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Advanced Oxidation for Biosolids Disinfection

Oxidation of Municipal Sludge using Chlorine Dioxide (ClO_2)

- Started ~24 years ago with the idea to disinfect wastewater effluent

  (before hypochlorite caught on and everybody was still using gaseous chlorine)
  - Testing was very successful at meeting fecal coliform reductions while still being able to pass acute toxicity testing for marine surface water discharge
- Next logical step was to abandon the research and add biosolids disinfection…
  - Chlorine dioxide really does a number on municipal sludge…
    - but you can't kill Ascaris eggs, therefore no Class A biosolids
      - We can generate nitrous acid in-situ to finish the job!
        - Everybody wants Class AA biosolids, few people want to pay for it…
- Class B is easy!

  - Is the beneficial use of biosolids going away because of PFAS concerns???

Chlorine dioxide does lots of really cool stuff…

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Class B Biosolids in 10 minutes

- Plug-flow Class B biosolids disinfection process that greatly reduces odors from biosolids
- National EPA approved PSRP Equivalent Process (2015)
- Highly scalable process – 55 gpm to 270 gpm WAS feed (0.5 MGD – 20 MGD)
- Digestion not required (secondary sludge feed)
- Small footprint
- Automated process control, remote monitoring & data logging capabilities

- What does it do?
  - Disinfects to Class B Standards in 10 minutes compared to 28-30 days in digesters
  - Volumetric and/or solids-based addition of Chlorine Dioxide (ClO_2) to WAS
    - Combination of Sulfuric Acid (H_2SO_4)with Sodium Chlorite ($NaClO_2$) to form Chlorine Dioxide.
  - Meets VAR (SOUR method – Option 4)
  - Reduces energy consumption
  - Enhances dewatering - decreases polymer consumption and increase cake solids
  - Reduces nutrient loading (N and P) return to the plant
  - Reduces odors normally associated with biosolids processing
  - ClO2 is a strong oxidant with a good combination of selectivity and reactivity
    - Performs extremely well as a disinfectant for municipal biosolids.
    - Effective odor control against sulfides, phenols and mercaptans.
    - The ClO2 is reduced to chlorite (ClO2-) as an intermediary step, and then reacts further and reduces to chloride (Cl-)
    - No chlorinated organics, THMs or HAAs are formed.

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Class B Disinfection is Good…

- What else does it do?
  - Provides a means to preserve the energy content of biosolids
  - Changes the charge of the sludge and enhances dewaterability, resulting in ‘better’ cake (finer, smaller particle size with no odor)
  - Increases the conductivity of biosolids while still in liquid form
  - Kills cell… which can result in ???

- What doesn’t it do?
  - Provide stabilization in the traditional sense

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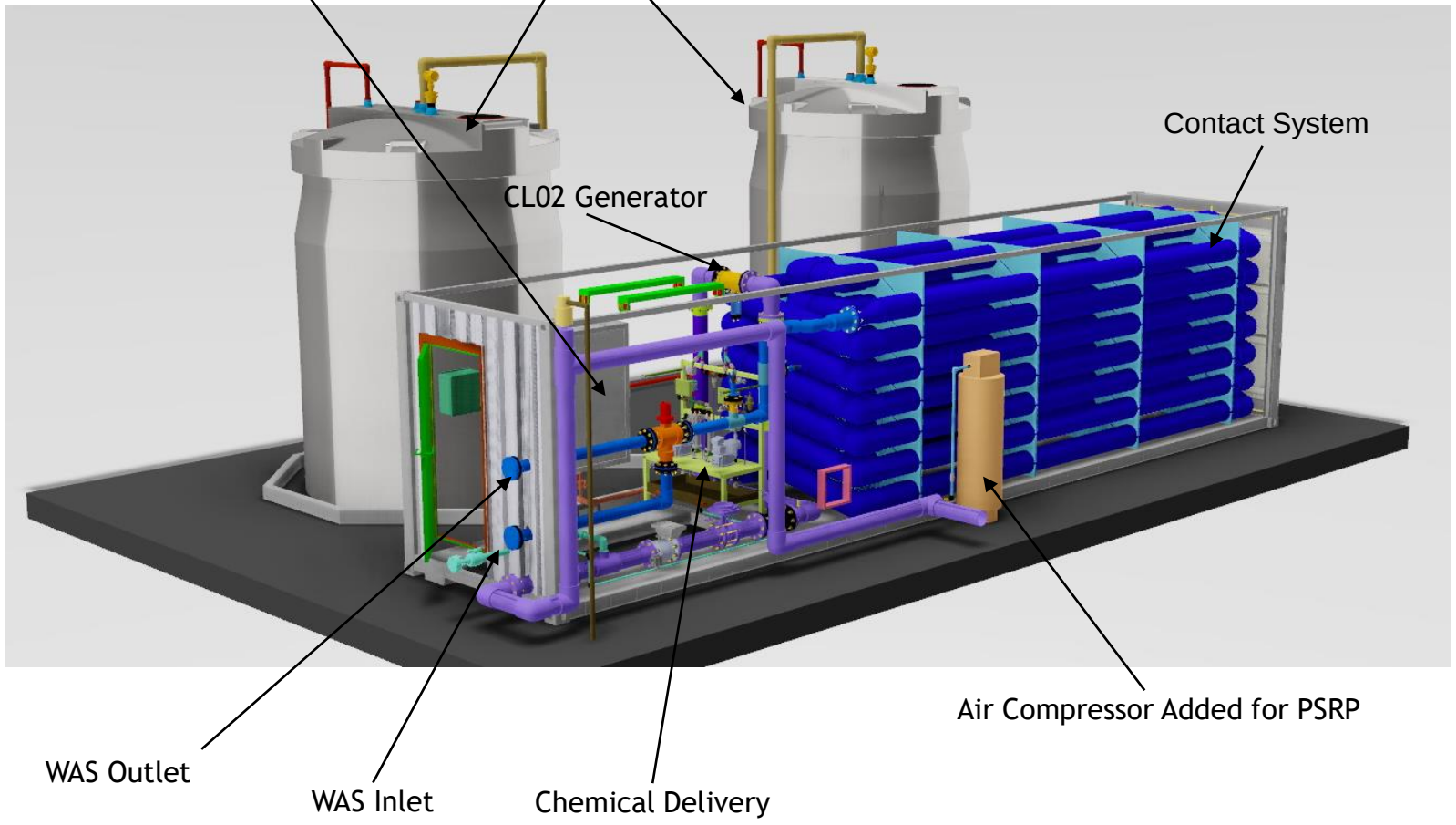
Standard CleanB® Components - Modular Design Package



