Sludge recovery from industrial wastewater treatment

M. T. Santos[1], P. Lopes[1]

[1] Área Departamental de Engenharia Química, Instituto Superior de Engenharia de Lisboa - ISEL, Instituto Politécnico de Lisboa

TOPICS

- Introduction – Industrial sludges
- Goals
- Materials and Methods
- Results and discussion
- Conclusions
- Future perspectives

Main Industries in Portugal

Food | Textiles | Chemicals | Paper | Wood and Cork

Industrial wastewater (IWW)

Composition – depends on the type of industrial activity.

Industrial sludges

With proper treatment are **valuable material resources** → **sustainable circular economy**

How to treat industrial wastewater?

Based on **processes and operations** units more suited to its characteristics.

- **Industrial WWTP**

Liquid Phase Treatment

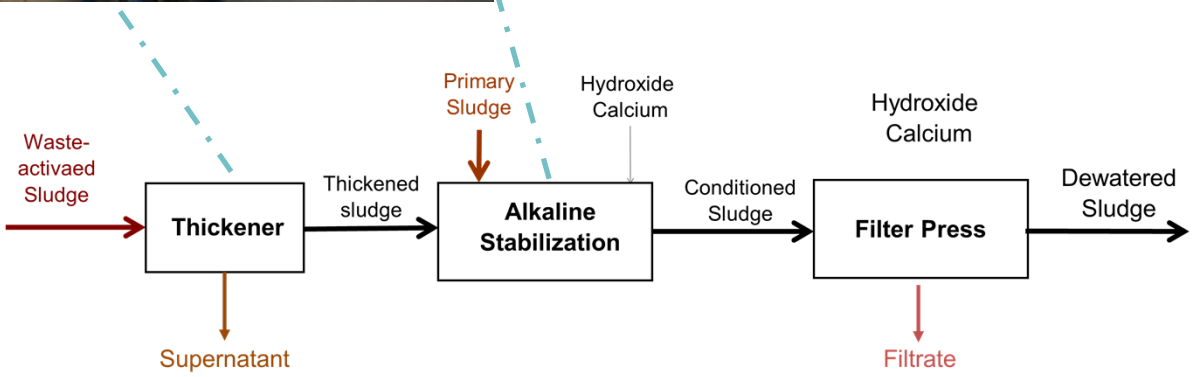
Aeration tank

Sedimentation tank

Sludges

How to treat industrial wastewater?

Solid Phase Treatment



Composting or Landfill

Sludges

How to treat or disposal industrial Sludges?

co-composting with MSW – problems due to the sludges composition.

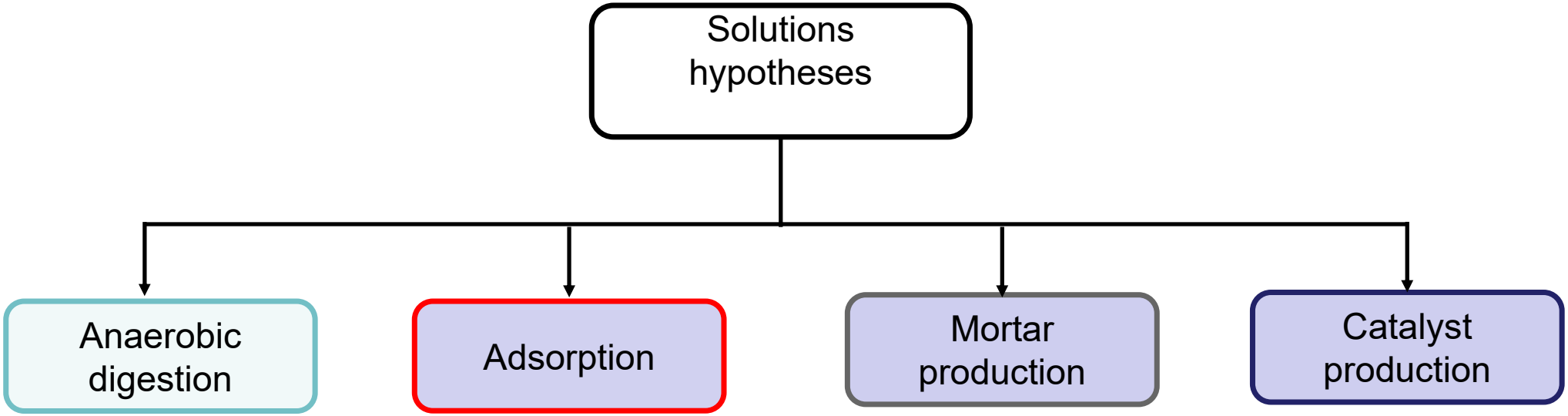
700 ton/year industrial sludges – Composting 35€/ton e 395€/transport (31,800€/ year)

Industrial Sludges Composition

Parameter	Units	value
Dry Matter	%m/m	68.2
Organic matter	%m/m	56.2
pH	Escala de Sorensen	12.6
Calcium	g Ca/kg	210
Phosphorus	g P/kg	0.22
Potassium	g K/kg	0.23
Magnesium	g Mg/kg	1.81
zinc	g Zn/kg	0.06

GOALS

- Identify and analyze treatment/valorization options for these wastes, giving priority to their recovery to the detriment of disposal.



