Aeration Systems
Past, Present and Future.
What to Expect from Aeration System Upgrades

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Outline

• Aeration system types
• Terminology
• Mechanical (surface) aerators and combined (jets and turbines)
• Diffused aeration
  – Coarse
  – Fine pore
• Current Performance Estimates
• Maintenance and Economics
• Conclusions
Terminology

• Efficiency
  – Standard oxygen transfer efficiency (SOTE) (percent oxygen transferred)
  – Standard oxygen transfer rate (SOTR) (mass transferred per unit time)
  – Standard aeration efficiency (SAE) (mass transferred per unit time per unit power)
Terminology Cont

• SOTE - percent
• SOTR – lb O2/hr or kg O2/hr
• SAE – lb O2/hp-hr or kg O2/kW-hr
• All above at standard conditions (e.g. 20°C, clean water, etc.)
• OTE, OTR, AE – at process conditions
Standard and Process Conditions

- Adjustment formulas based upon driving force, temperature, barometric pressure, water quality, saturation concentration, etc.
- Driving force and water quality the most significant
- Driving force = \((\text{DO}_S - \text{DO})/\text{DO}_S\)
- Water quality – alpha factor, 0 to 1
- Total correction can result in process water transfer of only 30 to 80% of clean water transfer
Mechanical Aerators

- Two types
  - High speed (900-1200 RPM)
  - Low speed (30-80 RPM)
- Operate at the surface
- Modest efficiency
- High heat loss
- Mist, spray
- Often simple to install, especially high speed
- Higher alpha factors (0.6 to 0.9) depending upon energy density
High Speed Surface Aerator (Axial Pumping)

Motor

Splash Guard

Impeller

Float

Bell or funnel

Water Flow

Water Level
Specifications

• 1 to 75 hp (1 to 56 kW)
• Up to 2.2 lb O2/hp-hr (1.3 kg O2/kW-hr)
• 900 to 1200 rpm motors, no gear box
• Floc shearing potential
• Quick installation, quick delivery
• 8 ft (2.5 m) depth without draft tubes
High Speed – Out of Service

Impeller Damage
For Sale !!!!
Low Speed Vertical (Radial Pumping)
Specifications

• 5 to 150 hp (112 kW), rarely greater, but possible
• 3 to 3.5 lb O2/hp-hr (1.8-2.2 kg O2/kW-hr)
• ~40 to 80 RPM impellers
• Depths to 15 ft (3.5 m) without draft tubes or lower impellers
• Usually pier mounted, but occasionally mounted on floats
• Long lead time for purchase and installation
• Less potential for floc shear
• Lower impellers and draft tubes for operation at greater depth
• New impeller designs
In Service
Maintenance
HPO-AS Application
Combined Types

• Turbines – using mechanical energy to make fine bubbles from a coarse orifice
  – Sparged
  – Down draft

• Jets – air and water flowing through a venturi creates fine bubbles without a small orifice

• Alpha factors similar to fine bubble diffusers, as opposed to mechanical aerators (0.3 to 0.6)
Down Draft Turbine

- Motor/Gear
- Support Columns
- Impeller
- Draft Tube
Nozzle and Piping

Air Supply

Mixed Liquor Supply

Nozzle
Diffused – Coarse Bubble

- Low maintenance, low efficiency
- 1 % /ft or (3%/m) SOTE
- 2.0-3.0 SAE (1.2 – 1.8 kg O2/kW-hr)
- Large orifices – 0.25 in (60 mm)
- Handles large air flow and high OTRs for many industrial applications
- Phased out in most municipal applications in favor of more efficient fine pore systems
- Alpha in the 0.6 to 0.8 range
Floor Coverage

- Spiral roll – least efficient but great mixing (0.3 to 0.5 % SOTE/ft)
- Cross roll and “ridge and furrow”
- Full floor coverage – most efficient
- Odd arrangements often work well
- Depth limited by blower restrictions
Floor Configurations

- Spiral Roll
- Cross Roll
- Diffusers
- Air Supply
- Surface Swell
Spargers
Fine Pore Diffusers

- Ceramic plates – original custom build systems
- **Ceramic domes** – imported from England, technology ruined in the US
- Ceramic discs – pioneered by Sanitaire
- Ceramic tubes – old and new versions
- Membrane discs – sometimes interchangeable with discs
- **Membrane tubes** – many manufacturers
- Plastic tubes and discs – some special uses
- Panels – proprietary geometry
Fine Pore Diffusers

