<a *href*="http://generalchemistry.chemeng.ntua.gr/uest/corfu2022/proceedings/XXI/1545.pdf" *target*="_blank">PDF

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9th International Conference on Sustainable Solid Waste Management

OUTLINE

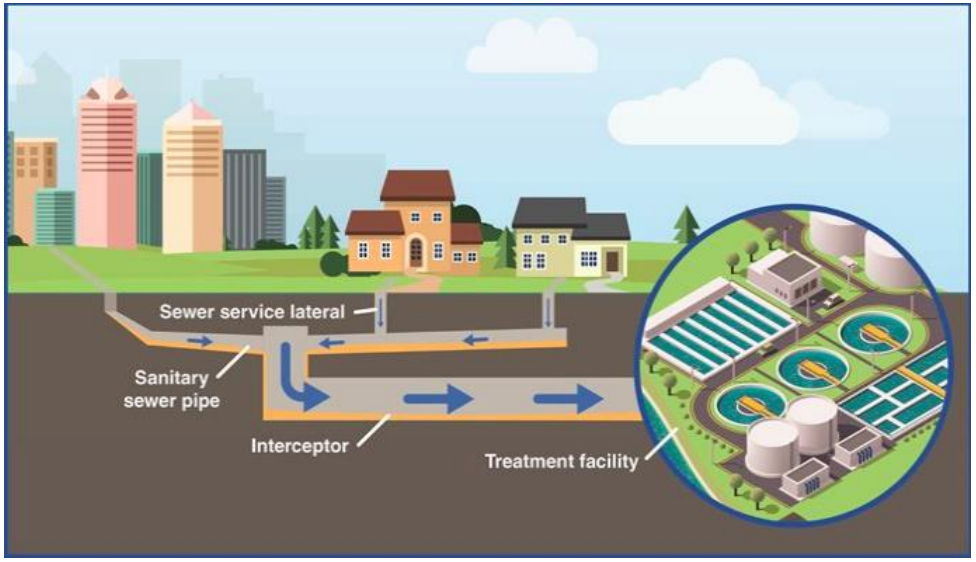
1) Sewage sludge generation an experimental scenario

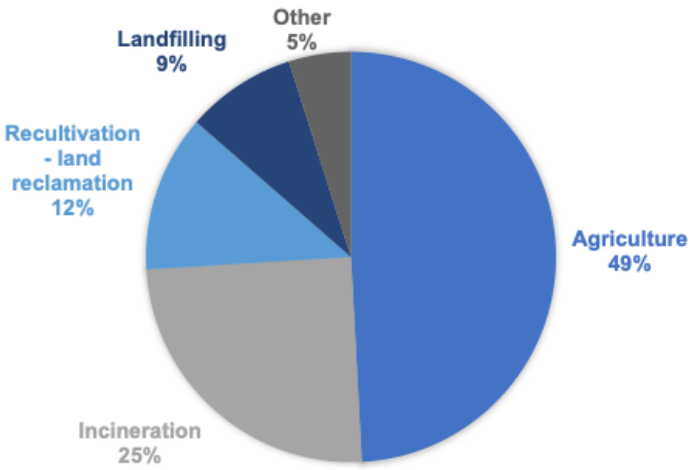
2) Aims and bioprocess layout

3) Sludge mild hydrolysis and acidogenic fermentation

4) The pilot-scale PHA production line

5) Downstream processing and PHA characterization





- Sewage sludge is currently one of the most available waste within urban scenarios (9.0 million tons of dry solids) *https://ec.europa.eu/eurostat/web/products-datasets/-/ten00030*

- Disposal problems are encountered and several legislations within European Union regulate sludge management