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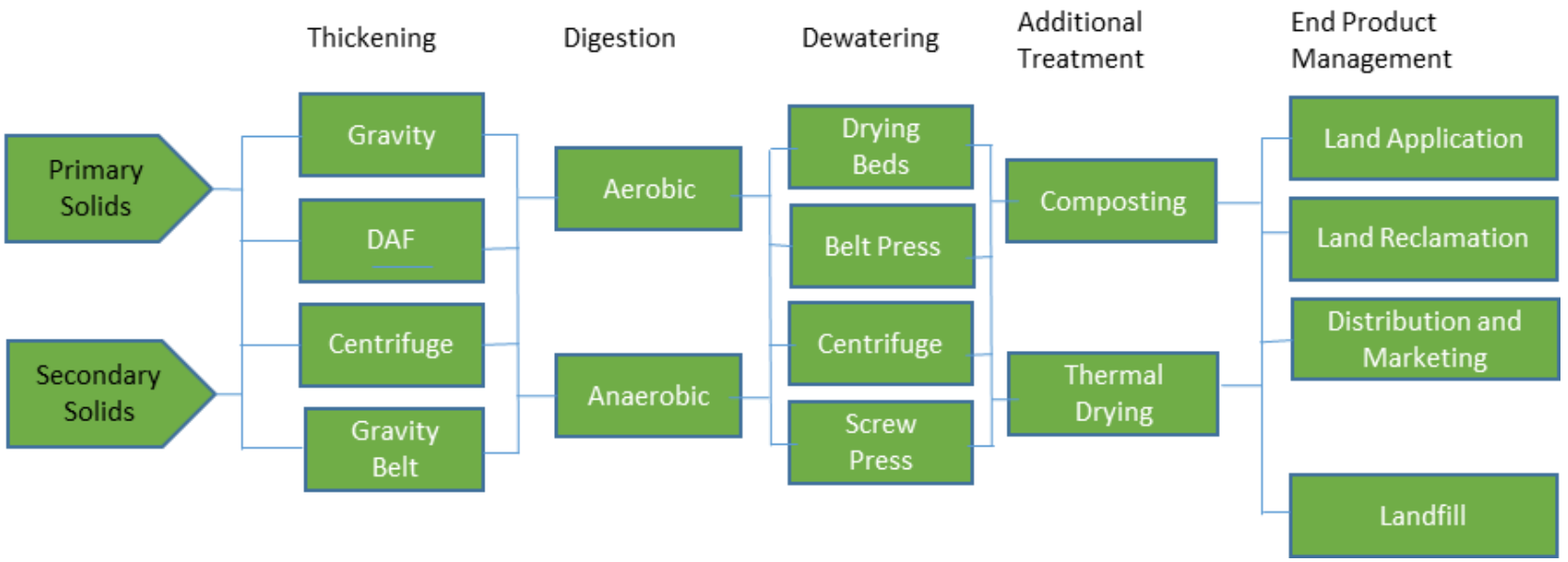
Simple, scalable, modular low cost Class B alternative

