MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS

UNIVERSIDADE DO ALGARVE

TARH

LNEC LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

MARSoluT
Managed Aquifer Recharge ITN

SOIL-AQUIFER TREATMENT AS A PASSIVE SOLUTION TO ENHANCE TREATED WASTEWATER QUALITY

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ÁGUAS DO ALGARVE

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Soil-Aquifer Treatment as a passive solution to enhance treated wastewater quality

PT2_6 Algarve, São Bartolomeu de Messines: INTRODUCTION

Goal: Improve WWTP effluent quality, currently being discharged to a river crossing a high yield karst aquifer

DEMEAU

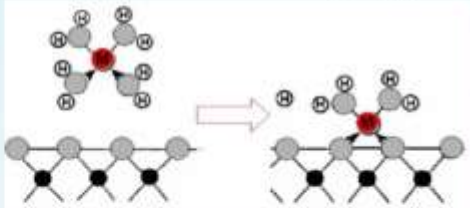
Demonstration of promising technologies to address emerging pollutants in water and waste water

CONTEXT

How can we enhance MAR to increase removal of emerging pollutants?

By increasing biodegradation

By increasing sorption capacity



Concept: Reactive layer in the bottom of the infiltration pond to promote the removal of micropollutants from recharge water during SAT

- Soil-column → WP14

LASUB, at LNEC

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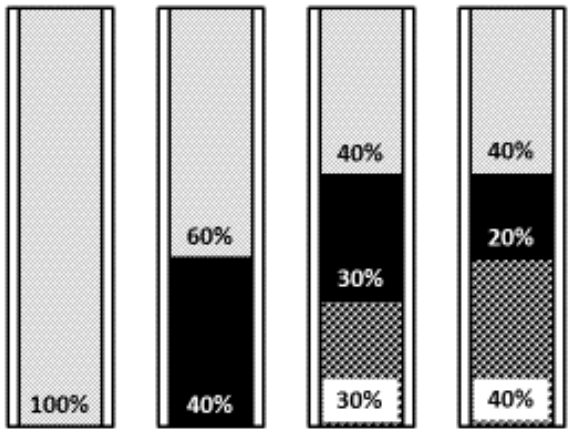
INTRODUCTION

Martins *et al.*, 2015 & 2016
Martins, 2016



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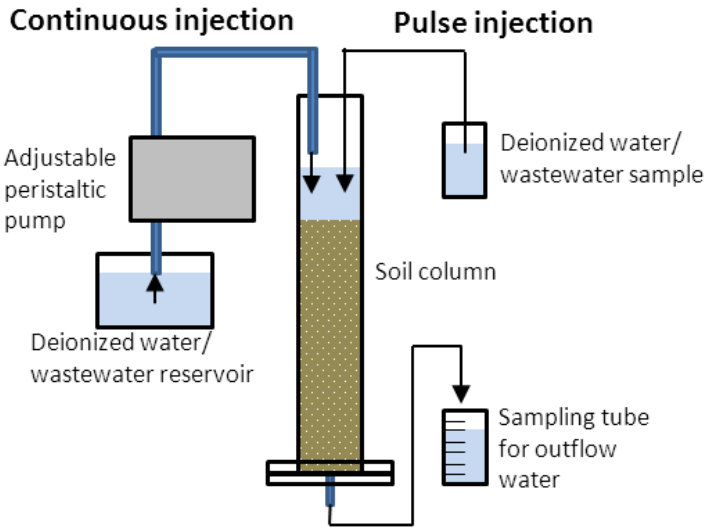

- Different sets of mixtures of SBMessines soil with artificial sand and vegetal compost were tested in soil-column experiments, aiming at:

  1) Obtaining higher infiltration rates
  2) Optimizing the conditions for the best contaminants reduction (retention time and soil properties)

