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**)

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Additional partners

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

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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

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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

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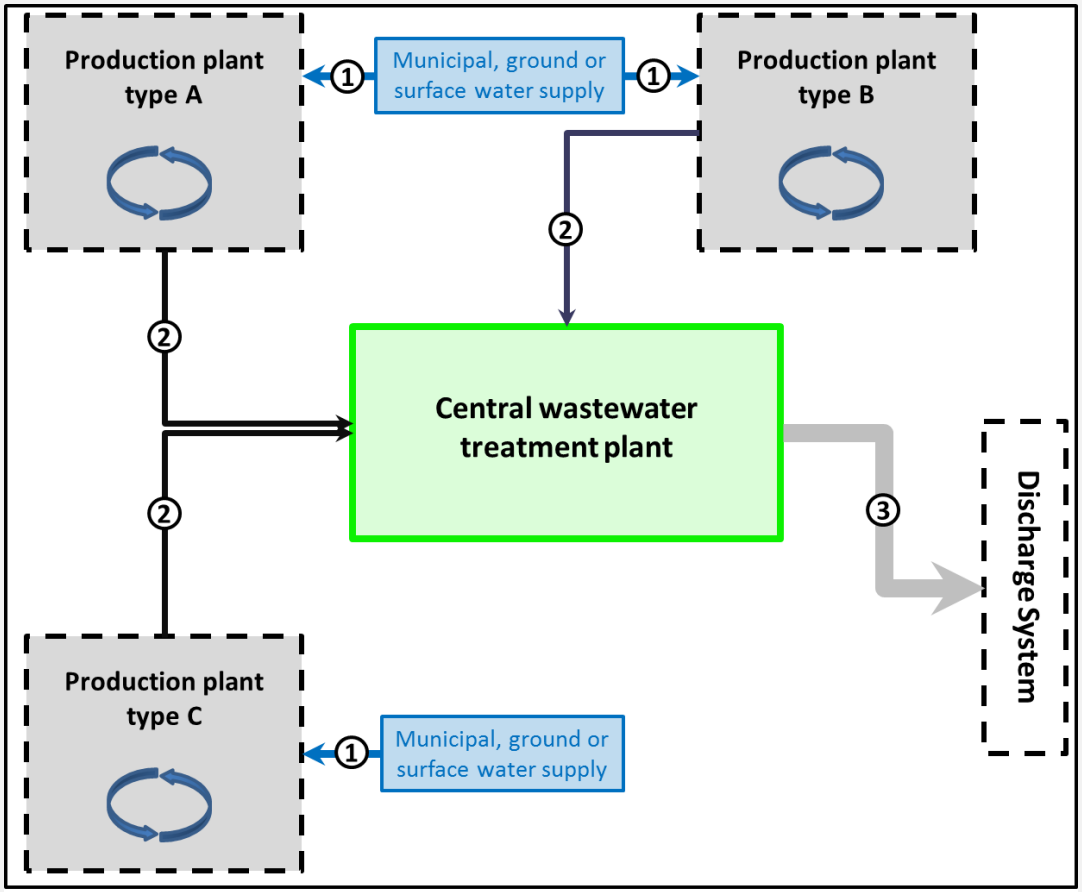
Initial situation

