WETPOL 2017

Advances in treatment wetland technology

North American and European Perspectives

Jaime Nivala

23 August 2017 | Big Sky, Montana

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

A few observations

North America

Research & Practice

- predominantly fundamental
- pilot testing & scale-up
- large-scale water reuse
- process-based design
- industrial applications

Europe

Research & Practice

- mix of fundamental and applied
- technology development in cooperation with small to medium-sized entities (SMEs)
- technology adaptation and transfer (developing regions, different climates), with SMEs
- best practices (DE, AT, FR, DK)
- industrial applications

Working together as a community

"Working together as a community has really advanced treatment wetland technology and its applications. Collaborations between academia and designer/installers have seen real advantages for both sides, and it strengthens the acceptance of wetland technology when compared to traditional technologies."

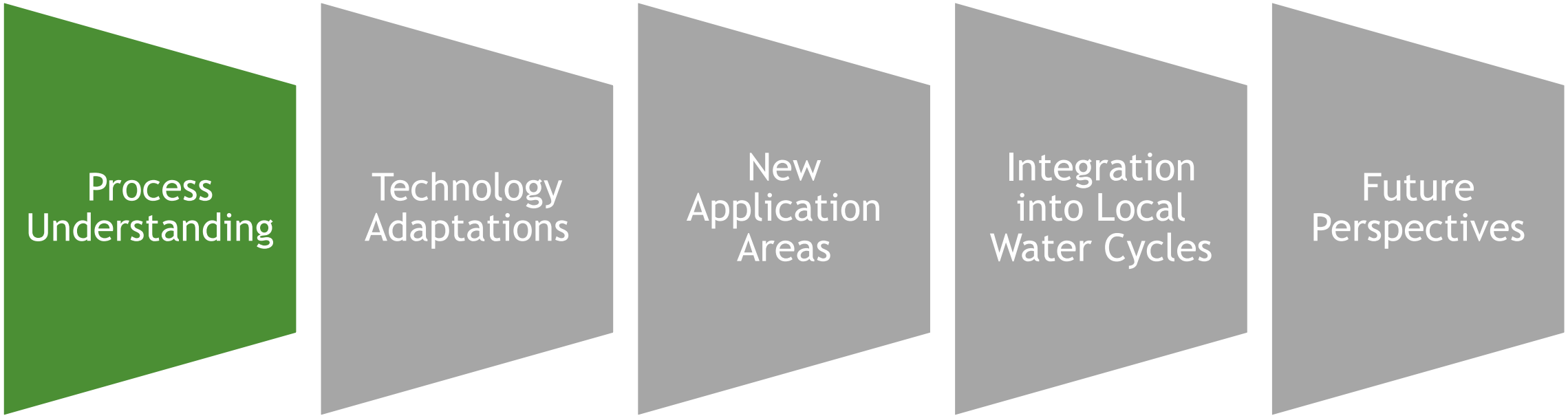
Clodagh Murphy, ARM Ltd., UK

Heartfelt thanks to…

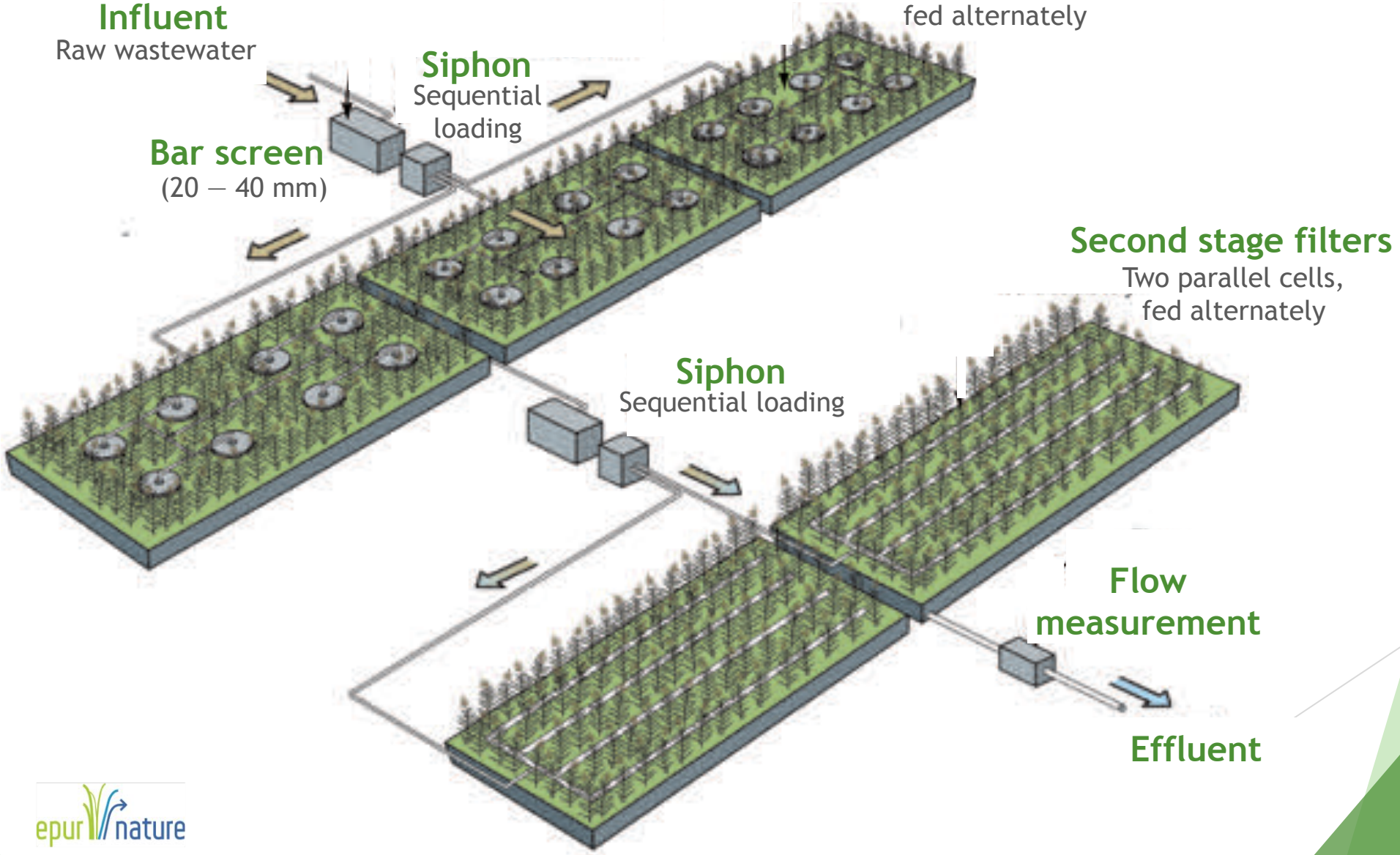
Otto Stein	USA
Carlos Arias	DENMARK
David Austin	USA
Thomas Aubron	GERMANY
Jim Bays	USA
Pedro Carvalho	DENMARK
Florent Chazarenc	FRANCE
Paul Frank	USA
Joan Garcia	SPAIN
Nicolas Forquet	FRANCE
Mathieu Gautier	FRANCE
Chris Keller	USA
Ganbataar Khurelbataar	GERMANY
Boram Kim	FRANCE
Rémi Lombard Latune	FRANCE
Luz Herrero	SPAIN
Margit Kõiv-Vainik	CANADA/ESTONIA
Pascal Molle	FRANCE
Jochen Müller	GERMANY
Clodagh Murphy	UNITED KINGDOM
Joëlle Paing	FRANCE
Diederik Rousseau	BELGIUM
Heribert Rustige	GERMANY
Dion van Oirschot	BELGIUM
Jan Vymazal	CZECH REPUBLIC
Scott Wallace	USA
Kela Weber	CANADA
Chris Weedon	UNITED KINGDOM

