Training Program on Sustainable Natural and Advance Technologies and Business Partnerships for Water & Wastewater Treatment, Monitoring and Safe Water Reuse in India

High Rate Algae Ponds

Prepared by: Enrica Uggetti, Antonio Ortiz and Nadeem Khalil

ALIGARH MUSLIM UNIVERSITY

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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Introduction to the authors

Enrica Uggetti

Senior researcher

Ph.D in Civil Engineering, since 2013 she is working as senior researcher at the Universitat Politècnica de Catalunya (UPC) within the Environmental Engineering and Microbiology Research Group (GEMMA). She is internationally recognized for her expertise in the field of nature-based solutions for wastewater treatment, with special focus on constructed wetlands and microalgae-based treatment.

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Antonio Ortiz

Post-doc

Ph.D in Environmental Engineering, he is currently working as post-doc carrying out research in the field of microalgae wastewater treatment design in collaboration between the GEMMA group from UPC and the group in Environmental Engineering of the Universidad de Cantabria.

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Learning objectives

At the end of this session, participants will:

- know the general concepts of wastewater treatment with microalage
- know features of high rate algae ponds
- Know examples of wastewater treatment with microalage

Agenda of the session

Time	Content
5 min	Introduction to the session
15 min	Introduction to the technology (background overview, principles, performance expected, appropriateness)
20 min	Design of the technology (key considerations, basic calculations, key formulas, etc.)
5 min	Operation and maintenance
10 min	Example: the PAVITR pilot
5 min	Final remarks

Introduction to the technology

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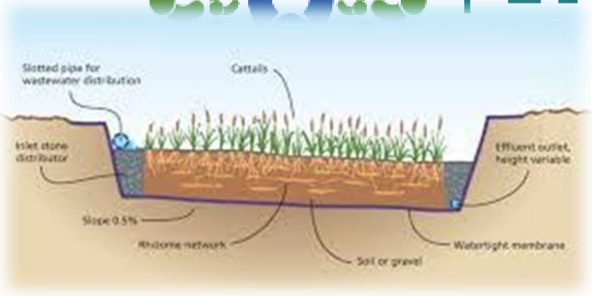
GEMMA Environmental Engineering & Microbiology

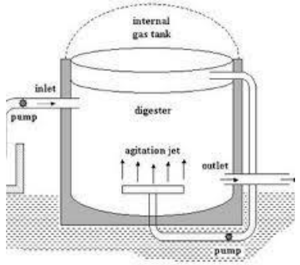
https://gemma.upc.edu/

GEMMA research group

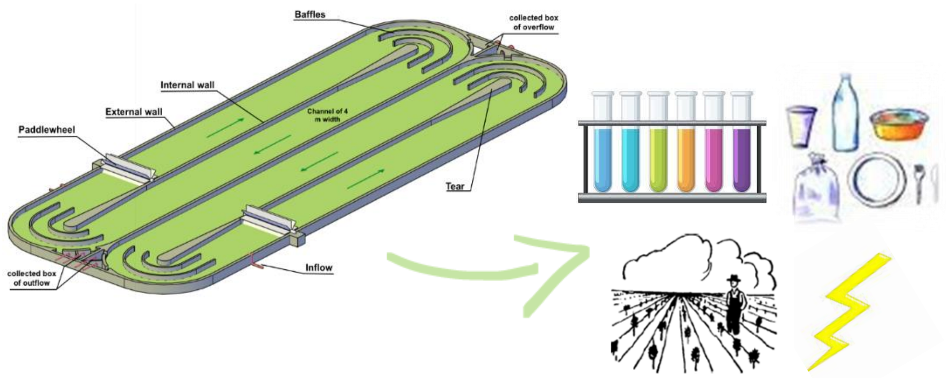
- **Nature-based solutions** for the treatment of waste streams



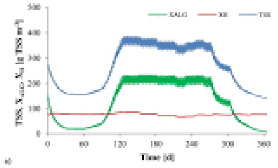
- **Biogas production** from residual biomass



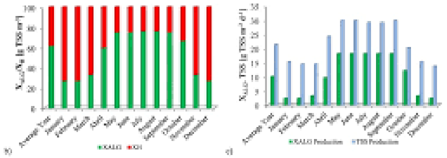
- **Resource recovery** from waste streams using **microalgae biomass** to generate **BIOPRODUCTS** (natural pigments, bioplastics, biofertilisers) and **BIOENERGY** (biogas)



- Mathematical modelling of bioprocesses → **BIO_ALGAE MODEL**



- **Life Cycle Assessment (LCA)**



Microalgae

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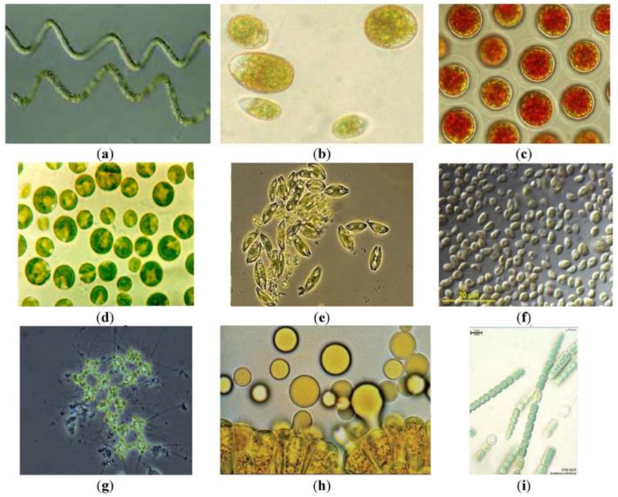


Microalgae are unicellular algae (μm) characterized by a huge biodiversity (50,000 species are described)

They 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

Microalgae for wastewater treatment

Primary Settler → Biological Treatment → Secondary Settler

☹

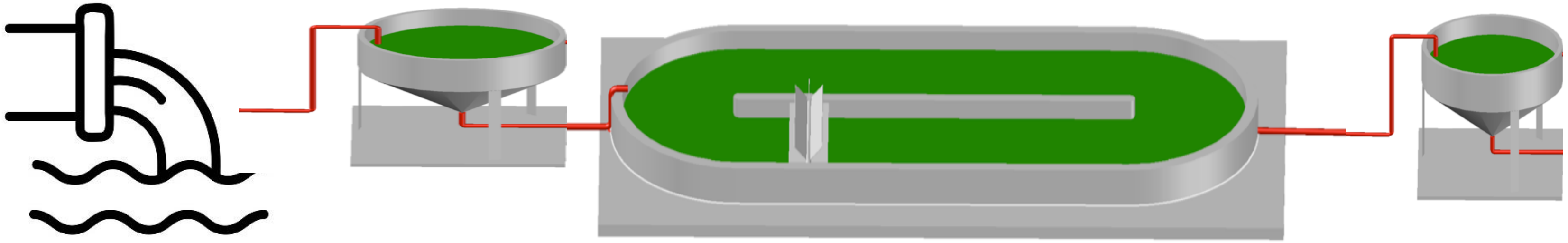
AERATION OF THE BIOLOGICAL REACTOR:

> 50% of the WWTP energy demand

↑ Cost

↑ Carbon footprint

Microalgae for wastewater treatment



Primary Settler → Biological Treatment → Secondary Settler

Microalgae for wastewater

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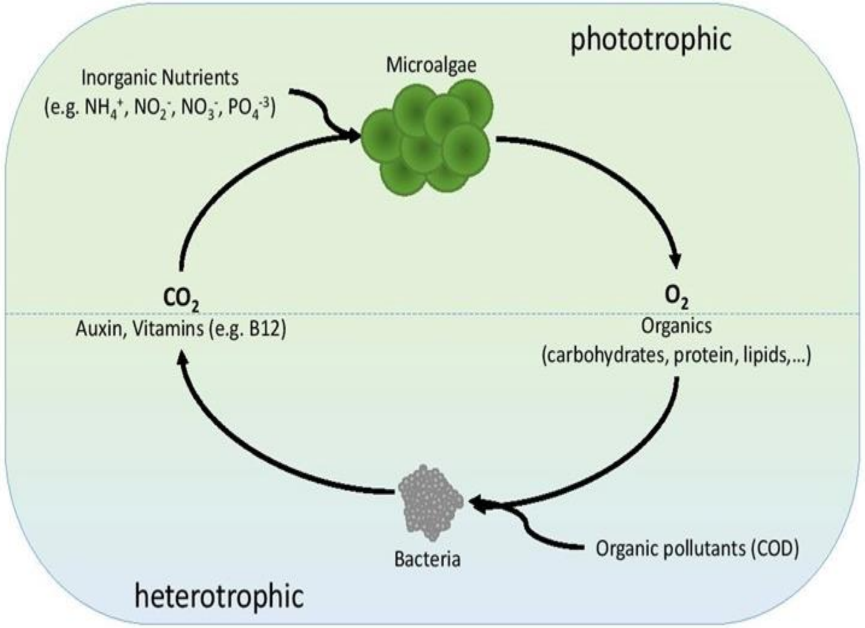

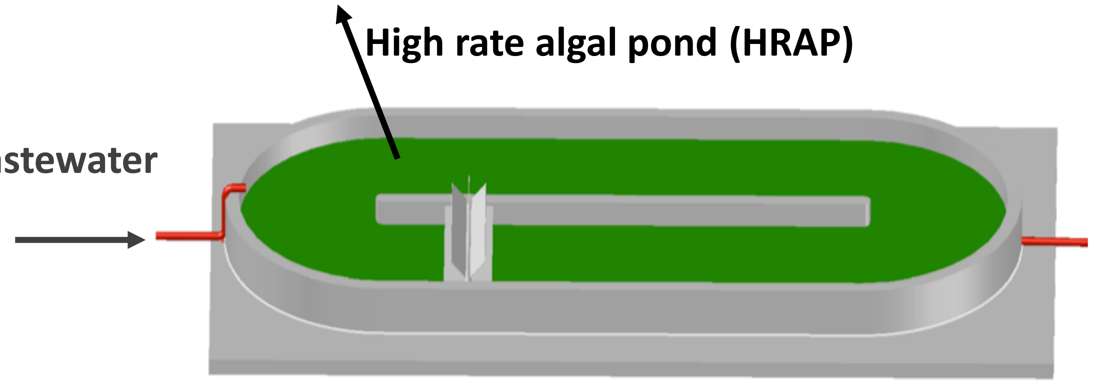

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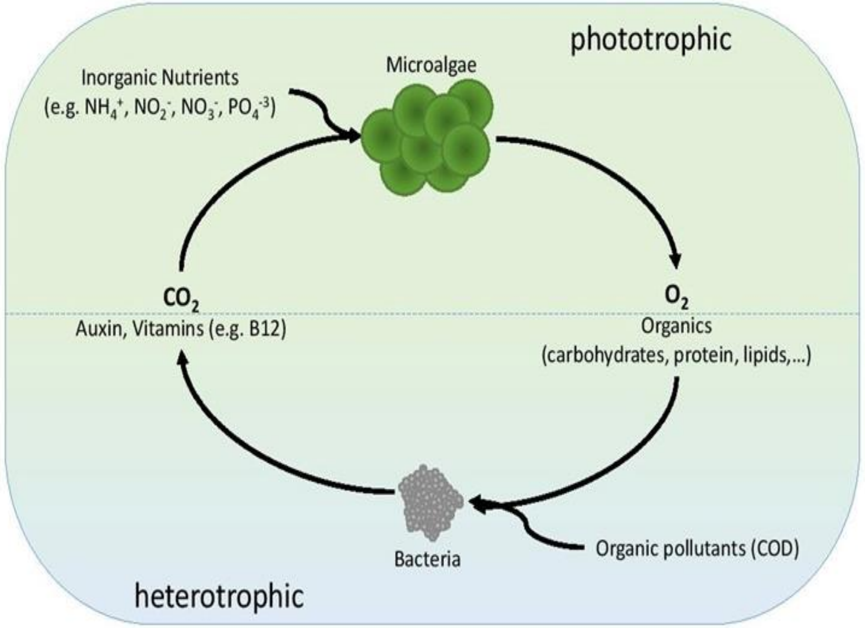
Reduction of the WWTP energy demand

(0.02 kWh/m^3 HRAP vs. 0.2-0.4 kWh/m^3 AS)

Production of valuable biomass

Microalgae for wastewater



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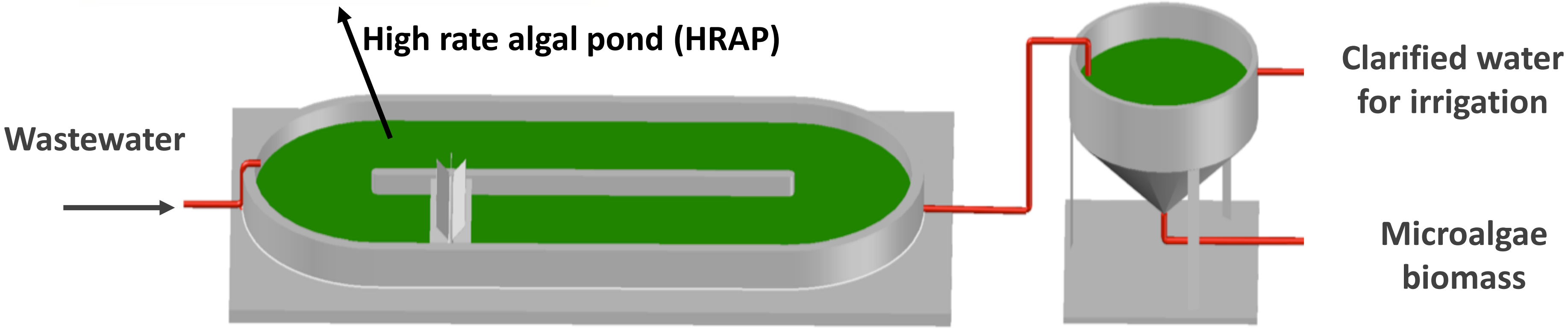