CleanB® Process Integration

Typical Process Flows



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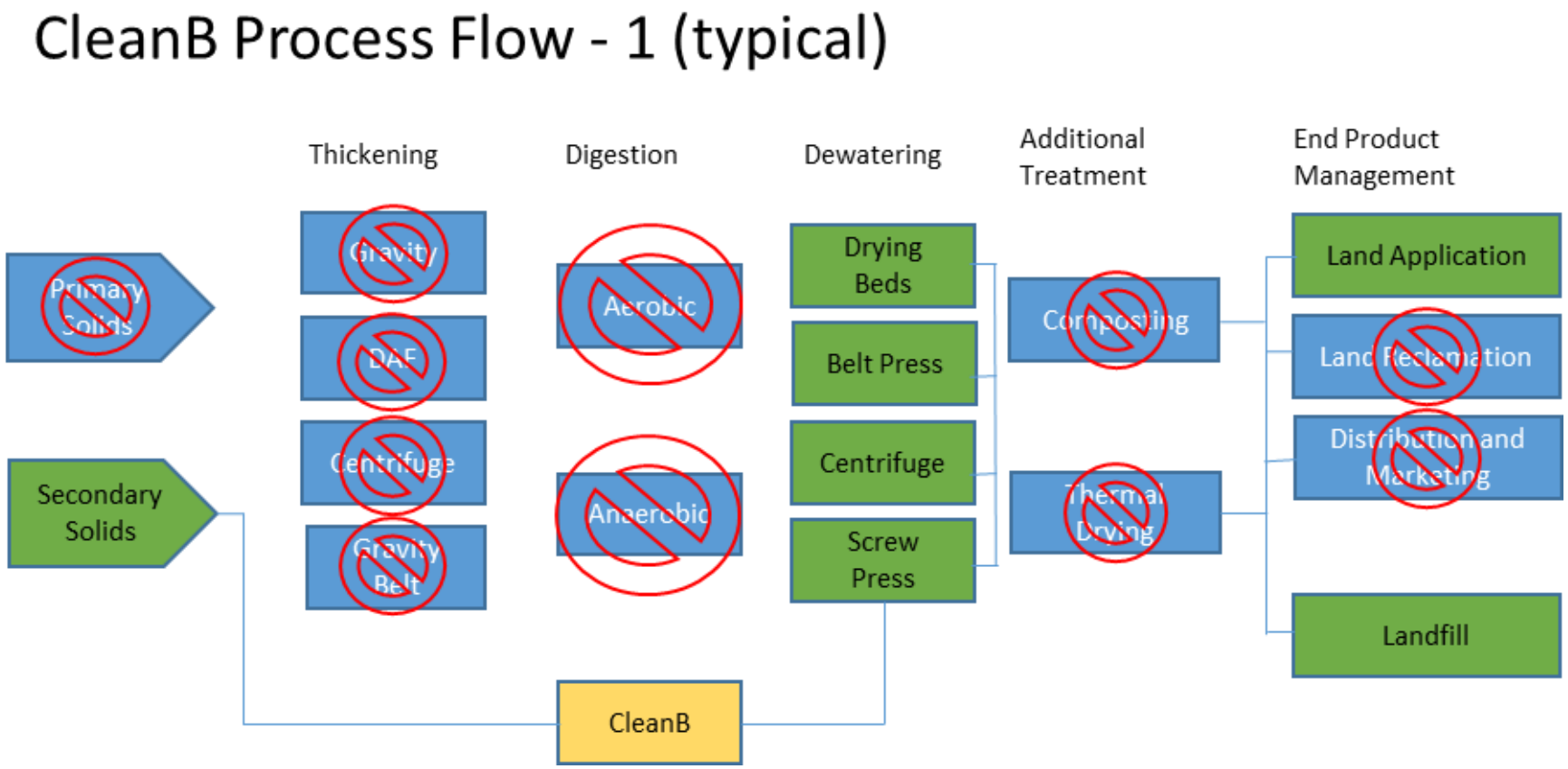
CleanB® Process Integration