Recent advancements

Recent advancements



French VF Wetlands



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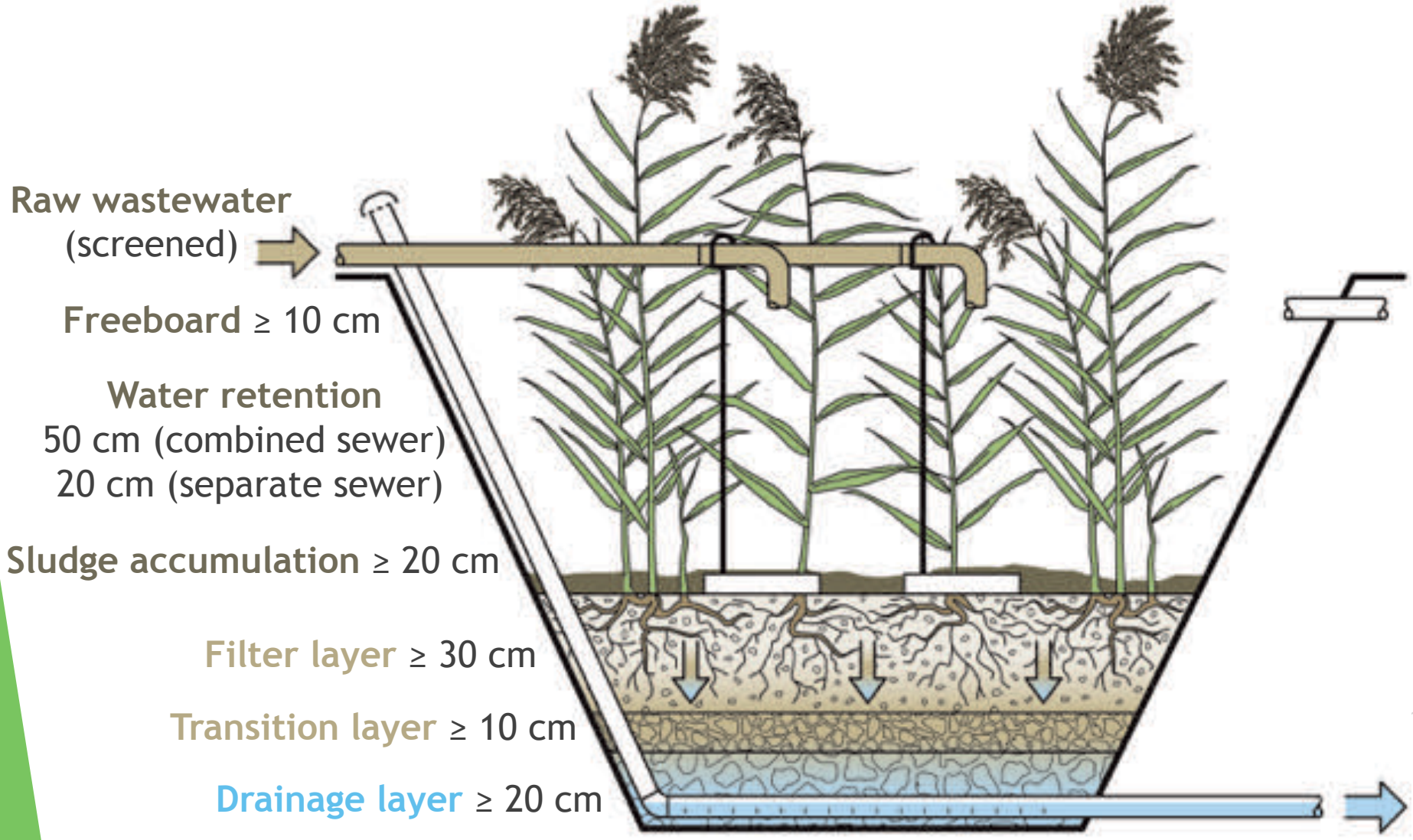
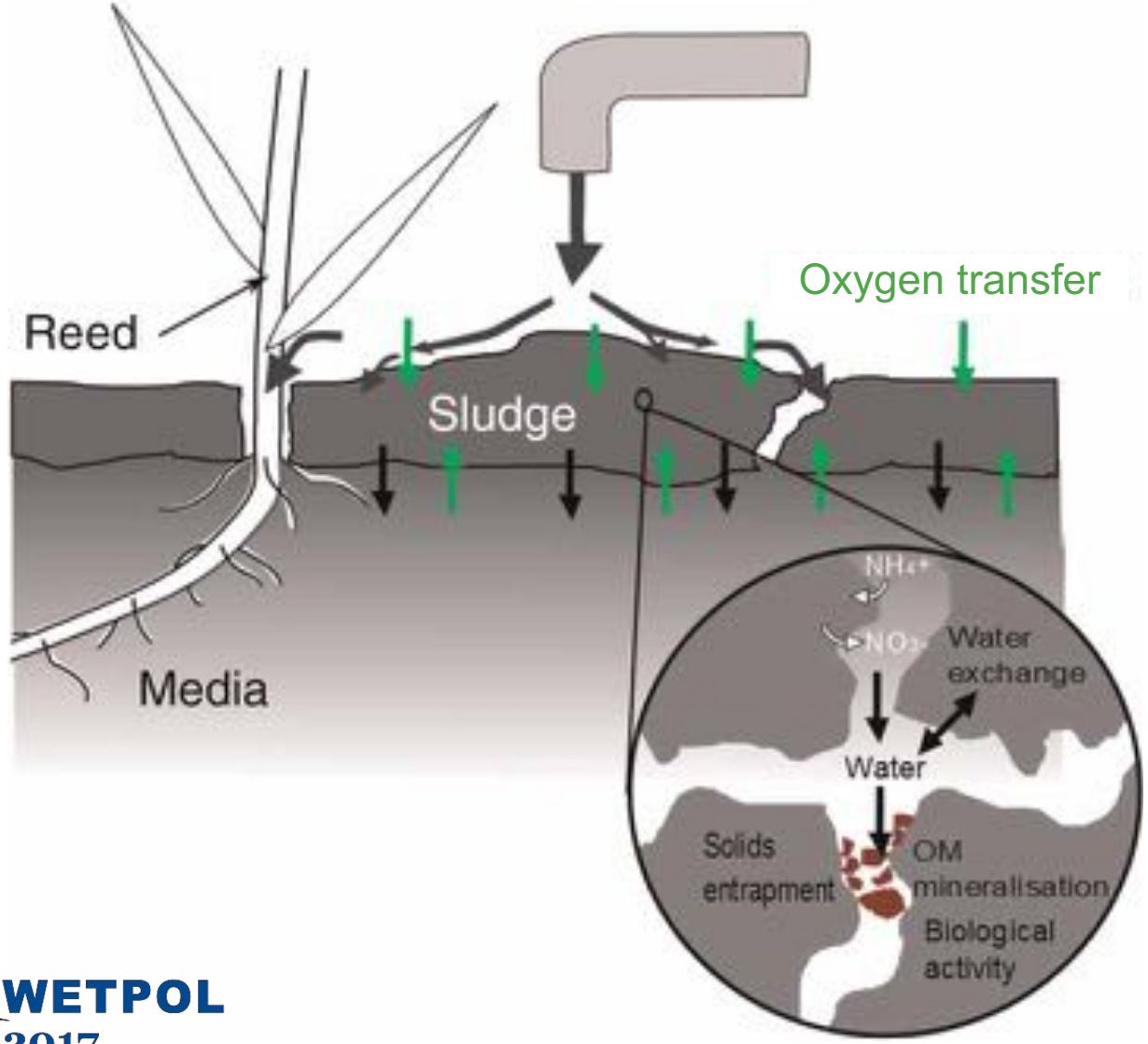
French VF Wetlands



Process Understanding: Deposit Layer



- Much more than just solids filtration
- Prerequisite for good operational hydraulics
- This "reactive barrier" plays an important role in pollutant removal (N, P, metals, micropollutants)
- Process dynamics of the sludge layer change over time (short- and long-term) still under investigation

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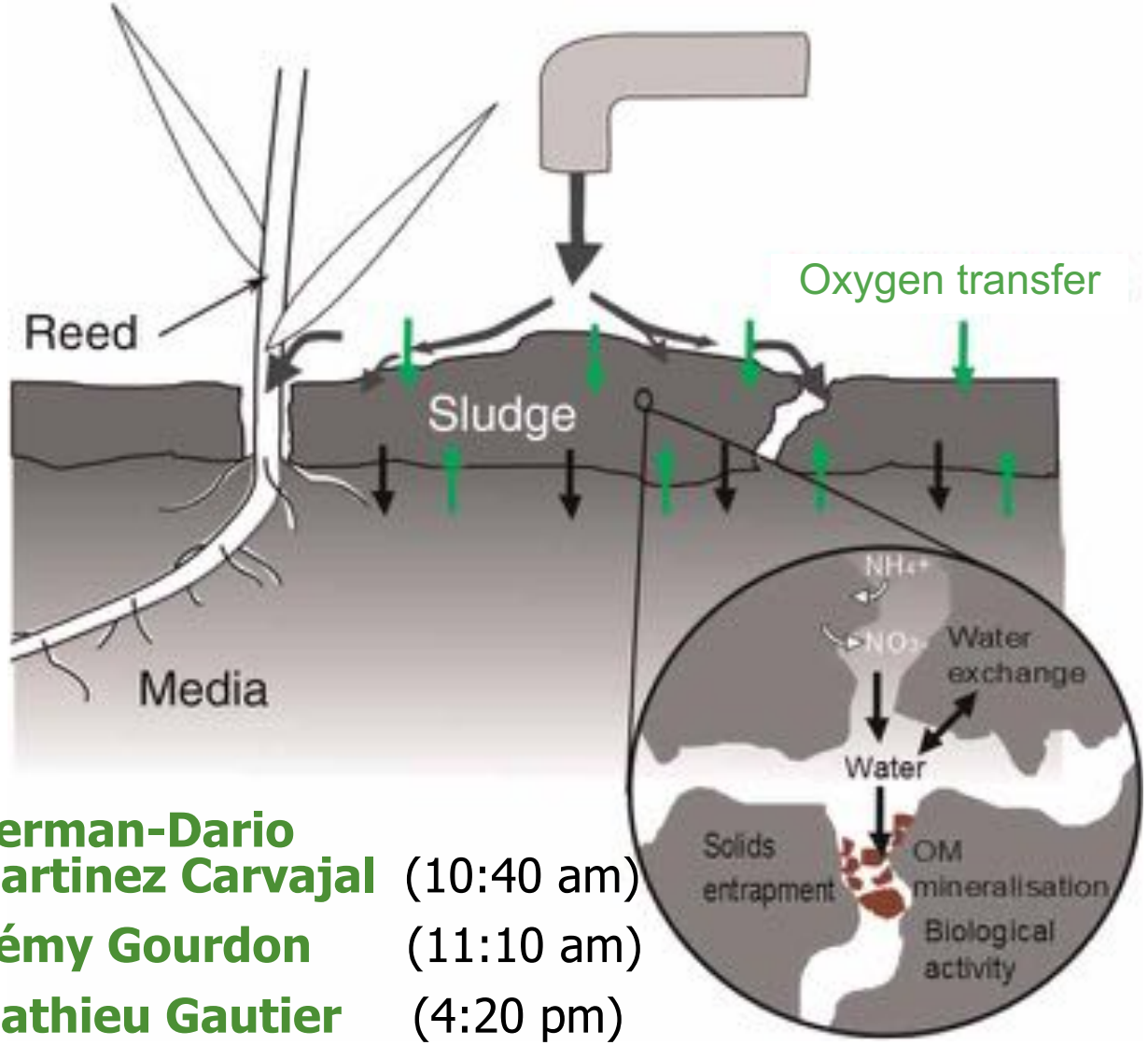
Process Understanding: Deposit Layer



- Focus on improved understanding of how operational and environmental parameters influence sludge layer properties and overall treatment performance
  - Aggregation
  - Micro-porosity
  - Water retention
  - Organic matter fractionation
  - FTIR
  - 3D fluorescence
  - C, N and H stable isotopes

German-Dario Martinez Carvajal (10:40 am)
Rémy Gourdon (11:10 am)
Mathieu Gautier (4:20 pm)

Process understanding: Phosphorus

- Strict phosphorus discharge standards limit use of wetlands for treatment of municipal wastewater
- Phosphorus removal depends on geochemistry, alkalinity and pH
- Predominant P removal mechanisms

