IWAS
Brazil
ÁGUA-DF

Universität der Bundeswehr München

Use of membranes for advanced wastewater treatment

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Final Workshop - Project IWAS ÁGUA DF
Integrated Water Resources Management in Distrito Federal – DF
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Overview

1. Background of advanced wastewater treatment

2. Selected examples of advanced wastewater treatment technologies

3. The pilot plant
   - Concept and operating mode of the plant
   - Results

Goals of advanced wastewater treatment

1
- Enhanced separation of supended solids

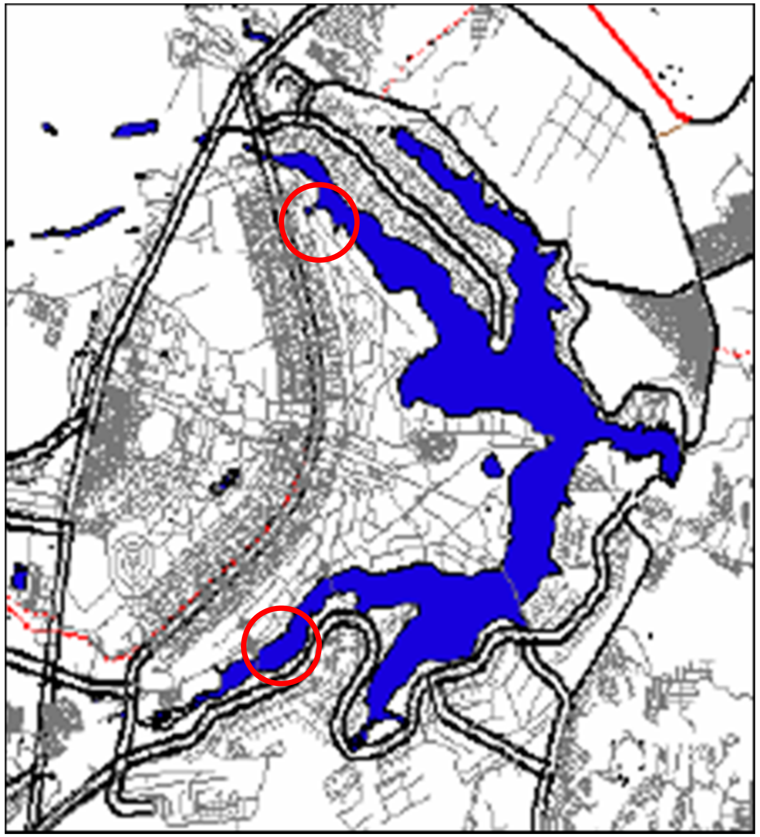
2
- Disinfection/removal of bacteria and viruses

3
- Removal of microsubstances

Background of the project

Quality improvement of receiving water body

Future usage of Lake Paranoá as source for drinking water



Position of the WWTP`s at the Lake Paranoá

Cooperation within the project

UniBw

Conception of the pilotplant and analytical program

Scientific accompaniment

Caesb

Operating company of the WWTP ETE Nortè and the pilotplant

Project:

Advanced wastewater treatment

UnB

Scientific accompaniment of the research work at the pilot plant

KIT

Analytics of mircosubstance samples

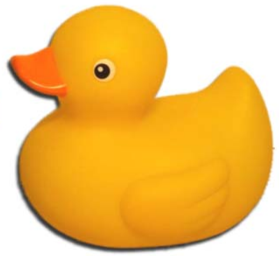
Special focus - removal of microsubstances

- In aquatic systems and drinking water detectable organic compounds in a range of nanogramm
- Detection of micropollutants due to technical advances

- Special attention to micropollutants with expectable negative effect for environment and humans
- Typical groups of substances:
  - Pharmaceuticals (human and veterinary pharmaceuticals)
  - Industrial and household chemicals
  - Plant protection products and pesticides (PPPP)
  - Body care products, perfumes, disinfectants
  - Additives in wastewater and sludge treatment
  - Food and feed additives

Hazardous substances

- Relevant active groups: components with…
  - … hormone-like substances (e.g. contraceptives, industrial chemical, plasticizer in plastics)

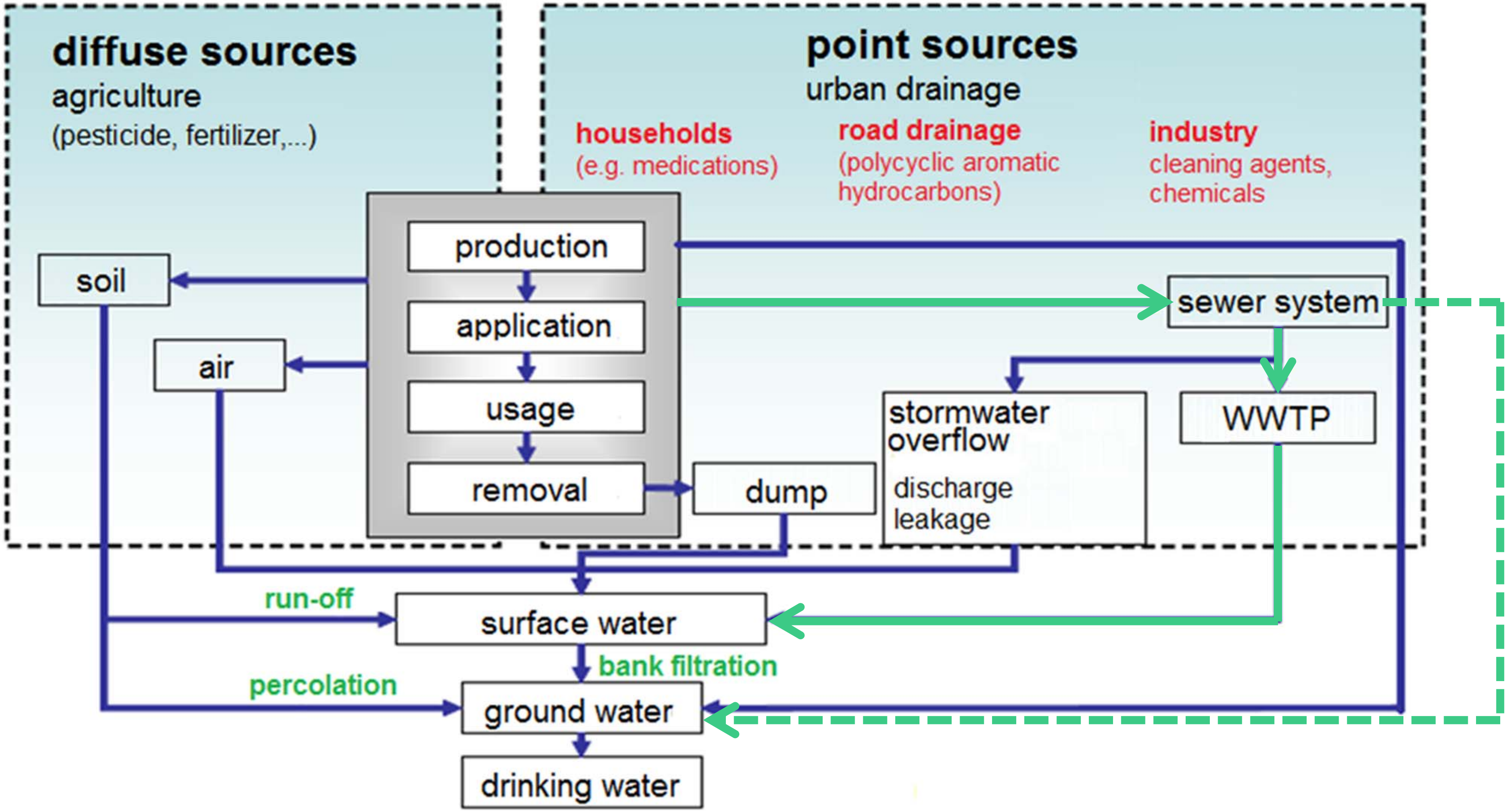


  - … genotoxic effects (e.g. cytostatics – drugs for chemotherapy)

  - … immunotoxic effects (e.g. chemical substances with adverse effects of the imune system)
  - … anti-infective effects (e.g. antibiotics)