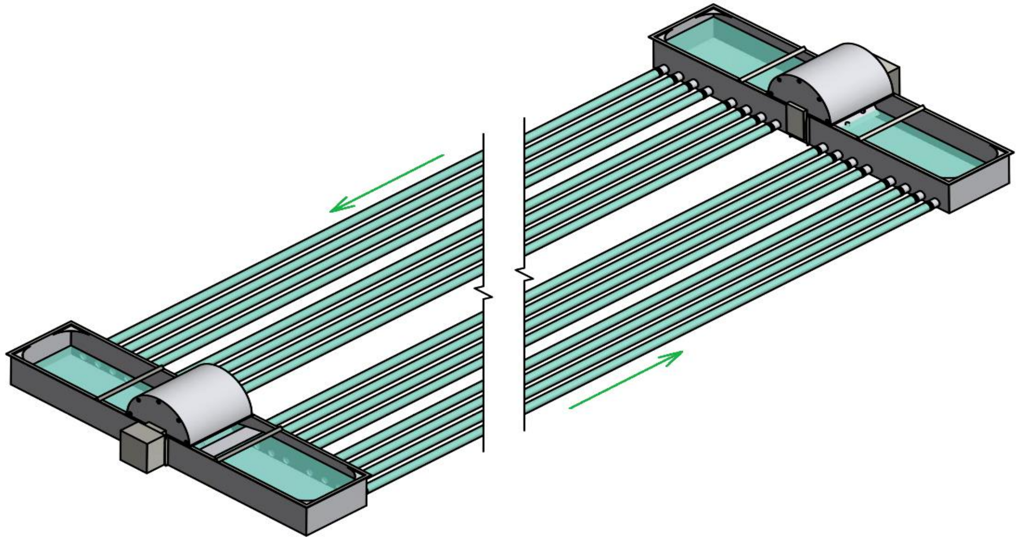
High rate algae ponds

Chiclana, Spain

El Toyo, Spain

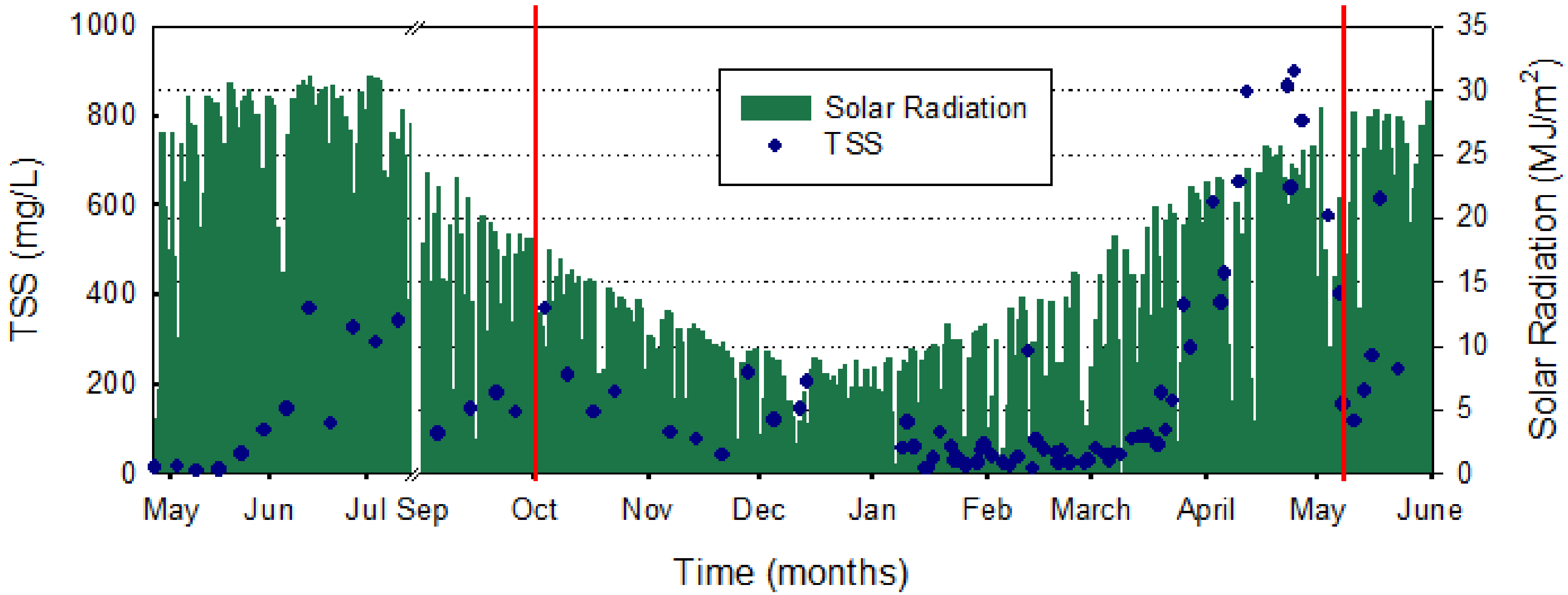
Results

INCOVER



Parameter	Value
Total volume (m^3)	11
Tank volume (m^3)	2.5
Tube diameter (m)	0.125
Tube length (m)	47
Number of tubes	16
Number of tanks	2
Engine power (kW)	0.35
HRT (d)	4.8
Agricultural runoff / wastewater	10:1

