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INNOQUA
innovation for wastewater treatment

NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR INDUSTRIAL ECOLOGY
ECOIND
EXCELLENCE IN RESEARCH AND ENVIRONMENTAL SERVICES

Nature-based Wastewater Treatment in Southeastern Europe and Turkey

Algae for decentralised wastewater treatment

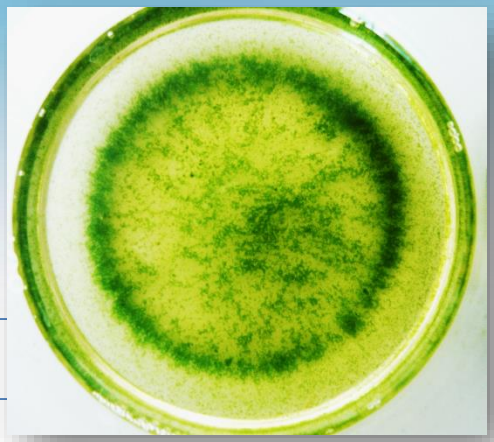
Olga Tiron, Costel Bumbac, Elena Manea (ECOIND, Bucharest)

3 November 2020

This project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement No.689817

Microalgae

3rd generation biomass



Microalgae

Nature

- Feedstock for biofuels
- High-value chemicals (pharmaceuticals, cosmetics)
- Food/feed supplements
- Bioplastic
- Fertilizer in agriculture

circular bioeconomy

- Carbon sequestration
- Sanitation
- Bioremediation
- Eutrophication

Microalgae biotechnology

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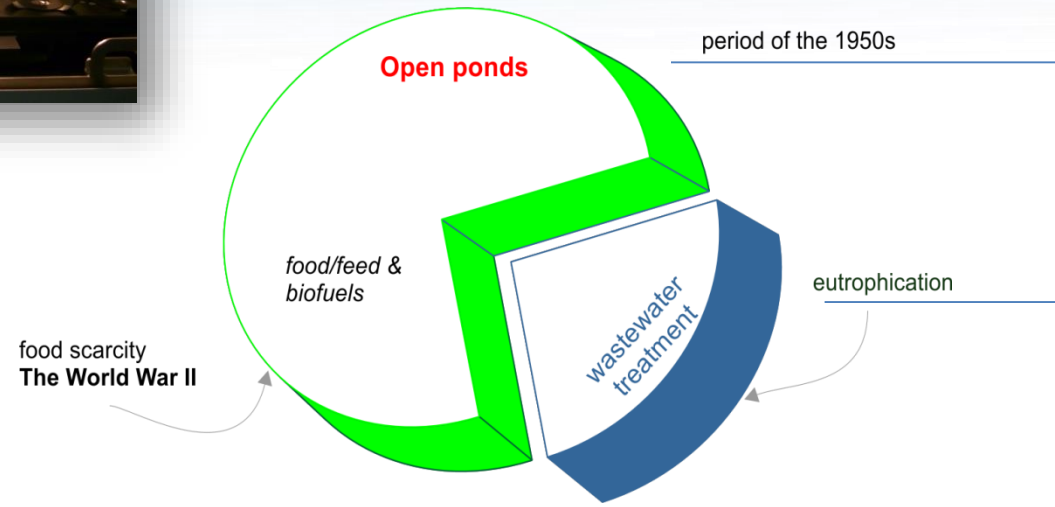
Microalgae biotechnology

Microalgae cultivation



Outdoor commercial production of microalgae (1950s)

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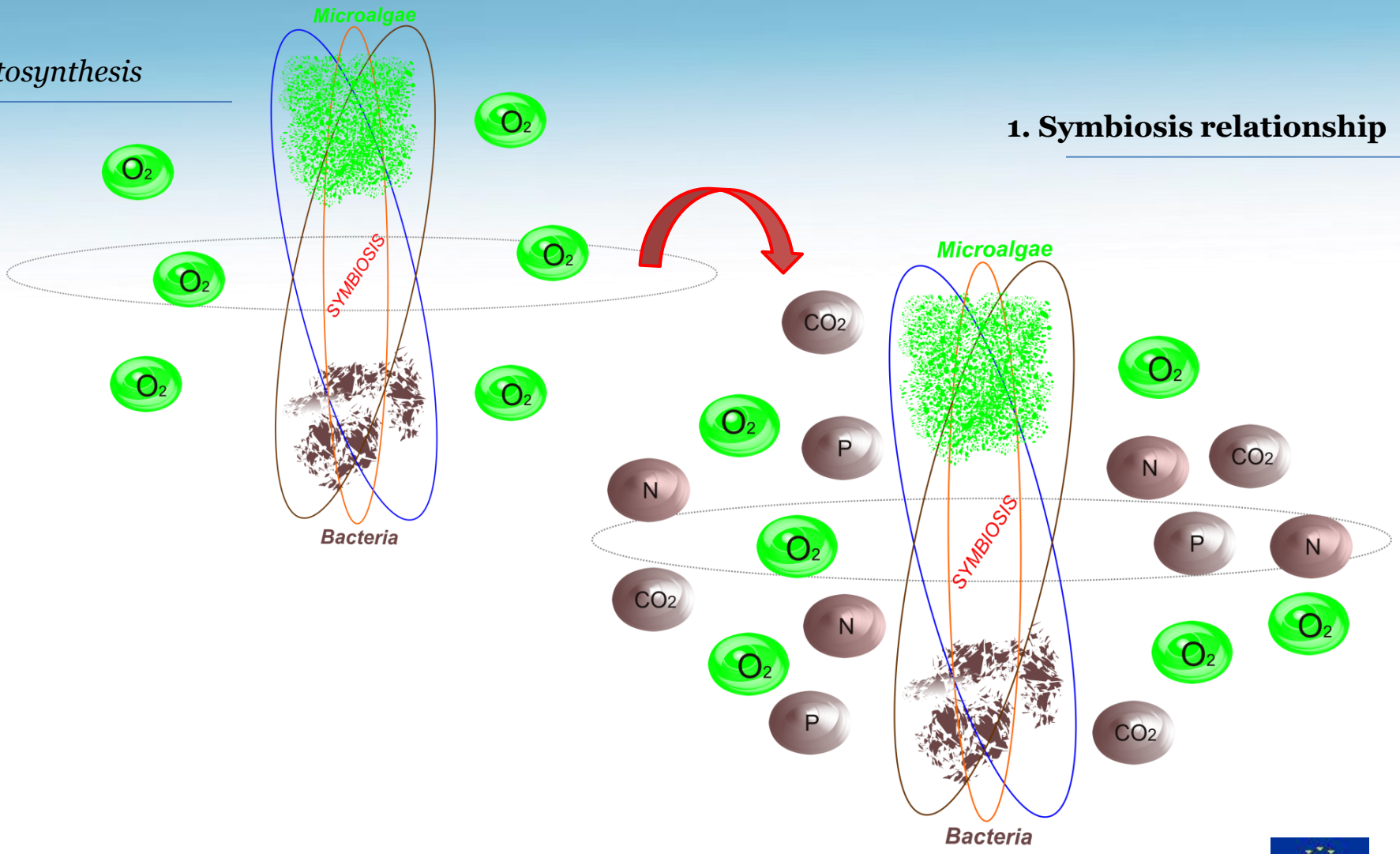
Microalgae bacteria interaction – core principle

