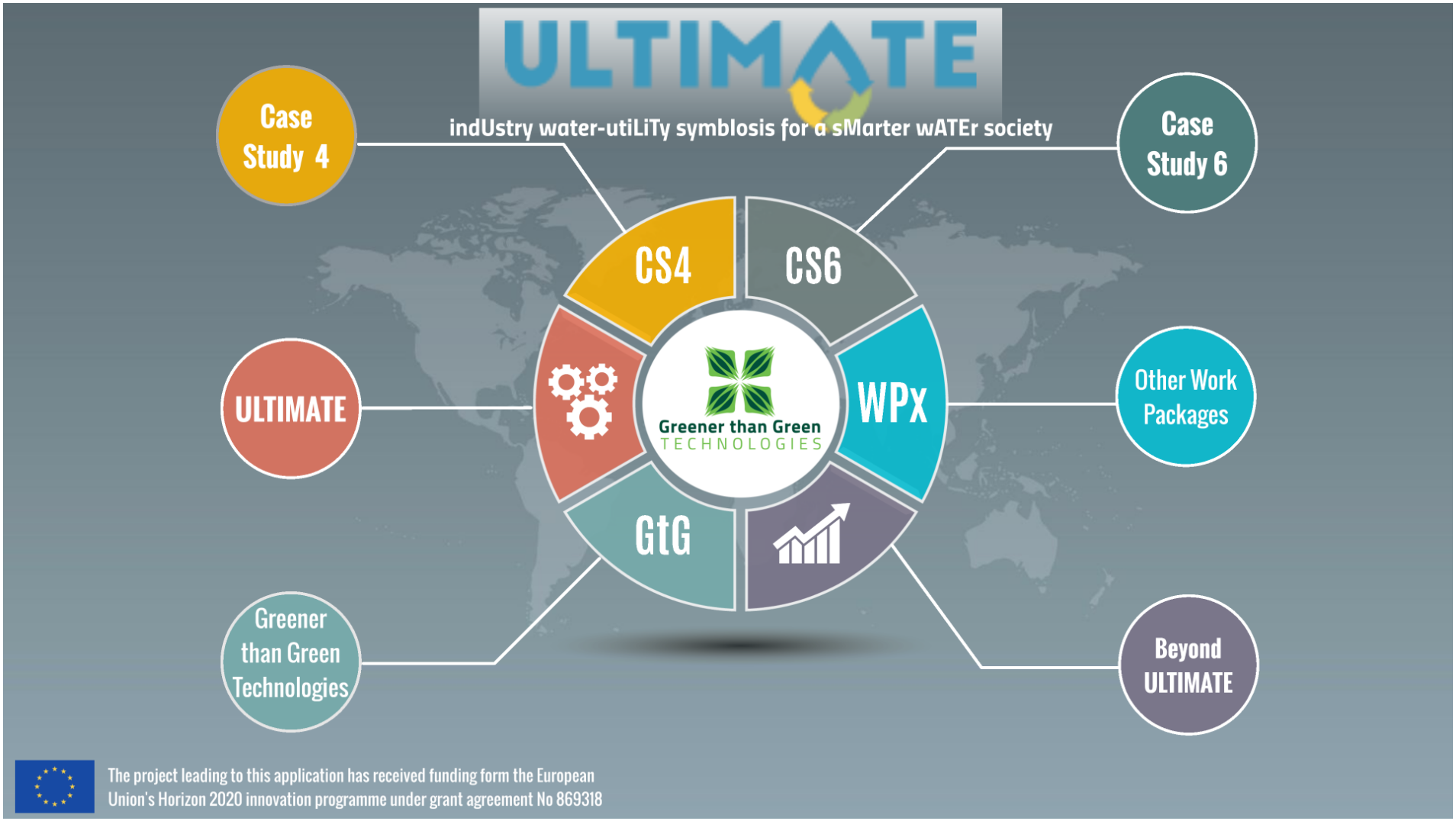
ULTIMATE
indUstry water-utiLiTy symbIosis for a sMarter wATEr society
Case Study 4
Case Study 6
CS4
CS6
ULTIMATE
Greener than Green TECHNOLOGIES
WPx
Other Work Packages
GtG
Greener than Green Technologies
Beyond ULTIMATE
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Greener than Green Technologies SA (GtG)

is active in R&D and marketing of disruptive water and **wastewater remediation** technologies and methodologies for the circular usage of water providing valuable tools for the transition of industries and communities towards a **circular economy** model, . In cases where high interest and **value added** compounds are present in the waste, these can be **reclaimed**, purified and reused, or can be commercially exploited, turning **waste into a resource**.

Established in 2014, we are start-up company that sprung out of pioneering university research. Our research efforts are funded by private capital as well as EU grants and we continuously seeking synergies in both the industrial and research partners. Since 2019 we are marketing and promoting in Greece and the wider southeastern European area novel and innovative environmental technologies.

The team

Greener than Green
TECHNOLOGIES

info@greenerthangreen.co

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The team

Christophoros Christophoridis
Chemist, BSc MSc PhD

Myrto Touloupi
Chemist, BSc MSc

Haris Magonis
Environmental Engineer
MEng MSc

Charalampos- Philip Iossifidis
Chemist, BSc MSc MBA

Dimitri Iossifidis
Chemist, BSc MSc PhD

Eri Bizani
Chemist, BSc MSc PhD

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Case Study 4

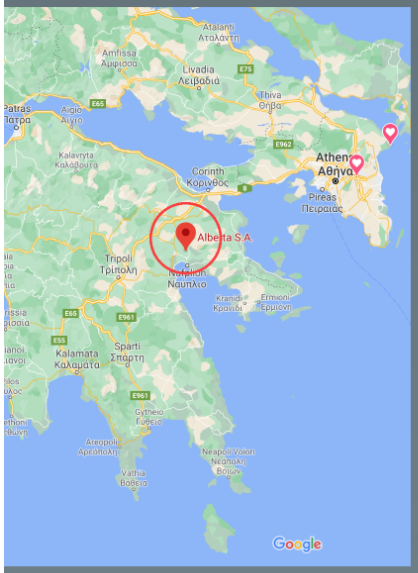
- Fruit processing industry

- Nafplio, Eastern Peloponese, Greece

- High water demand puts pressure in the aquifer

-Seasonality puts strain on the local biological treatment plant

- Under-performing biological treatment plant, leads to higher waste removal cost



Goals

The Unit

Value-added compound extraction

AOP

SBP

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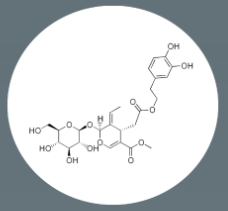
Case Study 4 Goals

- Treat individual & final waste streams

- Isolate useful/value-added compounds compounds (properties & market price) e.g. polyphenols, flavonoids, anthocynins etc

- Treat wastewater so it can be recycled:
  - **Irrigation of nearby orchards**
  - Reused within the plant for secondary uses or reduce the organic load sufficiently so the biological treatment plant can cope



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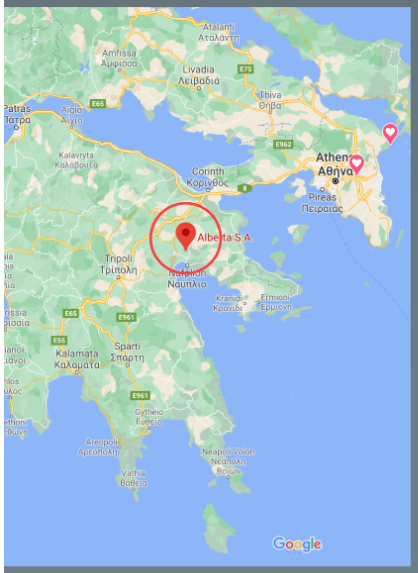

Goals

The Unit

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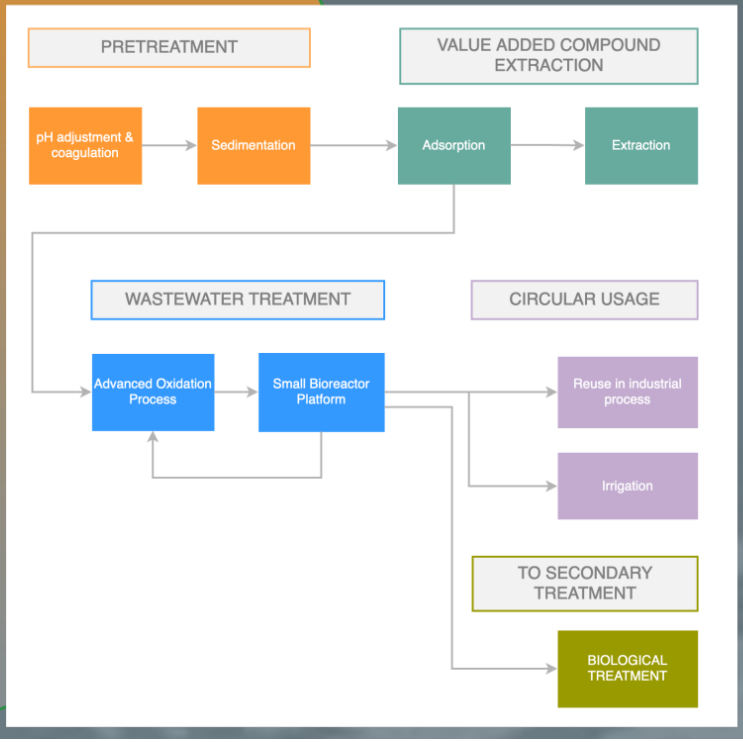
Unit Design