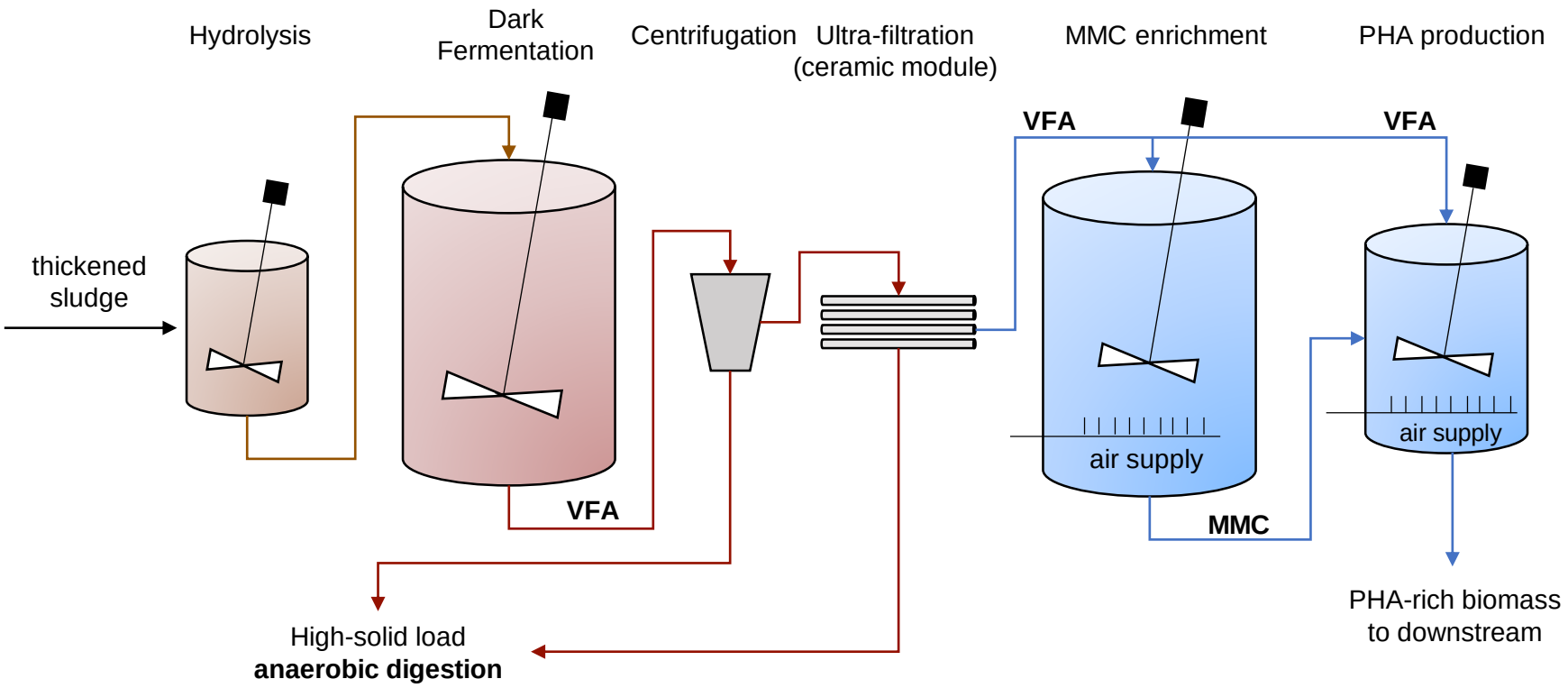
- Italian legislation included the production of **biopolymers** as one of the alternatives for energy-materials recovery from sludge ("*Disciplina della gestione dei rifiuti costituiti da fanghi di depurazione delle acque reflue* - **directive 86/278/CEE**)

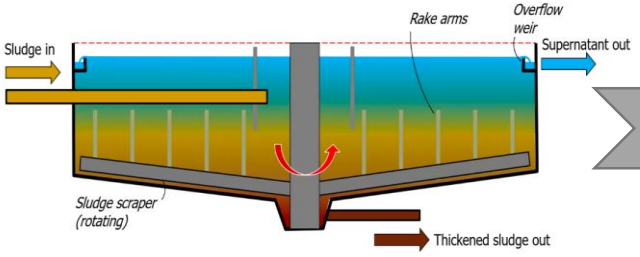
The municipal wastewater treatment plant of Treviso (ATS S.r.l.)