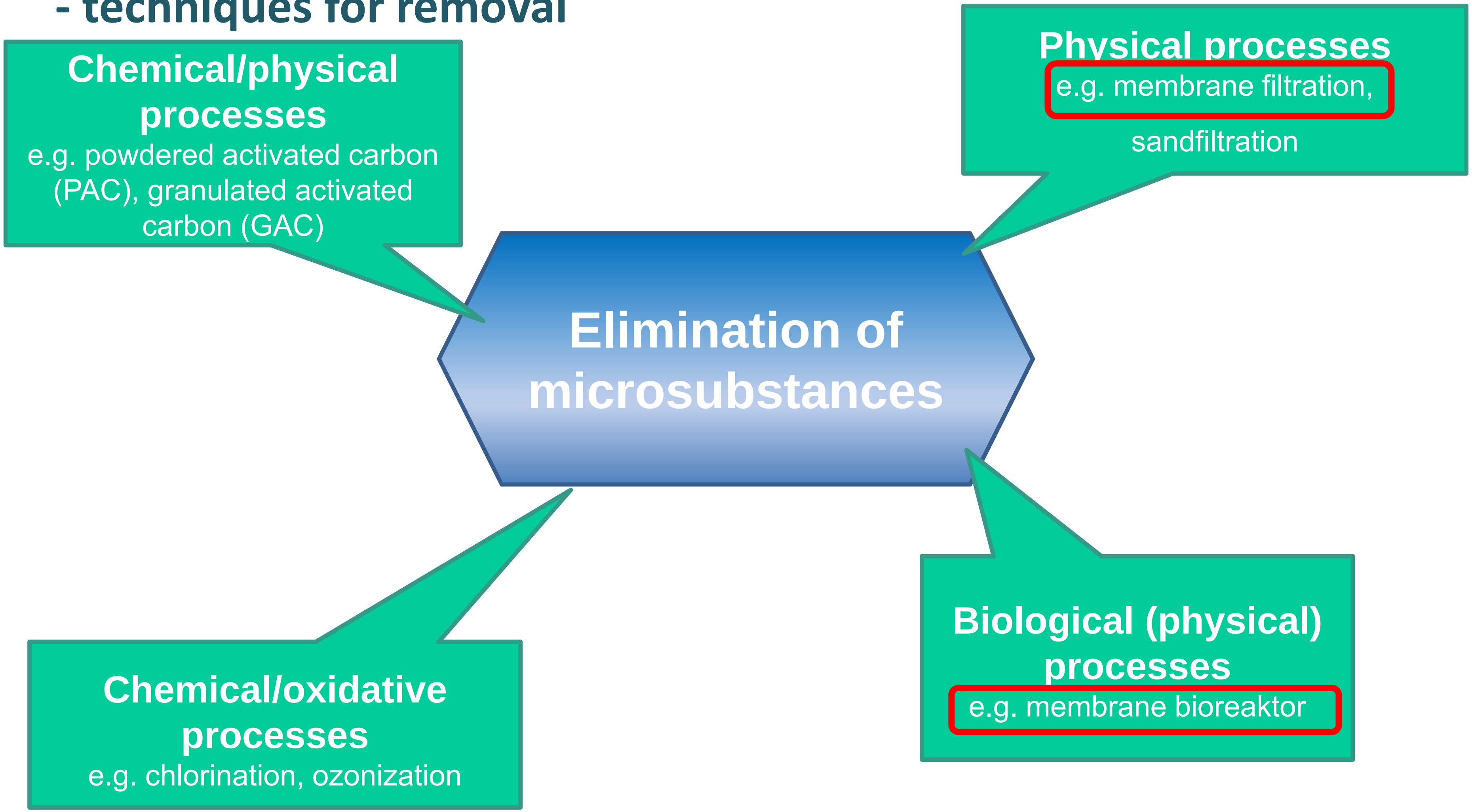
Microsubstances

Entry paths into drinking water



Advanced wastewater treatment

- techniques for removal



Spectrum of energy consumption of advanced wastewater treatment

Estimation of consumption from different literature references

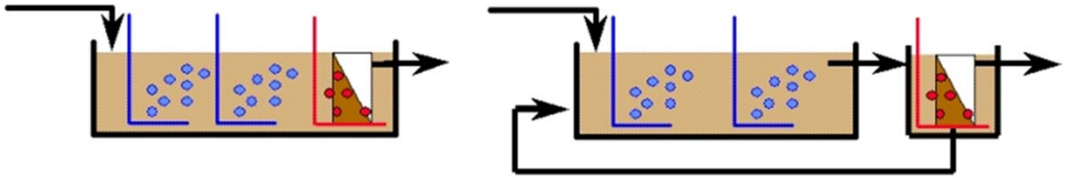
(Sources: Thernes and Joss, 2006; Fahlenkamp et al. 2008, Pinnenkamp et al. 2010, Bolle et al. 2011)

Advanced treatment technology	Energy consumption kWh/m³ wastewater
MBR	0,1 – 0,5
Microfiltration	0,1
Ultrafiltration	0,15
Nanofiltration	0,3 – 0,5
Reverse osmosis	0,6
Ozonization	0,05 – 0,48
PAC	0,01 – 0,07
GAC	0,01 – 0,17

→ **Depending on plant size and process combination**

Membrane bioreactor

- Combination of aeration tanks and membrane filtration for the removal of sludge
- typical membrane modules:
  - microfiltration modules
  - ultrafiltration modules
- integrated or downstream processes



Source: http://www.iwar.tu-darmstadt.de

Membrane technology in wastewater treatment

Cleaning capacity and limitations

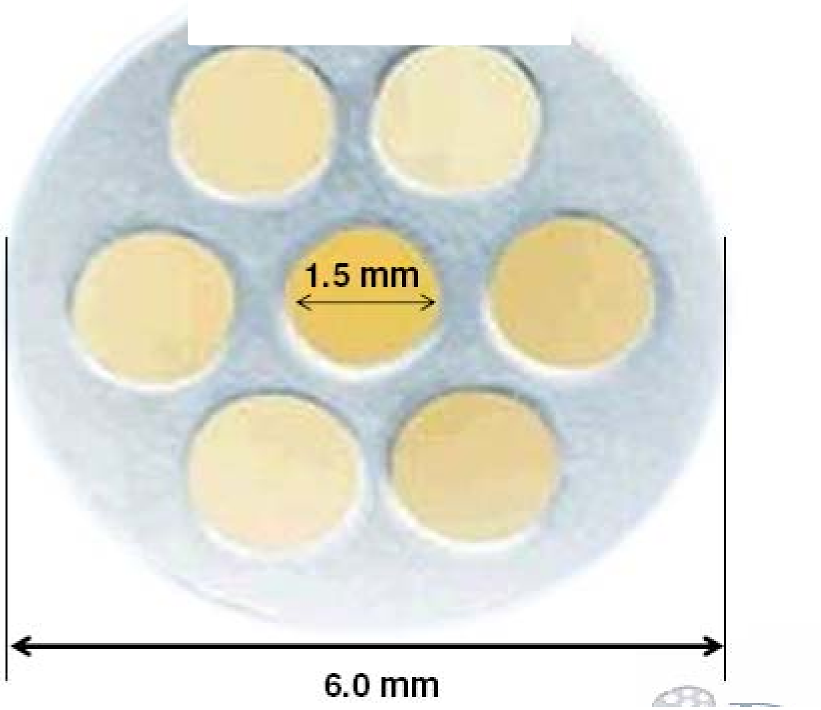
	Microfiltration > 0,1 µm	Ultrafiltration 0,1 - 0,01 µm	Nanofiltration 0,01 - 0,001 µm	Reverse Osmosis < 0,001 µm
Removal of	zooplankton algae turbidity bacteria suspended particle	macromolecule viruses colloids	organic compounds bivalent ions	monovalent ions
Pressure differential	0,1 – 2 bar	0,1 – 5 bar	3 – 20 bar	10 – 100 bar