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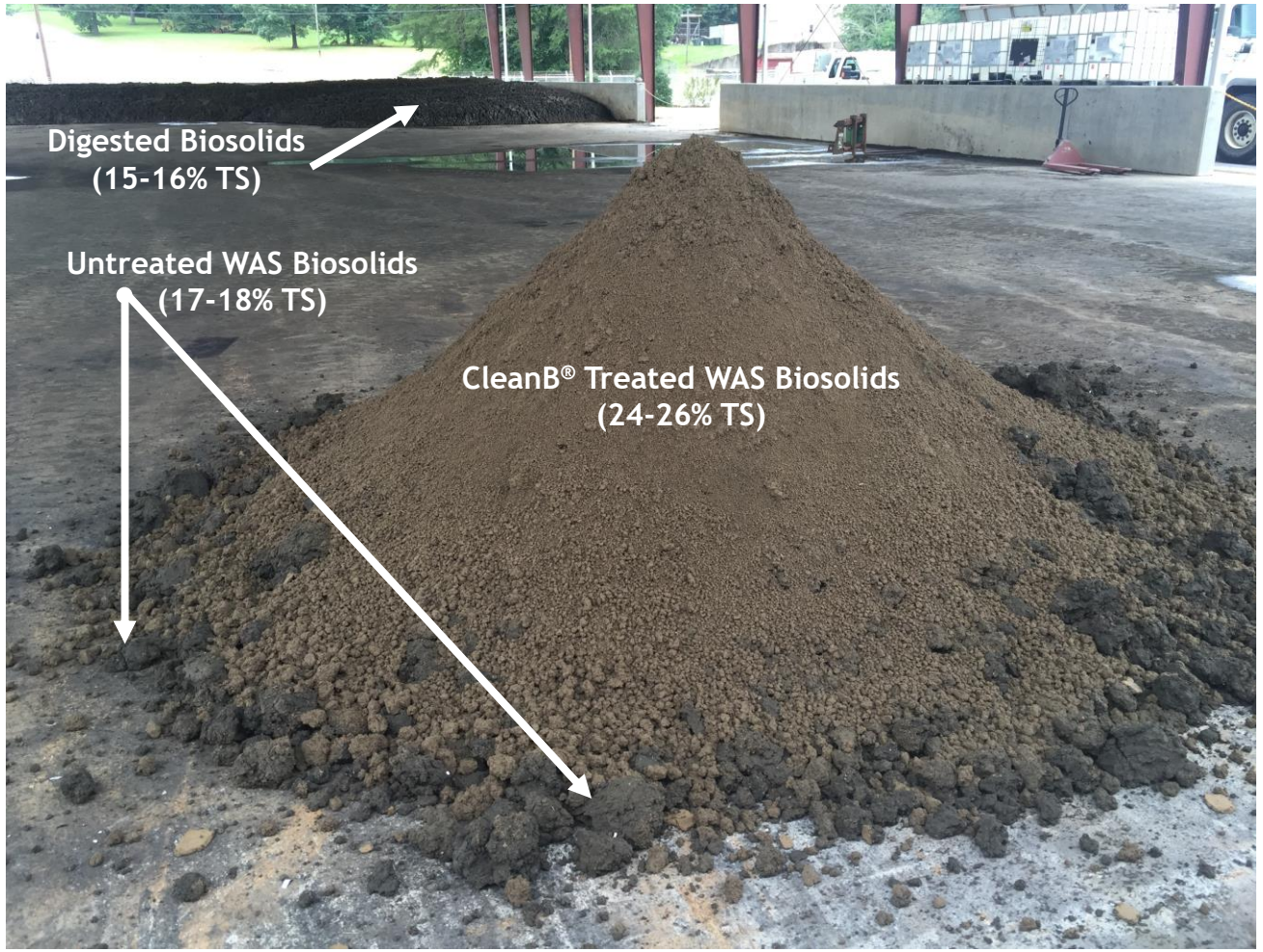
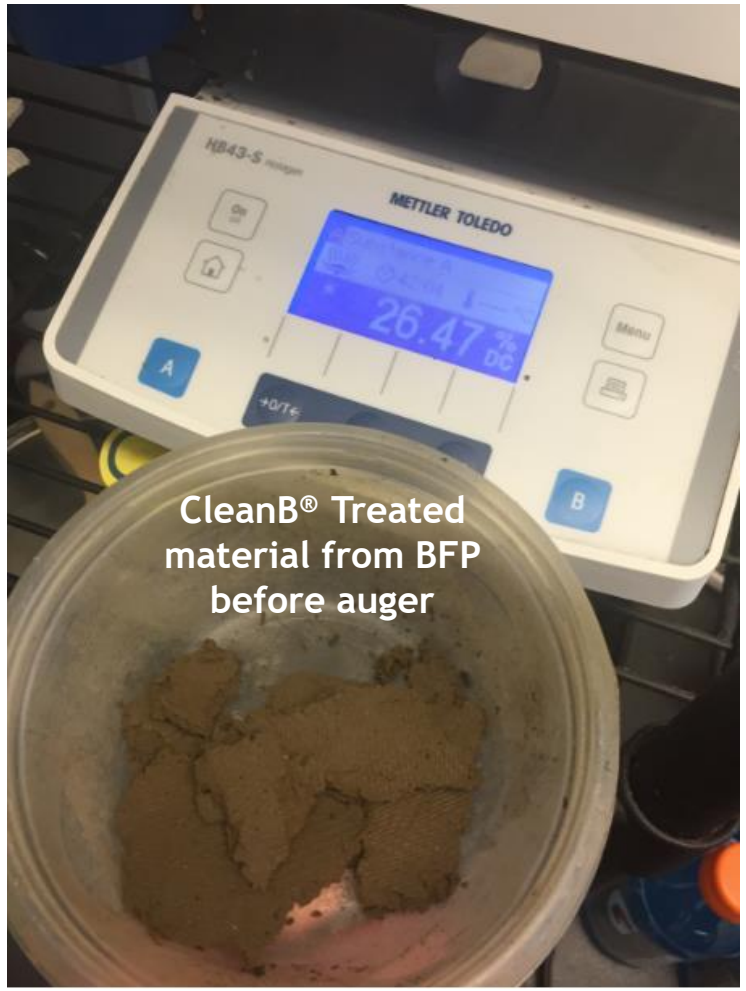
CleanB® Enhances Dewatering, Lowering T&D Costs