photosynthesis

1. Symbiosis relationship



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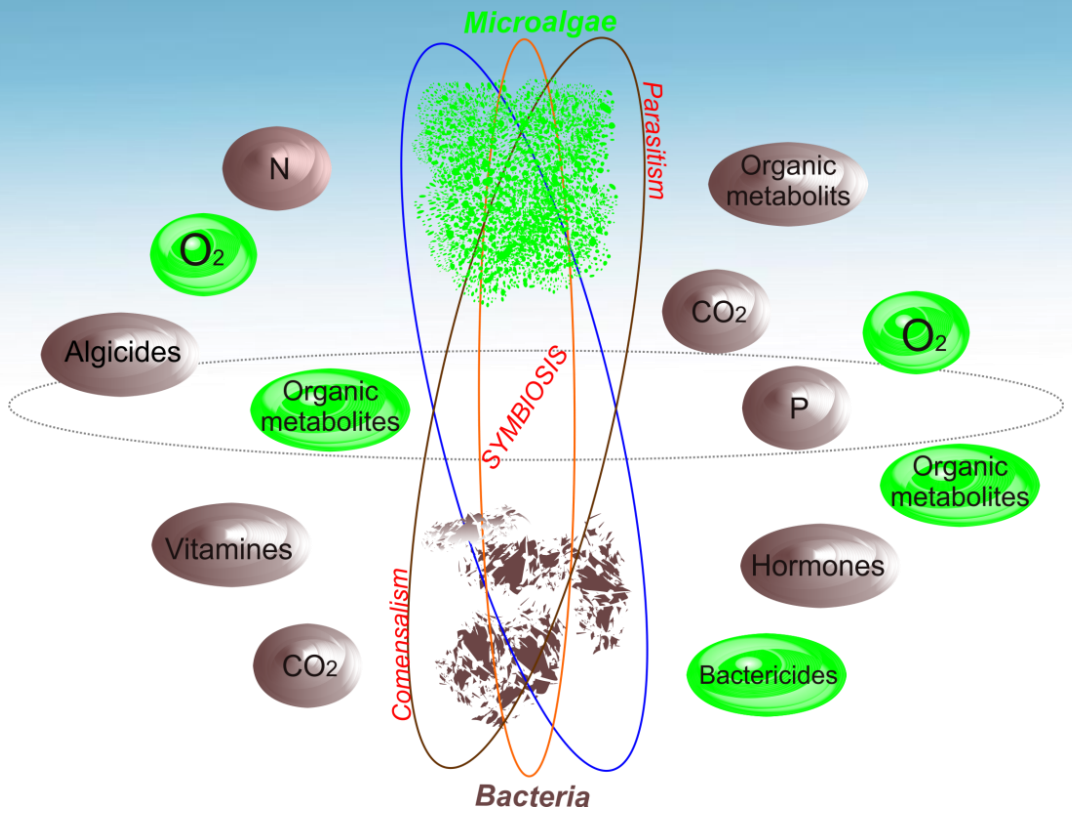
Microalgae bacteria interaction



Microalgae-bacteria metabolic interactions

2. Microalgae – N & P consumer

Total nitrogen < 10 mg/L

Total phosphorus < 1 mg/L

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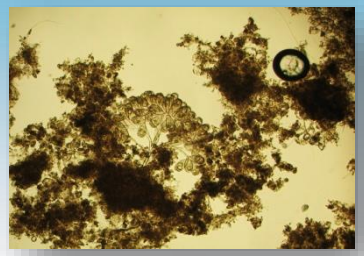
Microalgae-bacteria technology for wastewater treatment

solar irradiance

Microorganisms

Microalgae | **Activated sludge**



Alternative technology for wastewater treatment

overcoming constraints of

• production of microalgae biomass

no fertilizers costs
(source of organic carbon, N, and P)

free water resources

Socio-economic & environmental impact

conventional wastewater treatment •

flue gases

CO_2 capturing
1.83 kg CO_2/kg biomass

no aeration costs

increasing WWT efficiency

decreasing pathogens populations
(faecal coliforms)

waste management improvement
(low-cost by-products; increasing biomass value)

