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Design and Operation of Hybrid Aeration System

Marc Rhodes – Envirex Products

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It is generally agreed that fine bubble aeration has the highest oxygen transfer efficiency of any aeration device in clean water.

Some typical empirically measured value:

- Fine Bubble Aerator Clean Water Efficiency (SAE) = 4.4 kg/hr/kW
- Mechanical Aerator Clean Water Efficiency (SAE) = 1.9 kg/hr/kW

However, efficiencies are different in wastewater

In wastewater, contaminants affect aeration efficiencies by altering the process variables

- **Variables affecting oxygen transfer rate during aeration include:**
- **alpha** = $\frac{\text{KLa Waste water}}{\text{KLa Clean water}}$

  = $\frac{\text{mass transfer coefficient in waste water}}{\text{mass transfer coefficient in clean water}}$

Alpha is the most variable factor includes affects of loading, suspended solids, mixing, etc.

- **field process dissolved oxygen (D.O.) desired to be maintained.**
- **Beta (saturation factor - corrects for dissolved solids in wastewater)**
- **Theta (corrects for temperature)**
- **Barometric pressure**

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- **Many variables are different in wastewater than in clean water therefore,**

Aeration equipment performs differently in clean water than wastewater

- **Some variables change throughout the wastewater process**

  So, aeration equipment performs differently at different locations in the wastewater process

- **Each type of aeration equipment is uniquely affected by the process variables**

Alpha

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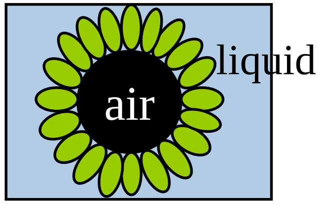
- Most important process variable affecting aeration efficiency is Alpha:

- Variations in Alpha are caused primarily by surfactants in wastewater
  - Surfactant concentrations differ throughout the wastewater treatment process due to breakdown by biological activity
  - Alpha values of 0.2 to 1.2 are reported
  - Alpha above 1.0 are for mechanical aeration in the presence of surfactants in wastewater

Effect of Surfactants on

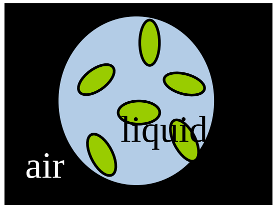
Diffused aeration

- **Surfactant molecules form a rigid surface on bubbles**
- **Aeration difficulty decreases with smaller bubbles**
  - **Lower Alpha for fine bubble than for coarse bubble**



Mechanical aeration

- **Surfacants reduce surface tension resulting in formation of smaller liquid droplets**
  - **Increases available surface area for transfer**
  - **Alpha factors can be greater than 1.0**



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Effect of Surfactants on:

- Fine Bubble Aeration at Front of Process
  - Relatively high concentration of surfactants
  - Overall effect is decreased oxygen transfer efficiency

Effect of Surfactants on:

- Fine Bubble Aeration Further Into Process
  - Reduced concentration of surfactants
  - Overall affect is increased oxygen transfer efficiency

Effect of Surfactants on:

- **Mechanical Aeration at Front of Process**
  - **Relatively high concentration of surfactants**
  - **Decreased water droplet size**
  - **Increased air transfer efficiency from air to droplet**
  - **Alpha factors can be greater than 1.0**

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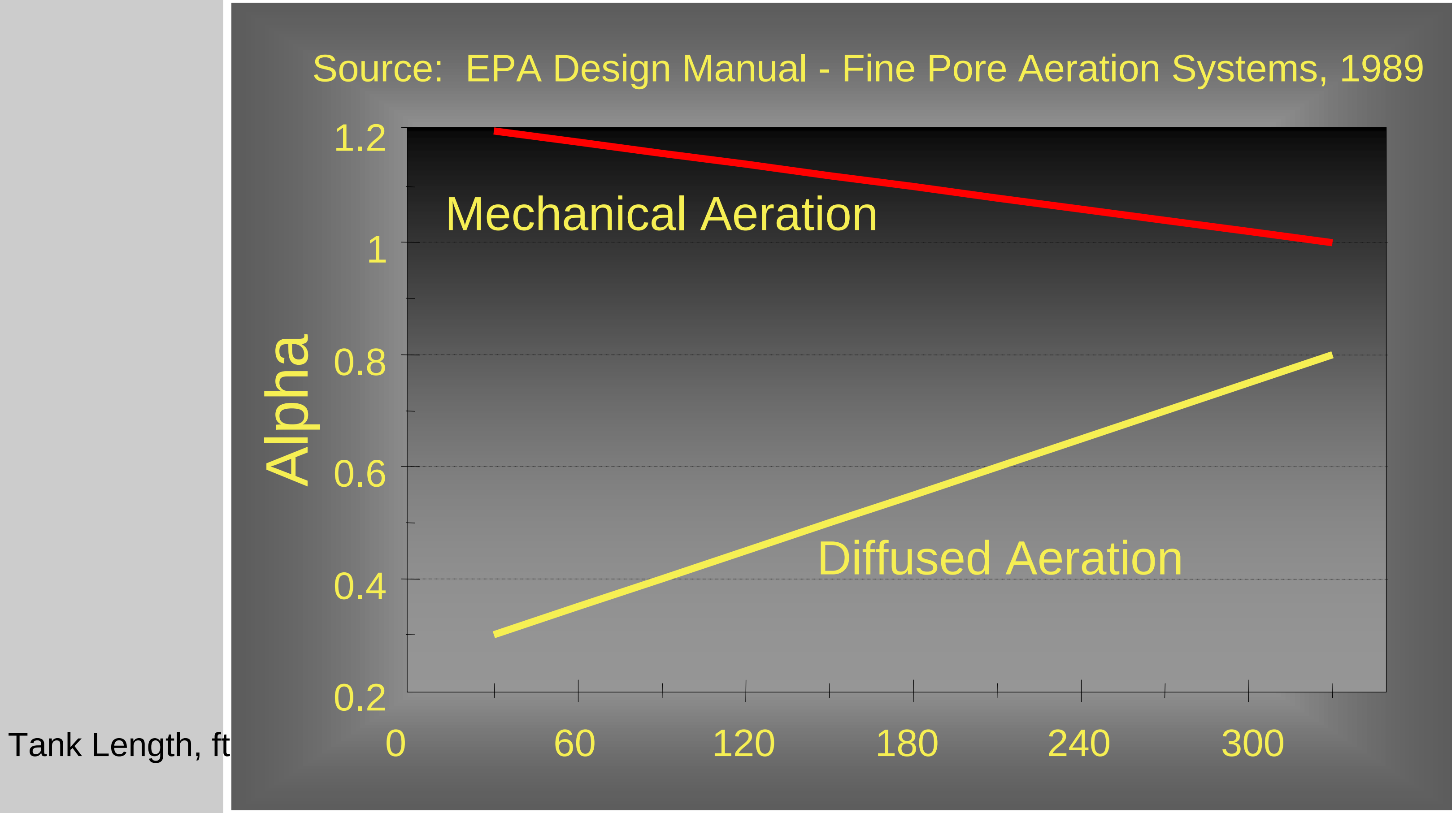
Effect of Surfactants on:

