A Review of the Current State of Knowledge on Phosphorus Removal

Sam Jeyanayagam, Ph.D., P.E., BCEE
Senior Associate
Malcolm Pirnie
sjeyanayagam@pirnie.com
Phone: (614) 430-2611

OWEA Conference
16 June 2010

MALCOLM PIRNIE

Available Phosphorous Removal Methods

Two methods available

- Chemical Phosphorous Removal
- Enhanced Biological Phosphorous Removal

- Basic concept:

Soluble P → Particulate P ↓

Phosphorus removal occurs when sludge is wasted

Presentation Outline

- Chemical Phosphorus Removal
- Enhanced Biological Phosphorus Removal (EBPR)
- Take Home Messages

MALCOLM PIRNIE

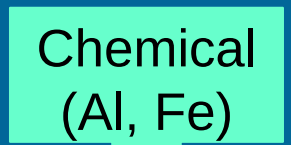
Presentation Outline

- **Chemical Phosphorus Removal**
- Enhanced Biological Phosphorus Removal (EBPR)
- Take Home Messages

MALCOLM PIRNIE

Chemical Phosphorus Removal Traditional Explanation

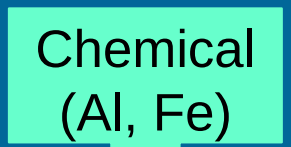
- Primary reaction:



Soluble P → Insoluble Metal Phosphate ↓

- Secondary reaction:

These reactions do not adequately explain higher P removal observed at WWTPs.



Alkalinity → Insoluble Metal hydroxide ↓

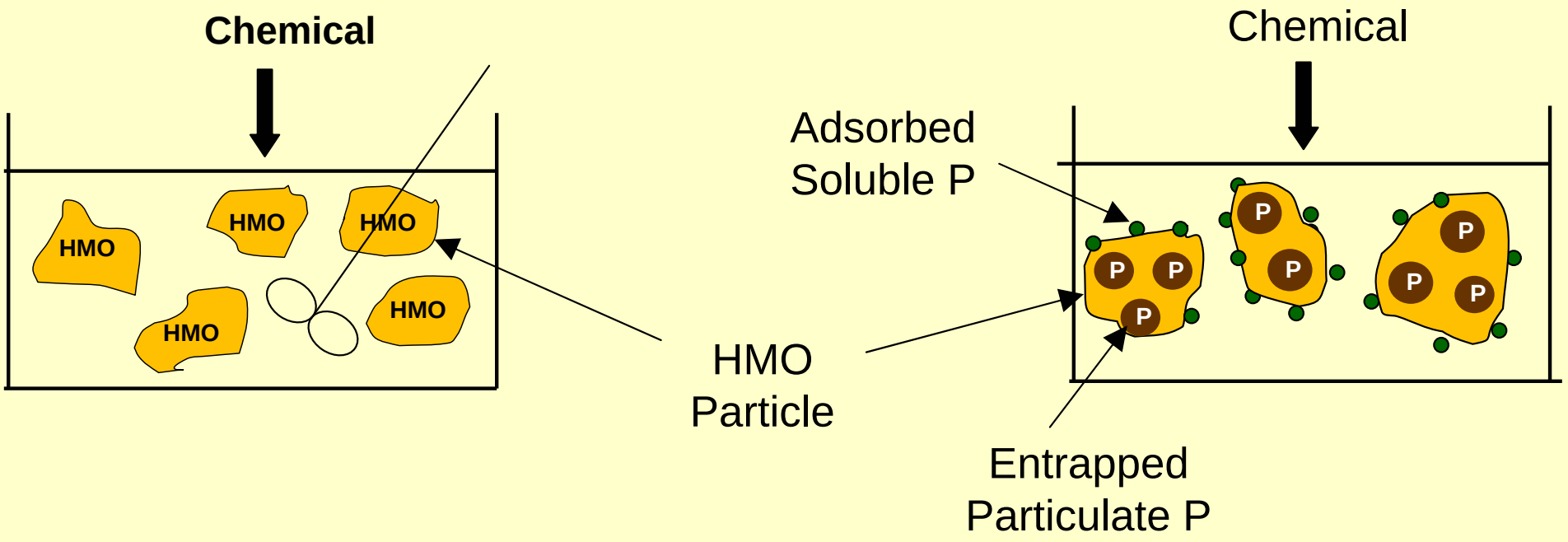
Chemical Phosphorus Removal Modern Explanation

- Predominant reactions

  - Soluble P adsorbs to HMO reactive sites

- Minor reaction
  - Co-precipitation: HMO enmeshes P containing colloidal particles:
    - P precipitate
    - Bugs

