Workshop

# Novel and Innovative Solutions for Safe Water Reuse in India

@ IWA Water Reuse Conference, 15 January 2023, Chennai

Organisers:
Nadeem Khalil
Guenter Langergraber

PAVITR

# Outline

PAVITR

| Time | Topic | Presenter |
|---|---|---|
| **10:30** | **Welcome and program overview** | Guenter Langergraber |
| **10:35** | **The general PAVITR concept** | Mirko Hänel |
| **10:50** | **Technologies for safe water reuse** (5 min each) | |
| | ○ Short Rotation Plantation | Mirko Hänel |
| | ○ High Rate Algae Pond | Enrica Uggetti |
| | ○ Richwater SBR | Antonia Lorenzo |
| | ○ Wetland Systems | Fabio Masi |
| | ○ Sensors | Santiago Cuervo |
| **11:15** | **Important factors for implementation** (5 min each) | |
| | ○ Planning | Ganbataar Khurelbaatar |
| | ○ Resources recovery & market exploitation | Carlos Arias |
| **11:25** | **Panel discussion with the presenters** | moderated by Guenter Langergraber |
| **11:55** | Closure | Mirko Hänel |
| **12:00** | End of the workshop | |

# The general PAVITR concept

Workshop
"Novel and Innovative Solutions for Safe Water Reuse in India"
@ IWA Water Reuse Conference, 15 January 2023, Chennai

Mirko Hänel
(ttz Bremerhaven) &
Nadeem Khalil (AMU)

ttz Bremerhaven

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# *PAVITR project*

**Potential and Validation of Sustainable Natural & Advance Technologies for Water & Wastewater Treatment, Monitoring and Safe Water Reuse in India**

- PAVITR (पवित्र [Hindi] ) = holy, sacred, clean, pure
- H2020 project, duration 5 years, 01.02.2019 – 31.01.2024
- Follow-up of NaWaTech and SWINGS
- 25 Partners (12 from EU and 13 from India)

# *Short Overview (Objectives)*

**Technology Enhancement**

- Natural-based treatment technologies
- High-innovative treatment technologies & sensors
- Emerging pollutants removal technology
- Drink Water and Rainwater Harvesting

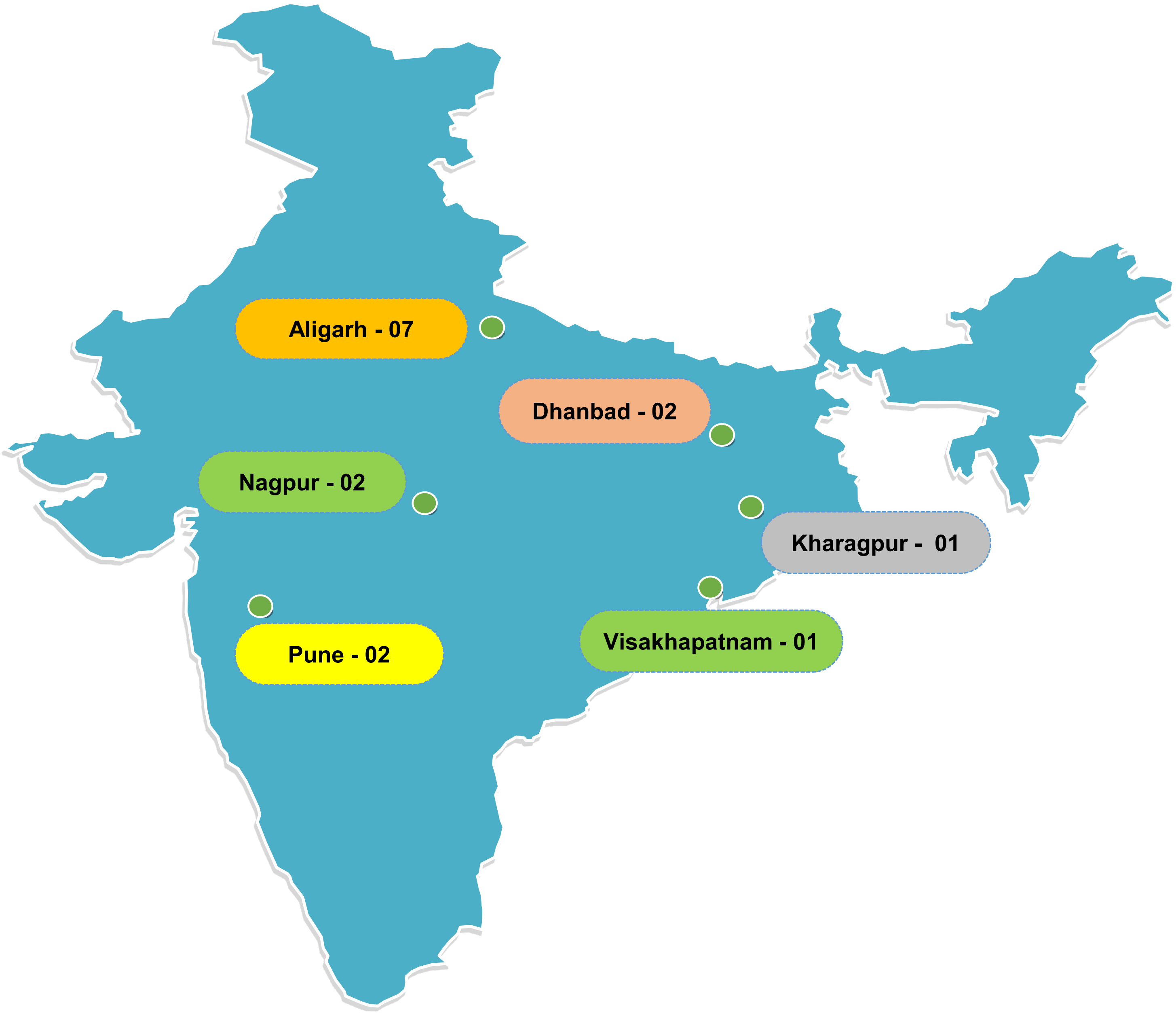
**Demonstrative Application**

- 14 prototypes in five Indian regions
- Treatment capacity to benefit ~46.900 people with sanitation and access to water.

**Road to the Market.**

- Training and expertise transfer.
- Creating new business opportunities and green jobs
- Future upscaling and multiplying
- Decision support system.

# *PAVITR sites*



# *State-of-Play*

| S. N. | Pilot Technology | Capacity $m^3/d$ | | Site | Partner | State of Play | Expected |
|---|---|---|---|---|---|---|---|
| | | Proposal | Installation | | | | |
| 1 | ECl2 (Drinking water technology) | 30 | 300 | Pune | AUTARCON + SIT-SIU | Installed and Running | |
| 2 | An Sys + CW (Anaerobic System & Constructed Wetland) | 5 | 50 | Pune | IRIDRA + SIT-SIU + NEERI | Installed and Start-up Phase | |
| 3 | Rain Water Harvesting | 100 | 100 | Dhanbad | KRETA + IIT – ISM | Installed. Start-up Phase | |
| 4 | Optimized SBR (Sequencing Batch Reactor) | 25 | 150 | Dhanbad | BIOAZUL + IIT – ISM | Equipments Delivered | August 2022 |
| 5 | RichWater® SBR (Sequencing Batch Reactor) | 25 | 75 | Aligarh | BIOAZUL + AMU | Civil Works Completed. Equipments Delivered. | September 2022 |
| 6 | HRAP (High Rate Algal Pond) | 7 | 50 | Aligarh | UPC + AMU | Constructed. Start-up after Minor Works. | |
| 7 | Short-Rotation Plantation (Willow + Bamboo System + Poplar) | 25 | 300 | Aligarh | TTZ + AU + AMU | Installed and Start-up Phase | |
| 8 | French Reed Bed | 50 | 50 | Aligarh | AMU + IRIDRA | Phase-II Site Selected | End 2022 |
| 9 | Sensors for UASB optimization | 25 | 250 | Aligarh | AIMEN + AMU | Developed Not validated | End 2022 |
| 10 | Fecal Sludge & Septage Mgt (FSSM) (NBS) | 5 | 5 | Aligarh | AMU + IRIDRA | Selection of Site under Consideration | End 2022 |
| 11 | MBBR (Moving Bed Bioreactor) | 50 | 50 | Nagpur | NEERI + LARS | Under construction | June 2022 |
| 12 | SAFF (Submerged Aerobic Fixed Film Reactor) | 50 | 50 | Nagpur | NEERI + LARS | Under construction | June 2022 |
| 13 | Fecal Sludge - Mechanical Dewatering & Drying System (MDDS) | 25 | 25 | Chandrapur | NEERI + IRIDRA (learning) | Phase-II Site Selected (Chandrapur Maharashtra) | End 2022 |
| 14 | MBBR – VFCW – TOXIDATION | - | 3 | Kharagpur | AUTARCON + IIT-KH | Constructed. Equipments under way | June 2022 |
| | | 422 | 1,458 | | | | |

Technologies for safe water reuse

# Short Rotation Plantation

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Mirko Hänel
(ttz Bremerhaven)
Carlos Arias (Aarhus University)

ttz Bremerhaven

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# INTRODUCTION

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**Actual situation in India**:

- Present **wastewater treatment systems** are expensive and not reuse oriented
- **Market demand** for resources & political pressure are growing
- Wastewater is freely available (supply side)
- Natural solutions needs to be developed, tested and adapted



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# DESIGN & FEATURES

- Area: 7500 m² of levelled agricultural land
- Capacity: 210 m³/d of screened domestic wastewater
- Plants: Populus tremula (2500/2500 m²)
- Salix alba, Salix bebylobica (2500  m² each)
- Dendrocalamus strictus, Bambusa vulgaris, Bambusa bambos (5250 on 2500 m²)

# SCHEMATIC VIEW

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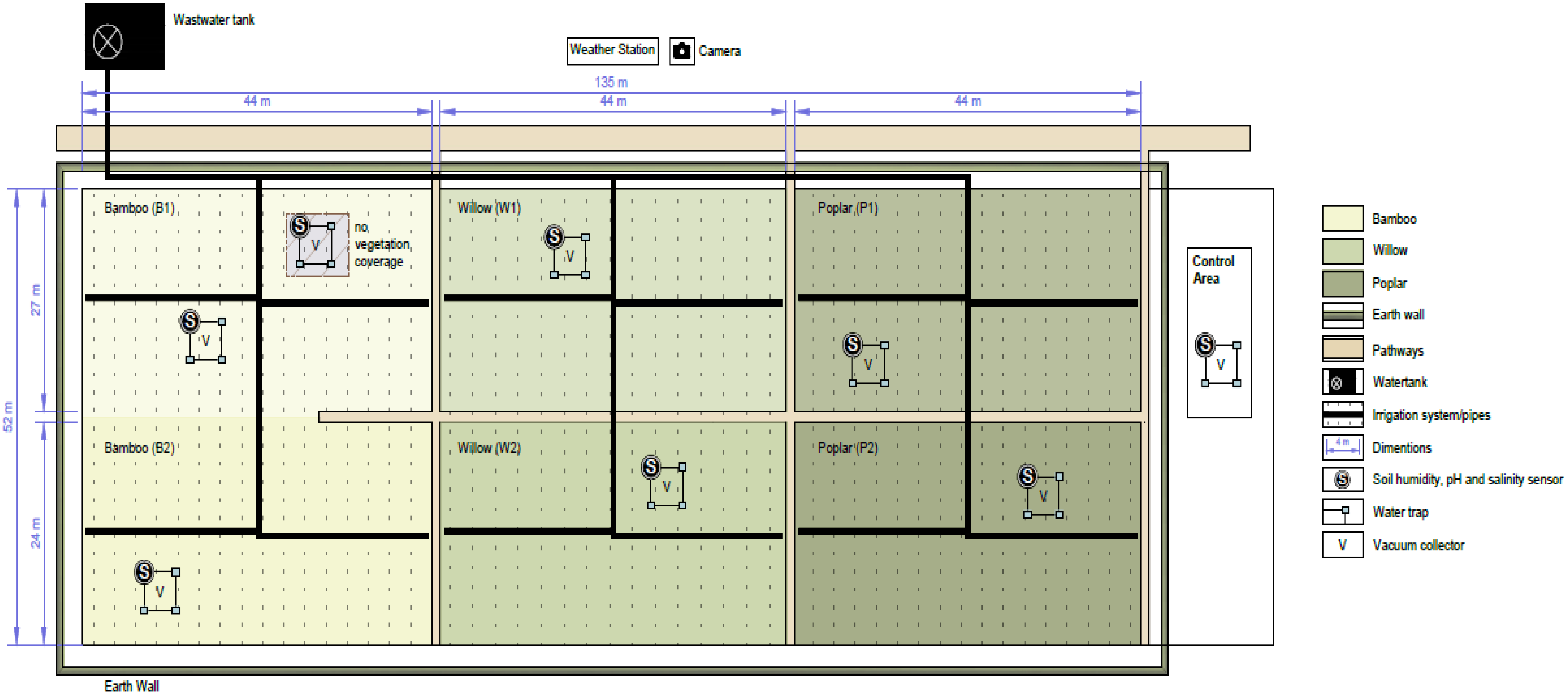