- Mechanical Aeration Further into Process
  - Reduced concentration of surfactants
  - Increased water droplet size
  - Decreased air transfer efficiency from air to droplet

Diffused vs Mechanical Aeration
Effect of Tank Length on Alpha



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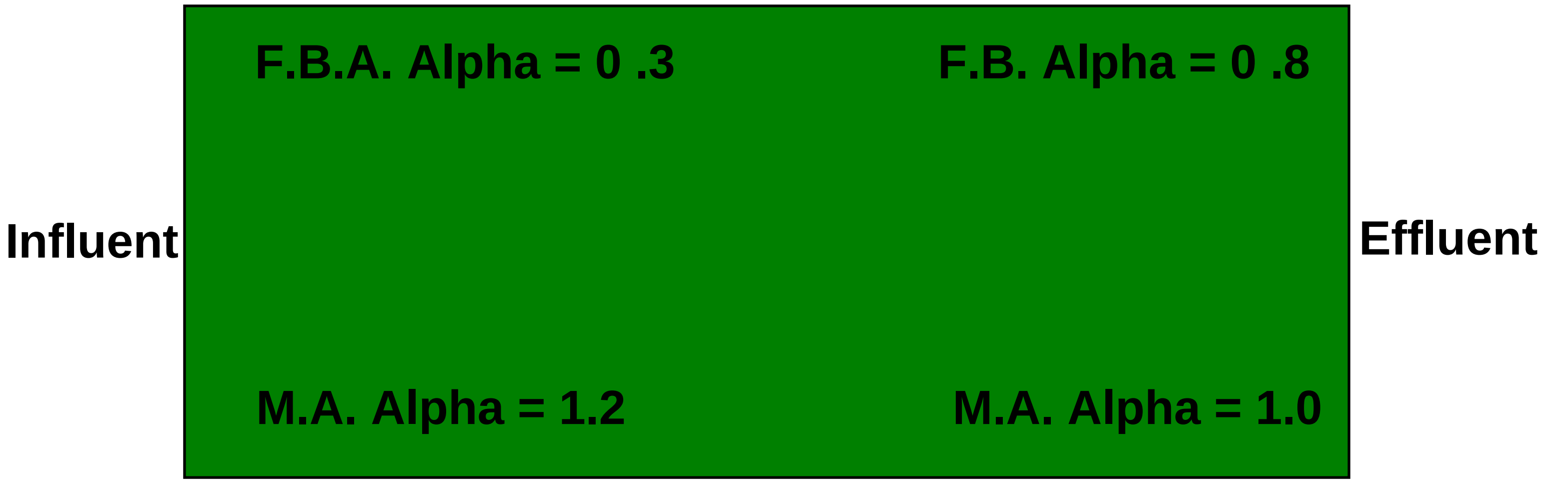
Plug Flow Reactor



F.B.A. = Fine Bubble Aeration
M.A. = Mechanical Aeration

- Depending on where in the process aeration equipment are used:
  - Fine Bubble aeration
  - Mechanical aeration
- Aeration Efficiencies Change
- Location of use determines optimal choice of equipment

Another Important Process Variable is Field Dissolved Oxygen (D.O.)

Oxygen Transfer rate is $\propto$ (C* - C)

- **The larger the difference between the set point D.O. (C*) and the field process D.O. (C), the more efficient the transfer process is.**
  - **Important because the driving force in aeration i.e. difference between desired D.O. and aeration set point determines rate of oxygen transfer.**
  - **One of the benefits of aerated anoxic – more on this to come.**

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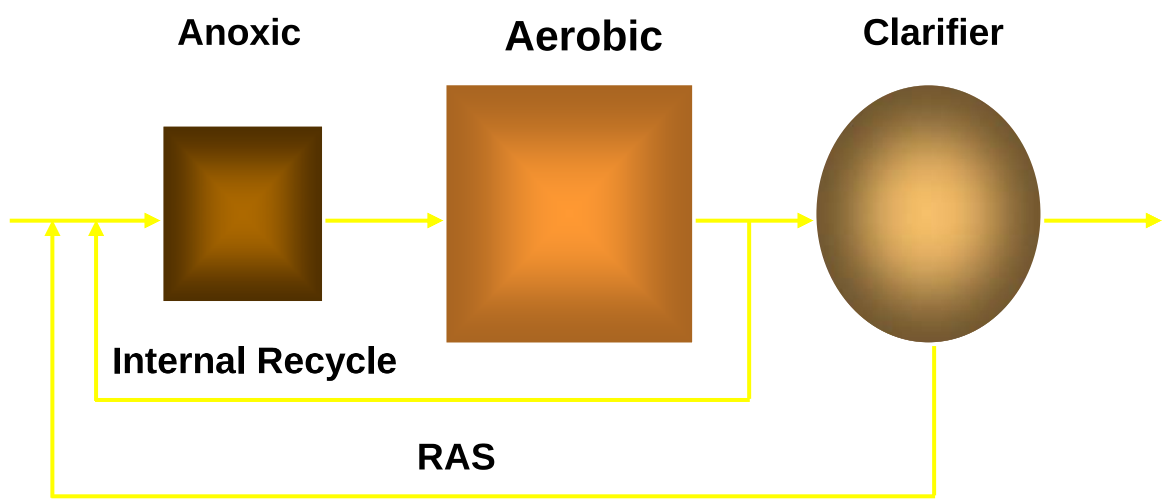
A Quick Review of Anoxic Reactors