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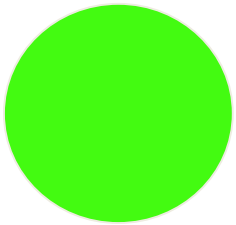
Biotechnology

constraints

Harvesting

- the major concern of the biotechnology scaling
- factors to consider: energy, cost, time & biomass contamination potential
- influences reactors' design and specie selectivity
- microalgae removal efficiency rarely exceeds 95%



< 30 µm

Poor settleability

< $3.6 \cdot 10^{-4}$ m/h

after centrifugation

Dewatering

- another downstream step recognized for its high costs requirements

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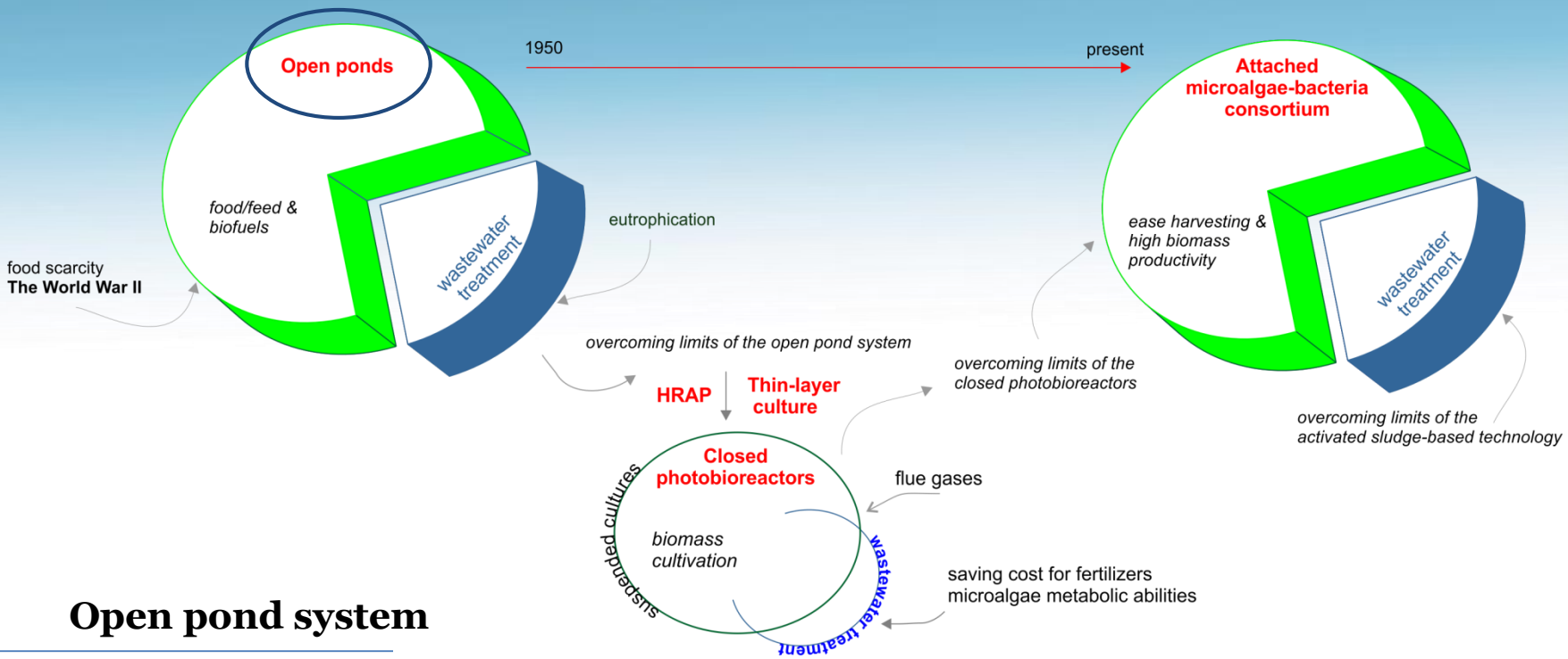
Biotechnology

view on systems

technical evolution



Open pond system

- deep deth (≈ 1 m) & low microalgae concentration (< 500 mg/L)
- irregular photosynthetic activity - O_2 gradient
- low BOD efficiency removal (5-10 g/m² day)
- high HRT (10-40 days)
- biomass productivity: 10-20 g/m² day
- requires high land surface