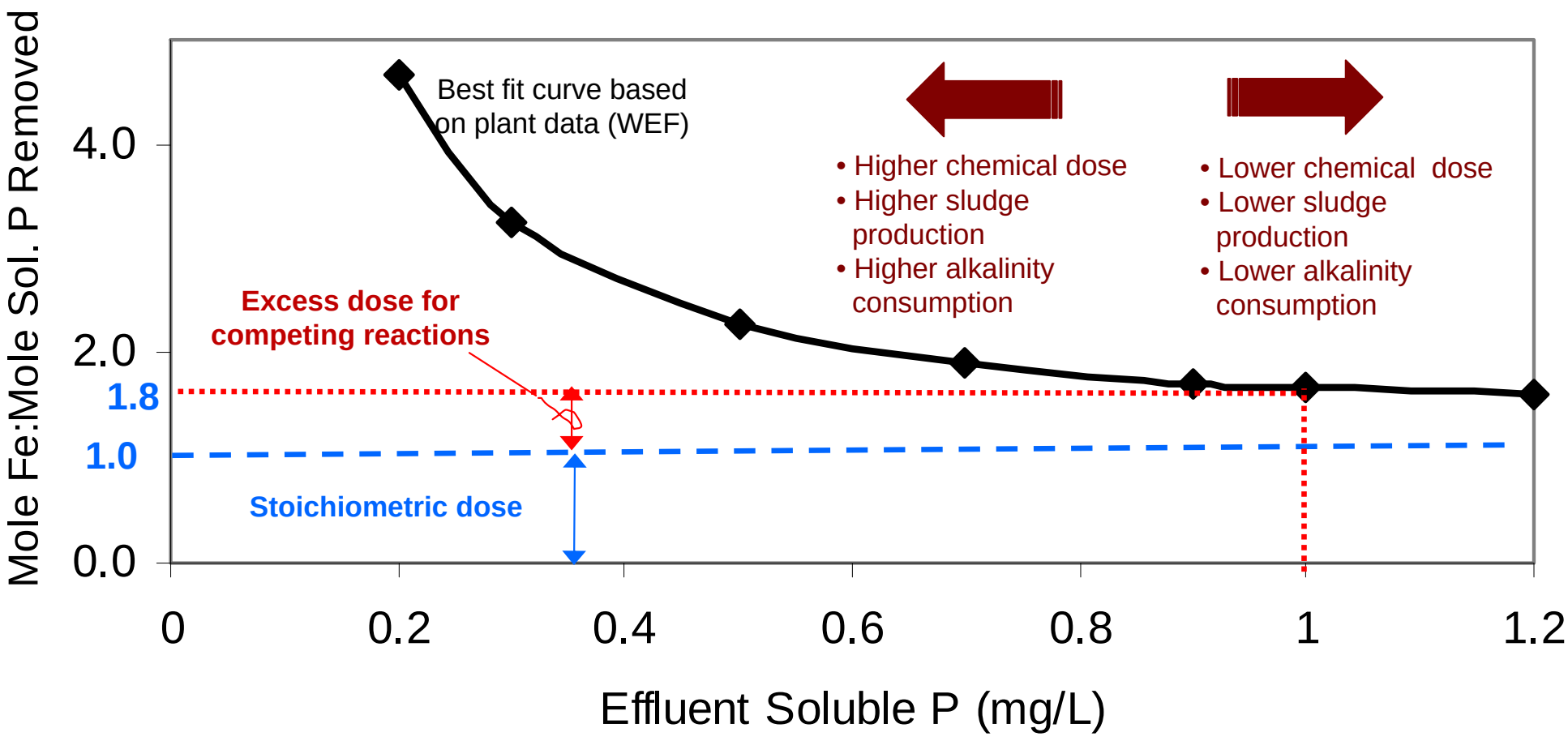
Chemical Phosphorus Removal Modern Explanation



Commonly Used Chemicals

- Iron Compounds
  - Ferric Salt
  - Ferrous Salt
  - Waste Pickle Liquor
- Aluminum compounds
  - Alum
  - Sodium Aluminate
  - Poly Aluminum Chloride (PAC)
- Lime
- Polymers

