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PRELIMINARY STUDY OF GASIFICATION WITH STEAM / ENRICHED AIR MIXTURES OF SEWAGE SLUDGE AND OF THE CHAR OBTAINED IN ITS PYROLYSIS PROCESS

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OUTLINE

1. INTRODUCTION AND OBJECTIVES

2. MATERIALS AND METHODS
   - ❑ Materials
   - ❑ Experimental plant

3. RESULTS
   - ❑ Effect of H_2O/O_2 molar ratio used as gasifying agent
   - ❑ Effect of temperature

4. CONCLUSIONS AND FUTURE WORKS

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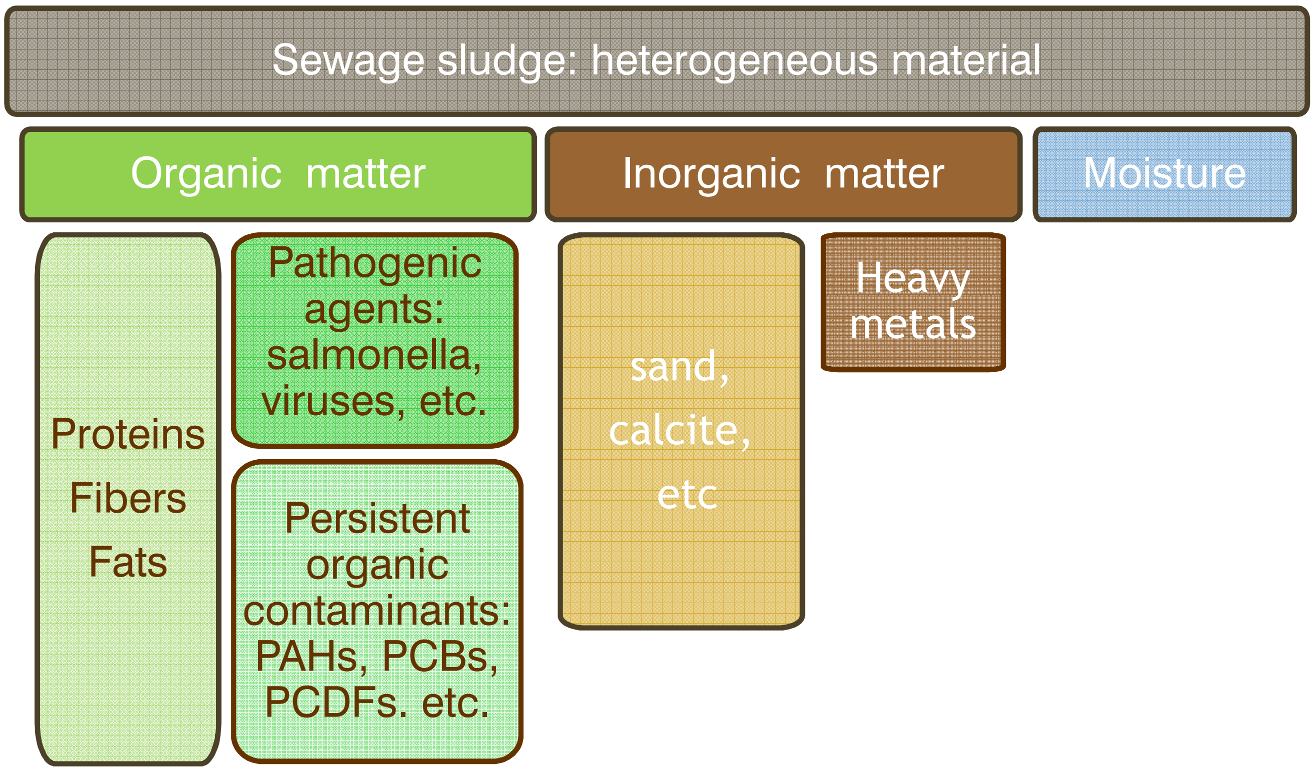
Sewage sludge is the waste produced during the purification of the wastewater in the wastewater treatment plants.