Materials and Methods

Anaerobic digestion

- Potential Metanogenic Assay (32 d)
- 2 substrate mixtures:
  - Reactors A - 80% MS + 20 % IS
  - Reactors B - 90% MS + 10% IS
- Inoculum – digested sludges from WWTP

MS – Mixed sludge from Municiapl WWTP
IS – Industrial sludge

Composition of mixtures for reactors AD

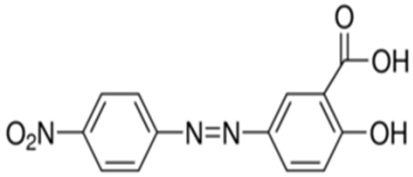
Item	Reactors A (g)	Reactors B (g)	Reactors I (g)
MS	4.85	5.45	-
IS	0.09	0.05	-
Inoculum	19.05	19.05	19.05
water	175.45	175.45	180.95

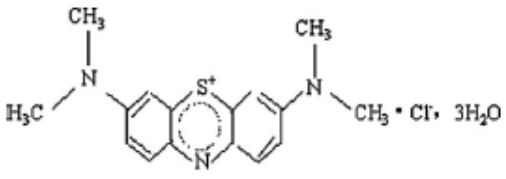
Materials and Methods

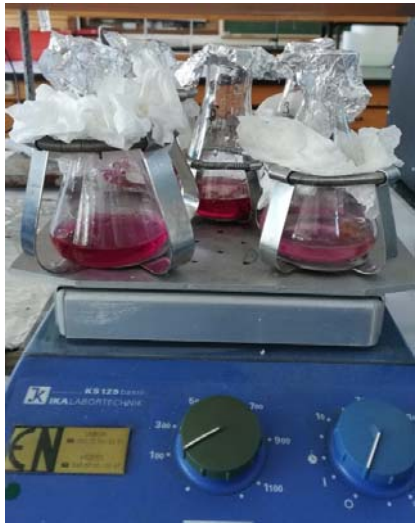
Anaerobic digestion

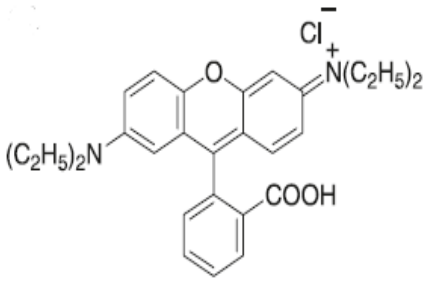
- ❖ Quantitative and qualitative analysis of Biogas
- ❖ Specific methane production

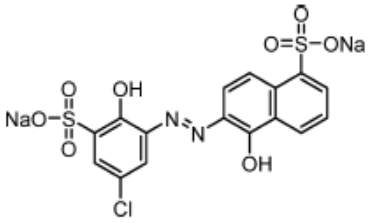
Materials and Methods











Adsorption

- Adsorbent (75% ADS e 25 % IS)
- 4 Dyes:
  - Rhodamine-B - $C_{28}H_{31}N_2O_3C$
  - Mordant Orange 1 - $C_{13}H_9N_3O_5$
  - Methylene Blue - $C_{16}H_{18}N_3SCl$
  - Mordant Blue 9 - $C_{16}H_9ClN_2Na_2O_8S_2$
- 6 concentrations and Vuseful of 30 mL
- Adsorbent masses (0,5, 1, 1,5, 2 e 3 g)
- Tests of 1h30min with measurements of ½ in ½ h

Materials and Methods

Mortar production

- Method: NP EN 191-1: 2006
- 5 mortar mixtures:
  1 reference (cement only)
  1%, 2.5%, 5% e 10% Sludge
- Test time 28 d

Composition	Reference	Sludge (1%)	Sludge (2.5%)	Sludge (5%)	Sludge (10%)
Cement (g)	450.02	445.52	438.71	427.51	405.03
Sand (g)	1,350	1,350	1,350	1,350	1,350
Sludge (g)	-	4.51	11.32	22,51	45.02
Water (g)	225.02	225.01	225.03	225,03	225.02

Materials and Methods

Mortar production

- ❖ Bending strength tests
- ❖ Compressive strength tests

Materials and Methods

Biofuel production - heterogeneous catalysis

- Used food oils
- Pre-treatment drying - 70 ºC
- Calcination pretreatment 850 ºC
- Convert calcium (sludge) to calcium oxide.

