Nutrient recovery from industrial waste water using microbial fuel cell technologies

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Closing waste water cycles for nutrient recovery

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101000752.

Project overview

WalNUT family

PROJECT COORDINATOR

CARTIF

BIOPHOSPHATE 100% NATURAL

Aquafin

CETAQUA WATER TECHNOLOGY CENTRE

aGRICULTURES & TERRITOIRES CHAMBRES D'AGRICULTURE

ICONS

INSTITUTO TECNOLÓGICO AGRARIO | Junta de Castilla y León

SDU

UNIVERSIDADE D COIMBRA

UNIVERSITY OF COPENHAGEN

GHENT UNIVERSITY

AGRINNOVA RESEARCH BEARS ITS FRUITS

VEOLIA

CE-RUR-08-2018-2019-2020 (sub-topic D): Closing nutrient cycles

Scope D: Bio-based fertilisers from waste water and sewage sludge

WalNUT is a EU funded project that aims to **redesign** the value and supply chain of nutrients from **waste water** and brine, creating innovative solutions for **nutrient recovery** while contributing to **circular economy** and sustainability in the EU agricultural sector.

Start: *September 2021*
End: *February 2026*
Duration: *54 months*

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Objectives

- Analyse **nutrient imbalances** within inter and intra-regional EU territories
- Develop, test and validate sustainable and resource-efficient technological solutions for **nutrient recovery** from different sources of waste water
- Environmental and socio-economic **impact assessment** of the proposed solutions
- Assess the **agronomic efficiency** of safe bio-based fertilisers (BBFs)

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WalNUT Full Picture

- WalNUT addresses the current **gaps in nutrient cycles** of different European waste water (WW) treatment systems and their related environmental problems.
- The project will develop concepts and technological solutions to **re-design** the **value** and **supply chains of nutrients** from WW and brine.
- WalNUT solutions will promote a new **circular strategy** to increase the sustainability of the **WW treatment industry** and help prevent the pollution of large bodies of water.
- Promote circular economy towards the replacement of **non-renewable mineral fertilisers** in the EU agricultural sector.

