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Water-Reuse in Industrial Parks

Funded by the **Federal Ministry of Education and Research (BMBF)**
Duration: October 2016 – September 2019

Prof. Dr.-Ing. Hans Joachim Linke

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*

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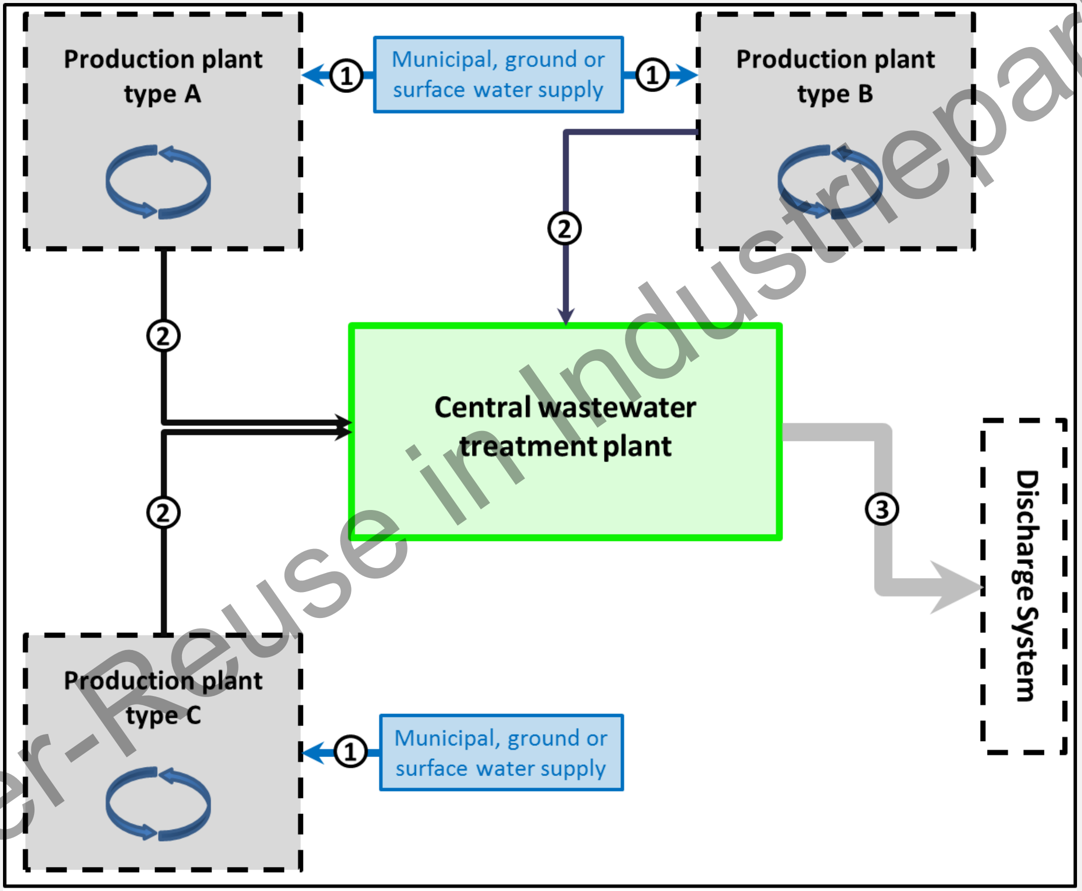
* Ante, Angela; Behrendt, Joachim; Bennemann, Helmut; Blöcher, Christoph; Bolduan, Peter (2014): Trends und Perspektiven in der industriellen Wassertechnik. Rohwasser, Prozess, Abwasser (Trends and perspectives in industrial water technology. Raw water, process, wastewater); Positionspapier der ProcessNet-Fachgruppe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

