Water-Reuse in Industrial Parks

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Joint partners

- Technische Universität Darmstadt
  - Landmanagement (LM)
  - Wastewater Technology (AT)
  - Material Flow Management and Resource Economy (SuR)
  - Work and Engineering Psychology Research Group (AI)

- Institute for Sanitary Engineering and Waste Management of Leibniz Universität Hannover (ISAH)

- Institute of Environmental Engineering & Management at the Witten/Herdecke University (IEEM)

- EnviroChemie GmbH (EC)

- Endress+Hauser Conducta (EH)

- Kocks Consult GmbH (KC)
Additional partners

- Associated Partner: Merck KGaA
- Tongji University Shanghai, China
- University of Technology Qingdao, China
- Hanoi University of Civil Engineering, Vietnam
Introduction

- Industrial parks usually rely on the availability of water

- In times of climate change, shortage of resources and the increasing importance of environmentalism it is important to ensure a sustainable water supply

- Integrated water management and reuse:
  - Water demand from natural resources can be reduced
  - Valuable materials recovered from the wastewater
  - Invest/Running costs can be reduced
  - Energy consumption can be reduced
Introduction

- Integrated water management and reuse:
  - Opportunity for industrial developments in regions with natural water shortage (e.g. in parts of South-East-Asia)
  - Because of the high water requirement/high amounts of wastewater, application potential for chemical-pharmaceutical industry is given*

* Ante, Angela; Behrendt, Joachim; Bennemann, Helmut; Blöcher, Christoph; Bolduan, Peter (2014): Trends und Perspektiven in der industriellen Wassertechnik. Rohwasser, Prozess, Abwasser (Trends and perspectives in industrial water technology. Raw water, process, wastewater); Positionspapier der ProcessNet-Fachgruppe Produktionsintegrierte Wasser- und Abwassertechnik., Frankfurt, M
Initial situation

Principle sketch of the current wastewater treatment in industrial parks

1. Input-water (different qualities: e.g. drinking water, industrial water, demineralized water)
2. Wastewater (different qualities: lighter arrows represent less pollution)
3. Treated wastewater (different qualities: lighter arrows represent less pollution)
4. Plant internal water loop

* thickness of arrows indicates the amount of water
Research objective

Reduction of the drinking water requirement in industrial parks by an appropriate treatment and reuse of wastewater

- **Input-Water** (different qualities: e.g. drinking water, industrial water, demineralized water)
- **Wastewater** (different qualities: lighter arrows represent less pollution)
- **Treated wastewater** (different qualities: lighter arrows represent less pollution)
- **Reclaimed water**: treated wastewater used as input-water (different qualities: lighter arrows represent higher qualities)

*thickness of arrows indicates the amount of water*
Possible application of treated wastewater as:

- **Process water**
  (E.g. as raw material, reaction water, solvent)

- **Cooling water**

- **Toilet flushing**

- **Irrigation water**

- **Fire-fighting water**

- **Water for road cleaning**
  ...etc.
Overview of the different research fields

- Determination of water savings potential *(using the example of chemical-pharmaceutical industrial parks)* (LM, AT)

- Development of new treatment technologies and their coupling (AT, ISAH, EC)

- Testing of technical implementation (technical infrastructure and measurement concept) (KC, EH)
Overview of the different research fields

- **Ecological and economic evaluation** of different treatment technologies (SUR, IEEM)

- **Multi-criteria selection support** for concept layouts (ISAH)

- **Socio-technical application** - stress analysis of employees (AI)

- Examination of **transferability** to other industrial park types and industrial locations (LM)
Practical experiments und surveys

- Development of new treatment technologies
- Tests with real wastewater
- Visit various industrial parks in Germany, China and Vietnam

Wastewater lab EnviroChemie
Test column
Visit of industrial parks
Laboratory pilot plants (activated sludge process with salt water) TU Darmstadt
Identification of appropriate treatment technologies…

… for linking existing water flows

<table>
<thead>
<tr>
<th>Wastewater Quality A</th>
<th>Reuse-Water-Quality A</th>
<th>Reuse-Water-Quality B</th>
<th>Reuse-Water-Quality C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Technology X or Treatment Technology Z</td>
<td></td>
<td>Tech. X</td>
<td>Tech. X or Tech. Y or Tech. Z</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wastewater Quality B</th>
<th>Reuse-Water-Quality A</th>
<th>Reuse-Water-Quality B</th>
<th>Reuse-Water-Quality C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low development need</td>
<td></td>
<td>No technical solution identifiable</td>
<td>Economic solution is not known</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wastewater Quality C</th>
<th>Reuse-Water-Quality A</th>
<th>Reuse-Water-Quality B</th>
<th>Reuse-Water-Quality C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low development need</td>
<td>High development need</td>
<td></td>
<td>Tech. X + Tech. Y</td>
</tr>
</tbody>
</table>
Characteristics of industrial wastewater

- High water requirement/wastewater flow
- High salinity and high organic content
- High concentration of refractory COD
Wastewater treatment

- Enhanced biodegradability
- Equalization
- Reduction of organic matter
- Nitrification/Denitrification and P-Elimination
- Elimination of none biodegradable contamination
Basics and Motivation

- **Activated Sludge Process** is the most popular method for (industrial) wastewater treatment.

