Design and Operation of Hybrid Aeration System

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SAWEA 2005
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** = \( \frac{K_{La \text{ Waste water}}}{K_{La \text{ Clean water}}} \)
  
  \( = \frac{\text{mass transfer coefficient in waste water}}{\text{mass transfer coefficient in clean water}} \)

  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**
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.
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
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
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

Plug Flow Reactor

F.B.A. Alpha = 0.3
F.B. Alpha = 0.8
M.A. Alpha = 1.2
M.A. Alpha = 1.0

Influent
Effluent

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.
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

- Anoxic
- Aerobic
- Clarifier
- Internal Recycle
- RAS
- Lutzack-Ettinger Process
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

Result = ‘0’ DO

O₂ Supplied < 75% of O₂ Demand

Deficit
Typical Schematic using Aerated Anoxic Reactors for Denitrification

Internal Recycle (may be used for high rate of denitrification)

Influent Q -> Aerated Anoxic Reactor -> Aerobic Reactor -> Aerobic Reactor -> Final Clarifier -> Effluent

RAS -> WAS
Benefits of Aerated Anoxic Reactors

- 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
Horizontal disk aerators in action with little spray or aerosol formation
Orbal Aeration Disk
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

- Influent
- Basin 1: 0 mg/L
- Basin 2: 1 mg/L
- Basin 3: 2 mg/L
- Internal Mixed Liquor Recycle
- Fine Bubble Diffusers
- Return Activated Sludge
- Tow-Bro Clarifier
- Effluent
- WAS (SAS)

Your Success is Our Goal

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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.
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
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.
VertiCel System

Mechanical Aerators

Influent

Effluent

Fine Bubble Diffusers

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Performance of Systems with Aerated Anoxic Reactors
Schematic of WWTP, Hammonton, NJ Orbal

- Bar Screen
- Influent
- Aerated Grit Chamber
- Orbal
- Secondary Clarifier
- UV Disinfection
- Post Aeration
- RAS
- Filtrate
- Belt Filter Press
- Cake to Incinerator
- Holding Tank
### Annual Data Summary

**Hammonton, NJ**

#### YEAR | BOD$_5$ | TSS | TKN | NO$_3$-N | TN | TPO$_4$
--- | --- | --- | --- | --- | --- | ---
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

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Power Consumption Comparison Summary

<table>
<thead>
<tr>
<th>Type of System</th>
<th>Power, kW</th>
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<tbody>
<tr>
<td>Conventional</td>
<td>542</td>
</tr>
<tr>
<td>Orbal</td>
<td>448</td>
</tr>
<tr>
<td>Bionutre</td>
<td>405</td>
</tr>
<tr>
<td>VertiCel</td>
<td>346</td>
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</table>
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

 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