Materials and Methods

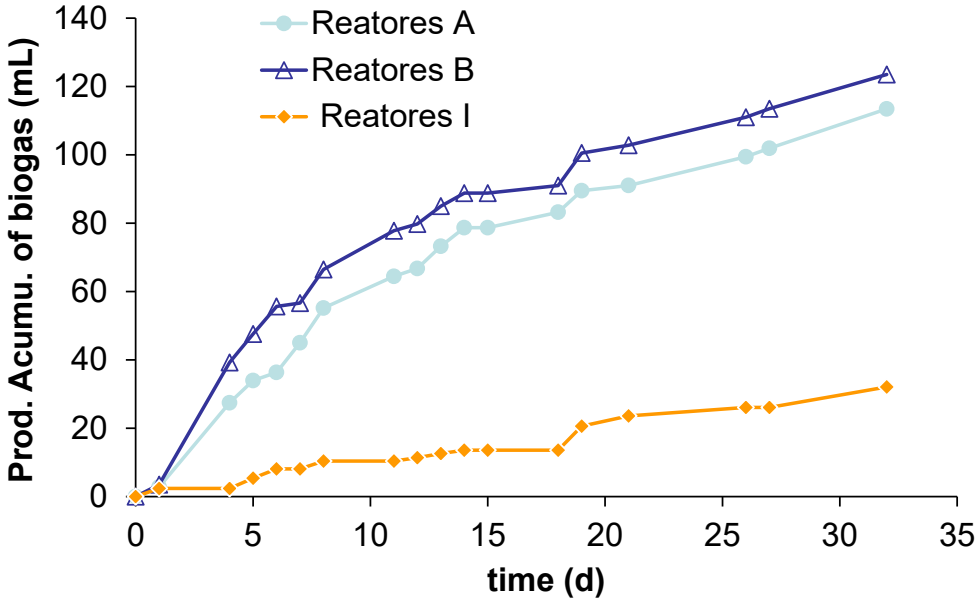
Biofuel production - heterogeneous catalysis

