Sludge Minimization
A Paradigm Shift in Sludge Management

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Our Profession Will Continue to be Fueled by Paradigm Shifts

Dr. John Snow

Broad Street Pump

Broad Street Pump Today

Presentation Outline

- Key Drivers
- Background
- Sludge Minimization at the Source
- Sludge Minimization ‘After the Fact’
- Sustainability Perspective
- Summary

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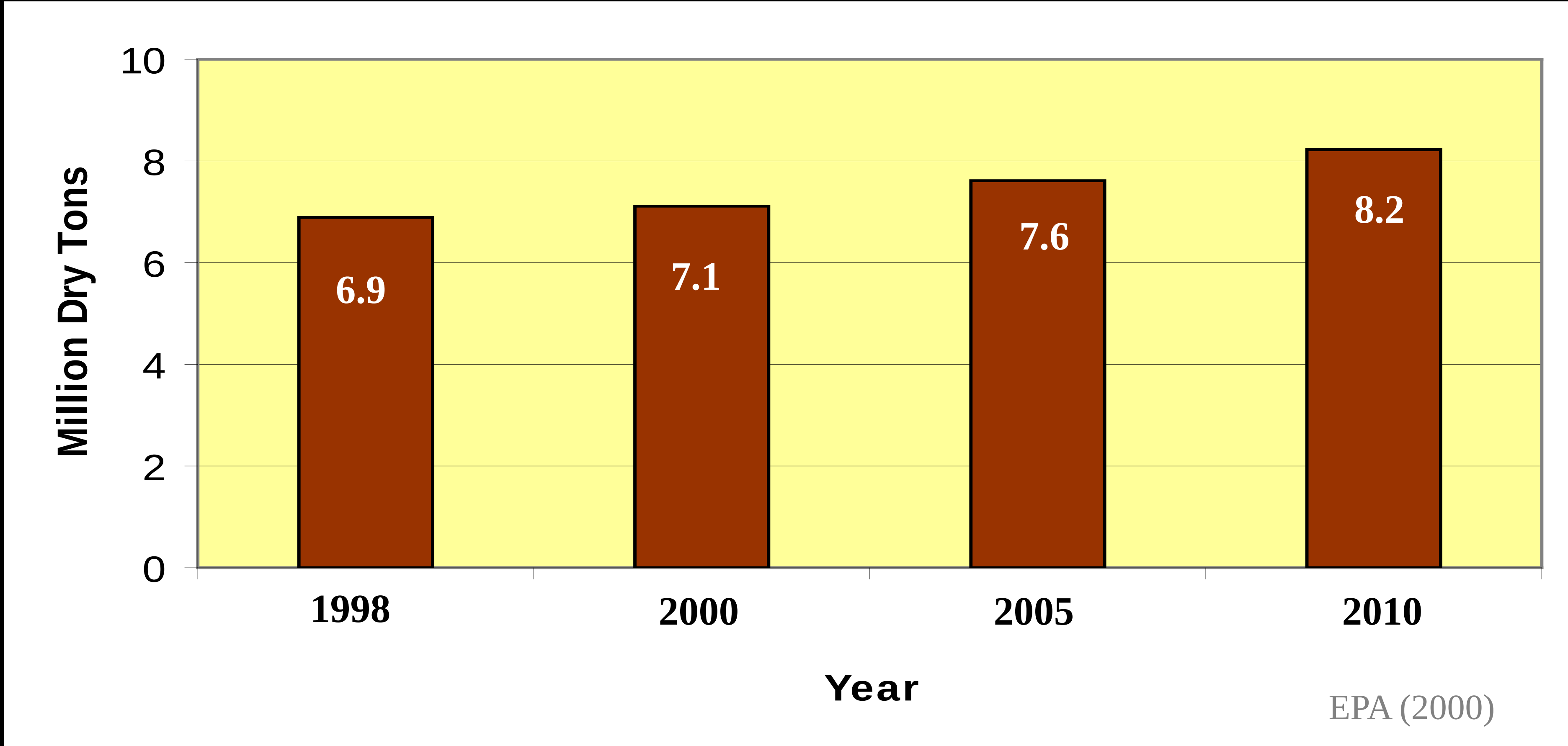
Key Drivers for Sludge Minimization

- Steadily increasing sludge production (500-800 lb dry weight per million gallons treated)
- Sludge operations represent >50% of a plant's O&M cost



Key Drivers for Sludge Minimization

- Three primary disposal alternatives
  - Land application (51%)
  - Landfilling (38%)
  - Incineration (11%)
- All three face varying degrees of pressures
  - Land application costs are escalating
  - Landfill availability is rapidly declining
  - Regulatory controls are increasing
  - Closer public scrutiny (NIMBY)

It is clear that we cannot keep doing the same thing and expect a different answer.

Benefits of Sludge Reduction

- Reduce costs (capital and O&M) in sludge processing and ultimate disposal/reuse.
- Optimize energy use
- Reduce carbon footprint