# CROSS SECTION VIEW

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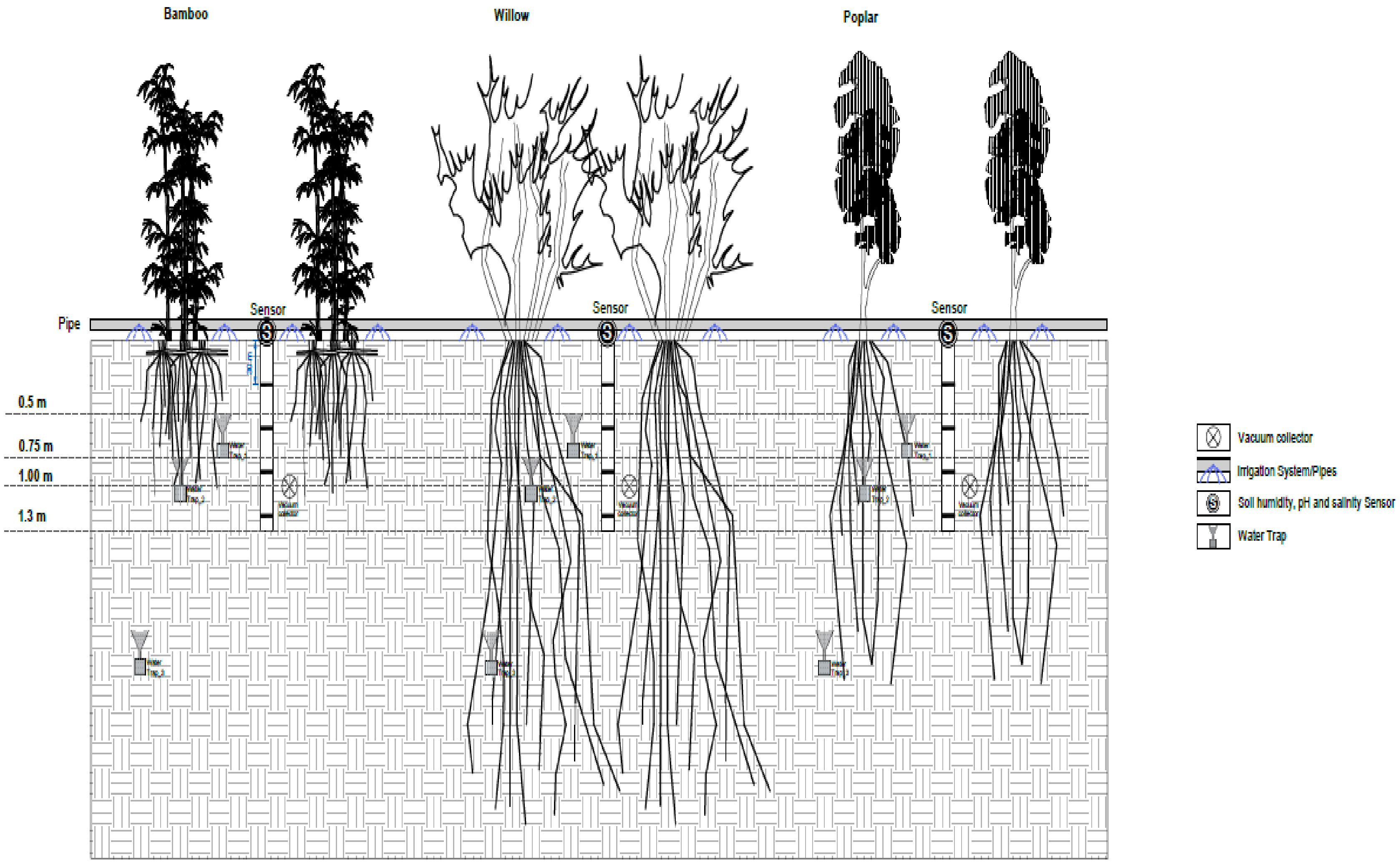

# RESULTS

August 2021

November 2022

Technologies for safe water reuse

# High Rate Algae Pond

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Enrica Uggetti
(UPC)

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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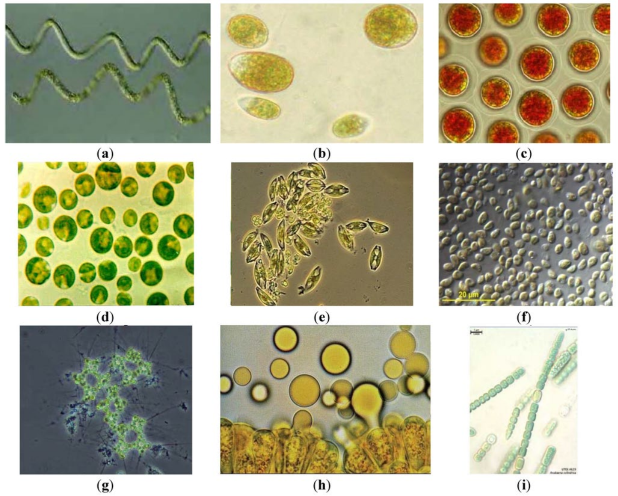
# Microalgae




Microalgae are unicellular algae (µm) characterized by a huge biodiversity (50,000 species are described)

Thet are able to generate unique products:
carotenoids, antioxidants, fatty
acids, enzymes, polymers, peptides, toxins and sterols

**BIOPRODUCTS**

natural pigments, bioplastics, biofertilizers, food, feed


**BIOFUELS**

biogas, biodiesel, bioethanol

# How do HRAPs work

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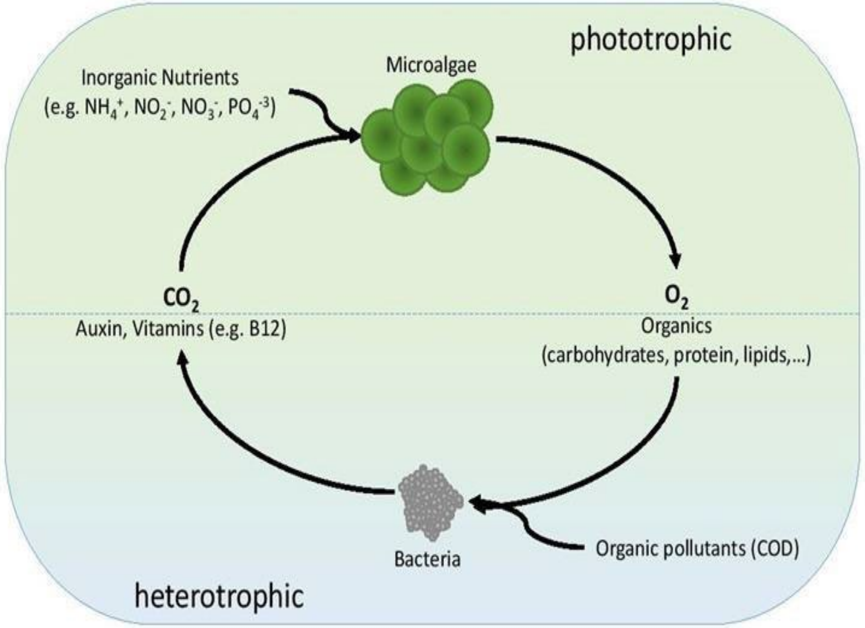
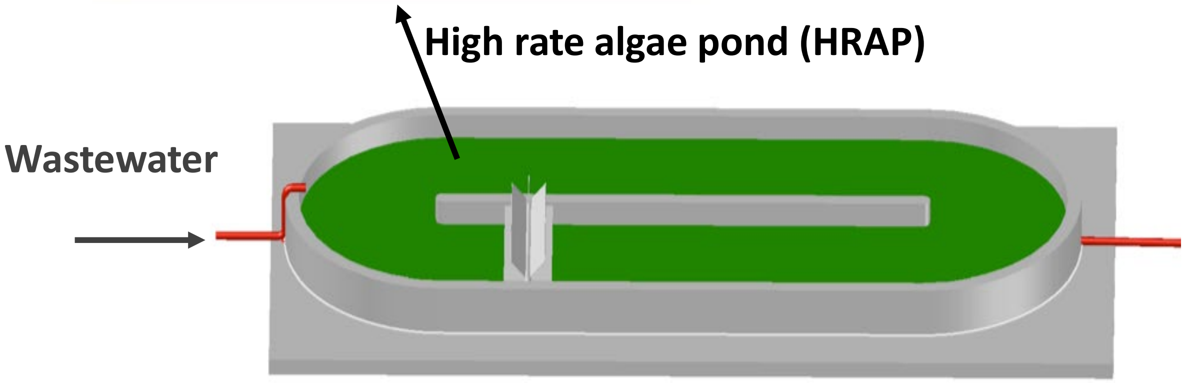
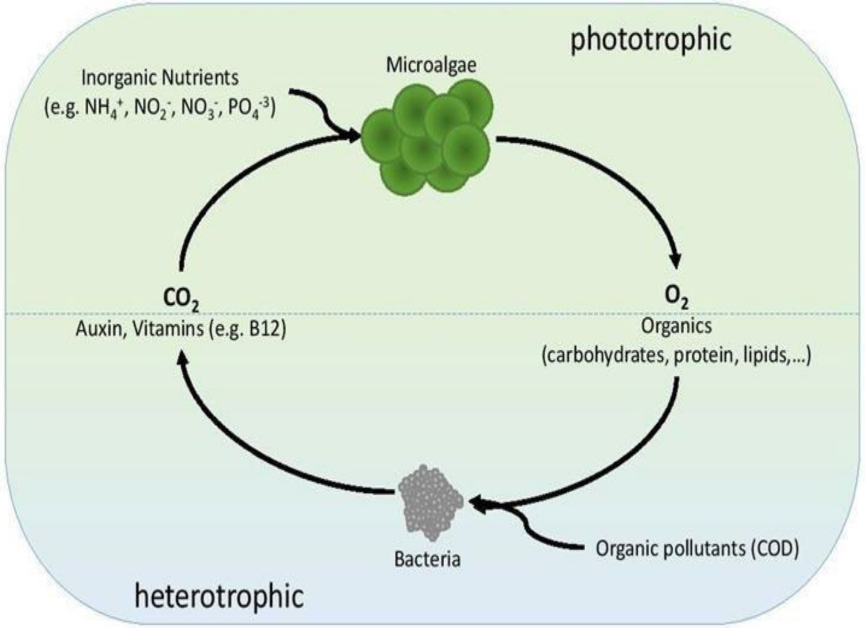