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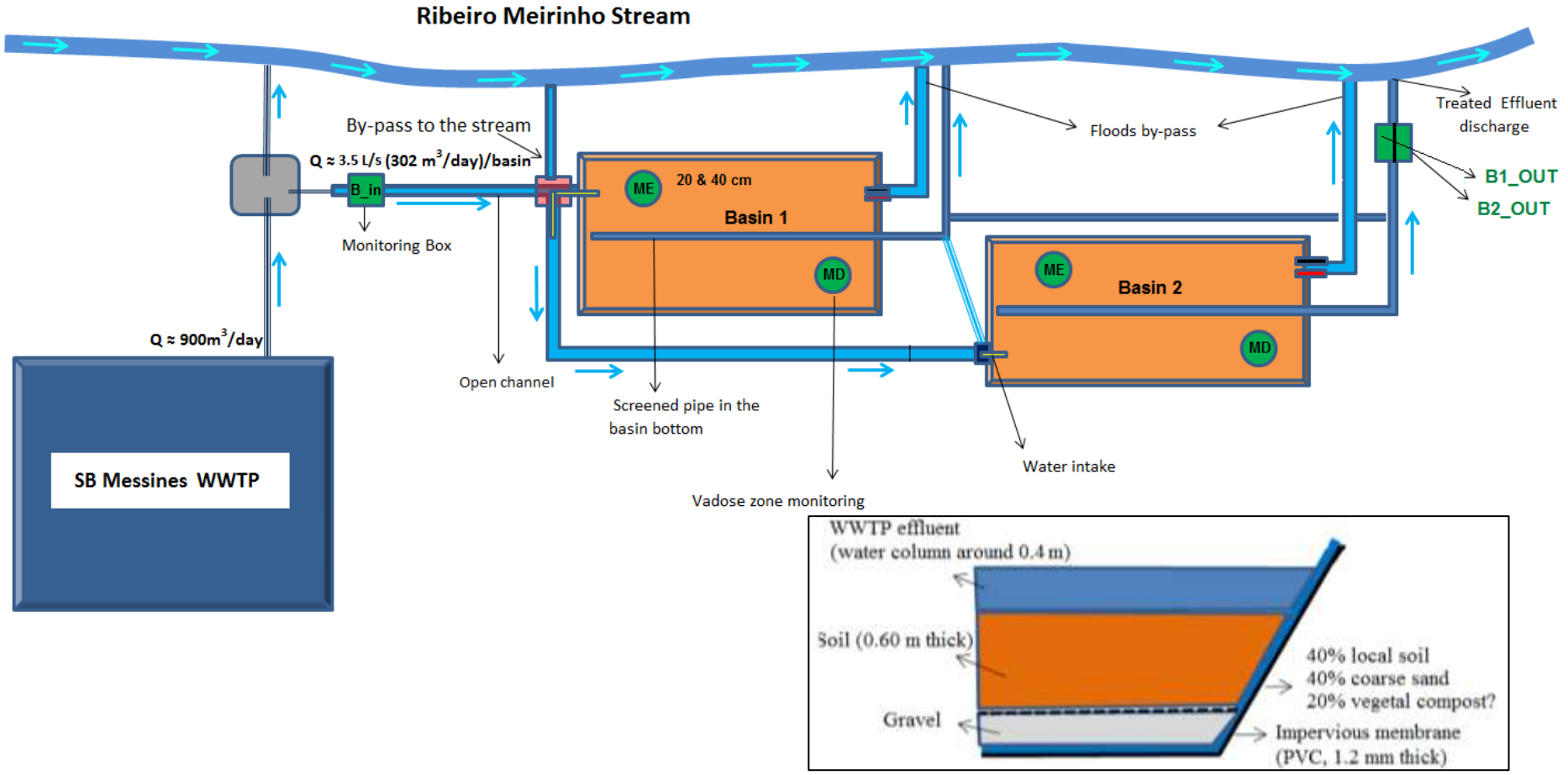
MATERIALS AND METHODS



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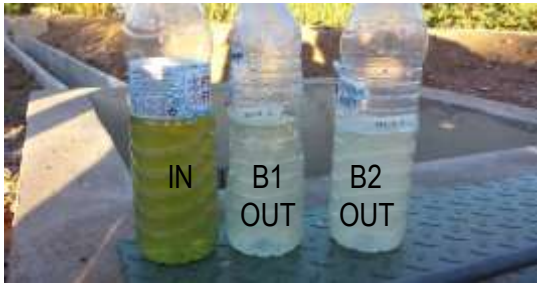
MATERIALS AND METHODS

3 months of experiments:

- September to November 2016

Conditions:

- Equal experiments in parallel for both basin 1 and 2
- Non-saturation and saturation



Monitoring:

- Continuous inflow and outflow monitoring of EC, pH, Redox, T
- Manual inflow and outflow sampling
- Vadose zone sampling (20 cm and 40 cm) in each basin
- Monitoring of pH, TSS, COD, BOD5, N total, P total, N-NH4, N-NO3, faecal coliforms, EC, all N forms, phosphates and sulphates (Águas do Algarve)
- Monitoring of pharmaceutical compounds (IWW), nutrients, major ions, B, Cu, Zn, TOC, DOC, A_{254}, A_{436}, SUVA