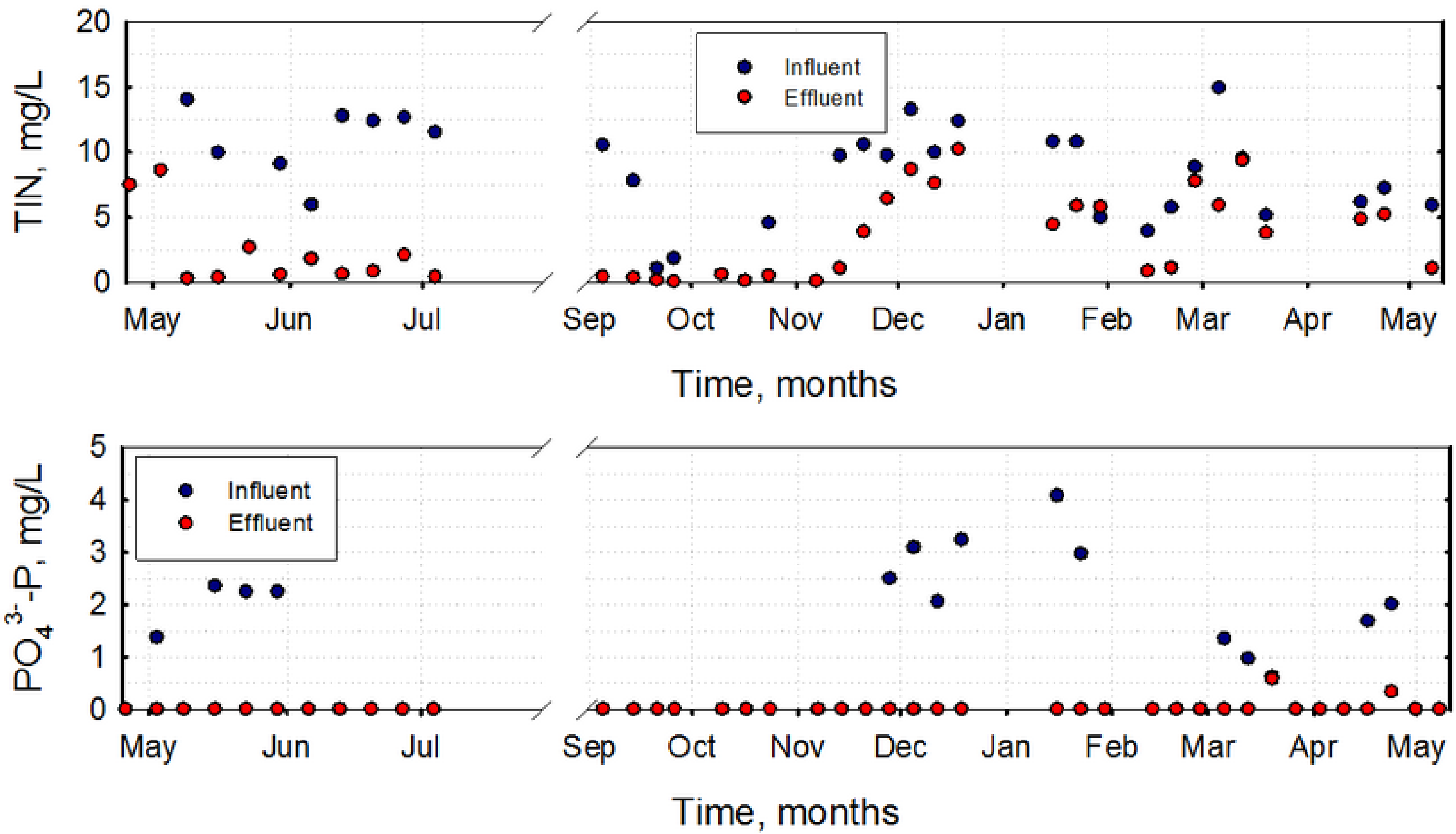
Results



Average biomass production

- 1.1 kgVSS/d in Autumn
- 0.3 kgVSS/d in Winter
- 1.7 kgVSS/d in Spring

Results


20
15
10
5
0
TIN, mg/L
Influent
Effluent
May
Jun
Jul
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Time, months
5
4
3
2
1
0
PO4 3--P, mg/L
Influent
Effluent
May
Jun
Jul
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Time, months

Design of the technology

Design of the technology

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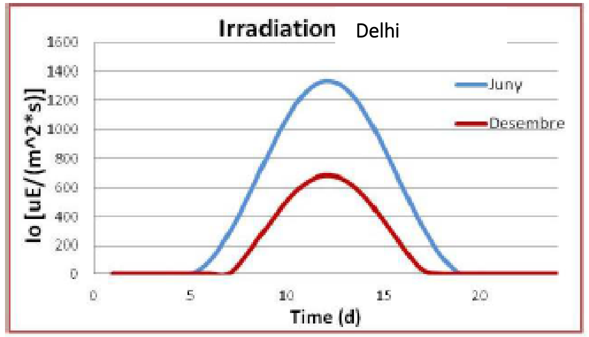
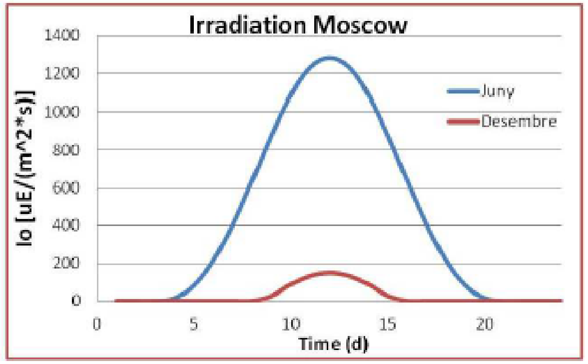
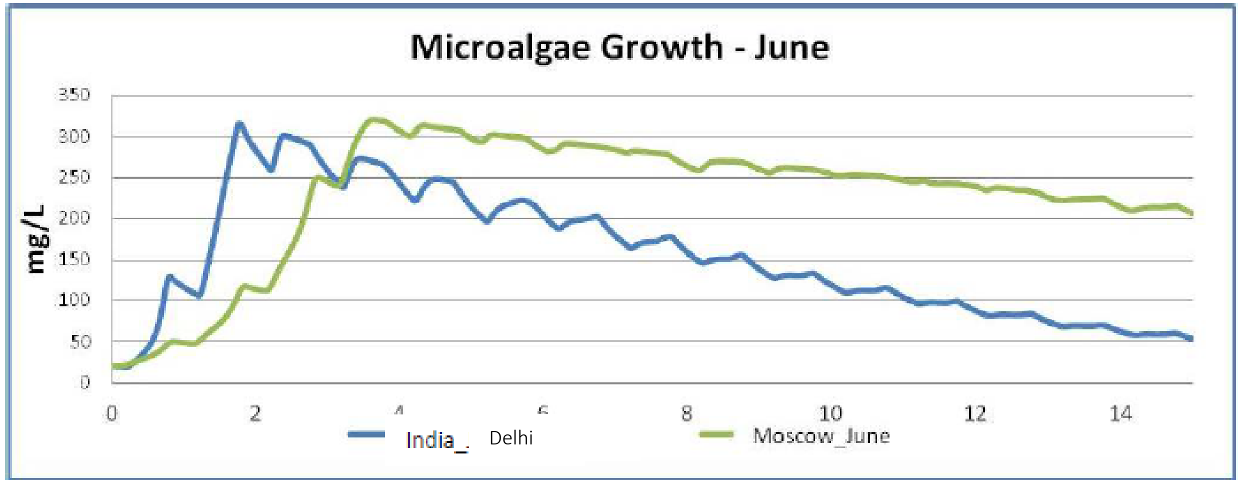
Nowadays there are no guidelines for HRAP design, for this reason we designed a mathematical model to help the optimization of HRAP design