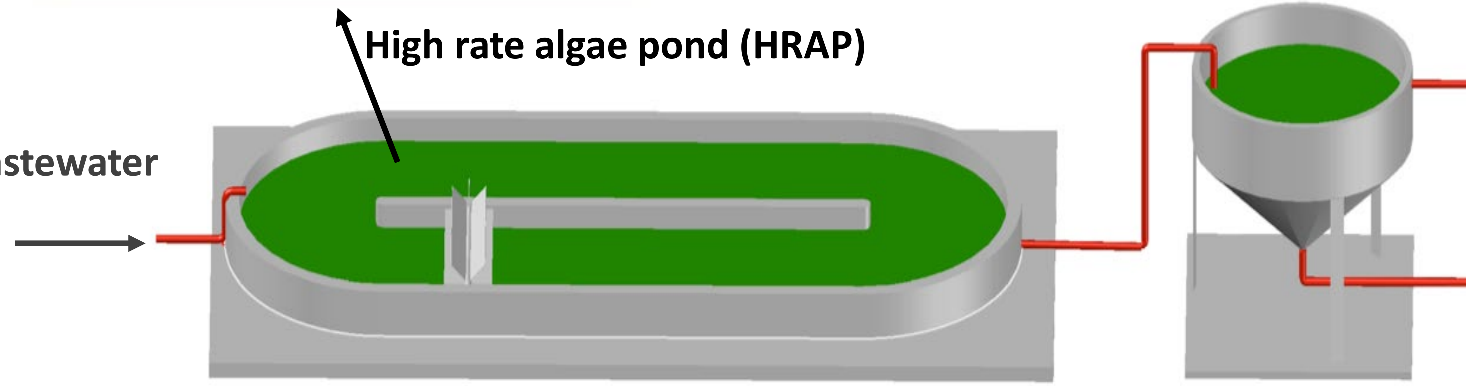




Reduction of the WWTP energy demand
Production of valuable biomass

# How do HRAPs work




Reduction of the WWTP energy demand
Production of valuable biomass




# HRAP within PAVITR project

1. Dimensioning with biokinetic and hydrodynamic modelling

2. Construction

3. Operation

# HRAP within PAVITR project

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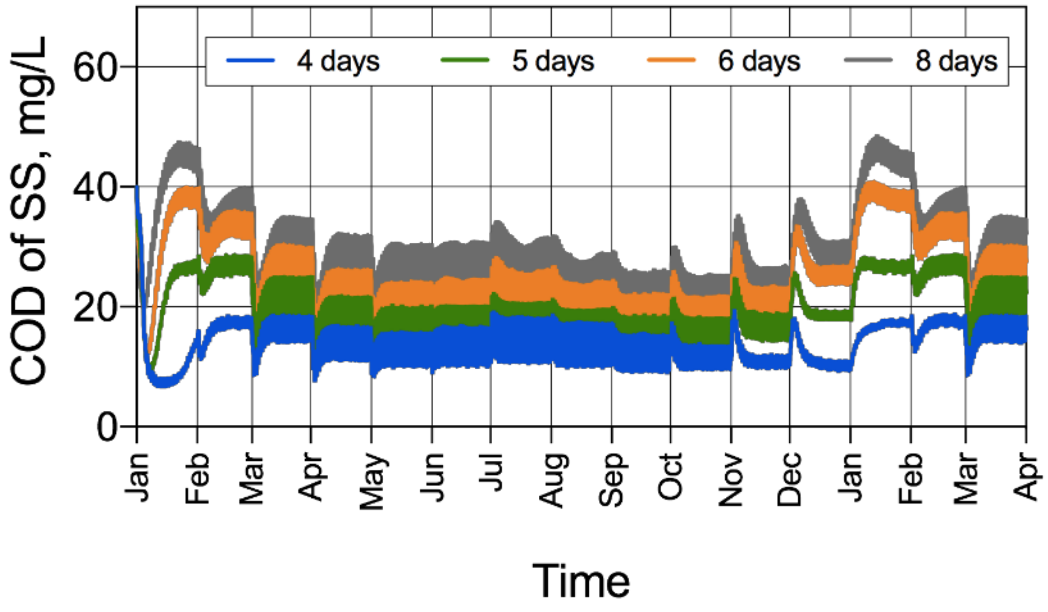
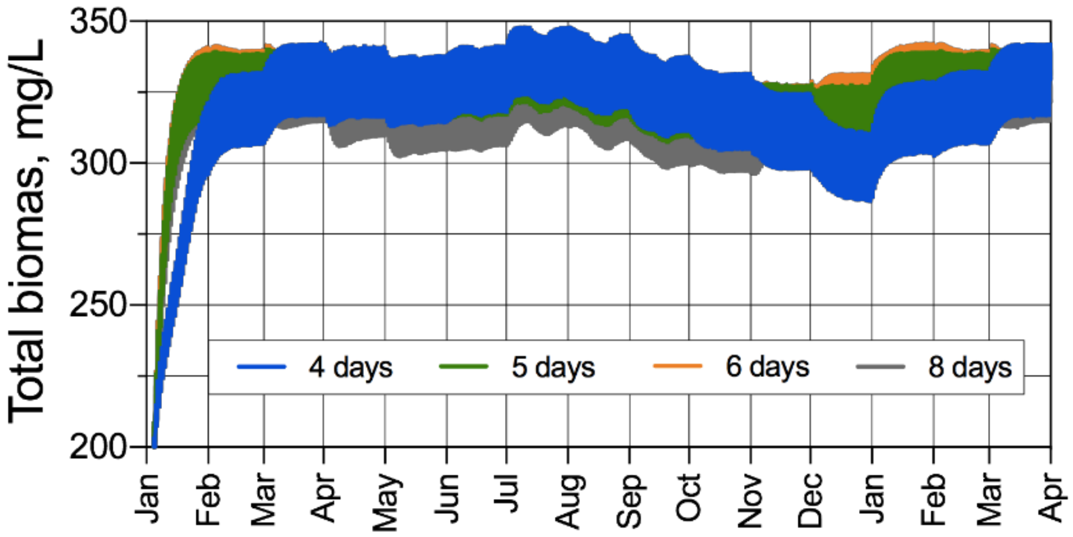
## 1. Dimensioning with biokinetic and hydrodynamic modelling

Biological sizing -> simulation of wastewater treatments parameters and biomass production with several HRT




15 kg · day$^{-1}$
0.5 m$^3$ · day$^{-1}$

# HRAP within PAVITR project

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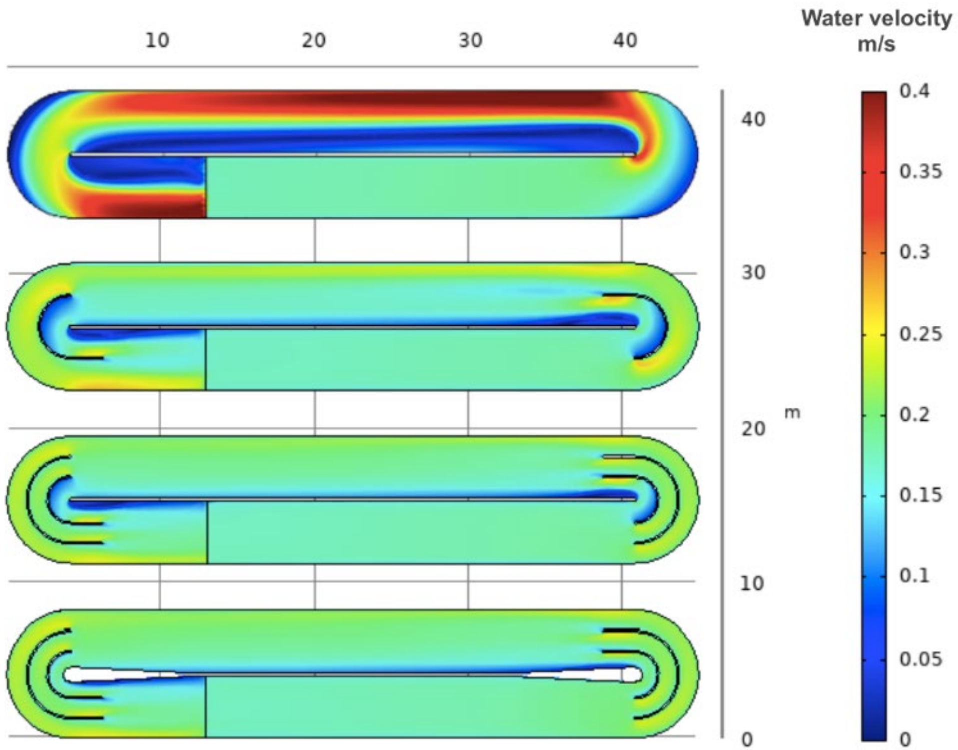
## 1. Dimensioning with biokinetic and hydrodynamic modelling

Hydraulic sizing -> simulation of velocities fields and dead zones with several designs



# HRAP within PAVITR project

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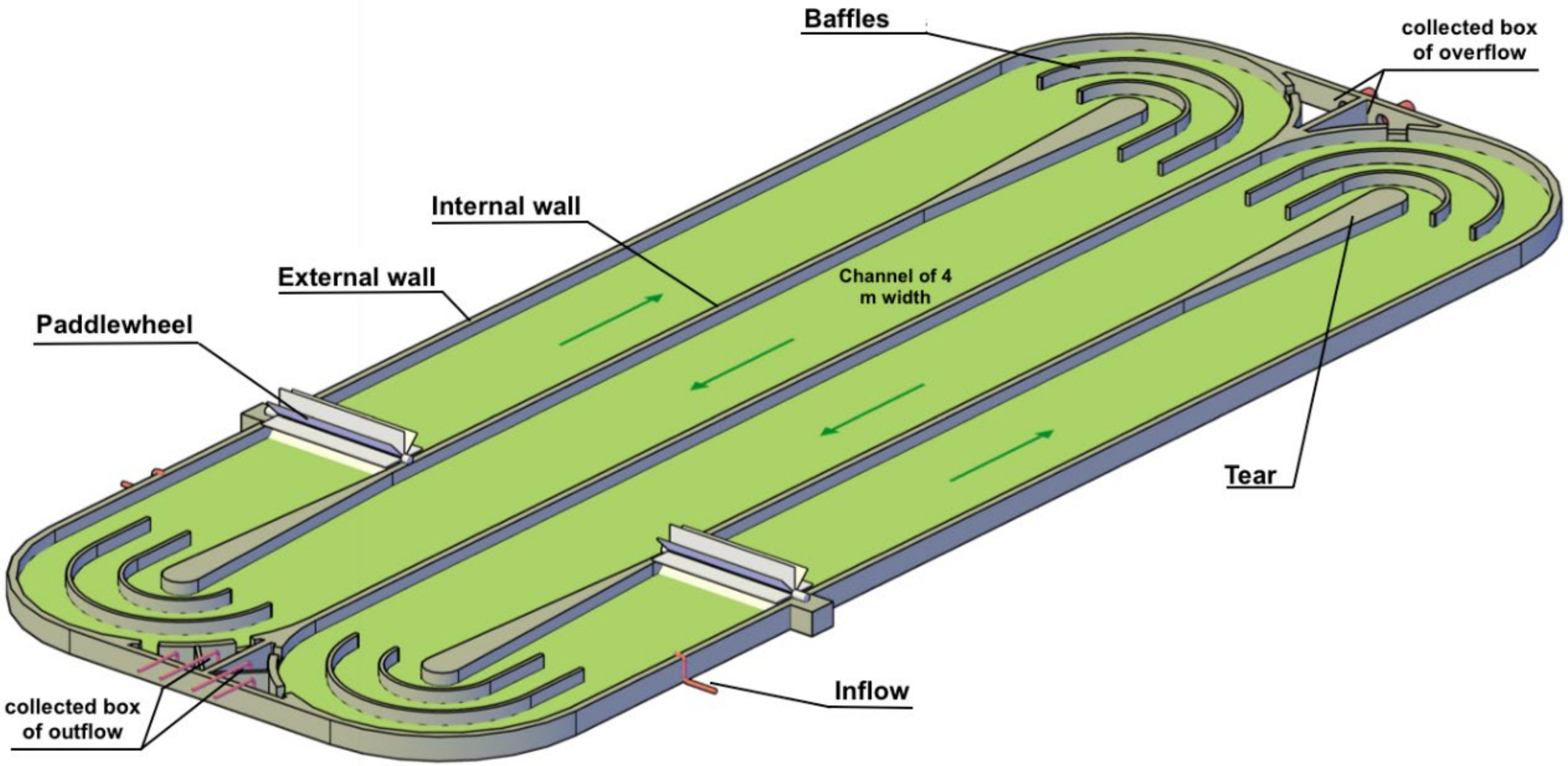
## 1. Dimensioning with biokinetic and hydrodynamic modelling

**Flow:** 50 $m^3$/day
**BOD**: 130 mg/L
**HRT:** 4 days
**Depth:** 0.3 m
**Volume:** 200 $m^3$

**Channel width:** 4 m
**Water velocity:** 0.15 m/s
**Water depth:** 0.3 m



# HRAP within PAVITR project

# HRAP within PAVITR project

Technologies for safe water reuse

# Richwater SBR

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Antonia Lorenzo
(BIOAZUL)

BIOAZUL WATER • ENERGY • ENVIRONMENT

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# Richwater SBR

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Wastewater has, if treated and reclaimed correctly, a huge fertigation potential in agriculture.

There is a loss of profit in keeping some of these nutrients even after treatment, and in spreading them directly on the fields along with the reclaimed water, which means that less fertilizer from non-renewable sources should be applied.

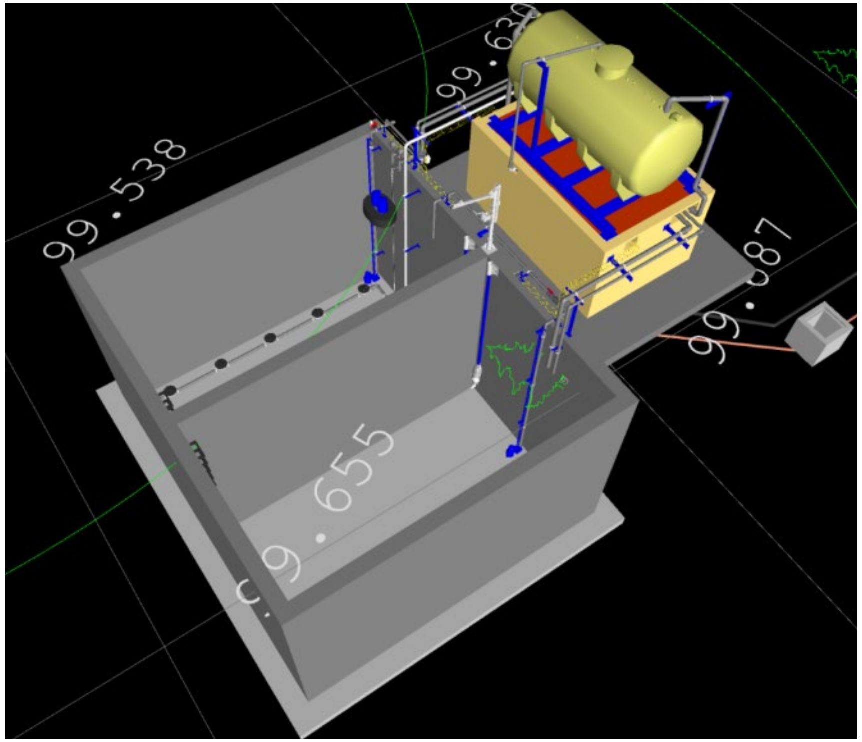
BIOAZUL launched RichWater® series, including the wastewater treatment technology relying on SBR process that is designed so that it maintains valuable nutrients in the effluent.

When talking about wastewater reclamation, specially for agriculture purposes, the reclaimed water should fulfil the needed quality for that use. In the case study, the Regulation (EU) 741/2020 of the European Parliament and of the Council on minimum requirements for water reuse in agriculture has been taken into account.

# Richwater SBR

The core of RichWater® is the way the SBR process is controlled and treats municipal wastewater and uses the effluent to supply a constant source of nutrient-rich reclaimed water for fertirrigation, promoting circularity not only for the water but also for the nutrients.

Although a wastewater treatment and reuse system has many environmental benefits, when designing and implementing a solution, not only the characteristics of the water to be treated must be taken into account, but also **the social, economic and environmental setting where it is applied.**



# Richwater SBR

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By implementing RichWater® SBR , allowing the irrigation of crops with nutrients rich water, not only does it provide a solution to pollution from untreated effluent discharges, it has other advantages.

First, this system reduces eutrophication and pollution problems due to discharges of treated wastewater, even of good quality.

Secondly, significant amounts of Greenhouse Gas could be avoided, due to the reduced use of industrial fertilizers because of the high concentration of NPK nutrients in the recycled water used for irrigation.

From the point of view of the social context associated with the technical solution, RichWater® SBR technology offers a reliable solution that meets the reclaimed water quality criteria established in the regulations with few technical training requirements for its operation due to the complete automation of the system. With this criterion, a safe and easy to maintain system is offered to the environment.