Cross-section

P&ID



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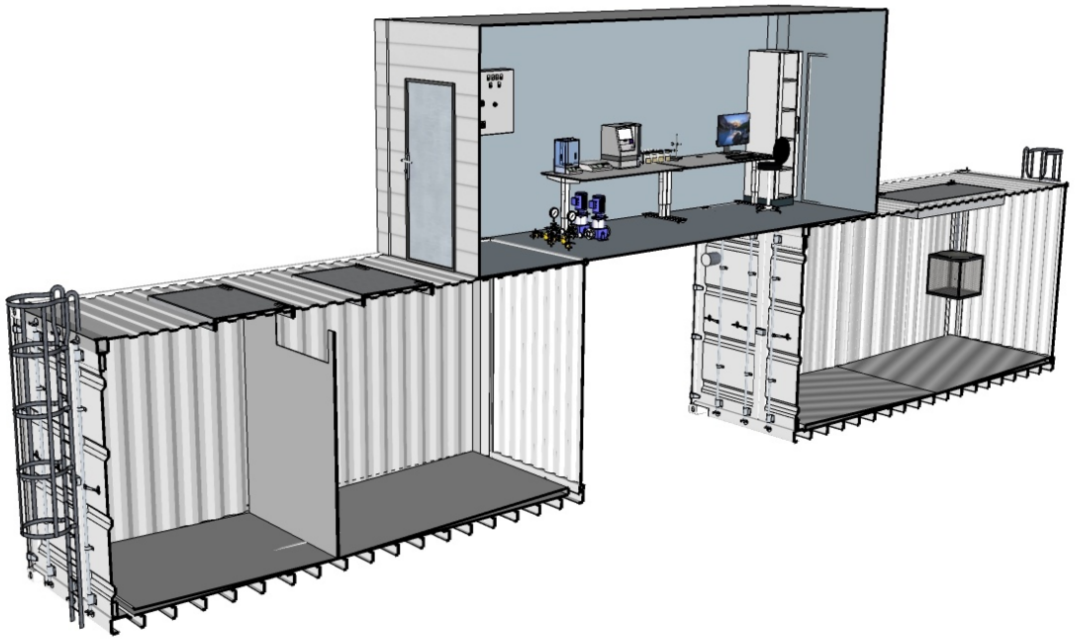
Unit Cross-section



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Unit Design

Cross-section

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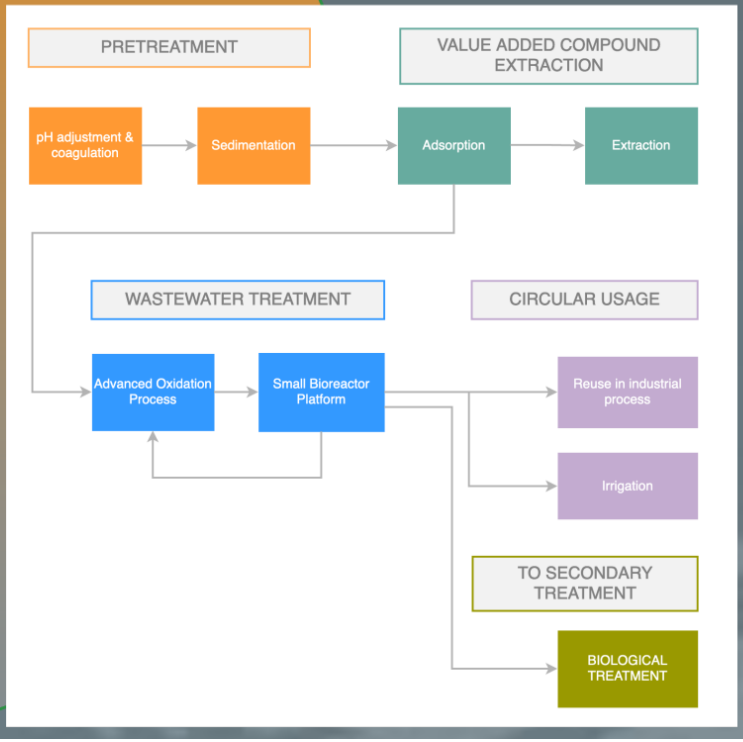

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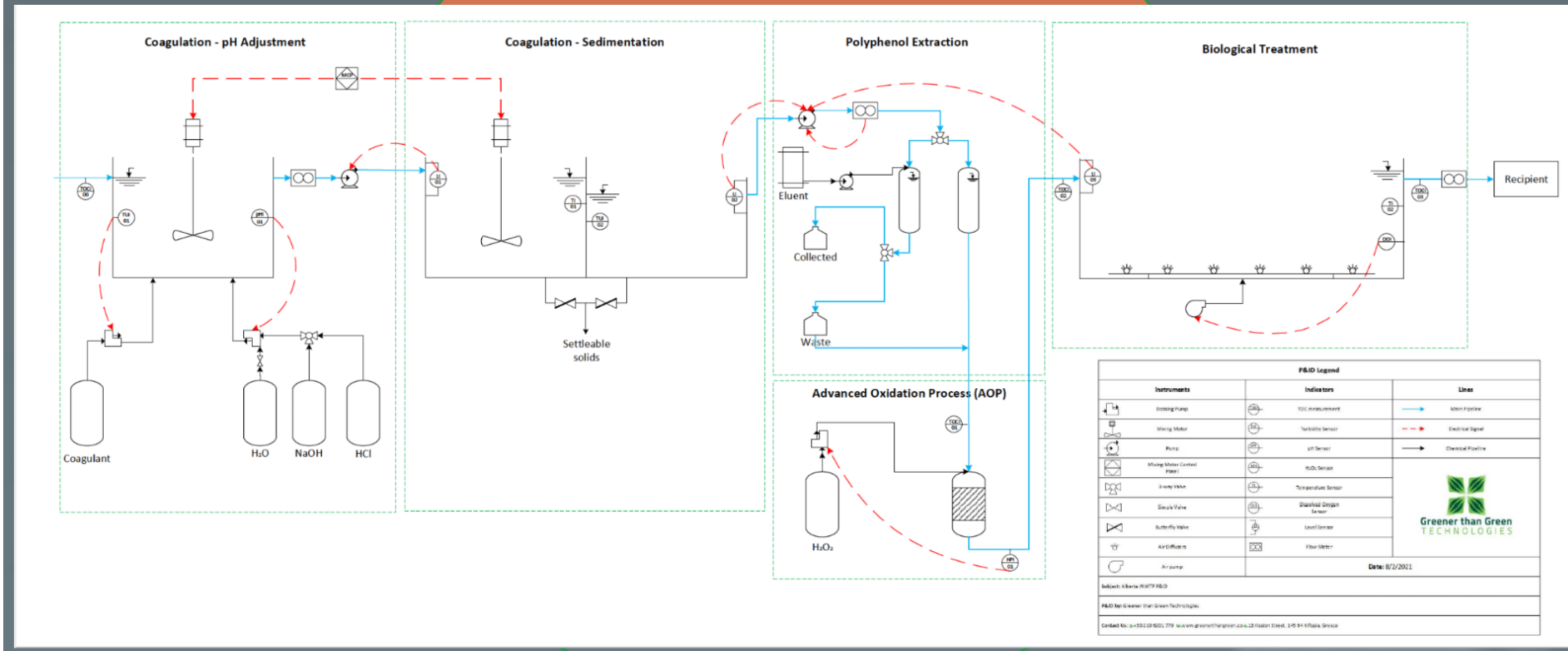
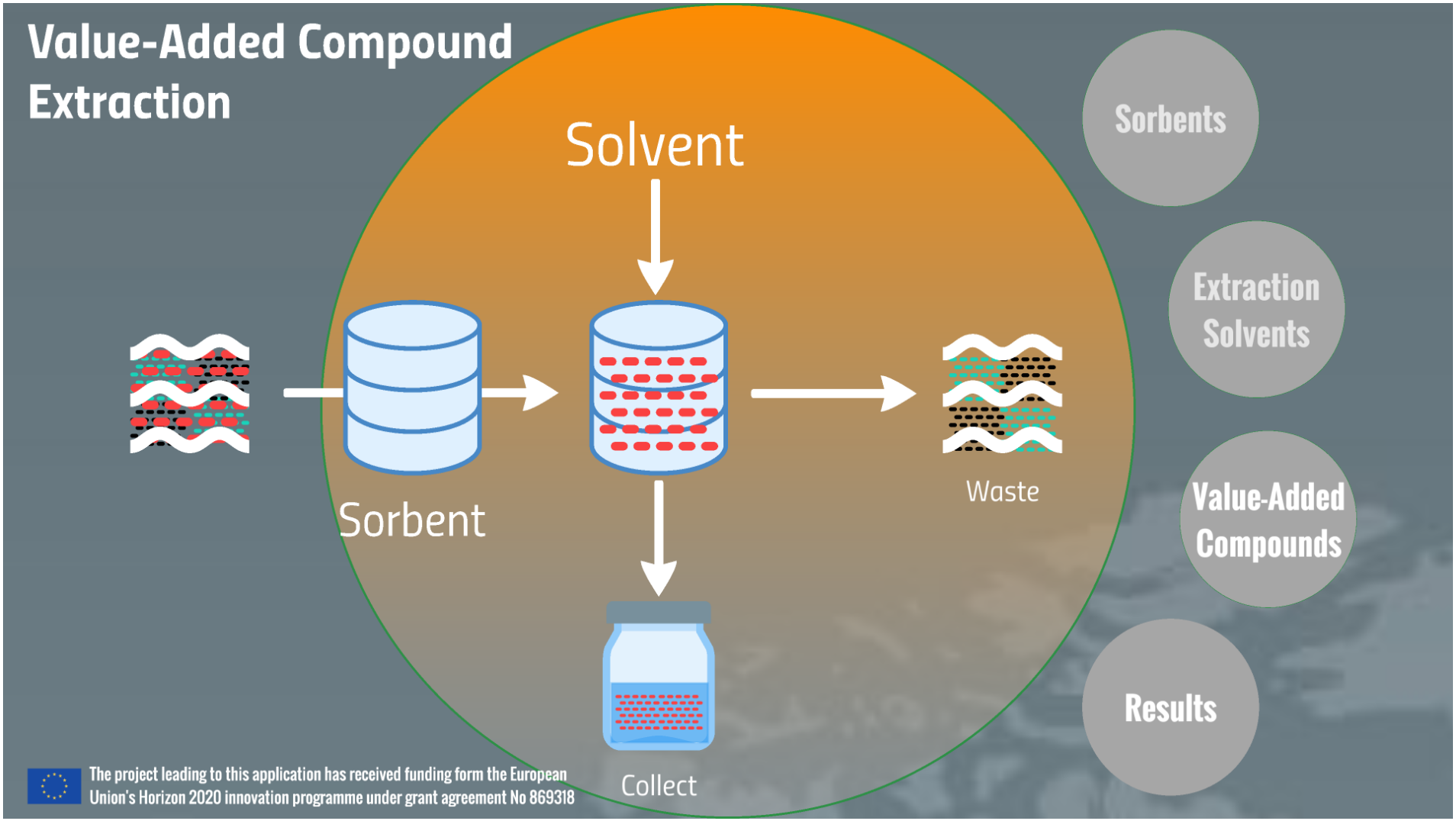
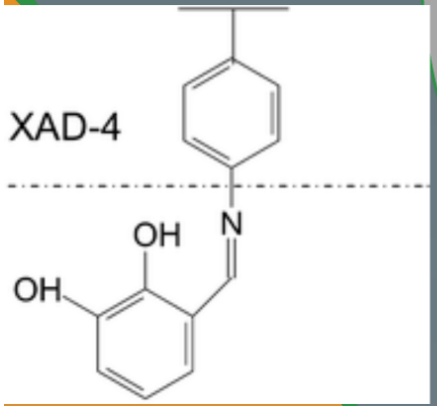

