Treatment of Industrial Wastewater

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Overseas Environmental Cooperation Center, Japan
Industrial Wastewater Treatment
– Food Processing Wastewater–

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Contents
1. Environment Control & Measures for Industrial Wastewater Treatment
2. Considering Aspects on Wastewater Treatment Plant Design
3. Wastewater Treatment Technologies
4. Examples of 9 Practical wastewater Treatment Plants

Original sources; Technology Transfer Manual of Industrial Wastewater Treatment, March, 2003, OECC
1. Environmental Control & Measures for Industrial Wastewater Treatment

**History**

'40's | Industrial rehabilitation ('45~'55)

'50's | Fisheries damages by paper mills w.w. ('58)
       | Water Quality Conserv. Law + Control of Effluent Emission from Factory Law ('59)

'60's | Basic Law for Environmental Pollution Control ('67)

'70's | Water Pollution Control Law ('70)
       | Inauguration of the Environmental Agency ('71)
       | Areawide Total Pollution Load Control Law ('78)

'80's | Law / Special Measures for Conserv. Of Lake Water Quality ('84)

'90's | Practical Environmental Assessment started ('92)
       | Basic Environment Law ('93)
       | Environmental Assessment Law ('99)

'00's | 5th Total Effluent Control System ('02) - COD + N, P
### Environmental Control & Measures for Industrial Wastewater Treatment

**Measures for Water Quality Conservation (1/3)**

<table>
<thead>
<tr>
<th>Laws</th>
<th>Protecting Human Health</th>
<th>Preserving Living Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Quality Standards</td>
<td>26 items</td>
<td>9 items</td>
</tr>
<tr>
<td></td>
<td>Heavy Metals,</td>
<td>pH, BOD, SS, DO,</td>
</tr>
<tr>
<td></td>
<td>Toxic Sub. Solvents,</td>
<td>Oil, T-N, T-P…</td>
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<td></td>
<td>Agriculture chem.</td>
<td></td>
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<tr>
<td></td>
<td>Nitrogen⋅⋅⋅⋅⋅⋅⋅⋅⋅⋅⋅⋅</td>
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<tr>
<td></td>
<td>Nationwide</td>
<td>Lake, Pond, Coast</td>
</tr>
<tr>
<td>Effluent Standards</td>
<td>27 items</td>
<td>15 items</td>
</tr>
<tr>
<td></td>
<td>ditto + Org. P</td>
<td>ditto + phenols,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cu, Cr, F⋅⋅⋅⋅⋅⋅</td>
</tr>
<tr>
<td></td>
<td>Nationwide</td>
<td>Nationwide</td>
</tr>
</tbody>
</table>
1. Environmental Control & Measures for Industrial Wastewater Treatment

**Measures for Water Quality Conservation (2/3)**

**Wastewater treatment**

- **Water Pollution Control Law**
- **Environment Assessment**
- **To Attain to the Goal (EQS)**
  - Prefectural Stringent Effluent Standards
  - Total Pollution Conytol
  - Prefectural Specified Effluent Regulation

- **Factory**
  - Cleaner Production
    - Criteria
    - Pollution Control System
    - Improvement
    - Record
    - Education
    - Accountability

- **Public Acceptance**

- **Monitoring**
2. Considering Aspects on W.W. Treatment Plant Design

(1) Cleaner Production

End of Pipe Production

COD 220

430

Cleaner Production
- Process Improvement 58% ↓
- Black Liquor Recovery 26% ↓

Advantages
- Production Cost reduction
- Energy saving
- Resources Saving
- Waste Reduction

Paper & Cardboard
1,300 (1970)

2,680 (1989)

Unit: million ton / year
2. Considering Aspects on W.W. Treatment Plant Design

(2) Selection of Treatment Process
3. Wastewater Treatment Technologies

(1) Screening: Remove Floating Material

Grid Effective Spacing
- Coarse Screen: > 50mm
- Normal Screen 15~50 mm
- Fine Screen < 15 mm
3. Wastewater Treatment Technologies

(2) Separation of settling & floating particles

Stokes’ Law

$$V_r = \frac{g}{18 \mu} (P_w - P_o) D^2$$

- $g$: Gravity, $m/s^2$
- $P_w$: Water density, $kg/m^3$
- $P_o$: Oil density, $kg/m^3$
- $D$: Diameter of particle, $m$
- $\mu$: Viscosity coefficient

$L = \left( \frac{V_H}{V_r} \right) \delta$

Inlet

Oil Zone

Oil Free Zone

Outlet
3. Wastewater Treatment Technologies

(3) Sedimentation: Removing SS
3. Wastewater Treatment Technologies

(4) Floatation: Removing SS & Oil

Dissolved Air Floatation

Influent → Retention tank → Air → Pump → Floating tank → Scraper → Circular type DAF → Floated scum

Sludge → Effluent

Recycle
3. Wastewater Treatment Technologies

(5) Coagulation: Enlargement of Particle

Why ?