- **No oxygen added to the reactor**
- **Mixing is achieved by mechanical mixers**
- **Nitrates are pumped from aerobic zone back to anoxic zone for denitrification (internal recycle)**
- **4Q internal recycle required to achieve 80% denitrification**

A Typical Schematic for Conventional Denitrification using Anoxic Reactors



Lutzack-Ettinger Process

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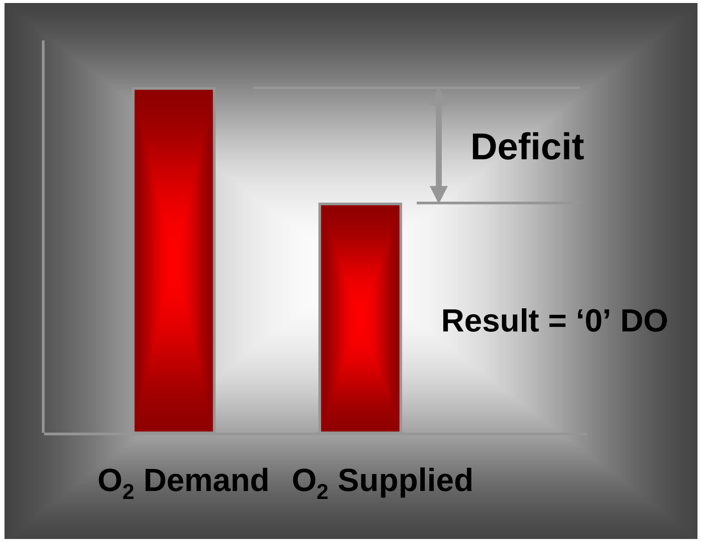
Aerated Anoxic Reactors

Definition

- Reactor aerated to provide for aerobic processes with oxygen supplied less than the full demand.
- Because of constant oxygen deficit condition
- Provides anoxic conditions



O_2 Supplied < 75% of O_2 Demand

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Typical Schematic using Aerated Anoxic Reactors for Denitrification

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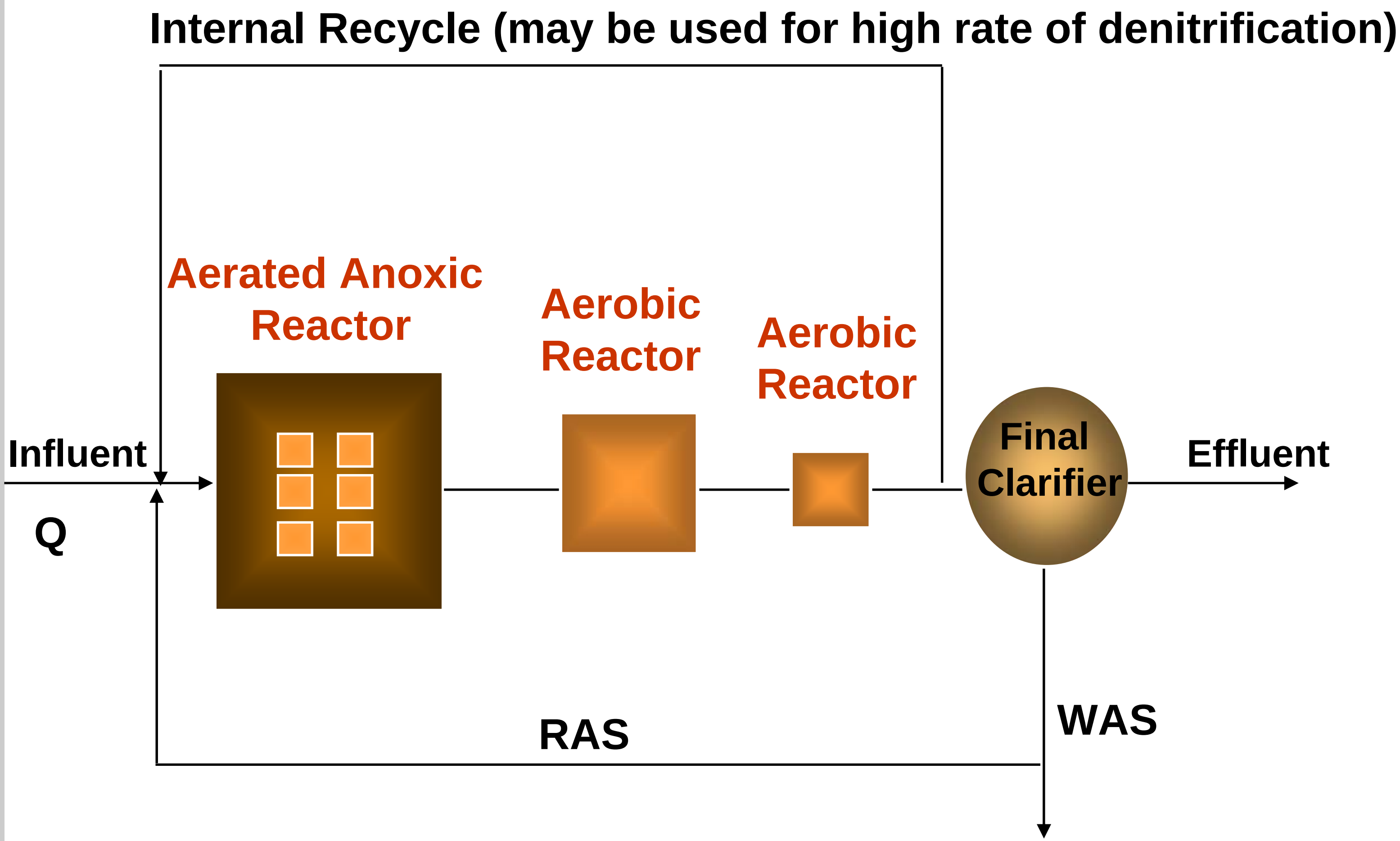