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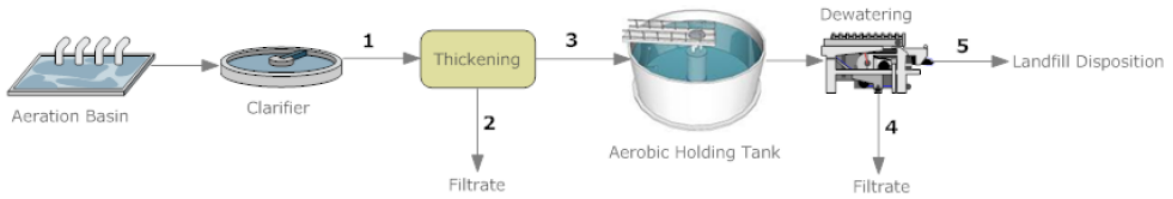
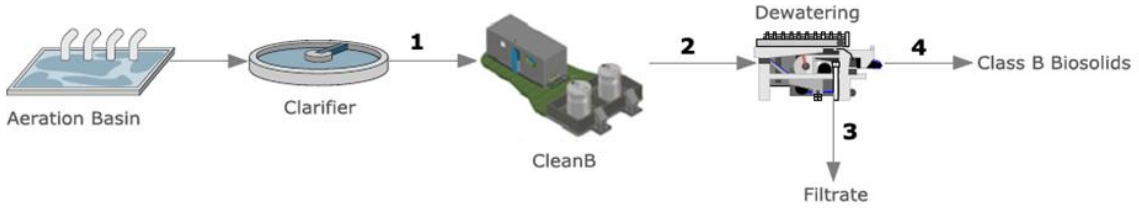
Eden, NC Demonstration. Dewatered using belt filter press (BFP) and transferred to pad via auger system. Polymer was continually dialed down after treatment to achieve >26%TS cake.

CleanB® Case Study - Ft. Pierce



Process Stream	Stream #	Total Solids [%]	Flow [gpd]	Wet Solids [lbs/day]	Dry Solids [lbs/day]	Total Nitrogen [lbs/day]	Total Phosphorous [lbs/day]
Thickener In	1	0.80	88,091	734,678	5,892	410	109
Thickener Filtrate	2	0.06	75,588	630,404	366	182	47
Thickener Out	3	5.30	12,503	104,273	5,526	228	62
Dewatered Filtrate	4	0.41	8,927	74,450	307	122	39
Dewatered Biosolids	5	17.50	3,576	29,823	5,219	106	23



Process Stream	Stream #	Total Solids [%]	Flow [gpd]	Wet Solids [lbs/day]	Dry Solids [lbs/day]	Total Nitrogen [lbs/day]	Total Phosphorous [lbs/day]
WAS in	1	0.62	104,706	873,244	5,405	322	160
CleanB Treated	2	0.62	104,706	873,244	5,405	322	160
Dewatered Filtrate	3	0.02	101,886	849,733	186	23	27
Dewatered Biosolids	4	22.20	2,819	23,511	5,219	299	133

Fort Pierce, FL Utility Authority

Conventional Activated Sludge Plant	Permitted at 9 MGD	AADF 4.4 MGD

CleanB® Process installed 3rd Quarter 2014

Verified Performance:

1) Operating cost savings ~$240k/year
2) %TS on dewatered biosolids improved by 21% (52 less Truckloads/year)
3) Total polymer consumption reduced by 34% (reduction of 26.8 lbs/DT)
4) Solids return via filtrate reduced by 70% (76 tons/yr.)
5) Total Nitrogen return via filtrate reduced 92% (45 tons/yr.)
6) Total Phosphorous return via filtrate reduced 66% (9 tons/yr.)
7) A $57k/year expense eliminated from the aerobic holding tank blowers being taken off-line.
8) Energy/GHG emission savings equates to 50.8 cars per year or 86.4 tons of waste sent to the landfill.