Adsorption

Attachment of phosphate to charged surface of filter materials (Fe and Al oxides)

Precipitation

Negatively charged phosphate bonds with positively charged ions (Ca, Fe, Al) provided by the filter media, forming insoluble compounds

Process understanding: Phosphorus

Natural materials
- Apatite
- Limestone
- Serpentinite (Quebec)

Industrial byproducts
- Fly ash
- Basic oxygen furnace slag
- Steel slag

Lightweight Aggregates
- Phoslock (Australia)
- Filtralite-P (Norway)
- LECA (Scandanavia)

- Influence of C, N, solids on P removal dynamics still not well understood
- Expensive; use sometimes limited to specific geographical regions
- Replacement of filter material for adsorption or precipitation is inevitable
- Potential for re-use of spent filter material as fertilizer?
- Potential P recovery from deposit layer (French VF) **Boram Kim** (Friday 4:20 pm)

Process understanding: Phosphorus

- Some large-scale SF wetlands can achieve sustainable phosphorus removal
- Low-dose alum addition for PO_4-P removal (no coagulation)
- Geochemical augmentation increases PO_4-P removal rates in wetlands by a factor of 20
- Influent TP = 0.6 mg/L
  Effluent TP < 0.1 mg/L
- **David Austin** (Friday 9:20)


Huie Constructed Wetlands, Clayton County, GA

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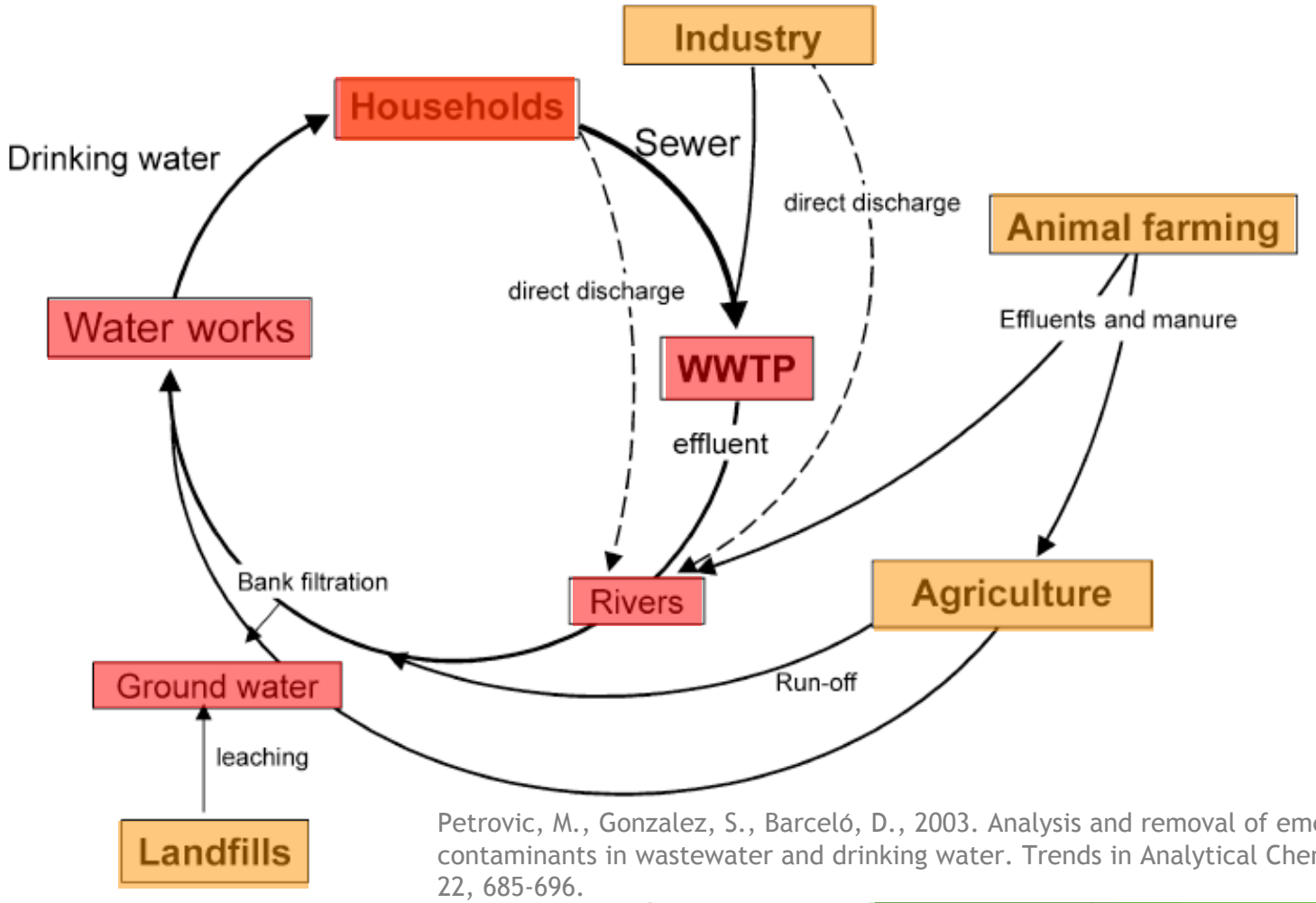
Micropollutants

- Four parallel sessions, 14 presentations (13%)
- Treatment efficacy: 9
- Occurrence, distribution and fate: 6
- Antibiotic resistance: 3
- Response of microbial communities: 2
- Aquatic risk: 1



Petrovic, M., Gonzalez, S., Barceló, D., 2003. Analysis and removal of emerging contaminants in wastewater and drinking water. Trends in Analytical Chemistry 22, 685-696.

Langenreichenbach, Germany

Micropollutants

- Seven wetland technologies
- Adjacent municipal WWTP (activated sludge w/ biological and chemical P removal; 16,000 PE)
- Direct-inject analysis method
  2 hours per sample → 20 minutes
- Weekly monitoring over the course of one year
- Seven selected micropollutants, representing different levels of biodegradability
  - Easy: caffeine, ibuprofen, naproxen
  - Moderate: benzatriozole, diclofenac
  - Recalcitrant: acesulfame, carbamazapine

Unpublished data removed


Process Understanding
Technology Adaptations
New Application Areas
Integration into Local Water Cycles
Future Perspectives

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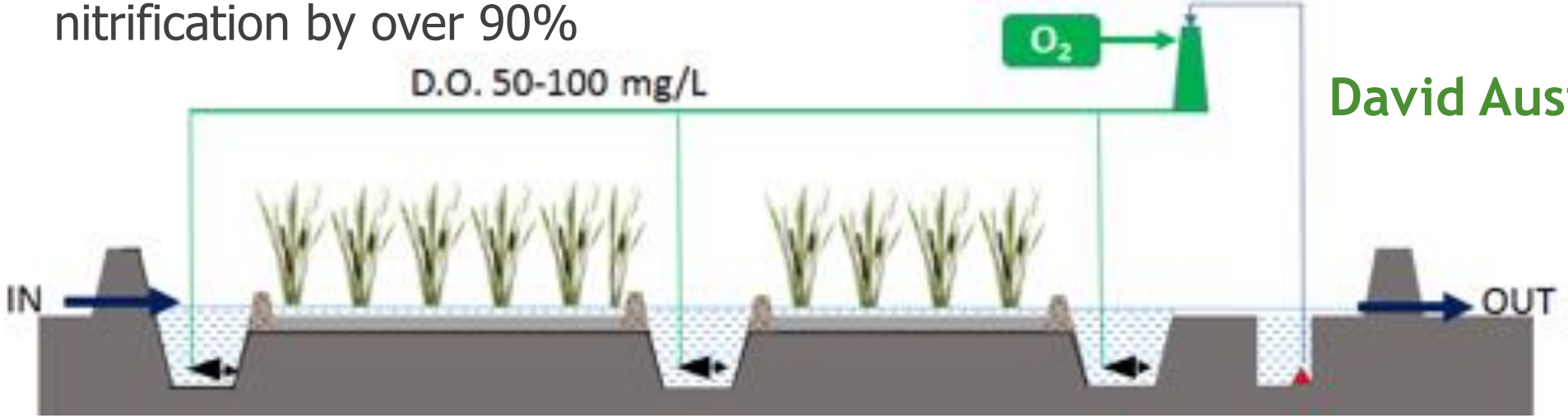
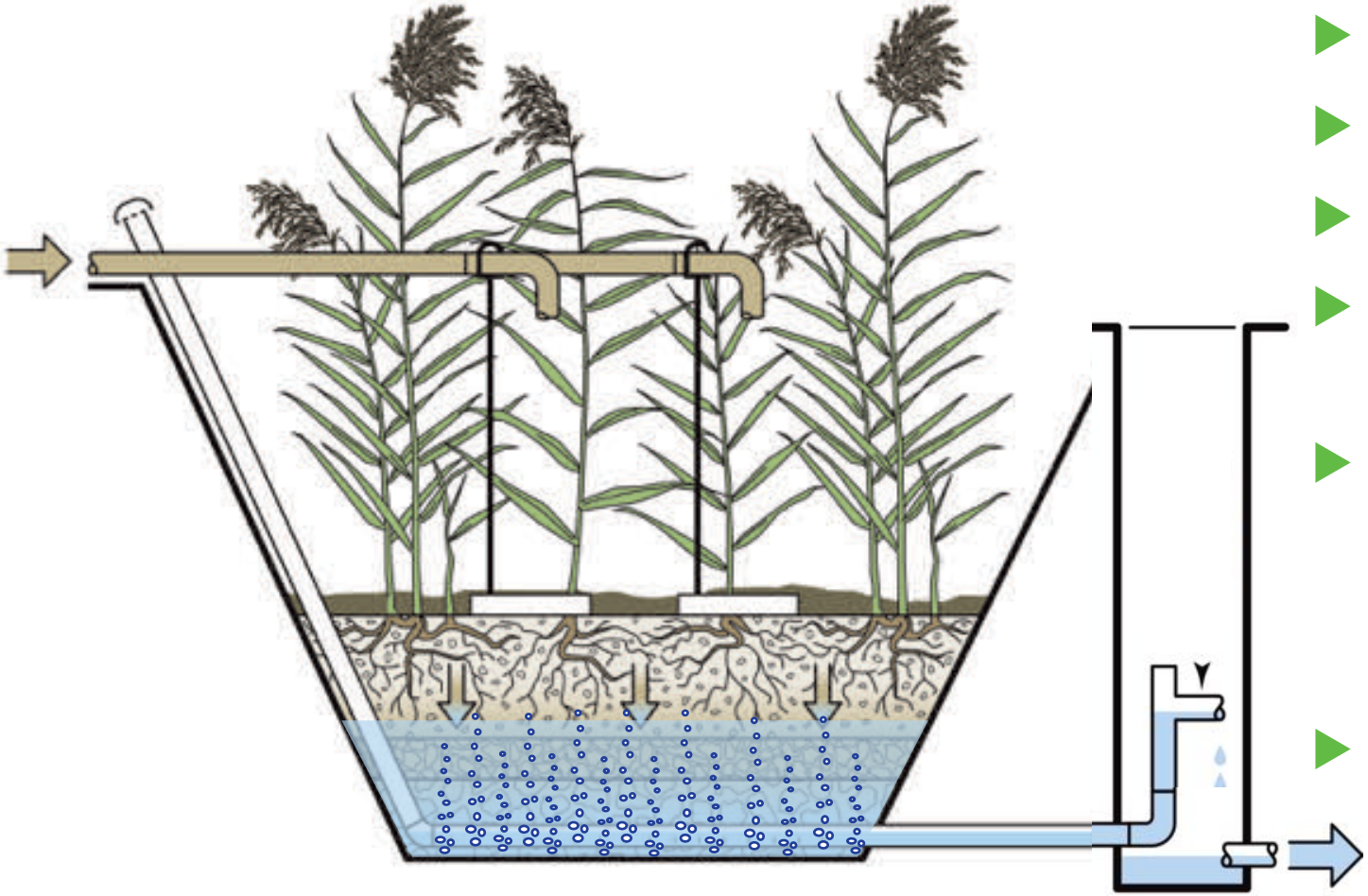
Technology adaptations: Sidestream oxygenation