Plant intern water loop

* thickness of arrows indicates the amount of water

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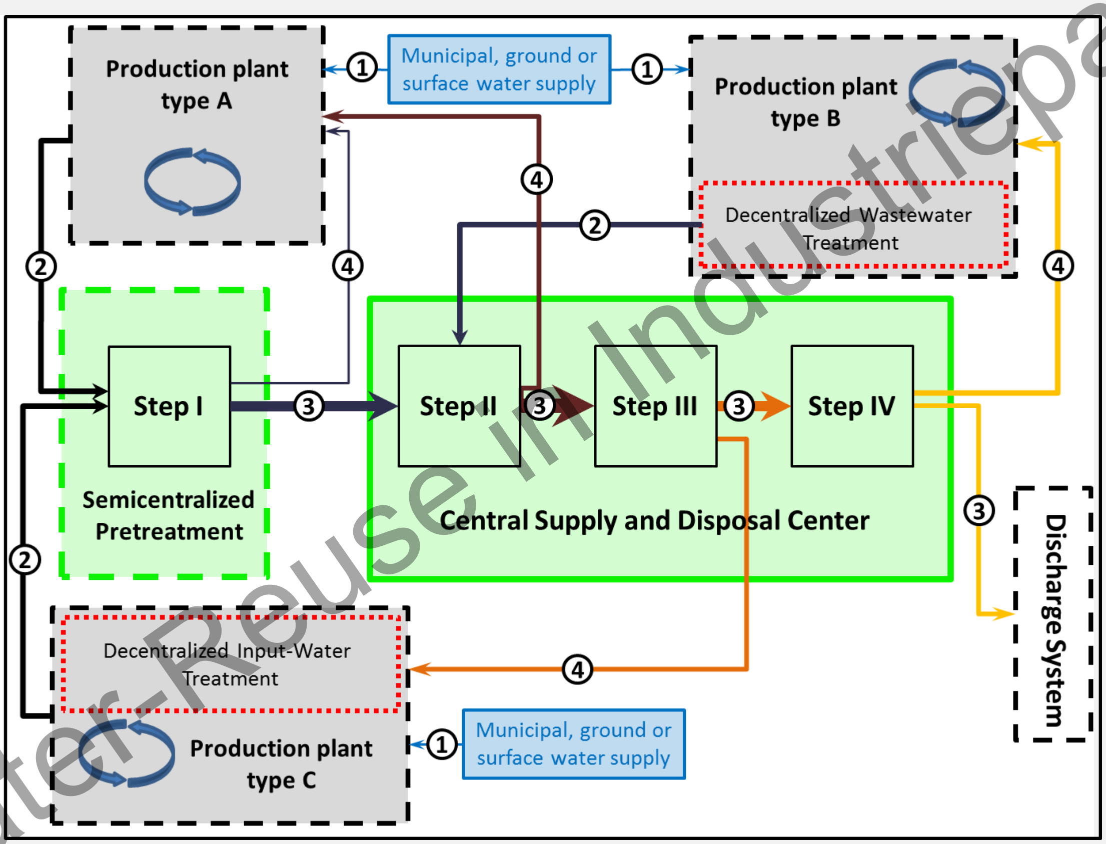
Research objective

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



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 **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**