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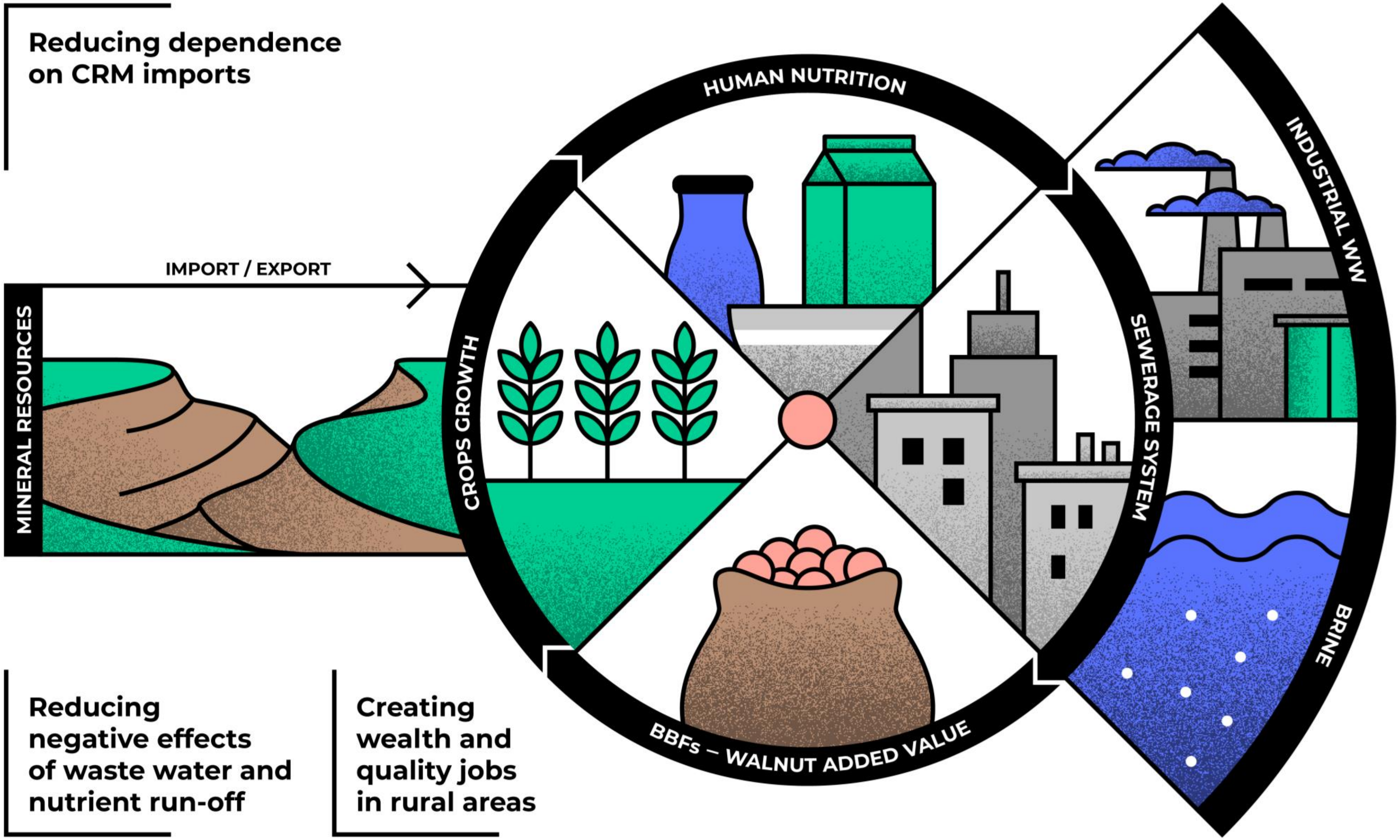
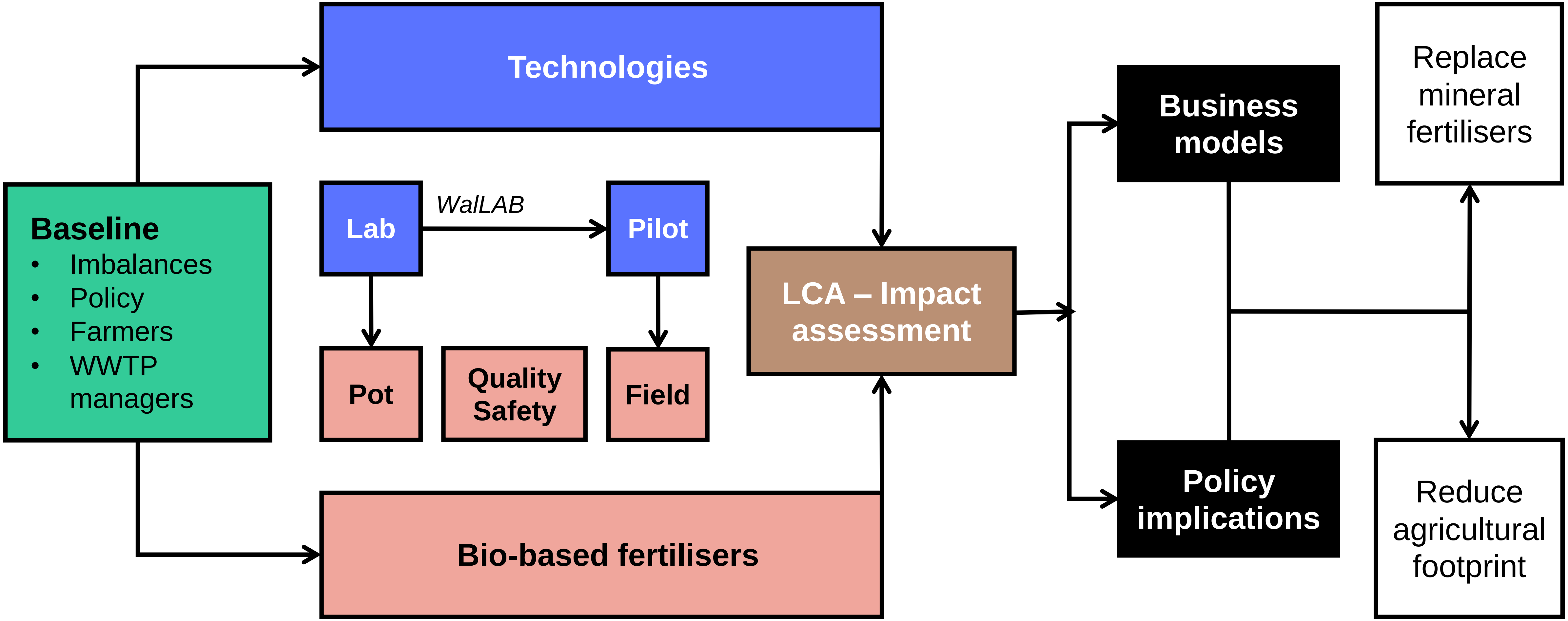
WalNUT Concept

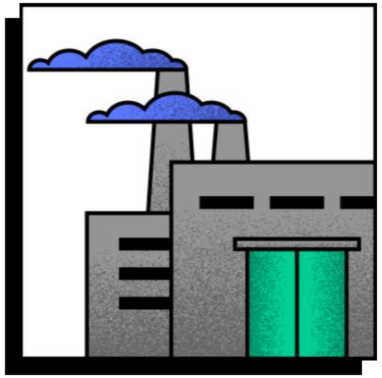


WalNUT Methodology



PILOTS

SPAIN (centre)