Coagulation - pH Adjustment
Coagulant
H₂O
NaOH
HCl
Coagulation - Sedimentation
Settleable solids
Polyphenol Extraction
Eluent
Collected
Waste
Advanced Oxidation Process (AOP)
H₂O₂
Biological Treatment
Recipient
P&ID Legend
Instruments
Indicators
Lines
Greener than Green
TECHNOLOGIES
Date: 8/2/2021

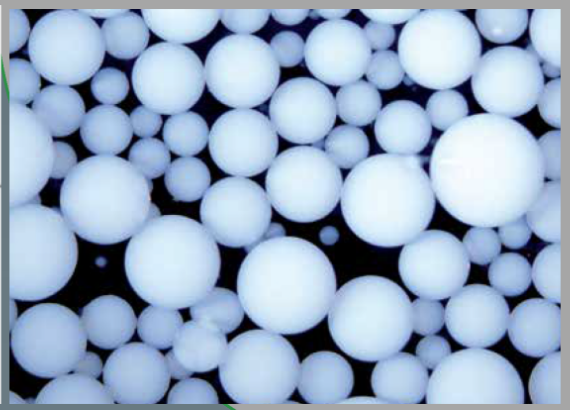

Value-Added Compound Extraction
Solvent
Sorbent
Waste
Collect
Sorbents
Extraction Solvents
Value-Added Compounds
Results
The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

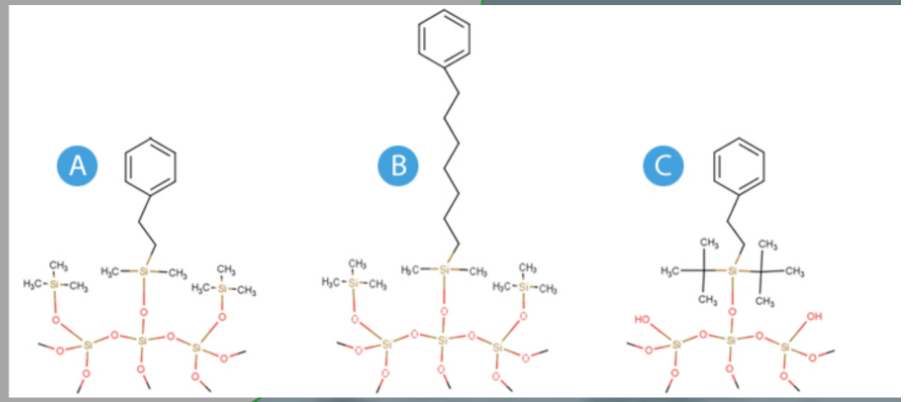
Sorbents

Adsorbent	Material	Structure	Particle size (µm)	Surface Area (m^2/g)	Pore Size (Å)
AmberLite™ FPX66	Resin	Aromatic	700	800	150
AmberLite™ XAD-4	Resin	Aromatic	640	750	100
Phenyl-Hexyl	Silica	Aromatic	15	400	100

?



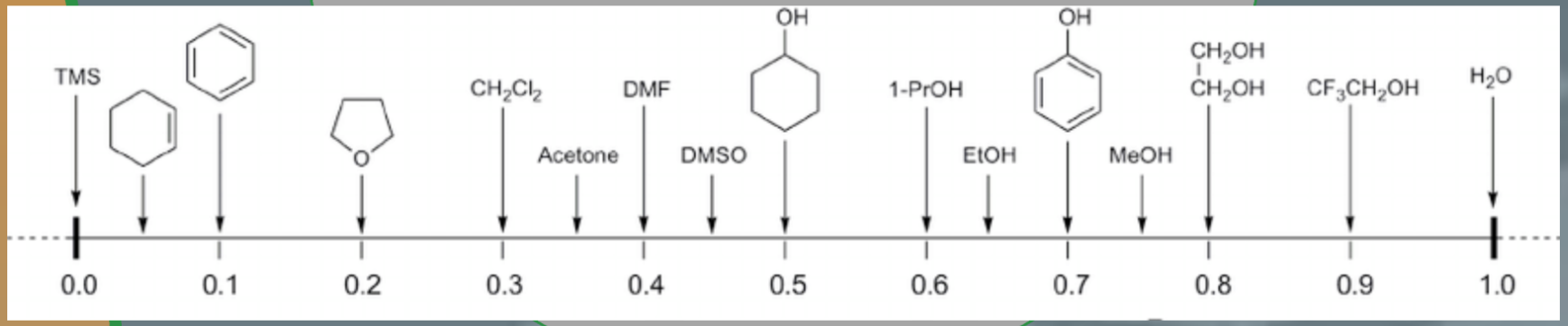




Extraction Solvents

Water - cheap, inefficient, non-toxic
Methanol - high cost, increased toxicity
Ethanol - very high cost, lower toxicity

Subcritical Water Extraction



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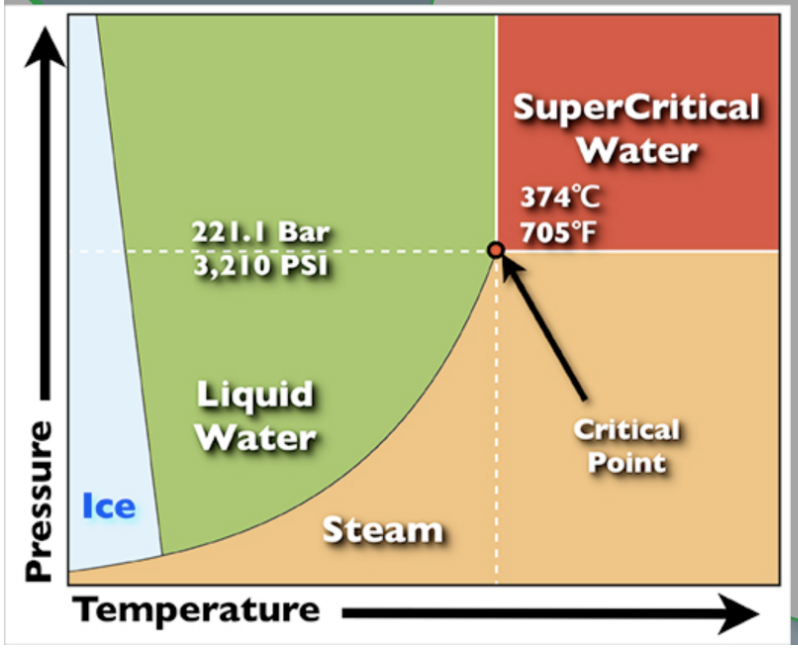
SubCritical Water Extraction (SCWE)