Chemical Requirements



Presentation Outline

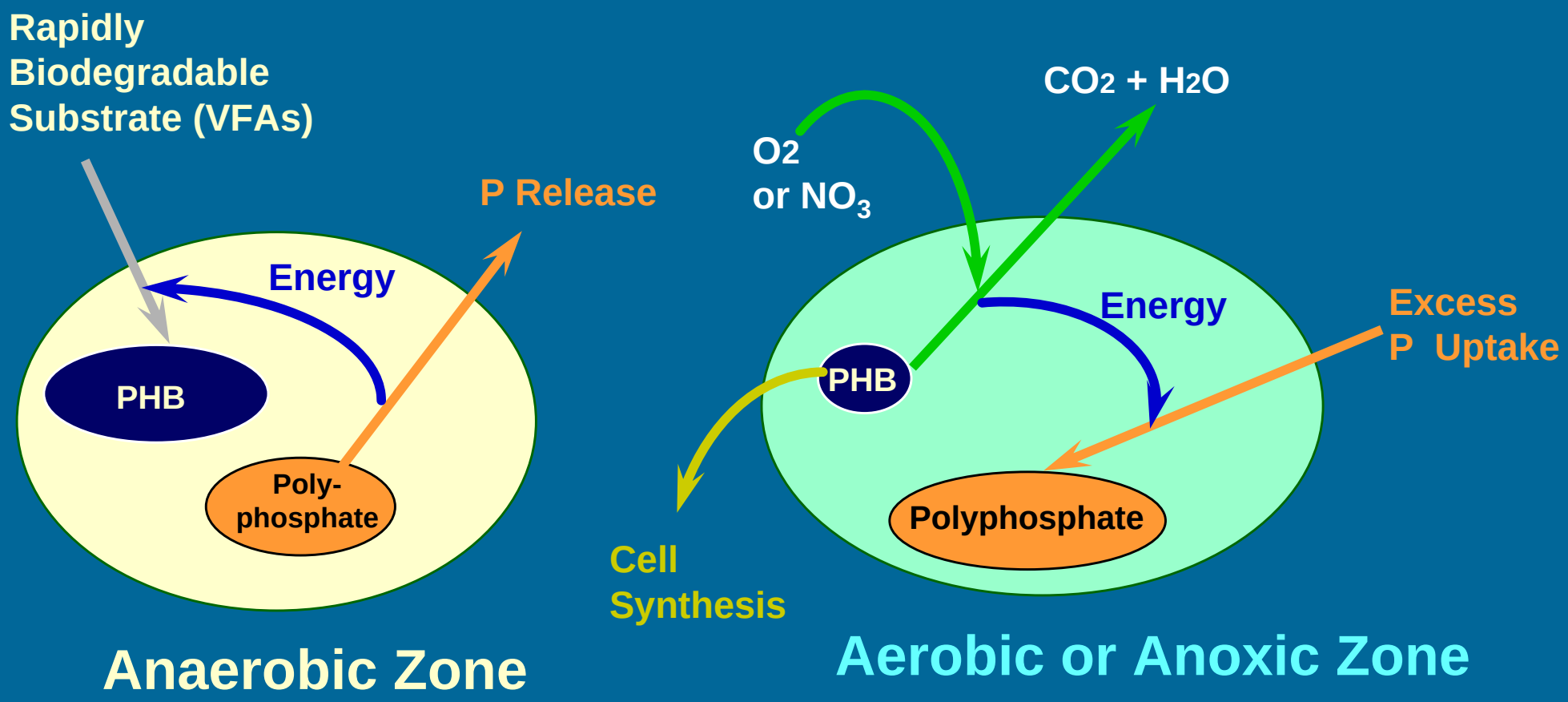
- Chemical Phosphorus Removal
- **Enhanced Biological Phosphorus Removal (EBPR)**
- Take Home Messages

MALCOLM PIRNIE

Enhanced Biological Phosphorus Removal

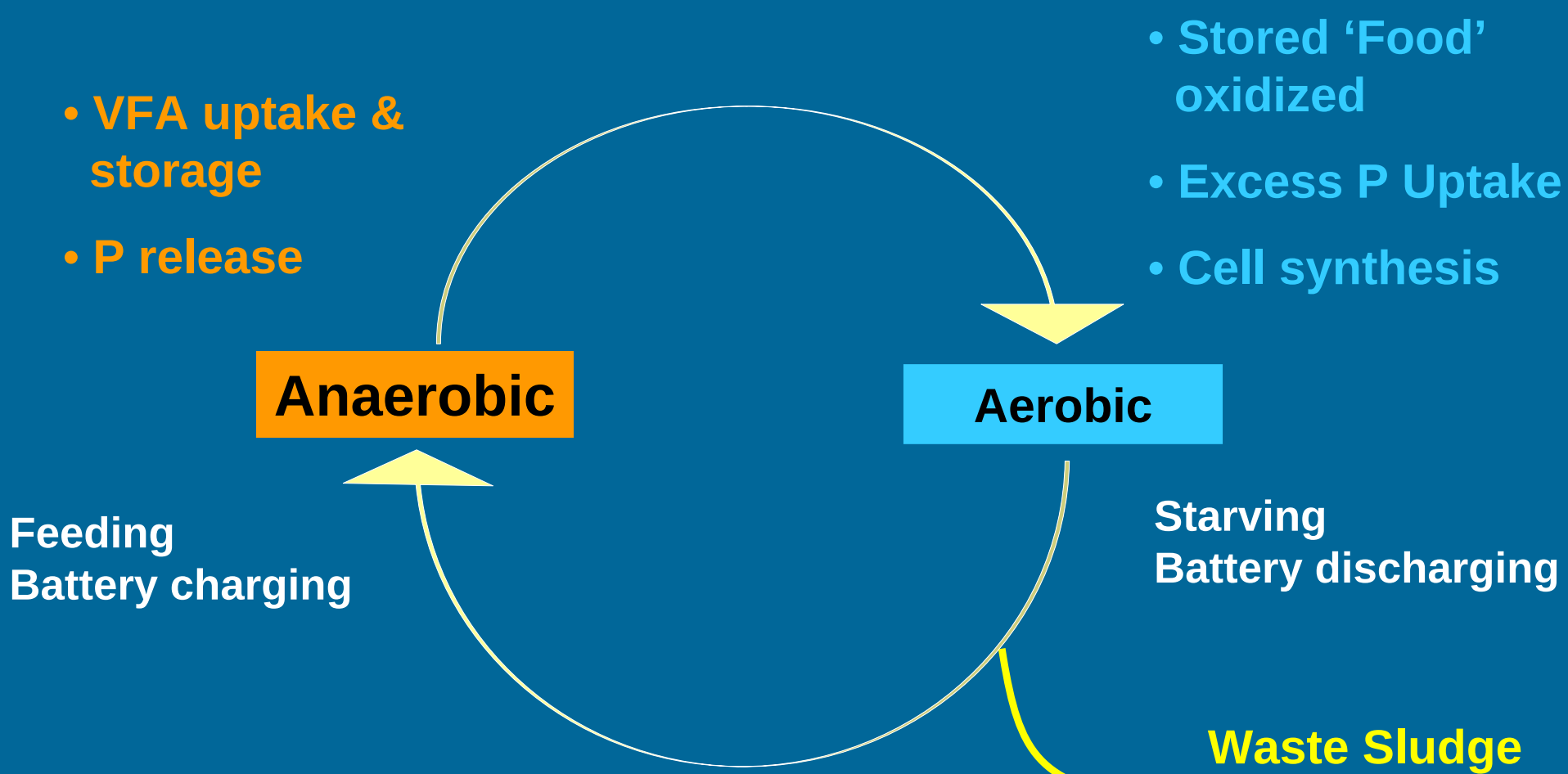
- Phosphorus is removed in ALL biological processes
  - Due to metabolic requirements
- Enhanced Biological P Removal (EBPR) is:
  - Removal exceeding metabolic requirements
    - Luxury P removal
    - Excess P removal
    - Enhanced Biological P removal (EBPR)
    - Bio-P
  - Mediated by Phosphorous Accumulating Organisms (PAOs)