Particle

- - - - - - - -

Repulsive Force

Conditioning
- Mixing
- pH

How to connect ?
- Electric Neutralization
- Bonding opposite Charged Ions
- Physical Adsorption
- Bridging

Coagulants
- Electrolyte
- Hydrated Metal Oxide
- Polyelectrolyte
3. Wastewater Treatment Technologies

(6) Aerobic Biological process (1/2)

- **O$_2$**
- **N**
- **P**
- **CO$_2$**
- **H$_2$O**

**Microorganisms**

**BOD / MLSS / D**

- $0.4 \div 30\%$
- $0.02 \div SS$ in Effluent

**Process Parameter**

- **Temp:** $5 \sim 40^\circ C$
- **pH:** $\sim 7 \sim$
- **DO:** $> 0.2 \sim$
- **BOD:**N:P=100:5:1
- **BOD / MLSS / D = 0.02 \sim 0.4**
3. Wastewater Treatment Technologies

(6) Aerobic Biological Process (2/2)

Process
- Conventional Activated Sludge
- Modified: Extended Aeration, Lagoon • • •
- Biofilm: Floating Media, Rotating Contactor
- Hybrid: Membrane

Aerators
- Fine bubble diffuser
- Mechanical aerator
- Fixed bed type

Media
- Floating media
3. Wastewater Treatment Technologies

(7) Anaerobic Biological Process (1/2)

Fuel: 0.35Nm3 / kg TOD

- CO₂
- H₂S
- NH₄⁻
- CH₄

Process Parameter:
- Temp: ~36°C ~ 55°C
- pH: 4.0 ~ 7.8
- TOD / VSS /D

3~12% / COD Removed

Microorganisms

Reactor

Granule

Media
3. Wastewater Treatment Technologies

(UASB) Upflow Anaerobic Sludge Blanket

- Treated Water
- Gas-Solids Separator
- Boundary layer
- Granule Sludge
- Wastewater
- Granule sludge
- Reactor
3. Wastewater Treatment Technologies

(8) Advanced Treatment – BOD, COD, SS

Secondary Treatment (mg/L)

BOD 5~15

AS+UF

UF

Bio Media

Air

Bio Media

Air

COD 10~40

Sand F.

AC Abs.

Coagulation

Advanced Treatment (mg/L)

BOD < 2

SS < 2

BOD < 5

COD 30% rev.

SS < 10

COD < 5
3. Wastewater Treatment Technologies

(8) Advanced Treatment – N Removal

Nitrification
\[ \text{NH}_4^+ + (3/2) \text{O}_2 \rightarrow \text{NO}_2^- + \text{H}_2\text{O} + 2\text{H}^+ \]
\[ \text{NO}_2^- + (1/2) \text{O}_2 \rightarrow \text{NO}_3^- \]

Denitrification
\[ \text{NO}_2^- + 3(\text{H}_2) \rightarrow \text{N}_2 \uparrow + 2\text{H}_2\text{O} + 2\text{OH}^- \]
\[ 2\text{NO}_3^- + 5(\text{H}_2) \rightarrow \text{N}_2 \uparrow + 4\text{H}_2\text{O} + 2\text{OH}^- \]

- Temp
- pH
- Microorganism - holding
- Process Parameter

Wastewater

Oxidation Nitrification

Denitrification

Settling

Treated Water
3. Wastewater Treatment Technologies

(8) Advanced Treatment – P Removal

Wastewater → P-luxurious-uptake → Aeration → Settling → Treated Water

P-release → P-Dissoluble (anaerobic) → Coagulation settling → Excess Sludge

Coagulants:
- aluminum sulfate
- iron chloride
- iron sulfate
3. Wastewater Treatment Technologies