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Benefits of Aerated Anoxic Reactors

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- **Aerating under low oxygen conditions results in lower Specific Oxygen Requirements (SOR) due to higher transfer efficiency.**
- **No mixers required**
- **No internal recycle required (unless high levels of denitrification are required)**
- **Simultaneous Nitrification/Denitrification**
  - **Immediate source of nitrates for denitrification**
  - **Possible short-cut nitrification/denitrification pathway**

Some treatment systems utilize aerated-anoxic for high aeration efficiency:

- **Orbal**
- **Bionutre**
- **Vertical Loop Reactor**

DO Profile in Orbal – Multichannel Oxidation Ditch

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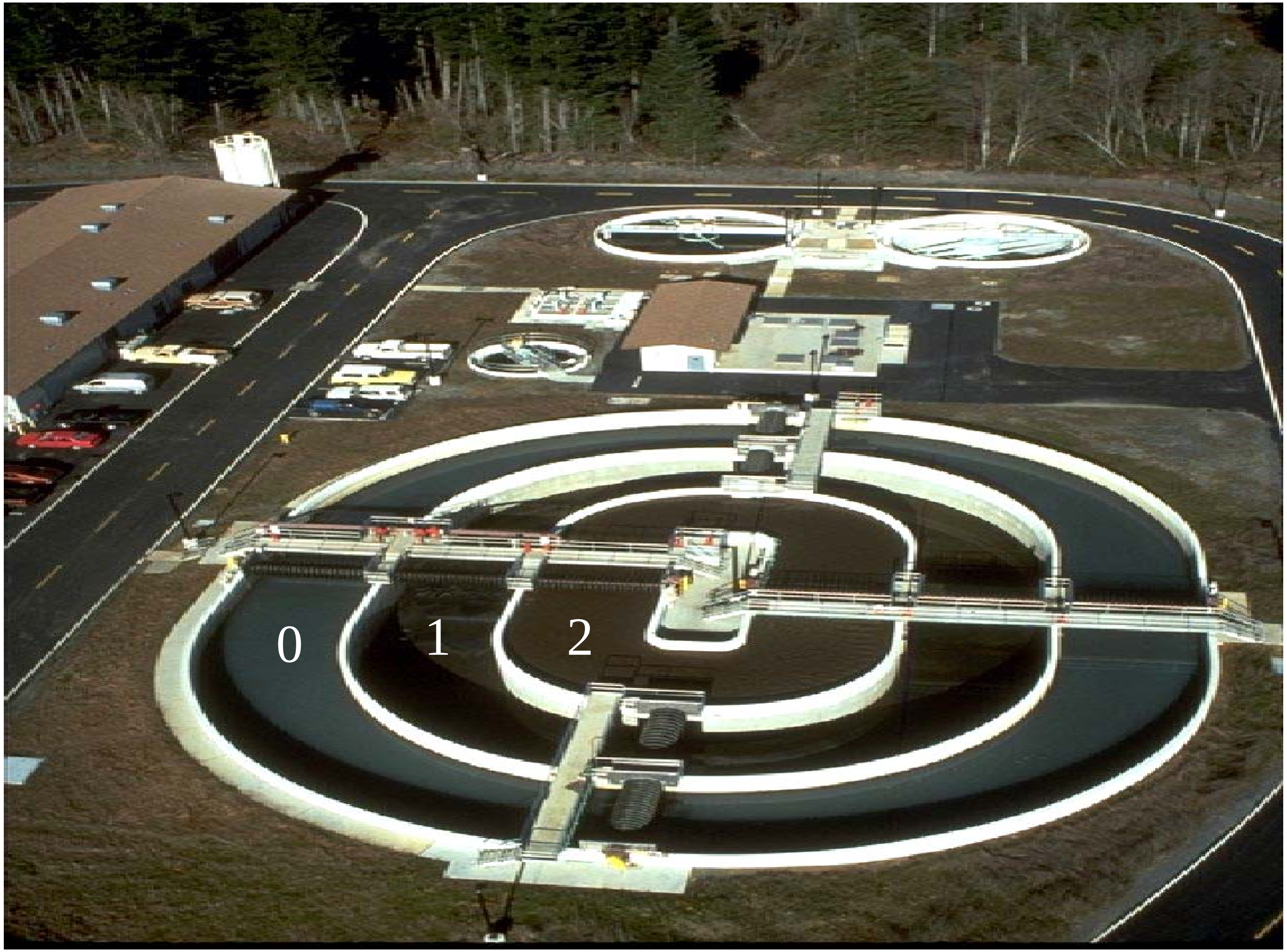