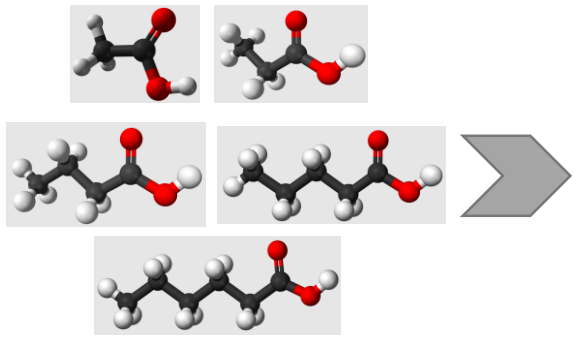
BNR process
thickened sewage sludge

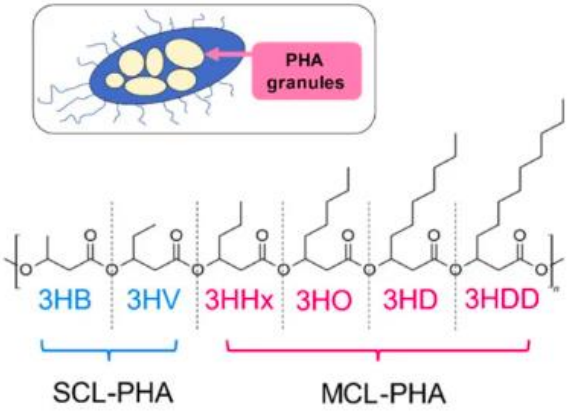
Parameter	Unit	Value
TS	g/kg	29 ± 1
VS	g/kg	22.0 ± 0.4
COD	g/kgTS	789 ± 66
COD_{SOL}	mg/L	589 ± 106
$N\text{-}NH_4^+$	mg/L	163 ± 22
$P\text{-}PO_4^{3-}$	mg/L	65 ± 9

Bioprocess layout







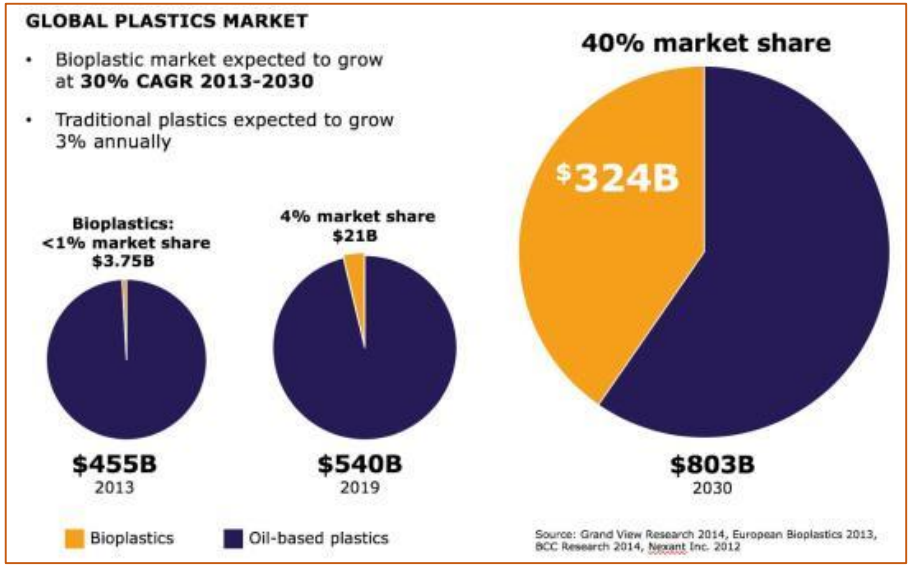


Why PHA?

Product related Pro's

Family of copolymers with tunable composition (wide portfolio of applications)

- Biodegradable commodity film
- Packaging interlayer film
- Specialty durables (such as electronics)
- Slow C-release for groundwater remediation



Production process Pro's

- **Open microbial cultures process** (not pure strains), to better cope with waste;
- Mostly **biological process**, reliable and under mild conditions.
- Easier integration with existing waste/wastewater treatment plant.

Appealing

- Produced from renewable feedstock (**no food**)
- Produced in biological process (**no OGM**)
- **Biodegradable**: not recycled but virgin material