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)*

Plant intern water loop

* thickness of arrows indicates the amount of water

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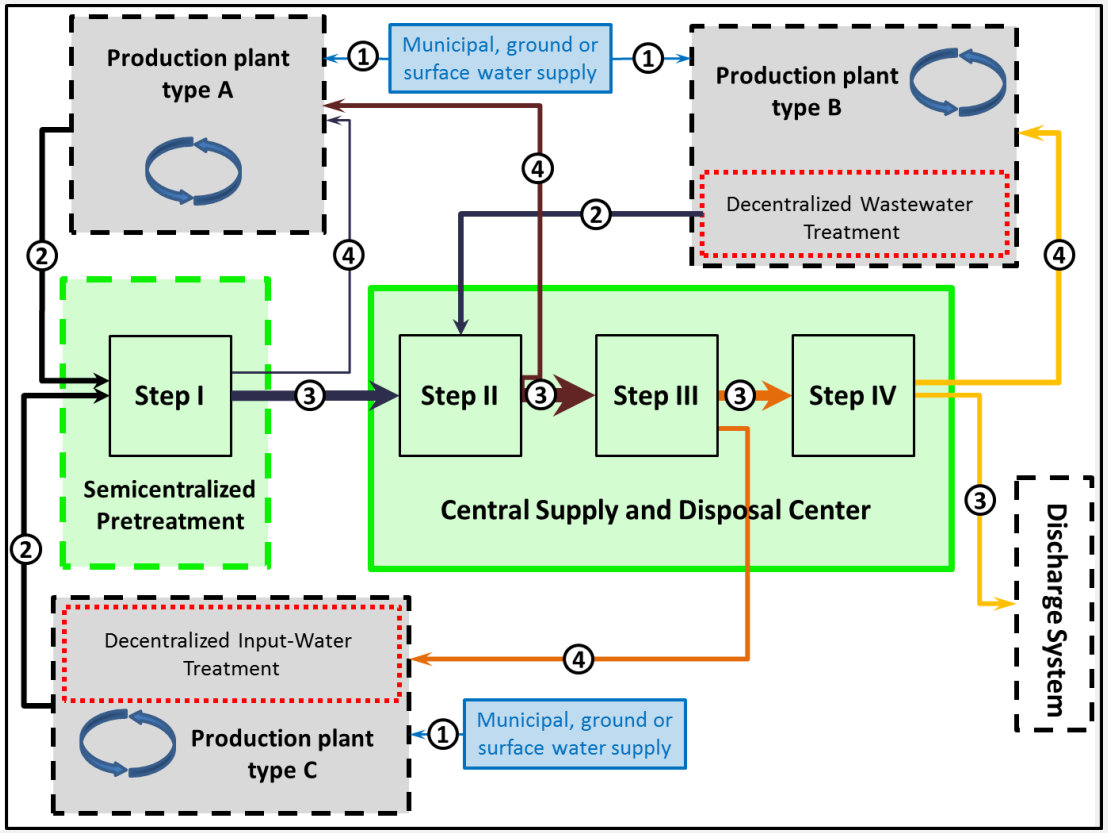
Research objective

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



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② **Wastewater** *(different qualities: lighter arrows represent less pollution)*

③ **Treated wastewater** *(different qualities: lighter arrows represent less pollution)*

④ **Reclaimed water:** treated wastewater used as input-water *(different qualities: lighter arrows represent higher qualities)*

Plant intern water loop

* thickness of arrows indicates the amount of water

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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.

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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)

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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)

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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

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Identification of appropriate treatment technologies…

… for linking existing water flows

	Reuse-Water-Quality A	Reuse-Water-Quality B	Reuse-Water-Quality C
Wastewater Quality A	Treatment Technology X or Treatment Technology Z	Tech. X	Tech. X or Tech. Y or Tech. Z
Wastewater Quality B	Low development need	No technical solution identifiable	Economic solution is not known
Wastewater Quality C	Low development need	High development need	Tech. X + Tech. Y

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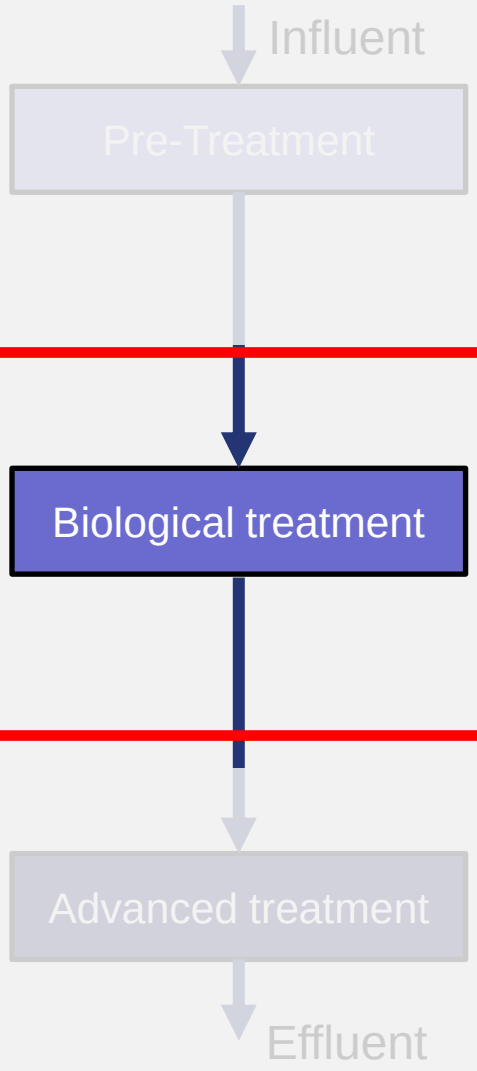
Characteristics of industrial wastewater