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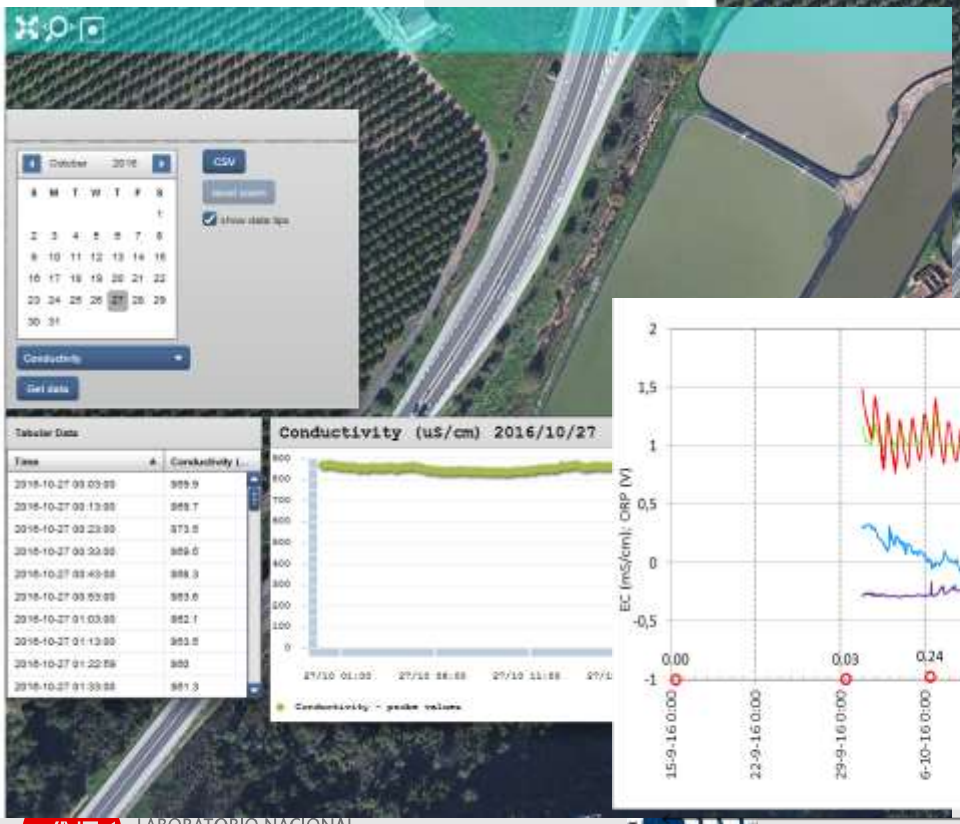
RESULTS

Online monitoring with real time data for: EC, T, pH and redox



SAT BASINS PERFORMANCE TO REMOVE:

	Parameter
SUSPENDED SOLIDS →	Turbidity
DISSOLVED ORGANIC MATTER →	DOC – dissolved organic carbon A_{254} – 254 nm absorbance <> organic matter with aromatic rings and double bonds <> pharmaceutical compounds A_{436} – 436 nm absorbance <> colour (organic matter)