- Temperature: 100 - 374°C
- Pressure high enough to be in the liquid phase 10-20 bar



- Efficiency
- Low cost
- Non-hazardous - green

Value-Added Compounds

Polyphenols:

- Naturally occurring compounds
- Complex structures containing multiple phenolic rings
- Two main classes **phenolic alcohols**, **phenolic acids**
- Further classification depending on the phenolic ring strength (phenolic acids, flavonoids, stiblins, phenolic alcohols, and lignans)

Structures

Examples

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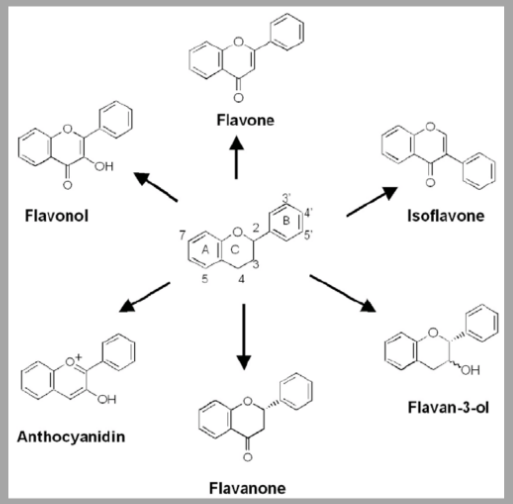
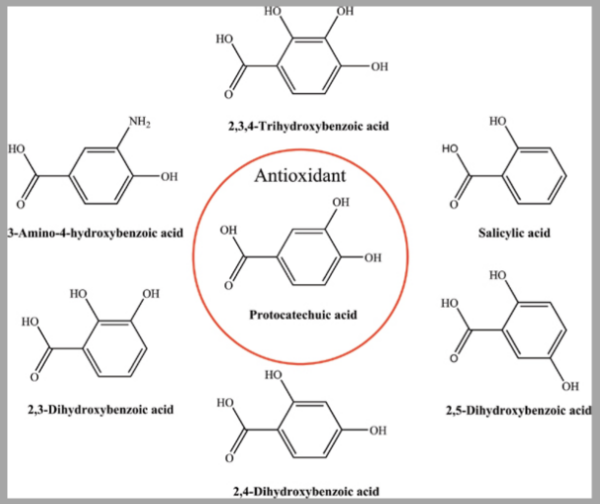
Structure of polyphenols

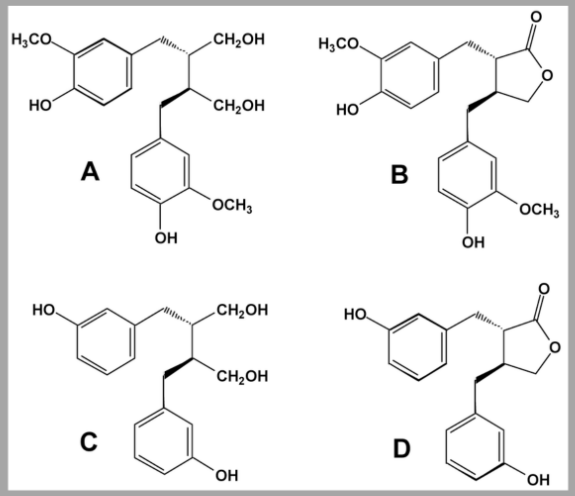
Flavonoids



Benzoic acids



Lignans



Examples of Value-Added Compounds

"Let food be thy medicine and medicine be thy food"
Hippocrates 460-377 BC

Fruit	Compound	Class	Properties & Uses	Price/g*
Orange	Hesperetin	Flavonone	Lowers cholesterols, Anticancer, Favourably favours lipids	€13
	Naringenin	Flavonone	Antioxidant	€1
	Kaempferol	Lignan	Reducing the risk of chronic diseases, especially cancer	€5.900
Redcurrant	Cyanidin 3-O-glucoside	Anthocyanin	Food colourant	€29
Beetroot	Luteolin	Flavone	Potentials for cancer prevention and therapy	€18.100
	Quercetine	Flavonoid	Anticancer activity	€9.600
Black Chokeberries	Cyanidin 3-O-arabinoside	Anthocyanin	Used as natural colorant	€84.000
Pomegranate	(+)-Catechin	Flavonol	Used in green tea extracts	€22.499
	(+)-Gallocatechin	Flavonol	Antibacterial, Antifungal, Antimalarial, Diuretic, Antiulcer, Xanthine oxidase inhibitor, Antiplasmodic…	€150.000
Carot	3,4-Dicaffeoylquinic acid	Phenolic acid	Antioxidant, anti-inflammatory, anti-cancer, DNA protective, Neuroprotective, Hepatoprotective, Anti-influenza viral activity	€374.000

*Price of analytics standards normalised to 1g

Results

Static Adsorption

Static Adsorption Methodology

Static Adsorption Results

Dynamic Adsorption

Dynamic Adsorption Methodology

Dynamic Adsorption Results

Recovery

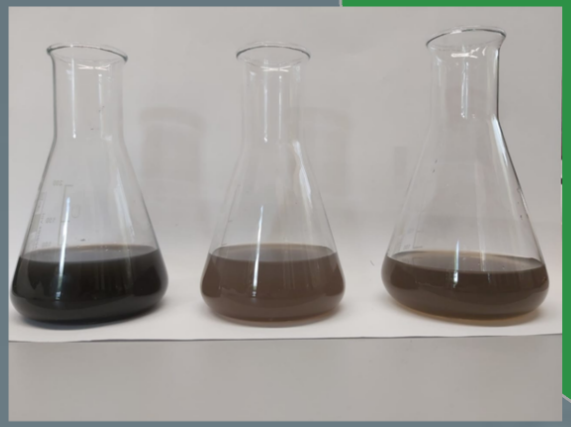
Recovery

The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

Static Adsorption Methodology

Determine most suitable material depending

- Batch experiment
- Constant volume of wastewater
- Different quantities of adsorbing material
- Sampling at regular intervals



- Maximum adsorption capacity of each material
- Adsorption kinetics - how fast
- Modelling of adsorption dynamics

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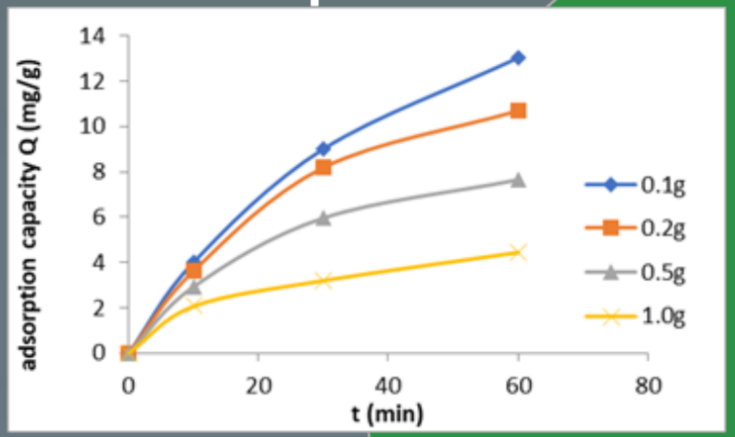
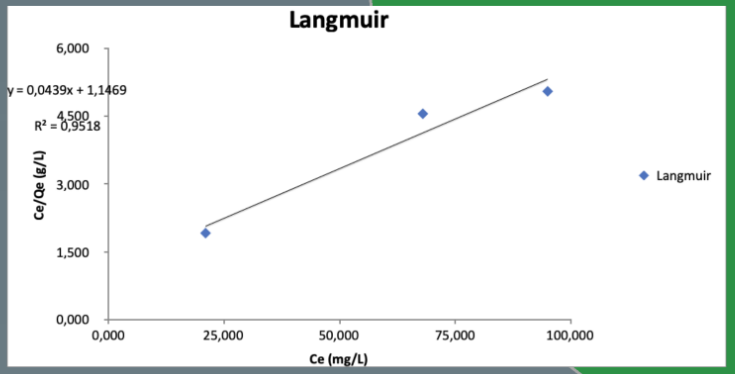
Static Adsorption Results





Maximum capacity 22,78 g/kg
(g of polyphenol per kg of resin)

Contact time vs Adsorption %

60 min	95%
30 min	60%

Yield = 130 g/m3
(mg of polyphenol per L of wastewater)