Applications and economics

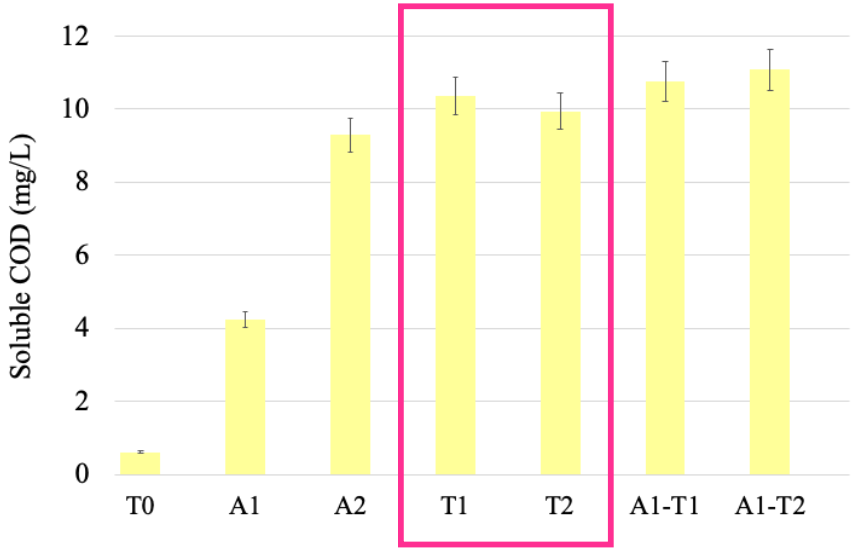
High market potential

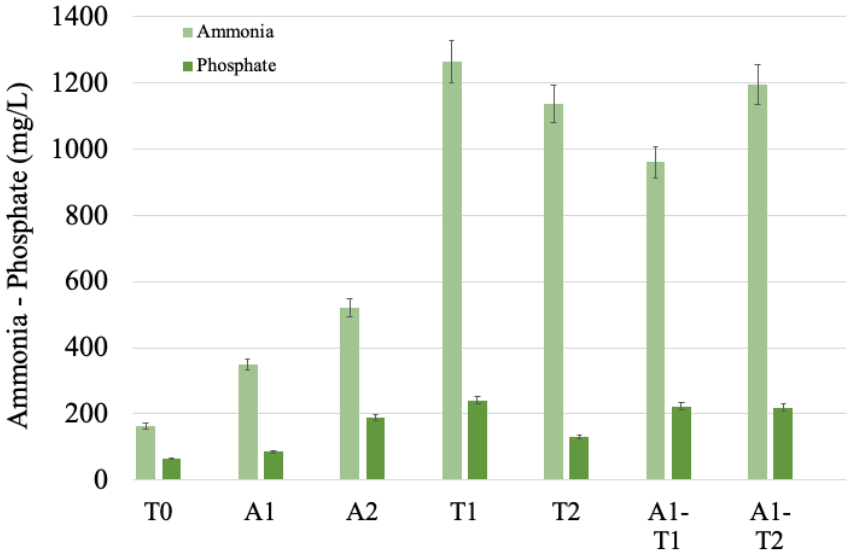
As higher as more PHA cost decreases; but still higher value than biogas and compost

Under investigation at TRL 8

Sewage sludge hydrolysis and acidogenic fermentation

Thermal (12 h)	
70°C	T1
90°C	T2
Alkaline (12 h)	
pH 9.0	A1
pH 11.0	A2
Combined (12 h)	
70°C, pH 9.0	A1-T1
90°C, pH 9.0	A1-T2





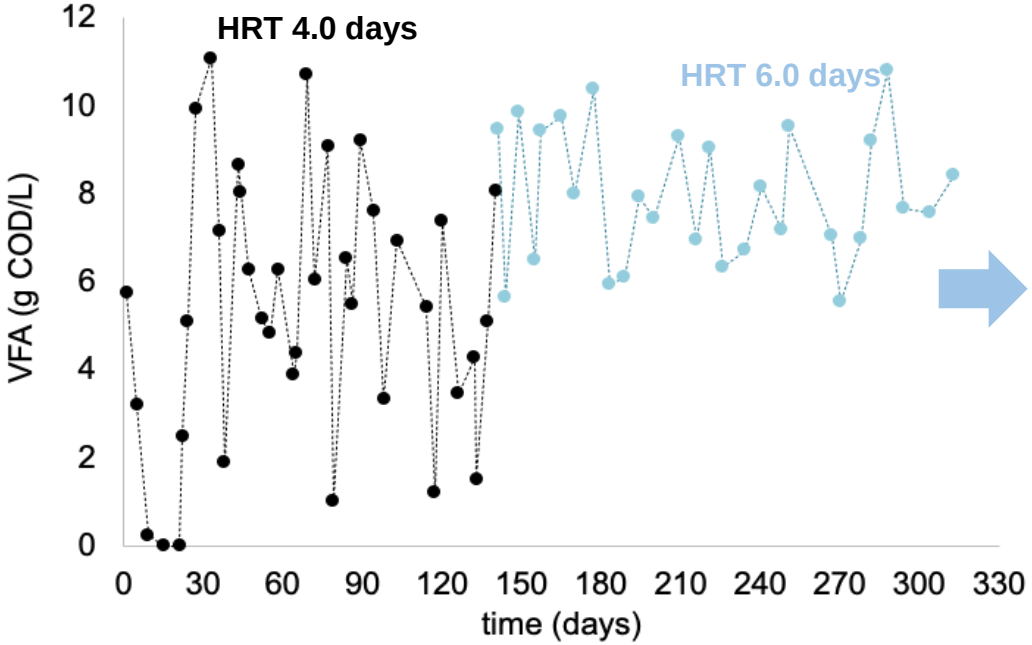
- Mild short-term thermal hydrolysis (70°C; 12 h) for higher solubilization
- Nutrients release (up to 770% and 360% increase for $N\text{-}NH_4^+$ and $P\text{-}PO_4^{3-}$ respectively)