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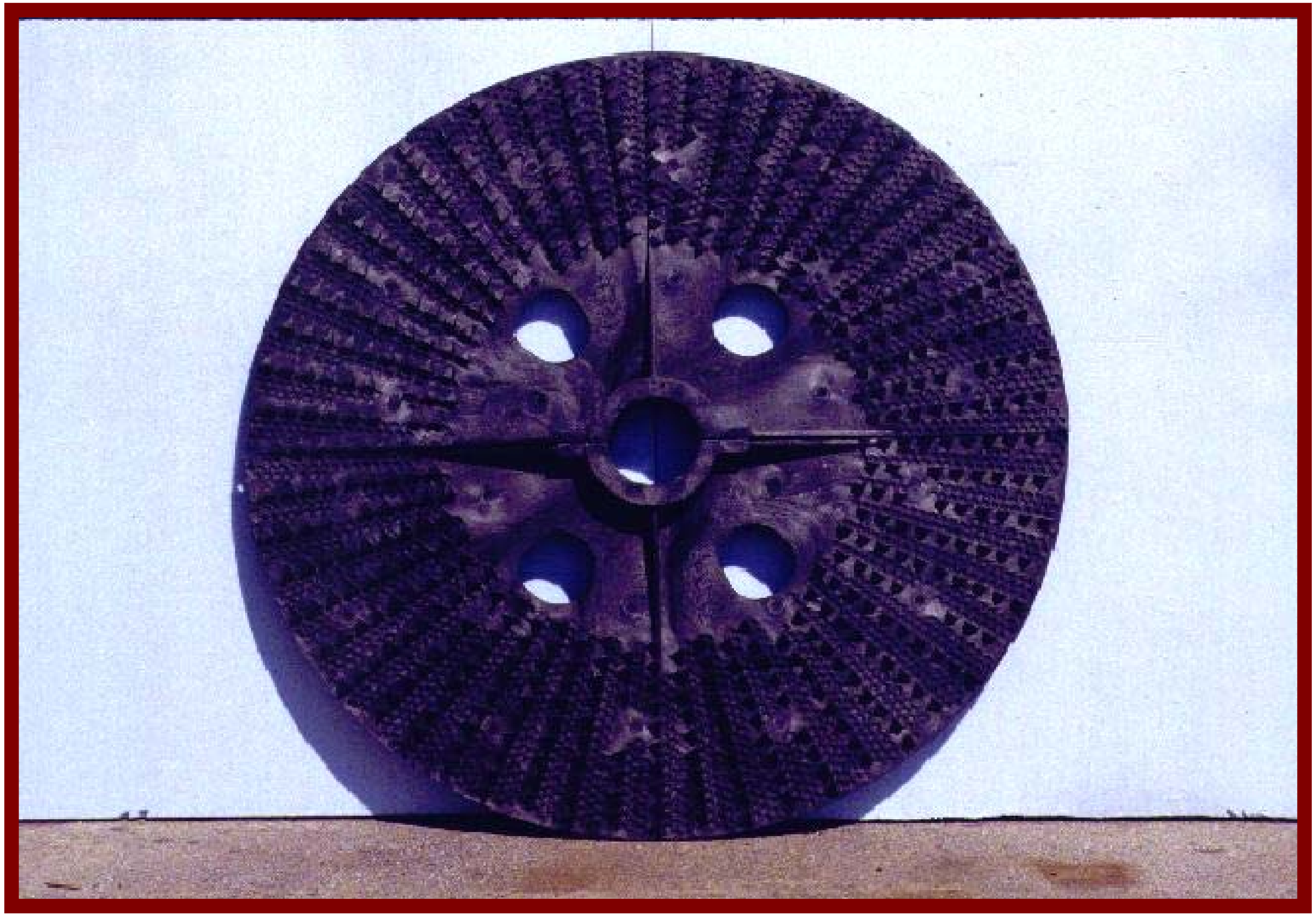
Horizontal disk aerators in action with little spray or aerosol formation

Orbal Aeration Disk



Bionutre

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- Complete mix reactors in series using diffused air.
- Stratified DO similar to Orbal
  - First 0 mg/L
  - Second 1 mg/L
  - Last 2 mg/L

- Disc-type fine bubble diffusers
- Provides high oxygen transfer efficiency under low process D.O. conditions.

Bionutre Process

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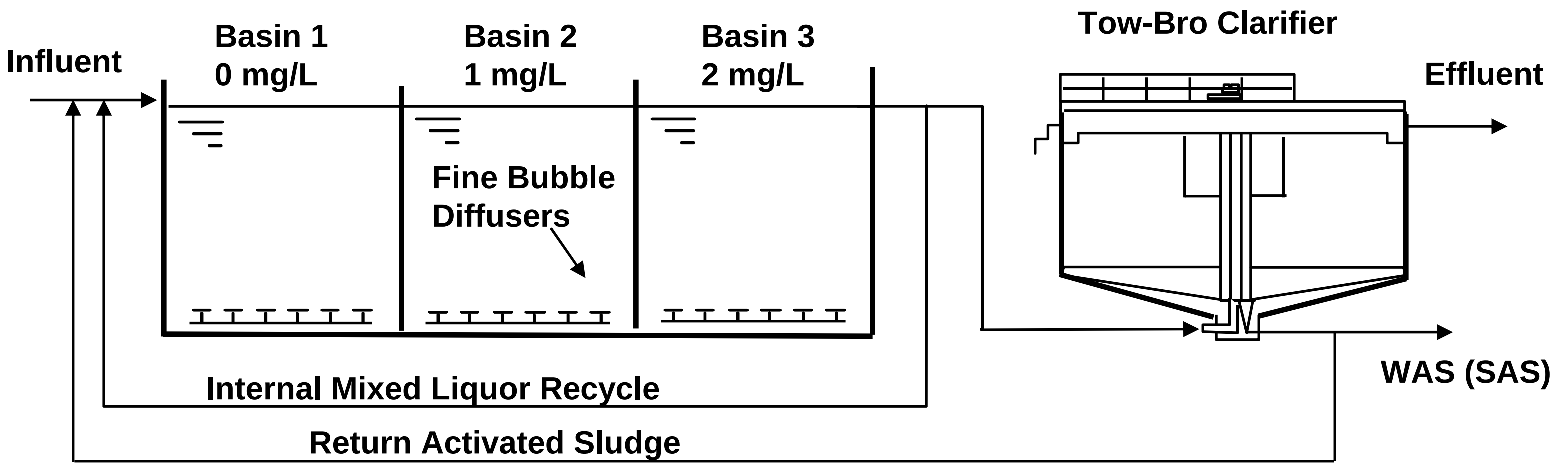