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

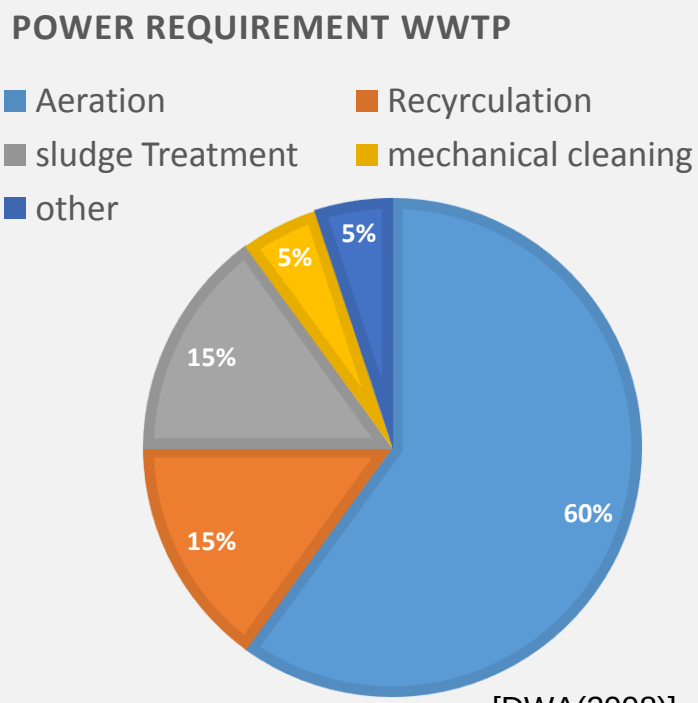
Wastewater treatment

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

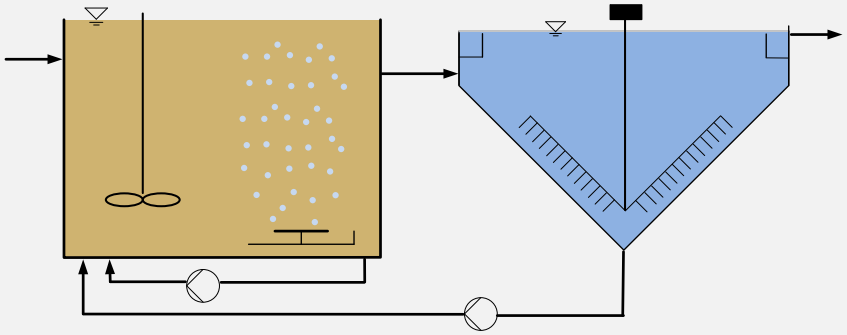


Basics and Motivation

- **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**



[DWA(2008)]



Activated Sludge Process

Water Reuse in Industrial Parks

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**

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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

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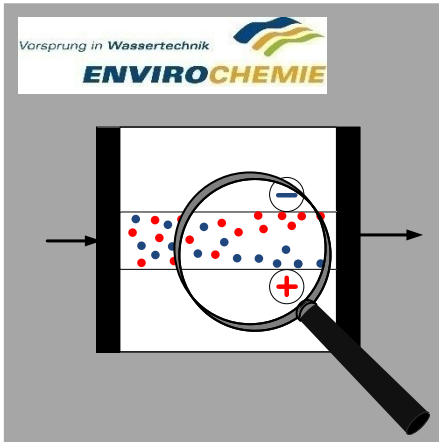
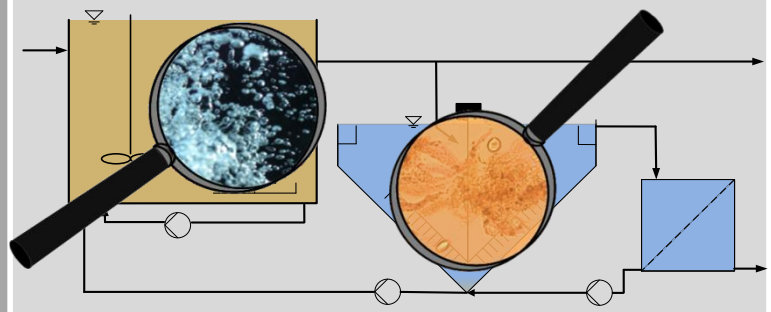
Practical experiments