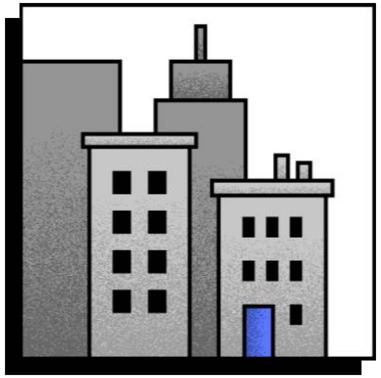


RESPONSIBLE PARTNER
VEOLIA and CARTIF

TYPE OF FEEDSTOCK
Industrial WW

NUTRIENTS RECOVERED
N, P

BELGIUM



RESPONSIBLE PARTNER
Aquafin NV

TYPE OF FEEDSTOCK
Real municipal WW / Urban WW

NUTRIENTS RECOVERED
N, P

HUNGARY

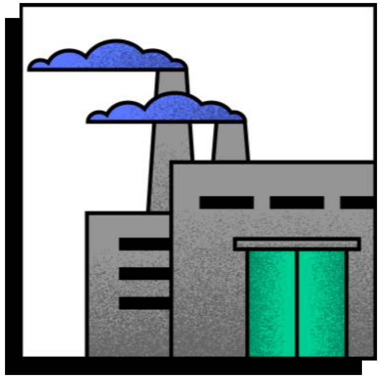
RESPONSIBLE PARTNER
3R-BioPhosphate Ltd.

TYPE OF FEEDSTOCK
Dairy and cheese dairy (acid whey)

NUTRIENTS RECOVERED
N, P, K, C and micronutrients

PILOTS

GREECE



RESPONSIBLE PARTNER

National Technical University of Athens (NTUA)

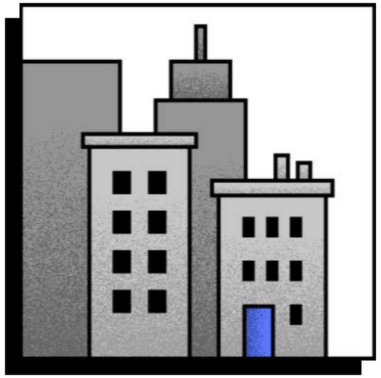
TYPE OF FEEDSTOCK

Seawater desalination brine

NUTRIENTS RECOVERED

K – KCl; Mg – Mg(OH)2

SPAIN (Northwest)