- FTIR-ATR
- Acidity index
- Density

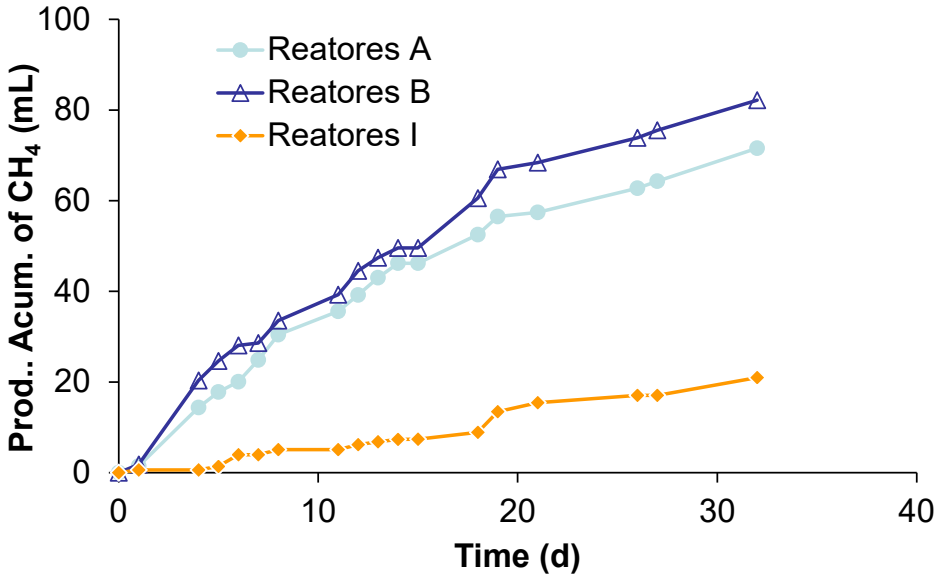
Results and Discussion

Anaerobic Digestion Assay

- Reactors A
  - **21% -** SV removal
  - CH_4 - **55 to 60%**



- Reactors B
  - **42%** SV removal
  - CH_4 - **60 to 65%**

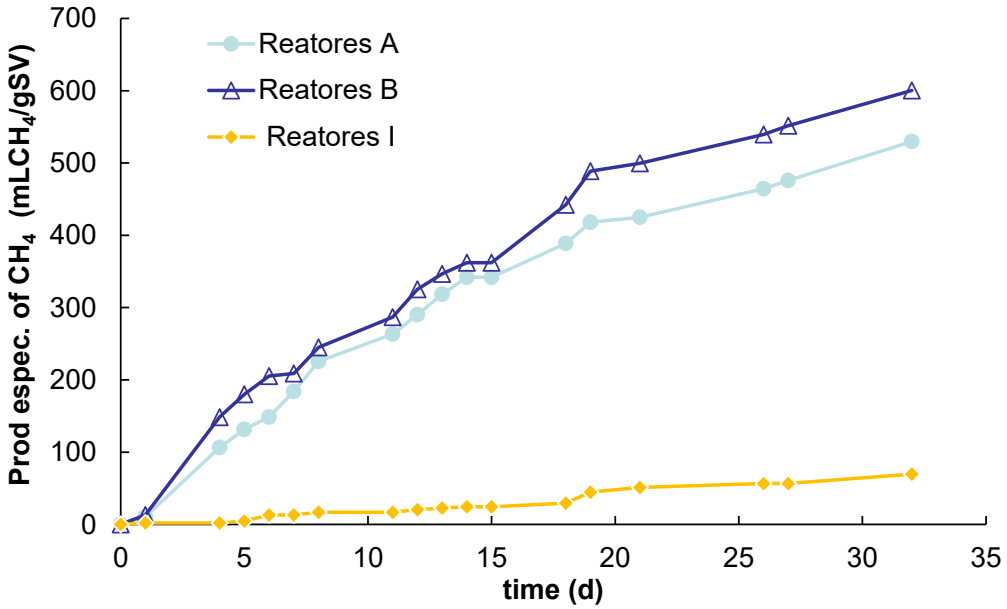


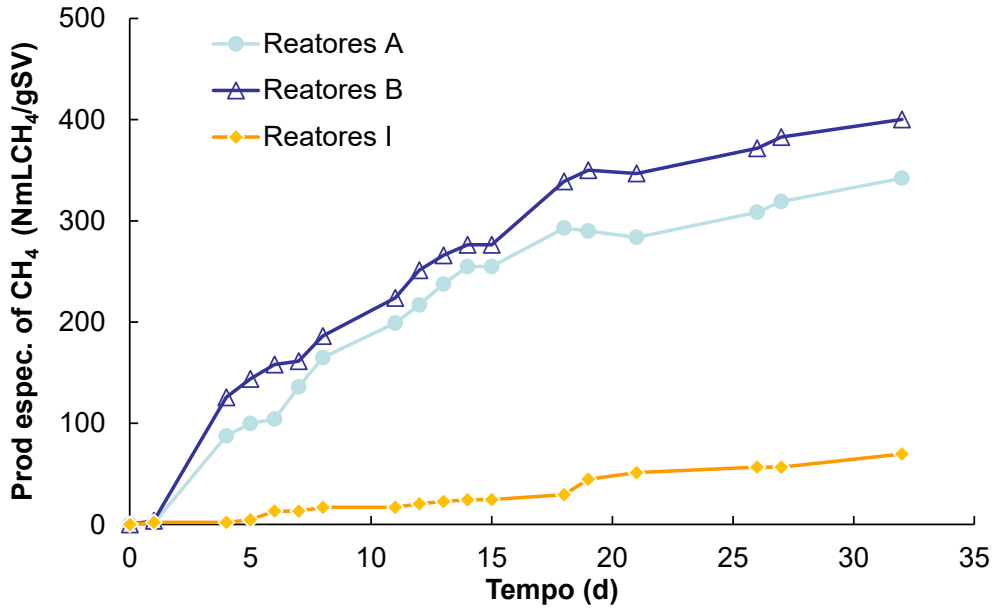
Results and Discussion

➢ Methane production

❖ Test Conditions – 1 atm and 35ºC
❖ Conditions PTN – 1 atm and 0ºC

Reactors	Prod. acumu. of biogas (mL)	Prod. acumu. of CH_4 (mL)	Prod. Espec. of CH_4 (mL CH_4 /gVS	Prod espec. of CH_4 (N.mL CH_4 /gVS)
A	113	71	529	342
B	123	82	600	400