- Free Water Surface (FWS) wetland for groundwater remediation
- **Pure oxygen** is injected into the deep zones in order to achieve nitrification
- Bench-scale pilot to full scale construction (1.5 MLD)
- Reduced the area required for nitrification by over 90%



David Austin (3:40pm)

Technology adaptations: French VF + aeration



- Raw wastewater
- Above: Sludge accumulation
- Middle: Unsaturated zone
- Below: Saturated zone with aeration
- Two French companies (Opure and EpurNatur/Syntea) have patented variations of this concept
- Evaluation and adaptation in cooperation with IRSTEA

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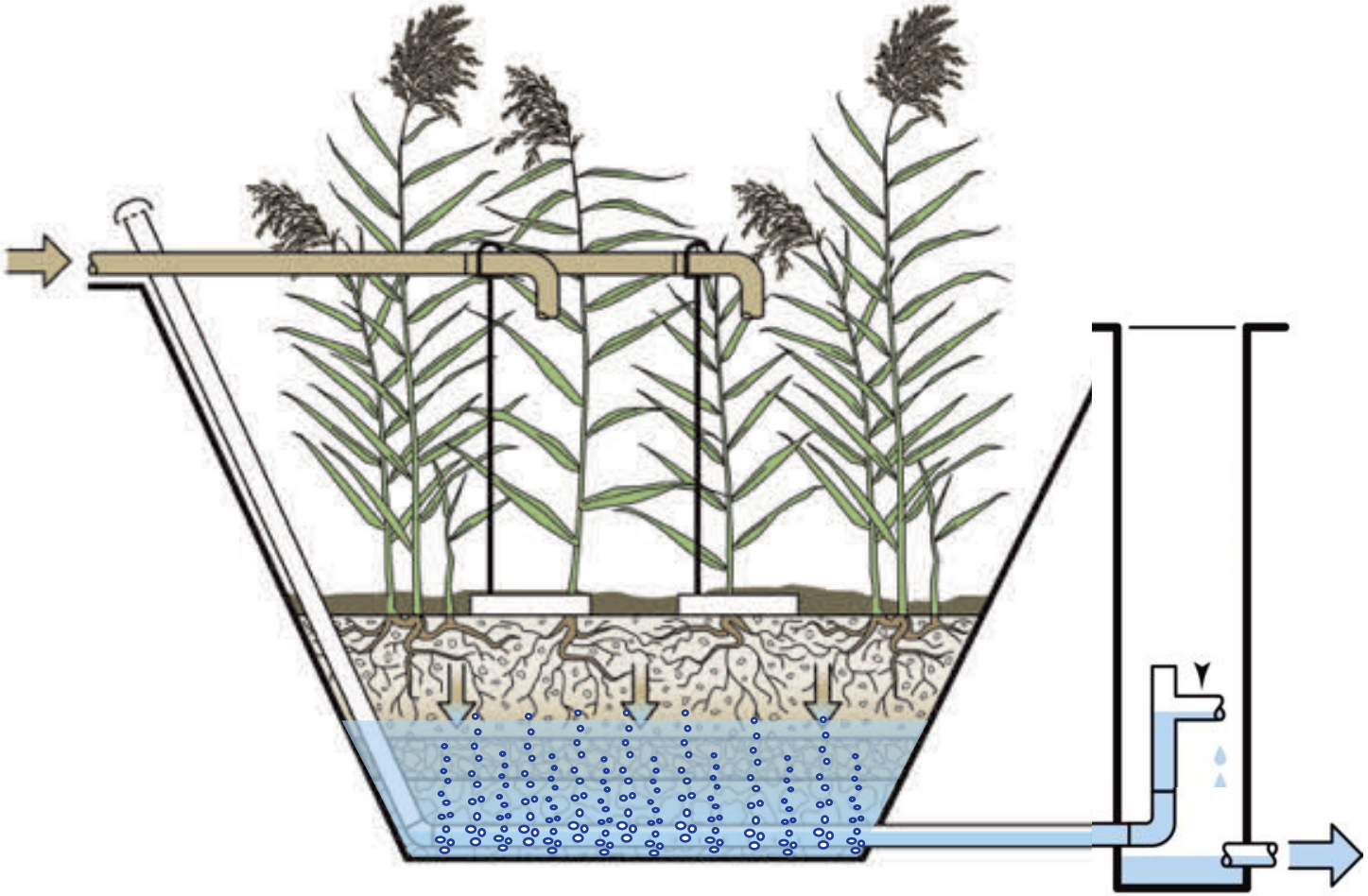
Technology adaptations: French VF + aeration



- No pretreatment needed
- Domestic wastewater, high-strength wastewater (agro-food industry, winery) with variable loads
- Populations up to 5,000 PE
- Potential for very good TN removal (< 15 mg/L)
- Relatively low energy requirements

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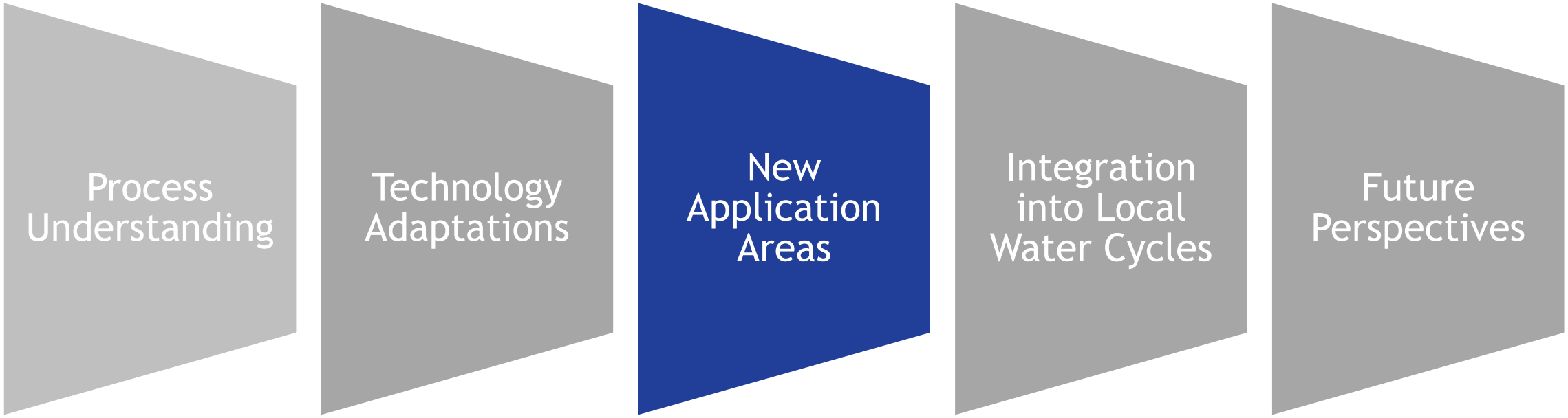
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New application areas: Aquaculture/Biofuel

- Abu Dhabi, UAE
- Saltwater biofuel production integrated with aquaculture and wetland treatment
- Farmed fish and seafood
- Salicornia harvested for production of bio-jet fuel
- 5-ha study system
- **Mark Madison** (Friday 10:15)

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New application areas: Waterworks sludge

- Water treatment works produces 150 million liters (40 MGD) potable water per day
- 2 – 4 million liters (0.5 – 1.0 MGD) ferric (iron sludge) generated from the clarifiers
- Mineral sludge with seasonally fluctuating concentrations of algae and suspended solids
- Successful pilot demonstration, six cells at 20m^2 (200 ft^2) each

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ORBICON

New application areas: Waterworks sludge

- Full scale system
  16 cells, 42,500 m^2 (10.5 ac) in total
- **Water-saving**
  99% of filtrate returned to water course
- **Low maintenance**
  no chemical dosing required;
  sludge removal every 10 years;
  minimal energy requirements
  fully SCADA controlled
- **Increased biodiversity**
  wetlands attract wildlife
- **Carbon management**
  lower C footprint than mechanical dewatering