suspended microalgae biomass

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Biotechnology

view on systems

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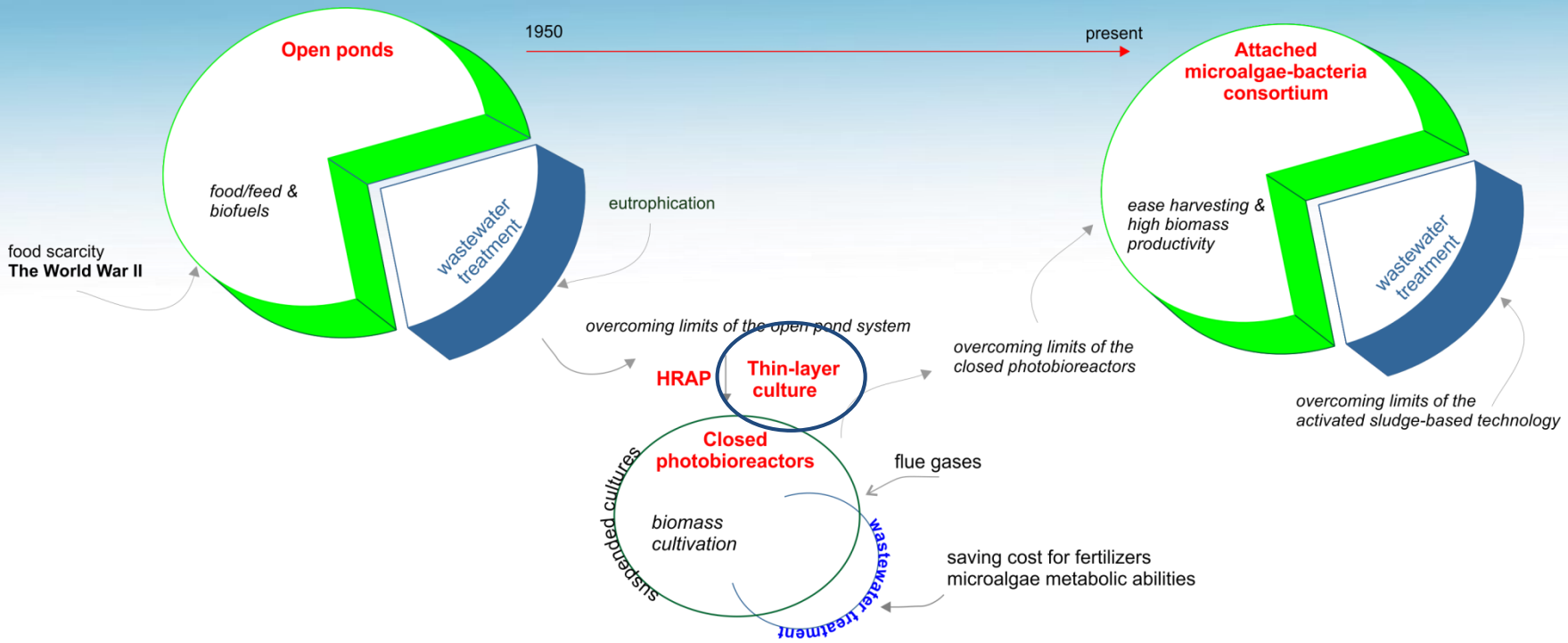

Thin-layer reactor

- slight slope (< 3%) & much lower water depth (< 0.05 m)
- higher biomass productivity (up to 55 g/m² day)
- lower HRT (3-5 days)

suspended microalgae biomass

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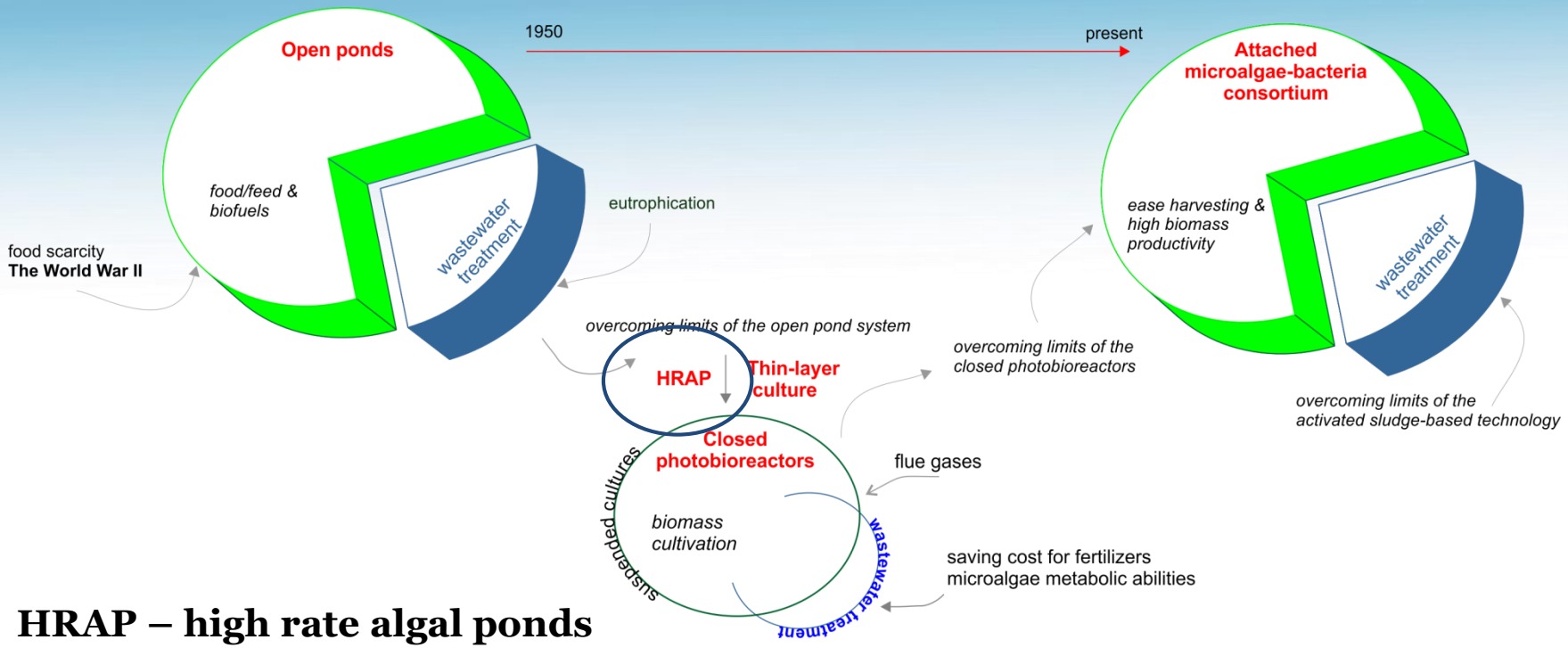