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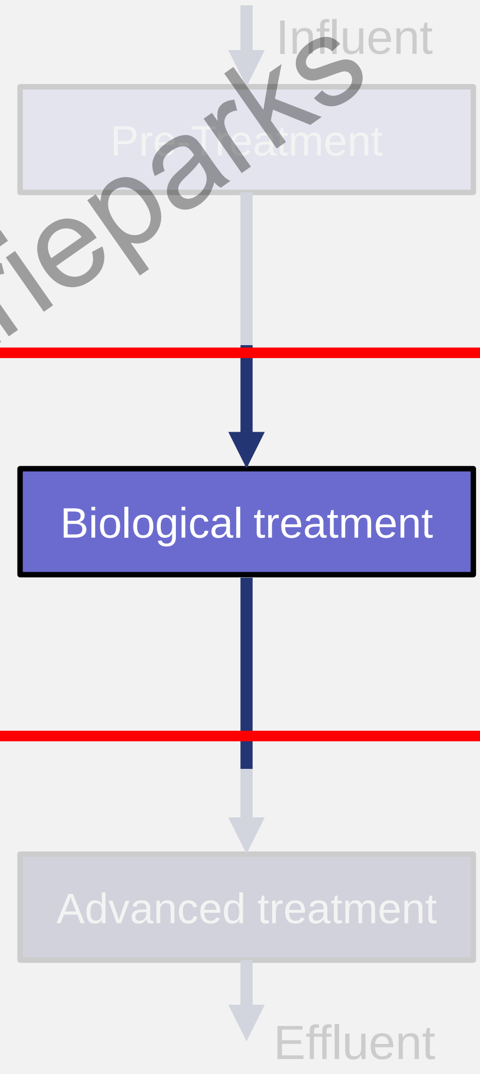
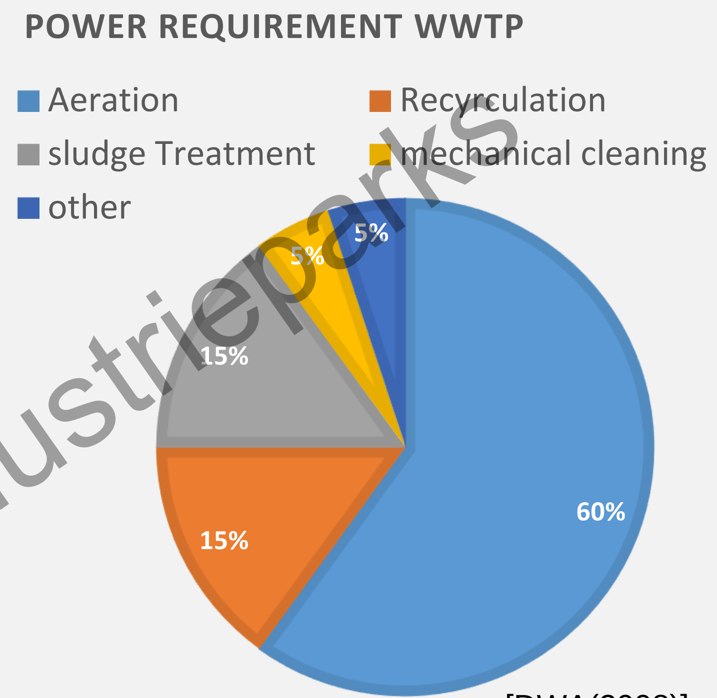
Wastewater treatment

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

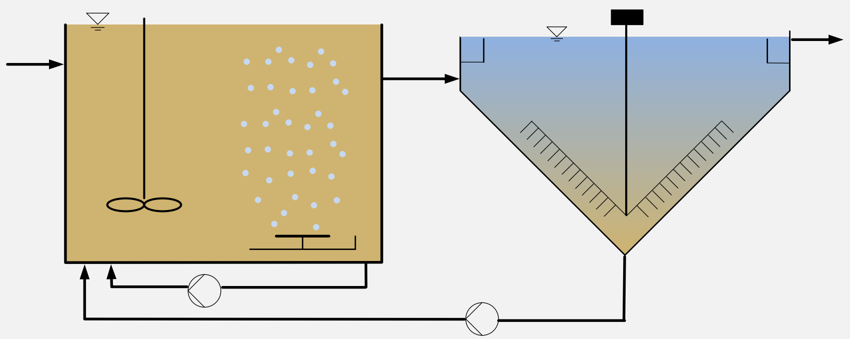


Basics and Motivation

- **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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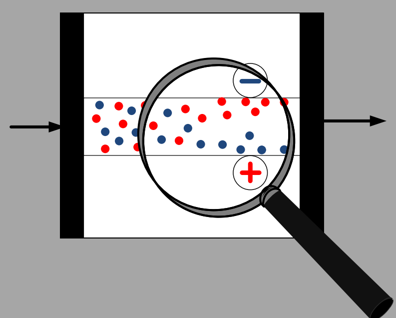
Practical experiments

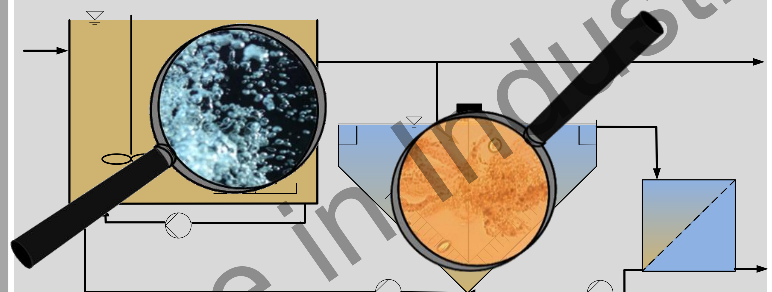
Key technologies have been identified for treatment of industrial wastewater