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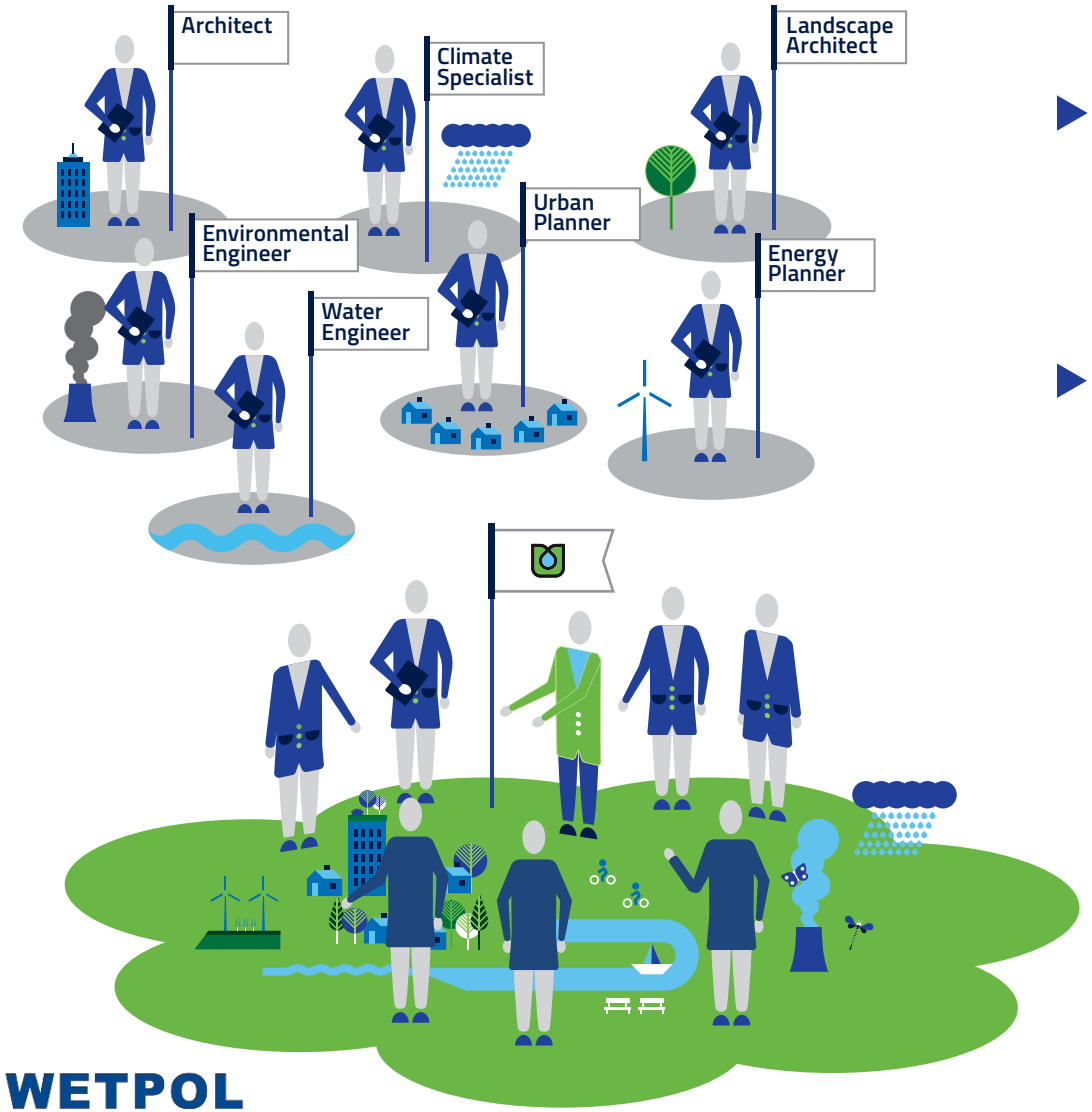
Integration into Local Water Cycles



- All aspects of water supply and treatment systems are interconnected
- Paradigm shift from **discrete, one-dimensional projects** to a systematic integration and **assessment of all possible ecosystem services**, including tangible and non-tangible benefits and costs
  - **Martin Regelsberger** (11:10)

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Bozovic et al. 2017:Blue Green Solutions. A Systems Approach to Sustainable, Resilient and Cost-Efficient Urban Development. Imperial College; London, UK. 53 pp.

Indirect Potable Reuse

- Declining water levels in underground aquifers and surface water reservoirs
- Rates of extraction exceed the rates of recharge via rainfall and infiltration
- Large-scale wetlands are being used for groundwater recharge and nutrient reduction to offset the net loss of groundwater and increase water available for potable reuse

Allison Lewis (Tuesday) CH2M

Timothy Noack (11:30am; Friday 10:35am) ALAN PLUMMER ASSOCIATES, INC. ENVIRONMENTAL ENGINEERS AND SCIENTISTS

Chris Keller (10:40 am; 1:00pm) Wetland Solutions Inc

Rafael Vázquez-Burney (1:20pm) CH2M

Flussbad Project, Berlin

- Large-scale urban development project for the Spree Canal, located in the heart of historical Berlin
- The Spree Canal has been largely neglected for over 100 years, is now planned to be a highlight of city living
- Ecologically sound, easily accessible site open to all Berlin residents and visitors

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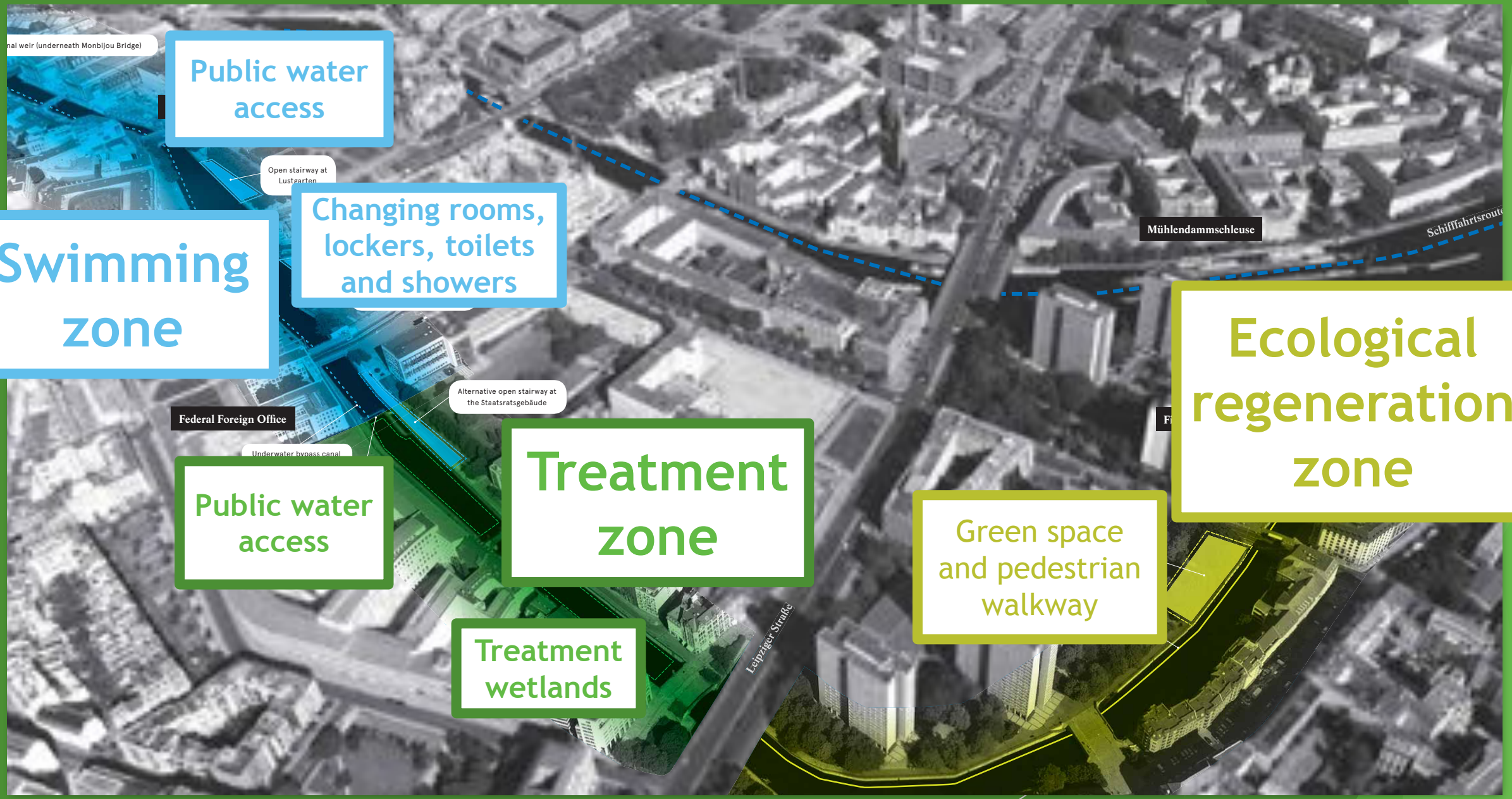
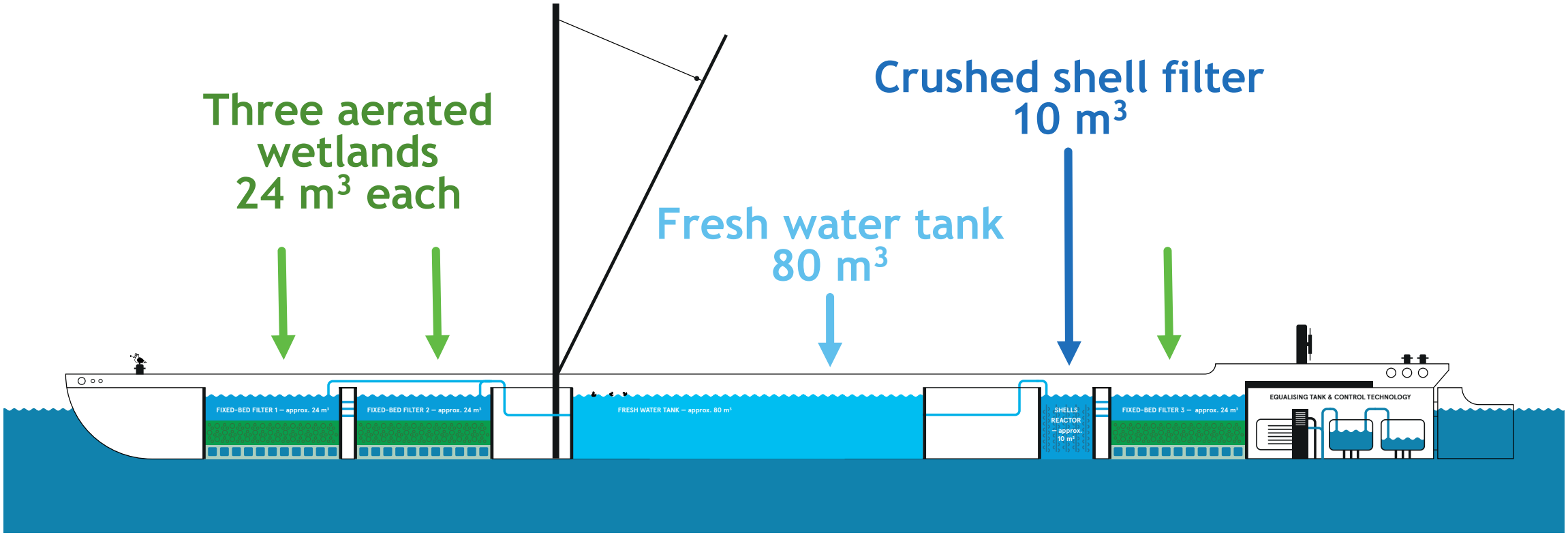
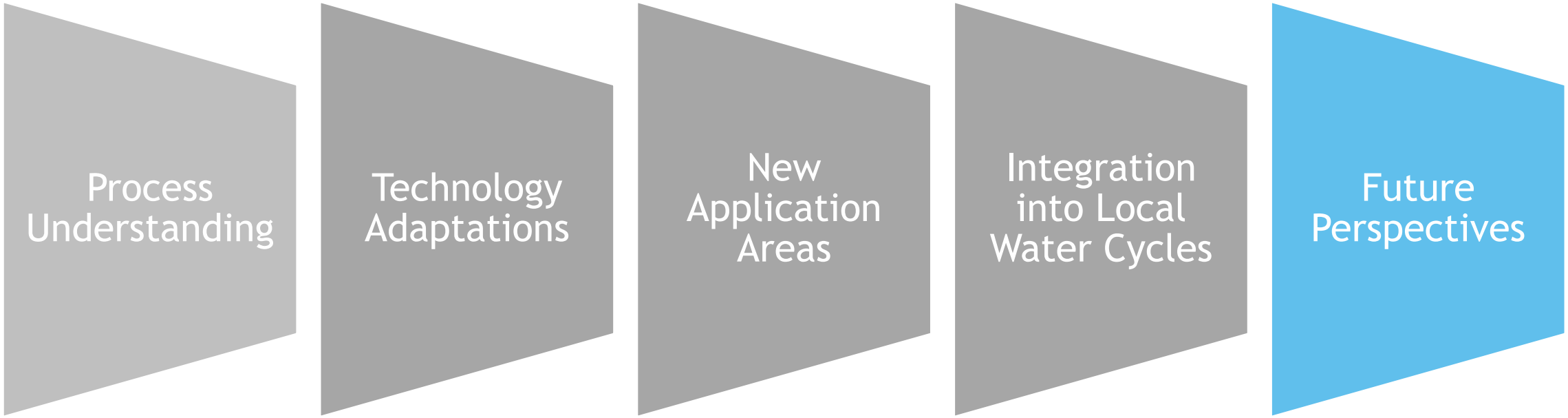