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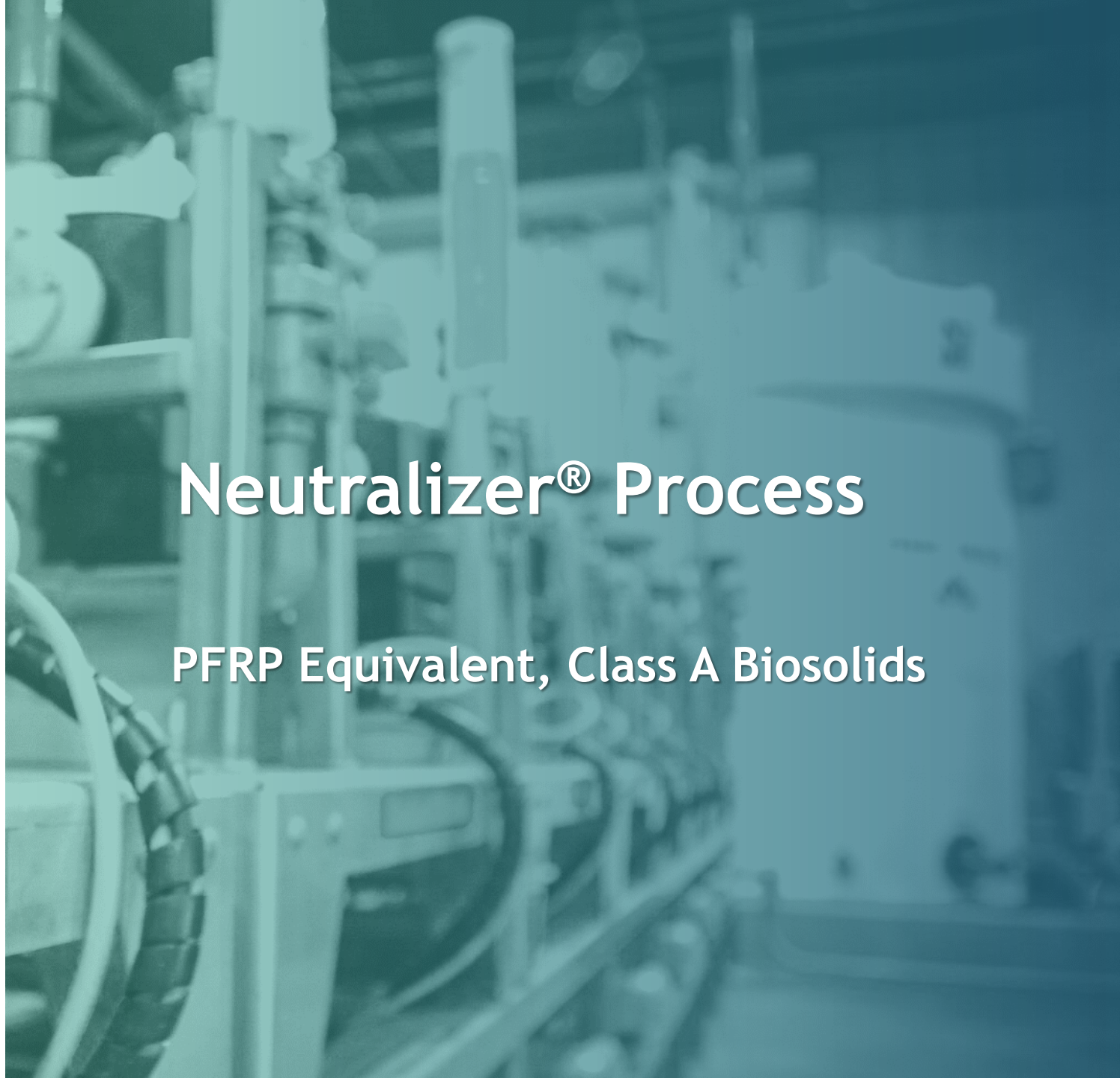
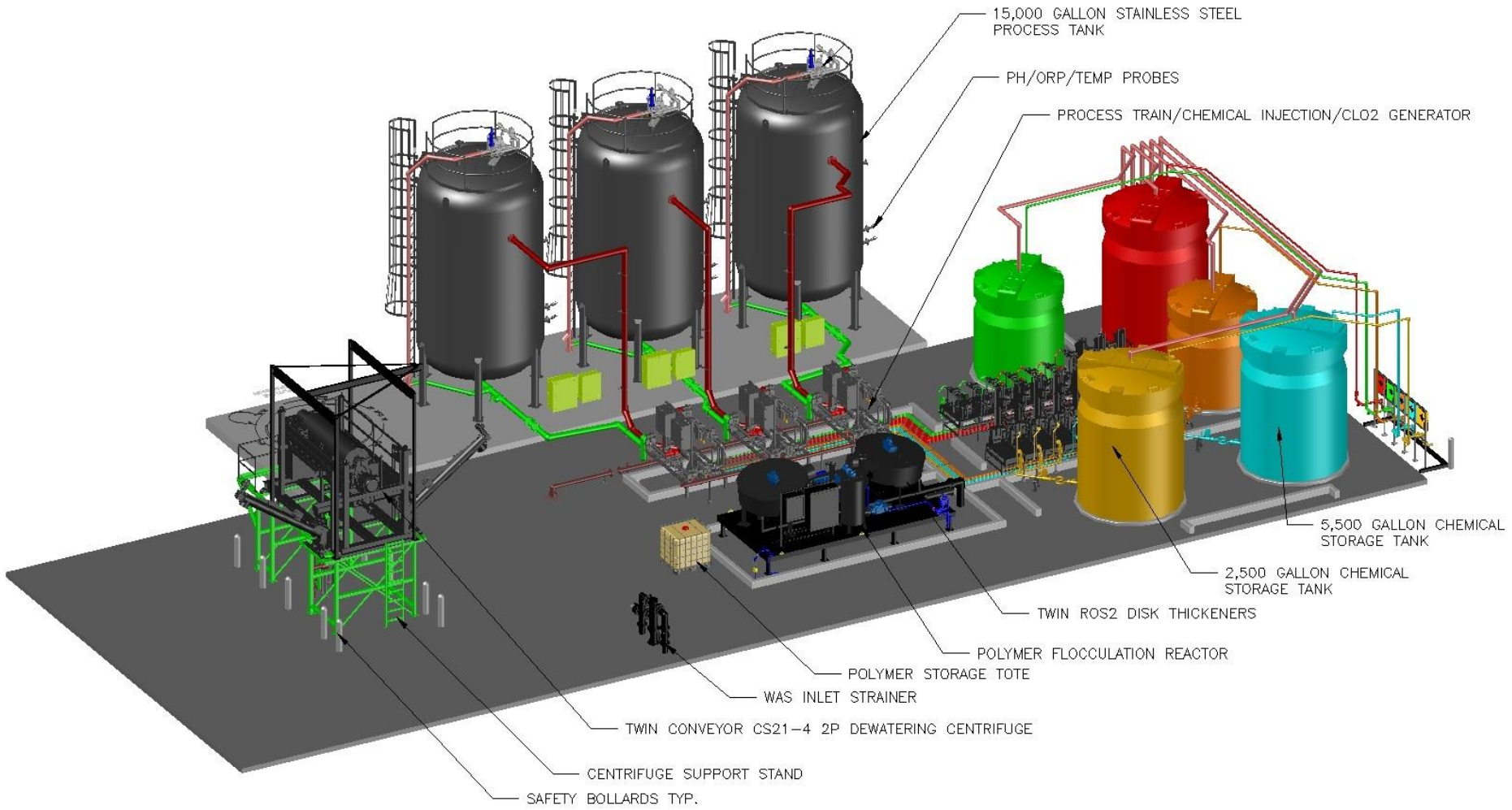