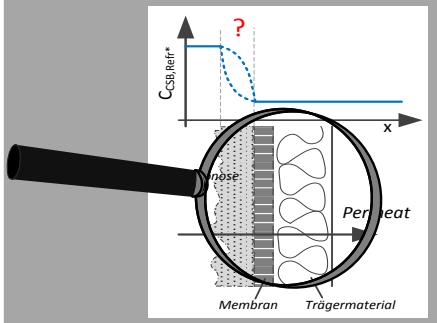
Key technologies have been identified for treatment of industrial wastewater



Desalination in the electric field



Biological wastewater treatment with high salt concentrations



Improved COD-Degradation

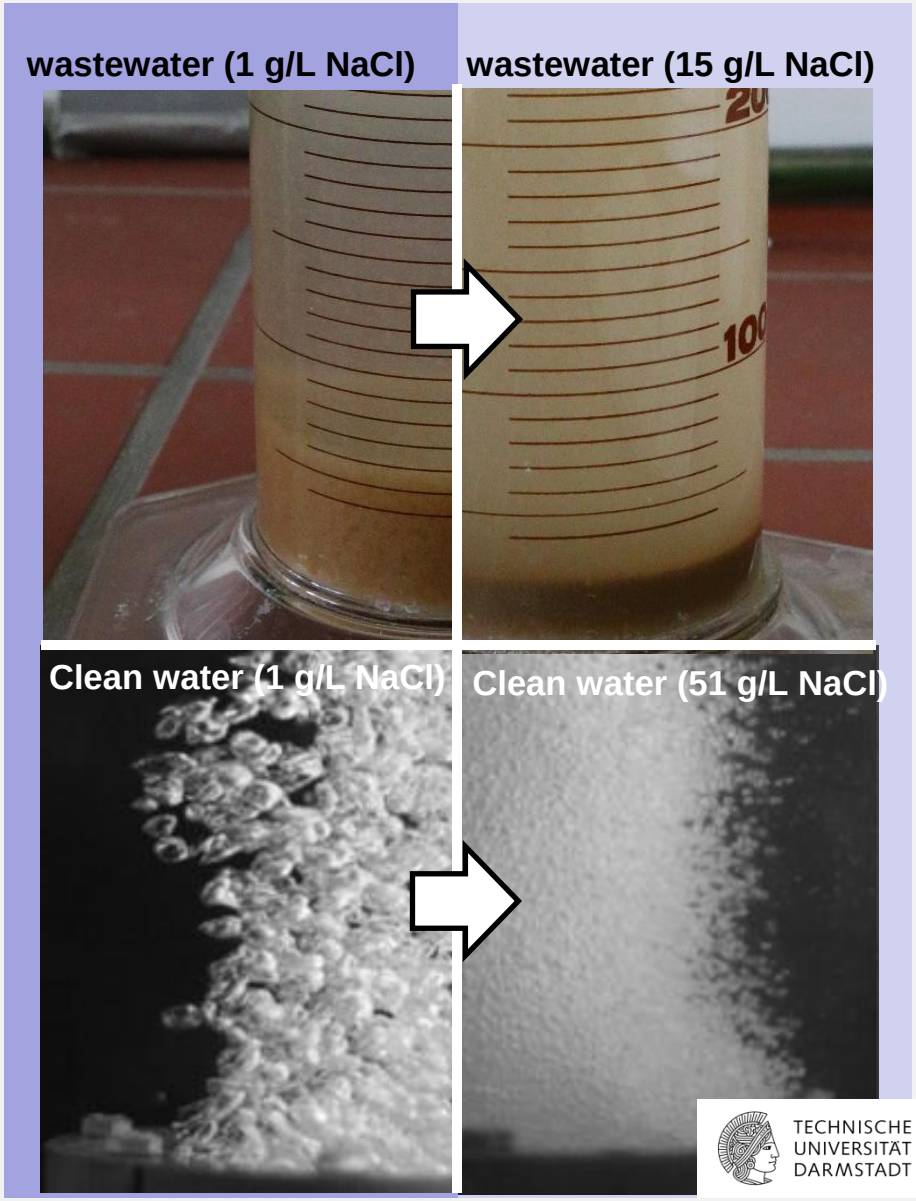
Practical tests with real industrial wastewater