Public water access
Swimming zone
Changing rooms, lockers, toilets and showers
Open stairway at Lustgarten
Mühlendammschleuse
Schifffahrtsroute
Ecological regeneration zone
Alternative open stairway at the Staatsratsgebäude
Federal Foreign Office
Public water access
Treatment zone
Green space and pedestrian walkway
Treatment wetlands
Leipziger Straße

Test phase planned for 2018

Flussbad Project, Berlin

Aim: to fulfill EU swimming water regulations

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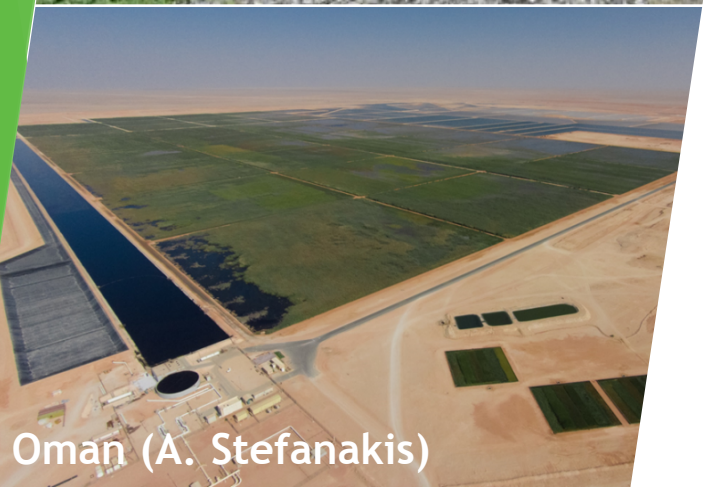
Mongolia (G. Khurelbataar)


Mayotte (R. Lombard Latune)


Oman (A. Stefanakis)

Extreme climates

- Most treatment wetland design guidance is based on experience in temperate climates
- Even within Europe, climate varies greatly
- Design parameters cannot be extrapolated outside the climate conditions in which they were produced
- Distinct need for experience in non-temperate climates (cold, hot, arid, tropical)

Alexandros Stefanakis (Tuesday)

Ganbataar Khurelbataar (Tuesday)

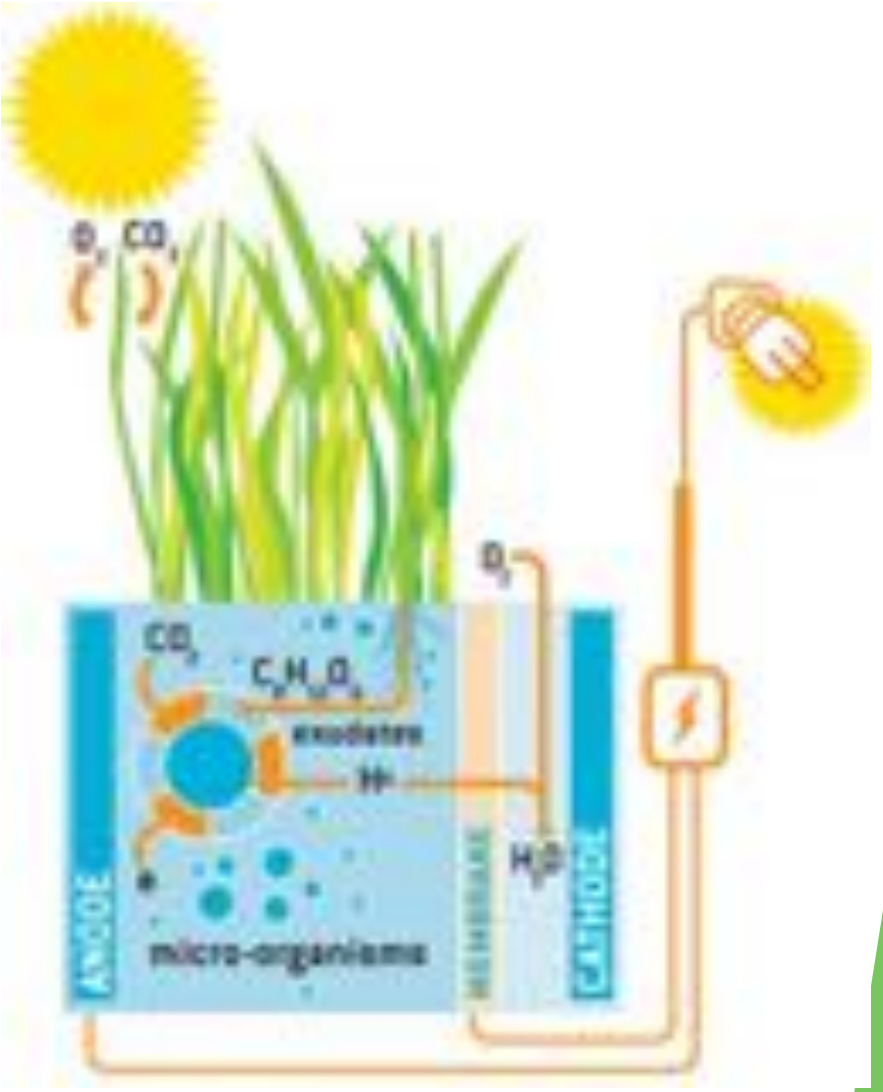
Remi Lombard Latune (2:10 pm)

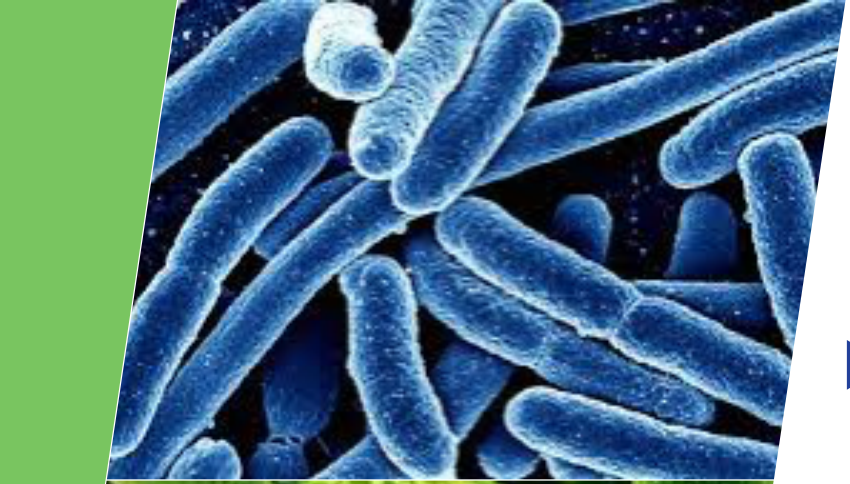
Audrey Hiscock (2:30 pm)