# Richwater SBR

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RichWater® SBR technology is based on a well proven wastewater treatment technology: the Sequencing Batch Reactor (SBR). A typical cycle comprises five sequences:

1 – 2 – 3 – 4 – 5

### 1. Fill

The wastewater enters the SBR reactor, where it is mixed with biomass from the previous cycle.

- Static filling
- Mix Filling
- Aerated filling

### 2. Reaction

At this stage two processes are combined. An anoxic stage and an aerobic stage. In this way, the reactions of denitrification and nitrification are favored by eliminating carbon and nitrogen compounds.

### 3. Decanting

Both aeration and mixing stop at this stage, allowing the decantation of solids. The clarified water is at the top of the water column.

### 4. Extraction of clarified

The treated (clarified) water is extracted from the reactor, considering only the height of the clarified water column.

### 5. Slude recirculation

In this last stage, part of the sludge in the reactor is recirculated to the buffer tank and the rest transferred to the dewatering system.

# Richwater SBR

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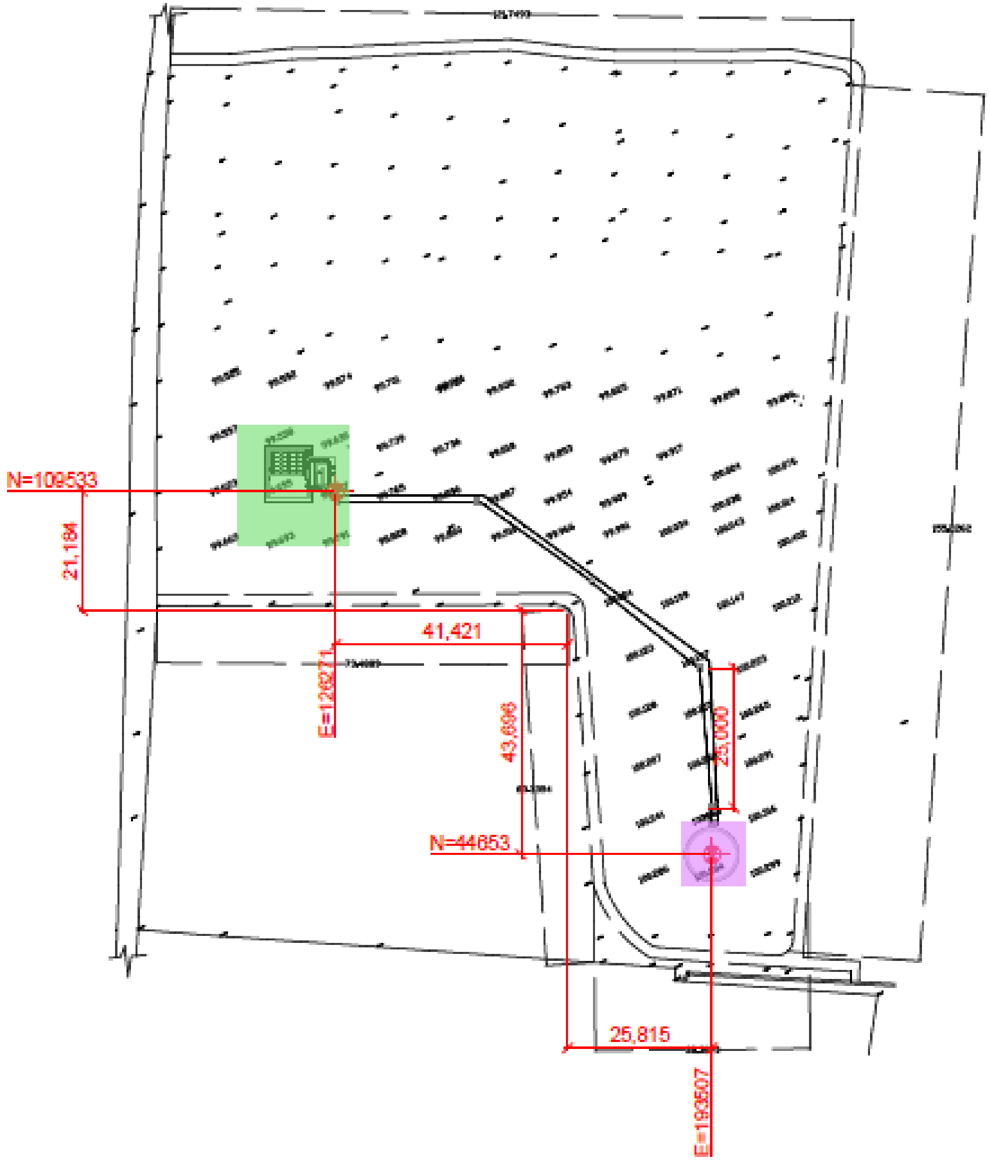
The RichWater® SBR has been designed considering the parameters stated in the following table. Those data were provided by AMU.

| CONTAMINANT LOAD | | | | | |
|---|---|---|---|---|---|
| **$BOD_5$** | | | **N-NTK** | | |
| Load per inhabitant | 64.62 | g/inhab/day | Load per inhabitant | 7.38 | g/inhab/day |
| Concentration | 175 | mg/l | Concentration | 20 | mg/l |
| Daily load | 13.13 | kg/day | Daily load | 1.5 | kg/day |
| **TSS** | | | **P** | | |
| Load per inhabitant | | g/inhab/day | Load per inhabitant | 3.69 | g/inhab/day |
| Concentration | 200 | mg/l | Concentration | 10 | mg/l |
| Daily load | 15.00 | kg/day | Daily load | 0.75 | kg/day |
| **COD** | | | **AVERAGE FLOW** | | |
| Load per inhabitant | 120 | g/inhab/day | Daily flow | 75 | $m^3/d$ |
| Concentration | 325 | mg/l | Average design flow | 3.125 | $m^3/h$ |
| Daily load | 24.38 | kg/day | Daily flow | 75 | $m^3/d$ |

# Richwater SBR




**Design premises:**

- Civil construction
- Tanks buried up to 4 m
- Location defined by AMU
- Treated Water Tank must be elevated at least 1.5m over the terrain level
- Wastewater to be catched from the main (existing) collection tank (Latitude 27.9206764 & Longitude 78.0605372)

# Richwater SBR

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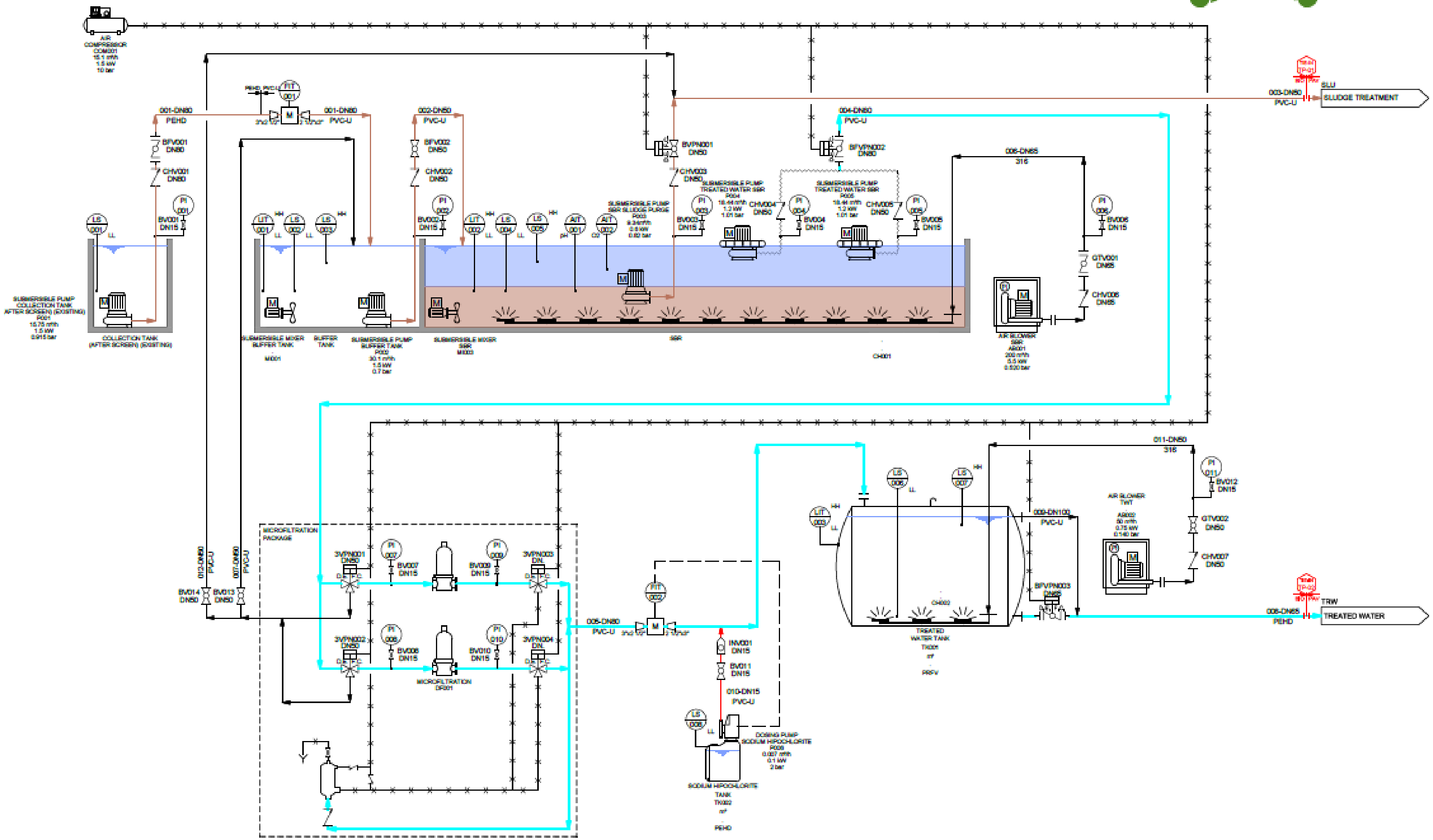

Technologies for safe water reuse

# Wetland Systems

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Fabio Masi
(IRIDRA)

IRIDRA S.r.l.

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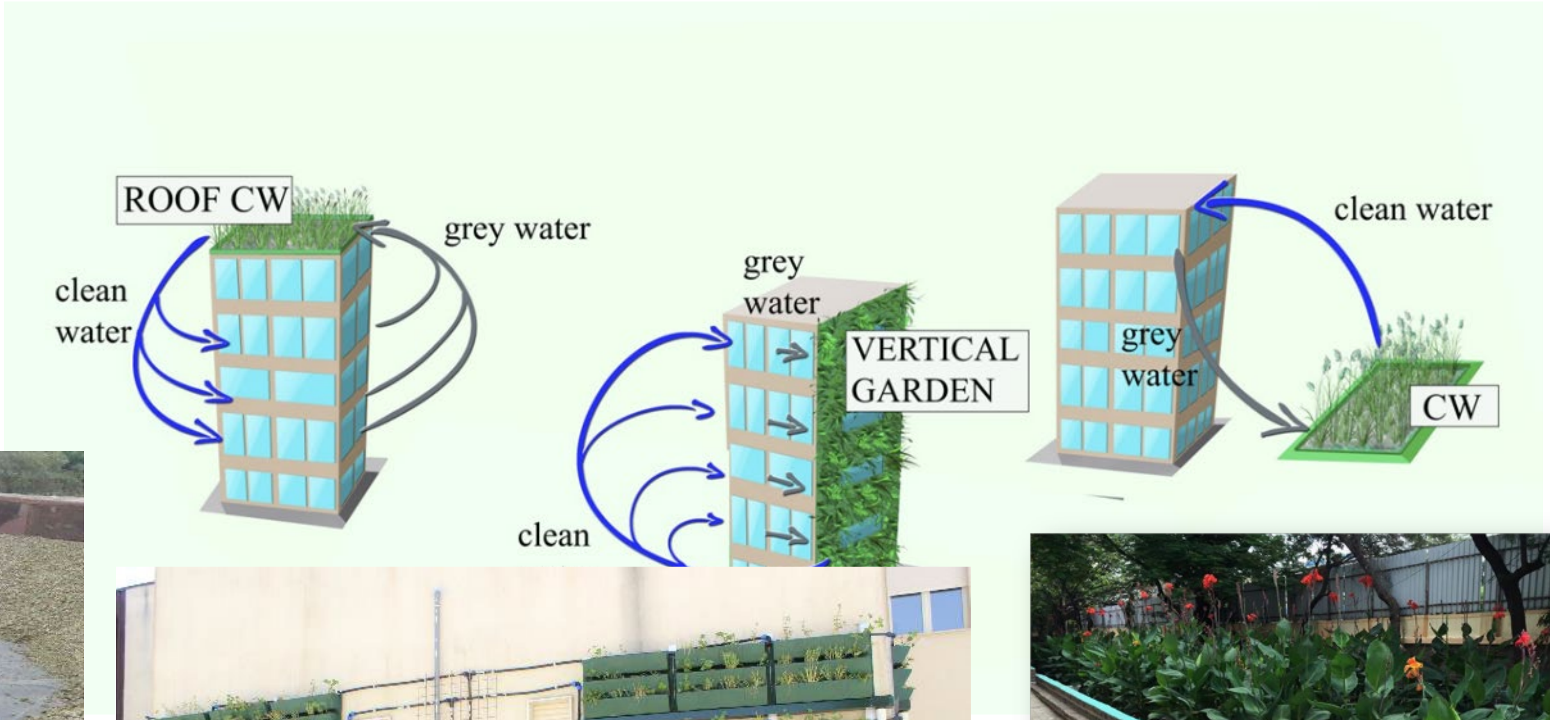
# WATER SCARCITY AND REUSE vs NBS