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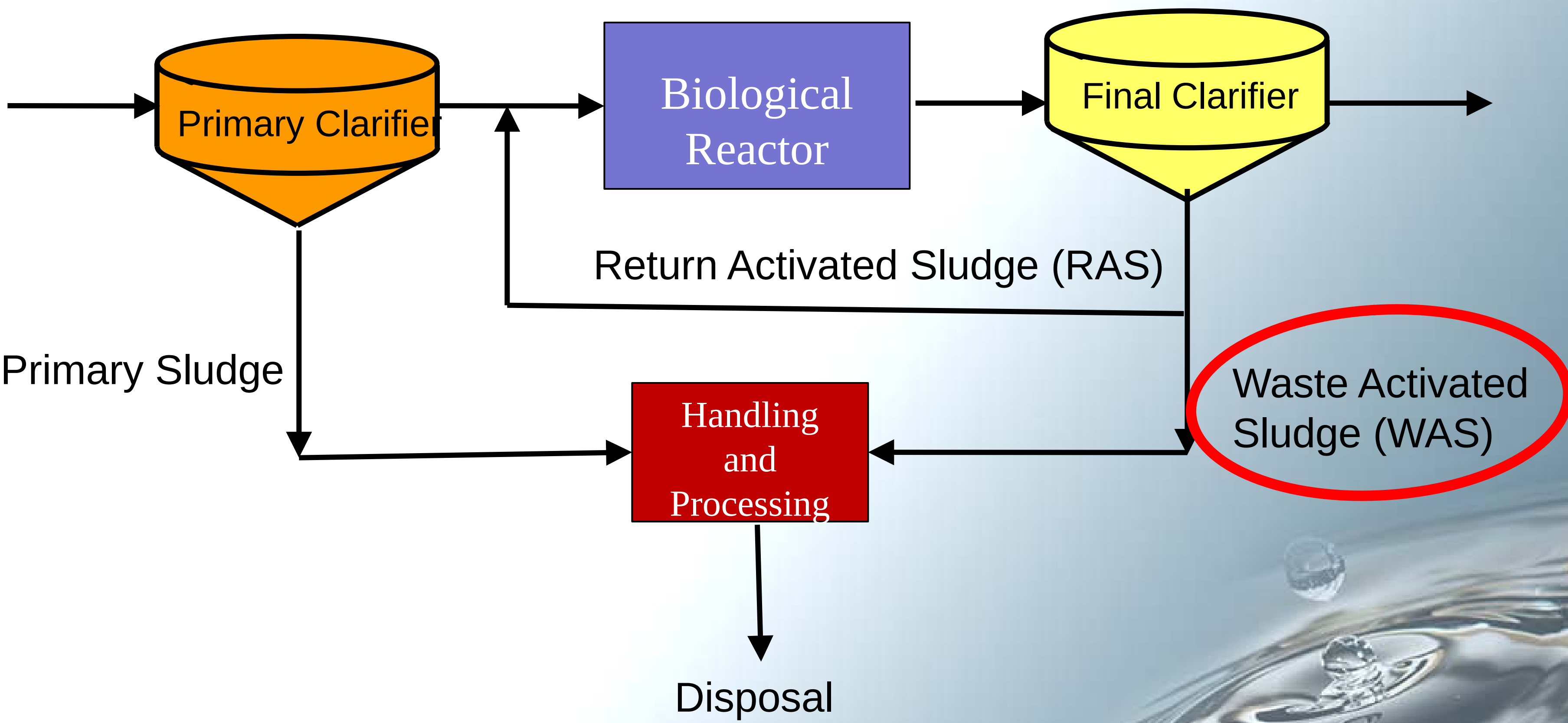
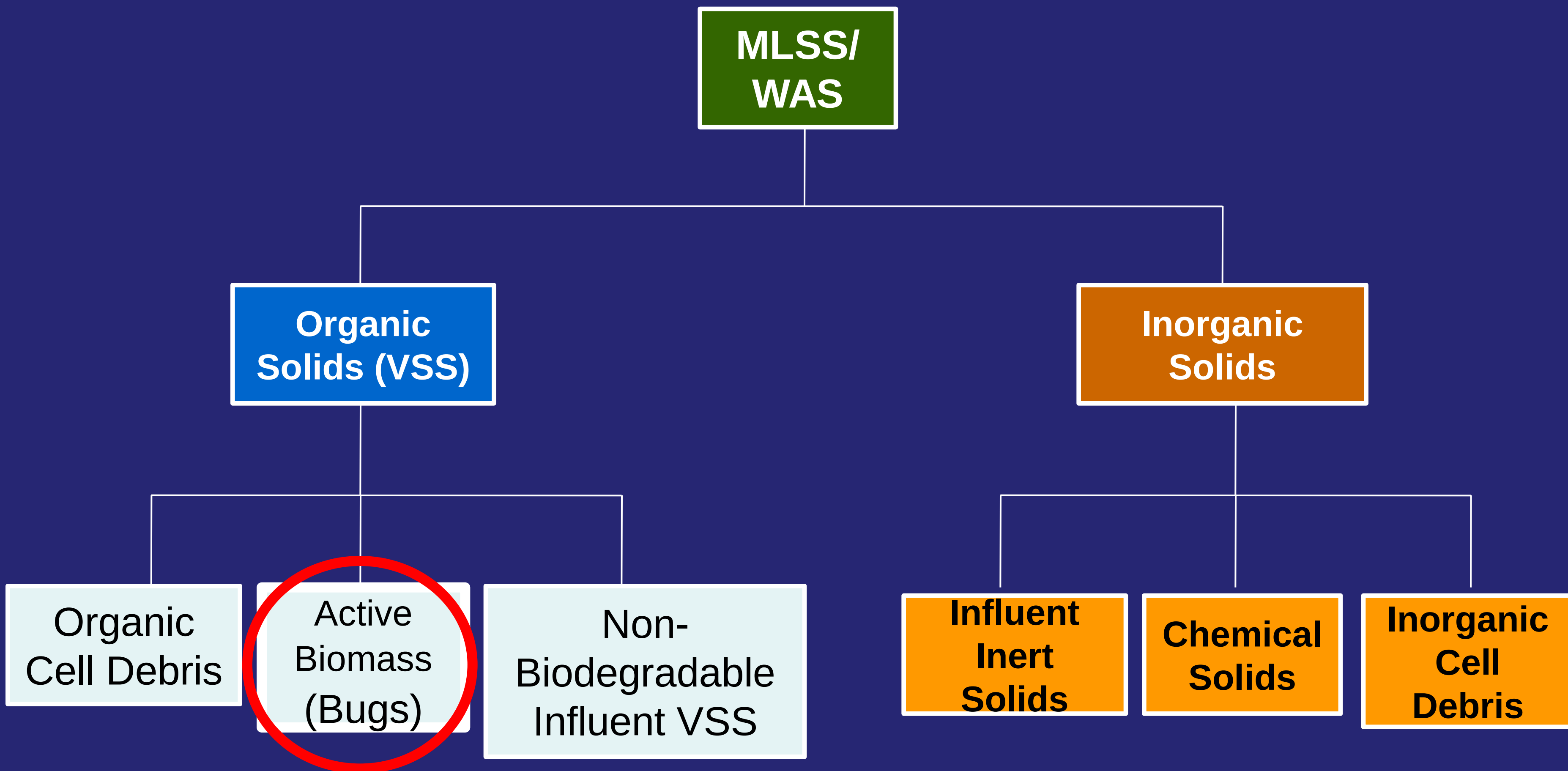
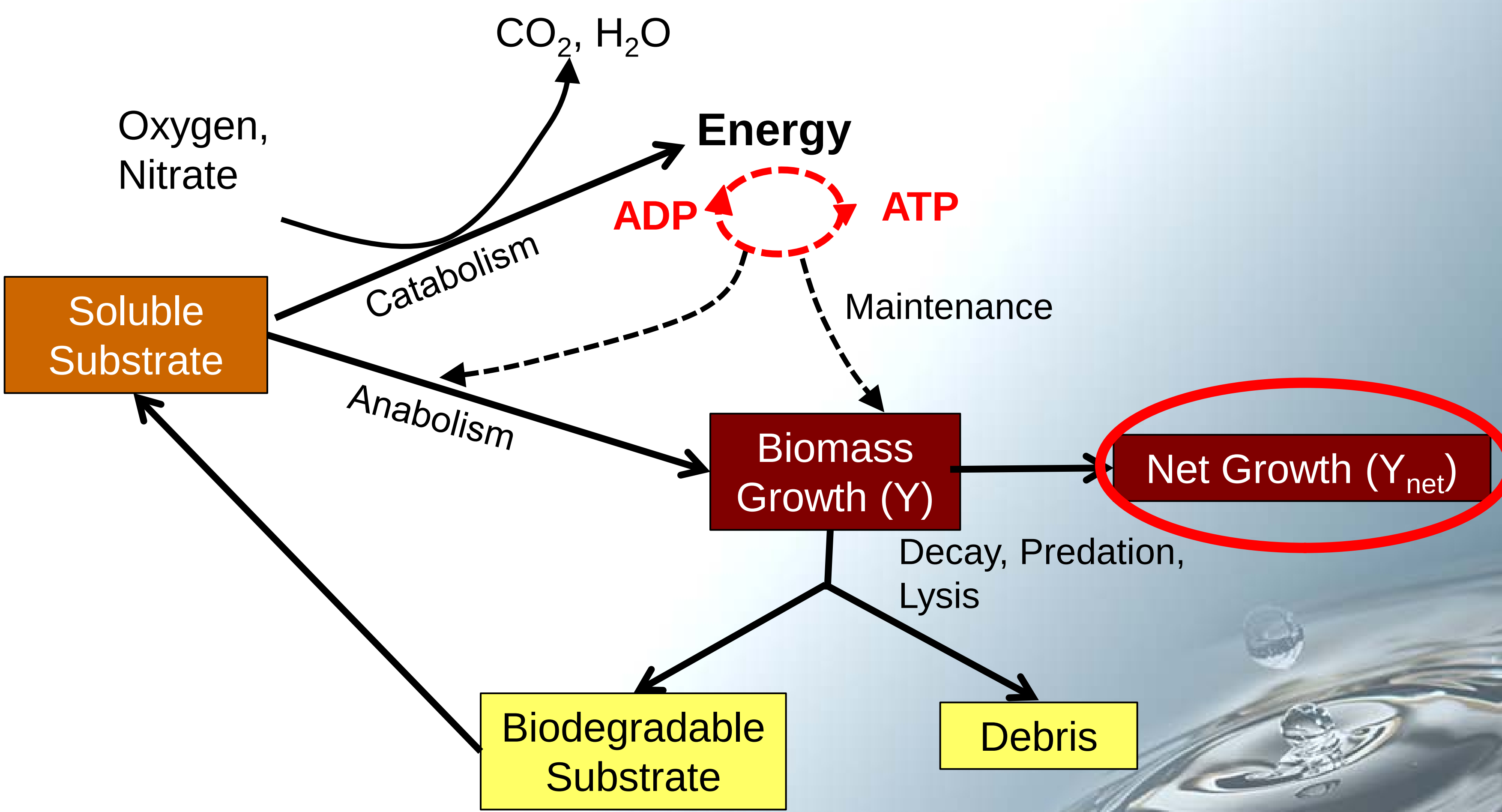
Sources of Sludge



What's in Your WAS?



Sludge is the 'Undesired' End Product of the Biological Process



Net or Observed Growth (Yield)
(Sludge Production)

Actual growth

$$Y_{net} = \frac{Y}{K_d * SRT} + (\text{Cell Debris}) + (\text{Inert solids}) + \ldots..$$

Endogenous
Decay Coefficient

Solids Retention
Time

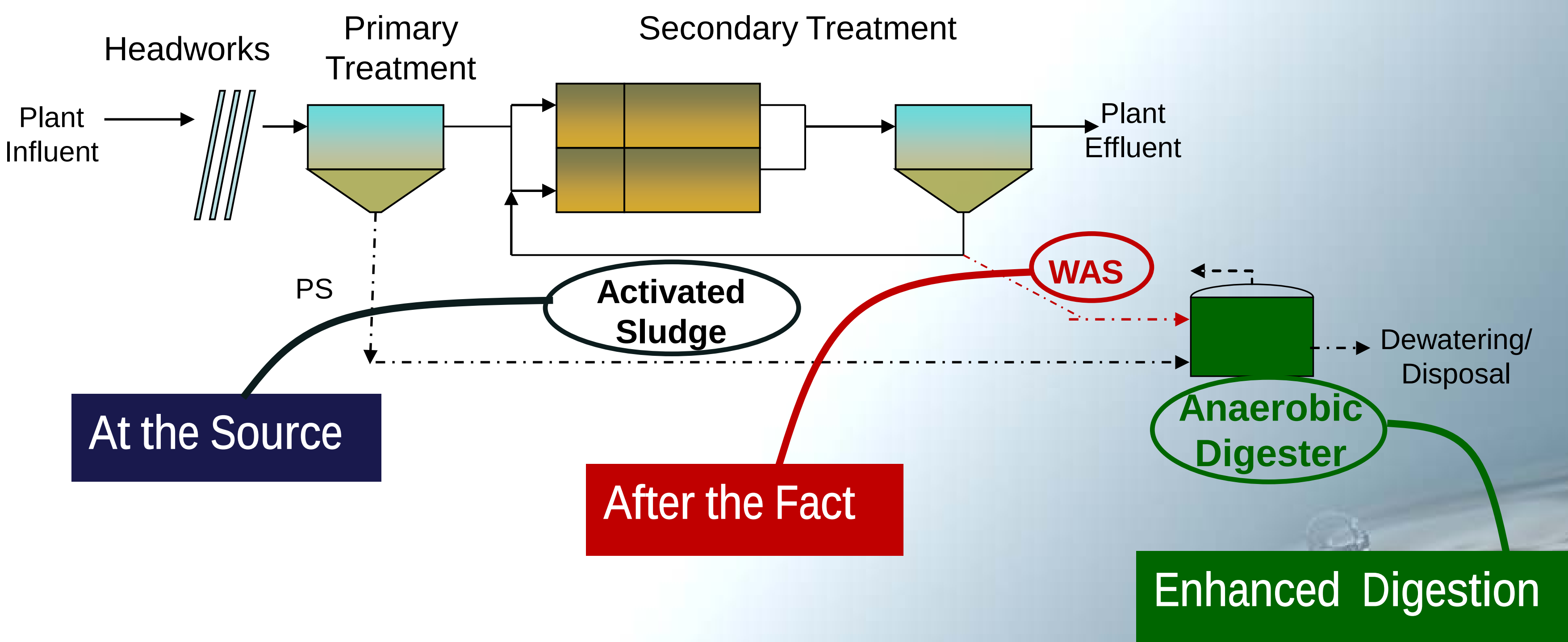
Biomass or Bugs

Sludge Reduction Technologies

Marketplace is actively responding to the paradigm shift. Available technologies can be classified based on:

- Location
  - At the source
  - After the fact
  - Enhanced digestion
- Process mechanism
  - Biological
  - Chemical
  - Physical

Based on Location



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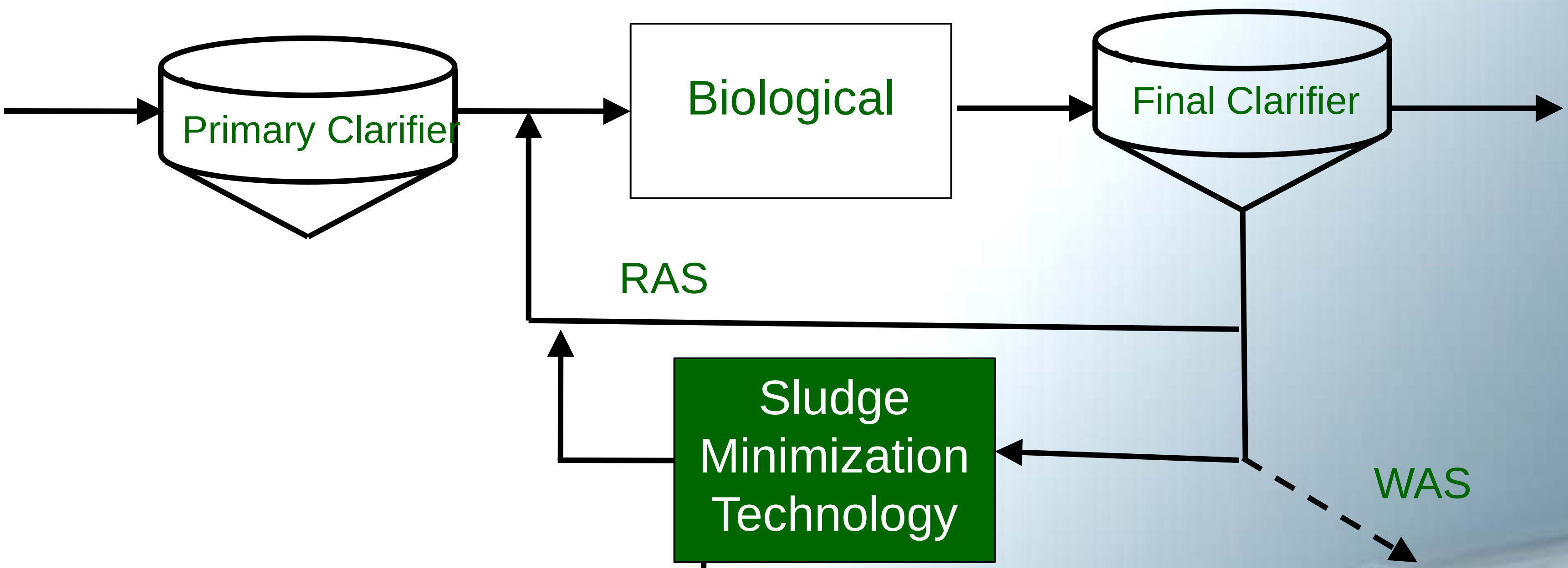
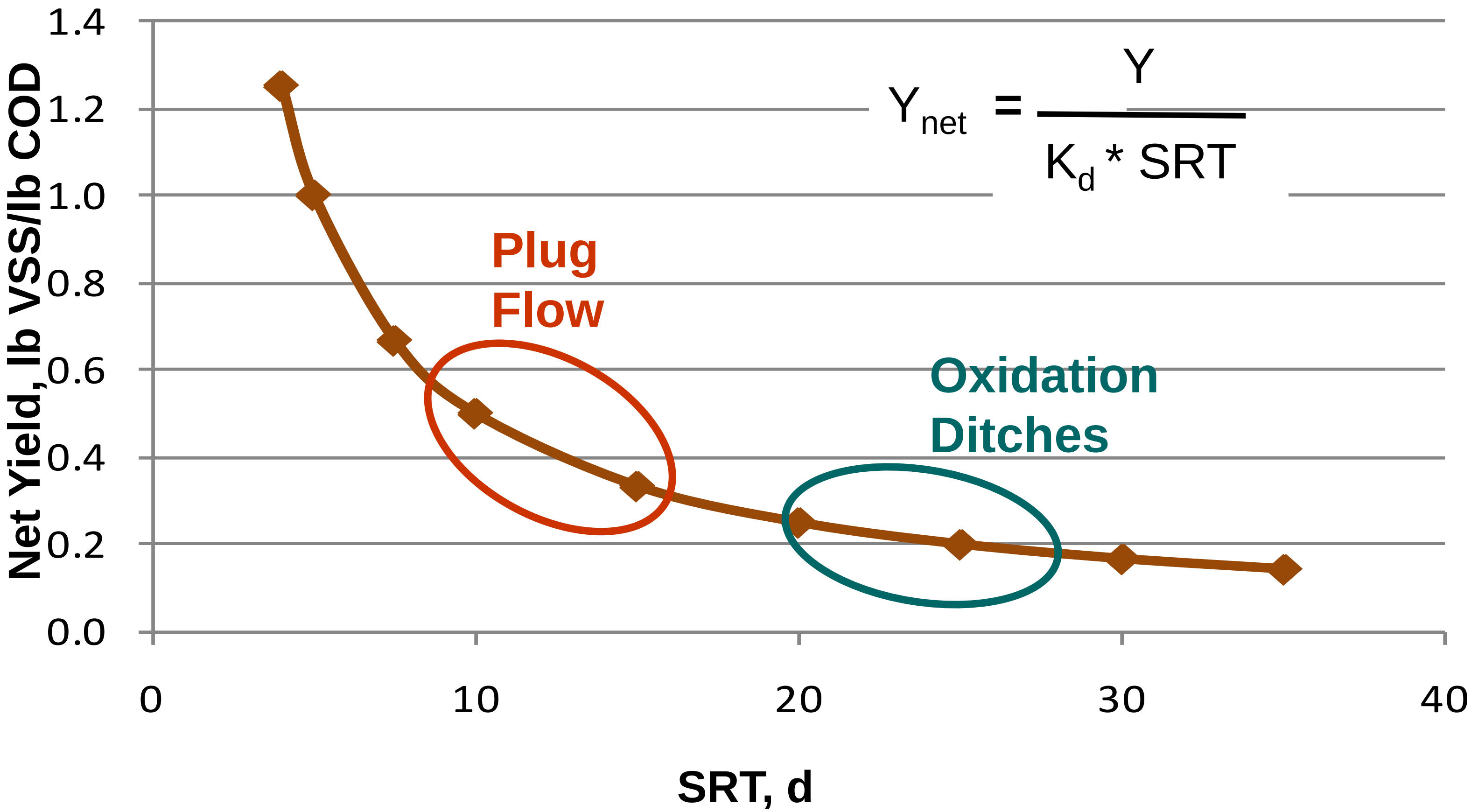
Sludge Reduction at the Source



- **Extended Aeration**
- **Cannibal**
- **Ozonation**

Extended Aeration



Cannibal^{TM} Process

- Been in operation since 1998
- Siemens licensed the technology in 2003
- In operation: 10 plants. Largest: 16 mgd
- Entails 2 mechanisms:
  - Physical separation of inert materials and grit
  - Biological process

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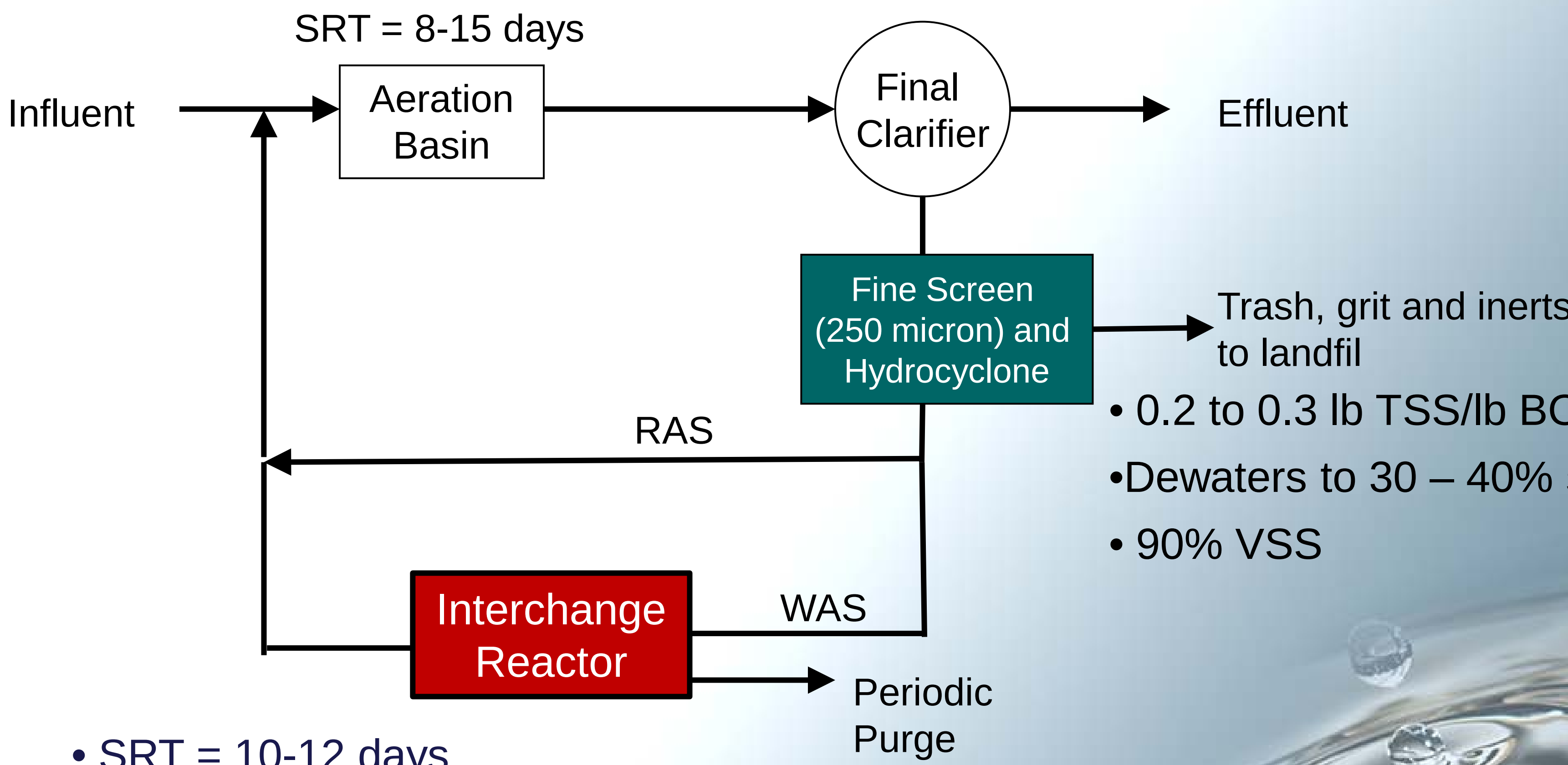
Typical Cannibal™ Process Flow Scheme