HRAP – high rate algal ponds

- shallow depth (<0.5 m)
- BOD efficiency removal - 35 g/m² day
- HRT < 10 days
- low biomass density
- biomass productivity – 15-25 g/m² day
- requires wide land surface *(even 50 times higher than that for activated sludge process)*

suspended microalgae biomass

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Biotechnology

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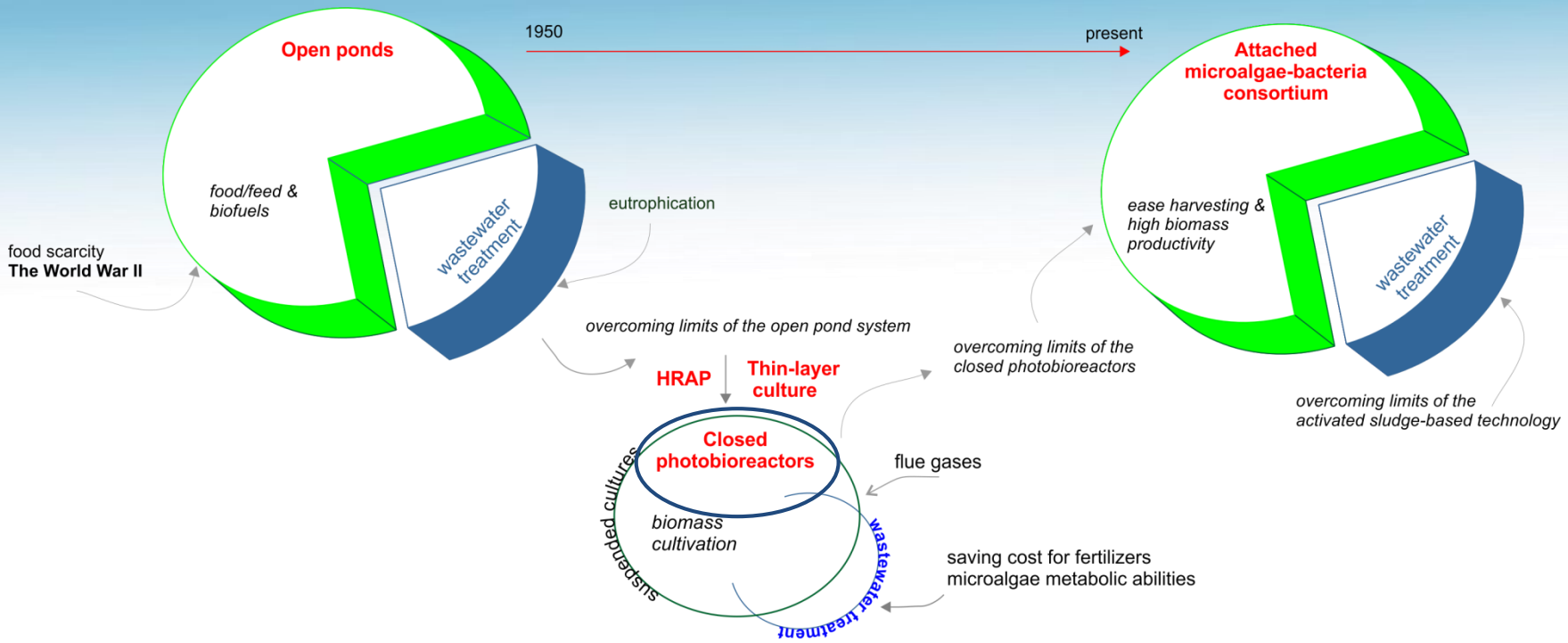
technical evolution



Closed photobioreactors

- ease operational control
- high biomass productivity (up to 47 g/m² day)
- requires high operational costs