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**



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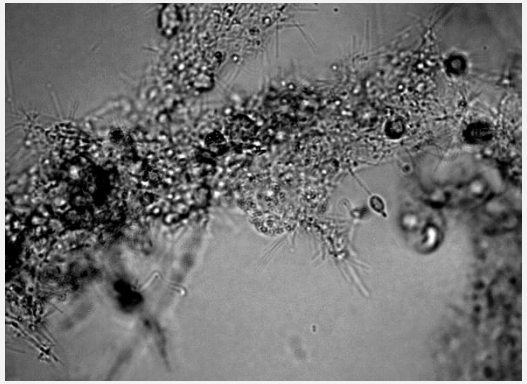
Practical experiments – Biological treatment

Laboratory 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



Activated sludge

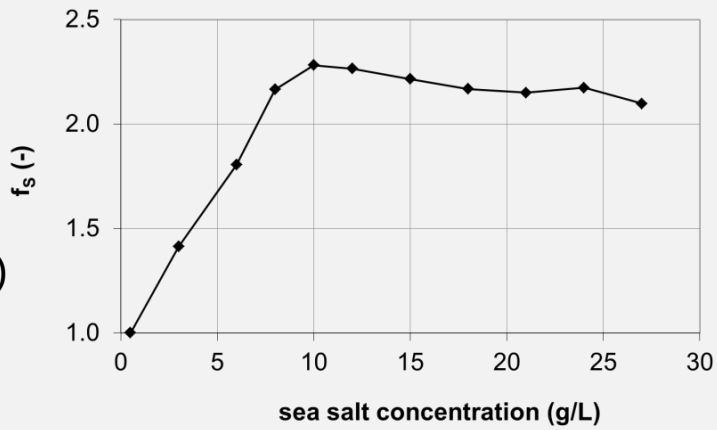
Oxygen transfer test

Lab-scale **activated sludge process**

Activity Batch-Tests

Effect of salt on oxygen transfer

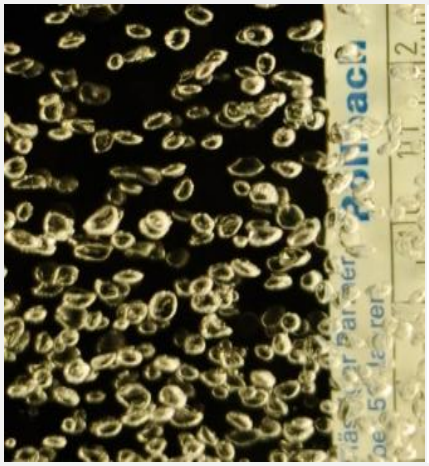
- Salt reduce **the mass transfer** (k_L)
- Increase the **interfacial area** (a)
- Results in a net increase of the **volumetric mass transfer** (k_La)



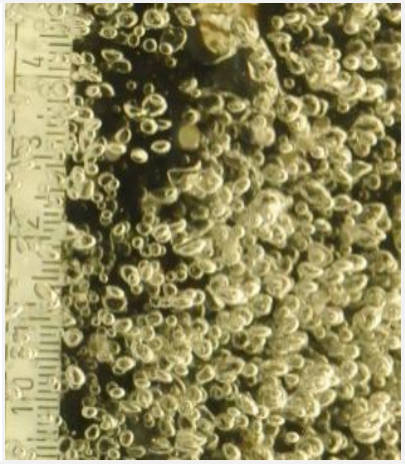
Oxygen transfer test

$$f_S = \frac{Oxygen\ transfer_{\mathbf{saline}\ water}}{Oxygen\ transfer_{\mathbf{clean}\ water}}\ (-)$$

- Well known for **seawater** (NaCl)



0 g/L NaCl



10 g/L NaCl

Design example: Aeration System with high salt concentration

WWTP:

- 20.000 PE
- T_W: 18°C
- Diffused aeration system

Variant 1: Normal salt concentration	Variant 2: High salt concentration
S_{TDS} < 2g/l	S_{TDS} = 10 g/l
SOTR = 172 kg/h O_2	SOTR = 111 kg/h O_2

- You need a **35% smaller** aeration System!
- Fewer invest and operating costs
- Fewer energy consumption
- Fewer space requirements