Source: www.trinkwasserspezi.de 2013

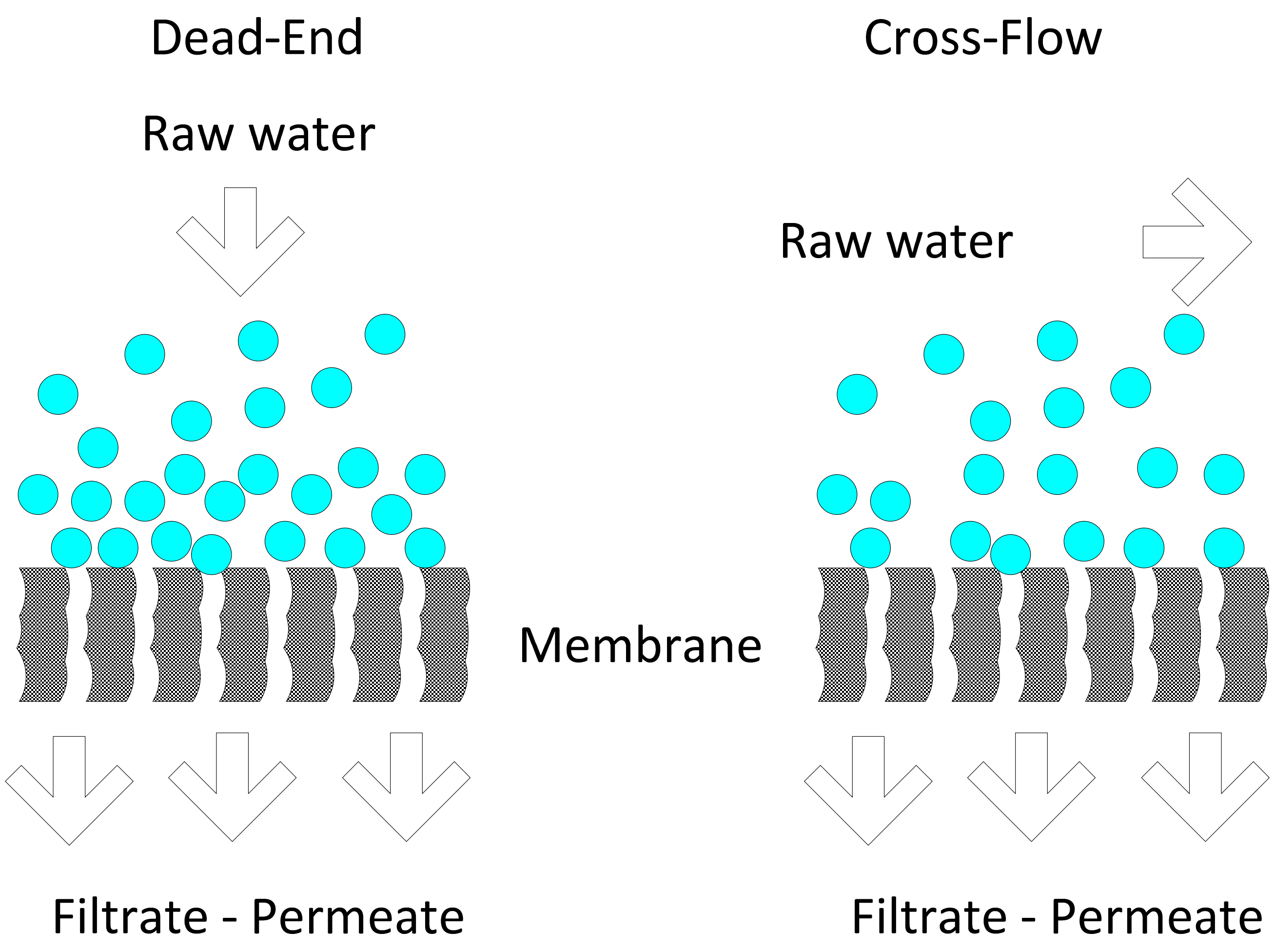
Increasing energy consumption and operational costs with increase of pressure…

Inge membrane: 1.5 mm capillary

Diameter: 1.5 mm
Membrane surface: 4 m²
Pore Size: 0.02 µm



Source: Buchta et.al, 2010

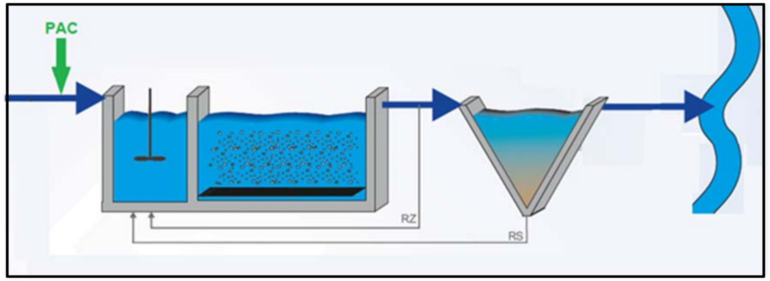

Dead-End
Cross-Flow
Raw water
Raw water
Membrane
Filtrate - Permeate
Filtrate - Permeate

Adsorption technique – PAC

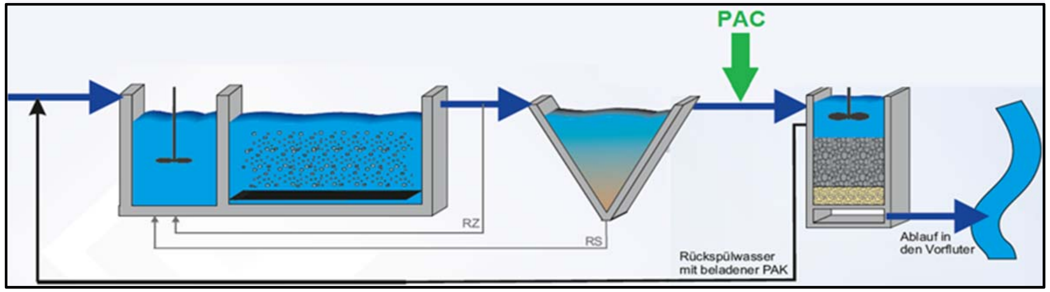
Powdered Activated Carbon (PAC)

- Dosing PAC in wastewater stream
- Separation and disposal of the loaded activated carbon with sewage sludge

- Dosing in aeration basin



- Dosing in the effluent of the clarifier



PAC materials

Name	Material	K in µg/mg	BET in m²/g
PAC 2	Wood	0,096	904,8
PAC 3	Wood	0,016	578,1
PAC 4	Bet Coal	0,025	609,4
PAC 5	Veg	3,545	851,3

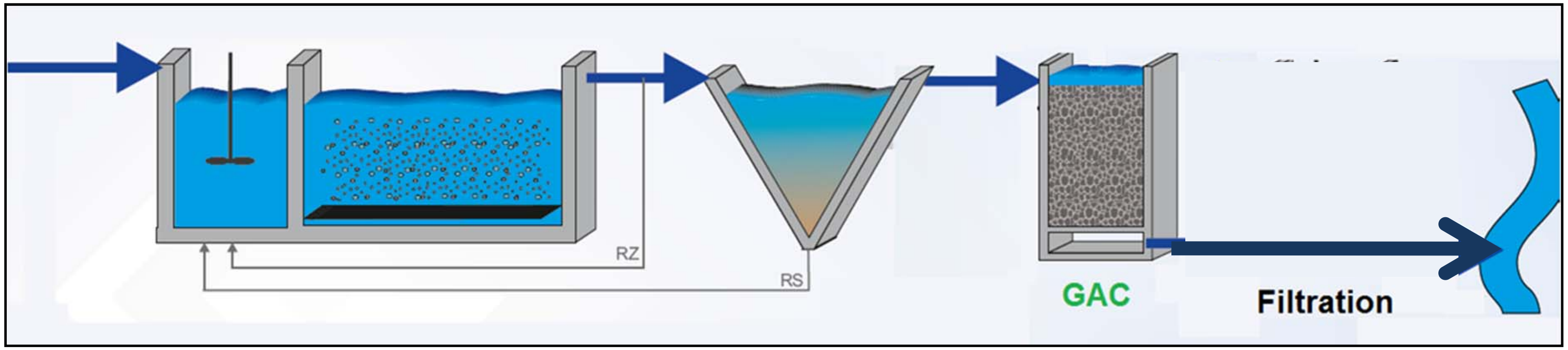
Influence on performance of AC	
Molecular weight	pH-value
Molecular structure	Temperature
Solubility	Ionisation
Polarity	