Enhanced Biological P Removal (EBPR) Mechanism



Why EBPR works? **Energy Released by PHB oxidation is 24-36 times energy required for PHB storage**

EBPR Mechanism



Six Prerequisites for Reliable EBPR

1. Consistent and adequate supply of VFAs

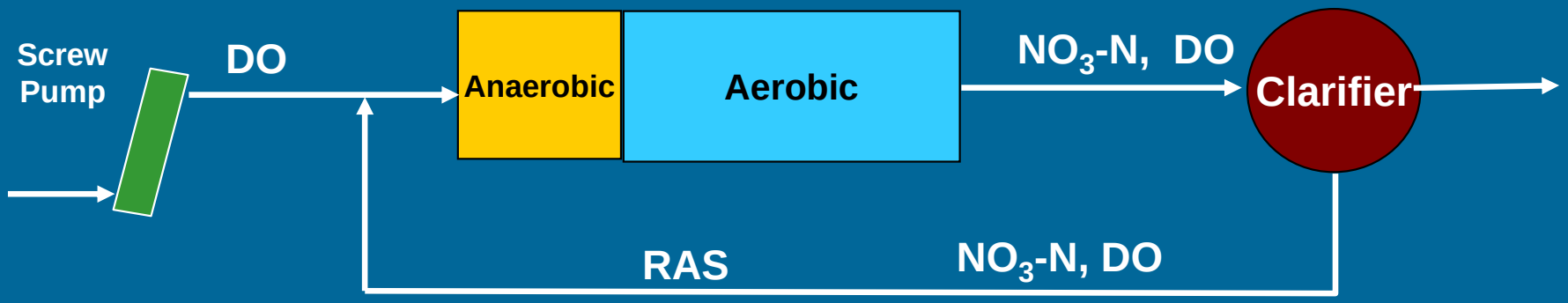
- Minimum requirements to achieve 1 mg/L efflux. TP:
  - cBOD: P 25:1
  - COD:TP 45:1
  - VFA:TP 10:1
  - rbCOD:TP 15:1

- Variable supply of VFAs stress the PAOs & delays recovery
  - Causes:
    - Excessive BOD removal in the primary clarifier
    - Wet weather flows & snow melts
    - High recycle P loads