RESPONSIBLE PARTNER

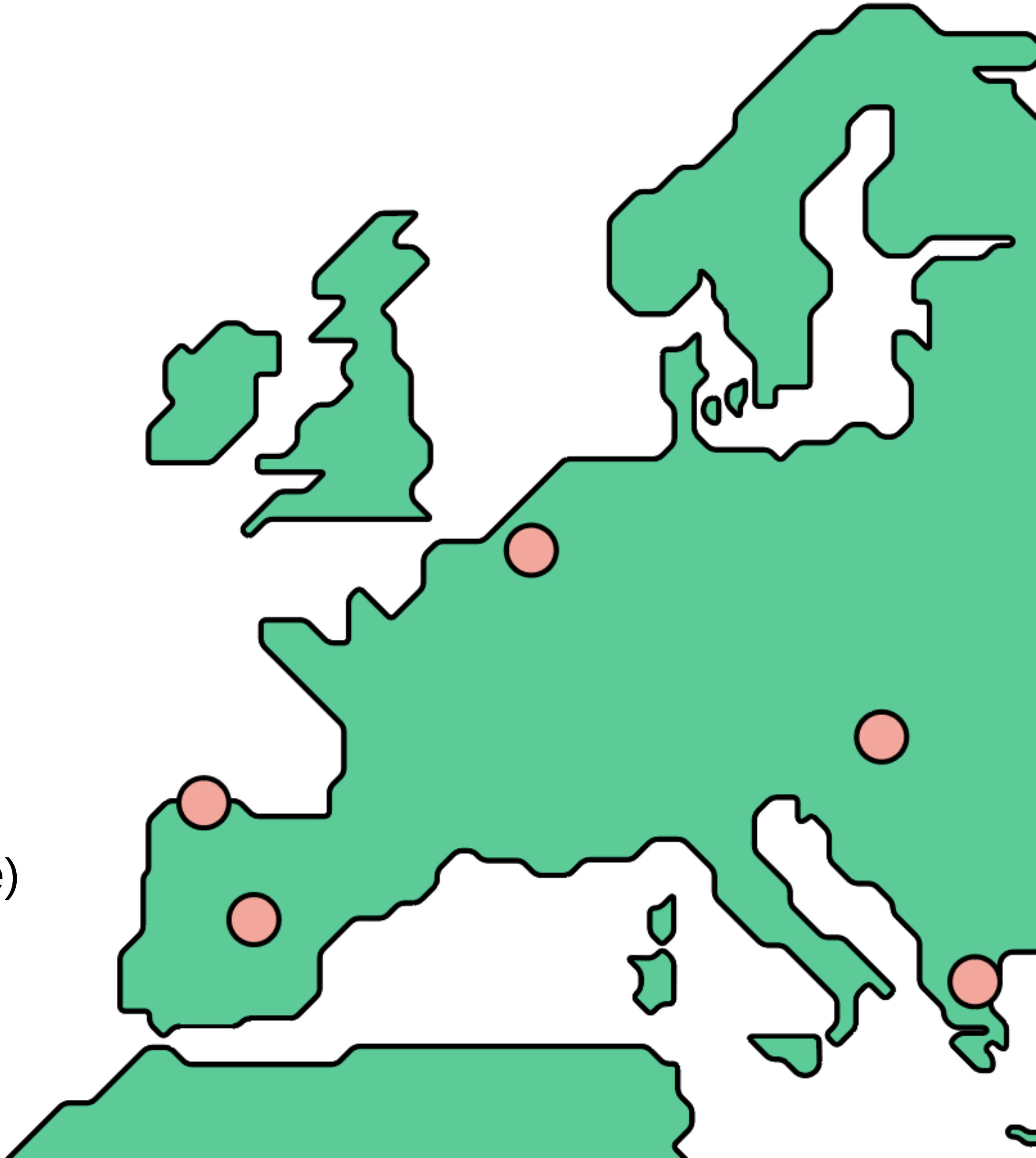
CETAQUA

TYPE OF FEEDSTOCK

Reject water

NUTRIENTS RECOVERED

N (as ammonium nitrate)



Microbial fuel cells technology

Microbial fuel cell technology

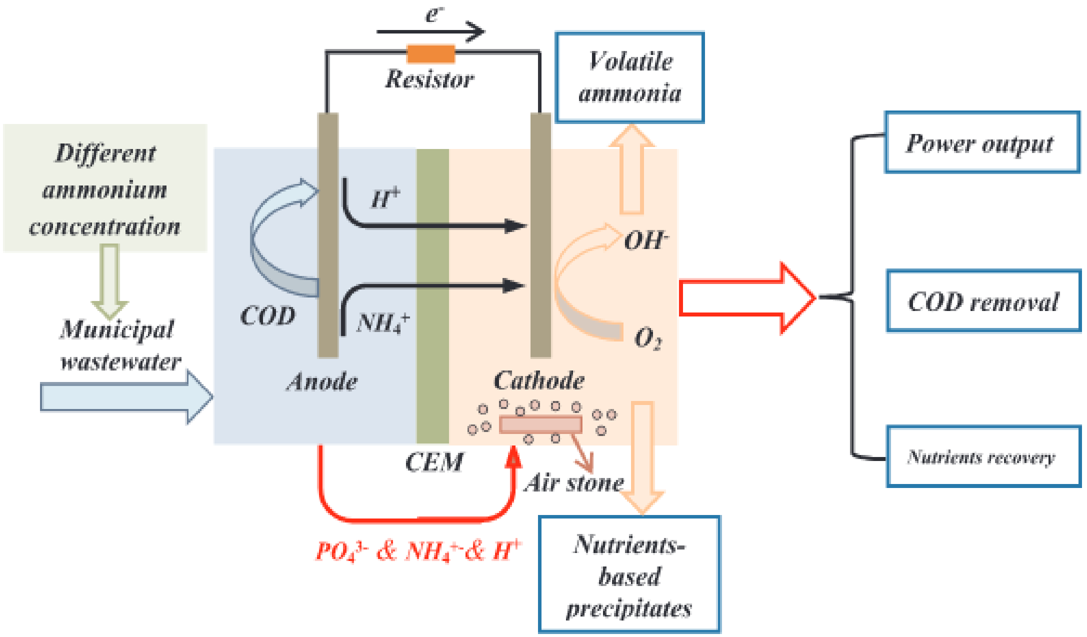
Microbial fuel cells (MFCs) are ecofriendly biotechnologies in which electrogenic or electroactive bacteria (EAB) convert chemical energy contained in their substrates to electricity.

Anode (left) was loaded with the WW to be treated and inoculated with bacteria.

Catode (right) was charged with deionised water.