(9) Reusing Treated Water

From AS-process

Coagulation-settling

Filtration-sand

Filtration-UF

Cl₂-diinfection

AC-adsorption

Filtration-UF

Filtration-RO

Water Sprinkling, flushing toilet
Coli < 10  Res. Cl₂ > 0.4  Color 40  BOD < 20

Scenery use
Coli < 0.5  Turbidity (degree) < 10  Color 10  BOD < 10

Industrial Water
Coli (No./L) < 1 (Public bath)  Volatile Solids (mg/L) < 250
Res. Cl₂ (mg/L) > 0.1 (Tap water)  Hardness (mg/L) < 120
Turbidity (degree) < 20  Color (degree) 2~80 (Boiler)
pH 6.5~8.0  5~10 (Food processing)
3. Wastewater Treatment Technologies

(10) Dehydration - Dehydrators

- Belt Press
- Centrifuge
- Vacuum Filter
- Filter Press
- Screw Press
3. Wastewater Treatment Technologies

(11) Drying, Incineration, Composting

Dewatered cake ($H_2O$ 75〜90%)

Rotary dryer

Dryer, Incinerator

Multi-stage vertical dryer

Dry sludge ($H_2O < 10\%)$

Ash

70〜80°C
1〜3 month

Composter

Compost

700〜1,000°C
3. Wastewater Treatment Technologies

(12) Sludge Reduction Process

Wastewater → Aeration tank → Treated water → Solubilizing reactor

Solubilizing reactor: Cell wall is broken by thermo or ozone

Return Sludge

Disposal

Dewatering

Excess Sludge
4. Examples of Food Processing WW Treatment

(1) Beverage ---- Coke

- Wastewater tank
- Sand & Oil Separator
- Lagoon 20,000 m³

Q = 4,000 m³/d
BOD = 400 mg/L (daily av.)
pH = 5.8 ~ 11
SS = 50 ~ 70 mg/L

Yearly

<table>
<thead>
<tr>
<th></th>
<th>Temp. (°C)</th>
<th>Water (°C)</th>
<th>pH</th>
<th>BOD (mg/L)</th>
<th>DO (mg/L)</th>
<th>SS (mg/L)</th>
<th>Trsp. (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av.</td>
<td>10.7</td>
<td>16.7</td>
<td>9.0</td>
<td>2.6</td>
<td>4.5</td>
<td>4.3</td>
<td>40</td>
</tr>
<tr>
<td>Max</td>
<td>33</td>
<td>25.4</td>
<td>11.3</td>
<td>5.4</td>
<td>9.2</td>
<td>11.3</td>
<td>50</td>
</tr>
<tr>
<td>Min</td>
<td>-15</td>
<td>7.1</td>
<td>7.8</td>
<td>1.6</td>
<td>1.7</td>
<td>2.4</td>
<td>20</td>
</tr>
</tbody>
</table>
4. Examples of Food Processing WW Treatment

(2) Breweries —— Beer (1/3)

<table>
<thead>
<tr>
<th>Date</th>
<th>May 8</th>
<th>May 15</th>
<th>May 22</th>
<th>May 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW Q^3/d</td>
<td>2,710</td>
<td>3,560</td>
<td>3,460</td>
<td>3,820</td>
</tr>
<tr>
<td>Inf. BOD mg/L</td>
<td>900</td>
<td>966</td>
<td>712</td>
<td>694</td>
</tr>
<tr>
<td>Inf. SS mg/L</td>
<td>140</td>
<td>357</td>
<td>260</td>
<td>143</td>
</tr>
<tr>
<td>Efl. BOD mg/L</td>
<td>84</td>
<td>120</td>
<td>50</td>
<td>46</td>
</tr>
<tr>
<td>Efl. SS mg/L</td>
<td>140</td>
<td>150</td>
<td>140</td>
<td>120</td>
</tr>
<tr>
<td>CH_4 m^3/d</td>
<td>1,100</td>
<td>1,210</td>
<td>924</td>
<td>969</td>
</tr>
</tbody>
</table>