➔ **Tests with different kinds of AC in order to get best results**

Adsorption technique - GAC

Granulated Activated Carbon

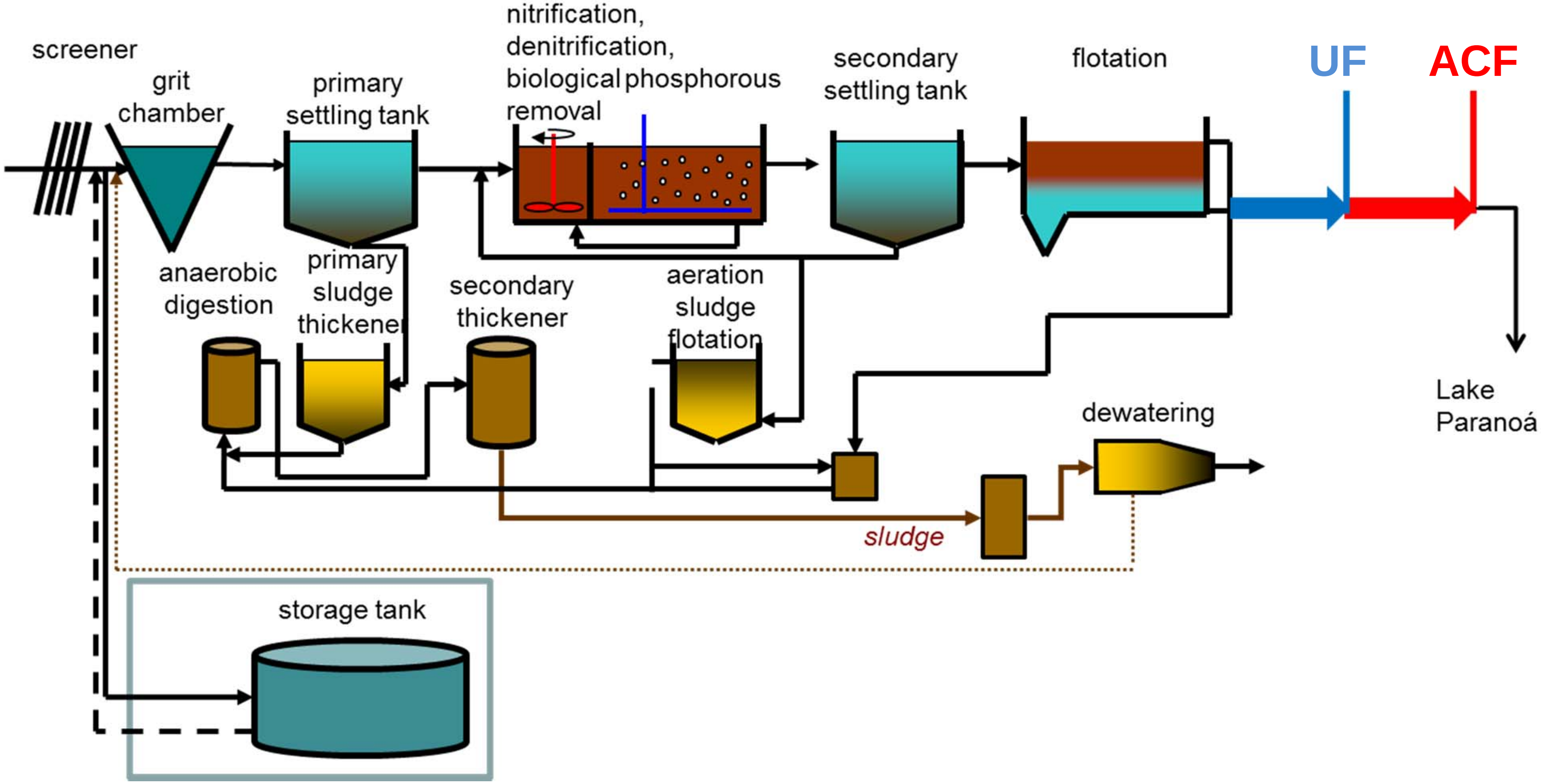
- using as a fixed-bed adsorber (activated carbon filter, adsorption filter)
- Wastewater flows through the granulated activated carbon
- when maximum capacity is reached, replacement of adsorbent necessary



Source: Taudien2012

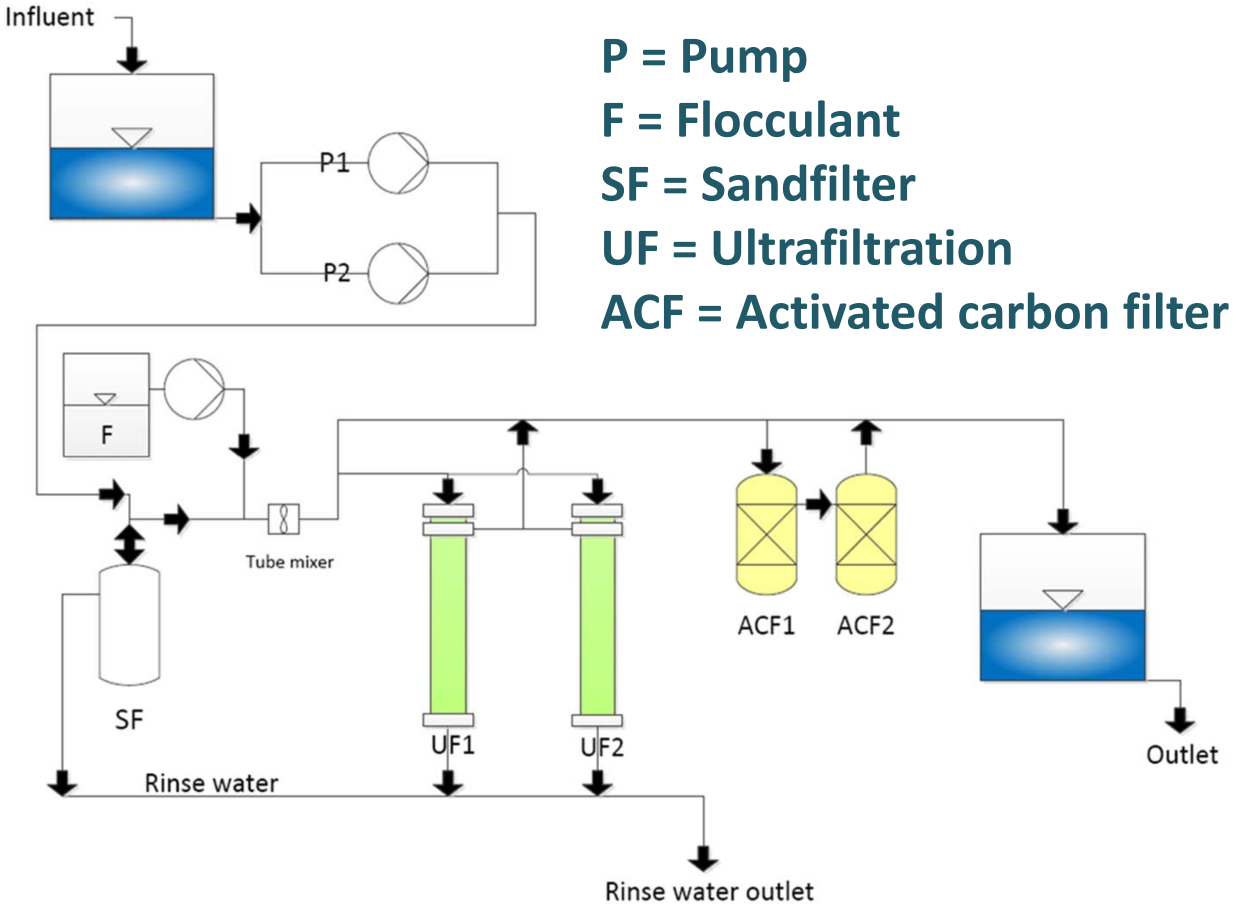
The pilot plant

Arragement at ETE Nortè



The pilot plant

Simplified flow scheme



P = Pump
F = Flocculant
SF = Sandfilter
UF = Ultrafiltration
ACF = Activated carbon filter

The pilot plant

Function of the components

- Sandfilter (safety filter for UF):
  - Particle removal > 25 µm
- (Inline-Flocculation:
  - Integrate smallest particles and a part of dissolved organic compounds as flocks

    → Avoid biofouling at UF)
- Ultrafiltration
  - Removal of residual turbidity and besides reduction of dissolved organic carbon (DOC) which are integrated in flocks

    → Avoid filter blockage at GAC

    → Enhances the adsorption capacity of GAC by elimination of competing organic matter

The pilot plant

Function of the components

- **Activated carbon filter ACF**

→ **Adsorption of dissolved organic substances to surface**

- Silver doped coconut carbon
- Contact time: 10 – 20 min,
- Filter flow rate: 10 – 15 m/h
- Filtration performance: 0,4 m³/h

Problems:

- Risk of filter blockage through high particle entry
- Number of free adsorption sites is limited
- Organic micropollutants come into competition with dissolved organic substances (DOC)