• Usually implemented with full floor coverage
• Quiescent systems – low turbulence and low fluid velocities
• Suitable for low to medium rate systems
• Requires routine cleaning
• Highest efficiency of all the systems, so far! 8.0 SAE (4.8 kg O2/kW-hr)
• Best system to minimize VOC release
Fine Pore Plates

Developed and used by many large US cities, in custom, site-specific designs.
Domes On
Air Headers
Ceramic Disc Diffusers
Other Discs

Plastic Sintered Disc

EPDM Disc
Five Different Tubes

- EPDM
- PVC
- Ceramic
- EPDM
- Plastic
Diffused Aerator Problems

- **Coarse bubble**
  - Piping failure
  - Corrosion
  - Leaks

- **Fine pore**
  - Fouling (biological)
  - Scaling (chemical)
  - Leaks into the piping system that foul diffusers
  - Back pressure build up
  - Material failures (membrane problems)
  - Piping failures
  - Leaks
Material Failures

• Hardening of the membrane from leaching of membrane components, resulting in increased pressure drop and reduced efficiency

• Softening of the membrane due to absorption of wastewater constituents, resulting in membrane expansion, increased pressure drop and reduced efficiency

• Change in pore size due to aging
Fouling and Scaling

• Fouling – biological growth on diffuser surfaces, coalescing bubbles, increasing pressure drop
• Scaling – precipitation of minerals (calcium carbonate, silica)
• Fouling from the inside due leaks into the piping system
Tank With Partial Cleaning From Hosing
How Does this Affect Design, Operation and Economics?

- Alpha factors – the mother of all fudge factors!
- Efficiency decline over time by fouling/scaling
- Economics of cleaning and replacement
- Monitoring – New instruments coming
A tale of two tanks

\[ \alpha \text{SOTE (\%)} \]

Distance (feet)

High MCRT

Low MCRT
Airflow Rate

\[ Q_{\text{air} \ sp} = \frac{\text{No.} \times \text{area} \times Z}{\text{(No. \ area \ Z)}} \]

\[ \downarrow \ AFR \Rightarrow \uparrow \text{transfer} \]

\[ \uparrow \ Z \Rightarrow \uparrow \text{transfer} \]

\[ \uparrow \text{area} \Rightarrow \uparrow \text{transfer} \]

\[ \uparrow \text{MCRT} \Rightarrow \uparrow \text{transfer} \]

20 years of field Results
What we learned?

• Fine pore diffuser performance is a function of the MCRT (sludge age or SRT)

• Higher MCRT means higher transfer efficiency!
Performance as a Function of Diffuser Age
Power Wasted Compared to Cleaning Cost
Efficiency per process type

- **NEW & CLEANED**
  - <24 mo.: 3.75%/m
  - >24 mo.: 4.30%/m
  - 4.60%/m

- **Used**

- **Cleaned**

- **Old**

- **Conventional**
  - N-Only
  - NDN

- **MCRT (d)**
  - 2 4 6 10 12 14 16 18 20 22
Cleaning effectiveness

- Aeration cost in WWTP is SIGNIFICANT
- Diffuser cleaning dramatically affects OTE
New Generation of Monitoring Equipment

- Most of the results you see where collected through off-gas testing
- Requires an expert operator, 8 to 24 hours of time
- Cost amounts to several thousand dollars per test
- New Generation of equipment -
  - Automatic
  - Digital
  - Inexpensive
  - Smaller!
Instrument sizes

Old instrument

Field-scale 1.0

Field-scale 2.0
Final Thoughts

• Engineers have a wide range of options for aeration

• Mechanical aerators
  – High speed – simple quick solution, usually not best on any specific parameter
  – Low speed - expensive but can be relatively efficient, good mixing
  – Both have high cooling rates and high VOC stripping rates. Not recommended for cold applications
Final Thoughts

• Coarse bubble diffusers
  – Low maintenance
  – Low efficiency
  – Never a good energy conserving solution but often the maintenance free solution

• Fine pore (bubble)
  – Best energy conservation
  – High maintenance
  – Commit to clean or do not purchase
Diffuser Cleaning

- Depending on fouling rates, diffuser cleaning will pay for itself in 9 to 24 months, depending on fouling tendency
- High MCRT systems foul more slowly
- Low MCRT systems foul more quickly
To BNR or Not?

• Our work shows that
  – LOW MCRT Systems have the lowest OTE
  – High MCRT Systems have much higher OTE
  – BNR systems like the MLE process have the highest OTE

• The improved OTE and the denitrification credit compensate for the additional oxygen requirements of High MCRT operation

• BNR systems, because of the selector effect of the denitrification zone, resist bulking and are inherently more stable.

• Why build new low SRT systems ????