Aerobic Treatment Units

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University Curriculum Development for Decentralized Wastewater Management
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Aerobic Treatment Units (ATUs)

- Objectives
  - provide descriptions of various engineered systems that maintain high-rate aerobic digestion of organic compounds found in domestic wastewater
  - provide an understanding of the operation and maintenance required to keep these systems functional
Application

- To provide predictable wastewater renovation when conventional methods will not work
  - shallow soils
    - too shallow to provide treatment
  - high BOD loads
    - too much organic loading into soil
    - wastewater from bakeries
    - wastewater from dairies
- Still must have someplace to discharge water
  - either surface or subsurface
ATUs are Biological Reactors

- Miniature Wastewater Treatment Plants
  - the biological processes are well-understood
  - the ability to mix microbes, wastewater, and dissolved oxygen is a fundamental expectation of environmental engineers
Packaging

- The Unique Features of ATUs include
  - packaging for easy installation
  - ease of maintenance
Primary Function is to Provide Secondary Treatment

- **Removal of Oxygen Demand**
  - bioavailable organic compounds converted to cell mass and into CO$_2$
  - Organically-bound nitrogen is oxidized to ammonium and then to nitrate

- **Removal of Suspended Solids**
  - colloidal organics are enzymatically degraded
  - biomass is slightly more dense than water and will settle
Positioned after primary tank (septic tank)

- must minimize the solids that enter an ATU
- primary tank can provide some flow equalization
Configurations

- Generally Speaking, ATU’s are:
  - Intermittent flow
    - not a constant flow from wastewater source
  - Complete mix
    - aeration provides complete mix of D.O., microbes and food
  - Constant volume
    - flow in is approximately equal to flow out
    - flow equalization is usually provided in the primary tank
ATU’s versus Packed-Bed Media Filters

- ATU’s are Saturated
  - water and solids
  - minimal air-water interface
  - mechanical aeration

- Pack-Bed Media Filters are Non-Saturated
  - water-air-solids
  - maximum air-water interface
  - passive aeration
Suspended Growth Reactors

- Suspended Growth
  - activated sludge process
  - biomass is thoroughly mixed with nutrients and biodegradable compounds
  - organisms flocculate and form active mass of microbes - biological floc
  - food mixed with bugs
Typical Suspended Growth Reactor

Influent (from Primary Tank) → Baffle → Maintenance Access → Suspended-Growth Chamber → Baffle → Aeration Device → Sludge Return → Settling Chamber (clarifier) → Effluent
Attached Growth Reactors

- Attached Growth
  - fixed-film process
  - inert medium provided for microbial attachment
  - wastewater flows through media
  - colloidal and dissolved organics compounds absorbed by biological film
  - food brought to bugs
Combination Suspended Growth and Attached Growth

- Influent (from Primary Tank)
- Maintenance Access
- Aeration Device
- Baffle
- Sludge Return
- Settling Chamber (clarifier)
- Effluent
Rotating Biological Contactor (RBC)

- Combines attached growth with suspended growth
- Rotating disks provide aeration and substrate
- Modular
Sequencing Batch Reactor

- Periodic process
  - flow equalization, aeration, clarification, and biomass wasting
  - sequential processes in same tank

- Typical application is two reactors in parallel
ATU’s Operate in Endogenous Respiration Mode

➢ Goal is to minimize the accumulation of biomass
  • provide plenty of oxygen
  • substrate becomes the limiting factor
  • microbes will feed on each other, resulting in the net decrease of cellular mass
  • process is not 100 percent efficient, stable cell components (not readily bioavailable) will accumulate
Typical Response Curve

- Remember, this graph is easy to understand in batch mode.
- Most ATU’s are more nearly continuous-flow and complete mix.
Aeration and Mixing

- Aeration system is generally used to provide mixing
  - displacement of water as air is injected causes turbulence
Oxygen Transfer into Solution

- Increasing the potential for oxygen to go into solution
  - bubble create air-water surfaces

- Air injection should be near bottom of tank
  - more time for oxygen to go into solution
  - more hydrostatic pressure on bubble
Diffused Aeration