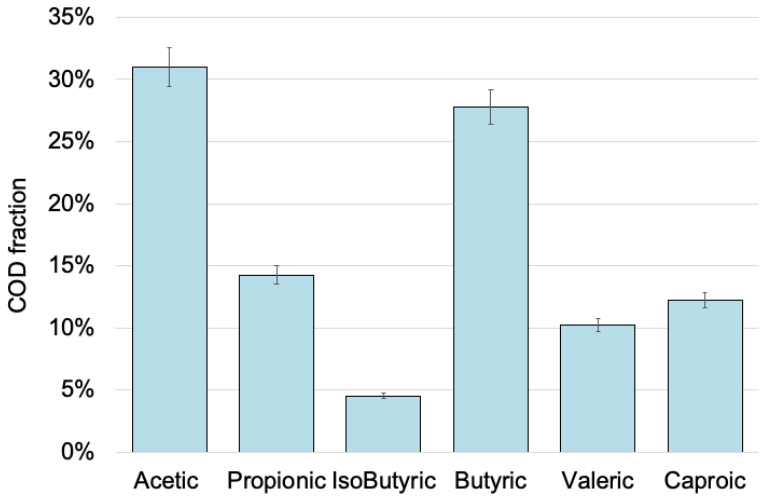
Sewage sludge hydrolysis and acidogenic fermentation

a) Thermally pre-treated sludge (70°C – 12 h)

b) Uncontrolled pH (∽ 5.5)

VFA Yield
0.38
g COD_{VFA}/g VS





The pilot-scale PHA line – Biomass selection and PHA accumulation

Sequencing Batch Reactor (SBR)

a) Fully aerobic feast-famine

b) Uncontrolled pH (∽ 9.0)

c) Inoculum: WAS from full scale WWTP

d) Temperature: 22 - 25°C

d) HRT: 2 days

e) OLR: 2.0 – 4.5 kg COD/(m^3 d)