Vorsprung in Wassertechnik ENVIROCHEMIE



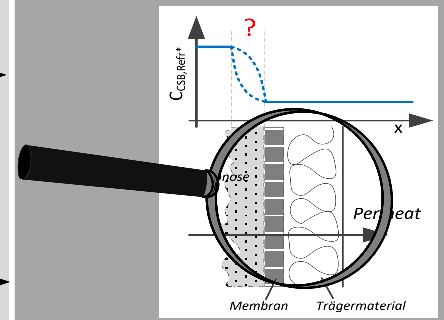
Desalination in the electric field

IWAR



Biological wastewater treatment with high salt concentrations

ISAH Leibniz Universität Hannover



Improved COD-Degradation

Practical tests with real industrial wastewater

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Practical experiments – Biological treatment

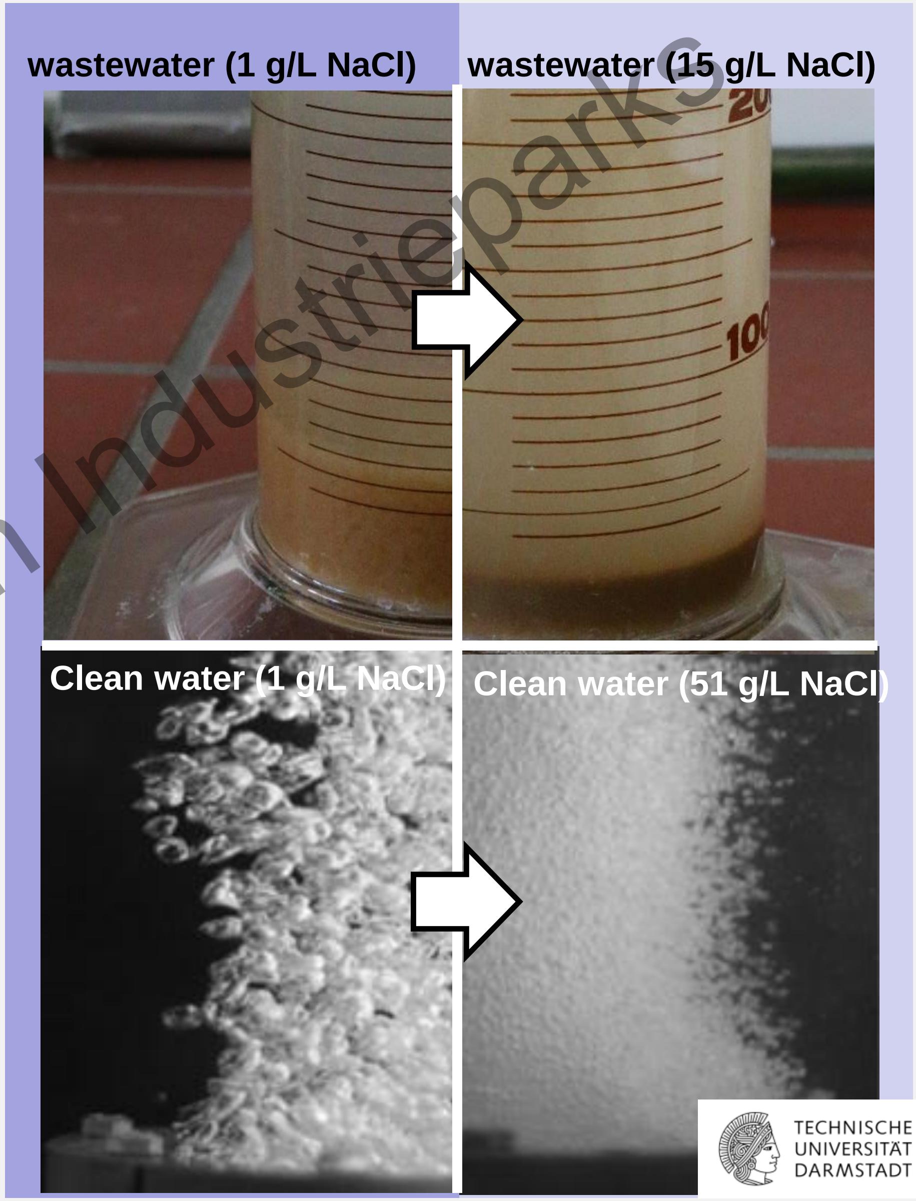
What we know about salt

- Influence sludge **characteristic**

- Reduce **cleaning performance**

- Inhibit **bubble coalescence** and oxygen transfer increases

⇒ More efficient aeration i.e. **energy saving**



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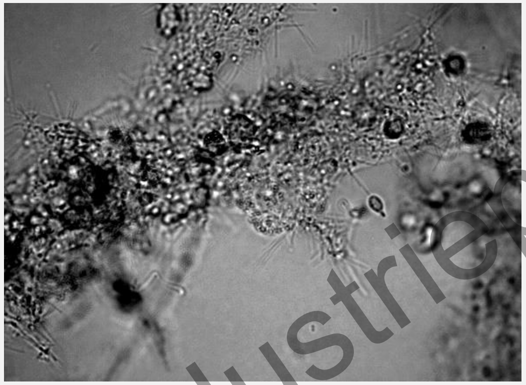
Practical experiments – Biological treatment

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

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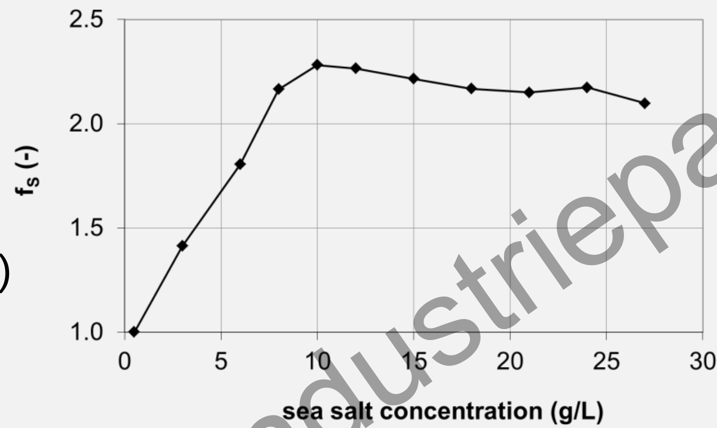
Effect of salt on oxygen transfer

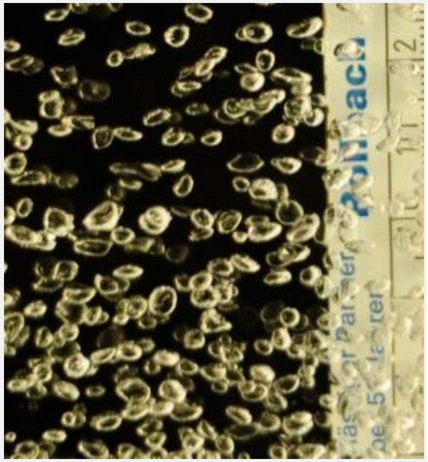
- Salt reduce **the mass transfer** (k_L)
- Increase the **interfacial area** (a)
- Results in a net increase of the **volumetric mass transfer** (k_La)