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Vertical Loop Reactor

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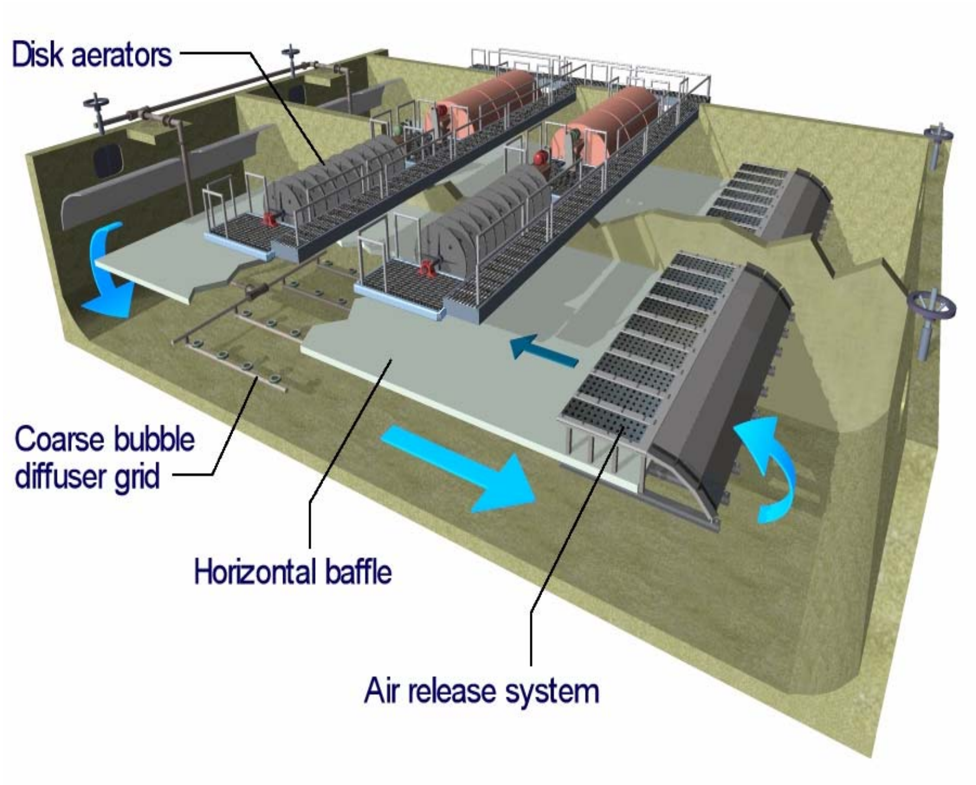
- Multiple reactors operated in series
- Different DO level in each reactor. 0, 1, 2 ppm.
- The first reactor is an Aerated Anoxic Zone.
- The last reactor is an Aerobic Zone.



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Brookfield, Ohio, USA

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- **High aeration efficiency is achieved through using aerated-anoxic treatment.**

- **Maximum aeration efficiency is achieved through using aerated-anoxic treatment and aeration equipment selected for optimal efficiency at the selected location within the process.**
  - **Envirex VertiCel Hybrid Aeration System**

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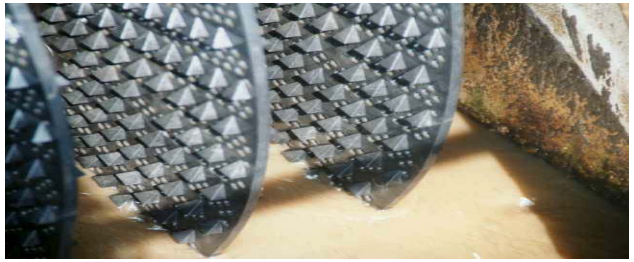
VertiCel System

- Combination of Orbal Disk aerators and Diffused Air aerators
- First: Vertical Loop Reactor with mechanical aerators
- Last: Conventional reactors with fine bubble diffusers
- Benefits from use of aerated anoxic treatment and highest efficiency aeration equipment for process location.



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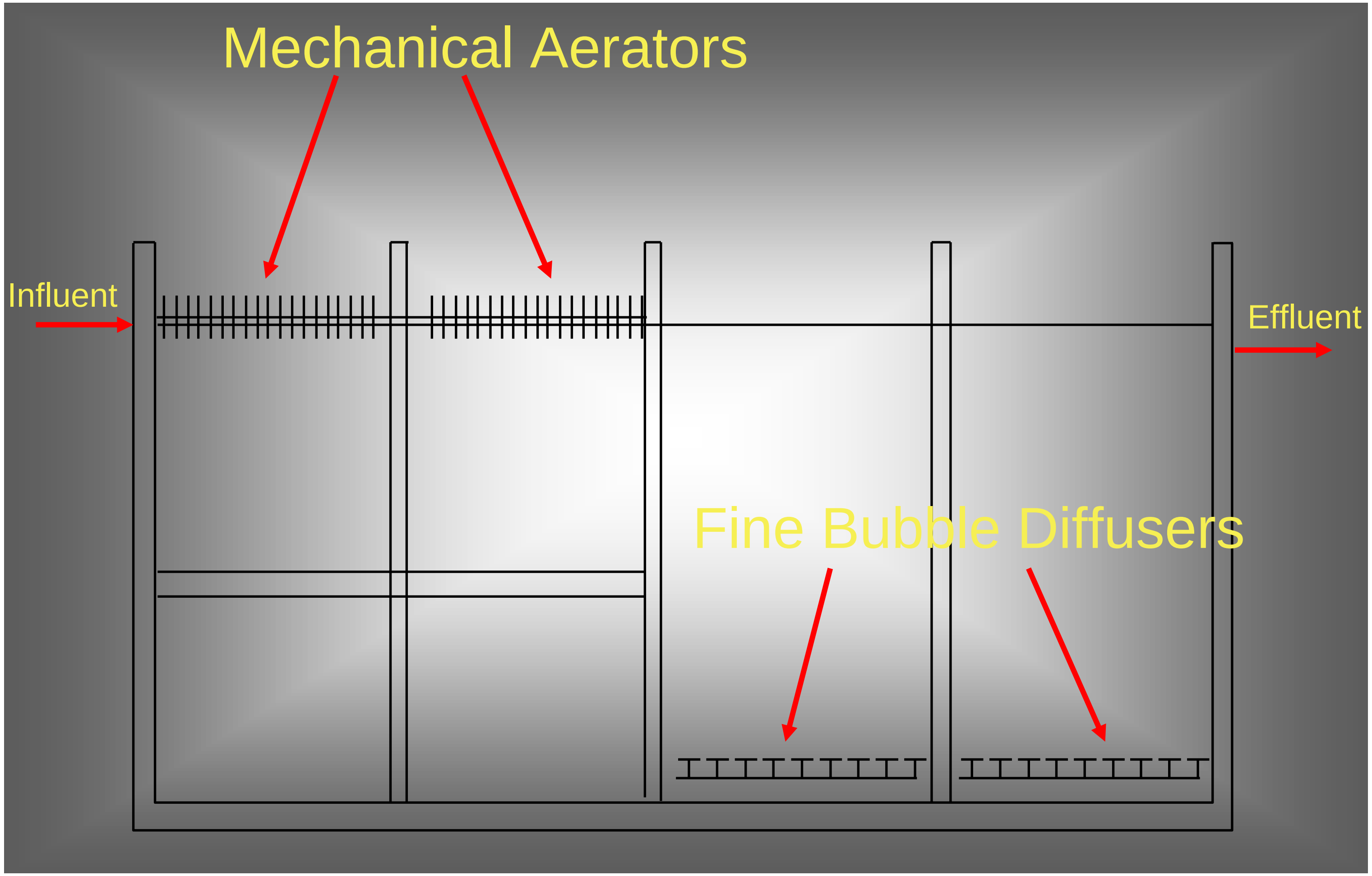
VertiCel System