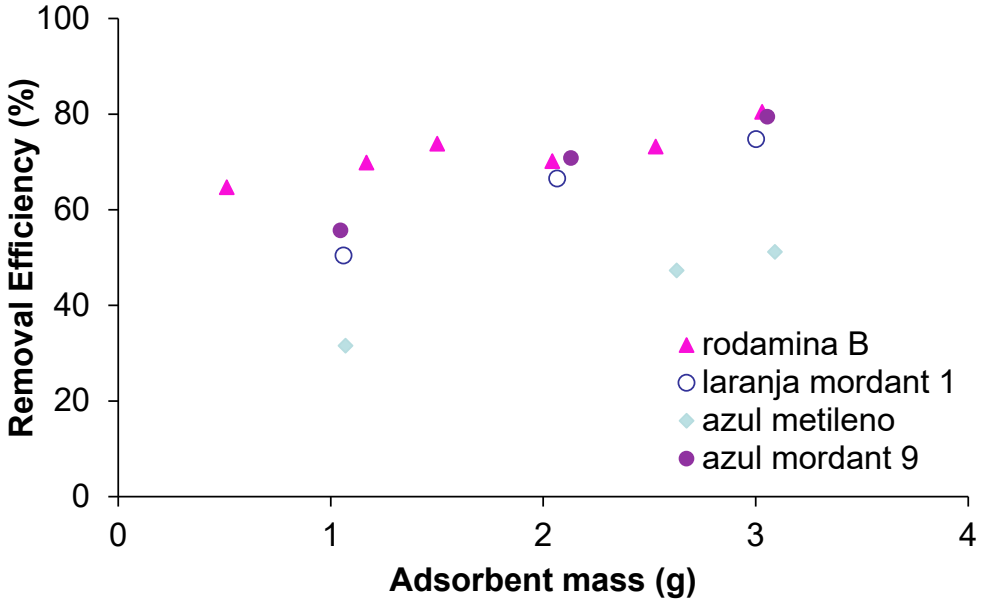


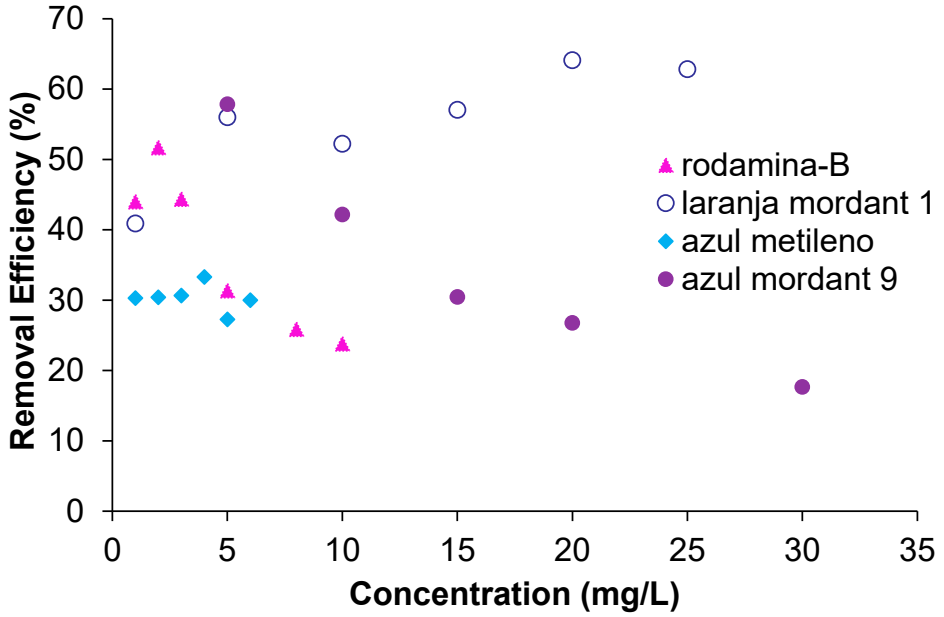


Results and Discussion

Adsorption tests

- It was obtained $R^2 \geq 0{,}989$
- Removal efficiency between 70 to 80%





Results and Discussion

- **Isothermics** of adsorption tests for each of the dyes

Linearized equation of Langmuir:

$$\frac{C_e}{q_e} = \frac{1}{q_{max}\, k_L} + \frac{1}{q_{max}} C_e$$

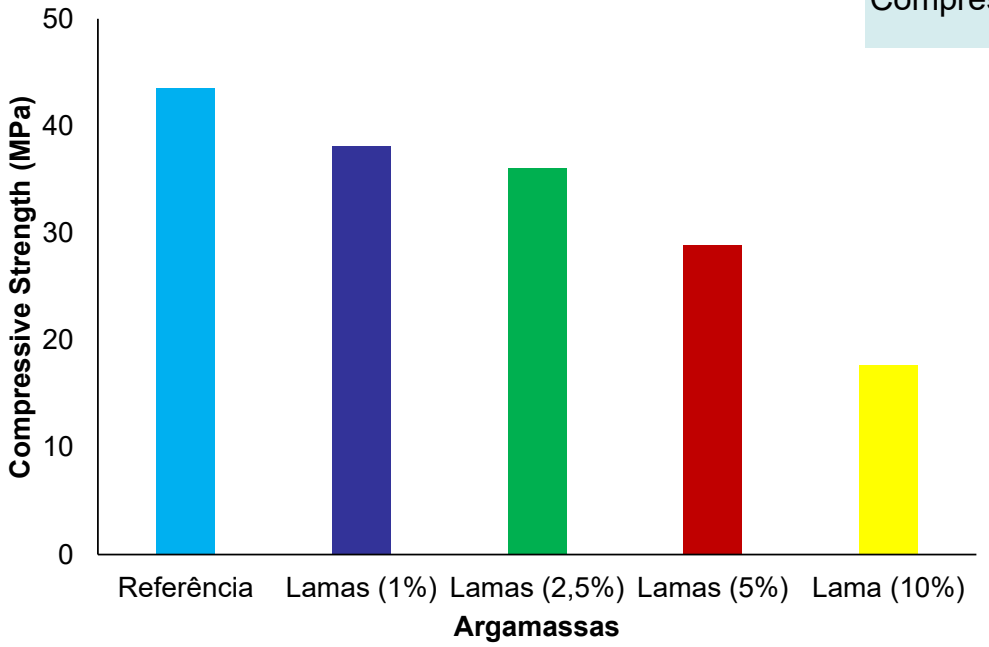
Linearized equation of Freundlich:

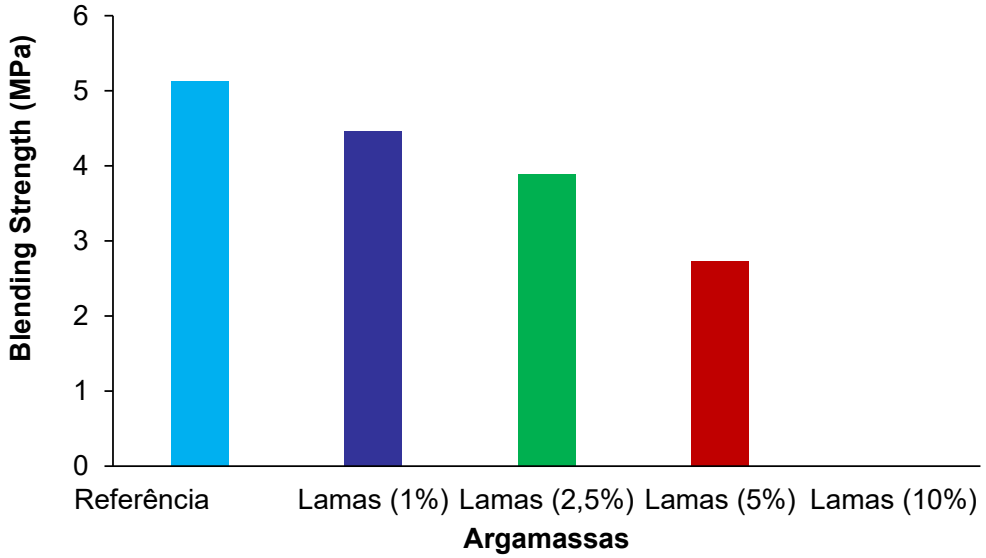
$$\ln q_e = \ln K_F + \frac{1}{n} \ln C_e$$

- The isothermal that best fits – **Langmuir Isothermic**
  - q_{max} = 0,780 mg/g - Mordant Blue 9
  - q_{max} = 0,274 mg/g - Rhodamine-B
  - q_{max} = 0,494 mg/g - Mordante Oranje 1
  - q_{max} = 0,010 mg/g - Methylene Blue