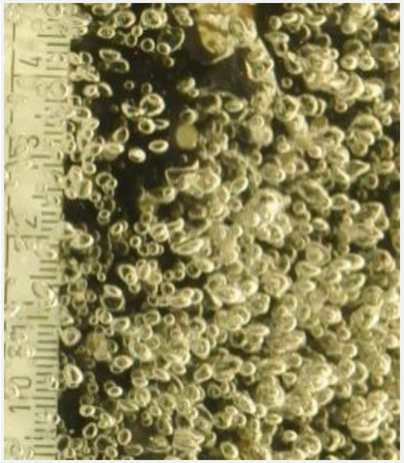
Oxygen transfer test

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

- 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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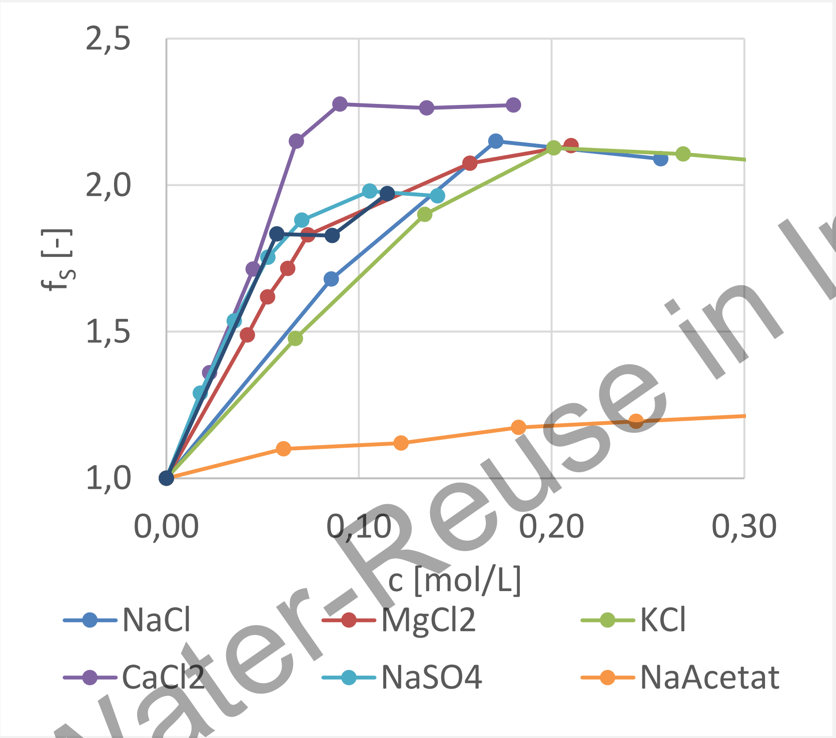
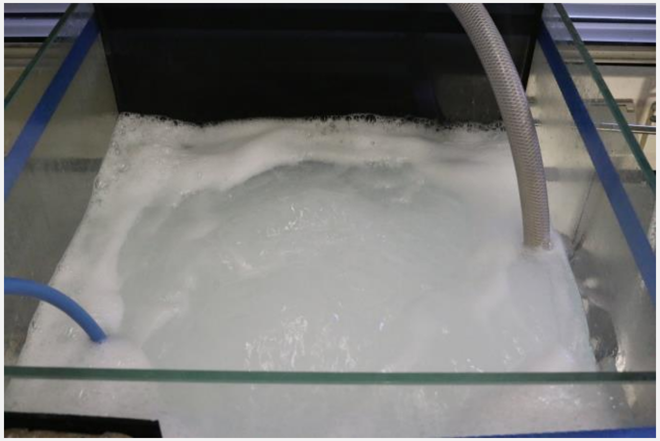