# A case study: Ferla School (IT)



**Wall2Water:** 260 m3/year of water saved by recycling (1 m3/student.year)

ENI CBCMED Cooperating across borders in the Mediterranean
Project funded by the EUROPEAN UNION
REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA
NAWAMED

….. Tunisia / Lebanon / Jordan / Italy

# A case study: COEP Pune (IN)

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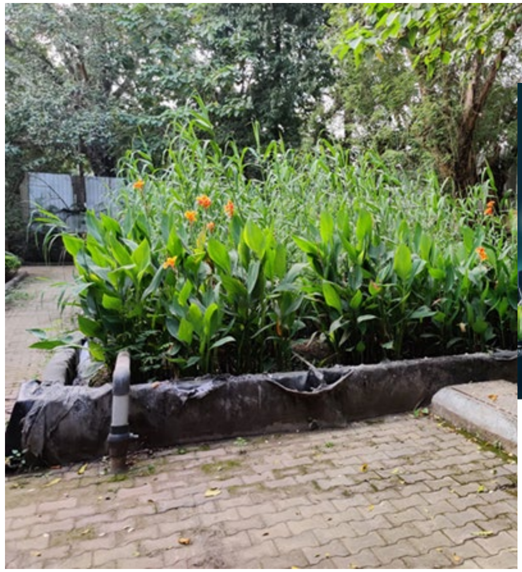



VOLUME 5

ADVANCES IN CHEMICAL POLLUTION, ENVIRONMENTAL MANAGEMENT AND PROTECTION


CHAPTER FOUR

Possibilities of nature-based and hybrid decentralized solutions for reclaimed water reuse

Fabio Masi, Guenter Langergraber, Marcello Santoni, Darja Istenic, Natasa Atanasova, and Gianluigi Buttiglieri

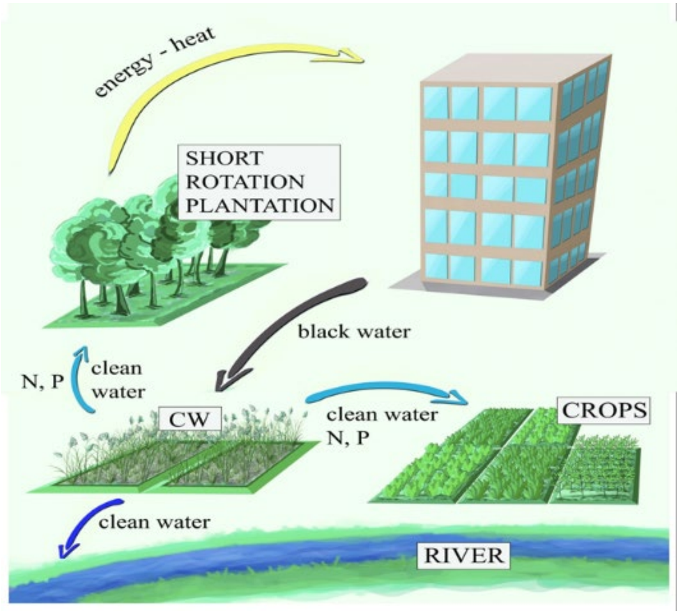

**Hostel campus of the College of Engineering, Pune (India)**:

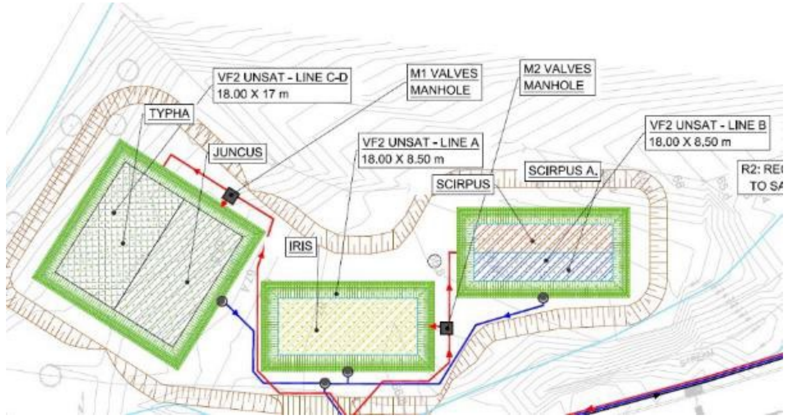
40 m3/d  greywater in 133 m2 VF CW  - 140 m3/d mixed B+G in 405 m2 ABR+VF-CWs

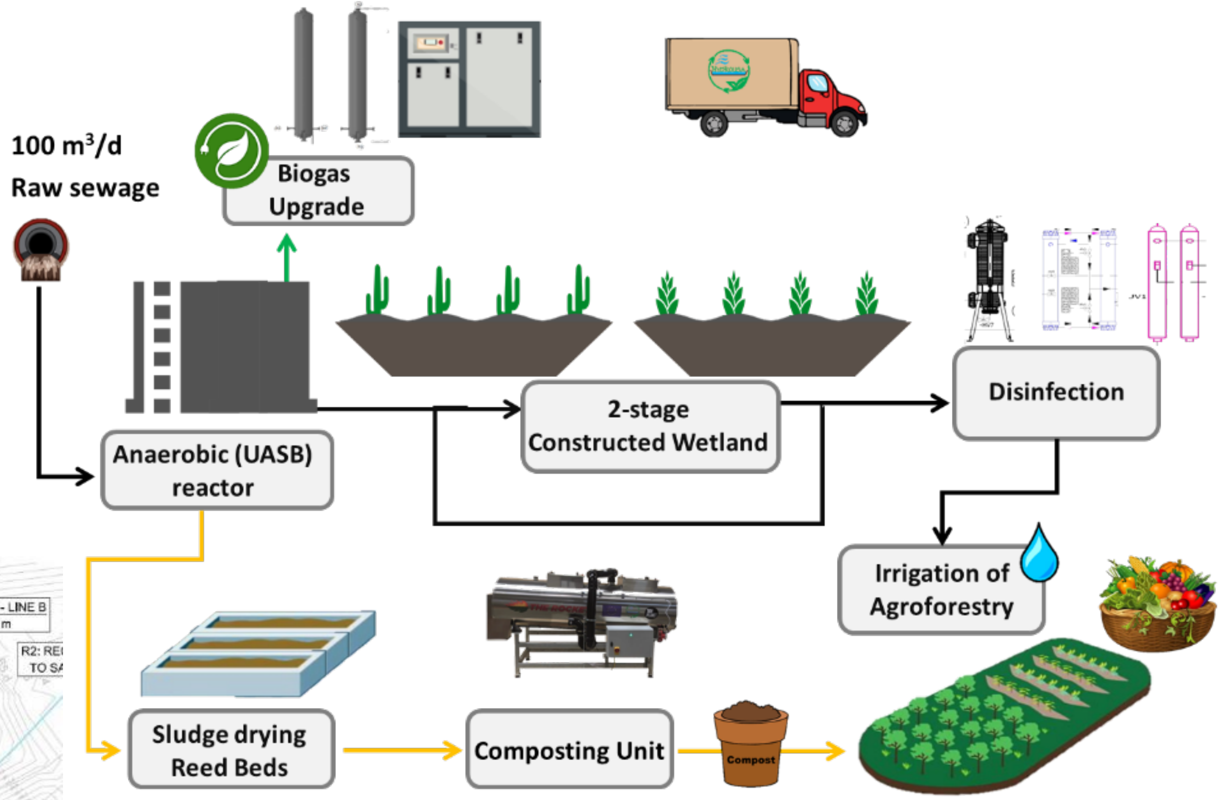
38000 m3 of tap water saved in 2019 (for a value of about 7500 USD with an OPEX of 2100 USD)

IRIDRA S.r.l.

# THE W-E-F NEXUS: Hydro1 Lesvos (GR)




## Advantages

- Low-cost treatment
- Nutrient recycling
- Versatility (fertigation or irrigation)
- Composting of sludge and green biomass
- Diversified agricultural production (agroforestry)

## Challenges

- Community engagement
- Dealing with variable flow rates
- Evidence of cost efficiency

# THE W-E-F NEXUS: Hydro2 Lesvos (GR)


# CHORFECH village

(TUNISIA)

IRIDRA S.r.l.

# SARRA village

(NABLUS – WESTBANK, PALESTINE)

IRIDRA s.r.l.

# Bedouin villages

(HEBRON PROVINCE, PALESTINE)

| | |
|---|---|
| **HF** | **70-120 P.e.** |
| Operating from | 2011-2012 |




# Case study: Dayanand Park Nagpur (India) – Sewer Mining


**Line 1: HF+VF (60m$^2$+60m$^2$ - 25 m$^3$/d)**
**Line 2: VF+HF (60m$^2$+60m$^2$ - 25 m$^3$/d)**
**Line 3: VF+VF (60m$^2$+60m$^2$ - 25 m$^3$/d)**
**Line 4: AEW (40m$^2$ - 25 m$^3$/d)**




| HF-HF, HF-VF, VF-HF, VF-VF, AEW | 1000 P.e. |
|---|---|
| Flow (m3/day) | 100 |
| Investment costs (€) | 105.000 |
| Management costs (€/y) | 16.000 |

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IRIDRA

# Symbiosis International University, Pune

(MAHARASHTRA, INDIA)

| | |
|---|---|
| **ABR + HF wetland** | **400 p.e.** |
| Flow (m³/day) | 80 |
| Net area (m²) | 350 |
| Investment costs (€) | 71.000 |
| Management costs (€/y) | 9.500 |
| Operating from | 2020 |

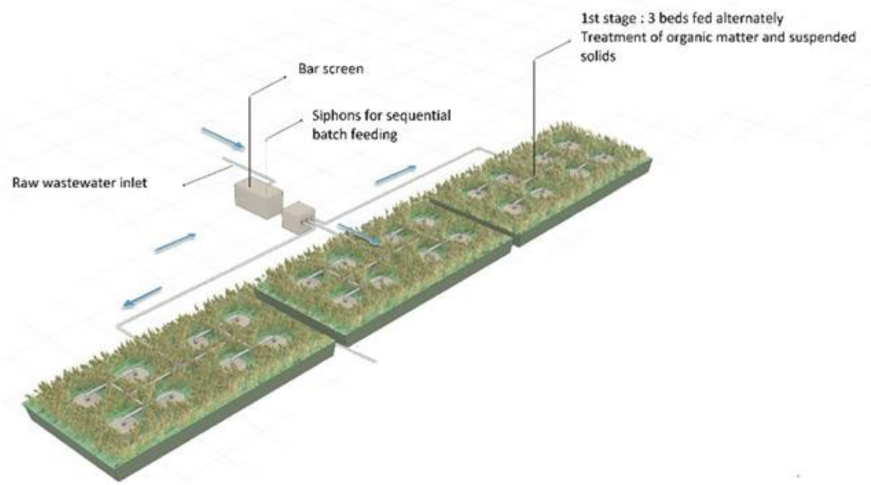
Banana Guava Mango

IRIDRA

# Aligarh Muslim University (AMU), Aligarh

(UTTAR PRADESH, INDIA)

| French Reed Bed | 142 p.e. |
|---|---|
| Flow (m³/day) | 50 |
| Net area (m²) | 250 |
| Investment costs (€) | 42.000 |
| Management costs (€/y) | 8.500 |

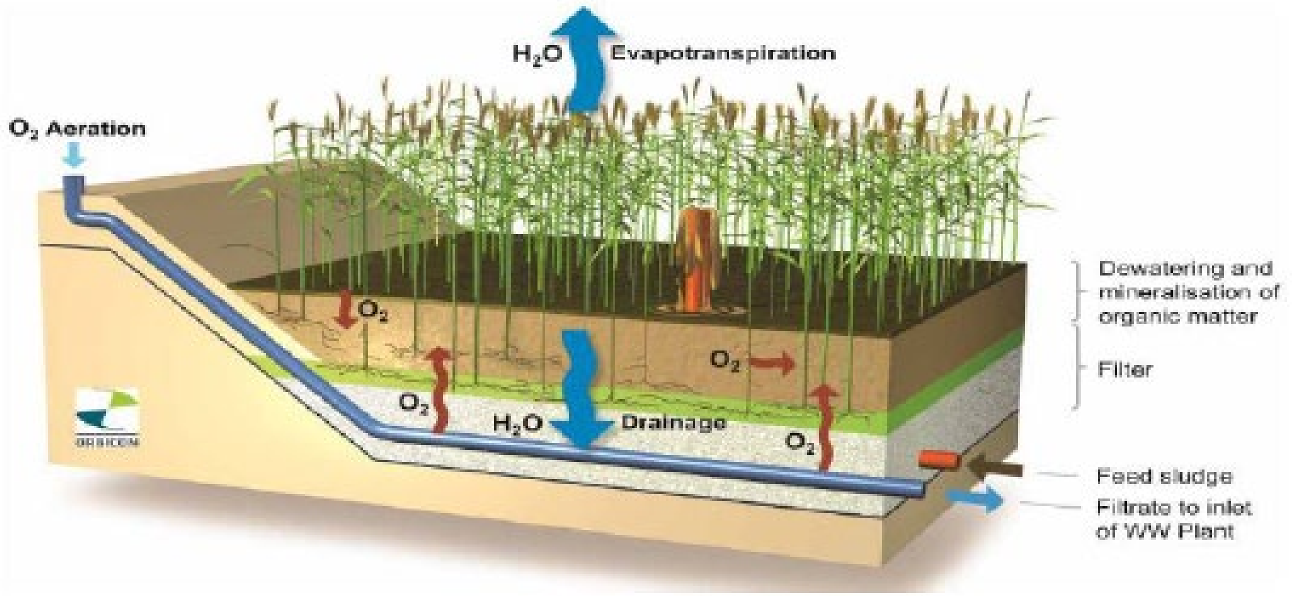




IRIDRA

# Aligarh Muslim University (AMU), Aligarh

(UTTAR PRADESH, INDIA)

| **Sludge Drying Reed Bed** | |
|---|---|
| Flow ($m^3$/day) | 5 |
| Net area ($m^2$) | 880 |
| Investment costs (€) | 186.200 |
| Management costs (€/y) | 22.000 |



Technologies for safe water reuse

# Sensors

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Santiago Cuervo
(AIMEN)

aimen TECHNOLOGY CENTRE

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# Sensor development

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PAVITR project aims the development of sensors to:

- **Wastewater process control:** at an Up-flow Anaerobic Sludge Blanket (UASB) for wastewater treatment and biogas production using wastewater as feedstock. → Volatile Fatty Acid sensor
- **Water quality monitoring** through a pathogens control in treated water prepared to reuse → Pathogen sensors

## Volatile Fatty Acid Sensor

- **Objective in the project:** Development of a **VFA-Sensor** for monitoring UASB Reactor operation
- On site monitoring VFA to determine trends of these acids in anaerobic reactors

## Pathogens sensor

- The sensor will determine the **presence/absence of colony-forming unit** (cfu) of patogens in the volume of water and an estimation of the range of concentration.
- *Escherichia coli* calibration to measure a concentration range, focused on the lower range expected for *E.coli* in treated water.