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Dynamic Adsorption Methodology

Determine conditions for optimal recovery

- Lab simulation of real process
- Continuous process
- Wastewater flows though a packed bed

- Breakthrough curve
- Relationship between contact time and flow rate
- Optimise flow conditions & packed bed design

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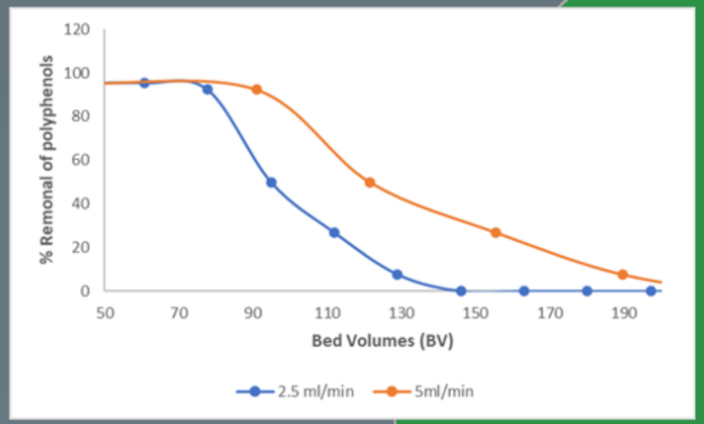
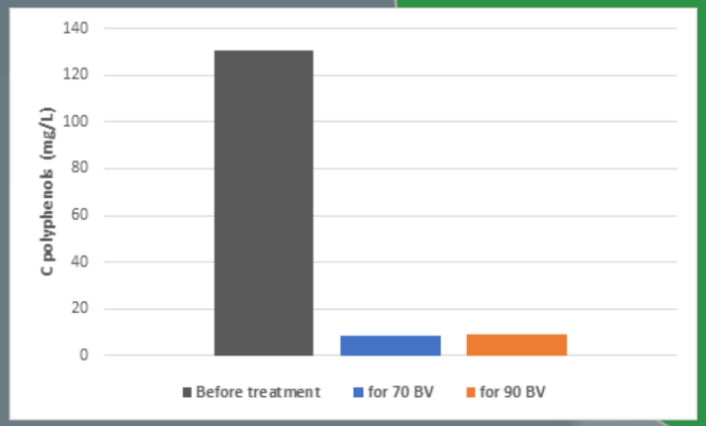
Dynamic Adsorption Results





- The adsorbent is capable of adsorbing polyphenols for at least 10 regeneration cycles
- 1.7 m^3 wastewater can be treated per kg of resin per cycle

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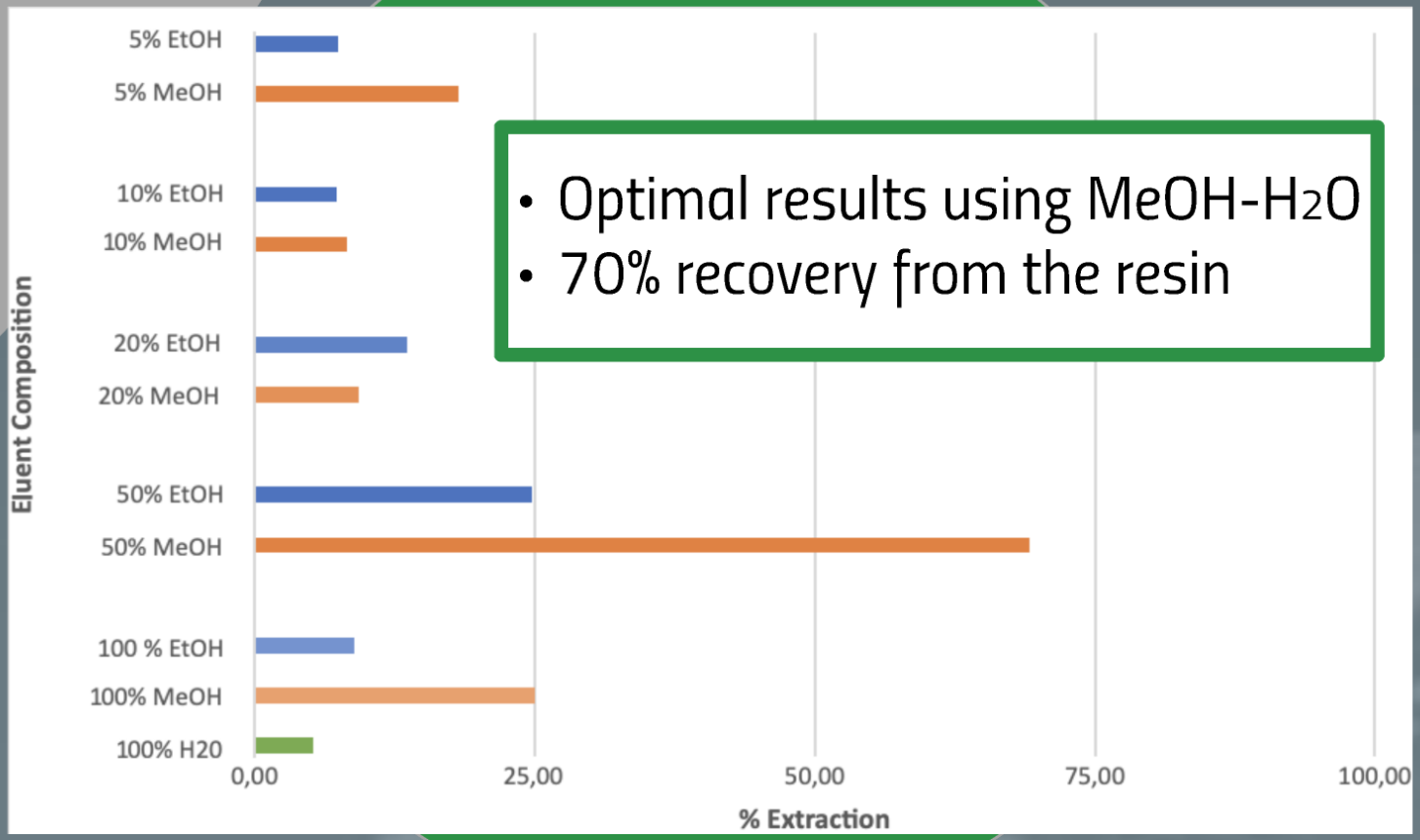
Recovery