Neutralizer® Process

PFRP Equivalent, Class A Biosolids

Standard Neutralizer® Components



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Neutralizer® system is a simple, scalable, and modular Class A/EQ alternative

Neutralizer® Process Steps

1. Waste activated sludge is thickened using disk thickeners. A polymer is added to help thickening, raising the solid concentration to 4 percent. Once the tank receives 5,000 gallons of thickened sludge, ferric sulfate is added to chemically precipitate phosphorus.

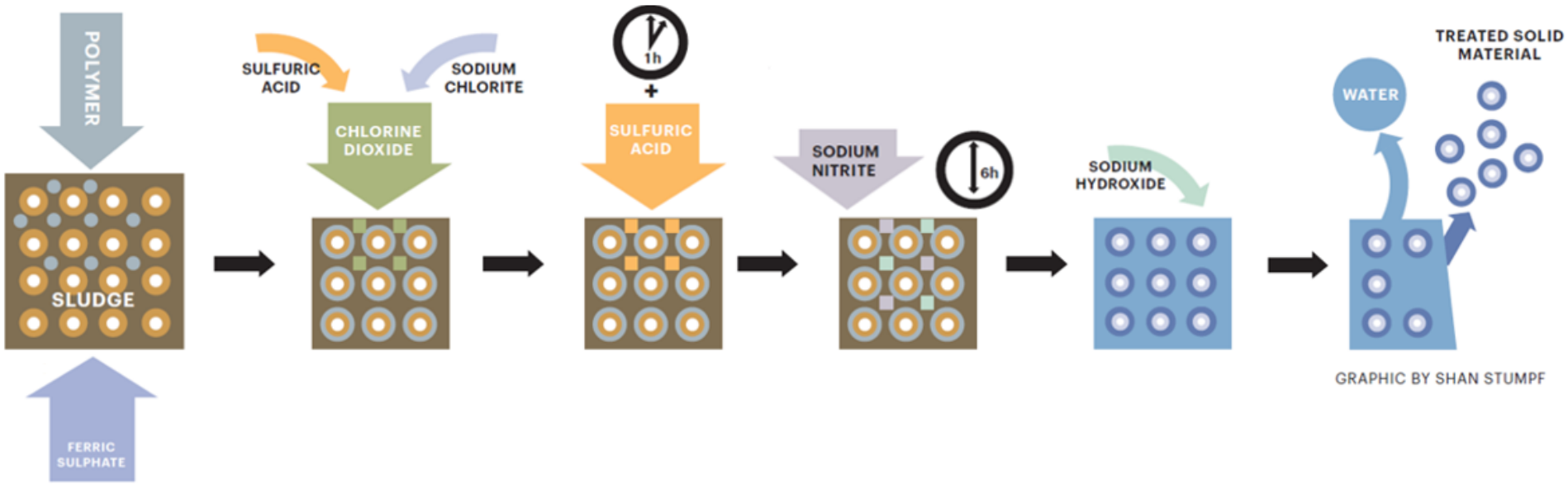
2. The sludge is pumped to a skid where it is injected with **chlorine dioxide** created by combining **sodium chlorite** and **sulfuric acid** through a highly controlled, patented process.

3. The sludge is moved to process tanks where it is allowed 1-hour contact time with the chlorine dioxide. The **sulfuric acid** is added to make the mixture more acidic.

4. Sodium nitrite is added for to the process tank. The low pH and high ORP converts the sodium nitrite to nitrous acid. The waste activated sludge then has a contact time of 6 hours with the nitrous acid.

5. Sodium hydroxide is added to bring the pH to a desired level.

6. Water is removed by traditional methods, such as a centrifuge or a belt press. The final product is a Class A material with an earthy smell that can be registered as a commercial grade fertilizer.



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Neutralizer® system is batch process utilizing 5 chemicals for Class A/EQ disinfection and sludge conditioning. Solids content is limited to 4% per PFRP equivalent requirements.