- Small diameter bubbles are best
  - more surface area per unit volume
  - transfer takes place through interface between air and water

- Spargers
  - small interconnected passageways inside a ceramic matrix
Blowers

- Regenerative Blowers
  - provide aeration and agitation
  - mounted in an accessible location
  - maintenance item
  - constant source of noise
Aspirated Propeller

- Hollow Shaft
  - air is drawn by a venturi-type effect as the shaft spins
Big Picture - Bioenergetics

Organic Carbon + O₂ → Energy + CO₂ + H₂O + Residue

+ O₂ → Energy + CO₂ + H₂O + Residue

Waste Heat (exothermic)

+ O₂ → Energy + CO₂ + H₂O + Residue

Waste Heat (exothermic)

Waste Heat (exothermic)
Cycling of Compounds

COHNS organic compounds + volatile fatty acids → heterotrophic microbes

\[
\begin{bmatrix}
\text{volatile} \\
\text{fatty} \\
\text{acids}
\end{bmatrix} + \text{CO}_2 + \text{H}_2\text{O} + \text{CH}_4 + \text{energy} + \text{residuals}
\]

\[
\begin{bmatrix}
\text{volatile} \\
\text{fatty} \\
\text{acids}
\end{bmatrix} + \text{O}_2 \xrightarrow{\text{aerobic microbes}} \text{energy} + \text{CO}_2 + \text{H}_2\text{O} + \text{residuals}
\]

simple precursors \xrightarrow{\text{microbes}} \text{energy} \xrightarrow{\text{microbes}} \text{C}_{60}\text{H}_{87}\text{N}_{12}\text{O}_{23}\text{P} \text{ new cells}

\[
\text{C}_{60}\text{H}_{87}\text{N}_{12}\text{O}_{23}\text{P} + \text{O}_2 \xrightarrow{\text{aerobic microbes}} \text{CO}_2 + \text{H}_2\text{O} + \text{PO}_4 + \text{NH}_3 + \text{residuals}
\]
Environmental Effects

- ATU Influent
  - must have primary treatment
  - strong biocides must not be used within the home or business
    - bleaches must be highly diluted
    - medications (such as antibiotics and chemotherapy drugs) can cause kill-off of bugs
    - latex paints contain mold and fungus inhibitors
Environmental Effects

- **ATU Influent**
  - **pH**
    - microbes will adapt to ranges of slightly acidic to slightly basic influent
    - may cause a population shift
  - **Temperature**
    - units will operate at soil temperature
    - cool temperatures - slow degradation
    - warm temperature - faster degradation
Hydraulic and Organic Loading

- **Two Primary Design Parameters**
  - **Hydraulic Loading**
    - rate that water will pass through the device
    - must provide sufficient retention time
    - wash-outs can occur on laundry day
  - **Organic Loading**
    - food (substrate)
    - more food than bugs – poor quality effluent
    - more bugs than food – high quality effluent
Variations in flow seriously complicate treatment process

- need stable flow and stable substrate supply to maintain stable microbial population
  - single family home can have extreme variations from vacations (no flow) to laundry (high flow)
- Equalization tanks (before ATU) can buffer flow
  - dose the ATU during low flows
  - store excess wastewater during high flows
What About N & P

- Not used for nitrogen removal
  - ATUs convert ammonium to nitrate
  - Some nitrogen is removed in biomass

- Not used for phosphorus removal
  - Phosphate will be released from organic form
  - Some phosphorus is removed in biomass

- Additional unit processes must be added onto ATU’s for effective N & P removal
Examples of ATU’s
Bio-Microbics FAST

- Suspended and attached-growth
  - bubbles trickle up through honeycombed surfaces
  - common application is aboard ships
Installing a Bio-Kinetic System
Package Plants

- Includes additional unit processes
  - anaerobic digestion with denitrification
  - disinfection
  - sludge recycling
Aerodiffuser
Tank is Separate Component
Zabel’s HOOT Plant

1. Pretreatment tank where influent enters.
2. Aeration chamber where oxygen is pumped into the waste water.
3. Clarifier chamber where the clear, odorless effluent rises.
4. Chlorinator where the clear effluent passes through for disinfection.*
5. Holding tank for disinfected* effluent ready for discharge.
6. Extremely quiet, efficient aerator and pump.
7. Unique solid-state HOOT Control Center monitors and controls the system.
Pre-Engineered

- Units are specified for flow and for BOD reduction
- Additional capacity is added by additional parallel units
Operational Issues

- **Biological**
  - need to sustain a microbial population
  - what happens if the electricity goes off?