- 0.2 to 0.3 lb TSS/lb BOD
- Dewaters to 30 – 40% solids
- 90% VSS

- SRT = 10-12 days
- MLSS = 10,000 mg/L
- Low/no DO conditions

0.1 lb TSS/lb BOD

Cannibal Process – Biological Step

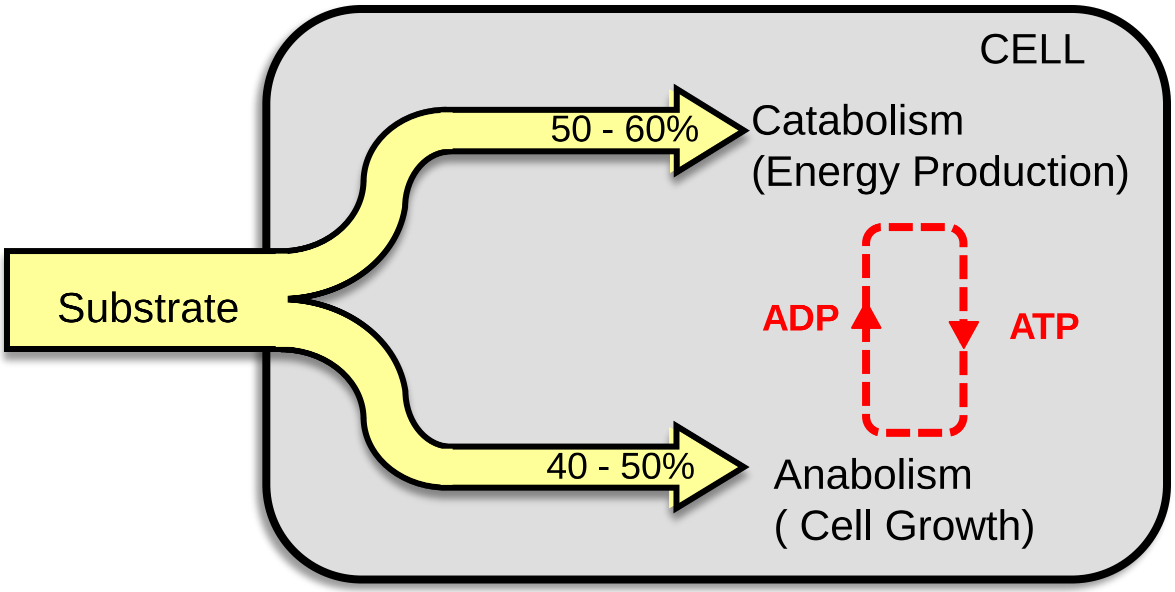

Interchange Reactor

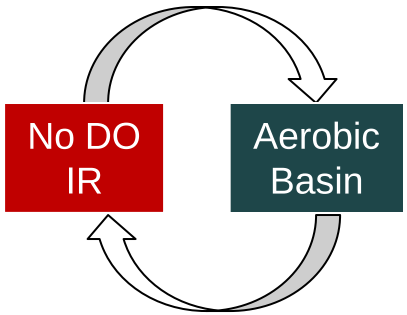
- Builds on the extended aeration concept
- Interchange Reactor operated on the cusp of anaerobic/anoxic conditions
- Several biological processes act in combination to reduce sludge production
  - Cycling between aerobic & low/no DO conditions selects organisms with low yield
  - Long SRT
  - Predation
  - Decay and lysis

$$Y_{net} = \frac{Y}{K_d * SRT}$$

Cannibal Process – Biological Step
(Chudoba et al. 1992)

- Anabolism and catabolism are closely coupled during aerobic metabolism





- Low/no DO interchange tank acts like a ‘speed bump’
  - Shock and starvation conditions – no oxygen, no substrate
  - ATP (energy reserve) consumed
  - Catabolism and anabolism are uncoupled
- In the aeration tank, substrate used to restock ATP and less used for growth
- Low DO - High DO sequencing selects organisms with low yield

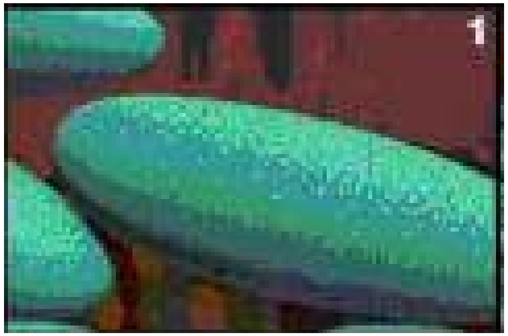
Cannibal System

- Proven technology-several full scale applications
- Relatively large interchange tank needed – may not be cost effective for large facilities
- Issues with phosphorus mass balance remain unresolved
- May not be compatible with biological phosphorus removal

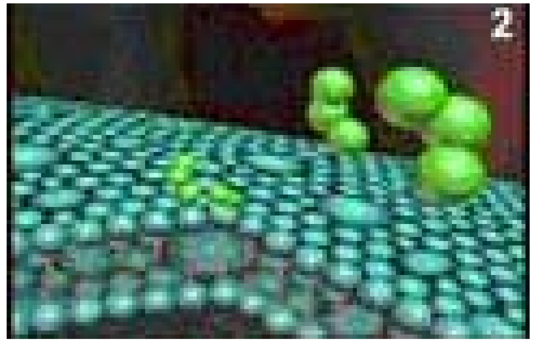
Ozonation

- Mechanisms involved
  - Solubilization of sludge solids and cell lysis cause an increase in the <u>rate</u> of degradation
  - Renders the non-degradable organic fraction degradable, thereby increasing the <u>extent</u> of degradation
- Solids that would otherwise contribute to sludge production are degraded resulting in sludge reduction