Effect of different salts on oxygen transfer

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**

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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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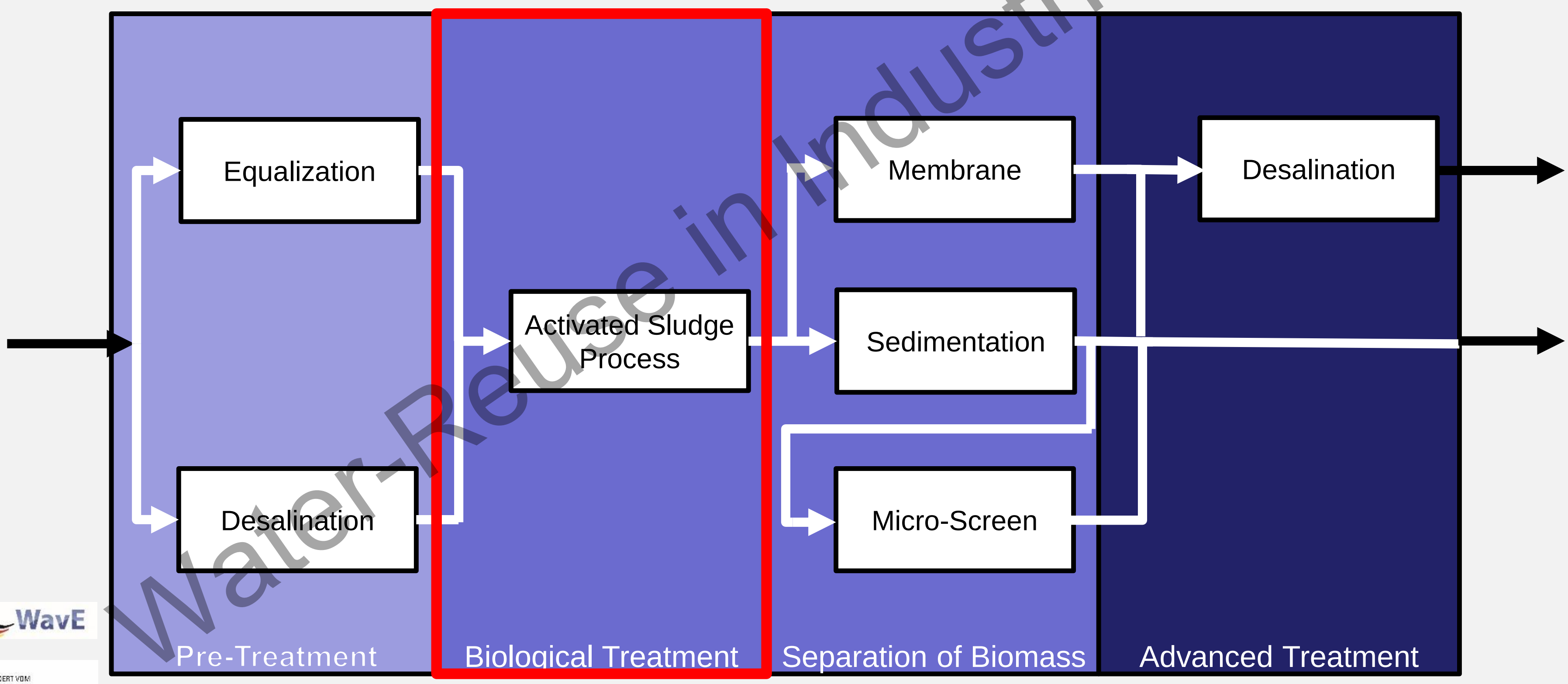
Concept WaReIp