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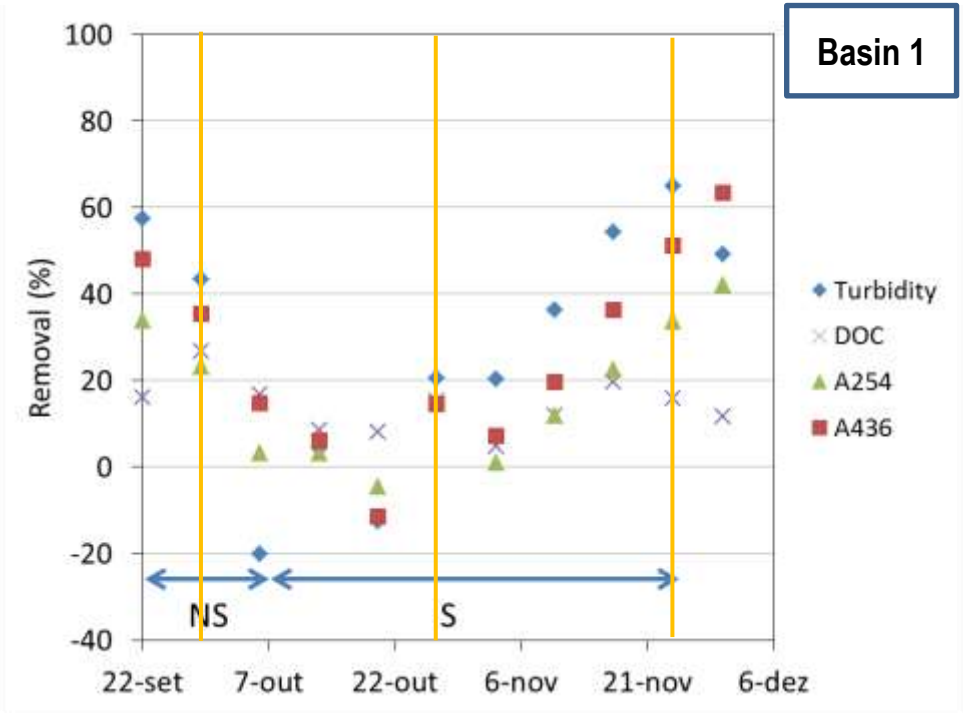
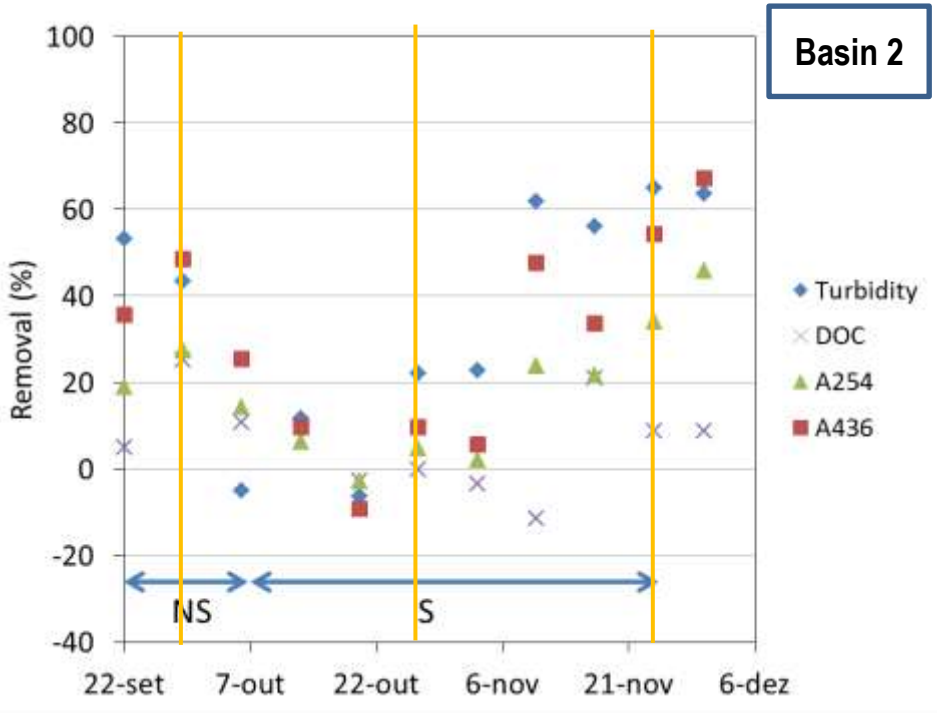
SAT BASINS PERFORMANCE

RESULTS

Sampling periods





NS – aerobic – decrease in the removal capacity for turbidity and organic matter

S – anaerobic, after an "adaptation " period (4 weeks), restitution of the removal capacity for turbidity and organic matter, including possibly pharmaceutical compounds