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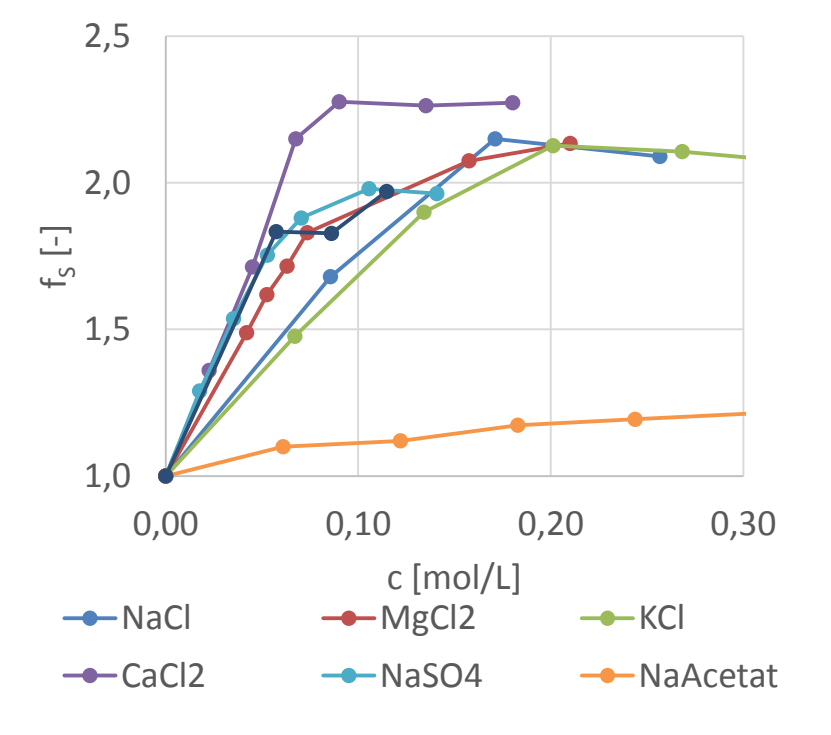
Effect of different salts on oxygen transfer

Effect of **different salts**



High salt concentration

Oxygen transfer test

Oxygen transfer tests – **view on the water surface**

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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**

Lab-scale **activated sludge process**
实验室规模**活性**污泥法

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**

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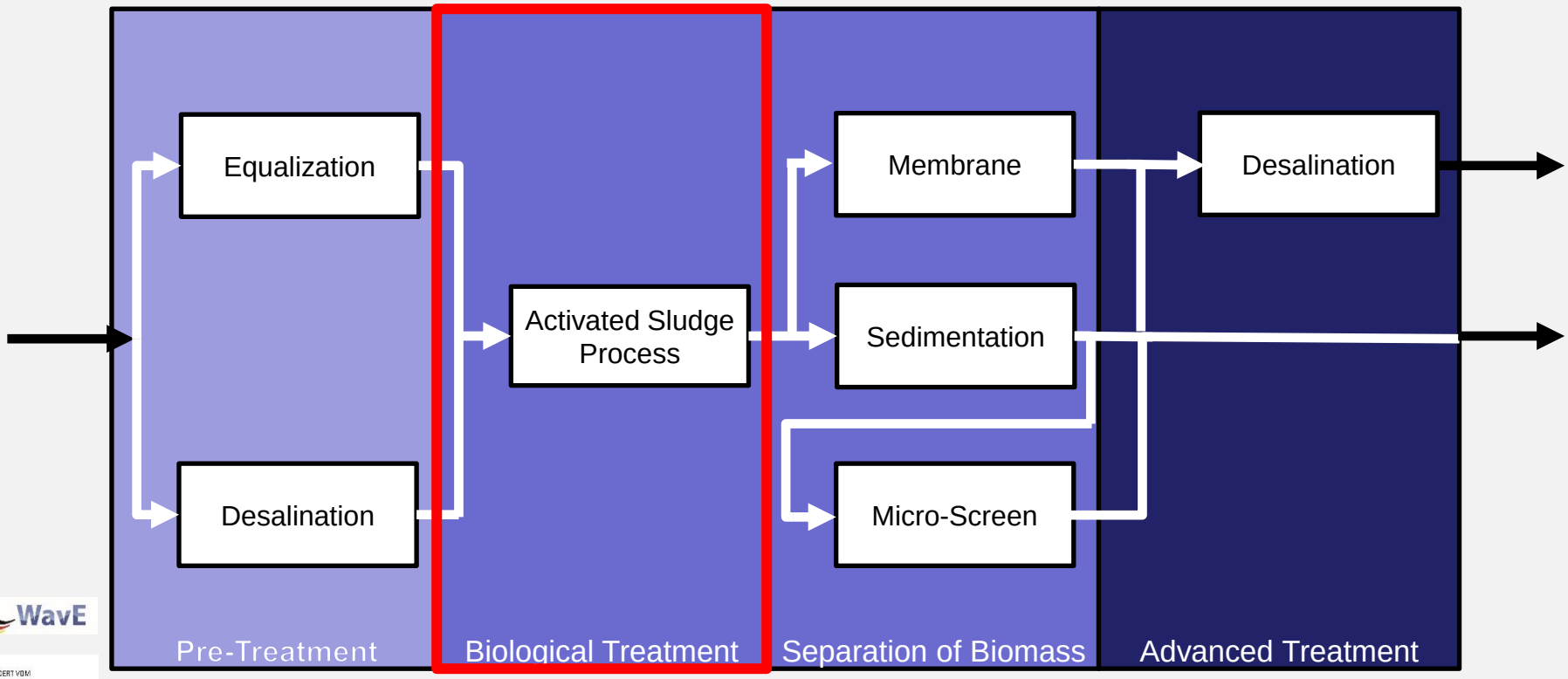
Concept WaReIp