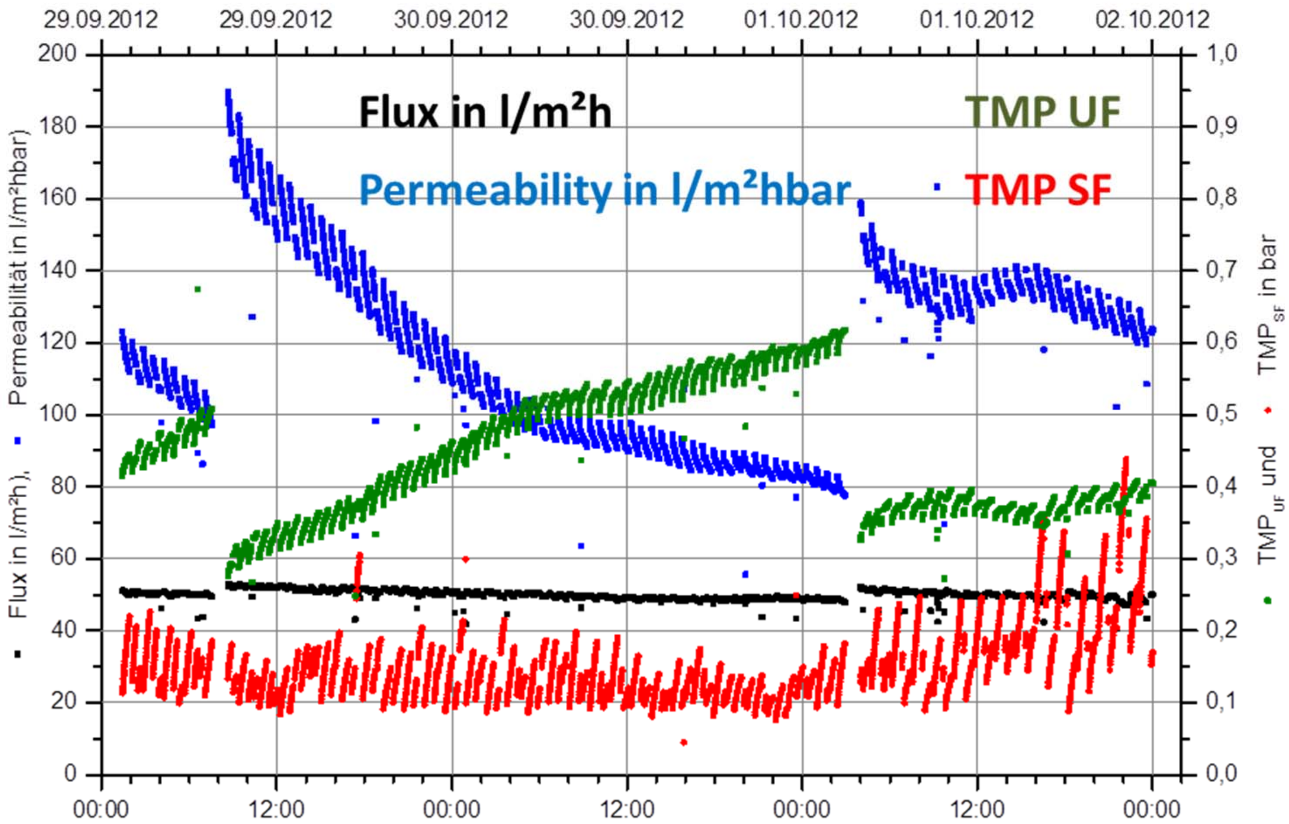
→ Pretreatment through ultrafiltration

Results of the pilot plant

Operational data from the pilot plant September/October 2012

Parameters				
Surface loading	l/(m²×h)	50		
Flush interval	min	25		
Rinse speed	l/(m²×h)	250 (Duration 45 – 60 s)		
Flushing after backwashing	l/(m²×h)	250 (Duration 30 s)		
Resulting operational data				
		Mean	Min	Max
Permeability	l/(m²×h)	117	56	208
Transmembranepressure UF	bar	0,44	0,27	0,62
Primary pressure Sandfilter	bar	0,15	0,05	0,44

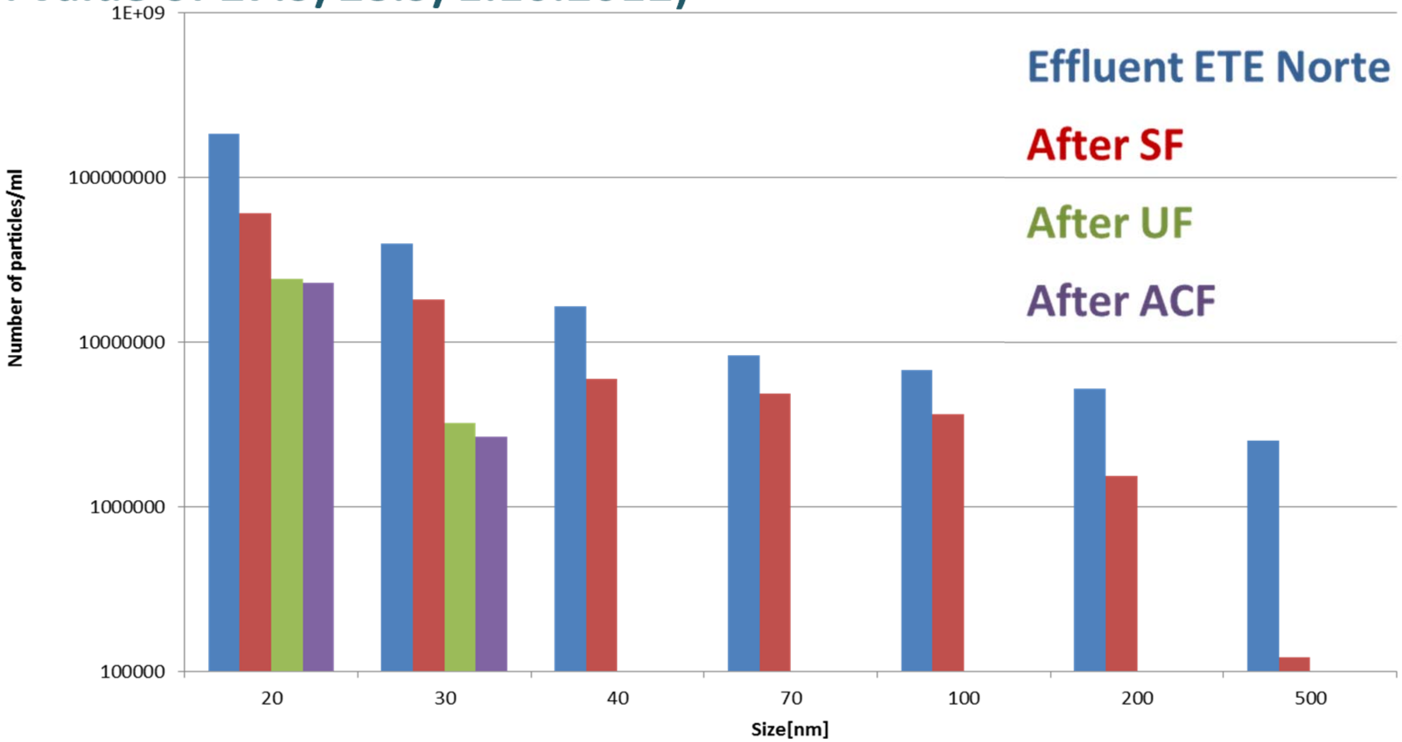
Results of the pilot plant



- Stable operation of pilot plant could be achieved
- Daily chemical flushing (acidic pH 2,5 and basic pH 12,5) was conducted to support the membrane

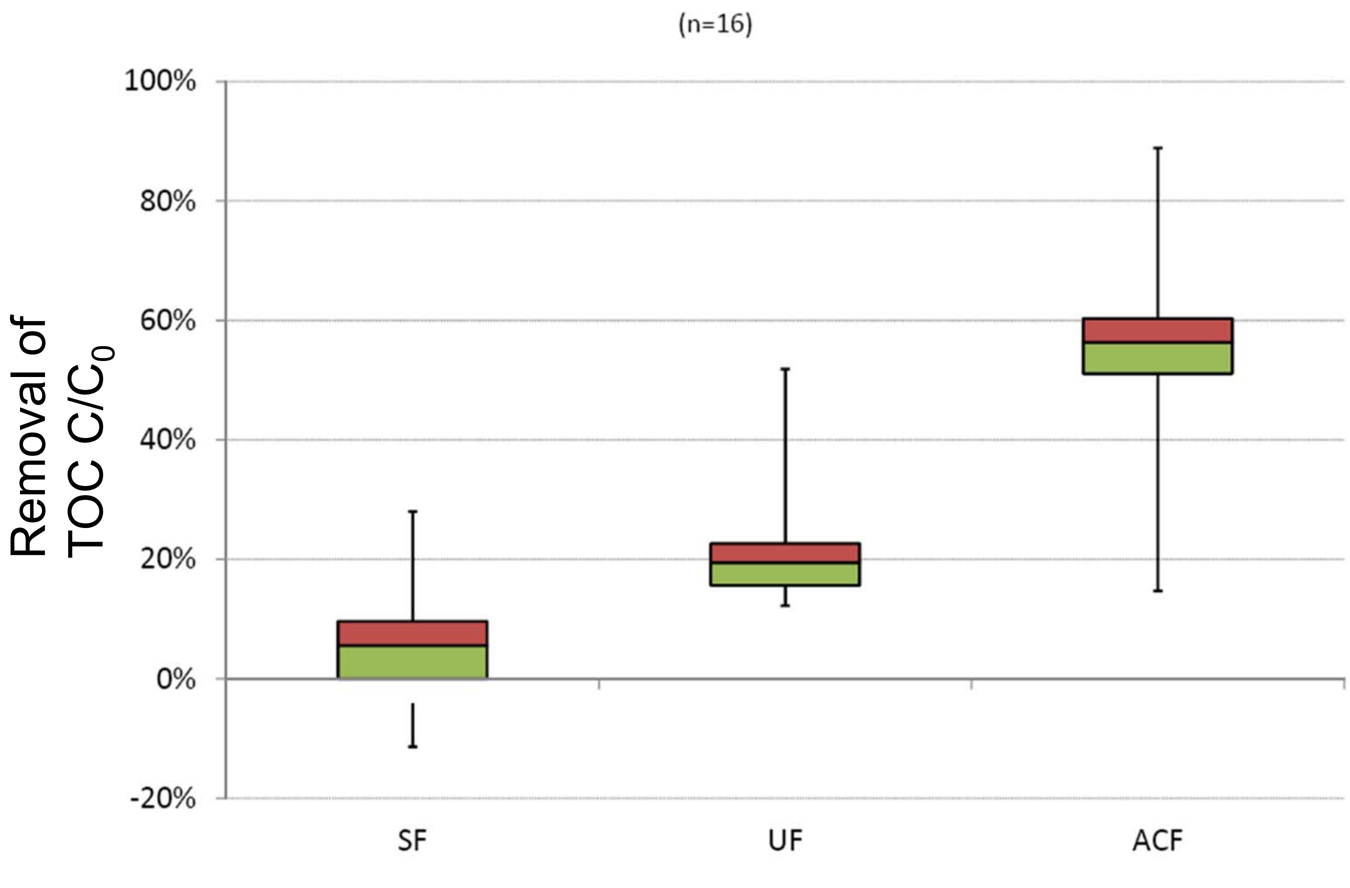
Particle size distribution in pilot plant