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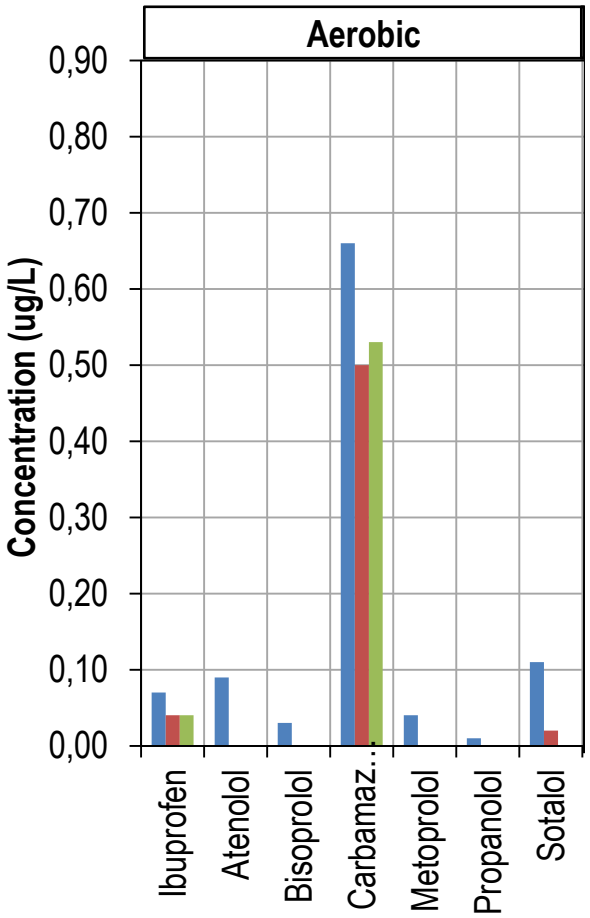
RESULTS – PHARMACEUTICAL COMPOUNDS

Pharmaceutical compounds with higher removal rates in <u>aerobic conditions</u>



Removal rates between 20% (Carbamazepine – B2) and 100%.

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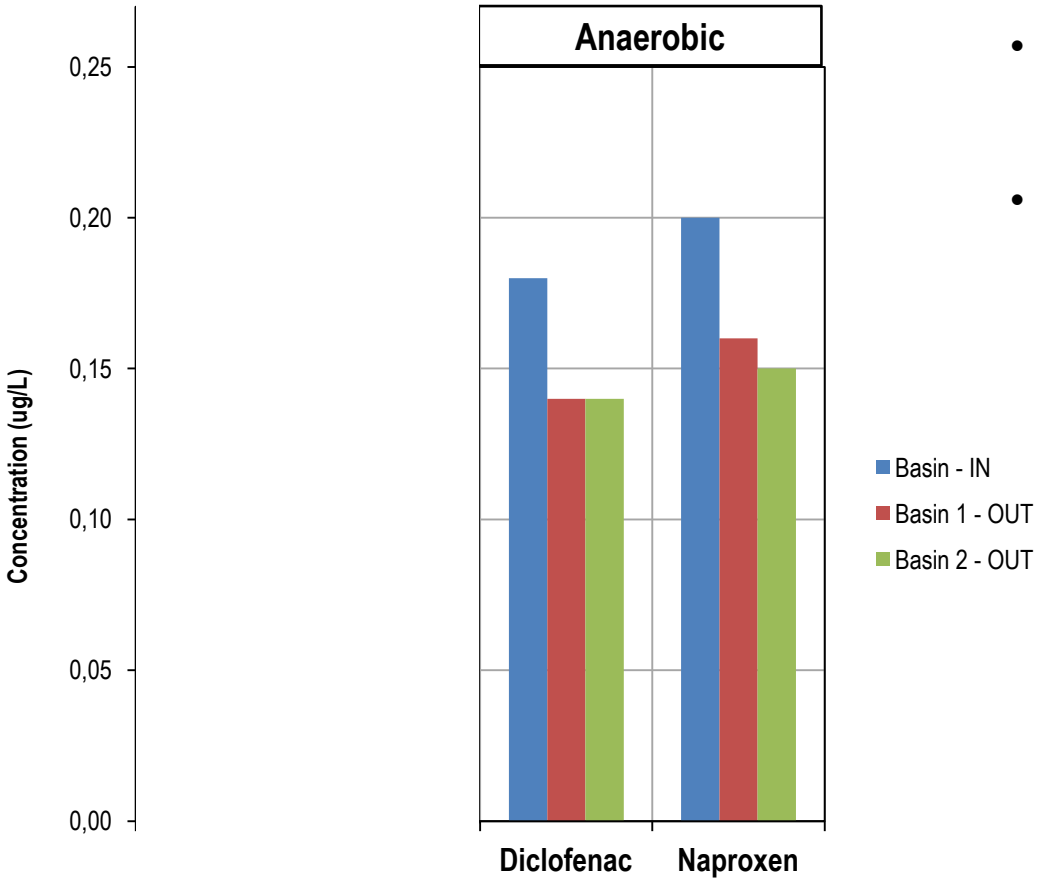
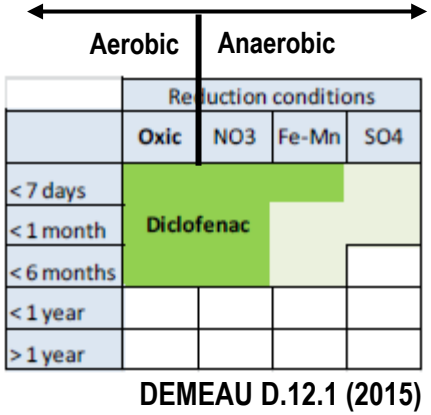
RESULTS – PHARMACEUTICAL COMPOUNDS