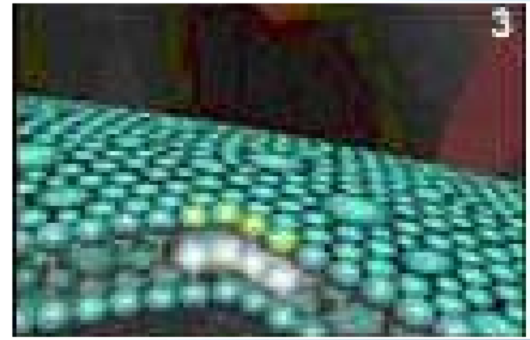
Cell Lysis Caused by Ozonation



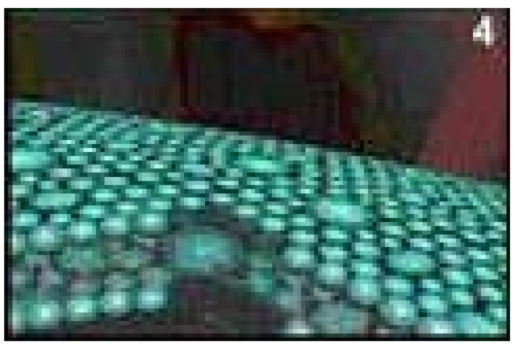
Bacterial cell to be ozonated



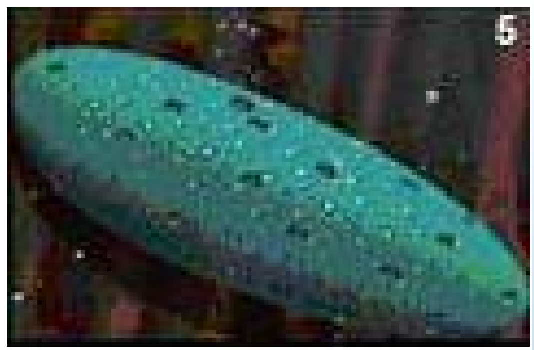
Ozone contacts cell wall



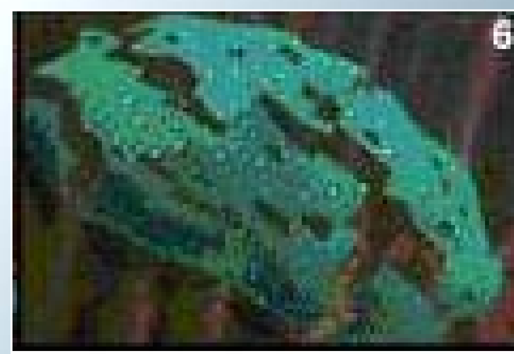
Ozone penetrates cell wall



Ozone oxidizes cell wall causing lysis



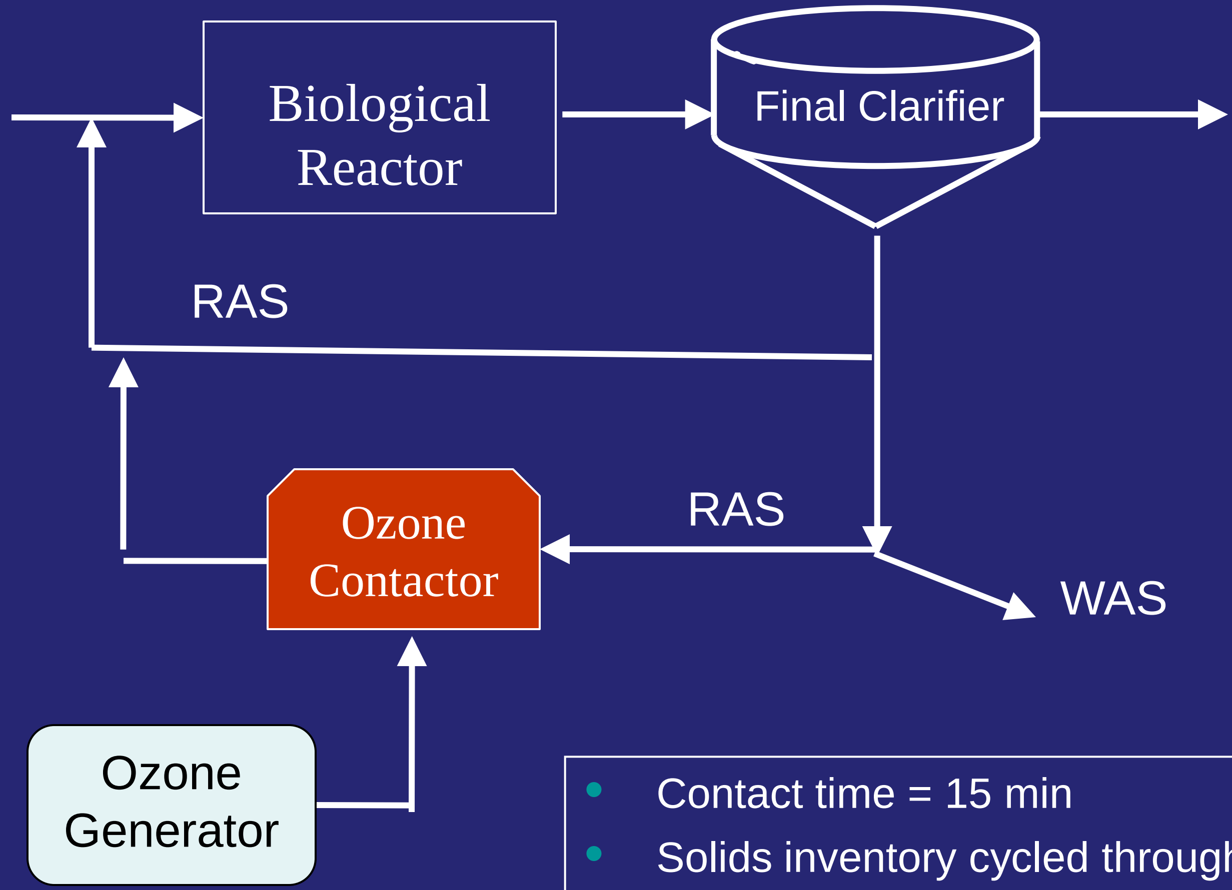
Cell with lysis ‘pockets’ after contact with ozone



Weakened cell wall ruptures in aeration basin

Praxair Technology

Ozonation



- Contact time = 15 min
- Solids inventory cycled through the contactor every 3-4 days
- Ozone dose: 0.05 – 0.4 g O_3/g TS red

Ozonation

- Solids reduction reported: 30-70%
- Side benefits
  - Filament control - avoid bulking and foaming
  - Lower SVIs - improved settleability
- Higher oxygen demand in aeration basin
- Require on-site ozone generation
- May not be compatible with biological phosphorus removal

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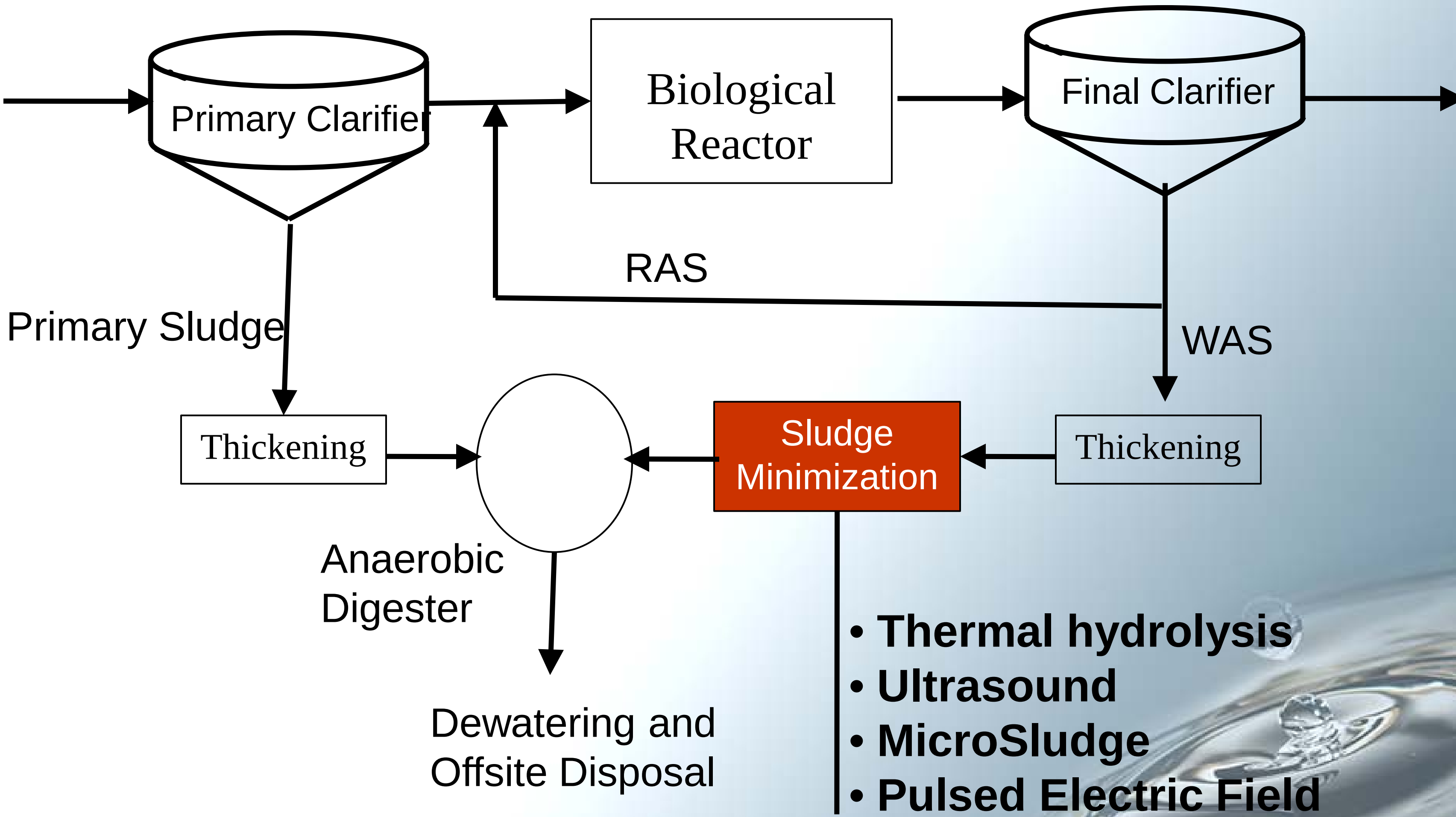
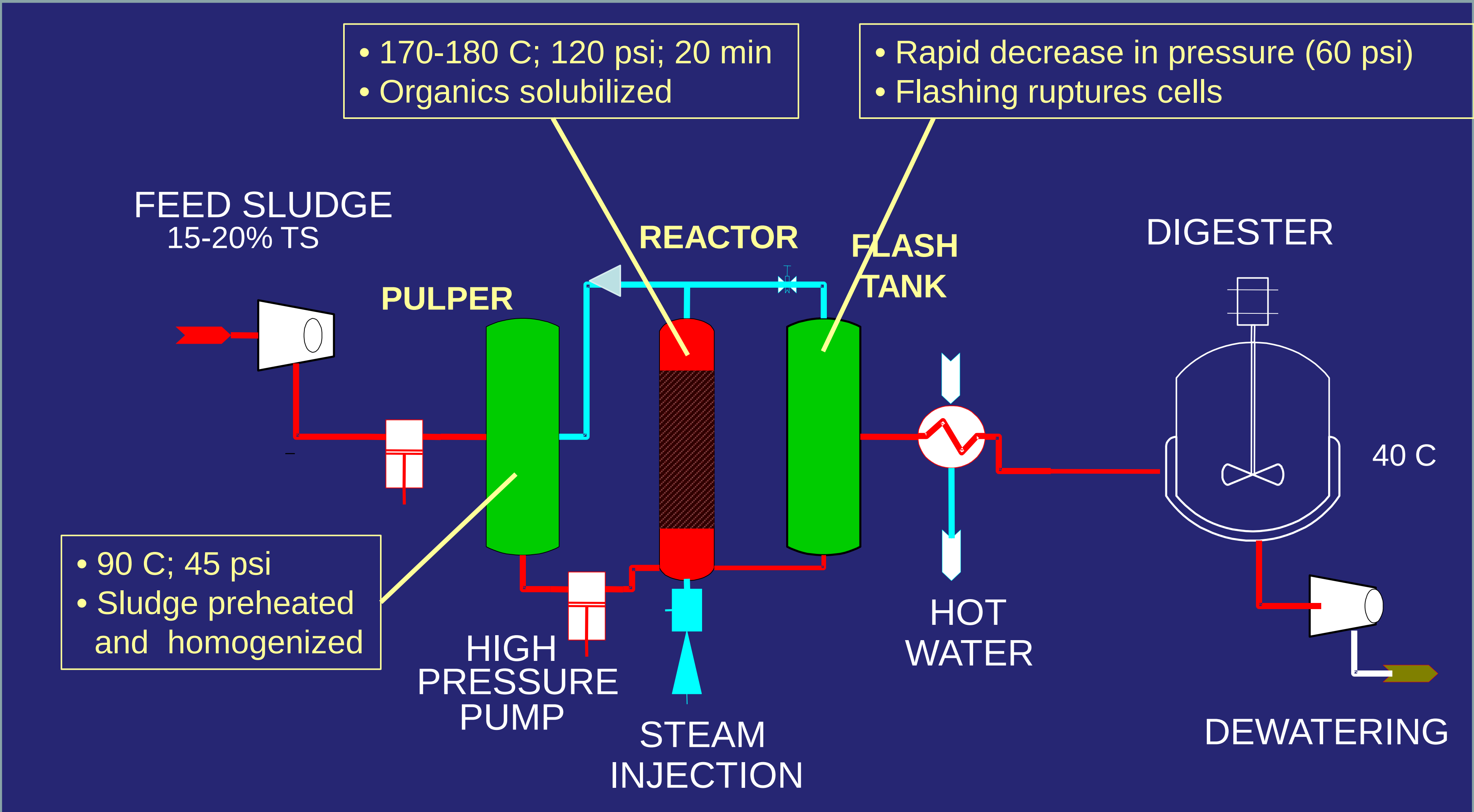
'After the Fact' Approaches