Six Prerequisites for Reliable EBPR

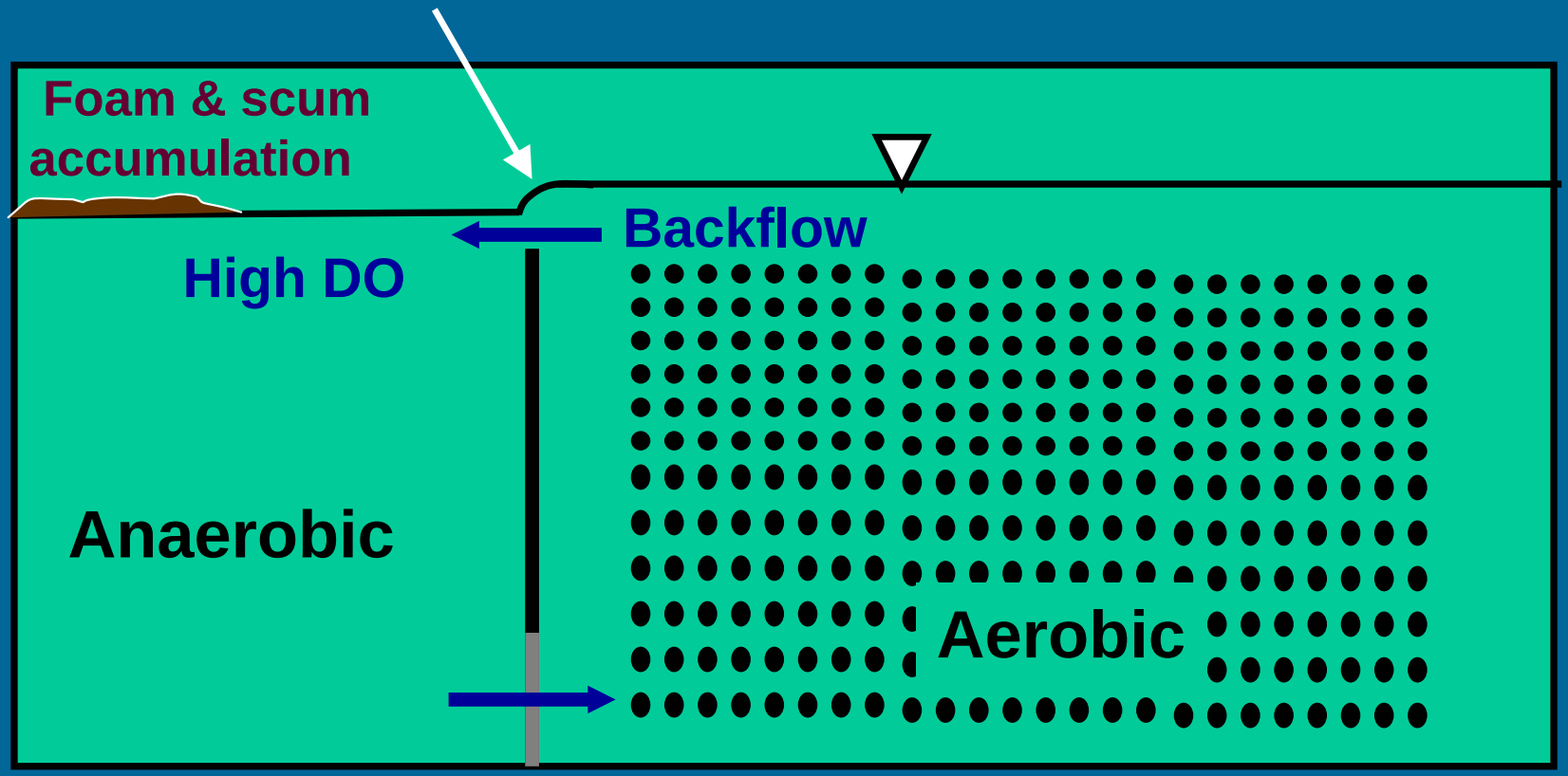
2. Integrity of Anaerobic Zone

- DO and NO_3 in anaerobic zone
  - Influent
  - RAS
  - Back mixing
  - Mixer too large