Laser-induced breakdown spectroscopy
(Mean value of 27.9/28.9/1.10.2012)



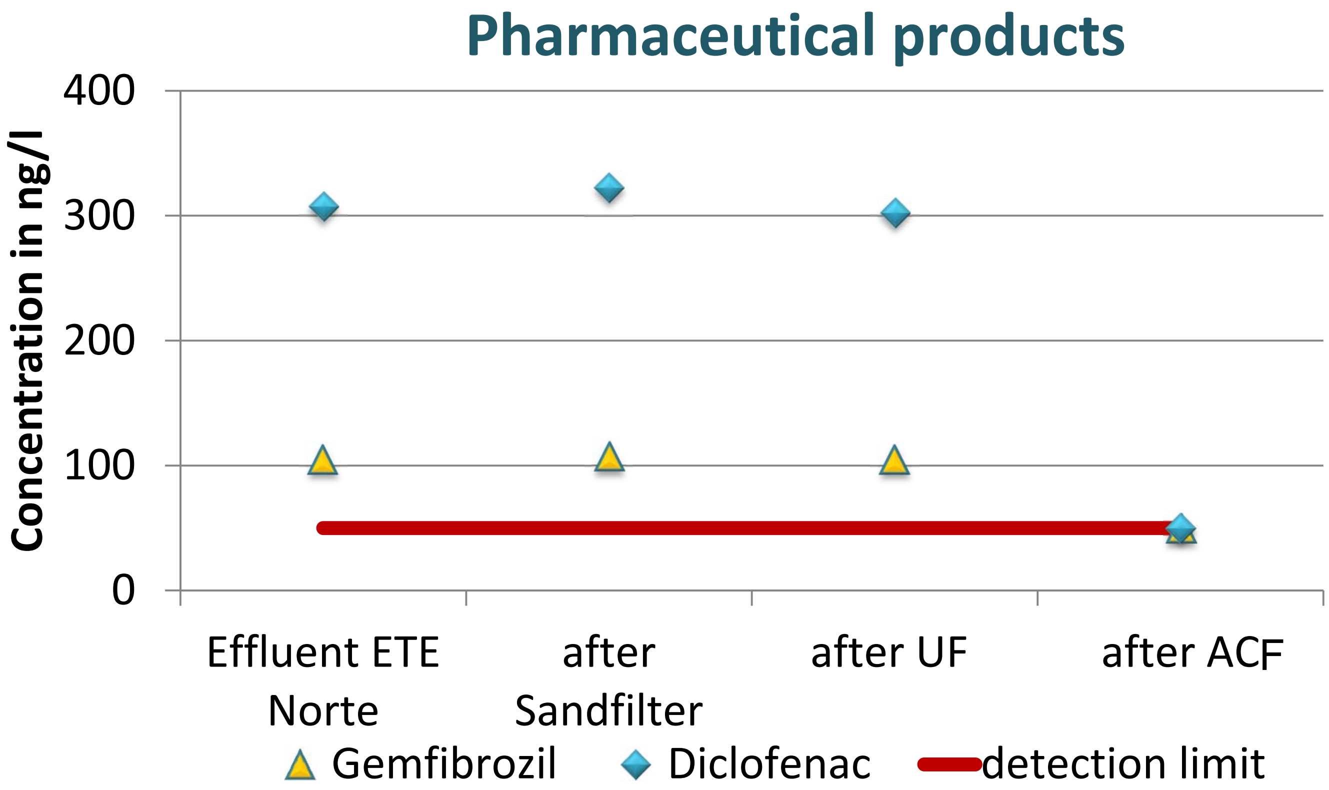
- Stepwise removal of particulate matter for most efficient protection of ACF
- Very sharp cut-off in UF indicates UF modules are in good order

Effect on removal of TOC (WWTP Holzkirchen)



Effect on removal of microsubstances

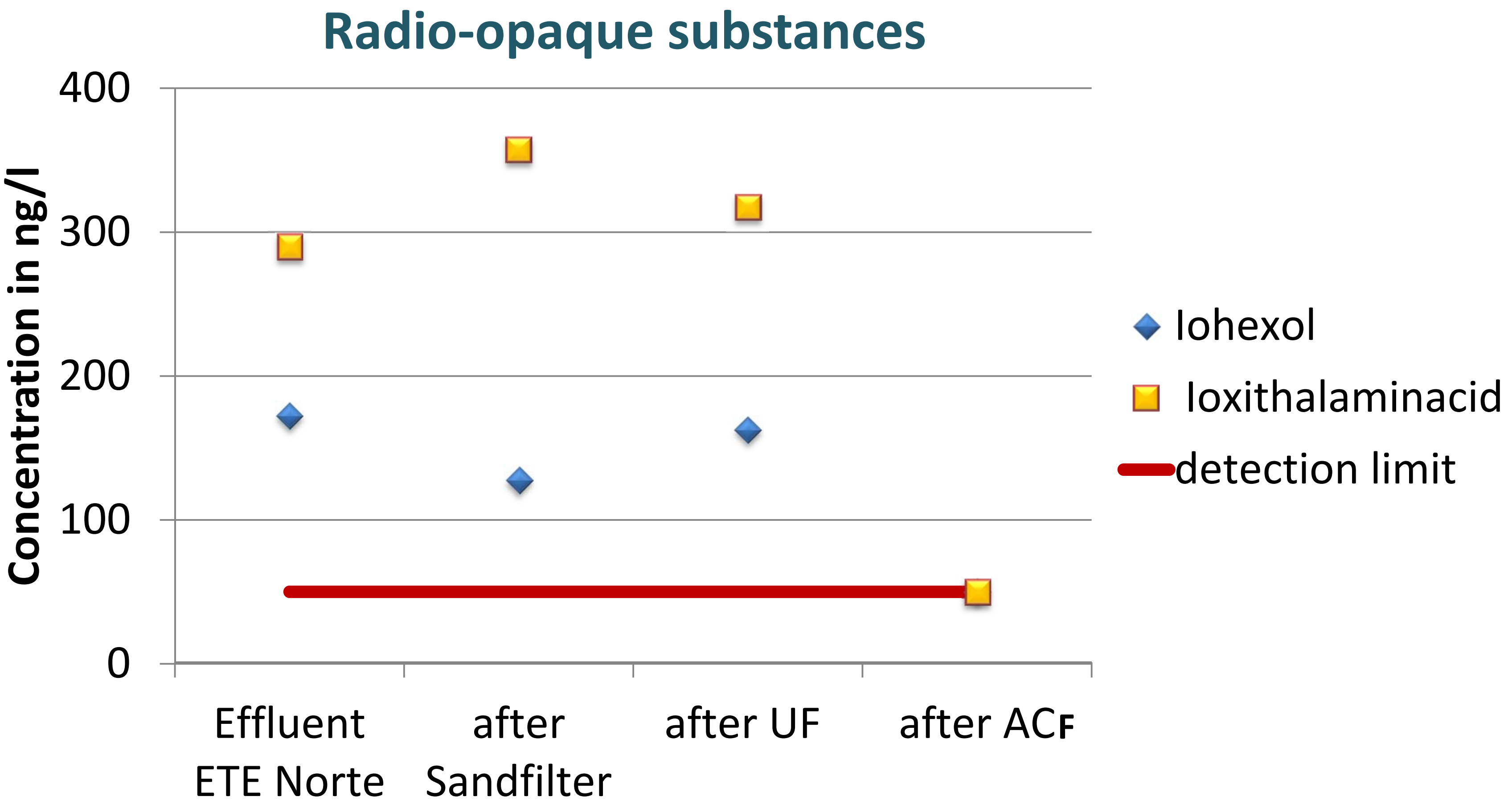
27.9/28.9/1.10.2012



- **Removal of micropollutants below detection limit by ACF**
- **Pretreatment has no effect on removal performance but is needed for protection of AC**