suspended microalgae biomass

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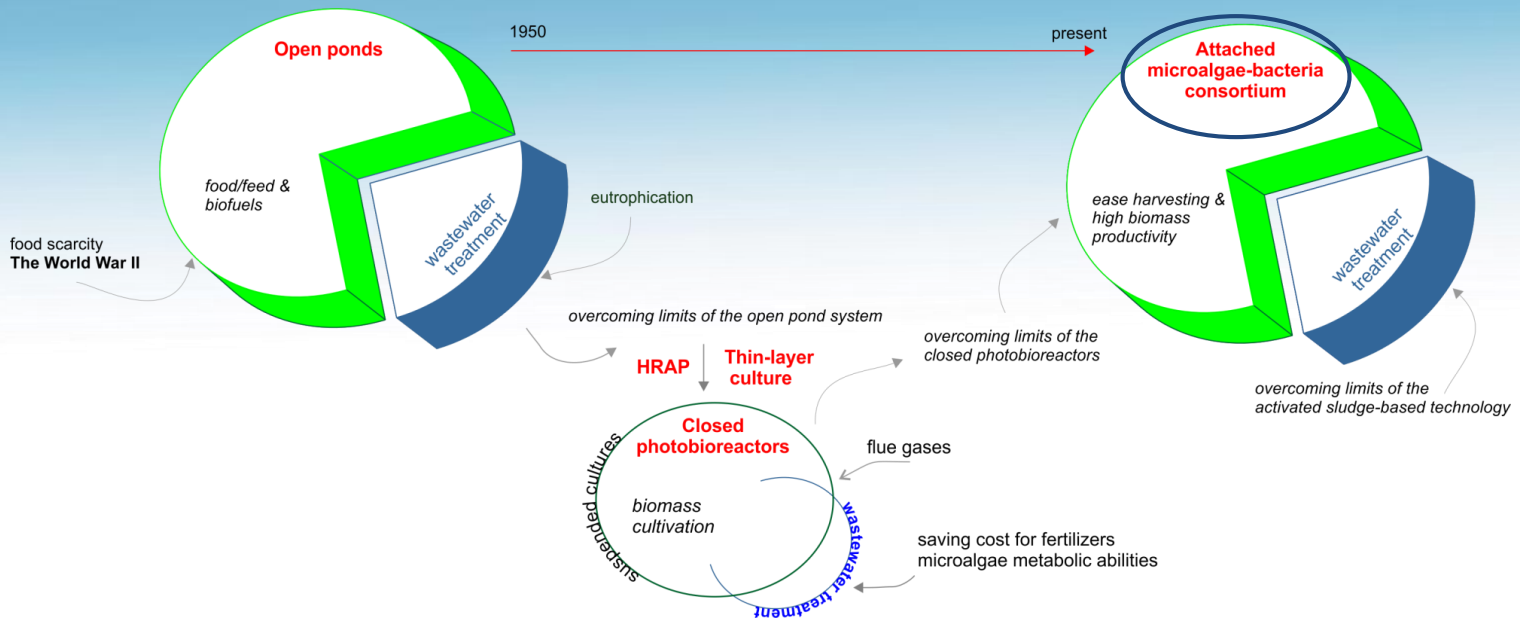
Biotechnology

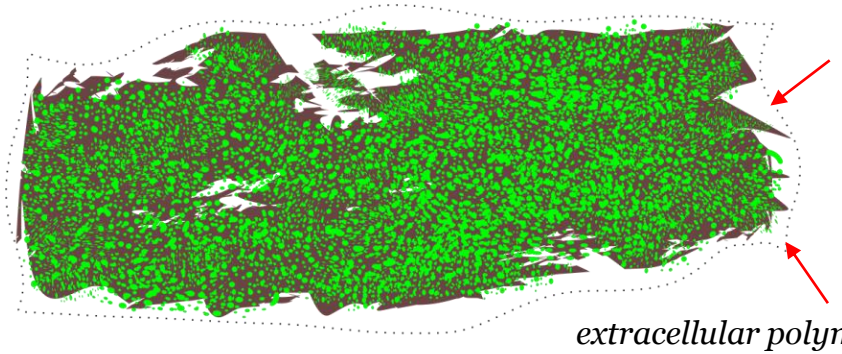
view on systems

technical evolution

Biofilm



Microalgae-bacteria biofilm



physico-chemical interactions

extracellular polymeric substances

attached microalgae-bacteria biomass

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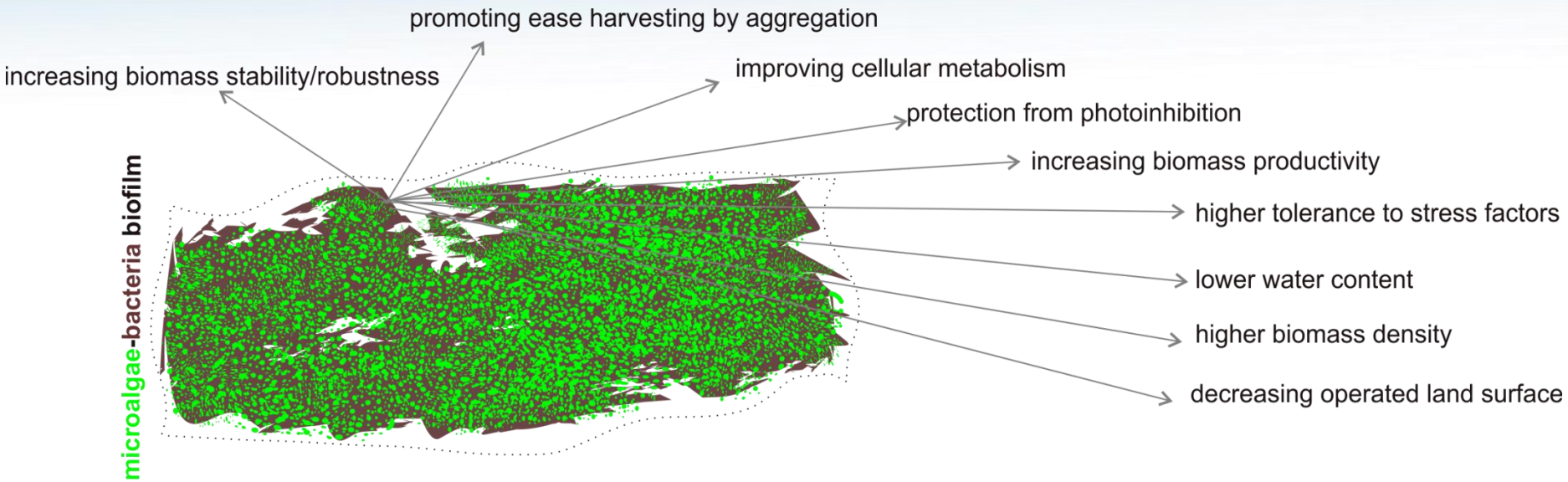
Biotechnology view on systems technical evolution