Backmixing

4” – 6” for 15’ SWD



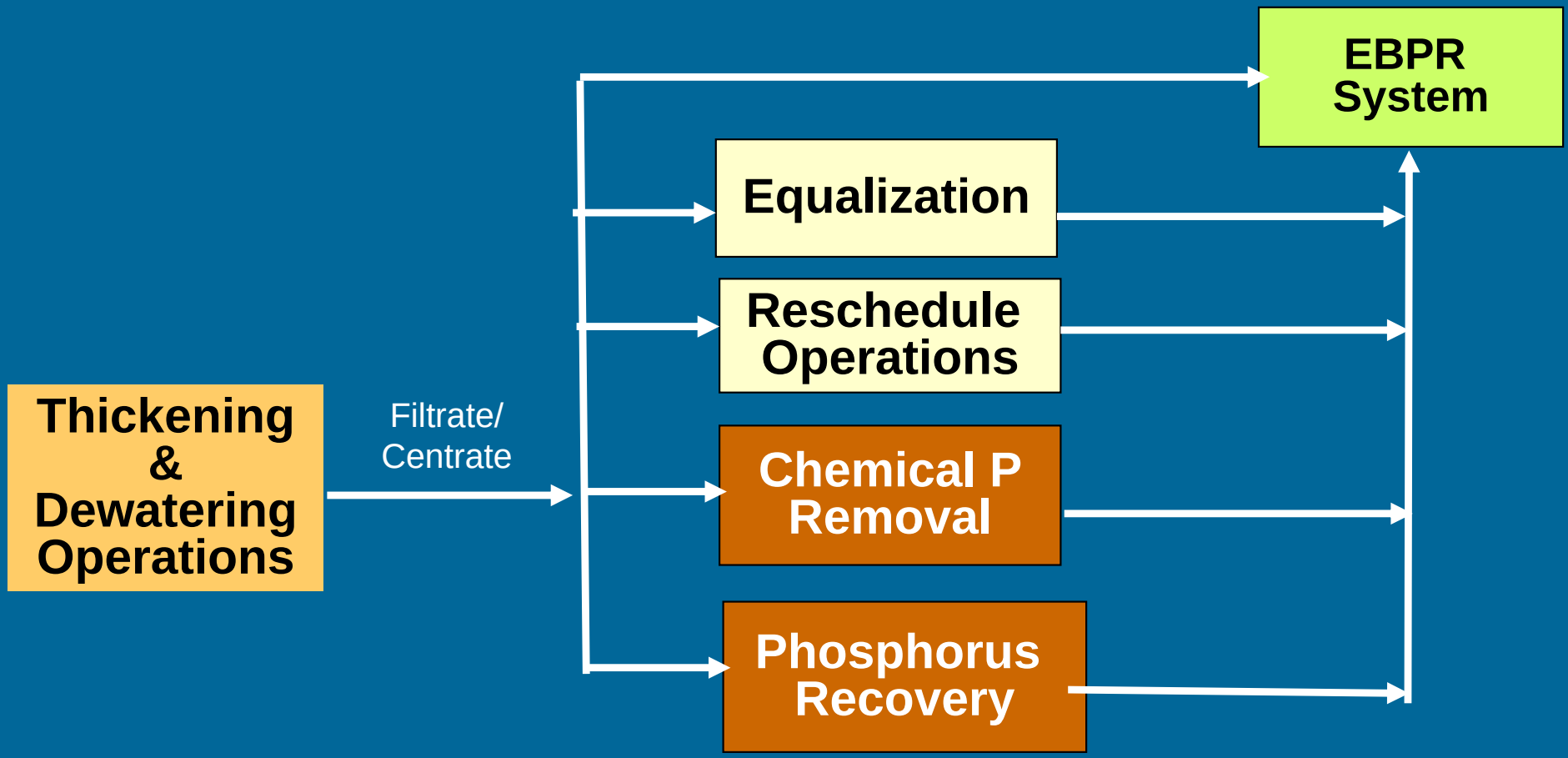
Six Prerequisites for Reliable EBPR

3. Minimize secondary P release

Conditions that favor secondary release

- Anaerobic conditions
  - Deep clarifier sludge blanket
  - Unaerated sludge storage
  - Co-settling PS & WAS in primary clarifier
  - Anaerobic digestion
- Long aerobic conditions
  - Aerobic zone too large
  - Long aerated sludge storage