Shayla Woodhouse (2:50 pm)

Electroactive Bacteria in Wetlands

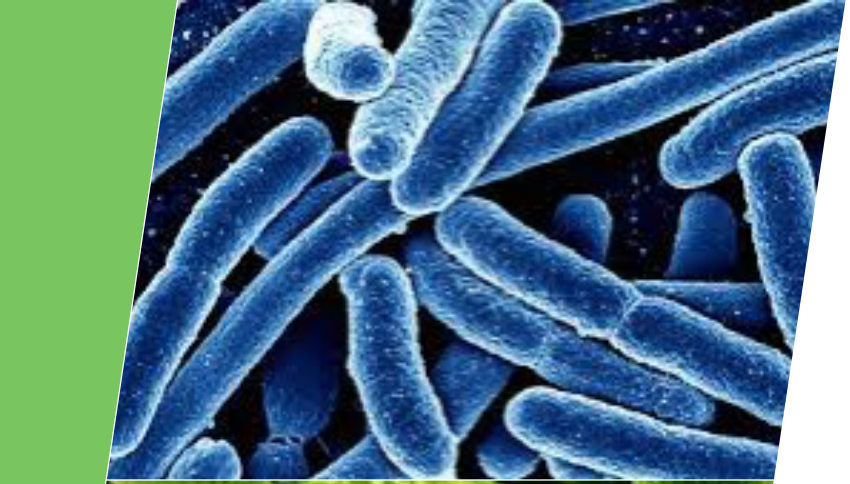
- Using the interaction between plants, electroactive bacteria and wastewater to improve treatment performance or generate electricity
- Real-time water quality assessment with constructed wetland microbial fuel cells
  - **Marco Hartl** (Tuesday)
- Application and performance of bio-electrochemical technology merged with treatment wetland technology
  - **Carlos Ramierez-Vargas** (4:50pm)
  - **Yaquian Zhao** (5:10pm)
  - **Carlos Arias** (5:30pm)





Microbiology

- Biofilm influences all aspects of treatment
  - Hydrology
  - Source and sink of pollutants (**Ana Galvão** Tuesday)
  - Integral part of the rhizosphere
- Stigma of the "black box" still exists
- Current and future efforts aim to better understand microbiological aspects
  - Function (who does what, and when?)
  - Dynamics (growth and decay; different time scales)
  - Selection of specific populations (ANAMMOX, etc.)
  - Response to external factors (operational or inherent)



Antibiotic Resistance

- What are the effects of micropollutants on microbial communities?
- Microbial response to antibiotics

  Yunv Dai (Tuesday)
- Antibiotic resistant bacteria, gene transfer

  Hua Li (Tuesday)

  Xiaomeng Zhang (Tuesday)
- Nanoparticles

  Gijs du Laing (Tuesday)
- Chemical analysis alone is not enough to fully understand the effects treated wastewater has on the environment.

Ecotoxicity of treated wastewater

- Over 99.9% of the toxic effects of wastewater are caused by unknown chemicals in a sample.
- **Bioanalytical tools** can be used to target specific **mechanisms of toxicity** and quantify the effects of all chemicals acting together in a water sample, even when concentrations of individual chemicals are below the limit of detection.

Diederik Rousseau (2:10)

Ecotoxicity of treated wastewater

Unpublished data removed

- Intensified wetlands perform better than the conventional WWTP
- Can ecotoxicology be used be used to inform design?

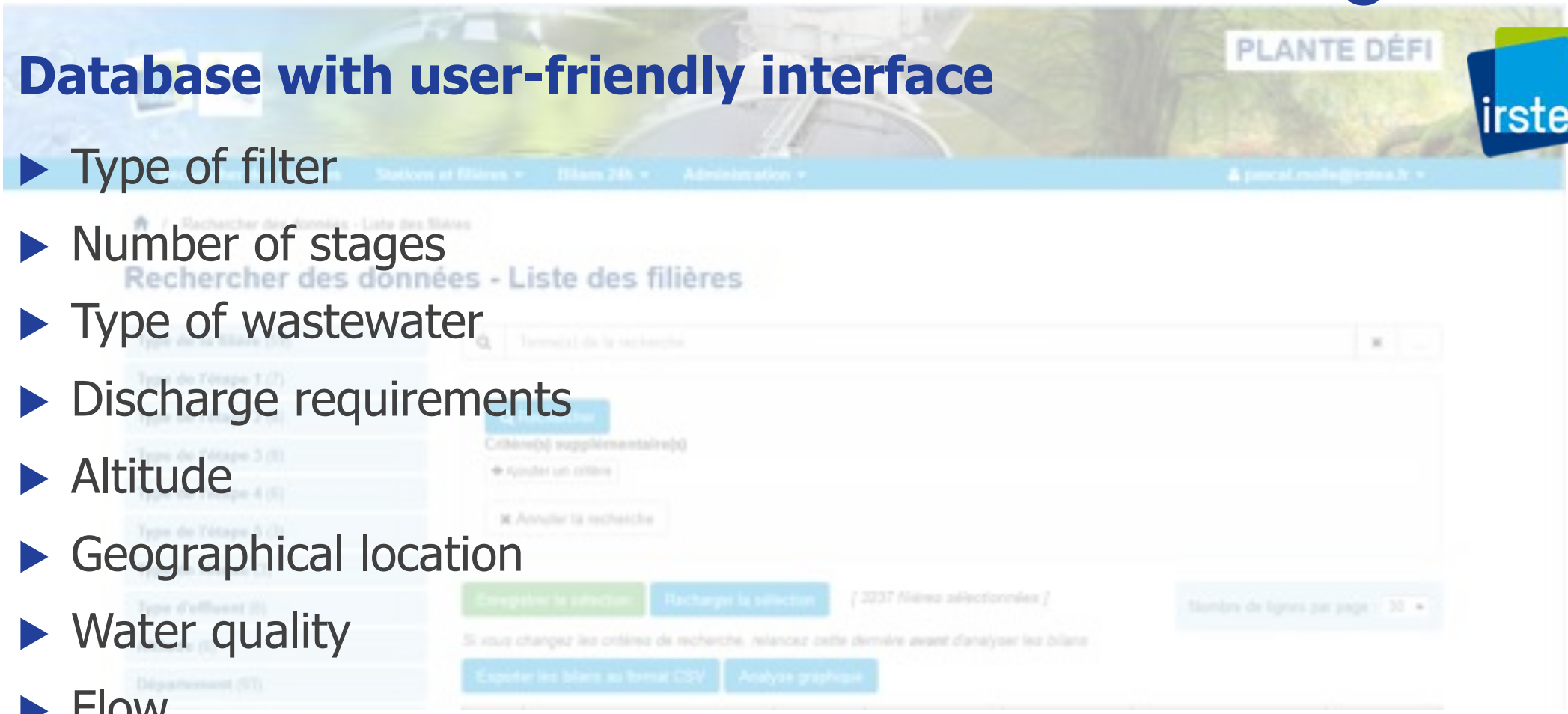
From uncontrolled to intensive monitoring

- Online sensors and robust monitoring tools
  - Clogging (excess biofilm)
  - Hydraulic problems (ponding)
  - Water quality
  - Mechanical components (pumps, etc.)
- Remote operational control
- Efforts towards long-term data collection on full-scale systems

From uncontrolled to intensive monitoring

Database with user-friendly interface

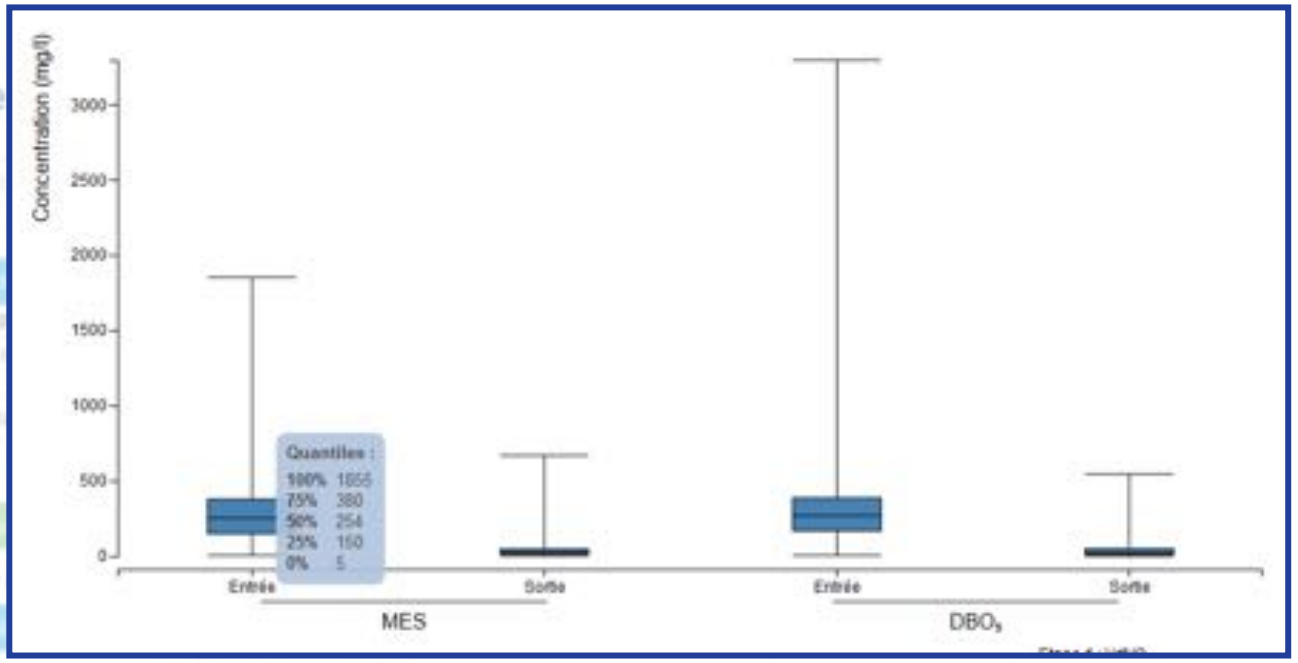
- Type of filter
- Number of stages
- Type of wastewater
- Discharge requirements
- Altitude
- Geographical location
- Water quality
- Flow



