Current Status and Challenges of Urban Wastewater Treatment in China

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Main Content of the Presentation

1. Development of Urban Wastewater Treatment

2. Key Factors Affecting WWTP’s Performances

3. Typical Examples of Urban WWTPs and WRPs
# 1. Development of Urban Wastewater Treatment

## Effluent Discharge Standard of Urban WWTPs

<table>
<thead>
<tr>
<th>Effluent Limits</th>
<th>COD</th>
<th>BOD$_5$</th>
<th>SS</th>
<th>NH$_3$-N</th>
<th>TP</th>
<th>TN</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBJ 4 -73</td>
<td>100</td>
<td>60</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GB 8978 - 88</td>
<td>120</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>GB 8978 - 1996 Class II</td>
<td>120</td>
<td>30</td>
<td>30</td>
<td>15</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>GB 8978 - 1996 Class I</td>
<td>60</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>GB18918 - 2002 Class II</td>
<td>100</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>GB18918 - 2002 Class IB</td>
<td>60</td>
<td>20</td>
<td>20</td>
<td>8(15)</td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td>GB18918 - 2002 Class IA</td>
<td>50</td>
<td>10</td>
<td>10</td>
<td>5(8)</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td>Future</td>
<td>?</td>
<td>20</td>
<td>3</td>
<td>1</td>
<td>0.1</td>
<td>5</td>
</tr>
</tbody>
</table>

Unit: mg/L
Rapid Growth of Urban WWTPs in Mainland China

Amount of Wastewater Treatment Plants (WWTPs)

Capacity

NMSUWT started in 2007

157 million m$^3$/d

3781

2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Capacity (million t/d)

0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0

0
500
1000
1500
2000
2500
3000
3500
4000

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## Trend of Urban WWTP’s Development

<table>
<thead>
<tr>
<th>Year</th>
<th>WWTPs</th>
<th>Total capacity (million m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>37</td>
<td>0.64</td>
</tr>
<tr>
<td>1990</td>
<td>87</td>
<td>3.17</td>
</tr>
<tr>
<td>2000</td>
<td>402</td>
<td>17.67</td>
</tr>
<tr>
<td>2005</td>
<td>792</td>
<td>57.25</td>
</tr>
<tr>
<td>2010</td>
<td>2624</td>
<td>122.13</td>
</tr>
<tr>
<td>2015</td>
<td>5000</td>
<td>170.00</td>
</tr>
<tr>
<td>2020</td>
<td>10000</td>
<td>200.00</td>
</tr>
</tbody>
</table>
WWTPs Need to Be Upgraded to Higher Standards

- Total capacity divided by effluent discharge standards

![Bar chart showing WWTP capacity](chart.png)

Upgrading to higher standard
WWTPs Need to Be Upgraded to Higher Standard

Number of WWTPs divided by effluent discharge standards

![Bar chart showing upgraded WWTPs by standard and year]

Upgrading to higher standard
Processes for Meeting the Discharge Standards

- **Class II Discharge Limits**
  - Organic matter → biological treat (AS or BF)

- **Class IB Discharge Limits**
  - Organic & nutrient → BNR systems

- **Class IA Discharge Limits**
  - Reclaimed water or sensitive regions (lakes)
    → EBNR + advanced treatments

- **More stringent limits for specific situations**
  - High quality reclaimed water
  - Highly sensitive regions
  - Special requirement

- MF/UF & RO
- Strict N & P control
- Chemical oxidation
Process Selection for Biological Nutrient Removal

**Modified A\(^2\)/O Process for improving the N & P removal**

* Process Design for Tai’an WWTP in 1988

- Anoxic/Pre-denit.
- Anaerobic
- Anoxic
- Oxic Zone (nitrification)
- Mixed liquor recycling
- Carbon source addition
- Chemical addition
- Return sludge
- Excess sludge
- Clarifier
- Effluent

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Process Selection for Biological Nutrient Removal

**EBNR process for meeting new effluent limits**

- Influent splitting
- Pre-Den. (Pre-denitrification)
- An (Anammox)
- Ax (Aerobic)
- Oxic (Oxidation)
- Mixing Liquor Recycling
- Carbon source addition
- Chemical addition
- Clarifier
- Effluent
- Inorganic & Sludge
- Return Sludge
- Excess Sludge
2. Key Factors Affecting WWTP’s Performances

- **Fluctuation of influent quality & flow-rate**
  - Wide distributions & variations
  - Change with regions, locations and time

- **Low BOD\(_5\)/TN ratio**
  - Degradation in septic tank and sewerage
  - Biological pretreatment of industrial effluent

- **High SS/BOD\(_5\) ratio → inorganic fraction**
  - Combined sewer system & urban runoff

- **Low temperature and industrial inhibitors**
  - Regions with low water temperature
  - Difficulty of industrial effluent control
Wastewater Differences with Location and Time

Wastewater COD Concentration by Regions
Wastewater Differences with Location and Time

- Wastewater TN Concentration by Regions

![Graph showing the TN concentration in wastewater across different regions.](image-url)
Key Factors Affecting WWTPs Performances