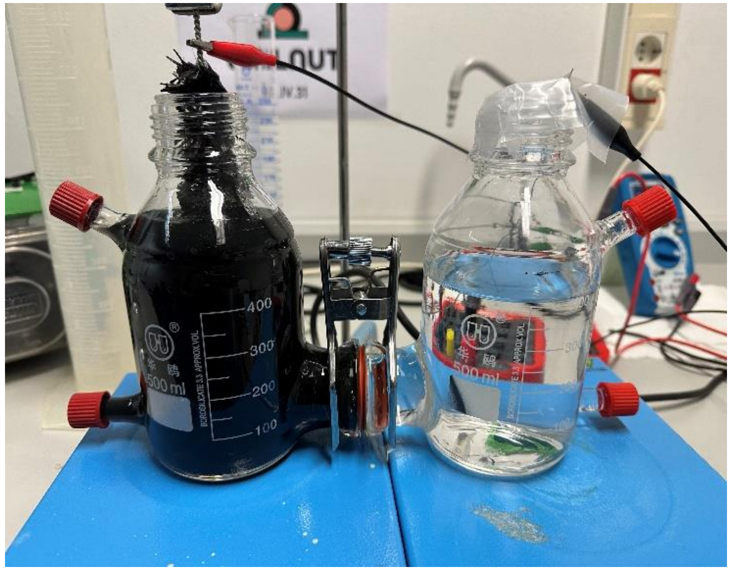
Each of the **electrodes** was connected to a **decade box** to introduce a certain electrical resistance into the system (3 kΩ).

In anode **electrons** were generated and **promote** ions **diffusion** for anode to catode.

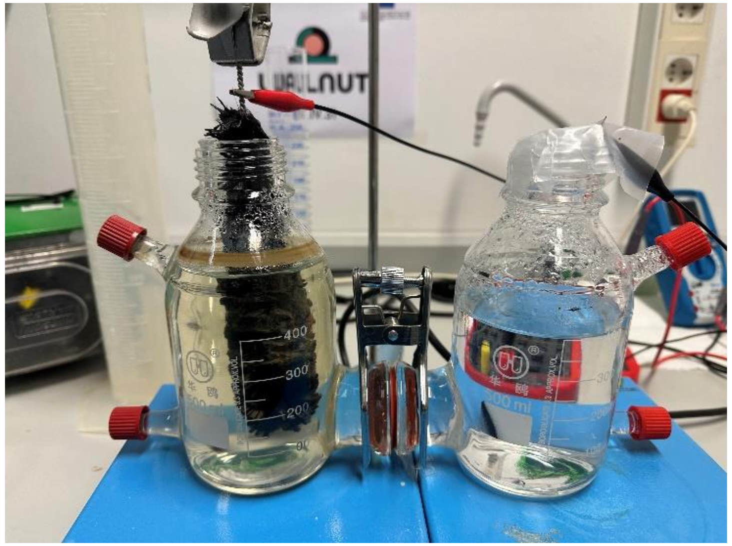


Lab test MFC technology

- **H-shape** cell was used as MFC.
- Each chamber: **500 mL** of volume.
- Membrane: **Nafion 117**
- **Anaerobic sludge** from WWTP was used as inoculum.
- Retention time: **7-10 days**
- Electrode material:
  - Graphite
  - Titanium
  - Platinum
- Electrode shape:
  - Brush
  - Bar
  - Sheet
  - Wire
- Type of waste water:
  - Synthetic WW
  - Dairy WW
  - Brewer WW
  - Plastic treatment WW



Start point test



After 7 days

CHANIA2023 21-24 JUNE

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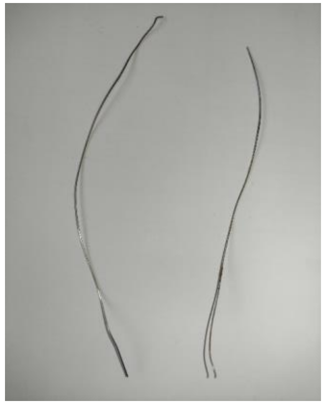
Design of experiments (DOE)

<table>
<tr><th>Factors</th><th colspan="7">Levels</th></tr>
<tr><td>Electrode material</td><td colspan="5">Graphite</td><td>Titanium</td><td>Platinum</td></tr>
<tr><td>Electrode shape</td><td>Brush</td><td colspan="2">Bar</td><td colspan="2">Sheet</td><td colspan="2">Wire</td></tr>
<tr><td>Type of waste water</td><td colspan="2">Synthetic</td><td colspan="2">Dairy</td><td colspan="2">Brewery</td><td>Plastic treatment</td></tr>
</table>

- Outputs:
  - % N nutrient recovery
  - % P nutrient recovery
  - COD degradation



Electrodes used in tests (before and after use)