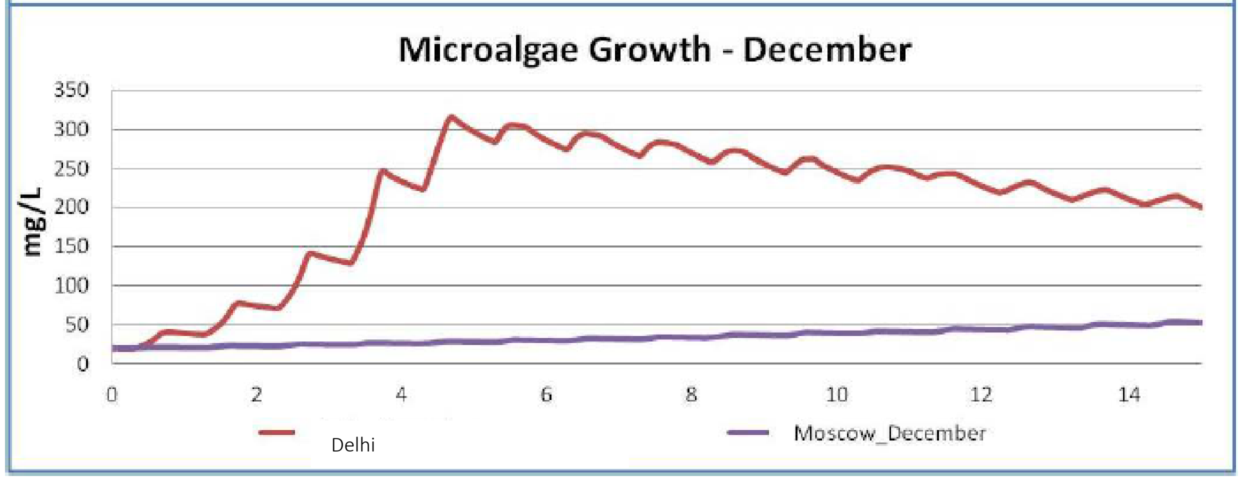
Design of the technology

Simulation of biomass production









Design of the technology

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1. Dimensioning with biokinetic and hydrodynamic modelling

Biological Sizing

Integral microalgae-bacteria model BIO_ALGAE (COMSOL Multiphysics)

Input data

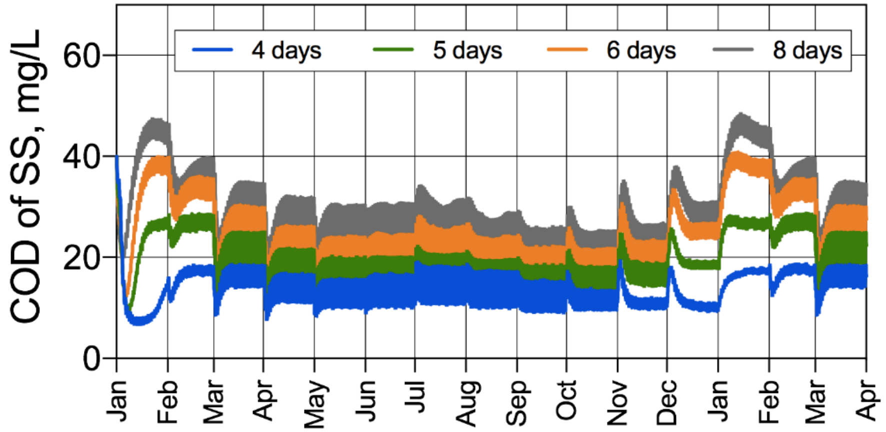
- Wastewater characteristics
- Weather conditions

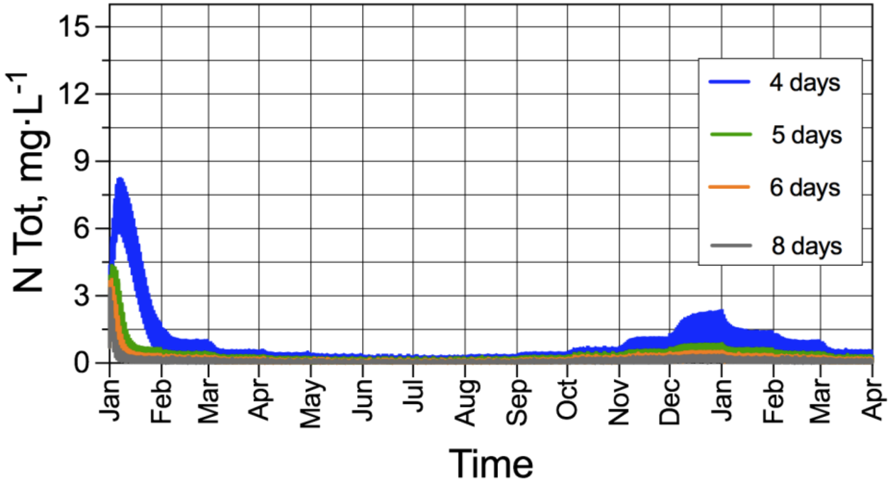
Simulations

- HRTs: 4, 5, 6 and 8 days
- Period: 1 year

Results

- Nutrients removal
- Organic matter removal
- Biomass production





Design of the technology

PAVITR

1. Dimensioning with biokinetic and hydrodynamic modelling

Biological Sizing

Integral microalgae-bacteria model
BIO_ALGAE (COMSOL Multiphysics)

Input data

- Wastewater characteristics
- Weather conditions

Simulations

- HRTs: 4, 5, 6 and 8 days
- Period: 1 year

Results

- Nutrients removal
- Organic matter removal
- Biomass production

Flow: 50 m^3/day
BOD: 130 mg/L

HRT: 4 days
Depth: 0.3 m
Volume: 200 m^3

Design of the technology

Hydraulic Sizing (Design Verify and Optimize)

Standard two-equation k-ε model (COMSOL Multiphysics)

Input data

- Channel width: 4 m
- Water depth: 0.3 m
- Water velocity: 0.15 $m \cdot s^{-1}$