- Optimal results using MeOH-H_2O
- 70% recovery from the resin

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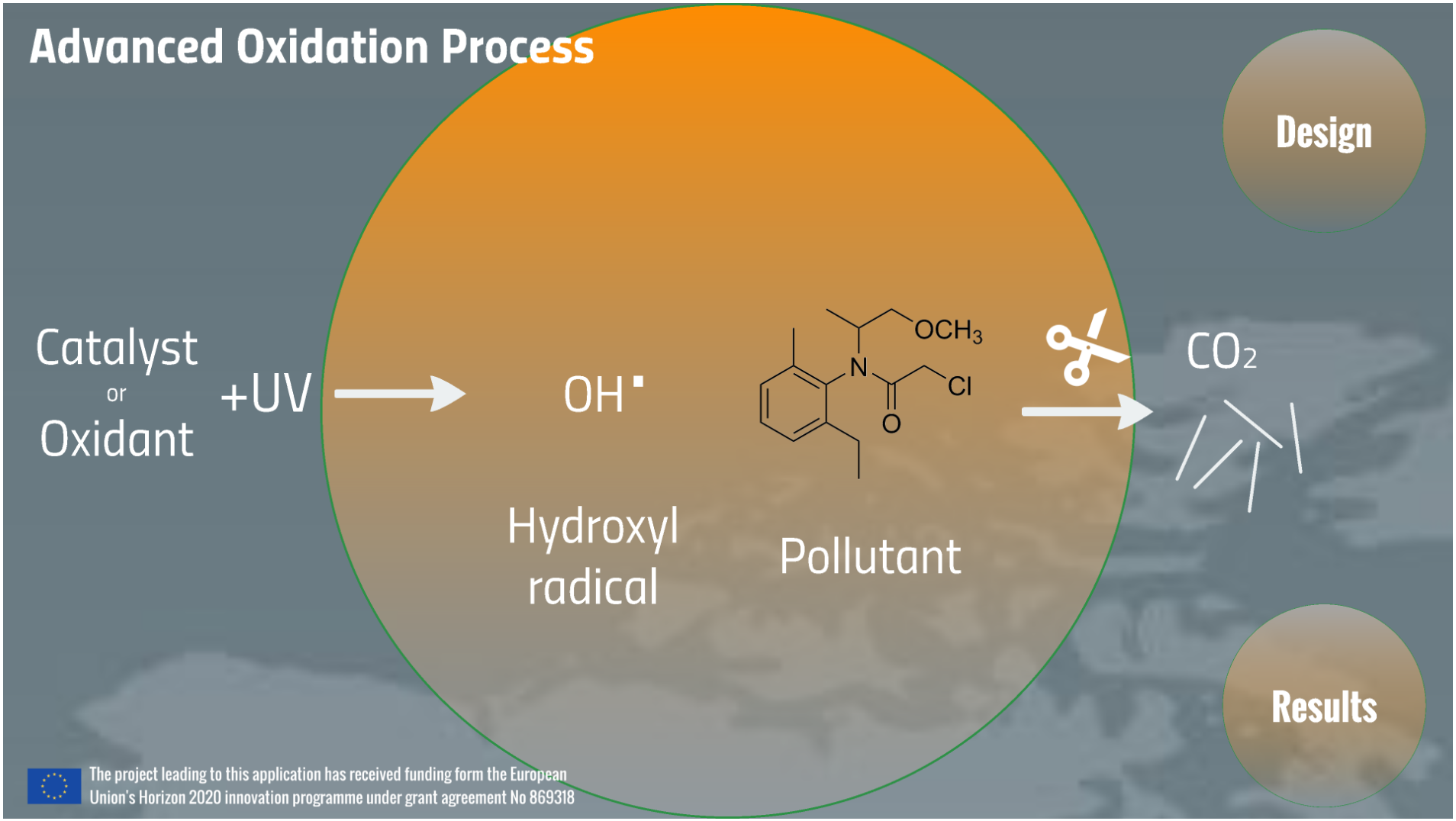
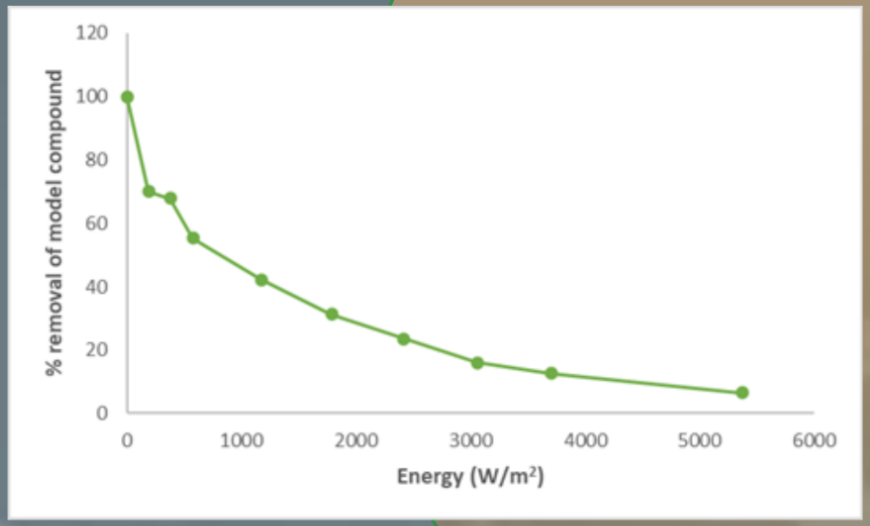

Advanced Oxidation Process
Design
Catalyst
or
Oxidant
+UV
OH·
Hydroxyl radical
OCH3
N
Cl
O
Pollutant
CO2
Results
The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

The CPC photocatalytic reactor

- Continuous flow
- Operates under either solar or artificial light

Degradation of model compound



Demonstrated ability to remove 90% of organic pollutants

Small Bioreactor Platform

BioCastle
Nature open-code inspired

SBP is a product of BioCastel, Israel

US Patent No. US 8,673,606
Europe Patent No. EP 2421544 (Germany, France, U.K, Nederland, Ireland and Switzerland)
Australia Patent No. 2010240486
Israel Patent No. 213072

Patented Technology by BioCastel, Israel

SBPs encapsulate bacteria within a porus membrane
Cellulose acetate
0.2 µm pore

The membrane:

- keeps bacteria safe from predators and other microorganisms
- prevents biomass from escaping to the environment

Problems addressed:
Controlling the type of bacteria needed
Defining the space they grow
Controlling the amount of biomass

How does it work

Benefits

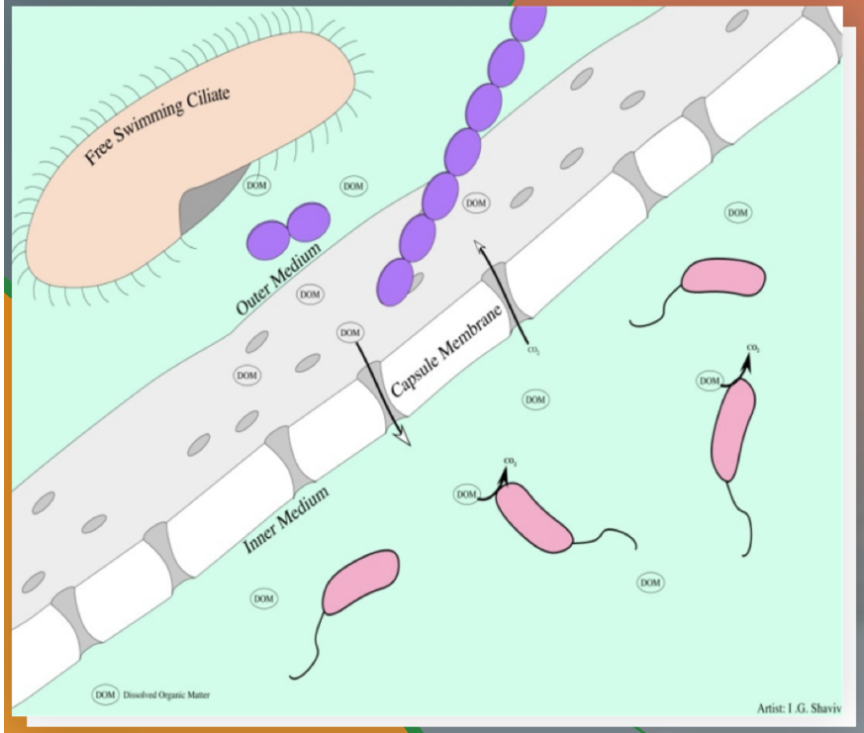
Applications

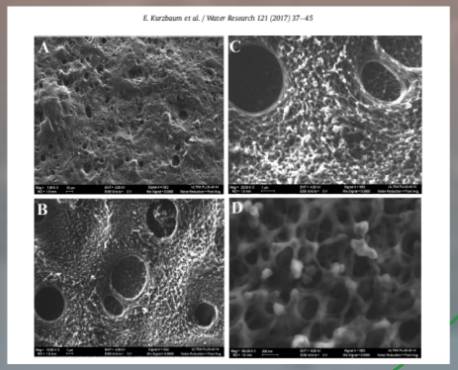
ULTIMATE

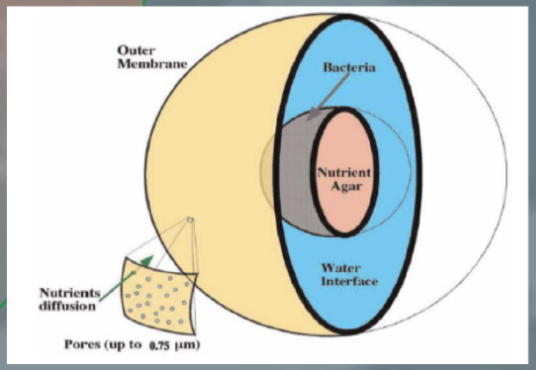
The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

How does it work

- A 0.2 µm cellulose acetate membrane encapsulates bacteria keeping it safe from predators and preventing biomass to escape
- Water and disolved pollutants migrate trough through the pores and are metabolised by bateria
- After the life cycle of the bacteria, approx. two month, the cellulose acetate membrane devomposes to sugars







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Defining the space they grow
Controlling the amount of biomass

How does it work

Benefits

Applications

ULTIMATE

The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

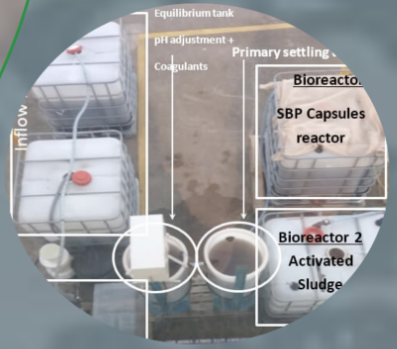
Benefits

SBP technology addresses certain biological treatment problems:

- Control of bacteria type growth
- Control of space bacteria grow
- Control of amount of bacteria

It can be implemented:

- to assist existing biological treatment units to cope with seasonal and unexpected shock load episodes
- to increase capacity with minimal CapEx
- as a small scale standalone solution with out the need of high-cost & extensive infrastructure



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Applications

Sanitary wastewater treatment examples:

- A20 5500 m3/d
- MBR 2400 m3/d
- AS 500 m3/d

Yield increase up to 15%
Increase in biodegradation rate
Increase in bioprocess stability

Industrial wastewater treatment:

- Food waste 200 m3/d
- Winery waste 0.5 m3/d

No need for natural biomass growing and all associated infrastructure
No need for professional manpower for plant operation
No need for waste sludge transporting and associated infastucture