WW: Wastewater, weekly average
## 4. Examples of Food Processing WW Treatment

### (2) Breweries — Beer (2/3)

**Cost comparison – Anaerobic vs. Aerobic**

<table>
<thead>
<tr>
<th>Item</th>
<th>Price ￥</th>
<th>Anaerobic + DAF Cons. /d (￥/d)</th>
<th>Aerobic process Cons. /d (￥/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td>18/kWh</td>
<td>3,200kWh 57,600</td>
<td>6,800kWh 122,400</td>
</tr>
<tr>
<td><strong>Steam</strong></td>
<td>3/kg</td>
<td>12,000kg 36,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>45% NaOH</strong></td>
<td>40/kg</td>
<td>1,600kg 64,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Coagulants</strong></td>
<td>1,400/kg</td>
<td>4kg 5,600</td>
<td>15kg 21,000</td>
</tr>
<tr>
<td><strong>Desulfer</strong></td>
<td>170/kg</td>
<td>4.2kg 714</td>
<td>-</td>
</tr>
<tr>
<td><strong>Sludge disp.</strong></td>
<td>10,000/m³</td>
<td>1.5m³ 15,000</td>
<td>6m³ 60,000</td>
</tr>
<tr>
<td><strong>CH₄</strong></td>
<td>28,000/kL</td>
<td>2kL 56,000</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>122,914</td>
<td>203,400</td>
</tr>
</tbody>
</table>

**Economics** +￥80,486/d

**DAF**: dissolved Air Floatation unit, **CH₄**: converted to A-heavy oil
4. Examples of Food Processing WW Treatment

(2) **Breweries** —— **Beer** (3/3)

- Top cover of digester
- Desulfurizer
- Centrifuge dehydrator
- DFA
4. Examples of Food Processing WW Treatment

(2) Breweries —— Sake (1/2)

Coagulation-settling ➔ Equalization tank ➔ Aeration tank ➔ Settling tank ➔ Dehydrator ➔ Livestock feed

Rice washing wastewater

Q 250 m³/d (120)
BOD 750 mg/L (4,000)
SS 120 mg/L (5,000)

( ) ; rice-wash wastewater

AC filter ➔ Sand filter ➔ Coagulation-settling ➔ Dehydrator ➔ Dewatered cake

Chlorination tank ➔ Effluent

BOD < 20 mg/L
SS < 30 mg/L
4. Examples of Food Processing WW Treatment

(2) Breweries —— Sake (2/2)

Purification of rice-washing wastewater by coagulation

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>SS (mg/L)</th>
<th>BOD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw WW</td>
<td>6.6</td>
<td>717</td>
<td>1,250</td>
</tr>
<tr>
<td>Effluent</td>
<td>6.8</td>
<td>&lt;30</td>
<td>185</td>
</tr>
</tbody>
</table>

Coagulants: alum; 1,000 NaOH; 365 Polymer; 10 (mg/L)

- Settling tank
- Aeration tank
- Equalization tank
- Sand filter
- AC filter
- Dual Cell gravity dehydrator
4. Examples of Food Processing WW Treatment

(3) Oil & Fat (1/2)

- **Wastewater**
  - Q: 600 m³/d
  - Cooling water

- **Wastewater tank**

- **Anaerobic tank**
  - BOD < 200 mg/L
  - SS < 200 mg/L

- **Denitrification tank**
  - Excess sludge

- **Aeration tank**
  - Denitrification tank
  - Re-aeration tank
  - Settling tank

- **Dehydrator**
  - BOD < 10 mg/L
  - SS < 20 mg/L
  - T-N < 80 mg/L

- **Dewatered cake**
  - BOD 8,000 mg/L
  - SS 1,700 mg/L
  - T-N 400 mg/L

- **Steam**
  - Desulfurizer
  - Boiler
  - Steam

- **HX**

- **Effluent**
4. Examples of Food Processing WW Treatment

(3) Oil & Fat (2/2)

- 1 kg TOD
- Anaerobic process
- Activated Sludge process

+ 0.35 Nm³ CH₄
3,000 Kcal
3.5 kWh

TOD = 840 kg/d
(BOD=480 kg/d)

- 0.5 kWh

Energy Production
+ 2,940 kWh/d

Energy Consumption
- 420 kWh/d

Difference 3,360 kWh/d
4. Examples of Food Processing WW Treatment

(4) Milk & Daily Product (1/2)

- **Wastewater**
  - 540 m³/d (12hrs)
  - BOD 200 mg/L

- **Equalization tank**
  - 190 m³

- **Screen**

- **Aeration tank**
  - 258 m³

- **Settling tank**
  - 120 m³

- **Chlorination tank**

- **Aerobic digestion tank**
  - 19 m³

- **Excess sludge**

- **Blower**

- **Cl₂**
  - BOD < 20 mg/L
  - SS < 20 mg/L

- **Effluent**
4. Examples of Food Processing WW Treatment

(4) Milk & Daily Product (2/2)