Pharmaceutical compounds with higher removal rates in <u>anaerobic conditions</u>

- Removal rates from 20% to 25% for Naproxen
- Removal rates of 22% for Diclofenac in B1 e B2



DEMEAU D.12.1 (2015)

	Removed (90-100% of removal)
	Significantly removed (50-90% of removal)
	Partially removed (20-50% of removal)
	Not removed (0-20% of removal)
	Partially removed or Not removed depending on the site (*)

Conclusions:

- Removal rates for pharmaceutical compounds are high, reaching 100% in several cases. Both aerobic and anaerobic conditions are favourable depending on the pharmaceutical
- About 1/10 of the overall WWTP flow rate can be treated daily
- Besides the WWTP outflow water quality, the performance of these systems depends on several other factors connected to soil properties like:
  - Hydraulic permeability and head – responsible for the water-soil contact time
  - Soil mineralogy
  - Organic matter
  - pH
  - Redox
  - Microbial activity

  which determines the biodegradation and adsorption potential processes responsible for the water treatment

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Open Questions from MARSOL

- Attenuation vs. Transformation vs. Adsorption
- Role of Microbial Communities *(degradation)*
- Non-Pharmaceutical emerging contaminants

Desirable Outcome - MARSoluT

- Operational Protocol
  - e.g. Materials, Wet/Dry Cycles
- Idea about up-scaling effects
  - Column → Sand Box → Field site

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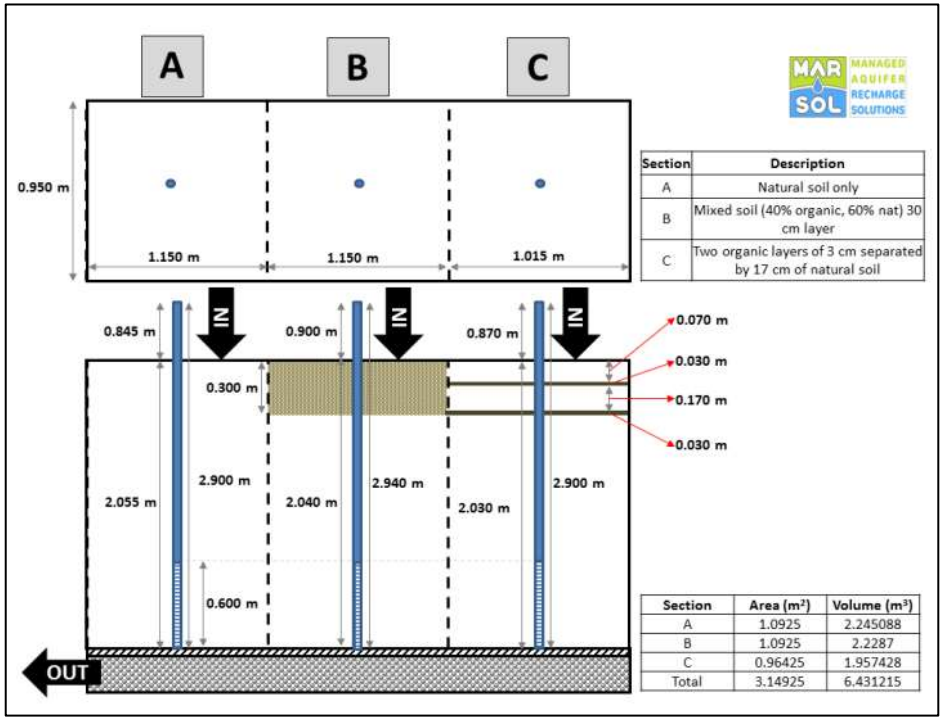
Test Facility – Laboratory Experiment – Current Setup