# Sensor development

PAVITR

**Volatile Fatty Acid Sensor:** Interest to monitor

**Presence in AD**: VFA are the pre-intermediate for the methane production.

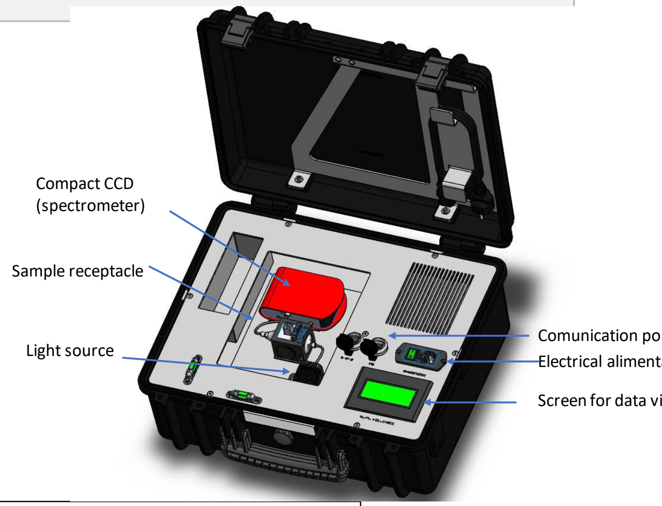
**Control VFA in AD→** indicative of AD process. Biogas production depends on VFA concentration

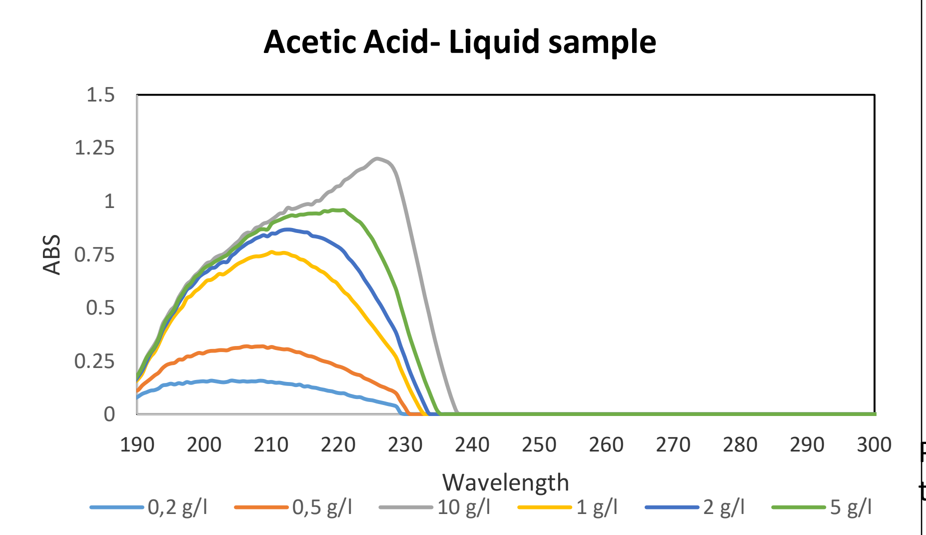
**Interest in VFA production**: Carbon source for products: Biopolymers (PHAs), Medium chain fatty acids, biofuels, hydrogen generation…

# Sensor development

**Volatile Fatty Acid Sensor:**

- Optical sensor based on **UV-VIS spectroscopy** with absorbance peak 220 -240 nm
- **Calibration** with acetic, propionic and butiric acid
- Validation in laboratory with real sludge
- Pretreatmen: Dilution and filtering



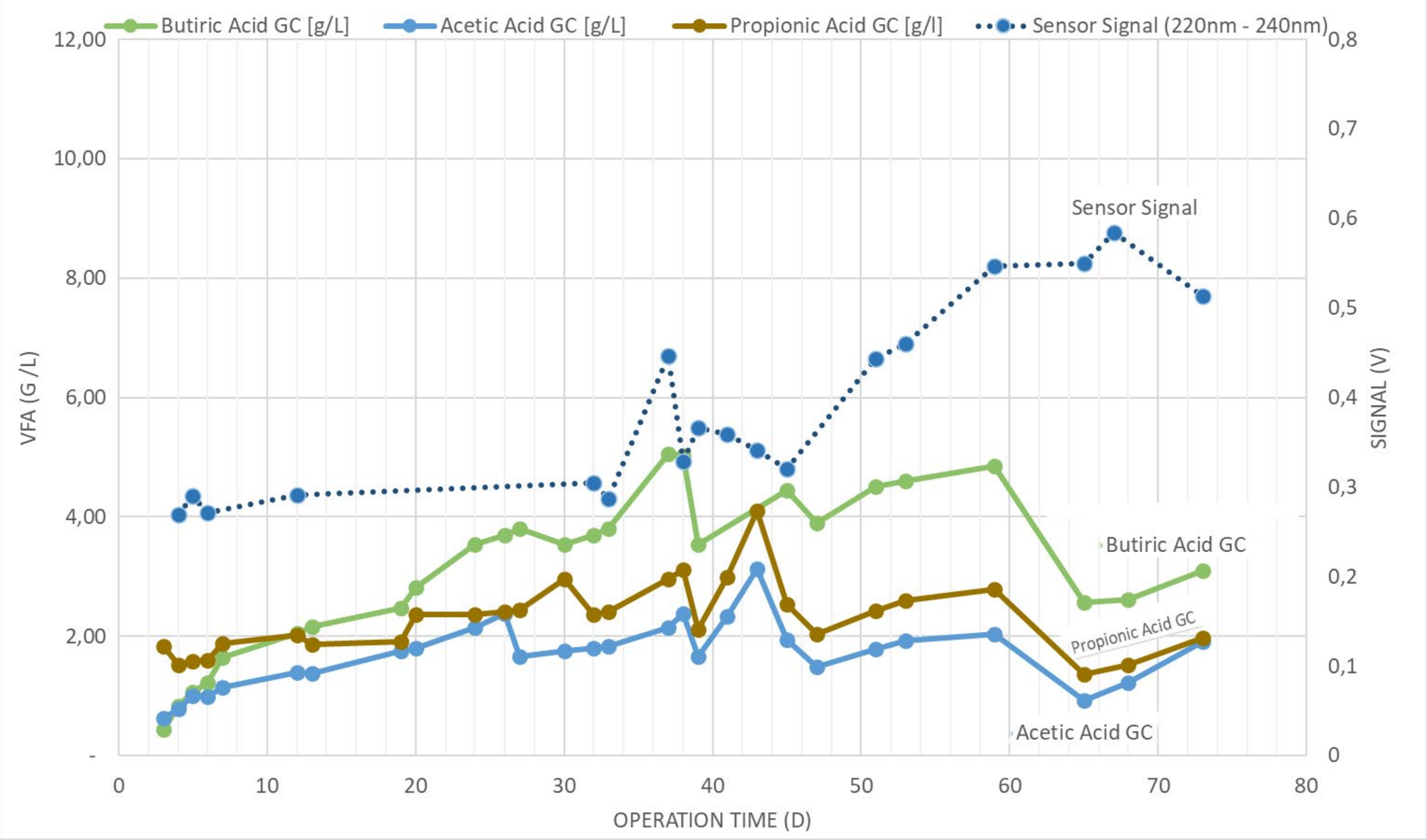

Patterns response of the sensor

# Sensor development

**Volatile Fatty Acid Sensor: Real validation on AD lab scale – 80 days**

Properties of sludge significant interference.

**VFA Trends detected along the operation**



# Sensor development

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Pathogens sensor

- Water Quality control required for avoiding healthy issues in the population
- **Coliforms** and ***Escherichia coli*** – mainly monitored pathogens → indicator of faecal pollution in the water.
- More restrictive legislations worldwide in water discharge and water to reuse.

# Sensor development

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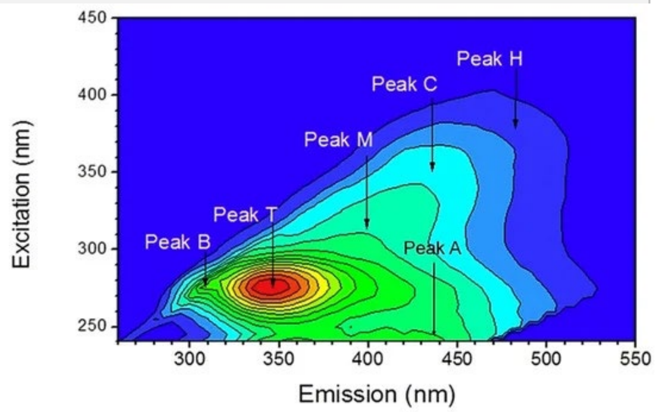
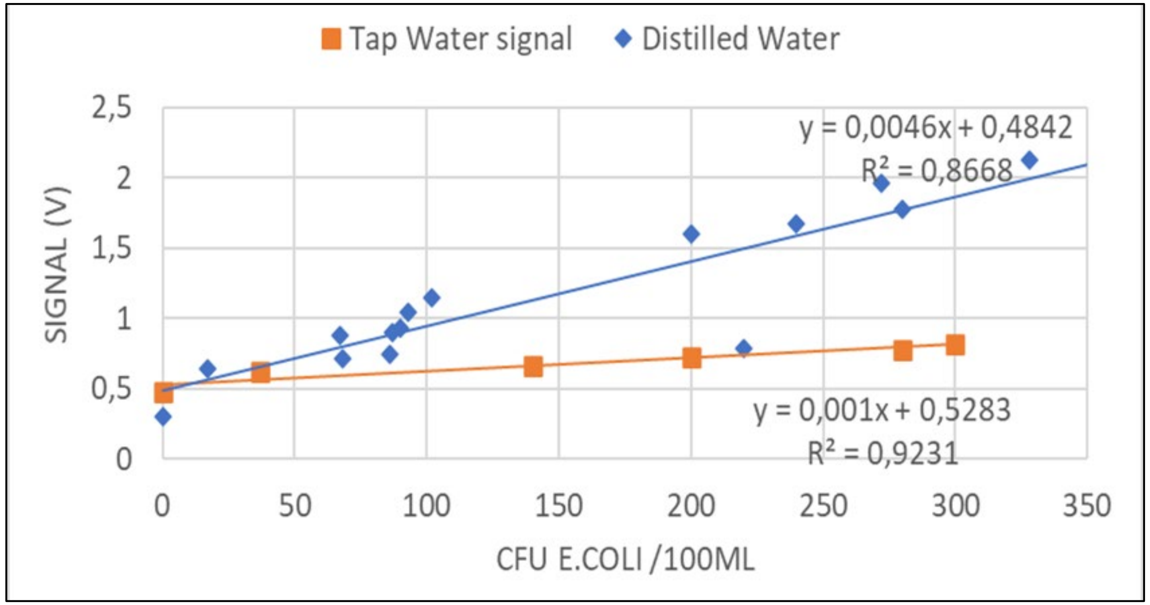
Pathogens sensor




- **Fluorescence-based** sensor - Optimal wavelengths: Ex 280 nm and – Em 350nm
- Direct correlation: signal intensity - Tryptophan – like material concentration (Peak T)
- Calibration to work at low E.coli range (legislation)
- Very good response at <300 cfu /100mL, at diferente matrix