The Goal is to Increase WAS Biodegradability

- WAS is slowly biodegradable during anaerobic digestion
  - Cell wall is like a walnut shell
  - The initial hydrolysis process (shell rupture) is rate limiting
- WAS biodegradability can be increased by pretreating digester feed
- Increased biodegradability means:
  - Increased VSS reduction
  - Increased methane production
  - Reduced biosolids to offsite disposal

Thermal Hydrolysis (Cambi)

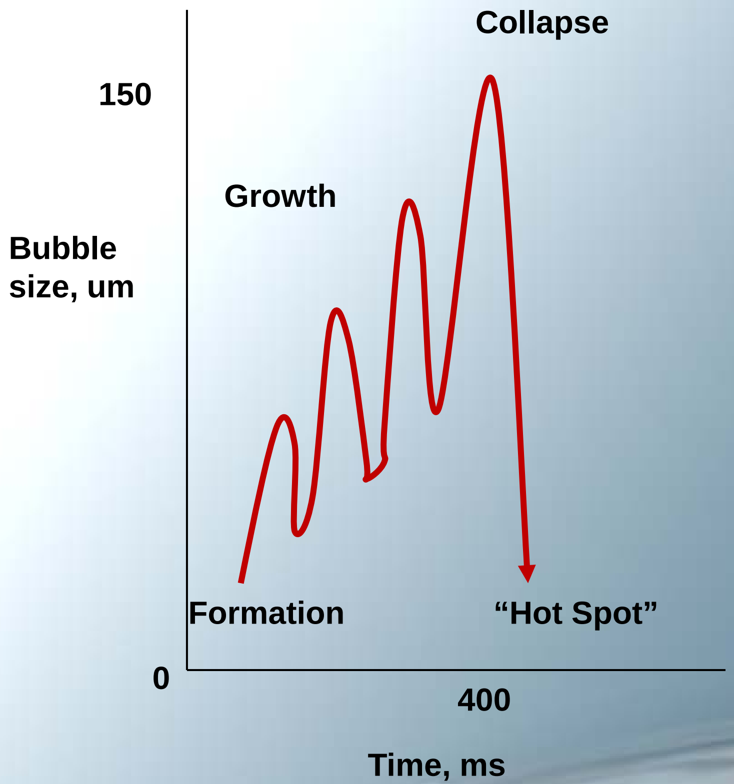


Thermal Hydrolysis (Cambi)

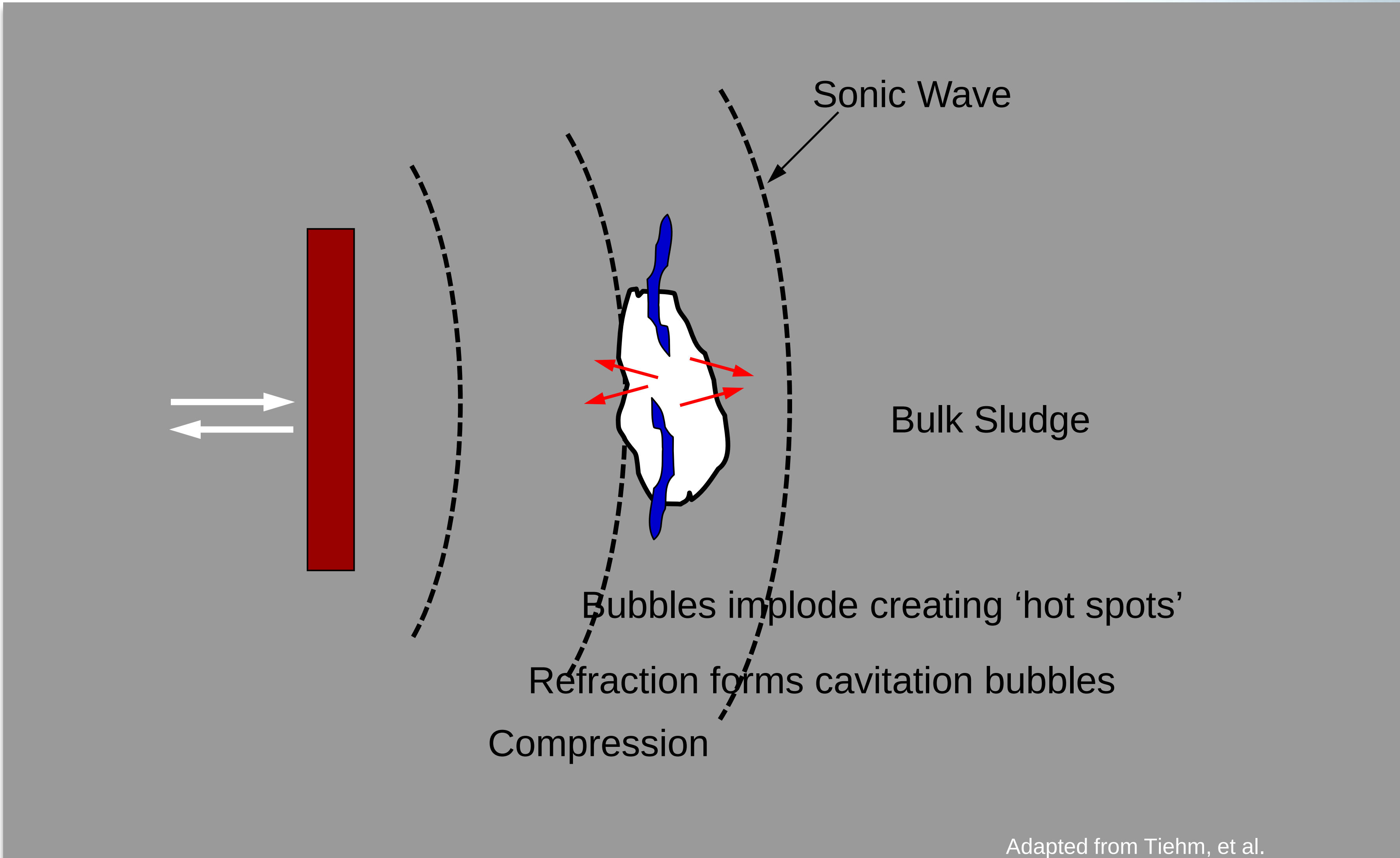
- Several full scale operations in Europe
- Blue Plains, Wash DC – First US installation, largest in the world. Operational in 2012.
- Smaller digester volume:
  - Homogenized feed - lower viscosity. Higher solids concentration in digester (15%).
  - Higher volumetric loading rate
- VS reduction: 55 – 65%
- Class A biosolids
- Dewatered cake: 30 – 35% TS

Ultrasound

- Sound frequency: 20 – 40 kHz
- Human threshold: 18 kHz
- Mechanism:
  - Formation, growth and collapse of microbubbles
    - Hot spots created
    - 4,700^{0}C; 7,250 psi
    - Jet stream velocities of 250 mph.
  - Causes cell rupture

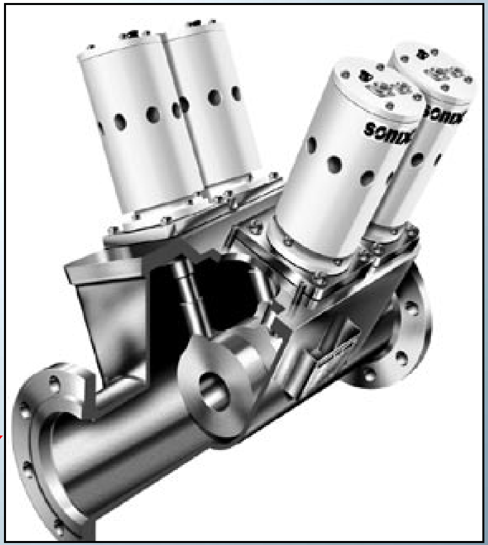


Ultrasound – How it works

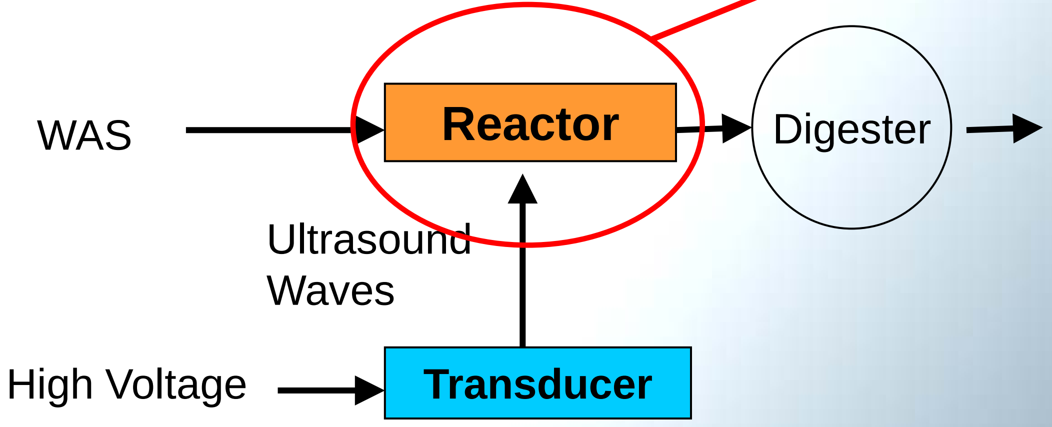


Ultrasound

- Small footprint
- Sludge reduction claimed: 20-50%
- Filament control achieved
- Improved SVI and settleability
- Improved dewaterability