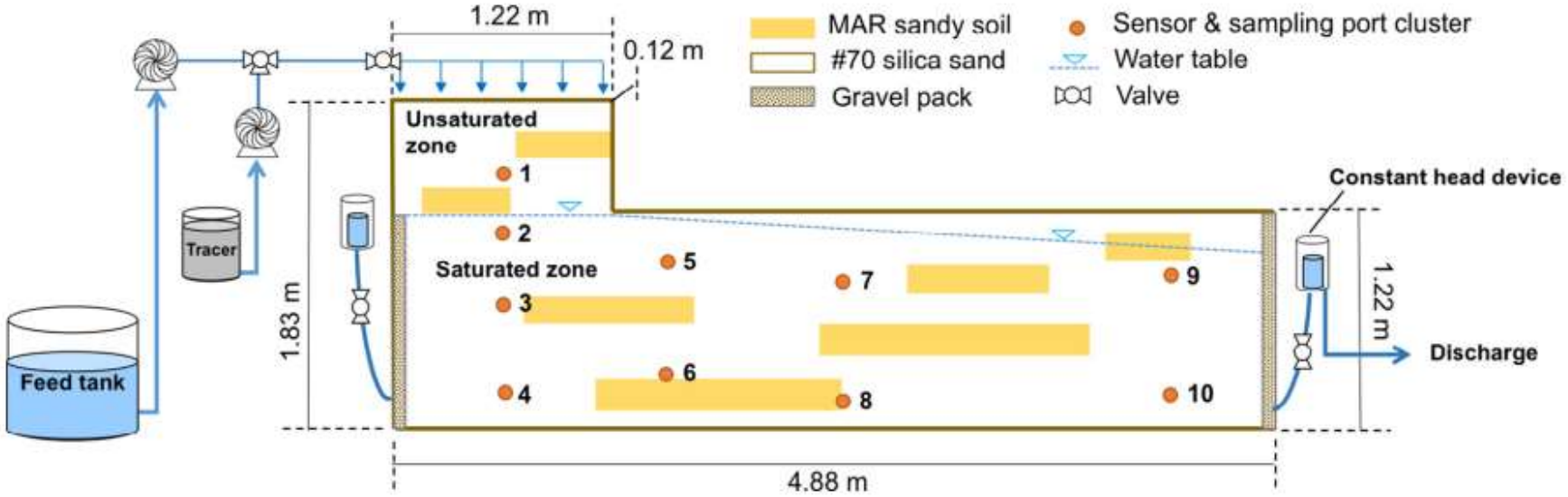
Section	Description
A	Natural soil only
B	Mixed soil (40% organic, 60% nat) 30 cm layer
C	Two organic layers of 3 cm separated by 17 cm of natural soil

Section	Area (m²)	Volume (m³)
A	1.0925	2.245088
B	1.0925	2.2287
C	0.96425	1.957428
Total	3.14925	6.431215

Source: MARSOL D12.7: White Book on MAR Modeling – Selected Results from the MARSOL Project

Experimental Setup Design Ideas:

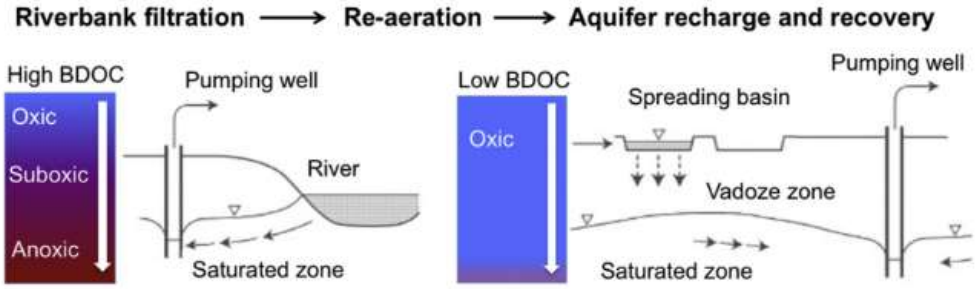
- Constant head conditions for synthetic aquifer
  - Saturated and unsaturated zone
  - Produce water flow regime closer to natural conditions