**Sludge Bulking**

**Causes**
- Operation
- Wastewater

- Low load: < 0.2kgBOD/kg SS/d
- High load: > 0.4kgBOD/kg SS/d
- Low DO: < 0.2mg/L
- Abnormal pH: < 6.5~8
- Short SRT

**Temporally measure:** Coagulant

**For Chronic bulking:**
- Plug-flow
- Batch-wise operation
- Pre-treatment - Anaerobic process
4. Examples of Food Processing WW Treatment

(5) Wheat Starch (1/2)

- Desulferizer
- Fuel: $\text{CH}_4 \equiv 3.150 \text{ Nm}^3/\text{d}$

- Steam
- NaOH

- Equalization Tank: 600 m$^3$
  - COD Rem. $>80\%$
  - Q: 500 m$^3$/d
  - COD: 18,000 mg/L
  - BOD: 11,000 mg/L

- COD Rem. 1,000 m$^3$

- Aeration Tank: 3,000 m$^3$

- Settling Tank: 120 m$^3$
  - Effl.: BOD < 50 mg/L

- Gas holder
- Dehydrator
- Cake
Advantages of Anaerobic Treatment

CH$_4$ → Fuel for Starch drying process
Sludge bulking in activated sludge process → Disappeared
Excess sludge generation → Reduced to about 1/5
4. Examples of Food Processing WW Treatment

(6) Potato starch (1/2)

- Lagoon 30,000 m³
- Floating aerator 37 kW
- Settling tank 900 m³

BOD loading (Ave.):
- 0.15 kg/m³·d
- 0.05 kg/kg SS·d

SS 176~3,730 Ave. 602
BOD 873~2,230 Ave. 1,440
Water temp. 7~17 °C

SS 54~188 Ave. 119
BOD 42~91 Ave. 68
Water temp. 2~17 °C

Unit: mg/L
4. Examples of Food Processing WW Treatment

(6) Potato starch (2/2)

Operation: End of summer ~ early of winter

Problem at restart-up: filamentous bacteria bulking

- Maintain sludge activity → Intermittent wastewater feed
- Dispersing AS → coagulants feed
- New sludge seeding → from sewage treatment plant
- Control of sludge septicity → minimum aeration

Lagoon, 30,000 m³
Aerator 37 kW x 5 units
DT = 8 days

Settling tank
907 m³ (DT = 6 hrs)
4. Examples of Food Processing WW Treatment

(7) Takeout dishes (1/2)
4. Examples of Food Processing WW Treatment

(7) Takeout dishes (1/2)

High Conc. W.W.
- Q: 1,050 m$^3$/d
- pH: 4.3
- BOD: 2,310
- SS: 550
- Oil: 110

Low Conc. W.W.
- Q: 550 m$^3$/d
- pH: 6.3
- BOD: 760
- SS: 130
- Oil: 50

Diagram showing the processing steps:
- Screen
- Equalization tank
- Anaerobic reactor
- Desulferizer
- Aerobic tank
- DAF
- CH$_4$
- pH: 5~9
- BOD: < 200
- SS: < 200
- Oil: < 30

Effluent

Dewatered sludge

Unit: mg/L

Graph showing BOD mg/L for different concentrations.
4. Examples of Food Processing WW Treatment

(8) Confectionaries (1/2)

Cleaner production in production lines

- Raw materials
  - Mixer
  - Filler
  - Calcination furnace
  - Sizing & packing
  - Wastewater

- Egg
  - Egg cracker
  - Washing water → pneumatic washing
    Reducing 30% of total BOD
  - Spill wall → recovering spilling syrup

- Fruit cans
  - Can opening

- Raw materials
  - Mixer
  - Filler
  - Sealer
  - Sterilization Refrigerator
  - Jerried fruit
  - Wastewater
4. Examples of Food Processing WW Treatment

(8) Confectionaries (2/2)

Wastewater
BOD 4,000 mg/l

Equalization T

Septic tank effluent
(domestic wastewater)

Tapered-aeration

10-stage plug-flow

MLSS adjustment

BOD → Sludge
< 20%
↓
N,P no-feed

Biological Contact T. Rapid Mixing T.

Coagulation-Settling T.

Chlorination T.

Effluent

BOD < 10 mg/L

Filamentous sludge → trap

Filamentous sludge → settling

NaOH, PAC
Polymer

Dewatered cake
Mobile dehydrator

Sludge T.
Thickener

Excess Sludge