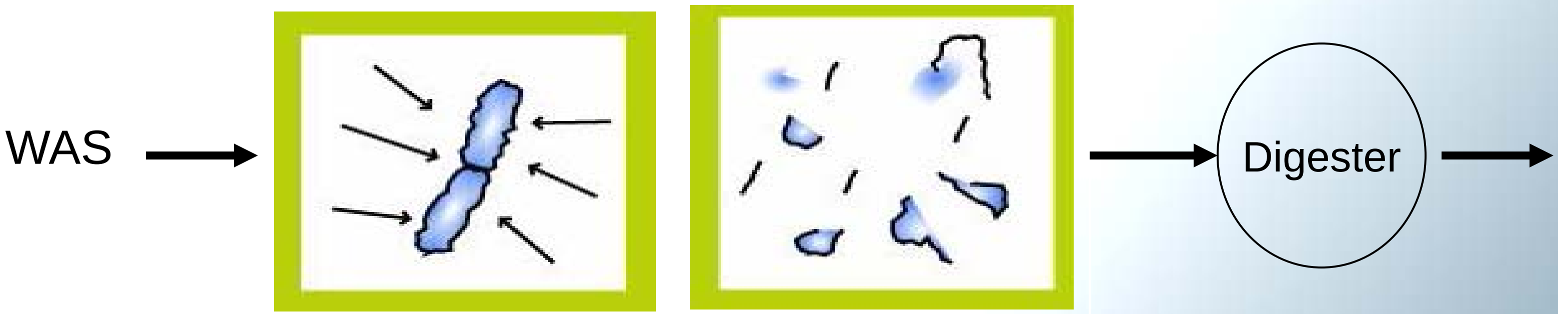


Sonico Ultrasound Horn



MicroSludge Process

MicroSludge Process



<u>Chemical/Physical Treatment</u>

- **pH: 9-10**
- **Weaken cell wall**
- **Mechanical sheer**

<u>High Pressure Homogenizer</u>

- **12,000 psi**
- **Cell rupture**

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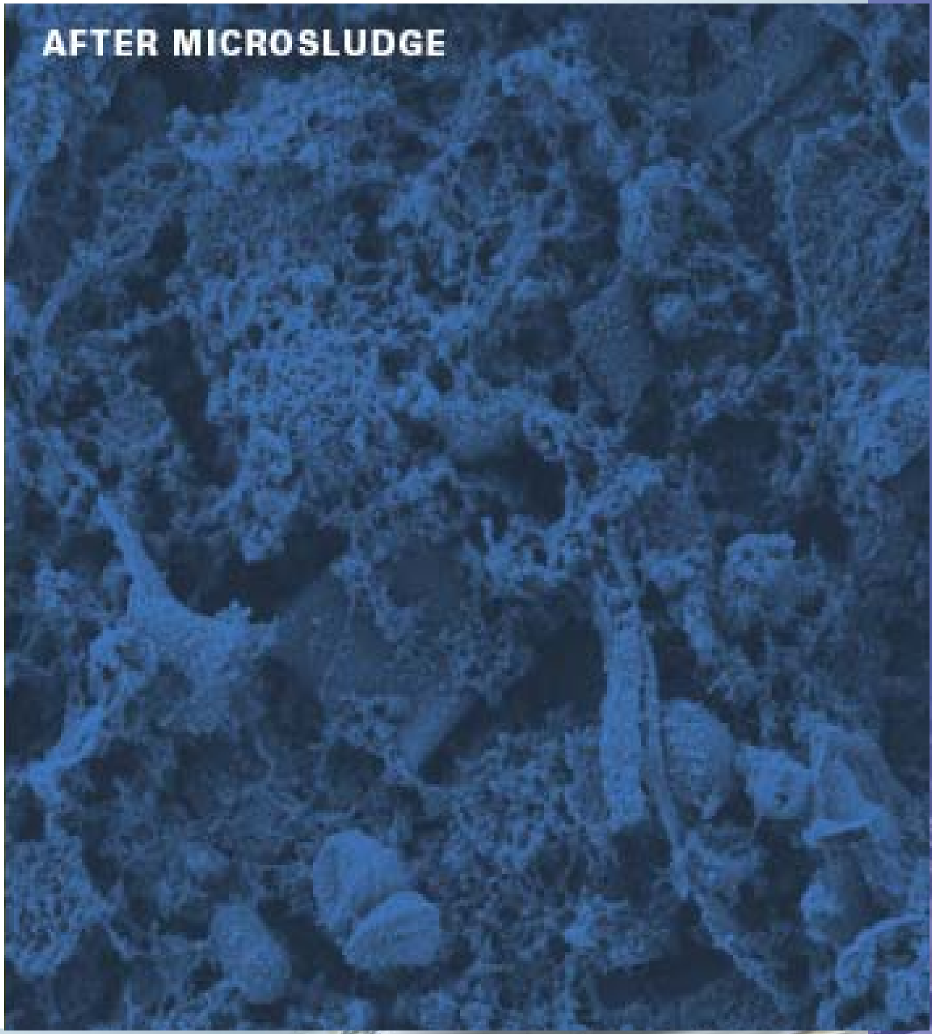
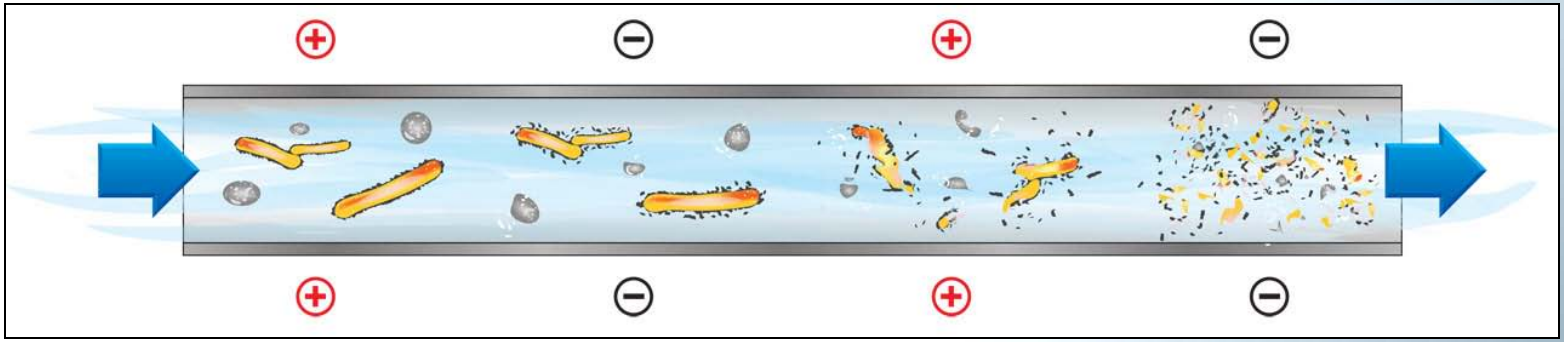
Impact of MicroSludge Pretreatment

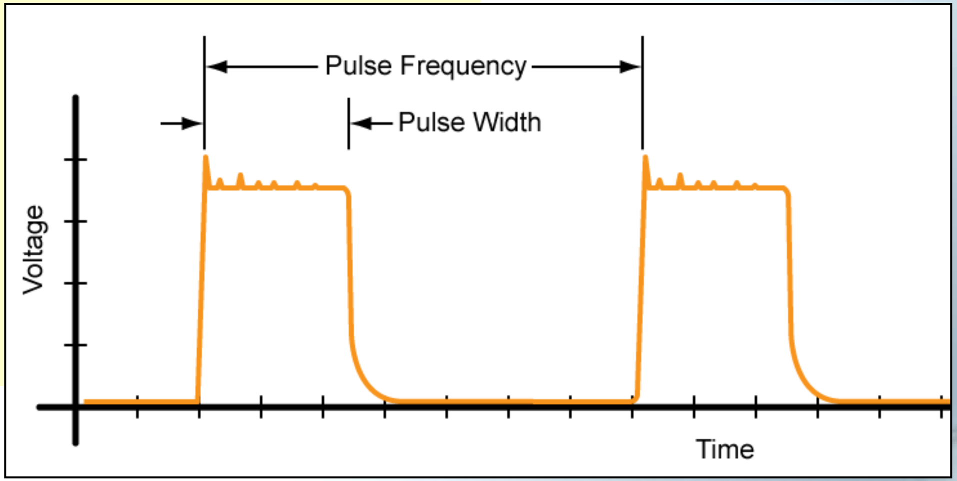


Pulsed Electric Field

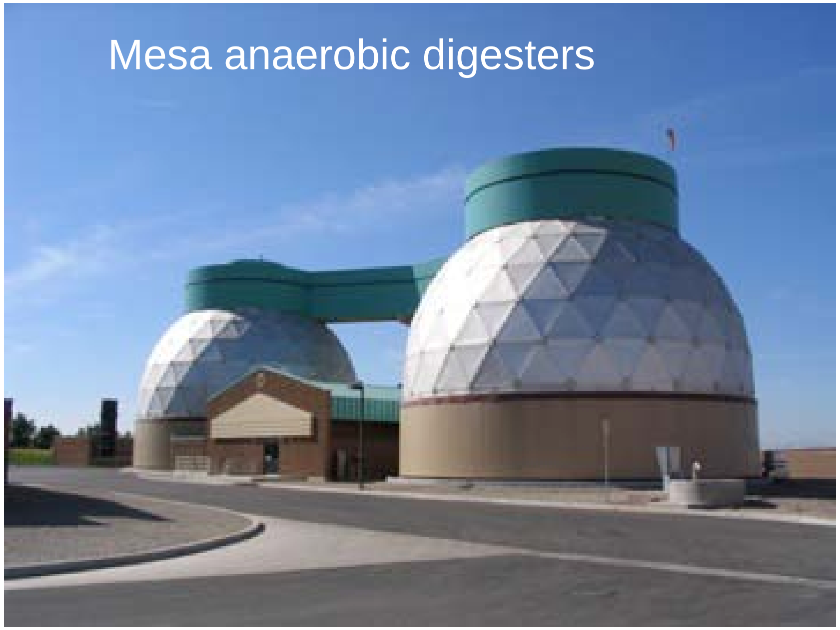
- Sludge is exposed to electric pulses:
  - High voltage and high frequency microbursts of conditioned electricity
- Application of electrical energy results in breaching of the cell membrane leading to:
  - Cell inactivation
  - Cell lysis
  - Release of intracellular material