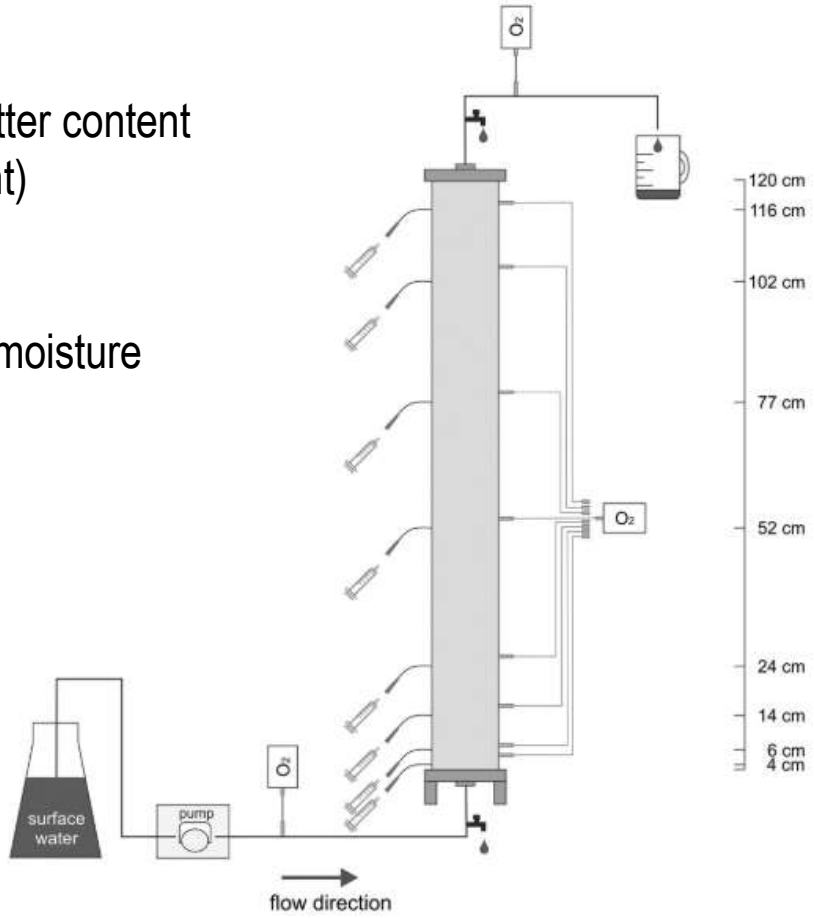
Source: Regnery et al., Journal of Hydrology 548 (2017)

Experimental Setup Design Ideas:

- Sequential Setup (anoxic conditions/high org. matter content followed by oxic conditions/low org. matter content)
- Probes and sampling ports over soil profile
  - e.g. redox profile probes, O_2 probes, pH, T, soil moisture



Source: Regnery et al., Chemosphere 154 (2016)



Source: Burke et al., Science of the Total Environment 482-483 (2014)

Soils for the Experimental Setup

- Natural soil *(mostly sand → prevail hydraulic conductivity / clogging issues)*
- Different amounts of organic matter
  - Low amount of Organic Matter favors diversity of Microbial community and reduces clogging issues due to Organic Matter
- Reactive Barriers *(different activated carbons)*
- Substances altering the redox conditions *(oxygen/hydrogen releasing materials)*

Emerging Organic Contaminants of Interest

- Broad range of physicochemical properties and metabolites
  - Substances from DEMEAU D12.1 + Indicator Compounds by Drewes et al. (2008)
  - Substances with **great risk for ecosystems** and/or **endocrine disruptors**
- Most prominent/studied substances: Carbamazepine, Sulfamethoxazole, Diclofenac, Gemfibrozil and Primidone
- Possible **non-pharmaceutical** substances of interest:
  - Daily Care Products: Oxybenzone (UV-Filter), Galaxolide (Fragrance), Acesulfame (Sweetener)
  - Pesticides: Mecoprop (Herbicide)
  - Industrial use: Benzotriazole (Corrosion inhibitor), Bisphenol A (Plastisizer), PFOA & PFOS (Surfactants), TCEP & TCPP (Flame retardants),

Artificial Wastewater Effluent vs. Real WWTP effluent

- Advantage of Artificial Wastewater → non-changing composition
  - WWTP effluent composition constantly changes
- Disadvantage: Artificial Wastewater not the same composition of microbial community as WWTP effluent
  - *Possibility: spike with microorganisms promoting degradation*
- Two sets of experiments to account for influence of different composition of the solutions and also:
  - Few compounds vs. several compounds
  - Microplastics in real WWTP effluent
  - Microorganisms

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THANK YOU FOR YOUR ATTENTION