All EBPR Plants must Have a Plan to Manage/Treat Recycle Loads

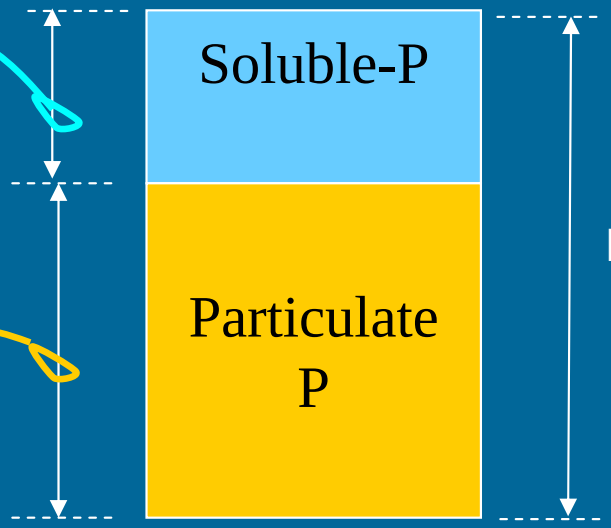


Six Prerequisites for Reliable EBPR

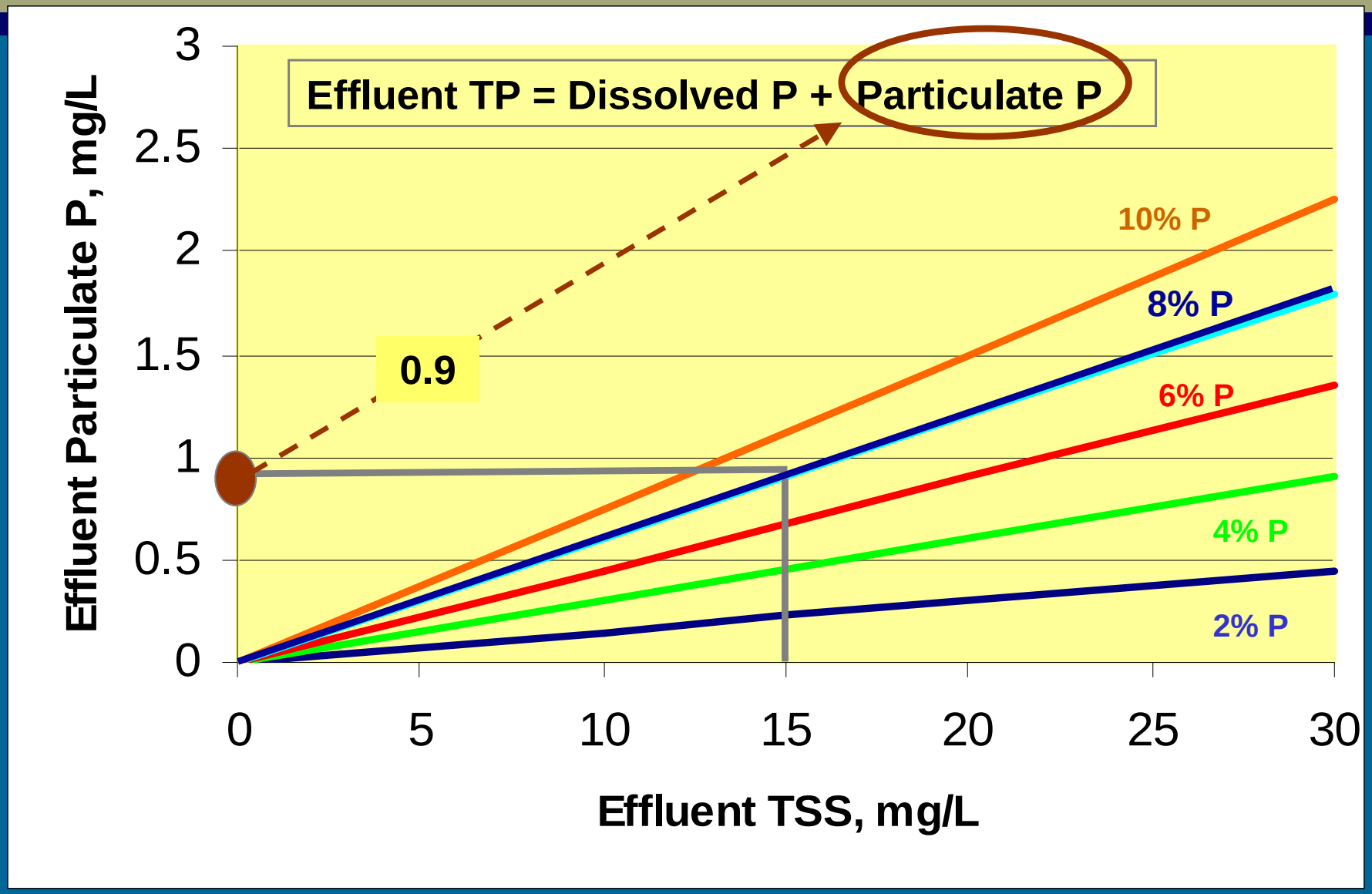
4. Maximize solids capture

Determined by EBPR or Chem-P removal efficiency

Determined by solids capture efficiency (clarifier & filter)



Importance of Tight Solids Control



Six Prerequisites for Reliable EBPR

5. Minimize Competition from Glycogen Accumulating Organisms (GAOs)

	Anaerobic	Aerobic
PAOs	• VFA uptake & storage • P Release	• Excess P Uptake • Stored food oxidized
GAOs	• VFA uptake & storage • No P release	• No excess P uptake • Stored food oxidized

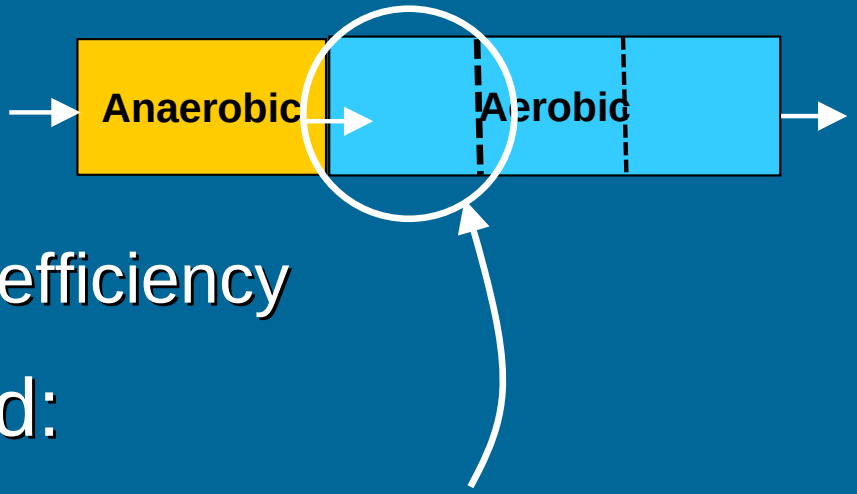
Adequate VFAs may not necessarily ensure reliable EBPR

Conditions Thought to Favor GAO Dominance

- Warm temperatures
- Long SRT
- Long Anoxic and anaerobic HRTs
- Variable supply of VFAs
- Continued use of acetic acid
- pH significantly less than 7

Six Prerequisites for Reliable EBPR

6. Aerobic zone design



- Staging increases EBPR efficiency
- Provide air where required:
  - Maintain high DO in the initial zone to satisfy high demand
  - Taper aeration in the subsequent zones

Presentation Outline

- Chemical Phosphorus Removal
- Enhanced Biological Phosphorus Removal (EBPR)
- **Take Home Messages**

Take Home Messages

- Chemical dose should be based on jar-testing
- Poor mixing is often the cause of excessive chemical dose
- Avoid indiscriminate use of chemical to supplement EBPR
- Iron salts can lower UV transmittance
- Chemical addition increases the inert fraction of the MLSS requiring higher MLSS
- P removal continues even after chemical feed is terminated due to residual chemical in the RAS.