Results

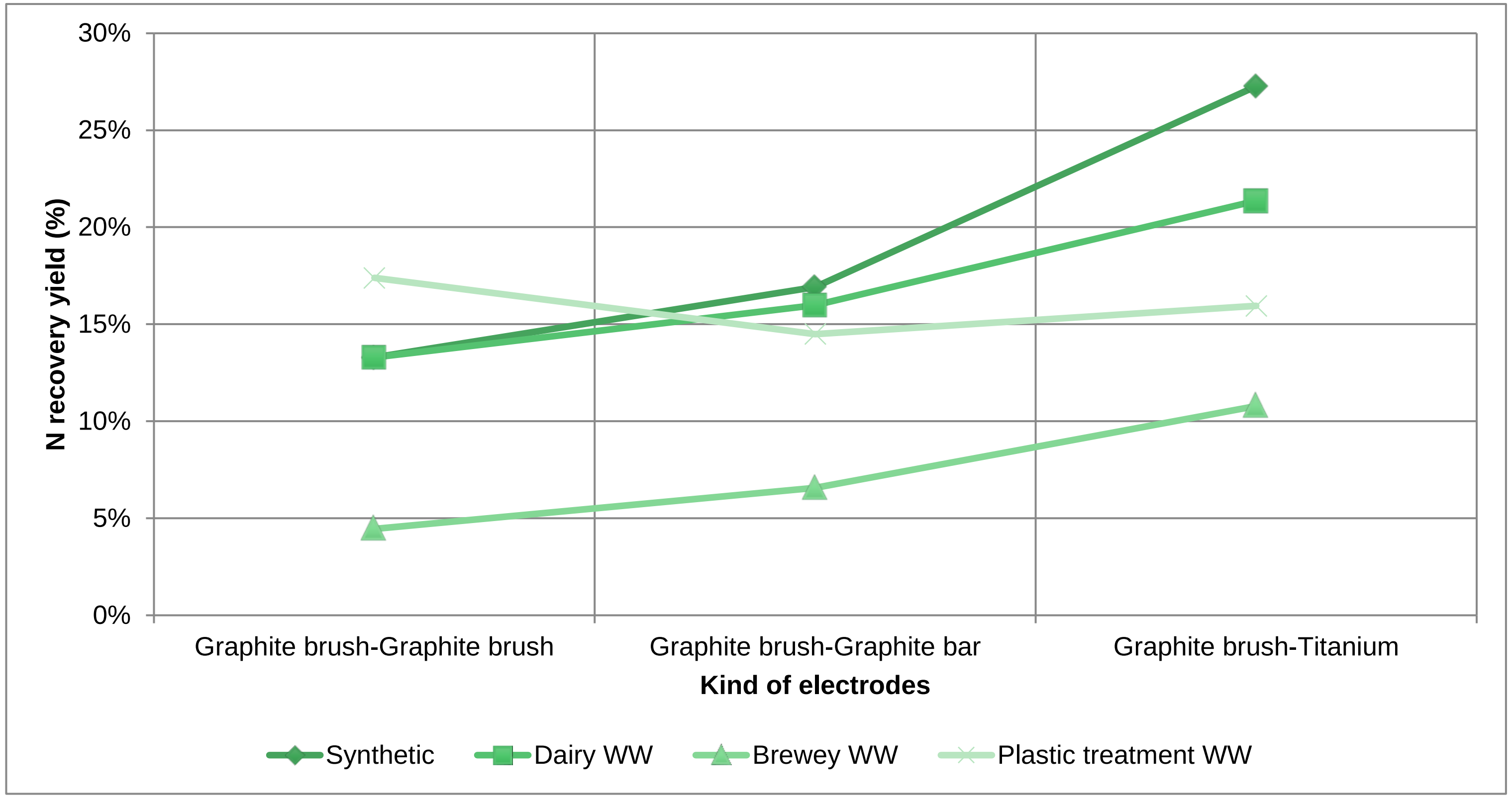
Results

Test #	[N total] initial (mg/L)	[P total] initial (mg/L)	[DQO] initial (mg/L)	[N total] final (mg/L)	[P total] final (mg/L)	[DQO] final (mg/L)	N recovery yield (%)	P recovery yield (%)
1	217.5	36.65	5410	188.6	35.1	3680	13.3	4.2
2	217.5	36.65	5410	180.7	35.7	3772	16.9	2.5
3	217.5	36.65	5410	158.2	34.9	3621	27.3	4.8
4	70.7	14.6	2700	61.3	14.0	1509	13.3	4.1
5	70.7	14.6	2700	59.4	13.7	1493	16.0	6.2
6	70.7	14.6	2700	55.6	13.3	1495	21.4	8.9
7	61.65	9.52	1343	58.9	9.3	869	4.5	2.3
8	61.65	9.52	1343	57.6	9.1	931	6.6	4.4
9	61.65	9.52	1343	55	8.9	974	10.8	6.5
10	6.9	0.22	573	5.7	n.d.	324	17.4	n.d.
11	6.9	0.22	573	5.9	n.d.	341	14.5	n.d.
12	6.9	0.22	573	5.8	n.d.	335	15.9	n.d.
13	70.7	14.6	2700	65.7	14.1	1866	7.1	3.4
14	70.7	14.6	2700	61.1	13.8	1802	13.6	5.5
15	70.7	14.6	2700	57.2	13.6	1568	19.1	6.8
16	70.7	14.6	2700	65.6	14.0	1671	7.2	4.1
17	70.7	14.6	2700	61.9	14.1	1157	12.4	3.4
18	70.7	14.6	2700	57.8	13.9	1384	18.2	4.8