VertiCel System

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Mexico

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Performance of Systems with Aerated Anoxic Reactors

Schematic of WWTP, Hammonton, NJ Orbal

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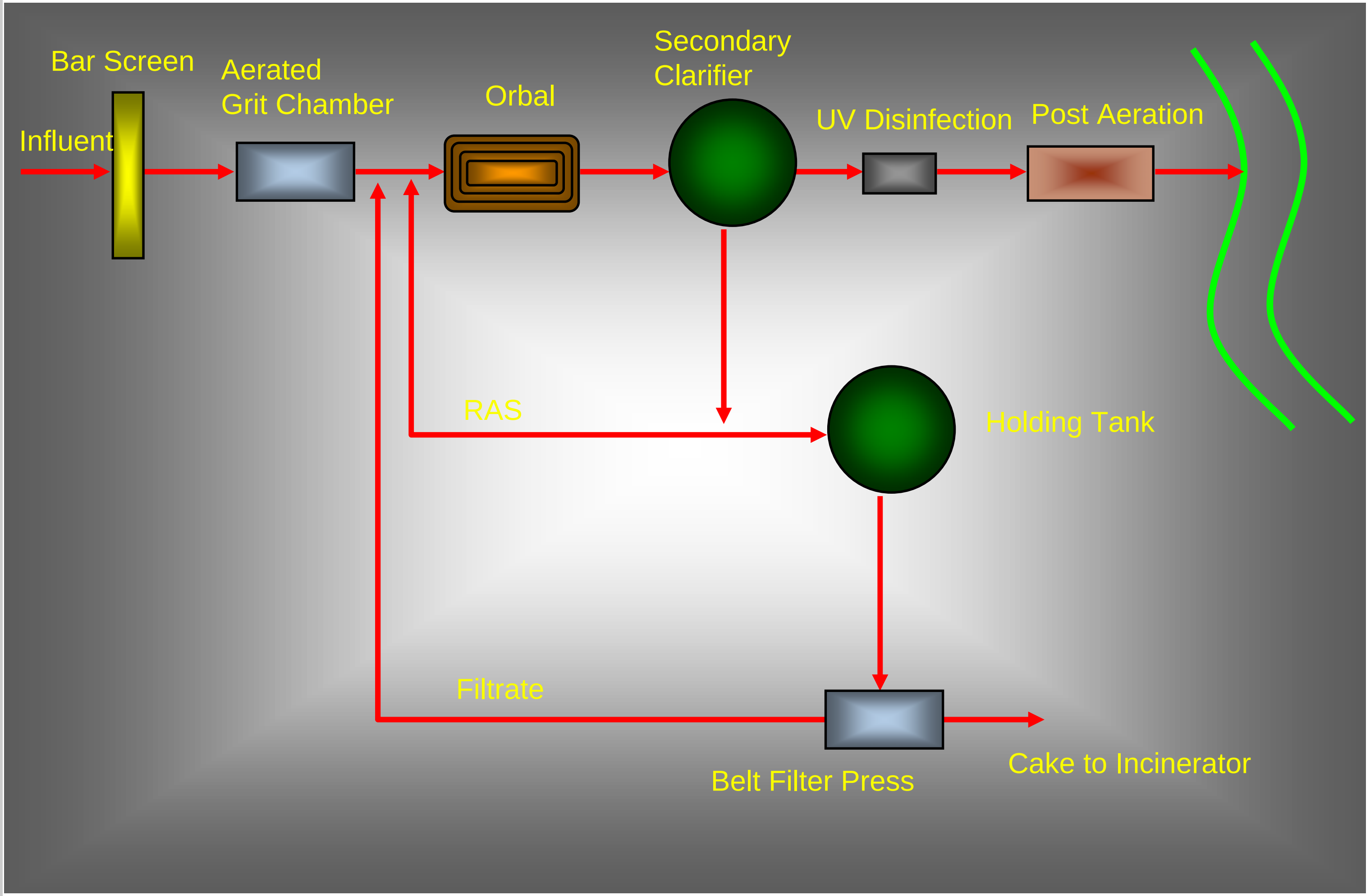

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Annual Data Summary Hammonton, NJ