Results and Discussion

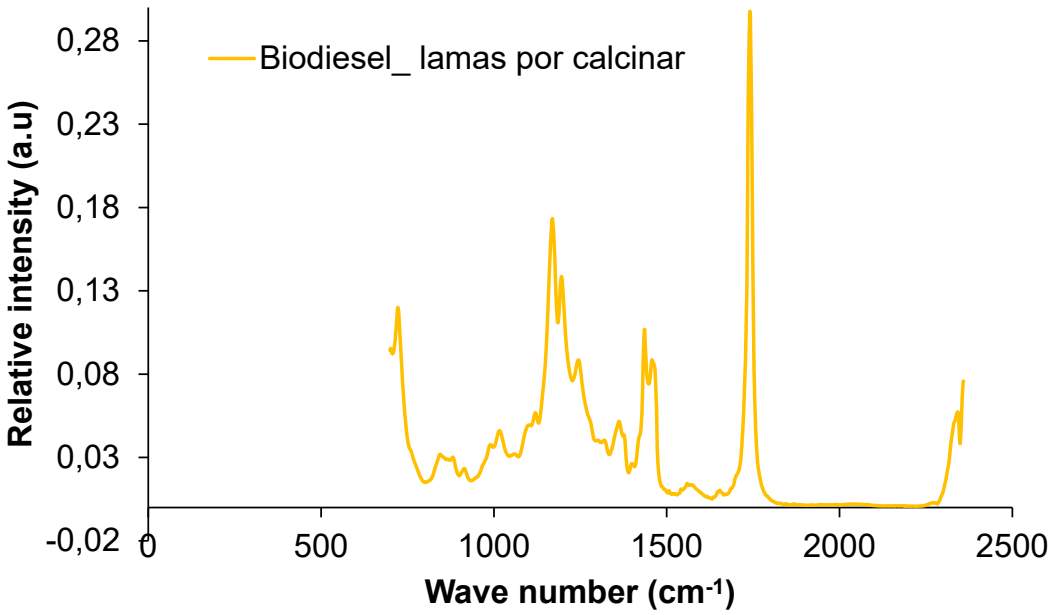
Strength	Reference	Sludge (1%)	Sludge (2.5%)	Sludges (5%)	Sludge (10%)
Blending (MPa)	5.13	4,46	3,89	2,73	-
Compressive (MPa)	43.54	38.14	36.04	28.90	17.12