Possible Treatment Processes:

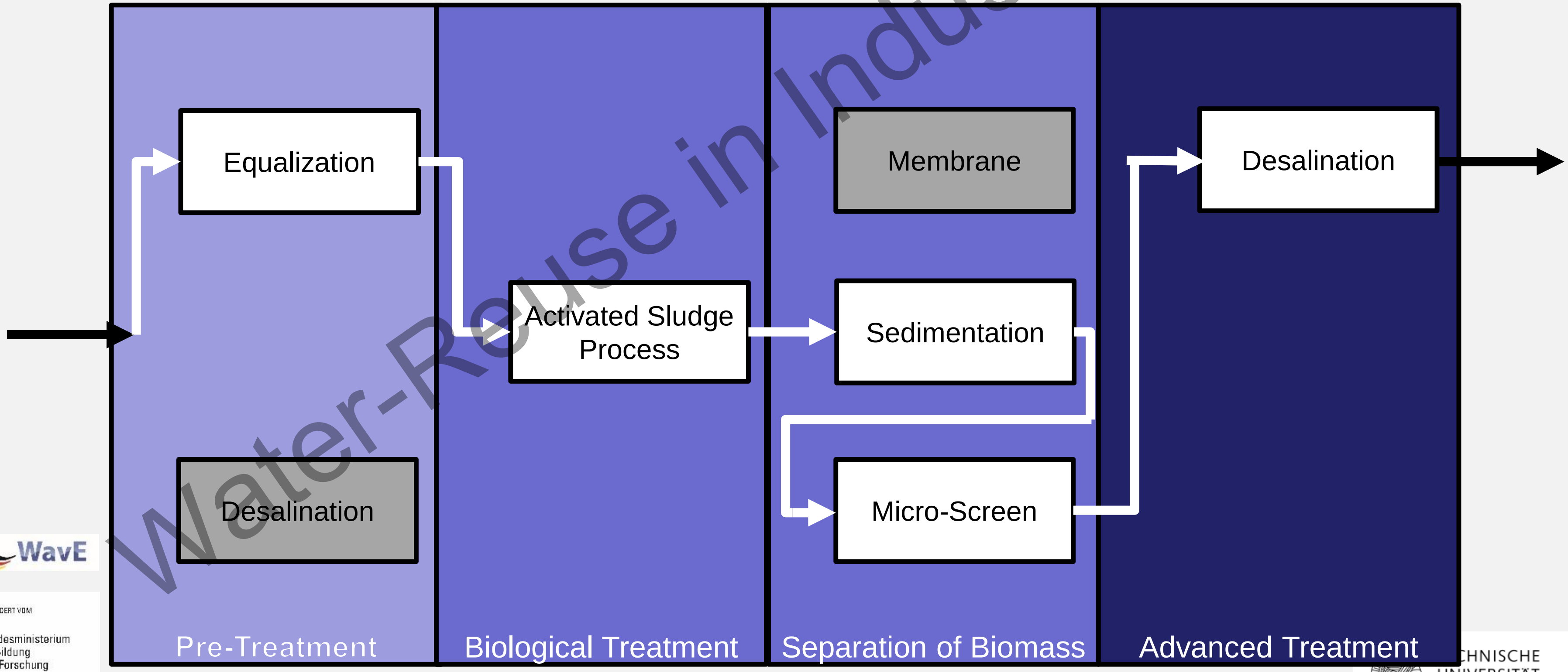
“Fit for Purpose”