Effect on removal of microsubstances

27.9/28.9/1.10.2012



Ultrafiltration as advanced treatement for ETE-Norte

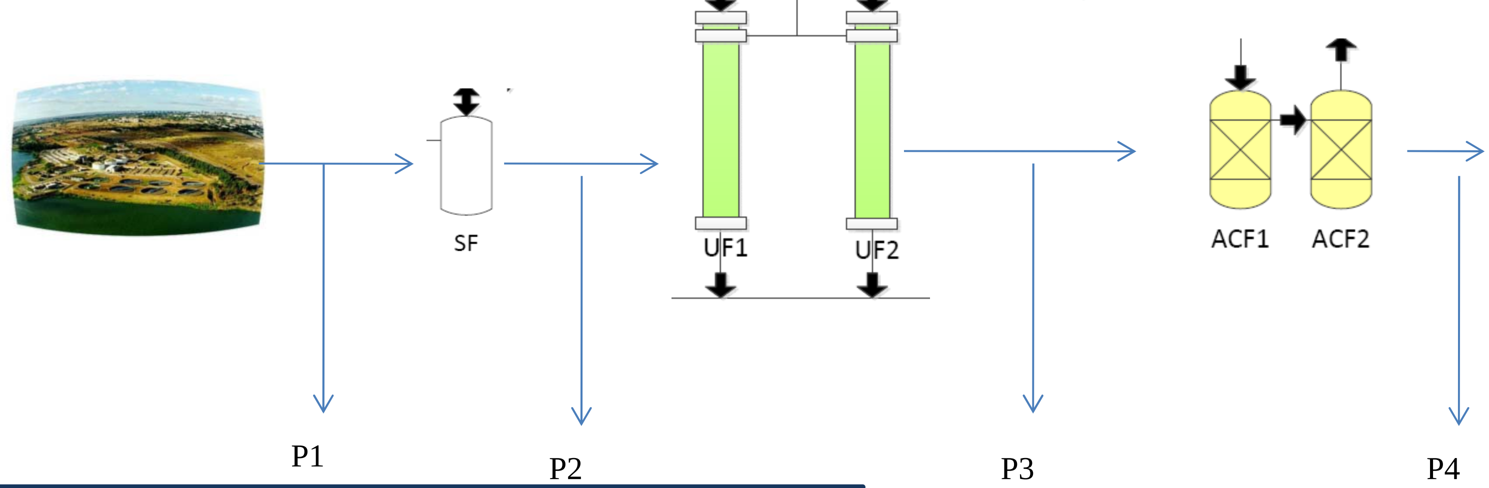
Research Team

- Brandão, Cristina – PhD, Supervisor, UnB
- Marques, Adriana- PhD Student, PTARH/UnB
- Bermond, Patricia - Master Student PTARH/UnB and Caesb
- Silva, Monica- Caesb
- Santos, Luana – Graduate Student UnB

Master Thesis

- **Ultrafiltration as advanced treatment for ETE-Norte**
  - **Phase 1** - Evaluation of the UF system as a complementary treatment of the existing WWTP.
  - **Phase 2** - Evaluation of the influence of flocculation time in the performance of hybrid ultrafiltration as tertiary treatment for Brasilia North WWTP.
  - **Phase 3** - Evaluation the UF system as an alternative tertiary treatment for Brasilia North WWTP – Substitution of DAF.

Phase 1 - Evaluation of the UF system as a complementary treatment of the existing WWTP



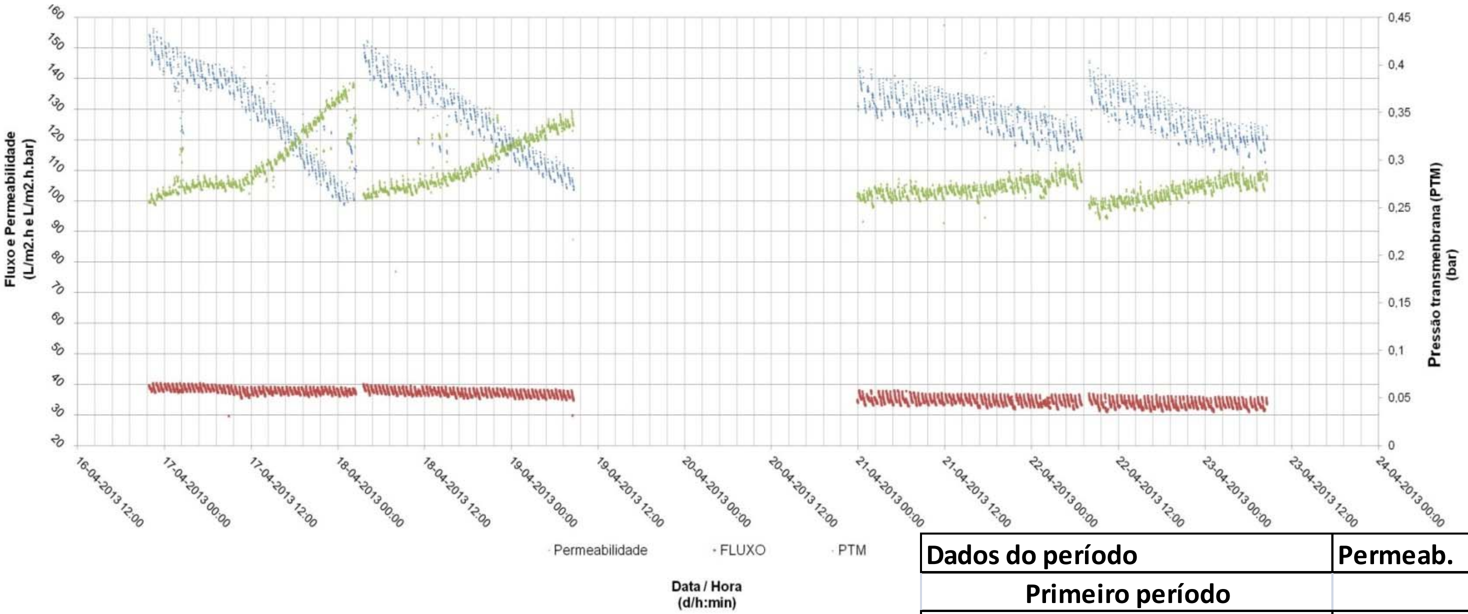
Parameter (Samples 1, 2,3 and 4)

- pH
- Suspended Solids
- Total Phosphorus and Orthophosphate
- Nitrogen Series
- E.coli

Monitoring Time - **192 hours**

Analyses Number - **54**

Operational Results (15/04 at 23/04)