Fed-batch accumulation

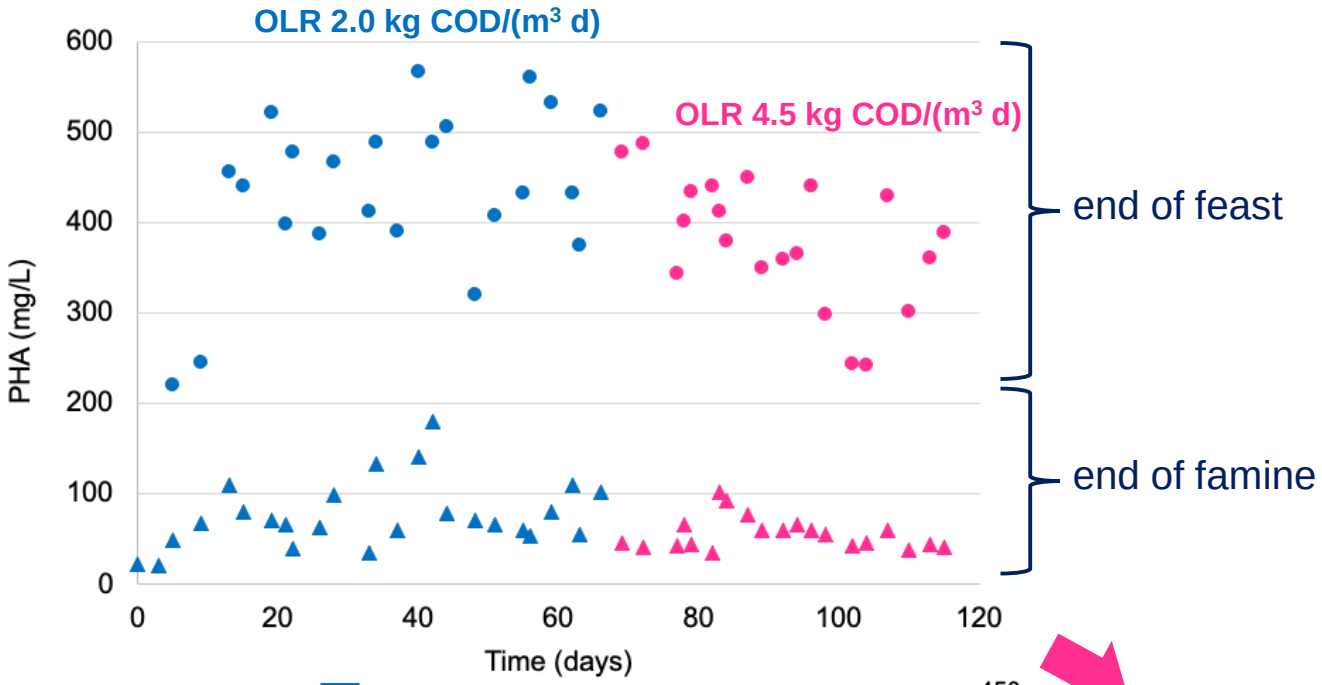
a) Fully aerobic feast

b) Uncontrolled pH (∽ 9.0)

c) Inoculum: SBR biomass

e) multi-spike based on oxygen control

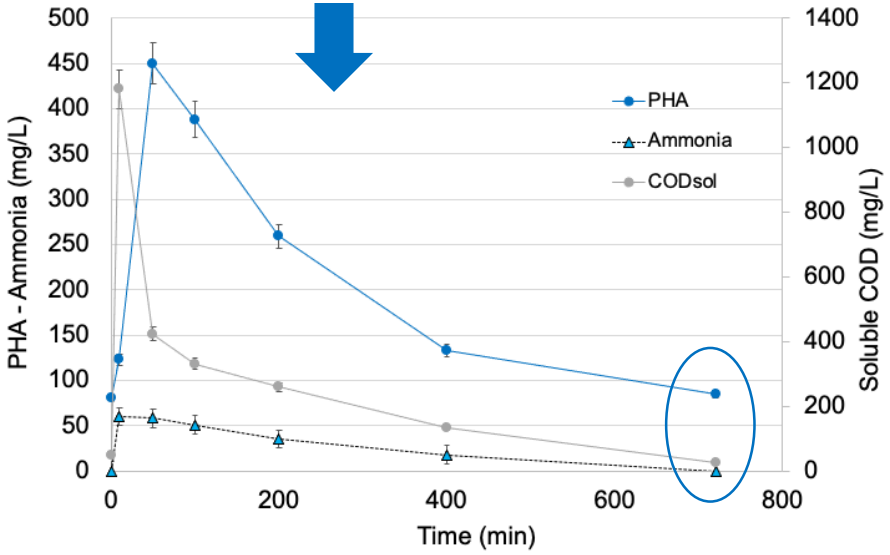
The pilot-scale PHA line – Biomass selection and PHA accumulation