Simulations

- Turbulent flow interface
- Stationary state
- 4 designs

Rsults

- Velocity field
- % Dead zones

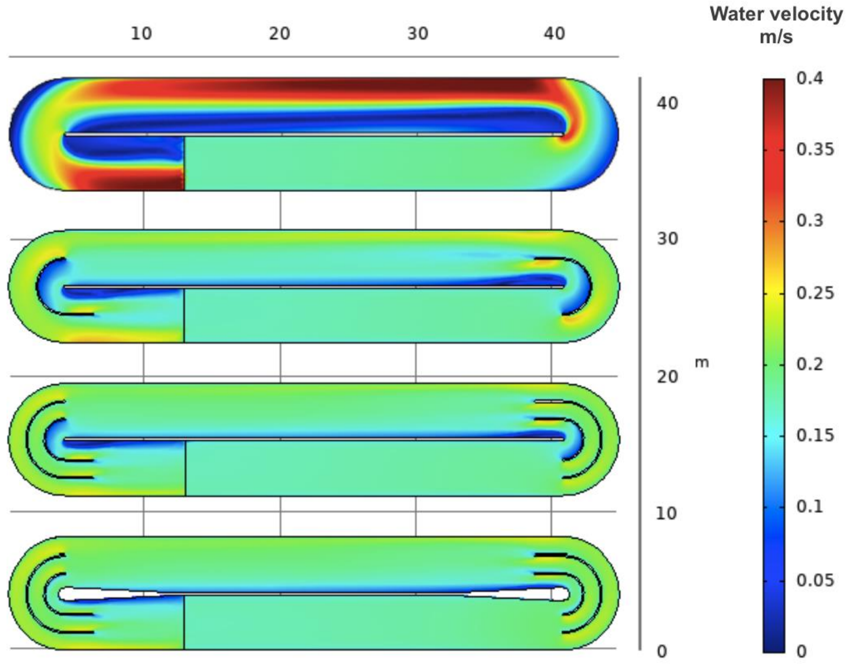
Dead zones

28,1%

12,3%

7,2%

4,3%



Design of the technology

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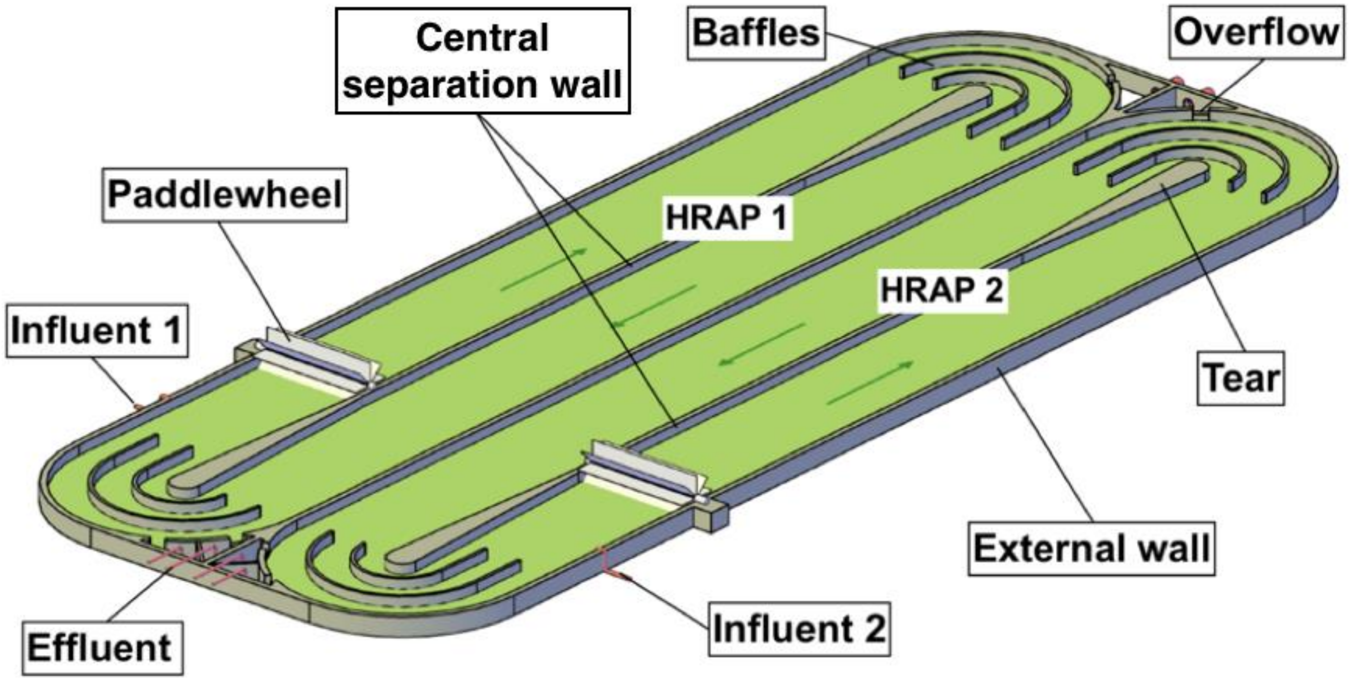
Parameter	Value
Influent flow rate (m^3/d)	50
Minimum Hydraulic Retention Time (d)	4
HRAP volumen (m^3)	200
HRAP useful depth (m)	0.30
HRAP total Surface (m^2)	667
Channels and reversal lenght (m)	86.2
Water velocity (m/s)	0.15
Paddlewheel power (kW)	0.5



Operation and maintenance

Daily maintenance tasks

For the correct operation of the system, several components should be daily checked and adjusted if needed. The parameters are listed below, and they should be checked in this order.

1. Visually verify the water level of the pond is correct (30-40 cm depending on the design). This indicates that the output system is working correctly.

2. Verify the paddle wheel works properly.

3. Verify that the inflow is equal to or lower than 25 m3/h for each pond. Otherwise, the speed of the inflow pumps should be regulated.

5. Check the harvesting system inflow (outflow of the HRAPs) turbidity in order to adjust the coagulant dosage.

6. Check the turbidity in the settler effluent. If the turbidity is higher that 10NTU, the coagulant dose has to be adjust according to the calibration curve.

7. Check that the pump of settler purge works properly. Each week the valve of the wetland open has to be closed and the next one should be opened.

Other maintenance tasks

Every month the settler has to be open and checked inside. If attached biomass is detected on the walls, it should be cleaned with clean water.