- **Mechanical**
  - need low-maintenance equipment
    - homeowners are very poor maintenance providers
  - what happens if blower fails on Friday night?
Start Up

- Establishment of microbial population
  - Recommended method is add a few gallons of mixed liquor from operational ATU or activated sludge plant
  - Could add a few shovels-full of an organic soil

- Poor treatment of water
  - more food than bugs
  - biomass will be poorly flocculated
Typical Problems

- **Sludge Bulking**
  - extreme growth of filamentous bacteria
  - attach to floc particles and impede settling

- **Foaming on Water Surface**
  - growth of hydrophobic bacterium
  - causes foaming and frothing on surface
  - froth spray available to reduce surface tension

- **Burping**
  - biogas release from sludge that disperses solids
Accumulated sludge must be removed

- most ATU owners have a service contract with a maintenance provider
- need to some biosolids to serve as seed to repopulate the biological floc
Performance Certification

- NSF/ANSI Standard 40-2000, Residential Wastewater Treatment Systems
  - National Sanitation Foundation
  - American National Standards Institute
- Standardized procedure for evaluation of performance and reliability of aeration units
  - minimum standards for materials, design and construction, and performance
  - for units that operate between 400 & 1500 gpd
Mechanical Evaluation

- ATUs are mounted *in situ*
  - structural integrity
  - watertightness
- Moving parts in a highly corrosive environment
  - certification procedure evaluates frequency of required maintenance and difficulty of providing maintenance
  - electricity and water DO MIX !!!!
Mechanical Evaluation

- **Controls and Sensors**
  - ATU’s must have sensors and controls that can detect failure
  - must be able to deliver visible and audible signal to homeowner

- **Must have ground-level access**
  - for maintenance
  - covers must be secured for safety
Performance Evaluation

Systems are evaluated for 96 consecutive days

- 16 weeks of design organic and hydraulic loading
- 7.5 weeks of stress loading
- 2.5 weeks of design loading
Performance Evaluation

- **Design loading**
  - Influent
    - \( c_{BOD5} \) 100-300 mg/L
    - \( TSS \) 100-350 mg/l
    - flow equals one-day of hydraulic retention

- **Stress loading**
  - Simulates
    - laundry day
    - working parents
    - power or equipment failure
    - vacation
## Classifications

### Table 2. NSF/ANSI Standard Number 40-2000 performance classifications.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>30 day average shall not exceed</th>
<th>7 day average shall not exceed</th>
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<tbody>
<tr>
<td>CBOD5</td>
<td>25 mg/L</td>
<td>40 mg/L</td>
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<tr>
<td>TSS</td>
<td>30 mg/L</td>
<td>45 mg/L</td>
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<tr>
<td>Color</td>
<td>Individual samples shall be less than 15 NTU units.</td>
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<tr>
<td>Threshold Odor</td>
<td>Non-offensive</td>
<td></td>
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<tr>
<td>Oily Film</td>
<td>None visible other than air bubbles</td>
<td></td>
</tr>
<tr>
<td>Foam</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>The individual effluent samples shall be between 6.0 and 9.0</td>
<td></td>
</tr>
</tbody>
</table>

### Class II

Not more than 10% of the effluent BOD5 values shall exceed 60 mg/L and not more than 10% of the effluent TSS values shall exceed 100 mg/L.
Summary

- ATU’s are an option for sites with limited soil conditions
  - used to provide secondary treatment
  - must be maintained
- Site still must be able to discharge the treated effluent
  - highly treated effluent can sometimes be applied to marginal soils
  - ATU’s are not a solution to every onsite problem
Questions