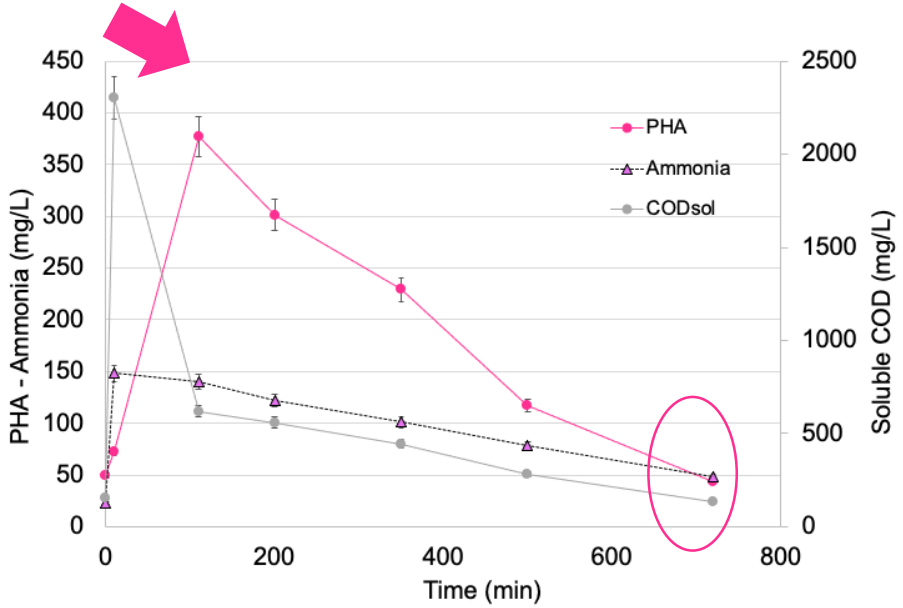


Observed Yield (Y_{OBS}^{SBR})
0.50 g COD_{XA}/g COD_{VFA}

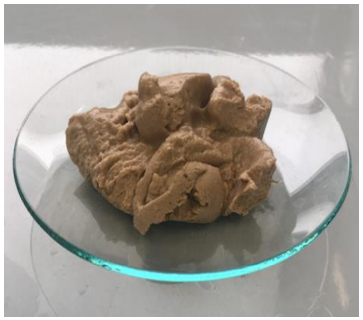
Storage Yield ($Y_{P/S}^{batch}$)
0.51 g PHA/g VFA

PHA biomass content
0.53 g PHA/g VSS



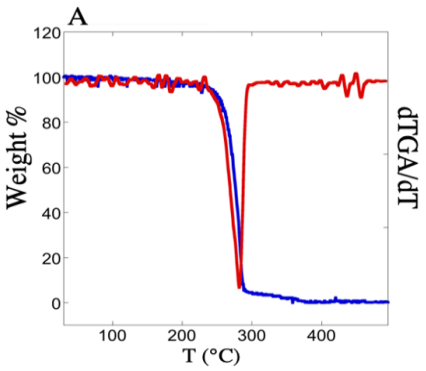


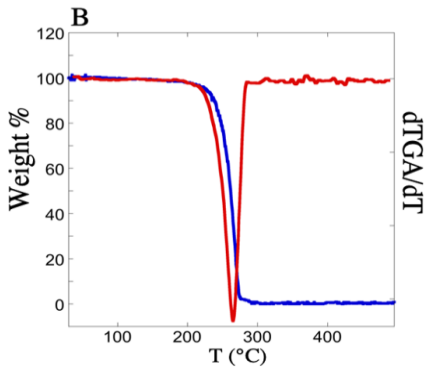
Downstream processing and PHA characterization