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Case Study 6

Karmiel, Israel

Olive oil mill wastewater treatment

Partners: The Galilee Society, MEKOROT, GtG

Olive oil mill wastewater is reach in **polyphenols** which are toxic to bacterial and inhibit aerobic or anaerobic digestion in biological wastewater treatment plants

Goal

Polyphenol Extraction

Design

Lab-scale

The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

Goal

To remove polyphenolic compounds from waste water:

- Low cost unit & process
- Prevent inhibition of anaerobic digestion
- Increase biogas yield
- Commercially exploit polyphenols

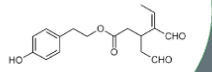
The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

Polyphenol Extraction

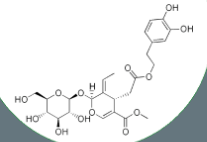
"Let food be thy medicine and medicine be thy food"
Hippocrates 460-377 BC

- Natural phytochemicals, a major class of semi-water-soluble compounds with one or more benzene rings that are generally found as glycosides
- Polyphenols from olives and grapes are probably the most studied

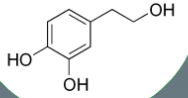
Oleocanthal



Oleuropein



3-Hydroxy tyrosol



Sorbents

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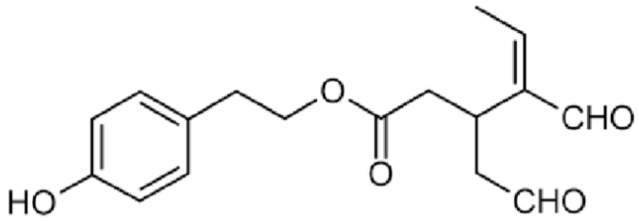
Oleocanthal

Market value:
€1620/g

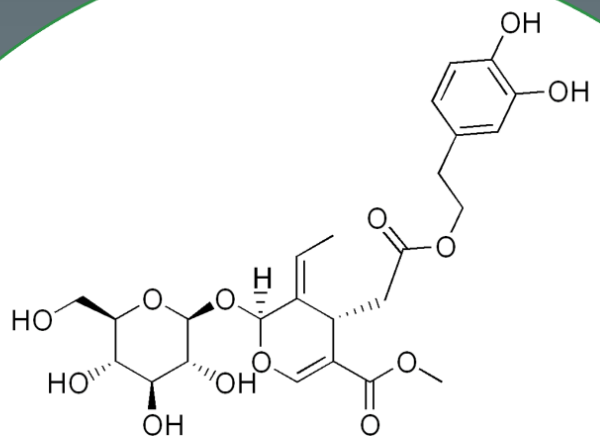


Properties:

- Antioxidant
- Anti-inflammatory
- Anti-cancer
- Reduce risk of AD
- Reduce risk of heart disease

Oleuropein

Market value:
€7.240/g

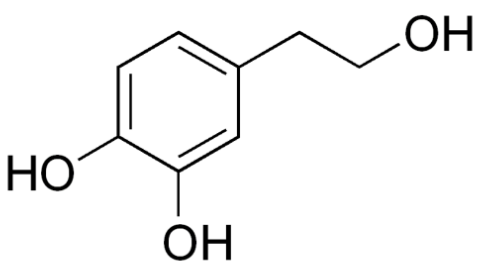


Properties:

- Antioxidant
- Anti-inflammatory
- Anti-cancer
- Protects skin & eyes
- Protection against pathogens

3-Hydroxy tyrosol

Market value:
€7.240/g

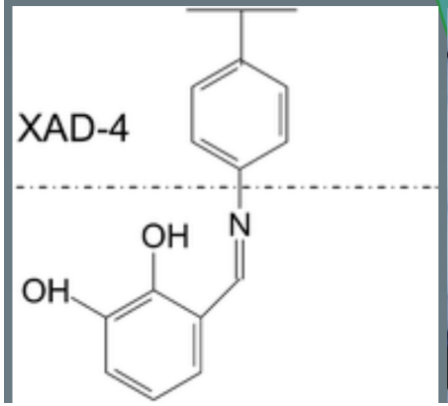


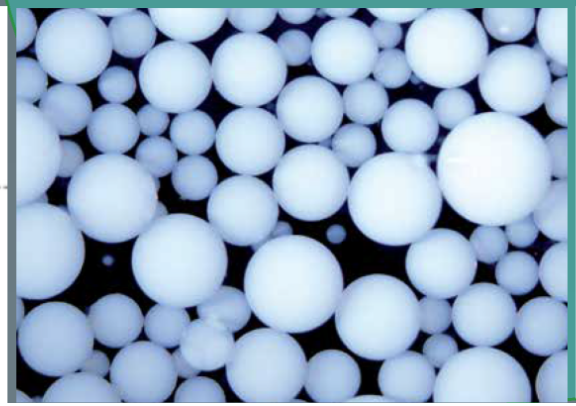
Properties:

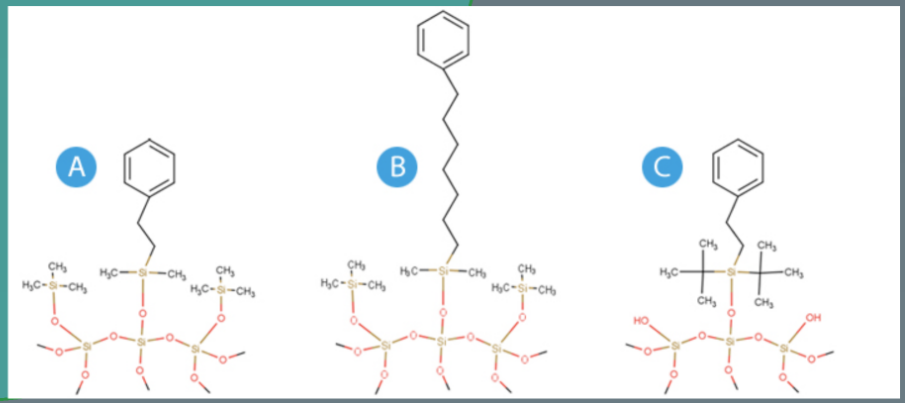
- Antioxidant
- Anti-inflammatory
- Anti-cancer
- Protects skin & eyes
- Protection from pathogens

Sorbents

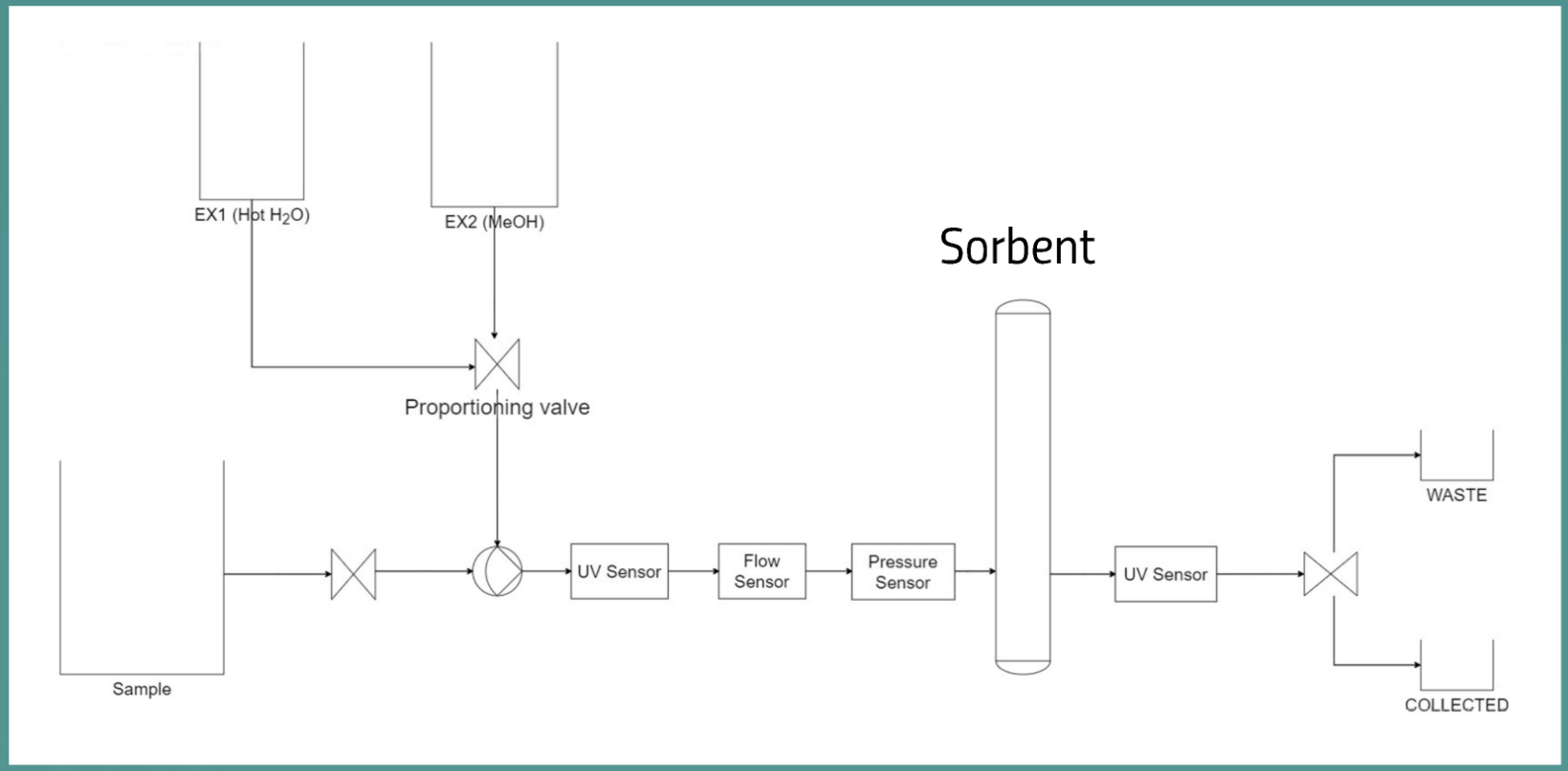
Adsorbent	Material	Structure	Particle size (µm)	Surface Area (m^2/g)	Pore Size (Å)
AmberLite™ FPX66	Resin	Aromatic	700	800	150
AmberLite™ XAD-4	Resin	Aromatic	640	750	100
Phenyl-Hexyl	Silica	Aromatic	15	400	100







