Wastewater Treatment Options For The Food Processing Industry

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Food Processing Categories

- Fruit and Vegetable Industry
- Dairy Industry
- Meat Industry
- Speciality Foods Industry
- Brewery and Wine Industry
Chemical And Physical Parameters Of Concern

- Organics- Biochemical Oxygen Demand (BOD)
- Suspended Solids (SS)
- Fat, Oil and Grease (FOG)
- pH
- Nitrogen
- Phosphorus
- Temperature
Treatment Options

- Discharge directly to a municipal treatment plant
- Pretreatment and discharge to a municipal treatment plant
- Treatment plan on site
- Stream discharge or land application
Wastewater Treatment Plant Flow Diagram
Picture Of Treatment Plant
Preliminary Treatment

- Flow Measurement - flow rate information needed for efficient operation, chemical addition, etc
- Flow Equalization - to cut down on flow variations for better treatment
- Screening - remove solids
- Dissolved Air Flotation - remove FOG
Dissolved Air Flotation
Primary Treatment

Primary treatment includes

- Screening
- Primary Sedimentation - designed to remove settleable solids and reduce the organic load (BOD) on the secondary units.
Rectangular Basin
Circular Basin
An Empty Primary Clarifier
Secondary Treatment
Activated Sludge
Activated Sludge Flow Diagram

Activated Sludge Wastewater Treatment Flow Diagram
Some Modifications To The AS System

- Complete mix AS
- Contact stabilization
- Extended aeration
- Tapered aeration
- Pure oxygen systems
- Oxidation ditch
- Membrane bioreactors
- Sequencing batch reactors (SBRs)
Type Of Reactors

- Plug Flow
- Complete Mix
Primary aeration tank
Oxidation Ditch
Oxidation Ditch
Sequencing Batch Reactors
Lagoon Systems
Types Of Lagoons

- Aerobic lagoons
- Facultative lagoons
- Partial-mixed aerated lagoons
- Tertiary lagoons
- Anaerobic lagoons
Typical Lagoon System

Influent

#1

#2

#3

Effluent
Facultative Lagoon

FIGURE 8-2
Definition sketch for the interactions occurring in a facultative lagoon (from Tchobanoglous and Schroeder, 1985).
Zonal Relationships in a Lagoon

- **Aerobic Zone** (Dissolved Oxygen Present)
- **Facultative Zone**
- **Anaerobic Zone** (No Dissolved Oxygen Present)
- **Dike**
- **Influent**
- **SUN**
Aerated Lagoon

A Typical Surface - Aerated Basin

Note: The ring floats are tethered to posts on the berms.
Nitrogen And Phosphorus Removal
Nitrogen Removal Systems
N

WASTEWATER “TREATMENT”
Of
Nitrogen

Primary Effluent
(Secondary Influent)

Organic Nitrogen (Less)
Ammonia
Nitrification of Ammonia Occurs in Two Steps

*Autotrophic Bacteria Utilize Inorganic Compounds (and CO₂ as a Carbon Source)

Nitrosomonas

NH₃-N
Ammonia N

NO₂⁻-N
Nitrite N

Nitrobacter

NO₂⁻-N
Nitrite N

NO₃⁻-N
Nitrate N
Biological Denitrification

- Nitrate Reduction: NO₃ → NO₂ → NO → N₂O → N₂
- Wastewater/methanol/acetate reduction of NO₃
  - C₁₀H₁₉O₃N + 10NO₃ → 5N₂ + 10CO₂ + 3H₂O + NH₃ + 10OH
  - 5CH₃OH + 6NO₃ → 3N₂ + 5CO₂ + 7H₂O + 6OH
  - 5CH₃COOH + 8NO₃ → 4N₂ + 10CO₂ + 6H₂O + 8OH
N Removal Technologies

1. Single Process for Nitrification-Denitrification
2. Separate Stage Nitrification
3. Separate Stage Denitrification

- These systems can be either suspended growth or attached growth systems or hybrid systems.
Modified Ludzack-Ettinger System

Figure 6-1. Modified Ludzack-Ettinger (MLE) process.
RAS = Return activated sludge; WAS = Waste activated sludge
Source: USEPA 2008b Figure 2-3
Downflow Denitrification Filter

Figure 6-7. Downflow denitrification filter. Source: USEPA (2006b), Figure 2-1
Upflow Sand Filter

Figure 6-8. Continuous backwash upflow sand (CBUS) filters. Source: Feldthuizen, 2004. © Nordic Water Products AB. Used with permission.
Phosphorus Removal

- Biological
- Chemical Precipitation
BIOLOGICAL PRINCIPLES

- Normal cellular uptake in aerobic respiration
  C : N : P ratios  100 : 5 : 1
  BOD : Total N : Total P

- Certain facultative microorganisms, when subjected to anaerobic conditions, can survive by assimilating and storing fermentation products (measured as soluble BOD). In the process, energy in the form of ATP (Adenosine Triphosphate) is used and dissolved (ortho) phosphorus is released from the cells.