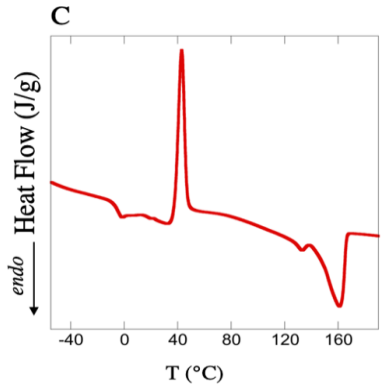


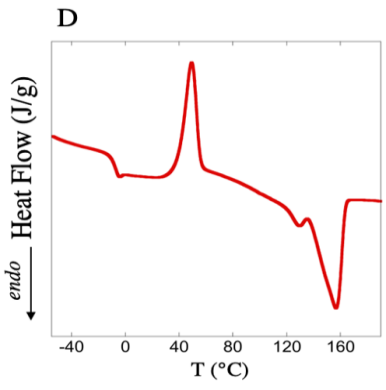
NaClO

Benchmark $CHCl_3$



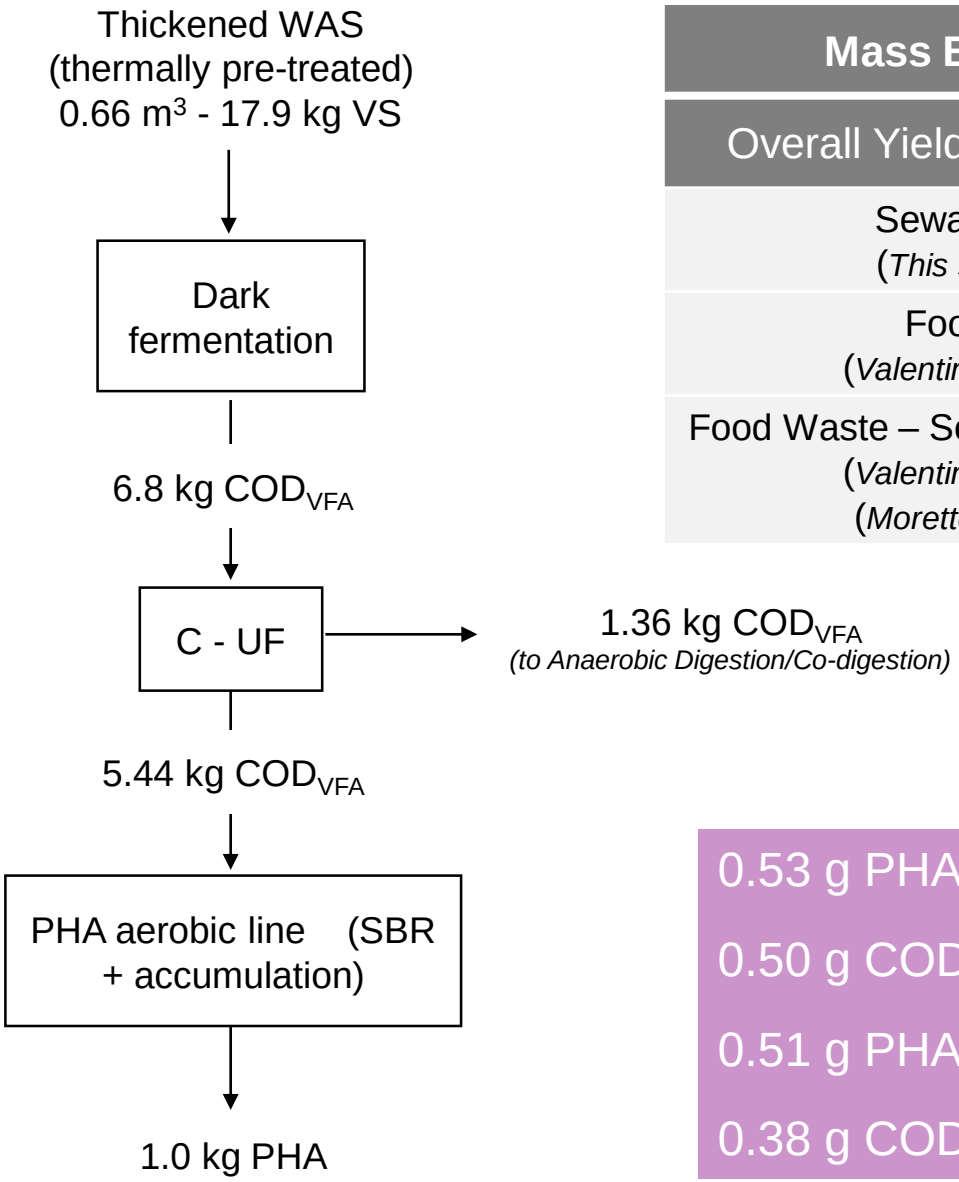






Parameter	Dried ($CHCl_3$)	Humid (NaClO)
Purity (%)	101	99.8
Recovery (%)	91.5	98.3
Composition (%3HV)	14.3	13.5
T_d^{MAX} (°C)	280	266
T_g (°C)	-5	-7
χ_c (%)	46	44
T_m (°C)	161	157
M_W (kDa)	405	396

The whole pilot-scale PHA line – Mass balance assessment



Mass Balance for the 3-stages process	
Overall Yield (g PHA/ kg VS_0)	Value
Sewage Sludge (*This study, 2022*)	56
Food Waste (*Valentino et al., 2018*)	37*
Food Waste – Sewage Sludge mixture (*Valentino et al., 2019*) (*Moretto et al., 2020*)	76 - 110

**Two phases anaerobic digestion*

0.53 g PHA/ g VSS	Max PHA content
0.50 g COD_{Xa}/g COD_{VFA}	Y_{OBS}
0.51 g PHA/g VFA	$Y_{P/S}^{batch}$
0.38 g COD_{VFA}/g VS	Fermentation yield

CONCLUSIONS AND PERSPECTIVES

- High stability and robustness in process performances (to be confirmed for the product in routine analysis)
- Overall PHA yield 56 g PHA/Kg VS (can be improved; the solids/liquids separation units are not optimized for a full-scale plant)
- Biogas from the overflows?
- Definition of the best scenario as income (€) per unit of TS-VS treated

2014/2020 POR FESR / REGIONE DEL VENETO
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Thank you!

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