Example:
the PAVITR pilot project

HRAP within PAVITR project

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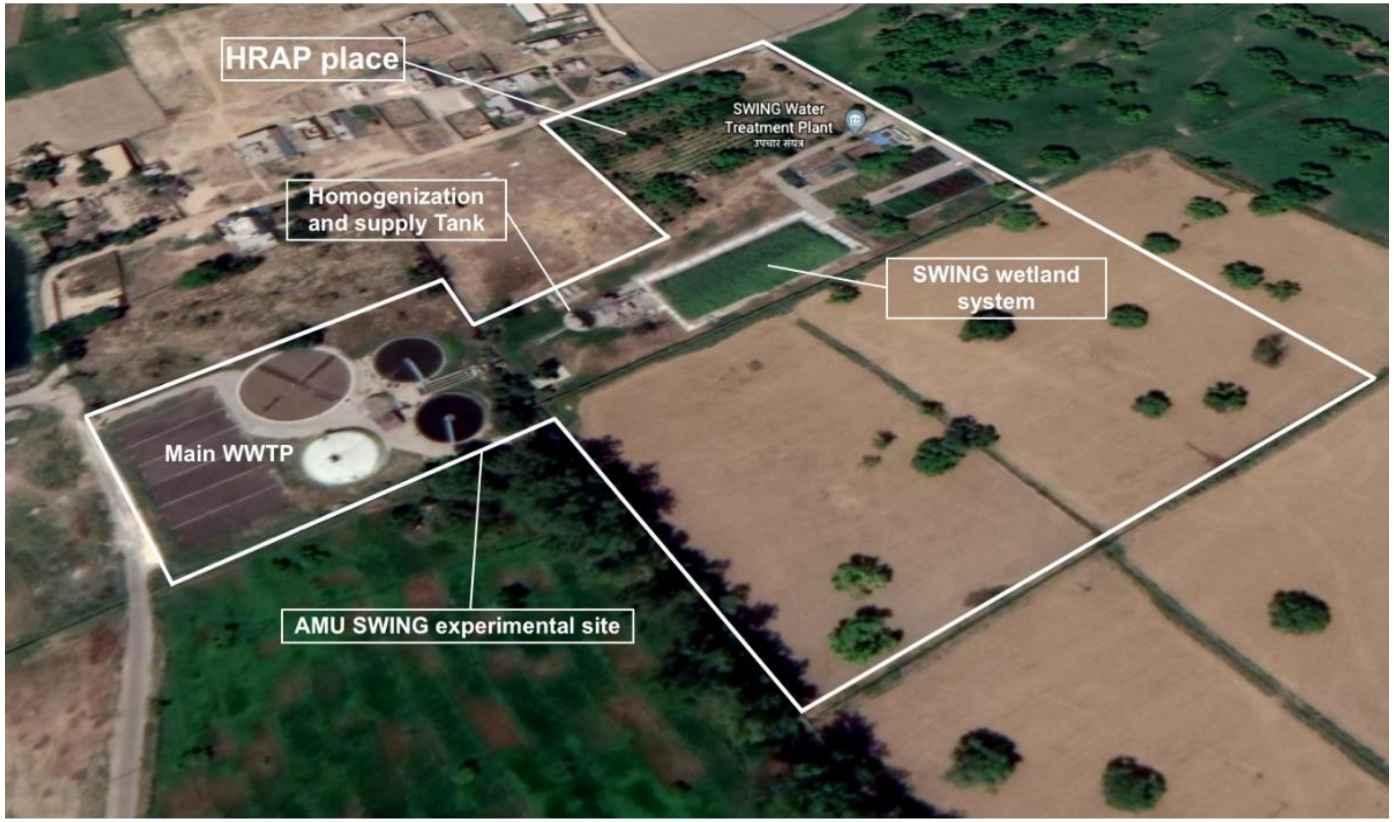

HRAP within PAVITR project

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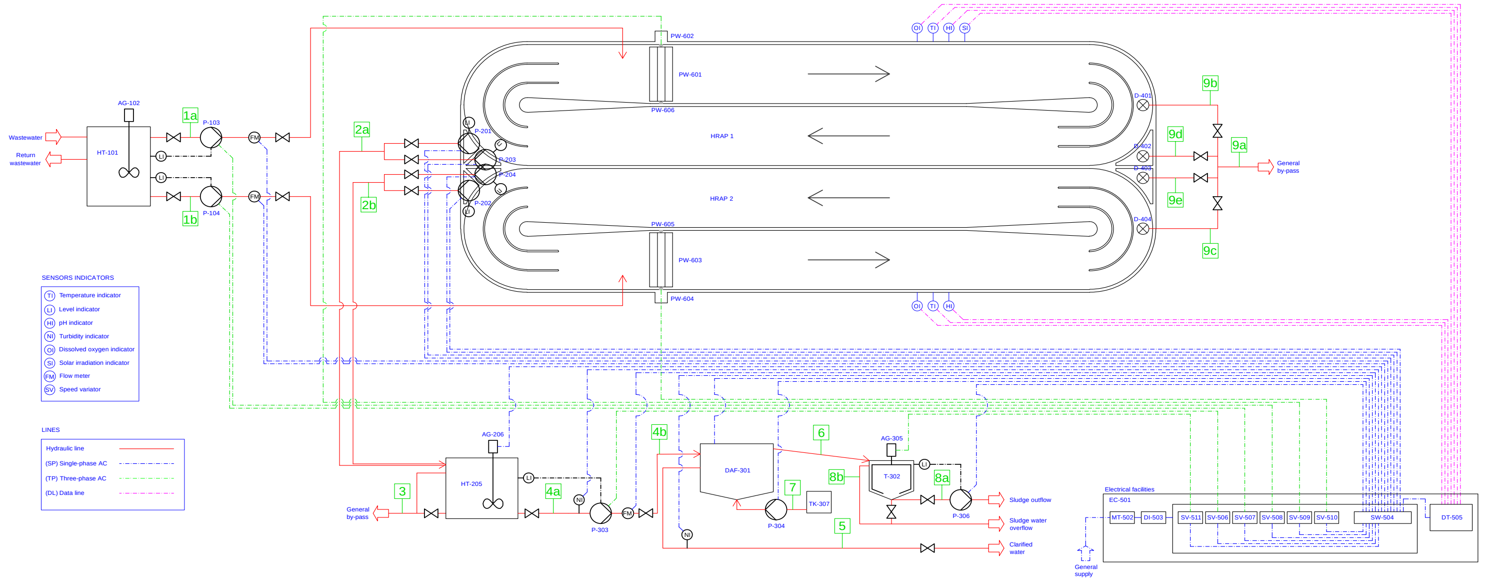

HYDRAULIC FACILITIES			
Stream	Name	Diameter (inc)	Flow [m3/h]
1a	HRAP1 inflow	3	2
1b	HRAP2 inflow	3	2
2a	HRAP1 outflow	1 1/2	variable
2b	HRAP2 outflow	1 1/2	variable
3	Storage tank overflow	2	0 - 2
4a	Storage tank outflow	1 1/2	2
4b	DAF inflow	1 1/2	2
5	DAF Clarified water effluent	2	2
6	DAF Harvested biomass outflow		0.0500
7	Coagulant ejection		variable

HYDRAULIC FACILITIES			
Stream	Name	Diameter (inc)	Flow [m3/h]
8a	Sludge outflow	1 1/2	variable
8b	Sludge overfow	2	0.0500
9a	General drain	5	variable
9b	HRAP 1 overflow	3	variable
9c	HRAP 2 overflow	3	variable
9d	HRAP 1 drain	3	variable
9e	HRAP 2 drain	3	variable

EQUIPMENT		
Label	Name	Size
HT-101	Waste water homogenization tank	5 [m3]
AG-102	Propeller agitator system	
P-103	Three-phase centrifugal pump with velocity control	
P-104	Three-phase centrifugal pump with velocity control	
P-201	Submersible pump with level sensor	1 KW
P-202	Submersible pump with level sensor	1 KW
P-203	Submersible pump with level sensor	1 KW
P-204	Submersible pump with level sensor	1 KW
HT-205	HRAP liquor closed homogenization tank	5 [m3]
AG-206	Propeller agitator system	

EQUIPMENT		
Label	Name	Size
DAF- 301	Dissolved air flotation system	4 [m3/h]
T-302	Closed thickener tank	10 [m3]
P-303	Three-phase centrifugal pump with velocity control	
P-304	Coagulant dosing pump	
AG-305	Propeller agitator system with three-phase motor	
P-306	Centrifugal pump	
TK-307	Coagulant tank	200 [L]
D-401	HRAP 1 drain	3 [inches]
D-402	HRAP 1 overflow drain	3 [inches]
D-403	HRAP 2 overflow drain	3 [inches]