Pulsed Electric Field – How it Works





Full-Scale Installation at Mesa, AZ



Operating data:

- Plant flow: 10-12 MGD
- Thickened PS/WAs mixture 50,000 - 60,000 gpd
- Solids content: 4 - 6%
- In operation since Sept. 2007

Performance data:

- Greater than 10% increase in VS reduction
- Increase in methane by 55-60%
- Sludge treated with pulsed electric field is a potential carbon source for denitrification

Enhanced Digestion

- Thermophilic
- Acid/Gas Phase
- Anaerobic-Aerobic

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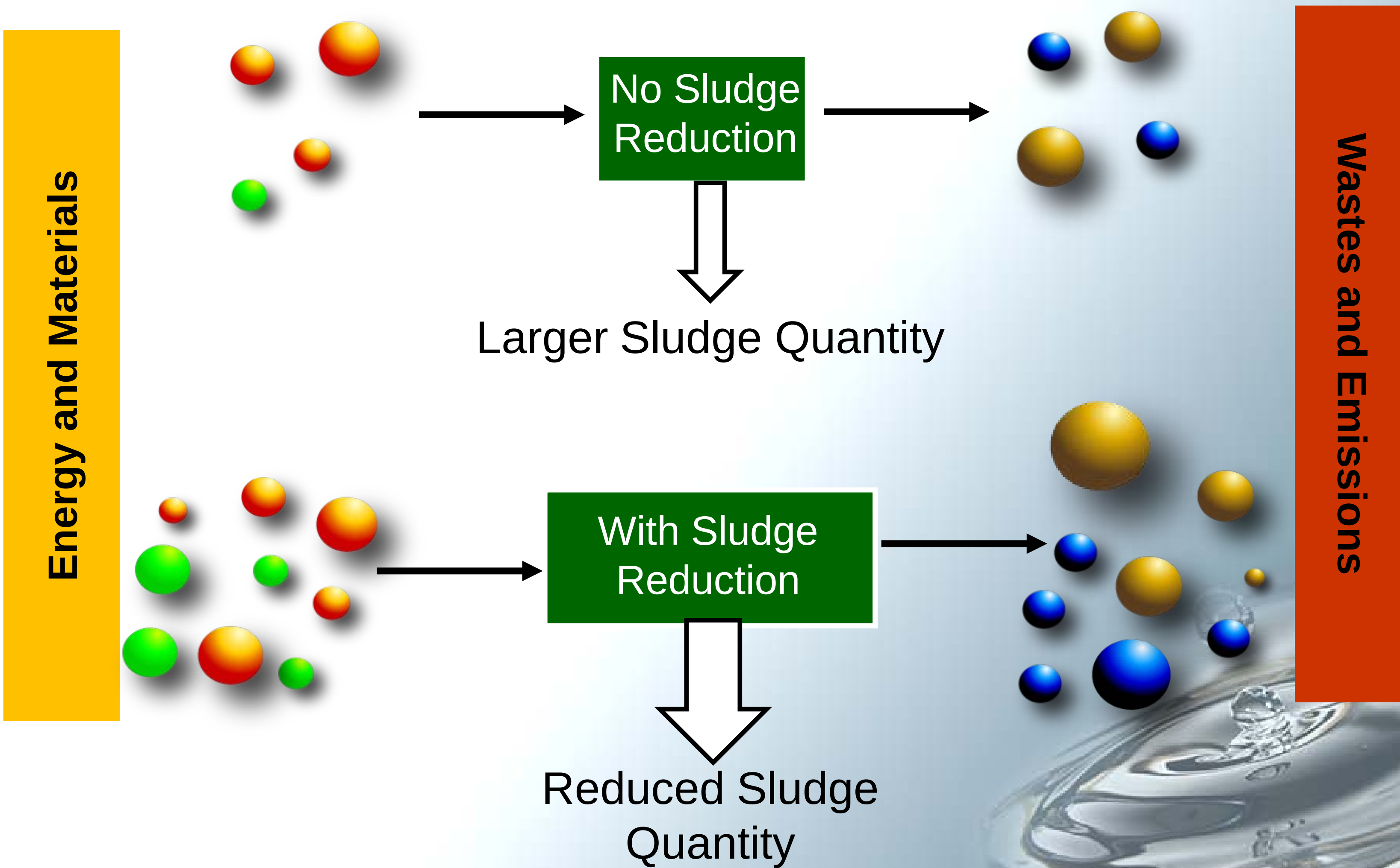
Life Cycle Analysis

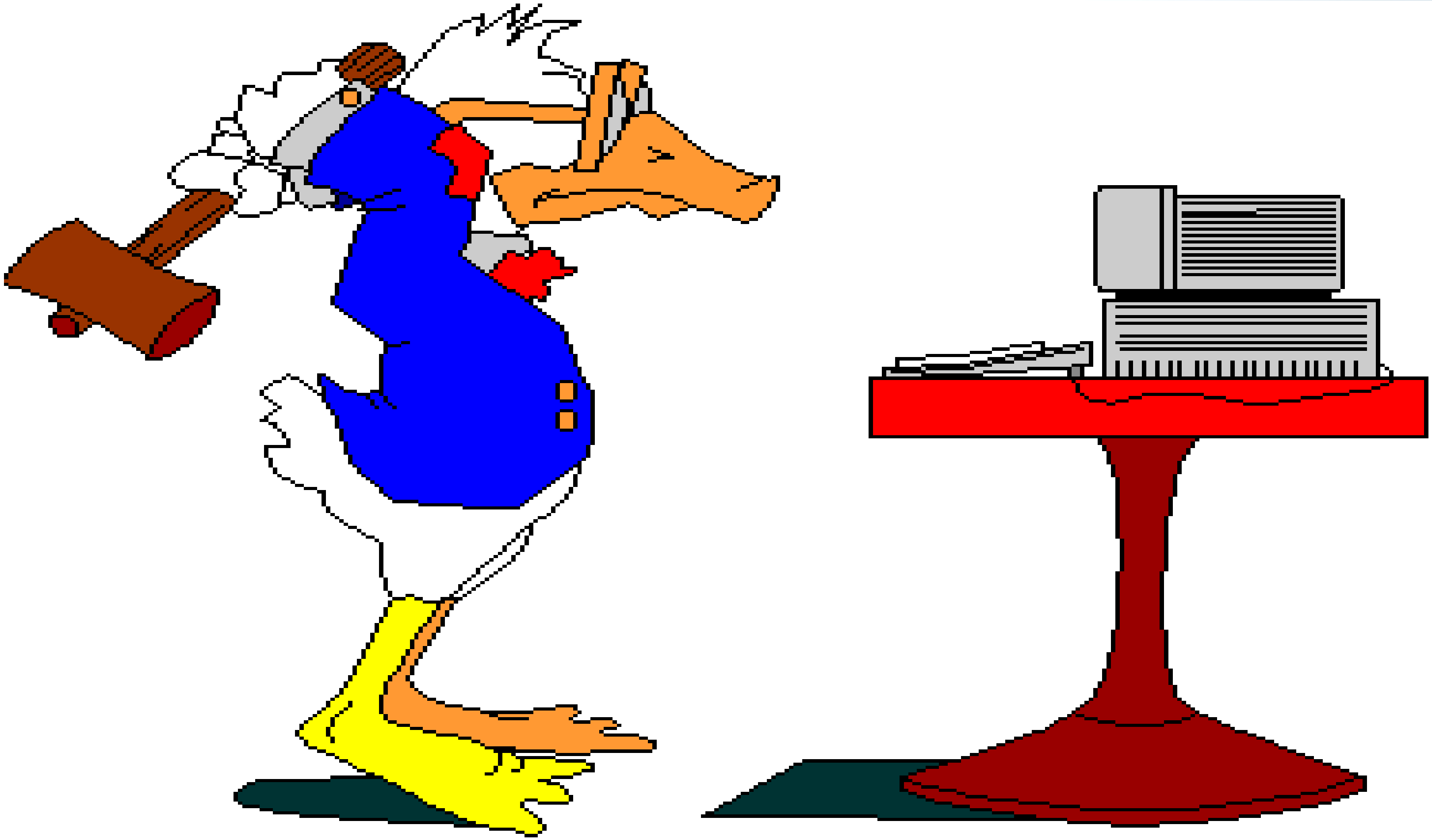
Holistic Approach to Achieve Net Environmental Benefit



Summary

- Sludge minimization provides O&M cost savings and net environmental benefit.
- WAS provides the greatest opportunity to implement sludge minimization.
- A wide range of technologies both emerging & proven are available.
- Process selection should be based on a Triple Bottom Line analysis
- Water Environment Research Foundation study outlines a methodology for evaluating candidate technologies

Questions?



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