n.d.: not detected

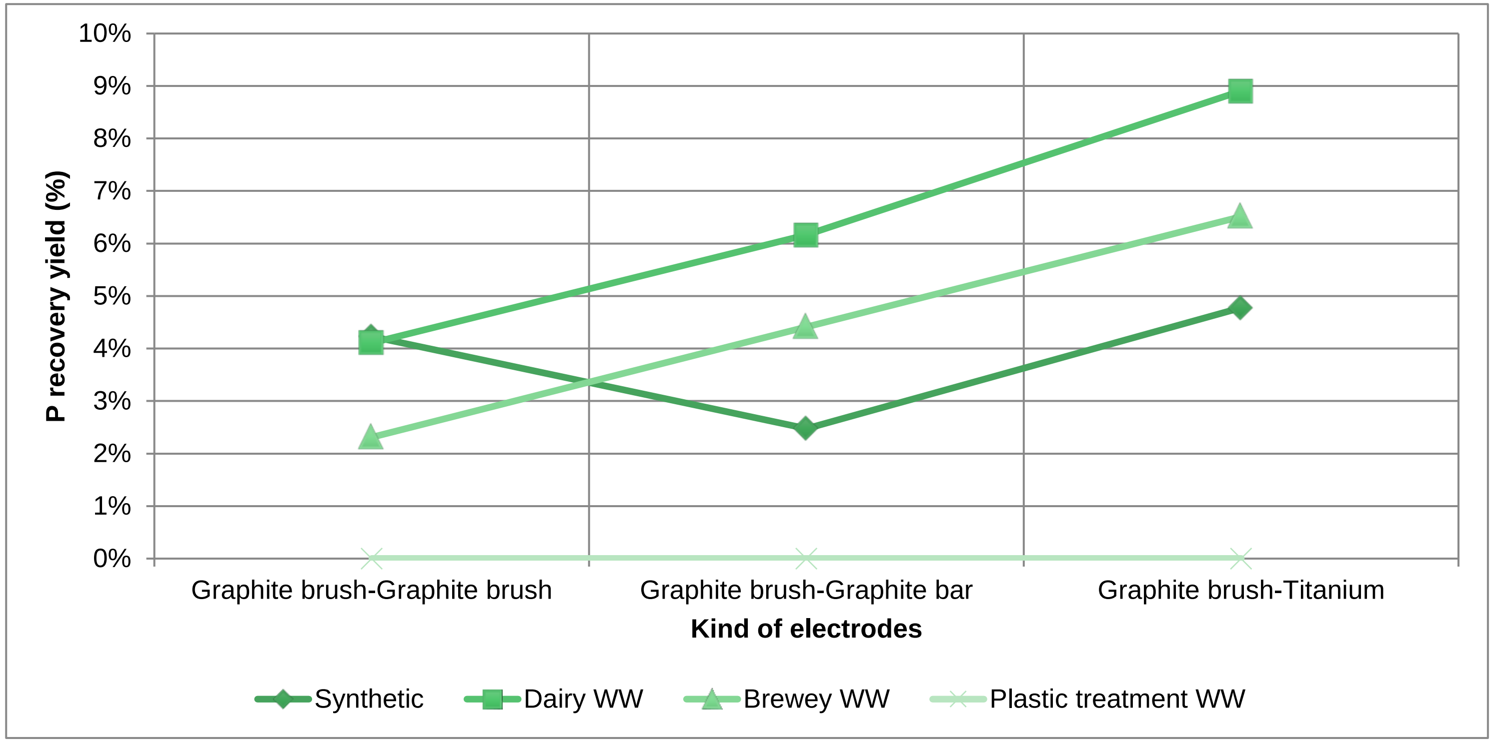
Results

- Nutrient recovery yield (nitrogen):



Results

- Nutrient recovery yield (phosphorous):