Concept WaReIp

Example #1:

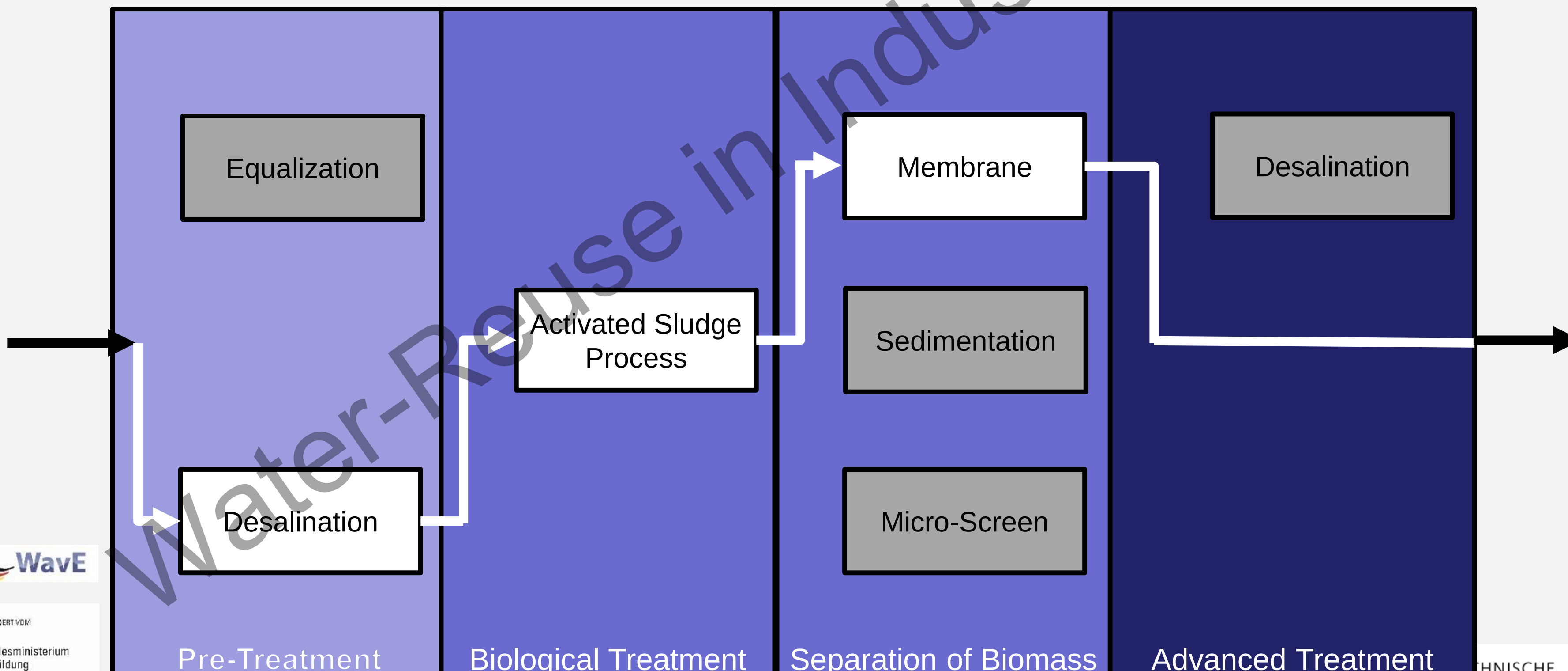
- Better Oxygen transfer i.e. energy saving (+)
- Better separation of biomass (+)
- Salt inhibit the biomass (-)



Concept 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

Contact

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