# Sensor development

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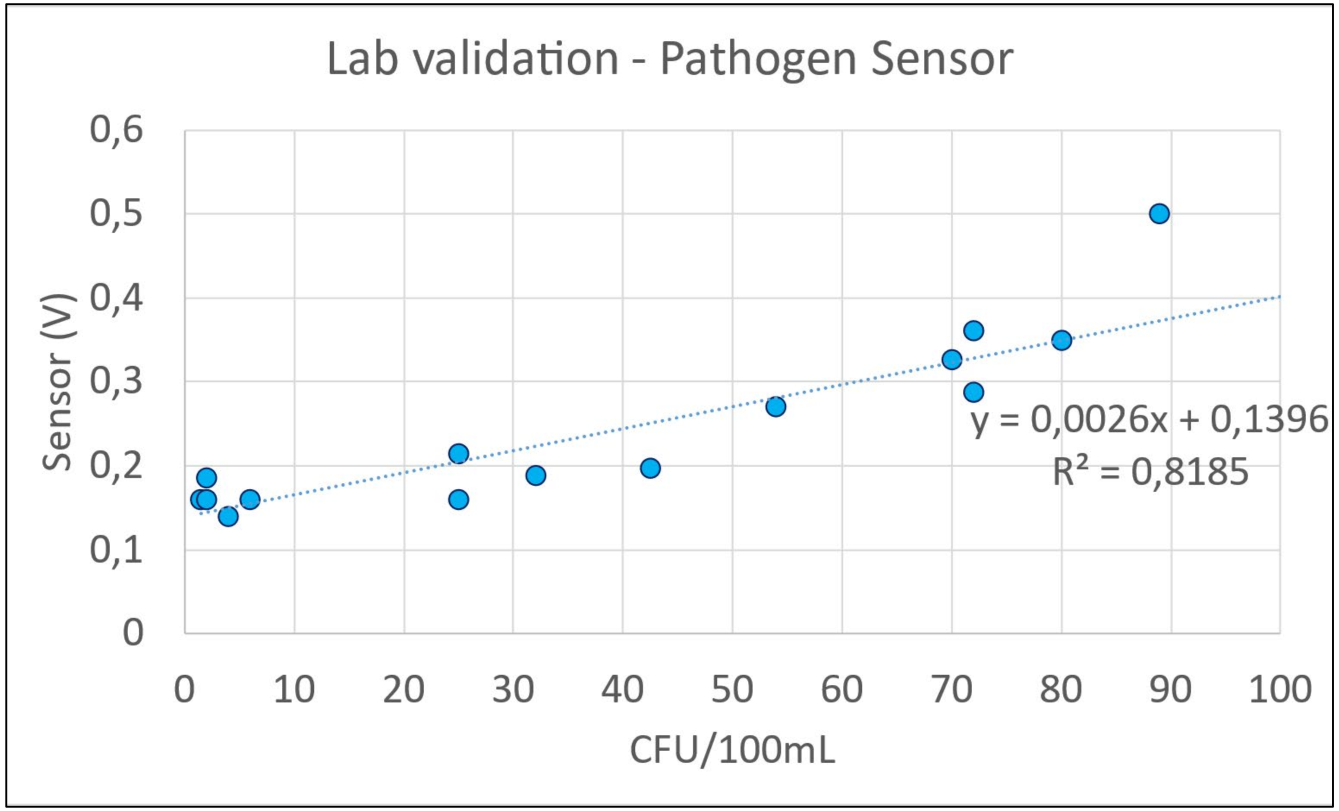
Pathogens sensor_ Validation on laboratory

- Real samples → lower range < 100 cfu /100mL.
- Good correlation at concentration <100 cfu/100mL
- Quantification limit is established at 20 cfu/100 mL.
- Lower than 10 cfu / 100 mL - estimation



# Sensor development

VFA and Pathogens sensor Integration in suitcase

Integration on a portable suitcase

# Sensor development

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General characteristics of the sensors:

- Both sensor development presented as main characteristics:
  - Satisfactory VFA trend variation monitoring
  - Early-warning pathogens contamination in water to reuse
  - Cost-effective materials and components.
  - Portable and robust
  - Reduction of laboratory dependency
  - Quick results (<1 min)
  - Easy-to-use – Not necessary qualified staff
  - Free chemical use
  - No waste generation

Important factors for implementation

# Planning

Workshop
"Novel and Innovative Solutions for Safe Water Reuse in India"
@ IWA Water Reuse Conference, 15 January 2023, Chennai

Ganbataar Khurelbaatar
(UFZ)

UFZ HELMHOLTZ Centre for Environmental Research

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# Preliminary Planning and Optimization of Regional Wastewater Infrastructure

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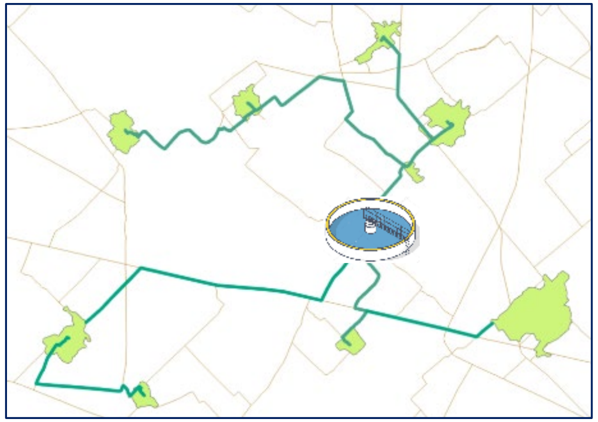
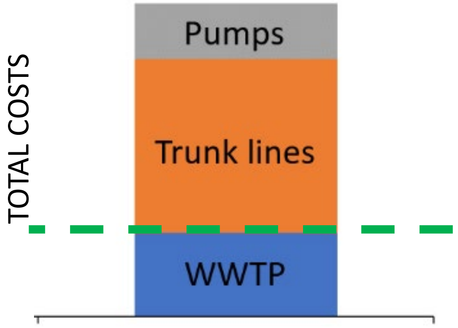
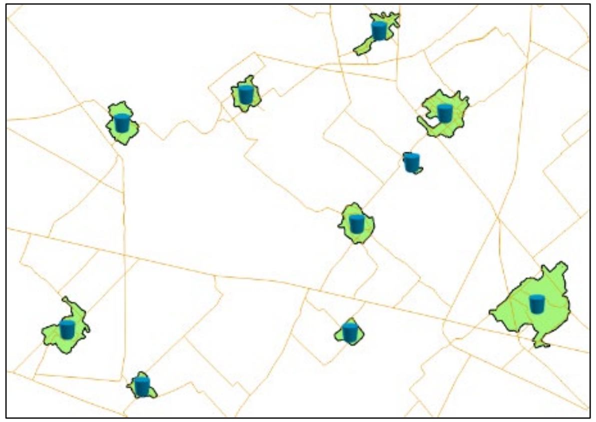
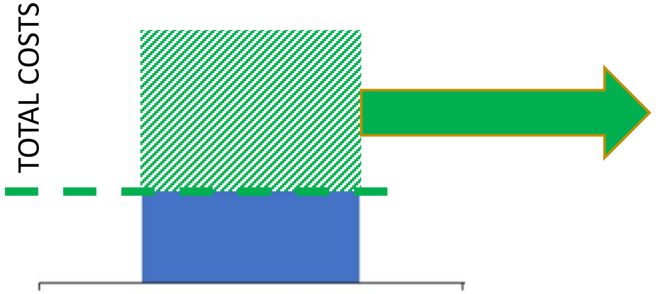
Centralised



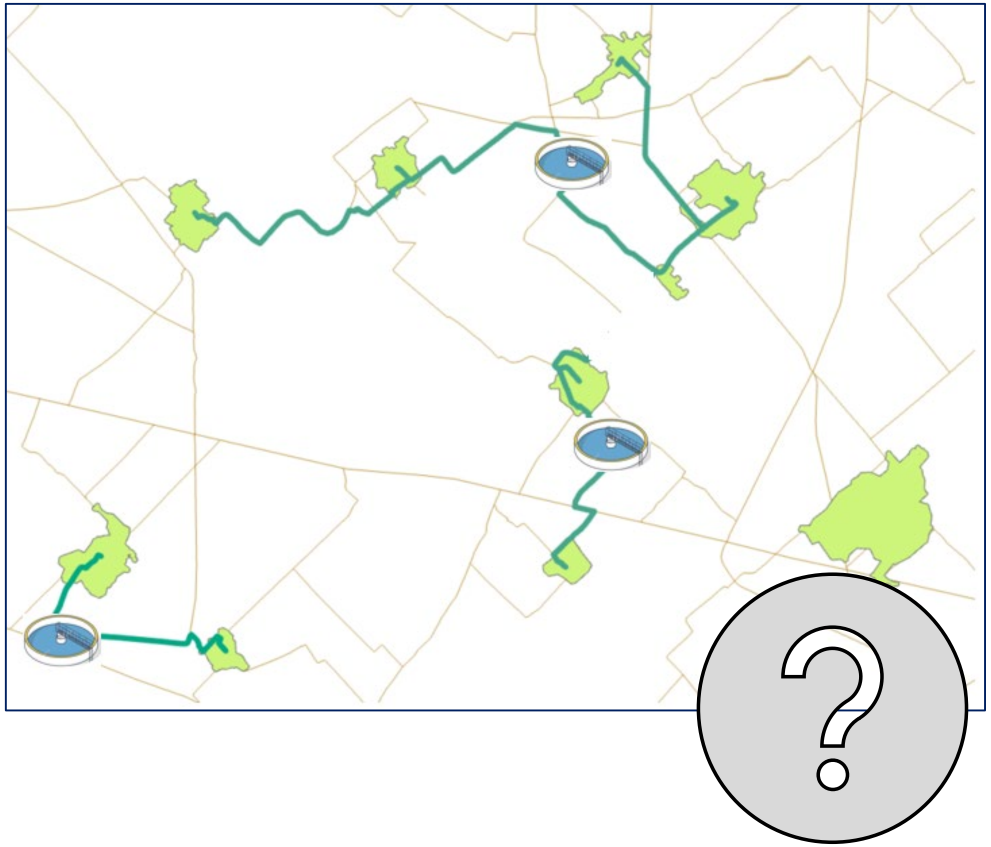



Decentralised






Clustered (Optimized)



# Study area
# ca. 300,000 inhabitants

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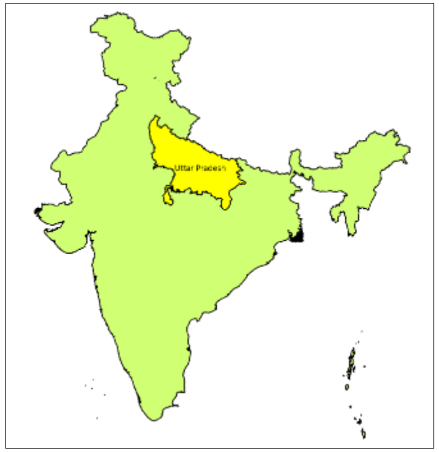


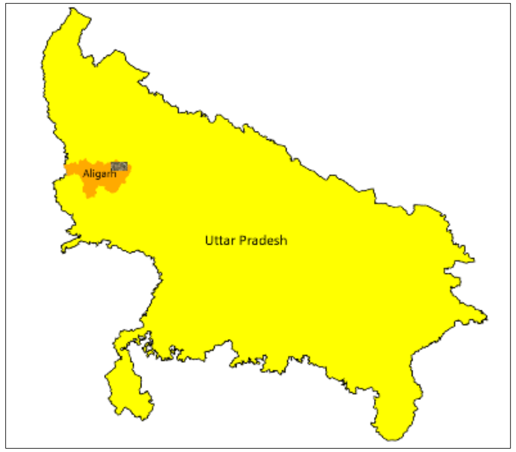



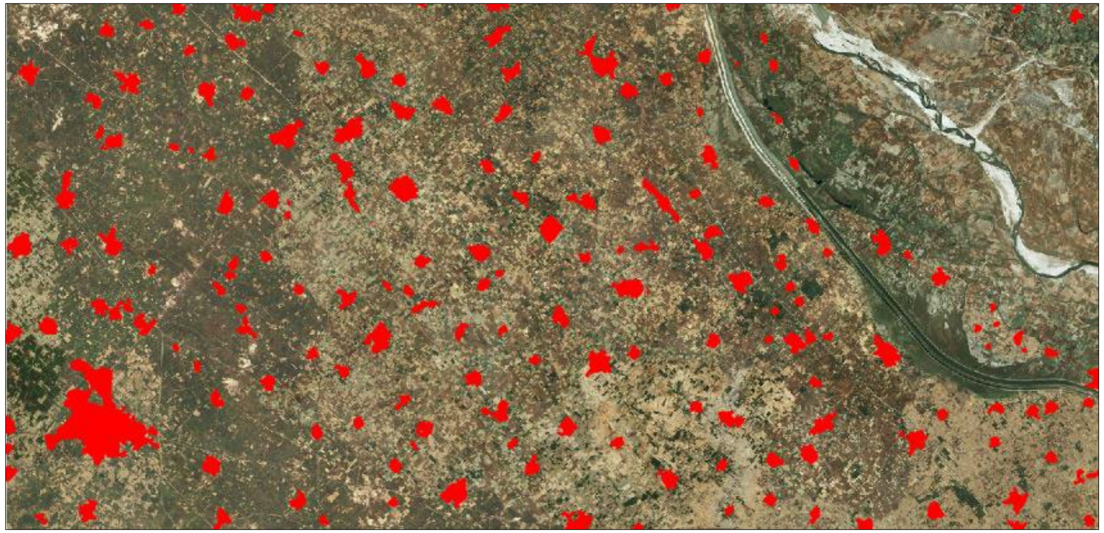

Country - India

State - Uttar Pradesh

District - Aligarh

Block - Atrauli

Study Area — Area: ca. 390 Km2

Villages — Number: 184 villages

Why this area?