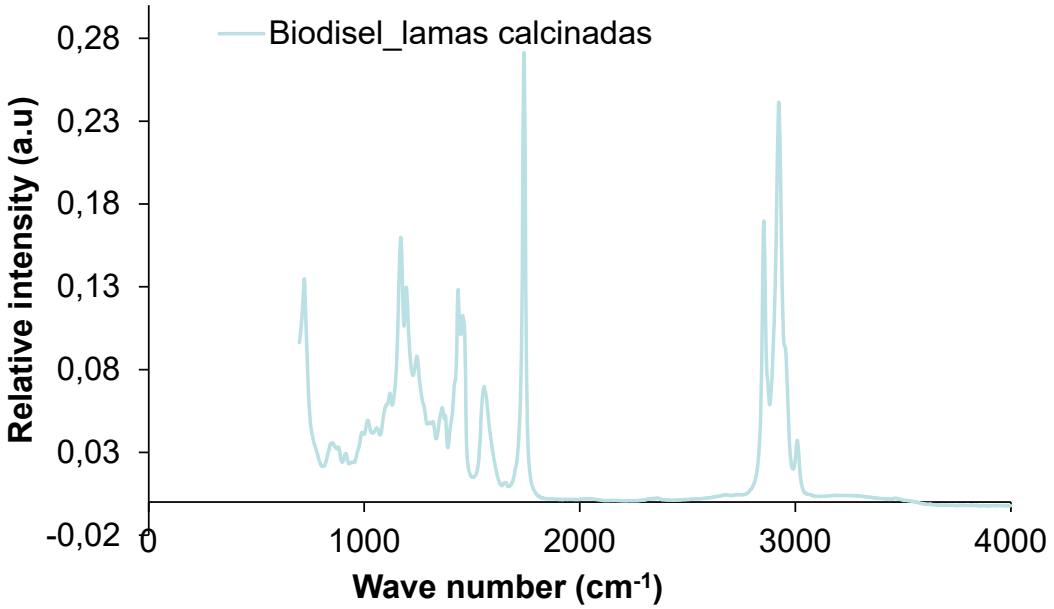




Catalyst production tests for biofuel production

- Conversion of 90%
- Acidity index : **0.17 e 0.18**

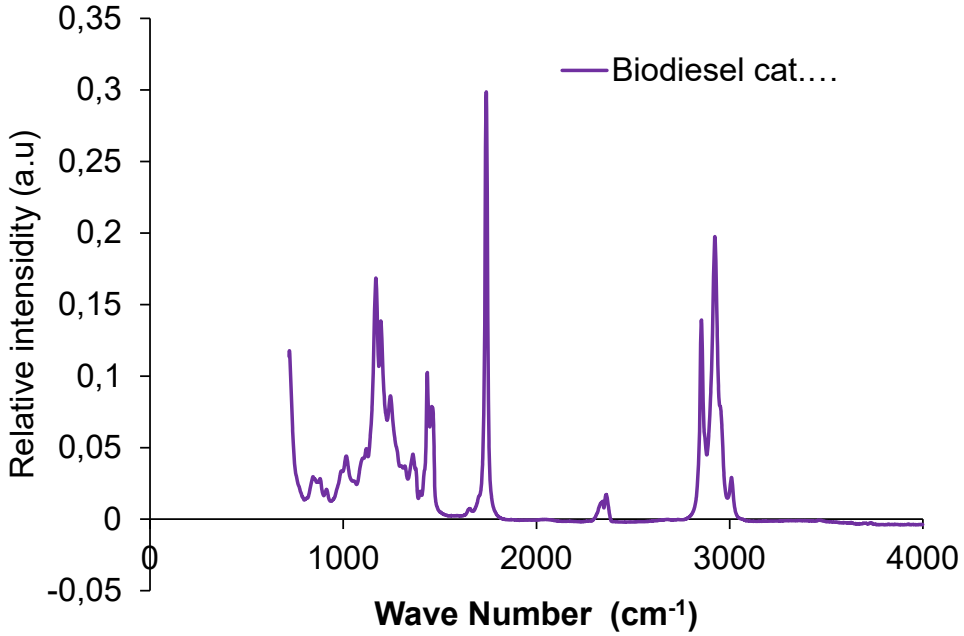




Results and Discussion

- Functional groups (FTIR-ATR)

Chemical bonding	Function	Wave Number (cm^{-1})
–O–H	Alcohol, phenol, enol, carboxylic acid	3650 –3200
$–R_2NH$	Secondary Aminas	3400 – 3140
$–NH_2$	Primary amines	3400 – 3350
–C–H	Alkanes	2962 – 2853
–C–H	Alkenes	3095 –3010
–CO–C–H	Aldehydes	2900 – 2800
–C≡C–, C≡N	Alcinos and Nitrites	2500 – 2000
$R_2C=O$	Carbonates	1630 – 1850
$H_2C=CH_2$	Alkenes	1680 – 1650
–C=C–	Aromatics	1450 – 1500



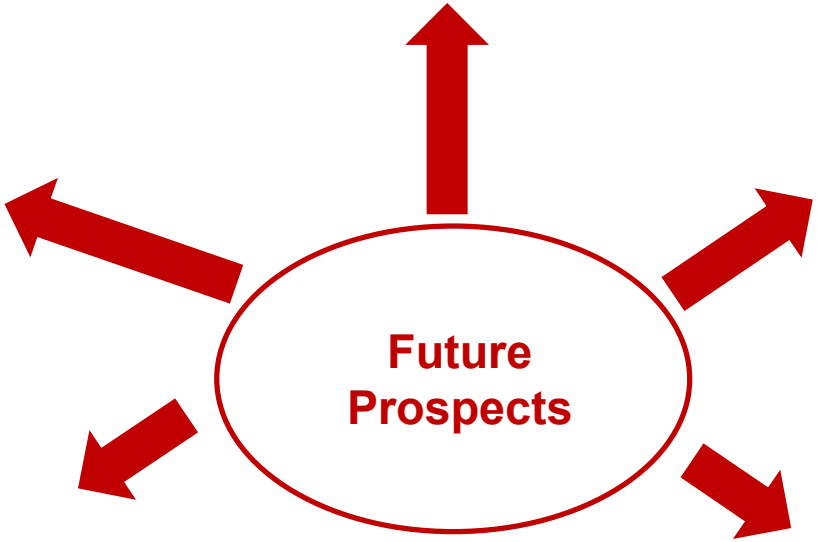
Conclusions

- It is possible to apply **anaerobic co-digestion** with energy recovery. Specific methane production **0.400 L/gSV added**, 4 kWh/kg SV corresponding to **2 kWh/kg industrial sludge**.
- It is possible to produce **adsorbents for removal of water dyes**. With blue mordant 9, a maximum removal of 80% - qmax = 0.780 mg/g was obtained .
- The **production of mortar** - Visual analysis similar aspect between the specimens with the sludge and the reference. The **bending and compression strengths are lower than** the reference resistance but present acceptable values.
- **Catalyst production - biofuel production was achieved 90% conversions and acidity indexes < 0.5**.

Future Work

➢ **Cement production:**
- Conduct pilot-scale trials

➢ **Anaerobic digestion:**
- IS with fractions >20%
- different substrates.



➢ **Adsorption:**
- Apply the adsorbent – different polluents.

➢ **Mortar production:**
- Curing times less than 28 d
- Replace the sand fraction.

➢ **Production of Heterogeneous Catalysts:**
- Test the number of uses.

Acknowledgements:

We thank to the Chemical Industry for the sludge and data.

email: tsantos@deq.isel.ipl.pt

Thank you for your attention

Questions ?