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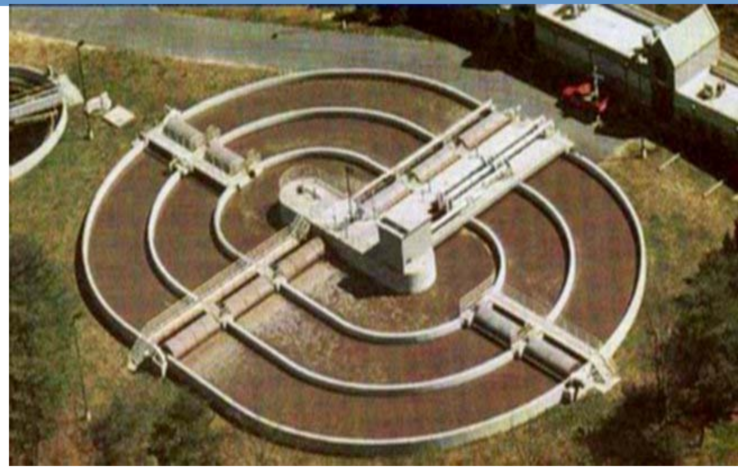

YEAR	BOD_5 Inf.	BOD_5 Eff.	TSS Inf.	TSS Eff.	TKN Inf.	TKN Eff.	NO_3-N Eff.	TN Eff.	TPO_4 Eff.
Limit		5.0		30		N/A	3.0	N/A	3.0
95	353	1.6	369	3.4	35.1	1.2	1.71	2.93	2.07
96	332	1.2	383	1.6	37.0	0.47	0.96	1.44	1.18
97	314	1.1	302	1.6	35.6	1.76	0.44	2.55	1.59

Note: All units mg/L

Power Consumption Comparison Summary

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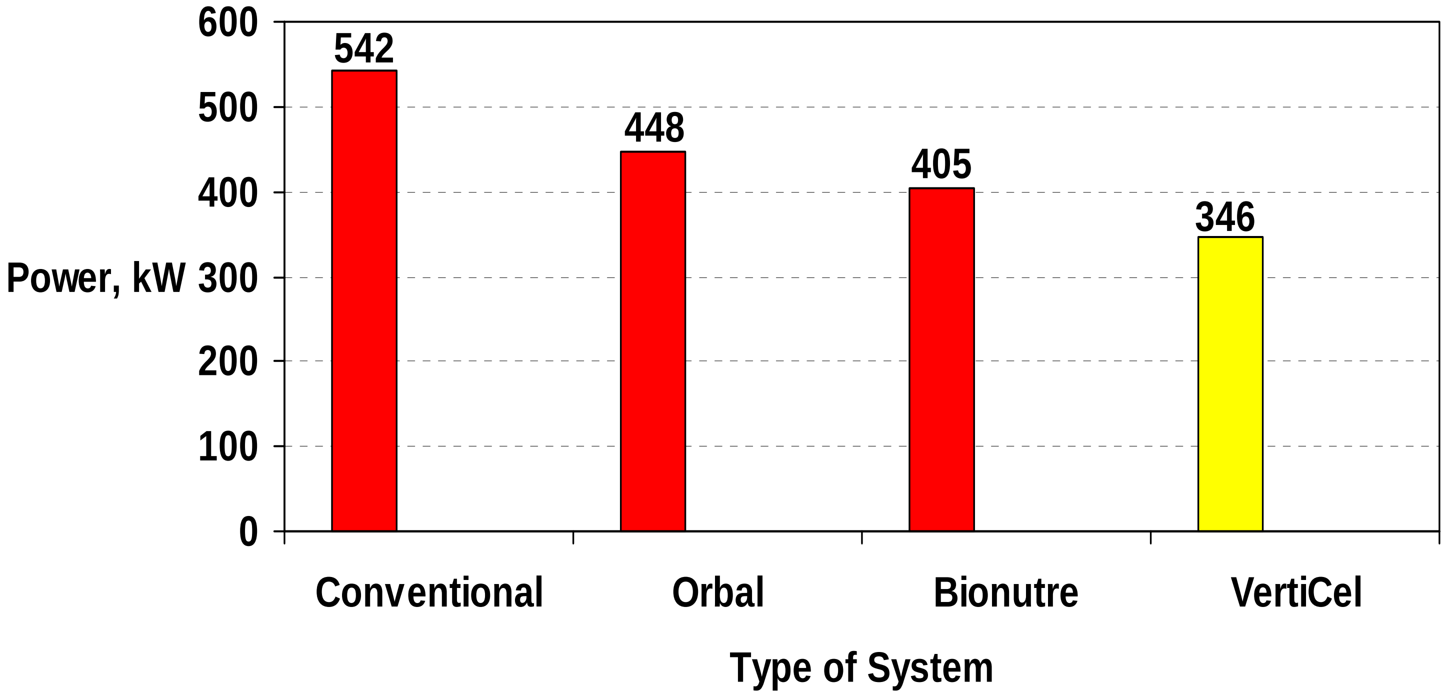

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Conclusion -

- By selecting the most efficient aerator for each location and by using aerated-anoxic conditions,
  - Mechanical aeration at head of process
  - Diffused aeration further into process
  - Aerated-anoxic treatment
- Able to achieve a high level of treatment and maximum process aeration (energy) efficiency.
- The VertiCel system (Vertical Loop Reactors with disc aerators followed by conventional fine bubble reactors) provides a simple process with high process aeration efficiency and offers common wall construction and relatively small footprint.

USFilter, Envirex's Experience with Aerated Anoxic Reactors

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Orbals

- Over 600 Installations worldwide
  - Preston, UK
  - Gwinnett County, GA
  - Hammonton, NJ,
  - McMinneville, OR

VLR

- Over 20 installations worldwide
  - Texas City, TX

VertiCel Aeration System

- 6 installations worldwide
  - Ratburana (BMA 3), Thailand
  - Nangkheim (BMA 3), Thailand
  - Gills Creek WWTP, IN
  - Cadeyreta, Mexico