From uncontrolled to intensive monitoring

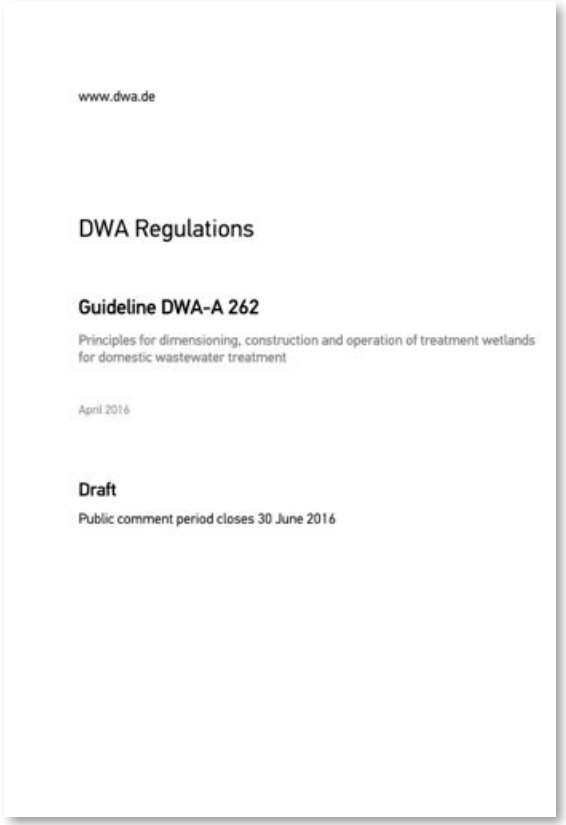
Instant Reporting

- Individual stage or total system
- Concentration or load
- Individual or groups of systems
- Scatter plots
- Box plots



Entry / uploading of new data by local water districts

Mainstreaming Wetland Technology



- New German guideline
- Revision process started in January 2014
- Multiple public hearings have been held in 2016/2017
- Reviewed by international experts
- Expected publication date November 2017

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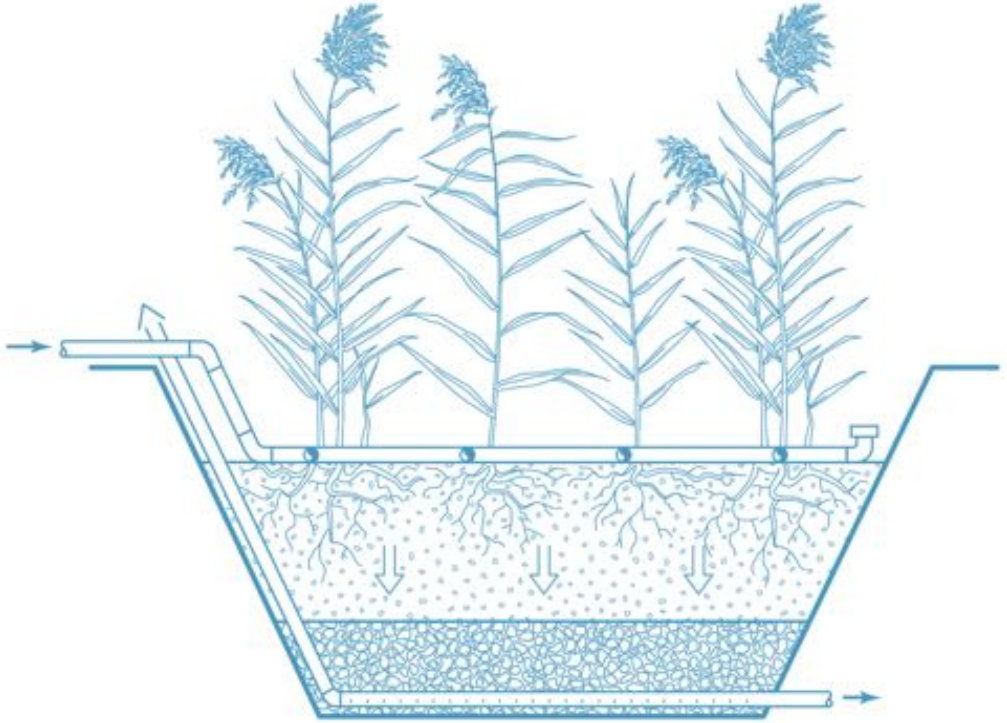
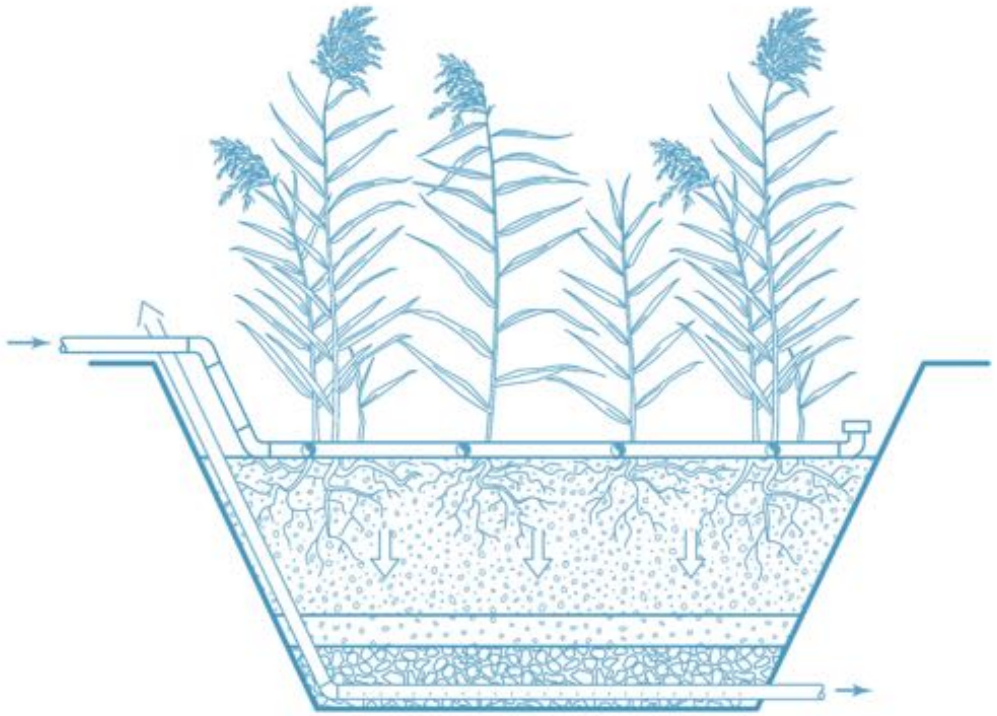
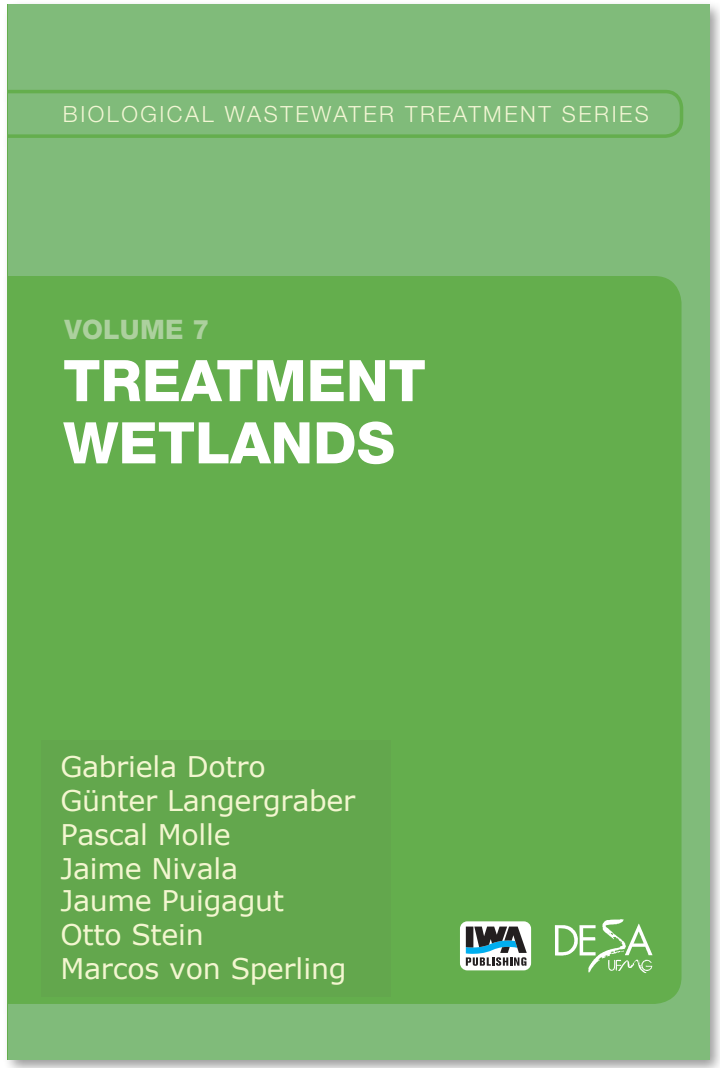
Mainstreaming Wetland Technology

- French VF wetlands (1st and 2nd stage) for separated sewer & combined sewer
- HF and VF aerated wetlands
- Two-stage VF wetlands
- Wetlands for treating seasonal flows
- Wetlands for graywater treatment





Mainstreaming Wetland Technology



- First open-access textbook on treatment wetlands
- Publish date: 15 September 2017
- Target audience: undergraduate students
- Removal processes, design, and operation of main wetland types
- HF, VF, French VF, FWS
- jaime.nivala@ufz.de

Thank you for your attention!