EQUIPMENT		
Label	Name	Size
D-404	HRAP 2 drain	3 [inches]
HRAP 1	High rate algae pond 1	335 [m2]
HRAP 2	High rate algae pond 2	335 [m2]
EC-501	Electrical cabinet	human-size
MT-502	Magneto-thermal circuit breaker	220 V
DI-503	Differencial circuit breaker	30mA
SW-504	Electrical switches panel	one for each equip
DT-505	Datalogger	>10 imputs
SV-506	P-103 speed variator	
SV-507	P-104 speed variator	

EQUIPMENT		
Label	Name	Size
SV-508	P-303 speed variator	
SV-509	P-602 speed variator	
SV-510	P-604 speed variator	
SV-511	AG-305 variator	
PW-601	Paddlewhell of HRAP 1	4 [m]
PW-602	Three-phase paddlewheel motor of HRAP 1 and gearbox	220V / 3KW
PW-603	Paddlewhell of HRAP 2	4 [m]
PW-604	Three-phase paddlewheel motor of HRAP 2 and gearbox	220V / 3KW
PW-605	Axis support	
PW-606	Axis support	

December 2019	Aligarh City, India	SCHEME	Print: A2
Construction project: High Rate Algae Pond	Aligarh Muslim University AMU Campus, Uttar Pradesh 202001	HRAP equipment and hydraulic and electrical facilities	Scale: - Dim: -

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

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Group of Environmental Engineering and Mictobiology

HRAP within PAVITR project

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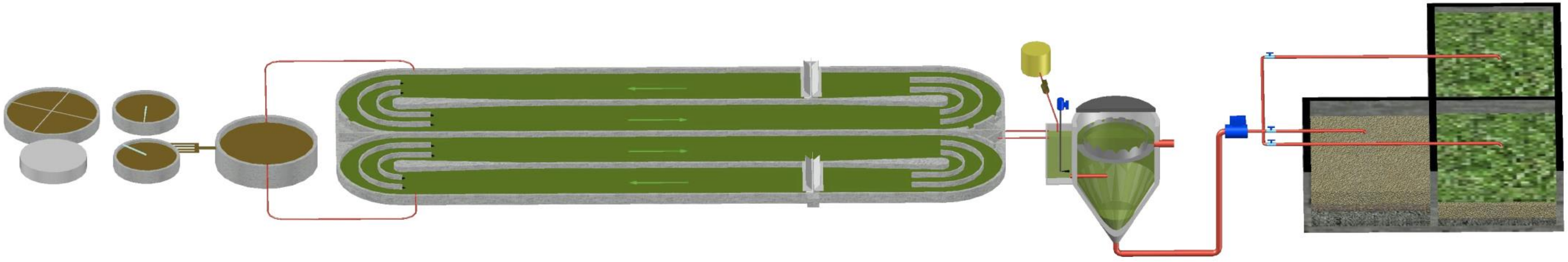

Pretreatment	Homogenization tank	High-Rate Algae Ponds	Biomass Harvesting system (Settler)	Biomass drying (Wetlands)

HRAP within PAVITR project

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Aligarh Muslim University
Campus

HRAP within PAVITR project

HRAP within PAVITR project

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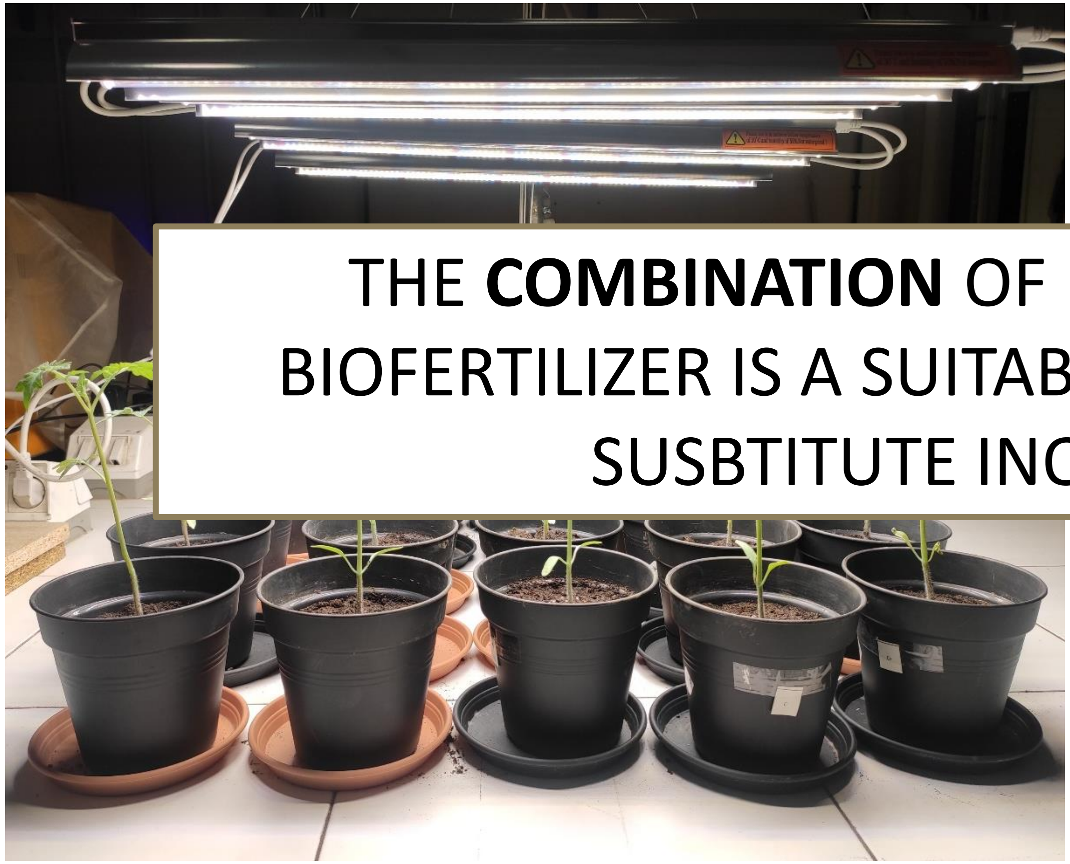

THE **COMBINATION** OF INORGANIC FERTILIZER AND BIOFERTILIZER IS A SUITABLE ALTERNATIVE TO PARTIALLY SUSBTITUTE INORGANIC FERTILIZER

Credits

This training has been created in the framework of the EU-Indian Joint Project “PAVIRT-Potential and Validation of Sustainable Natural & Advance Technologies for Water & Wastewater Treatment, Monitoring and Safe Water Reuse in India”. This project has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement No821410 and the Department of Sciences and Technology of India under the Grant DST/IMRCD/India-EU/Water Call2/PAVITR/2018 (G).

For more information, please visit: https://pavitr.net