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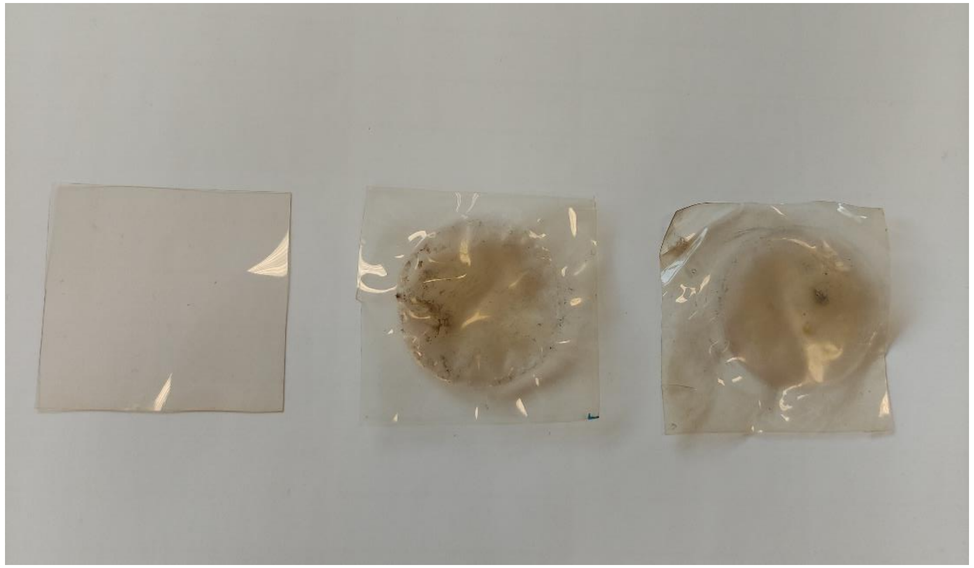
Results

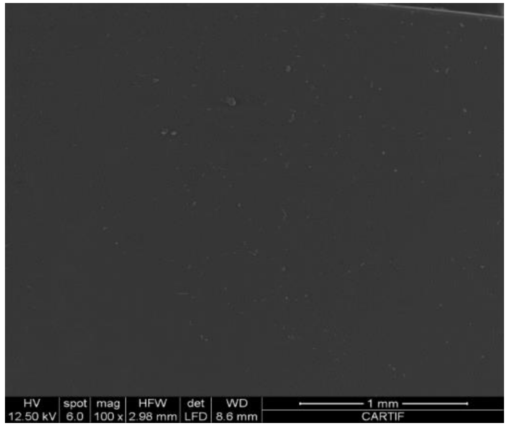
- Regarding **kind** of **WW** and **electrode**:
  - MFC best in **Dairy WW**
  - Electrode material: **graphite (brush) – Platinum.** Very expensive electrode
  - Electrode shape: **brush graphite best results**. More available surface area

- Best DOE outputs
  - % N recovery: up to **21%**
  - % P recovery: up to **9%**
  - COD reduction: up to **50%**

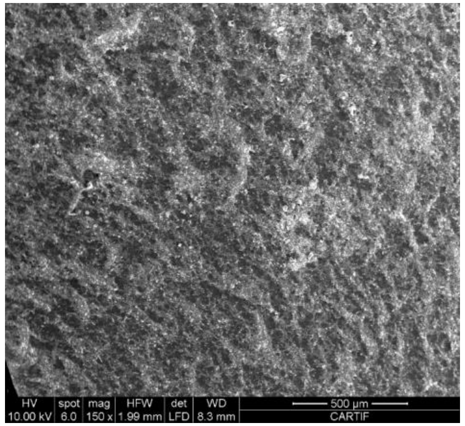
Nafion 117 membrane

- At the end of the experiments higher degree of **fouling** and **clogging**.
- Accumulation only occurs on the **anode side**.
- Cathode side surface remained largely intact.
- Direction of **transport and diffusion** of matter through the membrane occurs from anode to cathode and it is the anode chamber that contain the WW.





Initial Nafion 117 membrane



Final Nafion 117 membrane

Microbiological processes comparative

Microalgae vs MFC

- At the same time as the MFC test, a laboratory-scale study was carried out to treat the same WW by **heterotrophic microalgae cultivation**.
- **5 L heterotrophic reactors** at 25-30 ºC.
- Inoculum was obtained in a **photobiorreactor**.
- Inoculation of DWW with concentrations **1 g/ L** of algae showed the best performance, but operating with 0.5 g/ L is also adequate.
- The retention time **3 days**.
- Biomass production: current prediction **100-300 mg DM / L / day**.
- Nitrogen reduction up to **90.71%**.
- **99.25%** of Phosphorus was removed.
- Maximum COD removal **92.53%.**

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Conclusions

Conclusions

- A **nutrient recovery yield** of **20%** for N and **9%** for P is achieved with waste water from WWTPs, a for 7 days of operation.
- The organic load (**COD**) of the WW is reduced by **up to 50%** for 7 days of operation, but this is far from the limit set by legislation for the reuse or discharge of the final effluent.
- The WW with the best results is that from the **WWTP of the dairy industry**.
- The **electrode material** with the best prospects is **graphite** for the anode and **platinum** for the cathode. Alternatives due to the high cost: using two graphite electrodes or metal-doped graphite electrodes.
- The **electrode geometry** that favours better diffusion of species between the two cell chambers is **brush-shaped graphite**, followed by sheet-shaped graphite and finally bar-shaped graphite.
- **Microalgae cultivation** is the best option between the two microbiological processes.

Thank you • Gracias • Grazie • Merci
Obrigado • Ευχαριστώ • Tak • Kösz • Bedankt

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