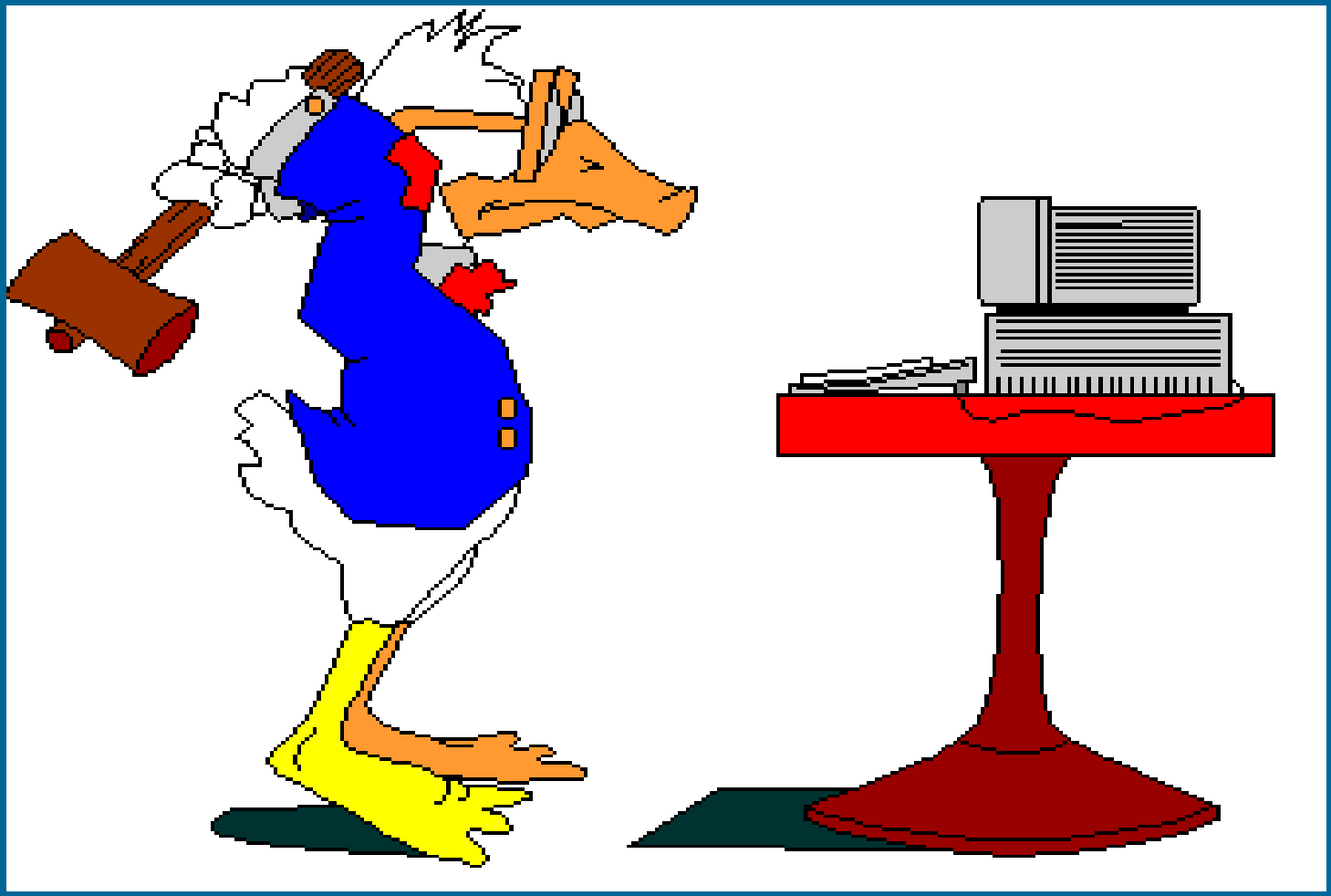
Take Home Messages

- Six key factors impact EBPR
  1. Adequate VFAs
  2. Integrity of the aerobic zone
  3. Secondary release
  4. Solids capture
  5. Microbial competition (GAO)
  6. Air distribution

Decreasing order of importance

- EBPR entails complex microbial interaction.
  - Designers – provide operational flexibility
  - Operators - use operational flexibility provided.
- Eliminate solids handling bottlenecks
- Use process automation judiciously
- *It's a spider web out there!*

Questions?



Safety matters in <u>everything</u> we do!

MALCOLM PIRNIE