Design



The project leading to this application has received funding form the European Union's Horizon 2020 innovation programme under grant agreement No 869318

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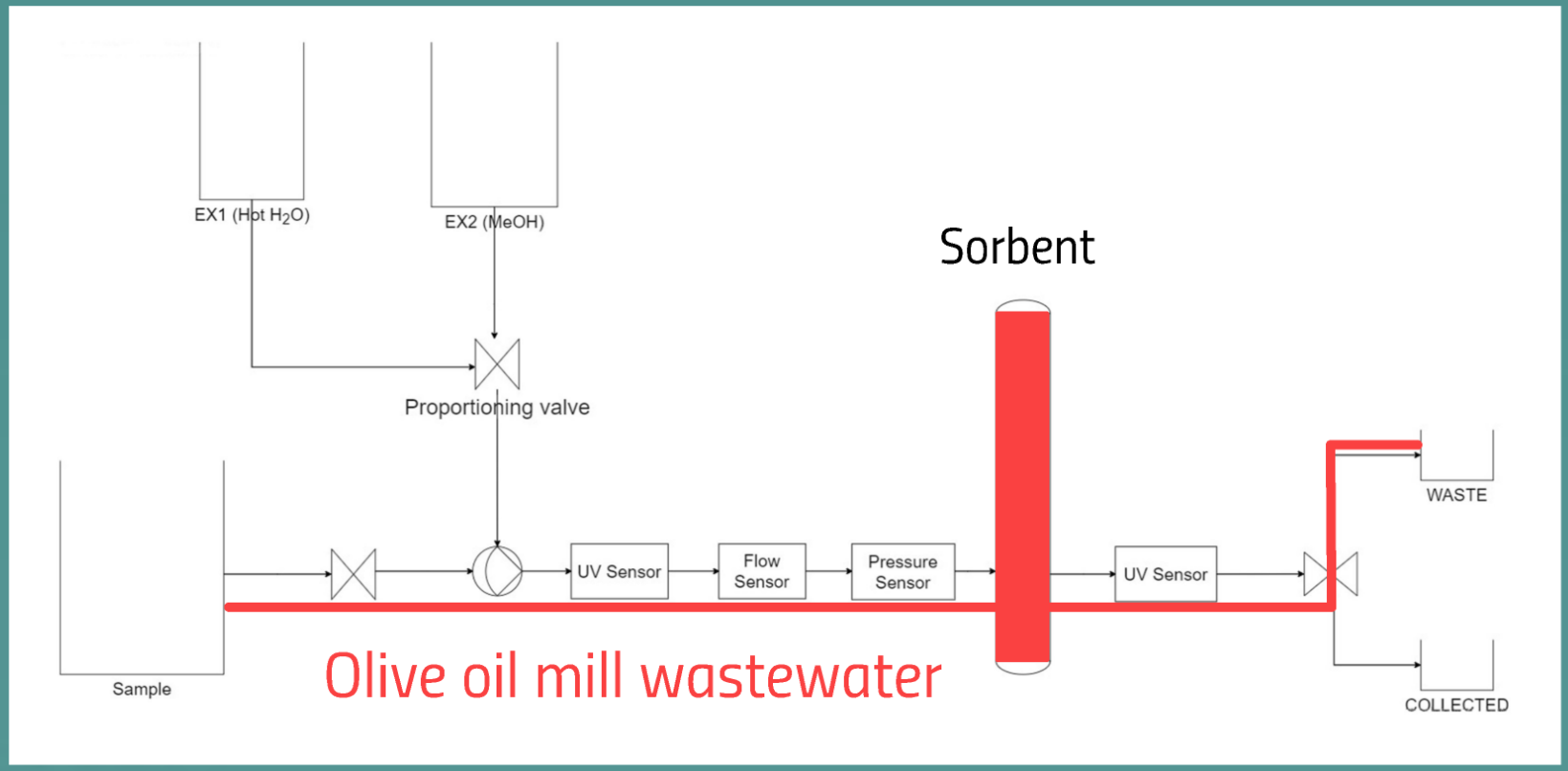

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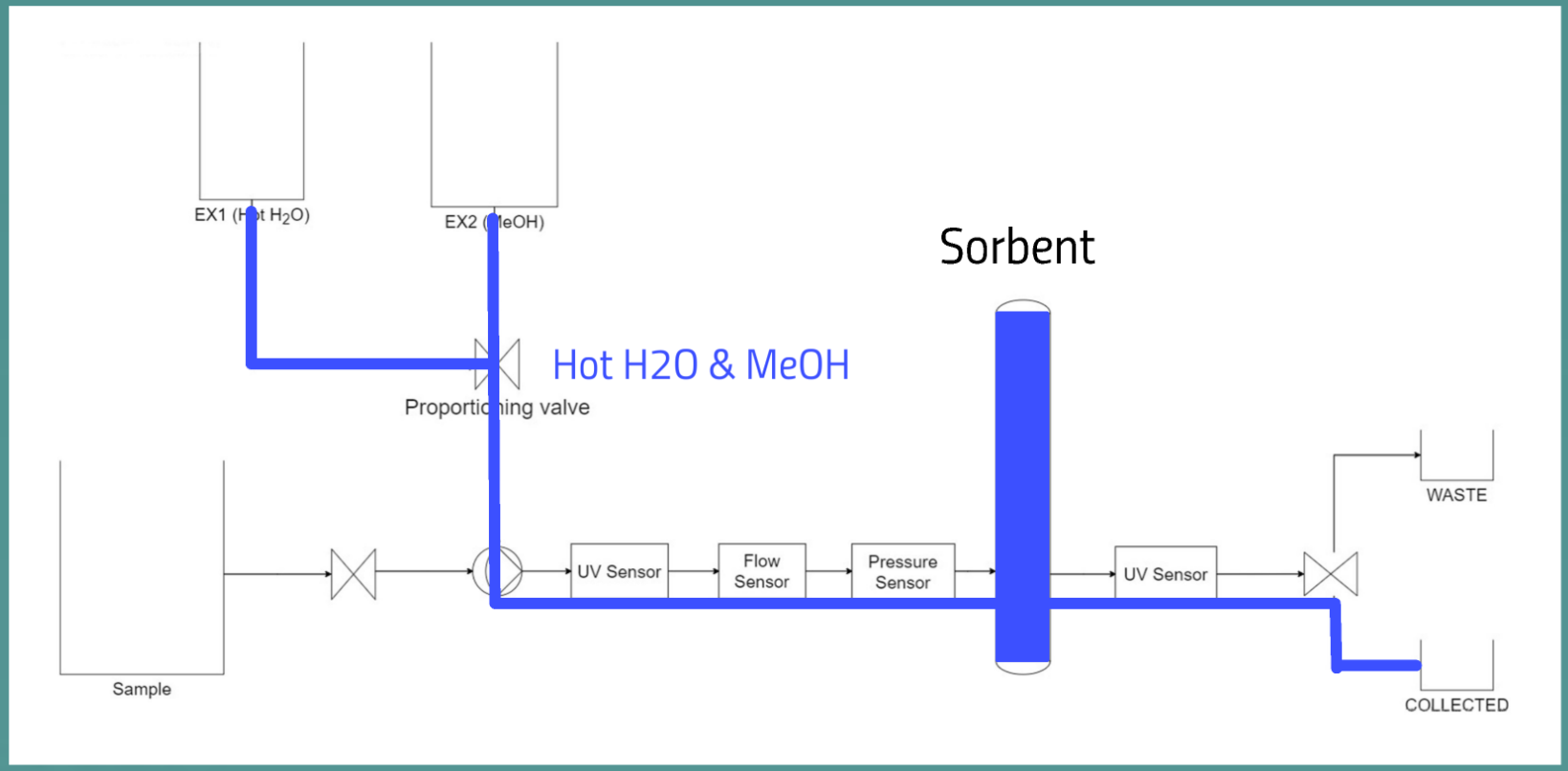
Extraction



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