- When these microorganisms (“stressed” under anaerobic conditions) come in contact with dissolved phosphorus under aerobic conditions, they “take up” excess phosphorus beyond normal amounts required for cell growth. Phosphate Accumulating Organisms (PAO).
EBPR

- **Initial Anaerobic Stage**: PAOs grab organics / Release cellular $\text{PO}_4$

- **Aeration**: Uptake $\text{PO}_4$ for Energy Production & Storage
Chemical Phosphorus Removal

- Total Phosphorus
- Organic Phosphorus
- Condensed (Poly) Phosphates
- Ortho Phosphates
- Metal Salt Addition

Diagram:
- WAS (Wastewater)
- RAS (Return Activated Sludge)
- Primary Clarifier
- Secondary Treatment
- Sludge to solids handling
Other Phosphorus Removal Processes

Chemical - Most organic & inorganic P readily removed by ppt.

- P in aqueous phase
  - Alum (Al₂(SO₄)₃) – most expensive & mostly used
  - Ferric salts (FeCl₃) – highly corrosive nature
  - Lime (Ca(OH)₂ – excess sludge produced (cost to dispose)

- P onto suspended solids
  - Polymers (with Alum or Fe salts)

Filtration

- Used in conjunction with biological or chemical processes (P < 1 mg/L)
Anaerobic Treatment Systems

- Anaerobic Lagoon
- Anaerobic Contact Reactor
- Anaerobic Filter
- Upflow Anaerobic Sludge Blanket (UASB)
- Expanded Granular Sludge Bed
- Anaerobic Sequencing Batch Reactor
Anaerobic Systems

- Require less energy than aerobic systems
- Low sludge production
- Produce biogas that can be used
- Cannot meet effluent discharge standards
Anaerobic Processes

- **Anaerobic contact reactor**
- **Upflow reactor**
Upflow Anaerobic Sludge Blanket
Anaerobic Filter
Membrane Bioreactors
Membrane Classification Processes

1. Microfiltration
2. Ultrafiltration
3. Nanofiltration
4. Reverse Osmosis
5. Dialysis
6. Electrodialysis
Membrane Bioreactors In U.S.

1. Zenon Environmental
2. US Filter
3. Kubota Corporation
4. Mitsubishi Rayon Corporation
5. Huber Technology
Huber Bioreactor
Kubota Membrane Bioreactor

![Diagram of Kubota Membrane Bioreactor](image)

**Specifications**
- **Average Pore Size**: 0.4 μm
- **Membrane Material**: Chlorinated polyethylene
- **Membrane Panel**: ABS resin
- **Dimension**: 0.49 x 1.0 m
- **Effective Area of Membrane**: 0.8 m² per sheet

*(Fig. 1: Membrane Cartridge with its specifications and a view of the submerged flat sheet membrane bioreactor system)*
Membrane Tanks
Application

- Replace activated sludge
- Replace sand filtration after conventional activated sludge
Effluent Quality

- BOD - 5- 10 mg/l
- Total N - 3mg/l
- Phosphorus - 0.1 - 0.5 mg/l
- Turbidity - 0.2 NTU
- Remove bacteria and viruses
Sludge Treatment And Disposal
Removal of These “Pollutants” Produces “Residuals”
Often called “Sludge”

Note: These residuals are sometimes called “Biosolids”, however that term is usually reserved for sludge that has been “stabilized” and meets specific requirements (pathogen reduction, vector attractions, metals concentration)
ANAEROBIC DIGESTION

Advantages
Low operating costs
Proven effectiveness
Burnable gas produced

Disadvantages
Long start-up time
Affected by changes in loading and conditions
Explosive gas produced
TYPICAL “Two-Stage” ANAEROBIC DIGESTER SYSTEM

Note: Two-Stage System here refers to two separate tanks (One for the treatment process and one for water-solids separation)
Sludge Dewatering And Disposal

- Belt Filter Press
- Centrifuge
- Sand Drying Beds
- Dewatered sludge may undergo composting before disposal
- Land application is the most common method of disposal
Centrifuge
Belt Filter Press