Neutralizer® Process Installation

Neutralizer® system is a simple, scalable, and modular Class A/EQ alternative

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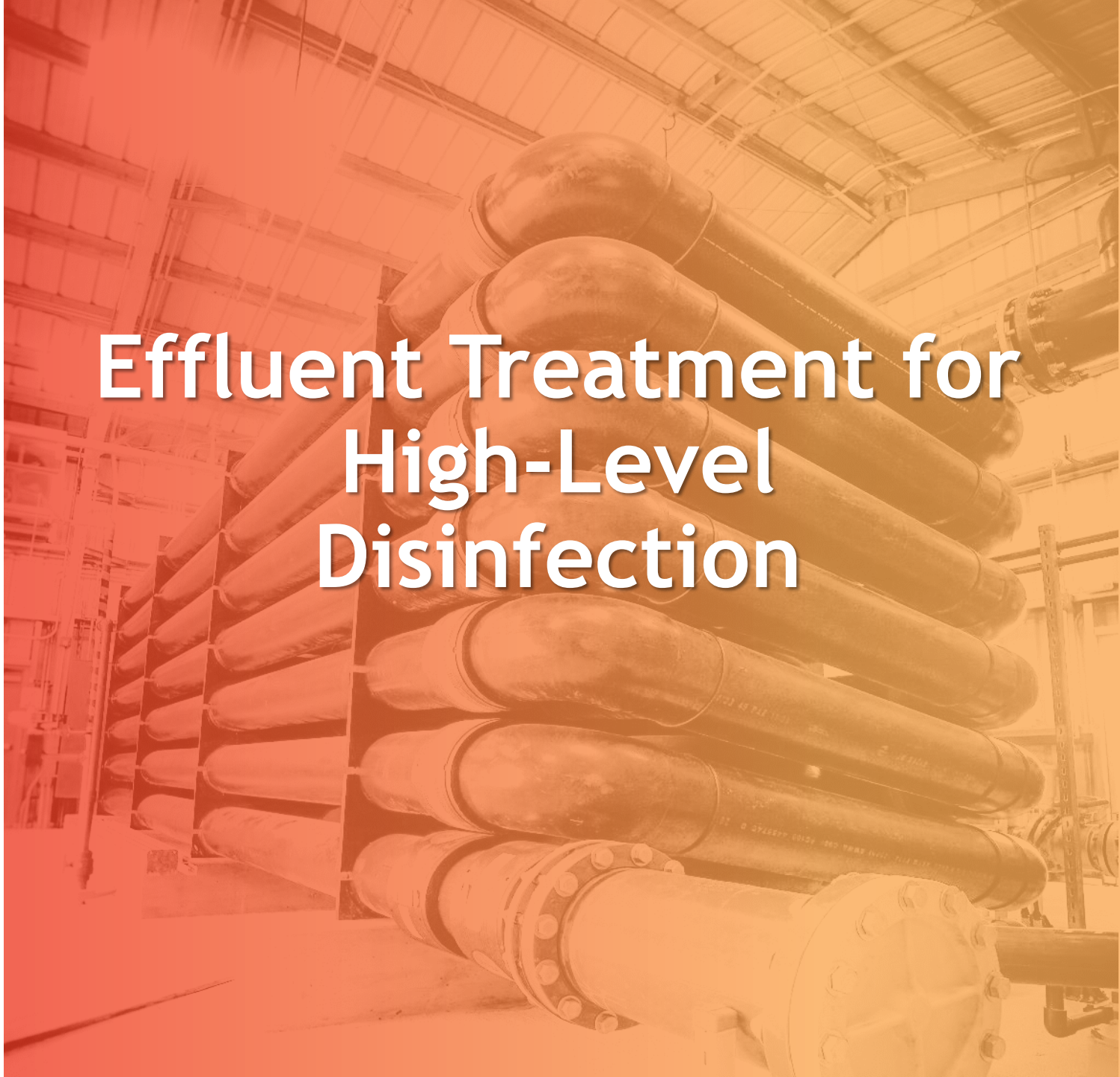
Effluent Treatment for High-Level Disinfection



ClO_2 Chemistry Benefits

- **ClO_2 Benefits**
  - Chlorine dioxide is not another form of chlorine; it does not chlorinate
    - No chlorinated organics, THMs or HAAs are formed
    - Does not react with ammonia to form chloramines
  - Lowest Oxidation-Reduction Potential (highest oxidation capacity among oxidizers)
    - Oxidation state: 5 ; Chlorine, Ozone, Peroxide: 2
    - 1 ppm ClO2 is as effective as 100 ppm chlorine
  - ClO_2 is extremely selective
    - Minimally affected by organic contamination
    - Chlorine, peroxide and hypochlorite and ozone are indiscriminate oxidants

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ClO_2 Chemistry Benefits (cont'd)

- **ClO_2 Benefits**
  - Highly soluble in water
  - Unlike chlorine and hypochlorite, it does not react with water to produce hypochlorous acid
  - Performs extremely well as a disinfectant for municipal water biosolids
  - Effective at broad pH ranges (2-10 pH)
  - Effective odor control against sulfides, phenols and mercaptans
- Synergistic disinfection with chlorine
  - Very similar to drinking water disinfection, or the use of ClO_2 as a 'pre-oxidant'

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Where's the Cool Stuff?

- **Energy, dewaterability, conductivity**
  - BTU Value – 6800-8000+ BTU/lb… with no odors
  - Drier cake therefore less water to evaporate, also TGA/DSC test demonstrated that water leaves earlier and faster, equating to a 25% energy savings with sludge drying
  - Conductivity must be useful for something…
    - Electro-kinetic dewatering

- **Combinations**
  - Prior to Aerobic Digestion - Classic stabilization in less time (5 day SOUR, 10-14 day VSR
  - Prior to Anaerobic Digestion; a 3-month bench-scale study showed a 30% increase in methane production from secondary sludge

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Thank You! Questions?

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