Water Reuse by Ozone: Experiences and Actions in Japan

May 25, 2015

Seiji FURUKAWA
Hirofumi TAKAHARA
Japan Ozone Association
Contents

- What’s “Ozone”?  
- Current state of sewage treatment in Japan  
- Standards for water quality and for facilities for water reuse  
- Application of ozonation for sewage treatment  
- Japanese Industrial Standards
What’s “Ozone”?

- Strong oxidizing power
- Effective for disinfection of microorganisms and virus
- No secondary pollution due to being back to oxygen after reaction
- Producible anywhere electric power is supplied

**Comparison of oxidation potential**

<table>
<thead>
<tr>
<th>Oxidizer</th>
<th>Oxidation Reduction Potential [V]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorine</td>
<td>2.87</td>
</tr>
<tr>
<td>Ozone</td>
<td>2.07</td>
</tr>
<tr>
<td>Hydrogen Peroxide</td>
<td>1.78</td>
</tr>
<tr>
<td>Chlorine</td>
<td>1.40</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1.23</td>
</tr>
<tr>
<td>Domain</td>
<td>Purposes</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td><strong>Drinking water</strong></td>
<td>Taste &amp; Odor control</td>
</tr>
<tr>
<td></td>
<td>THMs removal</td>
</tr>
<tr>
<td></td>
<td>Disinfection</td>
</tr>
<tr>
<td><strong>Waste water</strong></td>
<td>Disinfection</td>
</tr>
<tr>
<td></td>
<td>Color removal</td>
</tr>
<tr>
<td></td>
<td>Waste water recycle</td>
</tr>
<tr>
<td></td>
<td>Air odor control</td>
</tr>
<tr>
<td><strong>Aquarium &amp; Swimming pool</strong></td>
<td>Improvement of transparency</td>
</tr>
<tr>
<td><strong>Industrial application</strong></td>
<td>Food manufacturing</td>
</tr>
<tr>
<td></td>
<td>Waste water treatment</td>
</tr>
<tr>
<td></td>
<td>NOx removal</td>
</tr>
</tbody>
</table>
How to produce Ozone

Silent discharge is commonly used due to high efficiency
Ozone is formed by recombination of ionized oxygen atoms generated by applying high power AC and unionized molecular oxygen.
Replacement ozone system for WWTP, featuring patented generator technology designed to maximize efficiency and reliability, has doubled ozone concentration.

Getting ozone into water via side stream injection, instead of previous surface aeration method.
Current state of sewage treatment in Japan

- **High population cities:**
  - Almost completed.

- **Smaller population cities:**
  - Still to be constructed.

- **Advance treatment of sewage has not spread in Japan.**
Current state of sewage treatment in Japan
-Amount of sewage and water reuse-

- Total amount of treated sewage at fiscal 2008: 14.0 billion m$^3$/y
- Water reuse: 0.20 billion m$^3$/y (1.4%)

Waters for landscape use and for amenity oriented space: 26%
Discharge for flow maintenance of river waters: 32%
### Standards for water quality and for facilities for water reuse

<table>
<thead>
<tr>
<th>Standards for facilities</th>
<th>flush toilet water</th>
<th>sprinkling water</th>
<th>landscape use</th>
<th>amenity oriented water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E. coli</strong></td>
<td>not detected</td>
<td>not detected</td>
<td>1000CFU/100mL of coliform group (provisional)</td>
<td>not detected</td>
</tr>
<tr>
<td><strong>tubidity</strong></td>
<td>less than 2</td>
<td>less than 2</td>
<td>less than 2</td>
<td>less than 2</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>5.8～8.6</td>
<td>5.8～8.6</td>
<td>5.8～8.6</td>
<td>5.8～8.6</td>
</tr>
<tr>
<td><strong>appearance</strong></td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
</tr>
<tr>
<td><strong>chromaticity</strong></td>
<td>–</td>
<td>–</td>
<td>less than 40</td>
<td>less than 10</td>
</tr>
<tr>
<td><strong>odor</strong></td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
<td>not uncomfortable</td>
</tr>
<tr>
<td><strong>residual chlorine</strong></td>
<td>free residual chlorine more than 0.1mg/L or combined residual chlorine more than 0.4mg/L</td>
<td>free residual chlorine more than 0.1mg/L or combined residual chlorine more than 0.4mg/L</td>
<td>–</td>
<td>free residual chlorine more than 0.1mg/L or combined residual chlorine more than 0.4mg/L</td>
</tr>
</tbody>
</table>

Application of ozonation for sewage treatment

- Number of ozonation facilities -

First operation of ozone for sewage treatment

**Plant**
Benten sewage treatment plant

**Location**
Oita prefecture

**Date**
1988～

**Purpose**
To polish sewage effluent in order to supply treated water to a moat in Funai castle

- Increasing year by year constantly
- Reached more than 65 at fiscal 2008
Secondary effluent of WWTP is treated by ozone for various purposes, e.g. landscape water or sanitary water.
Application of ozonation for sewage treatment
-Purpose of ozonation-

- Reuse (out of the plants): 48%
- Removal of odor, taste and color: 30%
- COD removal: 12%
Application of ozonation for sewage treatment

-Ozone dose-

- 5~15 mg/L of ozone is commonly dosed
- More than 20 mg/L of ozone is dosed in some cases

- 5~15 mg/L of ozone is commonly dosed
- More than 20 mg/L of ozone is dosed in some cases
Examples of ozone application
Kohoku WWTP in Yokohama City

- Secondary treated wastewater is sand-filtered and ozonated to be reused.
- It is sent to Nissan Stadium, one of the largest ball game field in Japan, being used as heat sources of air conditioners and flushing water for toilets.