- High demographical development
- Diversified settlements
- Precarious local sanitation situation
- Focus of international funding agencies

# Data Base

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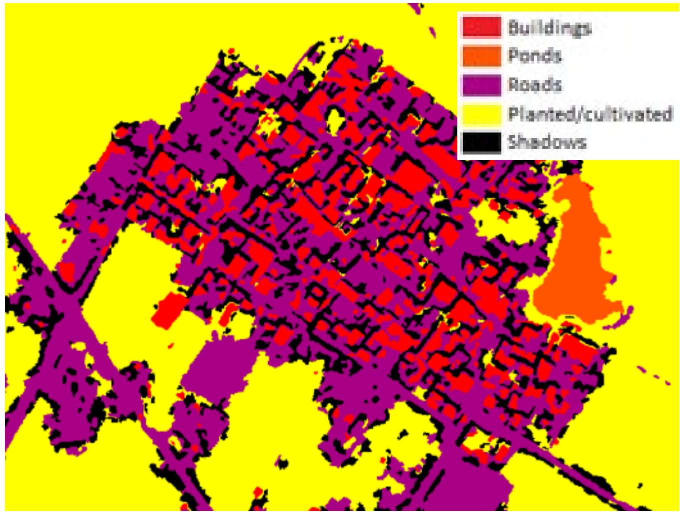
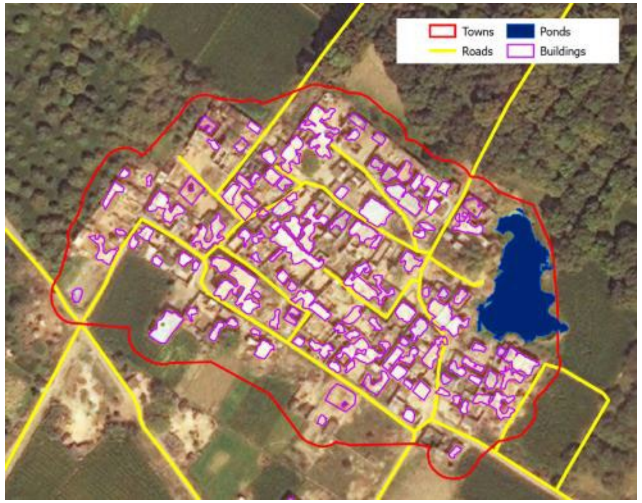
Global Data: Satellite Image
Data Extraction: through image processing
Data Calibration: Local data (Census)




Input for Scenario Development

# Scenario Development & Optimitzation

Centralized Decentralized Optimized

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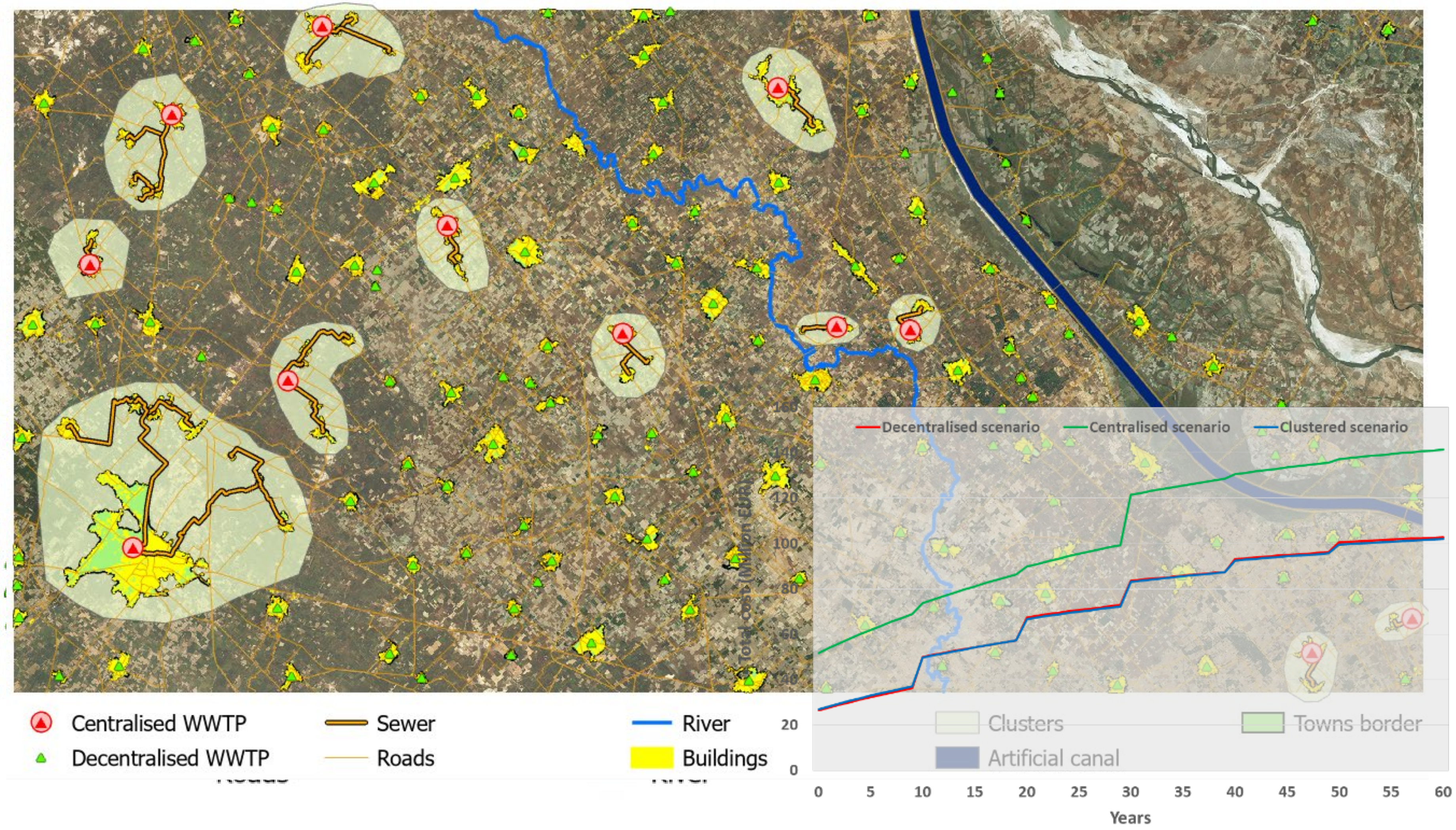

Important factors for implementation

# Resources recovery & market exploitation

Workshop
"Novel and Innovative Solutions for Safe Water Reuse in India"
@ IWA Water Reuse Conference, 15 January 2023, Chennai

Carlos Arias
(Aarhus University)

AARHUS UNIVERSITY

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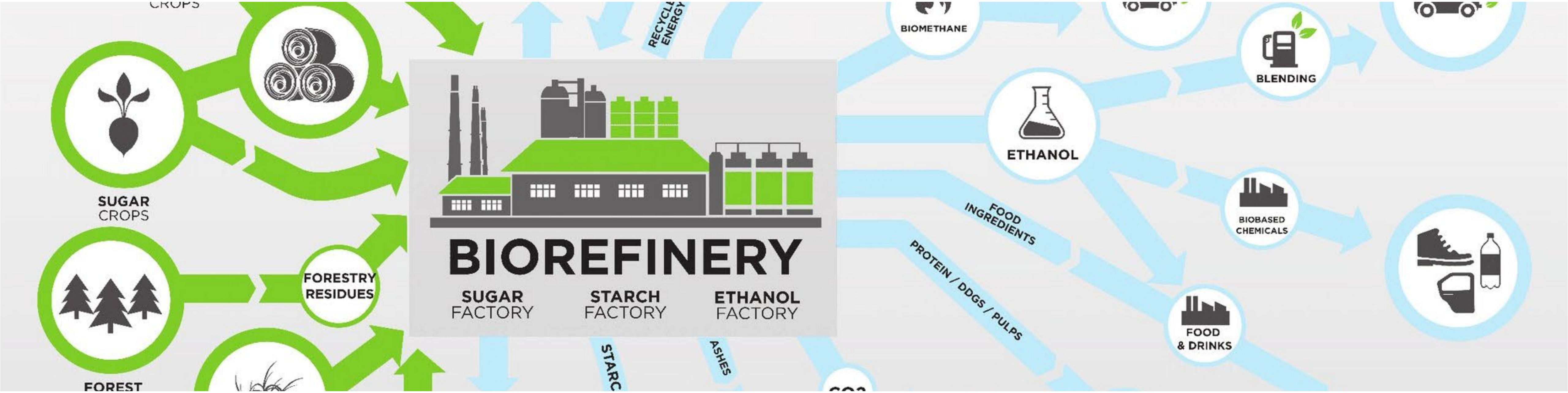
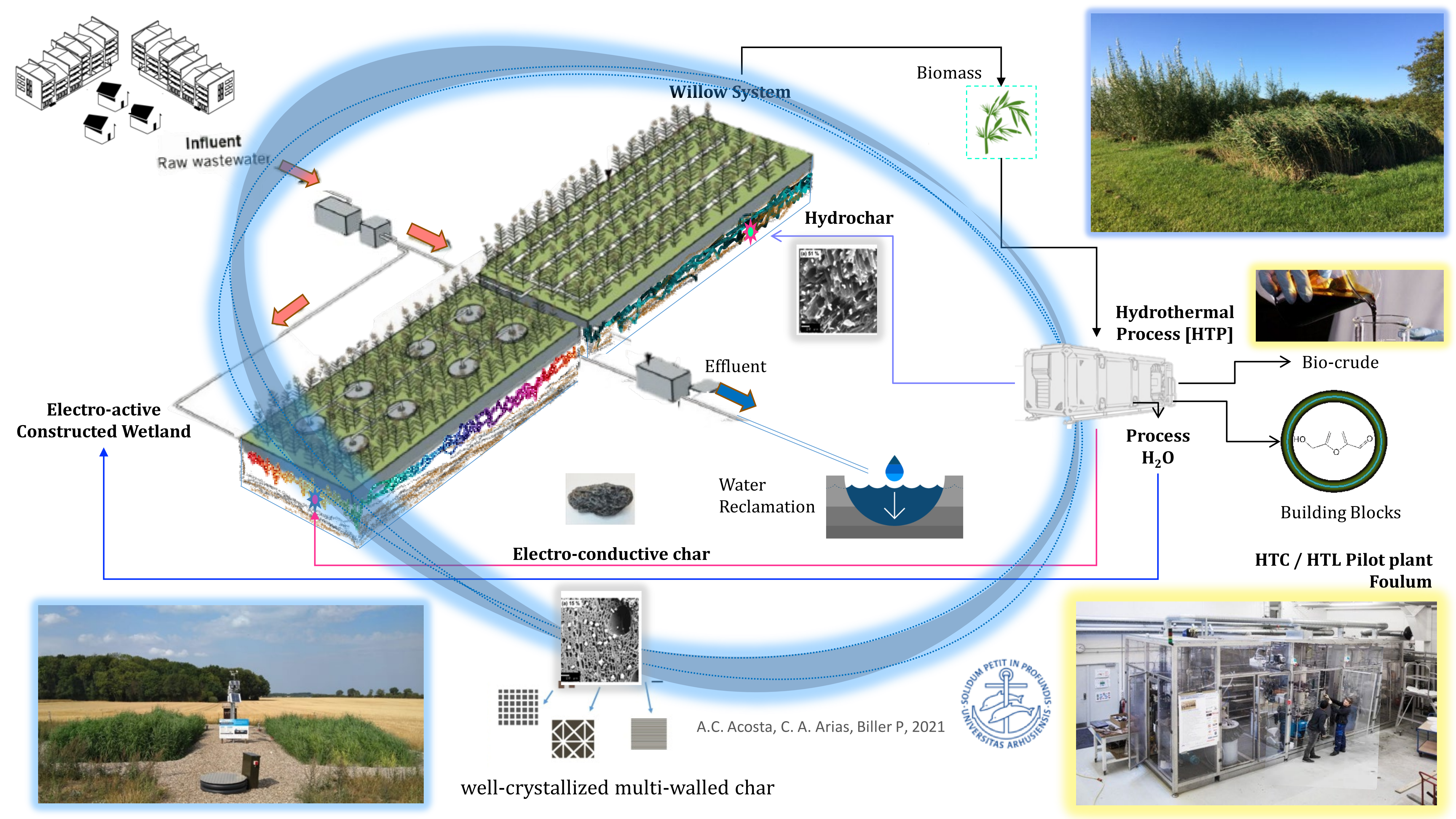
# Production of high value products from biomass




To use advanced bio-refining technologies and processes for the production of high value plant-based products from CW biomass  represents a gap of opportunity,

Image from: https://twitter.com/biconsortium/status/897742919024734208/photo/1


Influent
Raw wastewater
Willow System
Biomass
Hydrochar
Hydrothermal
Process [HTP]
Bio-crude
Effluent
Electro-active
Constructed Wetland
Process
$H_2O$
Building Blocks
Water
Reclamation
Electro-conductive char
HTC / HTL Pilot plant
Foulum
A.C. Acosta, C. A. Arias, Biller P, 2021
SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS
well-crystallized multi-walled char

# Outline

PAVITR

| Time | Topic | Presenter |
|---|---|---|
| **10:30** | **Welcome and program overview** | Guenter Langergraber |
| **10:35** | **The general PAVITR concept** | Mirko Hänel |
| **10:50** | **Technologies for safe water reuse** (5 min each) | |
| | ○ Short Rotation Plantation | Mirko Hänel |
| | ○ High Rate Algae Pond | Enrica Uggetti |
| | ○ Richwater SBR | Antonia Lorenzo |
| | ○ Wetland Systems | Fabio Masi |
| | ○ Sensors | Santiago Cuervo |
| **11:15** | **Important factors for implementation** (5 min each) | |
| | ○ Planning | Ganbataar Khurelbaatar |
| | ○ Resources recovery & market exploitation | Carlos Arias |
| **11:25** | **Panel discussion with the presenters** | moderated by Guenter Langergraber |
| **11:55** | Closure | Mirko Hänel |
| **12:00** | End of the workshop | |

Workshop

# Novel and Innovative Solutions for Safe Water Reuse in India

@ IWA Water Reuse Conference, 15 January 2023, Chennai

Organisers:
Nadeem Khalil
Guenter Langergraber

PAVITR