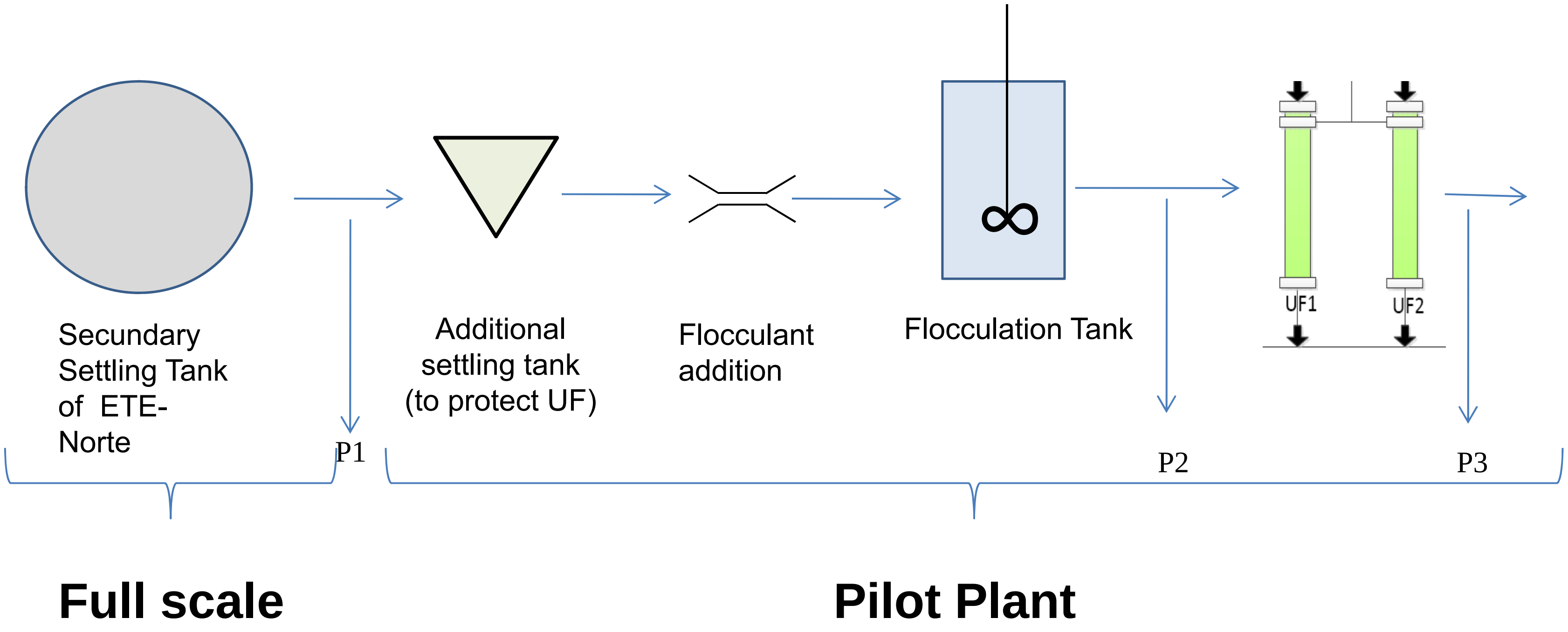


Dados do período	Permeab.	Fluxo	PTM
Primeiro período			
Dados Inicial	143,50	37,99	0,265
Dados inicio CEB	119,89	33,21	0,277
Perda na eficiencia	16%	13%	5%
Dados pós CEB	145,72	37,01	0,254
Taxa de recuperação	**100%**	**97%**	**96%**
Segundo período			
Dados Inicial	145,72	37,01	0,254
Dados inicio CEB	120,27	33,49	0,279
Perda na eficiencia	17%	10%	10%
Dados pós CEB	140,85	35,12	0,249
Taxa de recuperação	**97%**	**95%**	**98%**

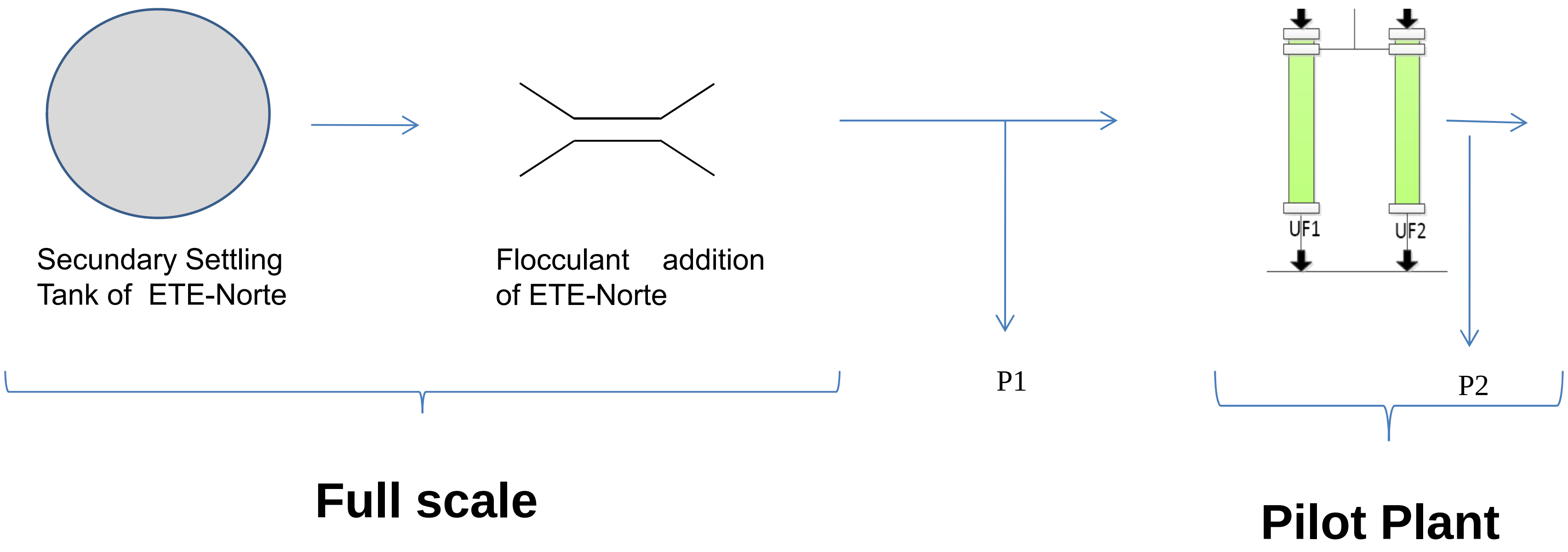
- Physico-chemical analysis
  - Quality results were not satisfactory results;
  - New analysis will be conducted

- Micropollutants analysis
  - 32 samples were prepared (extraction)
  - samples collected on alternate days for 5 days
  - The analysis will be conducted by German partners

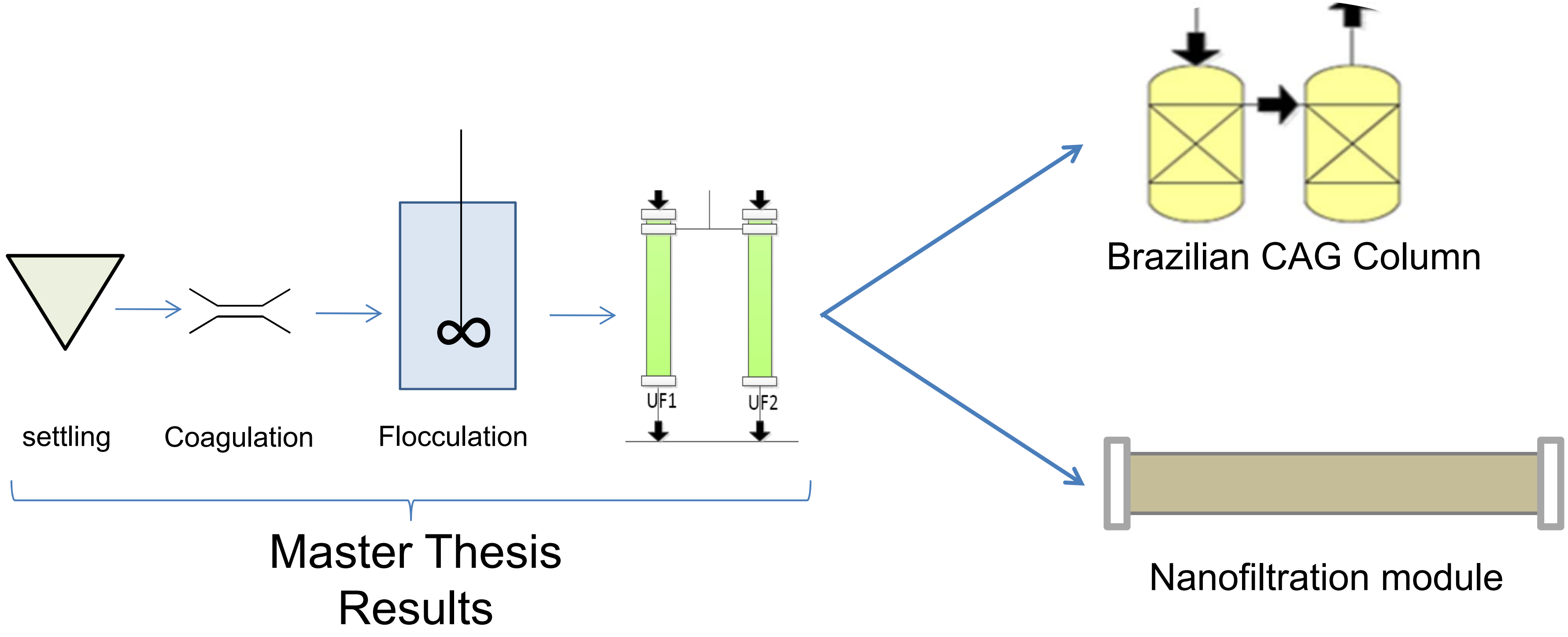
Phase 2 - Evaluation of the influence of flocculation time in the performance of hybrid ultrafiltration as tertiary treatment for Brasilia North WWTP



Phase 3 - Evaluation the UF system as an alternative tertiary treatment for Brasilia North WWTP – Substitution of DAF



- Doctoral Thesis
- Comparison: GAC versus NF membrane



- Micropollutants removal efficiency
- Operational cost

- Comparison of removal efficiency of selected micropollutants by nanofiltration membranes and granular activated carbon.
  - Part A – Experimental evidence
  - Part B – Model Development
- Regarding:
  - select drug residues, endocrine disrupting and detergent compounds;
  - influence of molecular wheigth, polarity and charge on the retention of both systems.
- Data discussion
  - Using simple logistic regression when checking the selected factors effecting the removal of micropollutants

Summary and prospects

- Removal of microsubstances is necessary with focus on water quality of the lake Paranoá and its future perspective for usage as drinking water reservoir
- The pilot plant shows good removal results
  - For the observed different groups of microsubstances
  - As well as for TOC
  - Protection of ACF by SF and UF as a unit is essential
- New fields of research are being examined (substitution of DAF, comparison to NF system)

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