Possible Treatment Processes:

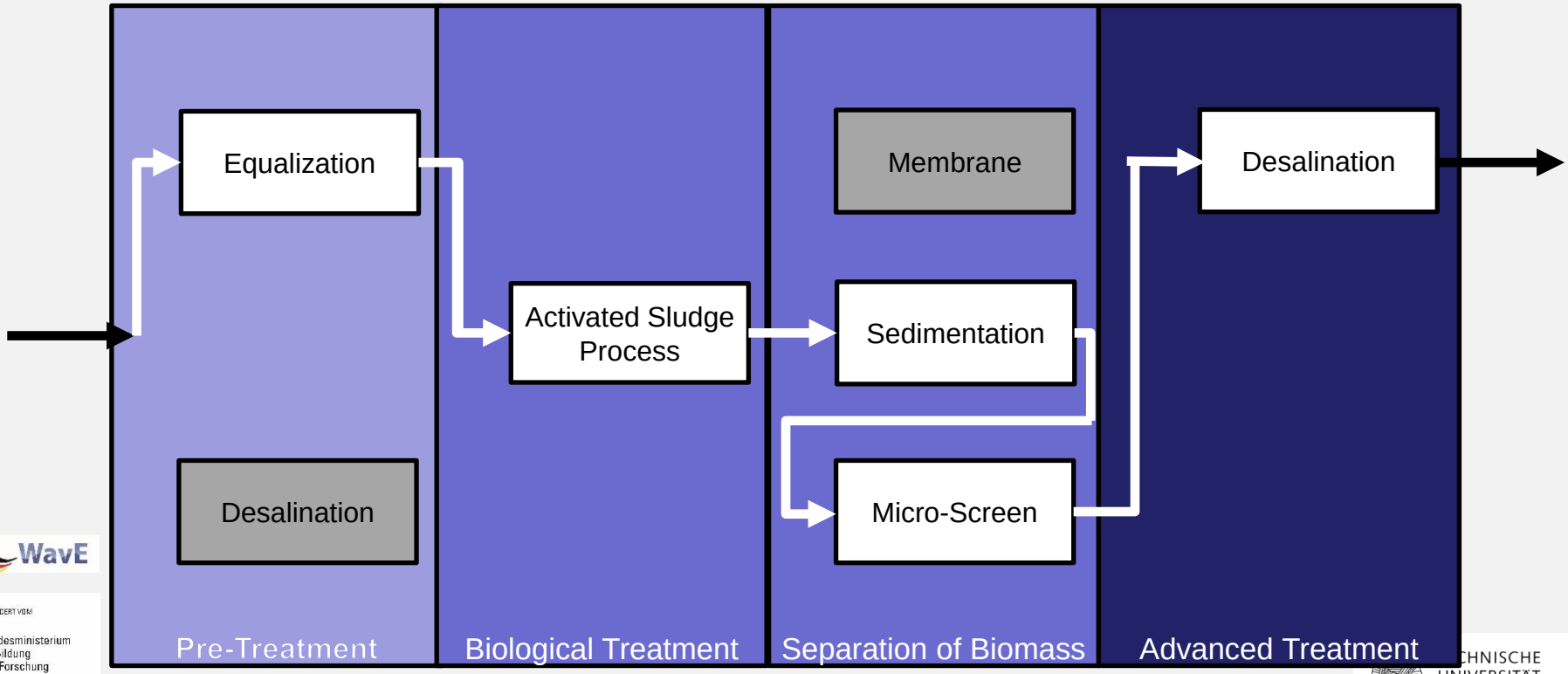
“Fit for Purpose”