Ozonation facilities
Capacity: 8070m³/day x 2
Ozone dose: 12mg/L (Max.) 8mg/L (Ave.)
Kisshoin WWTP in Kyoto City

- The oldest sewage plant in Kyoto City, started operation from 1934.
- Installed the ozonation process of 80,000m³/day in 1997, while total capacity of the plant is 114,000m³/day.
In addition, colored wastewater is discharged from fibers and dying related plants for “Kimono” in Kyoto.
Red-colored effluent water

Ozone-treated water
## Effluent Water Quality of Kisshoin TP

<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>Biological Treatment</th>
<th>Ozone Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Water Quality</td>
<td>Removal Rate (%)</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>99</td>
<td>3.2</td>
<td>96.8</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>52</td>
<td>7.4</td>
<td>85.8</td>
</tr>
<tr>
<td>SS (mg/L)</td>
<td>75</td>
<td>4</td>
<td>94.7</td>
</tr>
<tr>
<td>N (mg/L)</td>
<td>18</td>
<td>5.3</td>
<td>70.6</td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>1.6</td>
<td>0.52</td>
<td>67.5</td>
</tr>
<tr>
<td>Chromaticity</td>
<td>33</td>
<td>13</td>
<td>60.6</td>
</tr>
<tr>
<td>Coliforms (CFU/mL)</td>
<td>1.4x10^5</td>
<td>1.2x10^3</td>
<td>99.1</td>
</tr>
</tbody>
</table>

### Other Unit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Water Quality</th>
<th>Removal Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.6</td>
<td>97.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.8</td>
<td>85.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>98.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>44.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.86</td>
<td>46.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>57.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.6x10</td>
<td>98.9</td>
<td></td>
</tr>
</tbody>
</table>
Ozone Treatment of PPCPs in Wastewater

- The concentration of the antiviral drug "Tamiflu in Japanese river water is increased in winter season, due to an epidemic of influenza. It is concerned that this could lead to the appearance of drug-resistant virus.
- Based on a field research, “Tamiflu” is decomposed by 90% or more in WWTPs equipped with ozone process, while the removal rate in WWTPs w/o ozone is less than 40%.
- In a lab-scale experiment, pharmaceuticals such as “Ethenzamide” were remarkably decomposed.

Environmental Chemistry
20, 3, 269-272 (2012)
Japanese Industrial Standards on Ozone Treatment Apparatus
Japanese Industrial Standard (JIS)

JIS B 9946: 2011
Ozone treatment apparatus for waste and water in industry and other oxidation uses
– Specifications of apparatus and measurement methods for ozone concentration

✓ Specifications and requirements
✓ Ozone resistant materials
✓ Ozone concentration control in the treatment apparatus and its surroundings
✓ Ozone concentration measurement methods
✓ Regular maintenance and inspection
Ozone concentration measurement at process control points

Ozone treatment apparatus basic configuration

Air supply unit
- Air compressor
- After cooler
- Air dryer

Oxygen supply unit (on-site generation)
- Air compressor
- Oxygen concentrator

Oxygen supply unit (LOX)
- LOX storage tank
- Vaporizer

Power supply

Ozone generator

Cooling system

Ozone contactor (Liquid phase)
- M2

Ozone dissolution system

Waste ozone suction unit
- M4

Waste ozone destruction unit
- M3

Waste ozone treatment unit

Operation: M1～M3
Installation and replacement: M1～M5

Process control points

Feed gas supply unit

Ozone generation unit

Ozone contact unit

Waste ozone treatment unit

Ozone treatment apparatus basic configuration
# Ozone Resistant Materials

<table>
<thead>
<tr>
<th>Unit</th>
<th>Equipment</th>
<th>Applicable ozone resistant material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone generation</td>
<td>Ozone generator</td>
<td>SUS304, SUS316L, glass, ceramics, aluminum (with anticorrosion treatment), EPDM rubber, CSM</td>
</tr>
<tr>
<td></td>
<td>Cooling System</td>
<td>SUS304, titanium, FRP, brass</td>
</tr>
<tr>
<td>Ozone contact</td>
<td>Ozone contactor</td>
<td>Concrete, mortar, SUS304, SUS316L, FRP a)</td>
</tr>
<tr>
<td></td>
<td>Ozone dissolution system</td>
<td>Ceramics, SUS304, SUS316L</td>
</tr>
<tr>
<td>Waste ozone treatment</td>
<td>Waste ozone destruction unit</td>
<td>SUS304, PTFE, FRP a)</td>
</tr>
<tr>
<td></td>
<td>Waste ozone suction unit</td>
<td>SUS304, PVC, FRP a)</td>
</tr>
</tbody>
</table>

Note a) Recommended only where ozone concentration is below 100 ppm.
**Regular Maintenance and Inspection**

**Preparation of maintenance schedule and inspection manual**

Regular maintenance and inspection schedule for the treatment apparatus and ozone monitors, as well as the maintenance and inspection manual, shall be prepared prior to the apparatus startup by the parties involved.

**Workers**

Regular maintenance and inspection, including parts replacement, are required for the operation of treatment apparatus and ozone monitors. The operators, as well as the personnel conducting maintenance and inspection (referred to hereafter as “workers”) shall have a high level of knowledge of ozone.
Thank you for your attention!
Outline of Draft - Ozone Treatment -

**System Components**
a) Feed gas supply unit, b) Ozone generation unit, c) Ozone contact unit, d) Waste ozone treatment unit

**Evaluation method**
a) Water treatment performance
b) Energy consumption
   1) Power consumption, 2) Oxygen consumption
c) Dependability
   1) Usage of ozone resistant materials
   2) Ozone concentration control in the treatment apparatus and its surroundings
   3) Regular maintenance and inspection