- Mainly **fine-bubble aeration systems** are used to satisfy the oxygen demand.

- About **60 % of energy requirement of WWTP** is for aeration.

- Industrial wastewater is often characterized by **high salt and organic concentration**.

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**POWER REQUIREMENT WWTP**

- **Aeration**: 60%
- **Recirculation**: 15%
- **sludge Treatment**: 15%
- **mechanical cleaning**: 5%
- **other**: 5%

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[Activated Sludge Process diagram]

[DWA(2008)]
Water Reuse in Industrial Parks is characterised by:

- **Water demand** from natural resources can be reduced
- **Invest/Running costs** can be reduced
- Increasing **salt** and **refractory COD concentration**
Three Challenges to reuse industrial wastewater

1. Desalination:
   - Application of Capacitive deionization (CDI)
   - Possible application before or after biological treatment

2. Biological treatment of high saline industrial wastewater:
   - Influence on the aeration system
   - Biological treatment under high saline conditions

3. Membrane Filtration:
   - Improved biological degradation of (refractory) COD with Membrane filtration
Key technologies have been identified for treatment of industrial wastewater:

- Desalination in the electric field
- Biological wastewater treatment with high salt concentrations
- Improved COD-Degradation

Practical tests with real industrial wastewater
Practical experiments – Biological treatment

What we know about salt

• Influence sludge characteristic

• Reduce cleaning performance

• Inhibit bubble coalescence and oxygen transfer increases

⇒ More efficient aeration i.e. energy saving
Practical experiments – Biological treatment

Lab Experiments

- **Oxygen transfer tests** in water with different salt concentrations

- **Batch experiments** to investigate the effect of salt on the sludge activity

- **Lab-scale activated sludge reactors** for continuous measurement of sludge characteristics

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Activated sludge

Oxygen transfer test

Lab-scale activated sludge process

Activity Batch-Tests
Effect of salt on oxygen transfer

- Salt reduces the mass transfer \( (k_L) \)
- Increase the interfacial area \( (a) \)
- Results in a net increase of the volumetric mass transfer \( (k_La) \)

\[
f_s = \frac{Oxygen\ transfer_{saline\ water}}{Oxygen\ transfer_{clean\ water}} (-)
\]

- Well known for seawater \((NaCl)\)
Design example: Aeration System with high salt concentration

WWTP:
- 20,000 PE
- $T_W$: 18°C
- Diffused aeration system

<table>
<thead>
<tr>
<th>Variant 1: Normal salt concentration</th>
<th>Variant 2: High salt concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{TDS} &lt; 2\text{ g/l}$</td>
<td>$S_{TDS} = 10\text{ g/l}$</td>
</tr>
<tr>
<td>$\text{SOTR} = 172\text{ kg/h }O_2$</td>
<td>$\text{SOTR} = 111\text{ kg/h }O_2$</td>
</tr>
</tbody>
</table>

- You need a **35% smaller** aeration System!
- Fewer invest and operating costs
- Fewer energy consumption
- Fewer space requirements
Effect of different salts on oxygen transfer

Effect of different salts

![Graph showing the effect of different salts on oxygen transfer]

- **NaCl**
- **MgCl2**
- **KCl**
- **CaCl2**
- **NaSO4**
- **NaAcetat**

High salt concentration

Oxygen transfer test

Oxygen transfer tests – view on the water surface
Measurement of sludge activity

Lab-scale tests show:

• **Poor degradation** of COD and Nitrogen

• **Inhibition** of the biomass by salt

• Biological treatment process is more **unstable/sensitive**
Conclusion

- Lab-Scale experiments confirm **poor degradation under saline conditions**

- Influence of different salts on the oxygen transfer could be shown: Through better oxygen transfer **energy demand could be reduce**
Concept WaReIp

Possible Treatment Processes:

“Fit for Purpose”

Possible Treatment Processes:

Pre-Treatment

- Equalization
- Desalination

Biological Treatment

- Activated Sludge Process
- Membrane
- Sedimentation
- Micro-Screen

Separation of Biomass

Advanced Treatment

- Desalination
Concept WaReIp

Example #1:
- Better Oxygen transfer i.e. energy saving (+)
- Better separation of biomass (+)
- Salt inhibit the biomass (-)
Concept WaRelp

Example #2:

- No salt inhibition of the biomass (+)
- Effluent with low COD concentration and no solids (+)
- Poor Oxygen transfer i.e. more energy requirement (-)
Thank you for your attention.

The Project Team