Concept WaReIp

Example #1:

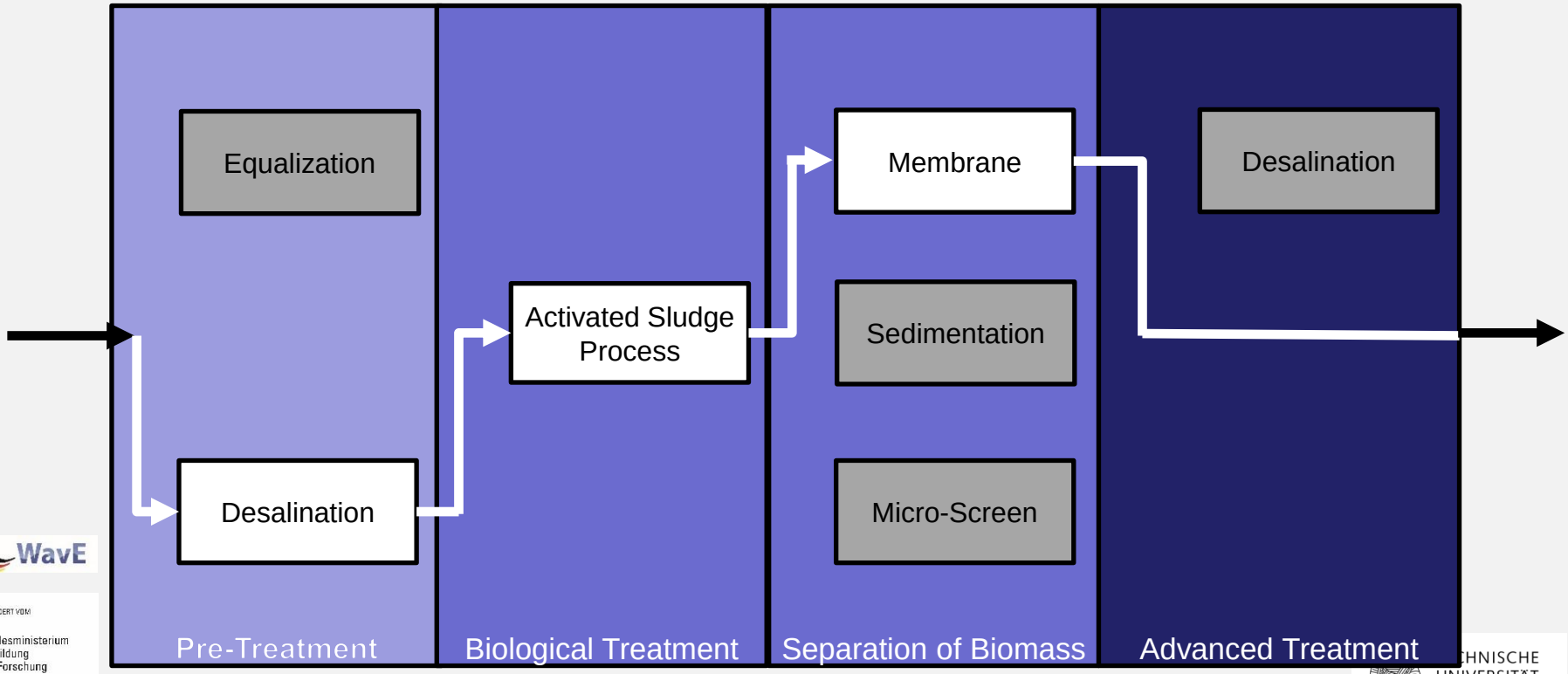
- Better Oxygen transfer i.e. energy saving (+)
- Better separation of biomass (+)
- Salt inhibit the biomass (-)



Concept WaReIp

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

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