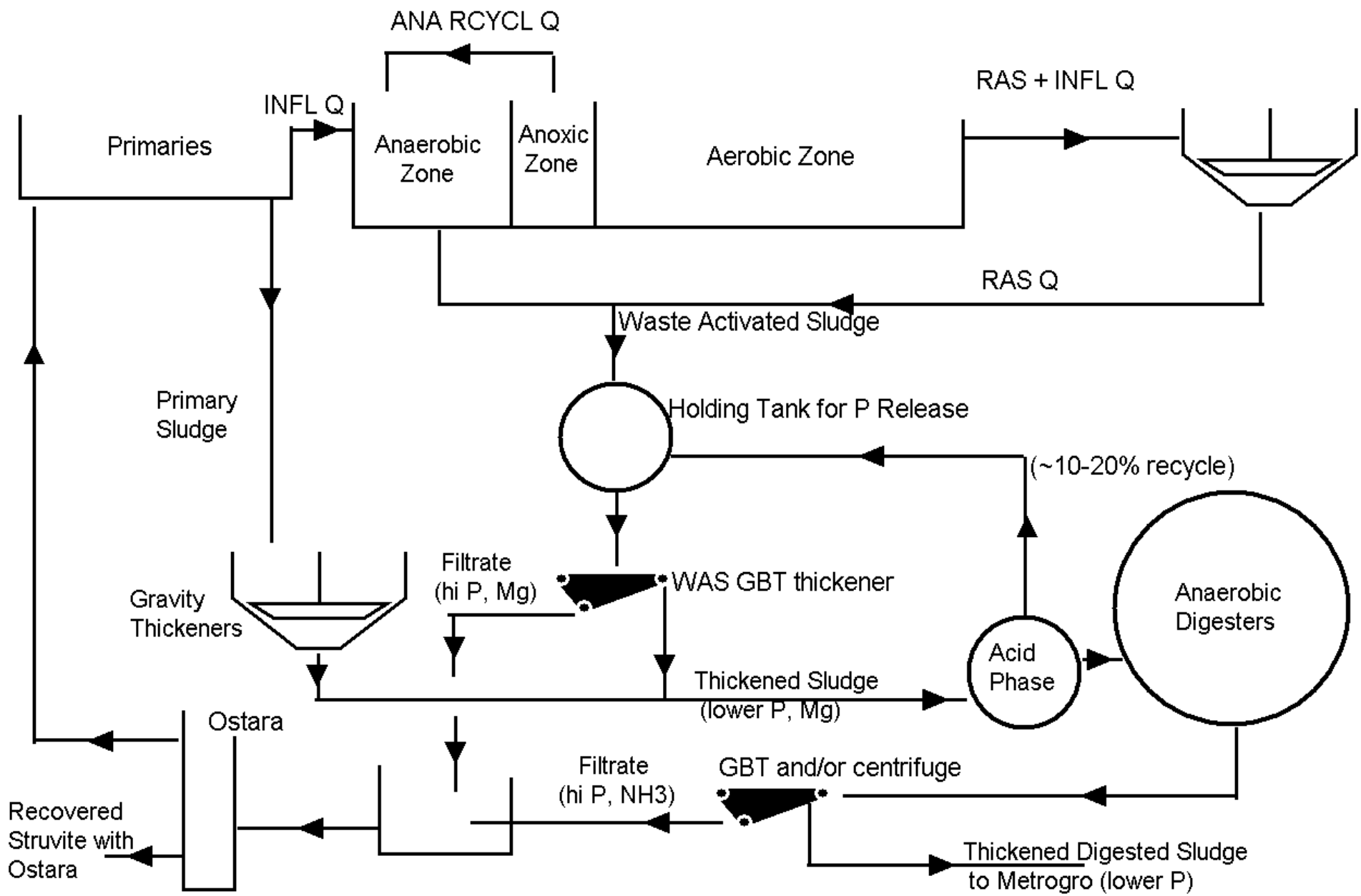
Summary of testing (continued)

- Non-VFA source of readily biodegradable carbon (RBC)—such as QLF—can be equally effective
  - Empirically determined ~ 4 ml QLF = 50 ml acid sludge
  - Advantages→less liquid vol., higher phosphorus conc.
- QLF with acid sludge more effective than either additive alone
  - Average ~ 10% more TP-release in 5 hours
    - This is 25% greater overall release, approaching "theoretical"

Plans for Madison Metropolitan

- Eleventh Addition project adding:
  - Acid phase digestion
  - WAS phosphorus release tanks
  - Struvite harvesting (Ostara Pearl® 2000 reactors)
- Advantages we hope to gain:
  - Decrease biosolids phosphorus content
  - Higher phosphorus concentration to harvesting
  - Reduce struvite formation in anaerobic digestion

MADISON P-RELEASE PROCESS SCHEMATIC



WAS phosphorus release options

- Co-thickening
- Fermentation
- Imitate MMSD
  - Need acid phase digestion or ATAD
  - Consider a small acid sludge generator?
- Add a chemical VFA source
- Add a readily biodegradable carbon source (QLF or similar)

Questions?

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