- High SS/BOD$_5$ ratio

![Graph showing the percentage of WWTPs affected by high SS/BOD$_5$ ratio](image-url)
Key Factors Affecting WWTPs Performances

- Influent SS/BOD$_5$ ratio of Wuxi Lucun WWTP

![Graph showing Influent SS/BOD$_5$ Ratio vs Date]

Typical MLVSS/MLSS: 0.3-0.5
Key Factors Affecting WWTPs Performances

- Low BOD$_5$/TN ratio of WWTP’s influent
Influent and Effluent NH$_3$-N (Average)

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3. Examples of Urban WWTPs and WRPs
1980s: Tianjin Jizhuangzi WWTP

First large-scale WWTP (AS)
Started operation in 1984
Capacity: 260,000 m$^3$/day
Extended to 540,000 m$^3$/day BNR in 2000
Development of Tianjin Jizhuangzi WWTP

2010s
Tianjin Jizhuangzi Water Reclamation Plant

Started to operation in 2002

Chemical Treatment

Micro-filtration in 2002

Submersible micro-filtration

RO system in 2010s
Upgrading from SF to SMF systems

Sand filter

Membrane system

SMF
1990s: Qingdao Licunhe WWTP

First phase: 80,000 m³/day (1998)

Second phase 90,000 m³/day (2008)
Qingdao Licunhe WWTP

- **Pre-denitrification for return AS**
- **Denitrification**
- **Anaerobic Zone**
- **Oxic Zone**

- Designed in 1994; started operation in 1998
- BOD: 488 mg/L, TSS: 558 mg/L, TN: 87 mg/L, TP: 7.0 mg/L
- 170,000 m$^3$/day
Qingdao Licunhe WWTP

Third Phase: 80,000m³/day under design
Total capacity: 250,000m³/day

- Typical Operation Modes
  - VIP process
  - Modified A²/O process
  - + IFAX in year 2010
Late 2000s: Upgrading of Wuxi Lucun WWTP

Conventional AS (1992)
A²/O process (1998)
Modified A²/O+IFAS (2008)
Wuxi Lucun WWTP, Jiangsu

Upgrade to Class I A

- High SS/BOD$_5$
- Low BOD$_5$/TN
- Low Temperature
# Process Upgrading of Lucun WWTP

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Process selection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Treatment</strong></td>
<td><strong>Screens:</strong> replacement, new fine screens</td>
</tr>
<tr>
<td></td>
<td><strong>Pumping station; sand &amp; grid removal</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Primary clarifiers:</strong> equipment renewal, odor control, fermentation function</td>
</tr>
<tr>
<td><strong>Biological Treatment</strong></td>
<td><strong>Modified A²/O system</strong></td>
</tr>
<tr>
<td></td>
<td><strong>IFAS system for nitrification</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Carbon source and metal salt addition</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Denitrification filters</strong></td>
</tr>
<tr>
<td><strong>Advanced Treatment</strong></td>
<td><strong>Mechanical and Membrane filtration</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Chlorine dioxide ; UV disinfection</strong></td>
</tr>
</tbody>
</table>
Primary Fermentation Clarifier System

Fermentation Clarifier
Process for Biological Nutrient Removal

Modified A²/O Process

Influent

Anoxic/Pre-denit. → Anaerobic → Anoxic

Mixed liquor recycling

Oxic Zone (nitrification)

Clarifier

Effluent

Return sludge

Excess sludge
Upgrading of Lucun WWTP, Wuxi City

Layout of biological treatment process

- **IFAS system**
- **Oxic Zone** (low aeration)
- **Oxic or Anoxic**
- **Anoxic Zone**
- **Anaerobic**
- **Pre-denit.**

HRT: 0.5/0.5/4.6/4.6 hour

Influent splitting

Return Sludge
Upgrading of Lucun WWTP, Wuxi City

- **IFAS system to improve the nitrification**

  - IFAS system
  - Biofilm carriers
  - Steel Sieve

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Upgrading of Lucun WWTP, Wuxi City

Mechanical filtration system
Qingdao Tuandao WWTP

Strong wastewater
TN: 50–120 mg/L
Qingdao Tuandao WWTP

Modified A²/O System
Qingdao Tuandao WWTP

IFAS for enhancement of total nitrogen removal
Upgrading of Chengbei WWTP, Wuxi City
2010s: Tianjin Jinnan WWTP

Design Capacity:
First stage 550,000m³/day

EBNR
Water reuse
Phosphorus recovery
Anammox
Sludge digestion
Green design
System Intergrading in Tianjin Jinnan WWTP

Five-stage Bardenpho
550,000 m³/d

Anaerobic digestion (10% solid)
160 DT/d

Boiler

Dewatered Sludge
drying using biogas

Biogas purification

Side-stream
2000 m³/day

CO₂ removal

B-LNG

Dried sludge

Struvite

Phosphorus recovery

Annammox

Reclaimed

Class I A

UF/RO

Side-stream

Hot water

Dewatered Sludge

drying using biogas

Steam

Hot water

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Thank you for your attention