Biofilm

Advantages:



attached microalgae-bacteria biomass

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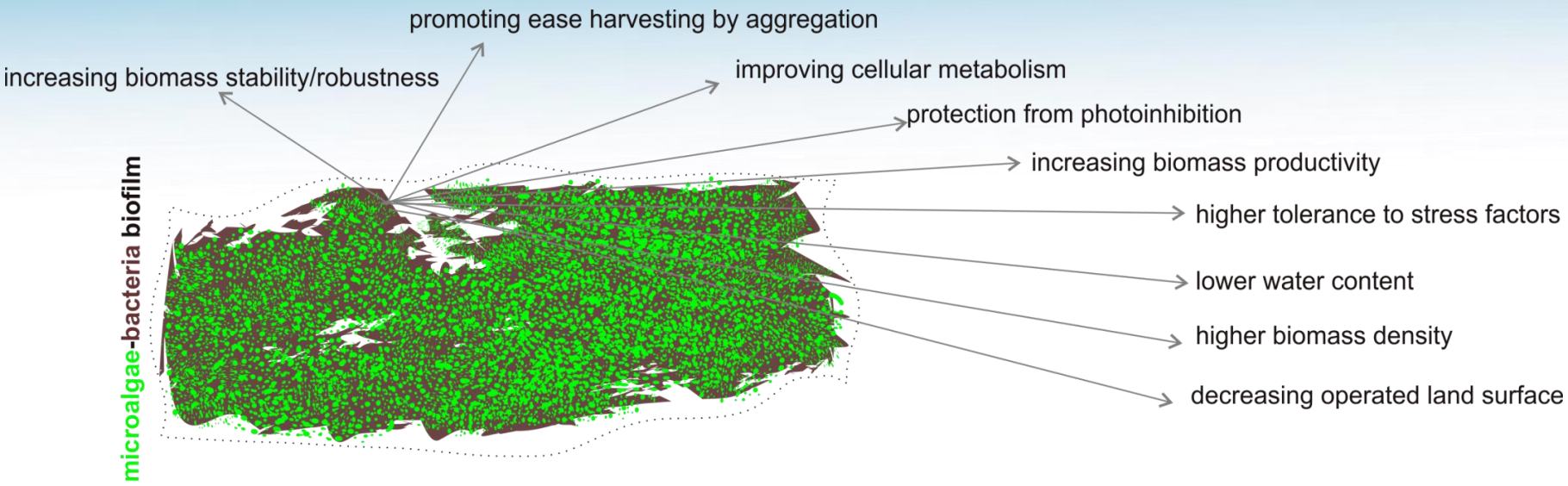
Biotechnology

view on systems

technical evolution

Biofilm

Advantages:



- biomass productivity: 0.5 - 3 g/m²·day , up to 20 g/m²·day
- ex. removal efficiencies:

TN: 3.6-3.9 g/m²·d; **N-NH_4+**: 3.2 - 3.7 g/m²·day; **TP**: 5-8.2 g/m²·day, **COD**: 27-50 g/m²·day

overall performance of COD, TN, TP, N-NH_4^+, and P-PO_4^{3-} removal efficiencies ranging between 78 and 93%

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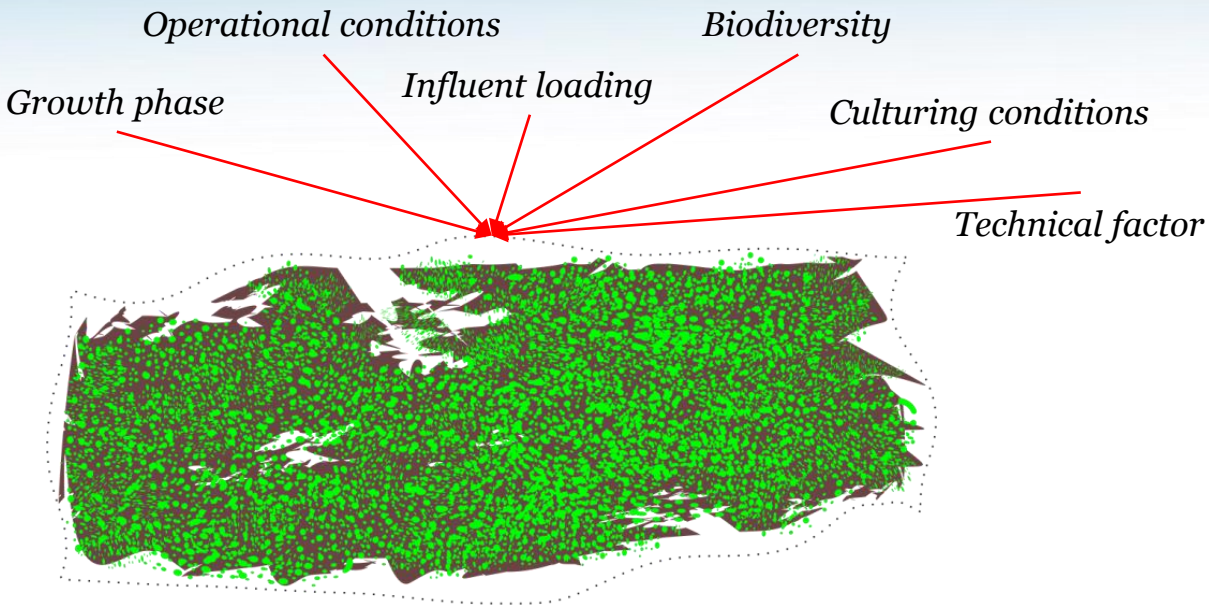
Factors influencing treatment performance



Harvesting frequency:

- photosynthetic activity
- ash content
- biofilm stability
- effluent quality
- predators community

Tested wastewater sources:

- municipal and industrial WW
  (effluent from food processing industries, textile, swine, aquaculture,other livestock manure, acide mine drainage)
- centrate fron anaerobic digestion
- domestic WW
- agricultural drainage

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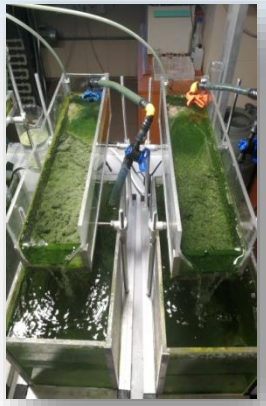
Expertise

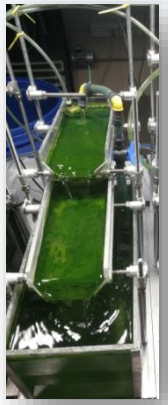
INNOQUA – BSP (*lab-scale*) Romania

Bio-Solar Purification system

Double-layer cascade reactor



Thin-layer cascade reactor



Single platform bioreactor

Short-term response (*start-up*)

Average mass removal efficiencies (**g/m²/day**)	**COD**	29.96	29.92	31.20
	Total P	1.14	1.23	1.32
	Total N	11.99	12.47	13.38

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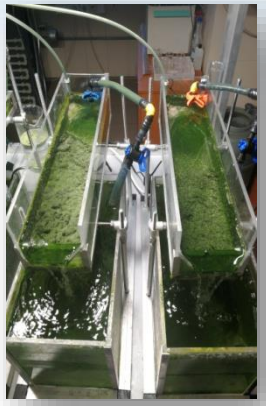

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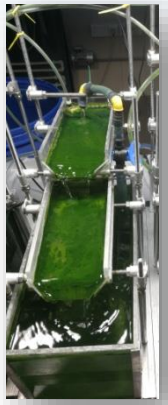

Single platform bioreactor

Long-term response

	Double-layer cascade reactor	Thin-layer cascade reactor	Single platform bioreactor
Average removal efficiencies (%)			
COD	52.9-91.7	32.7-94	42.7-91.3
Total P	3.7-73.7	0.4-78.7	-
Total N	24.1-27.9	9.4-91.7	-

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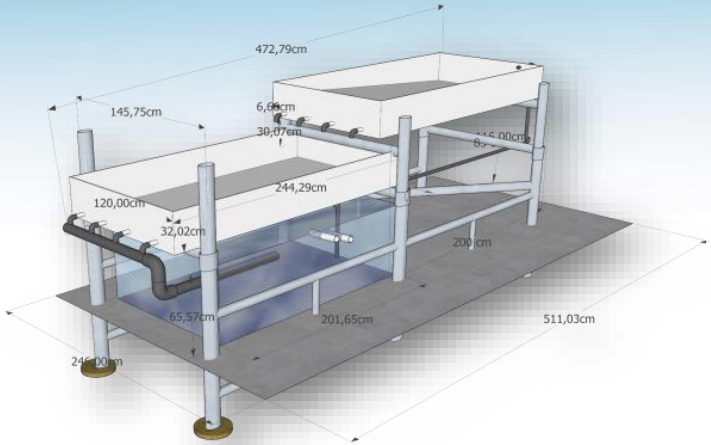
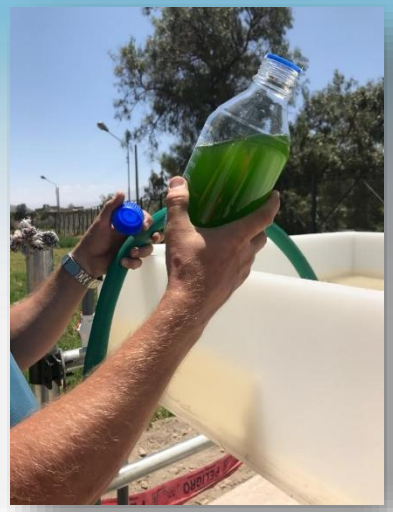
Expertise

INNOQUA – BSP / INDIA *demonstration site*

Effluent polishing – domestic wastewater





	Removal rate %			
	TSS	**BOD_5**	**COD**	**NH_4-N**
Average	67.1	66.57	58.97	76.15
Standard deviation	±22.33	±26.92	±23.85	±20.44

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Expertise

INNOQUA – BSP / GIRONA *demonstration site*

Effluent polishing – municipal wastewater

	Removal rate (%)				
	TSS	**BOD**	**NH_4-N**	**PO_4-P**	**Turbidity**
Average	62.55	39.52	57.48	35.07	59.35
Standard deviation	±29.09	±20.06	±41.46	±28.86	±30.09

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Expertise

INNOQUA – BSP / PERU *demonstration site*

Effluent polishing – university campus wastewater

	% Removal rate							
	TSS	**BOD_5**	**COD**	**NH_4-N**	**TN**	**TP**	**PO_4-P**	**Turbidity**
Average	69.73	23.35	12.59	47.62	22.09	22.02	22.96	56.48
Standard deviation	±35.08	±21.07	±20.76	±25.48	±16.95	±26.82	±26.29	±41.2

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Thank you for your attention!

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