Strict legislation (Directive 91/271/ECC)

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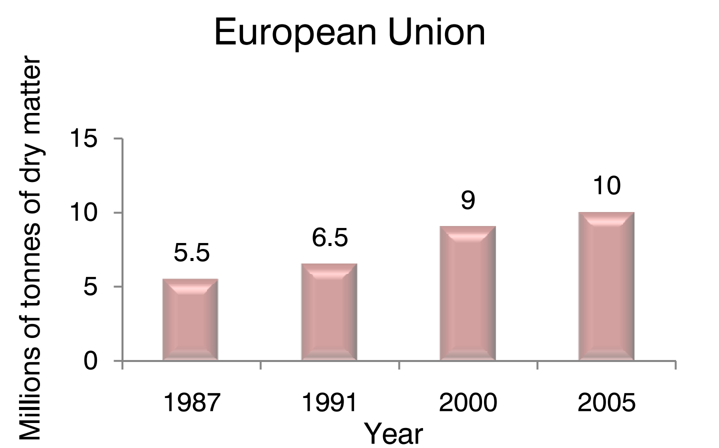
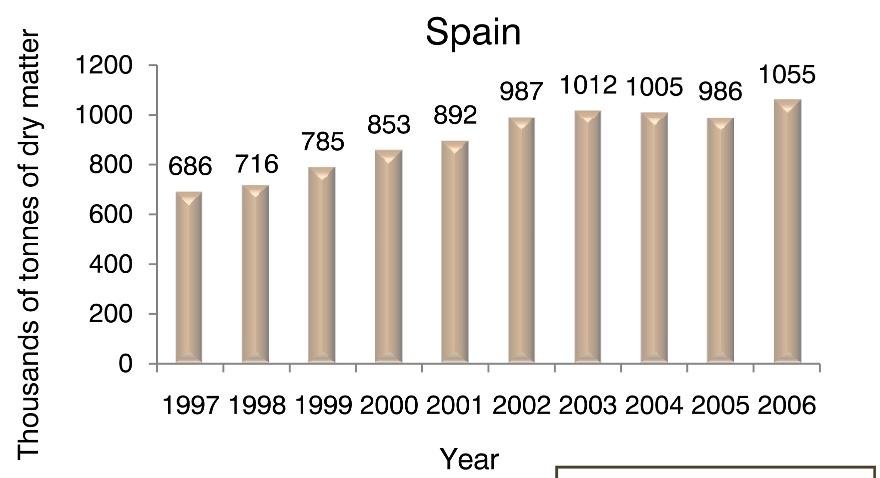
↑ sewage sludge generation

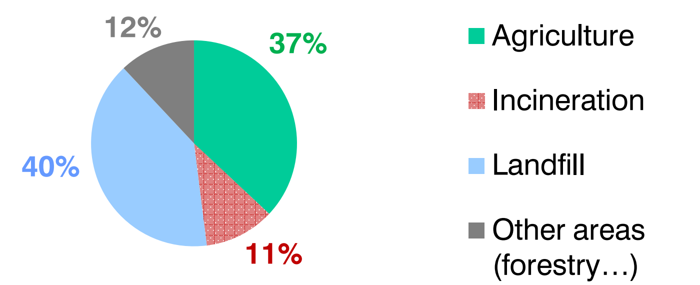


Source: Eurostat



Source: PNIR 2008-2015

Sewage sludge management ways in European Union (2008)



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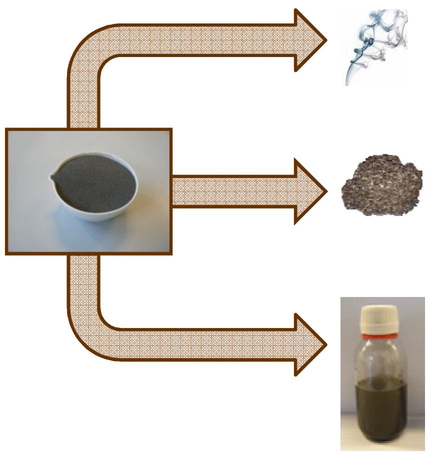
Thermochemical processes as a way of sewage sludge management

- **Gasification** is the thermal process during which carbonaceous content of sewage sludge is converted to a gaseous fuel by heating in a gasification medium such as air, oxygen or steam.



Gas: CO, CO_2, H_2, light hydrocarbons (CH_4, C_2H_6, C_2H_4, C_2H_2), N_2 (gasification with air), impurities (H_2S, NH_3)

- Electrical / heat energy
- Chemical feedstock

Char

Tar + water

Tar is undesirable → problems associated with condensation, formation of tar aerosols and polymerization.

- **Pyrolysis** is the thermal decomposition of a material in an inert atmosphere.

Char is the main byproduct in flash pyrolysis→ it still has carbonaceous content → raw material for gasification process.

OBJECTIVE OF THE WORK

Study the influence of some OPERATIONAL CONDITIONS:

- ✓ Raw material: sewage sludge and char obtained in sewage sludge pyrolysis.
- ✓ Gasification medium: mixtures of enriched air / steam (H_2O/O_2 molar ratio = 1 and 3).
- ✓ Temperature: 820ºC and 850 - 860ºC

on some RESPONSE VARIABLES of the gasification process:

- ✓ Distribution of products (mass yields of gasification products: gas, solid, tar, water)
- ✓ Gas composition and LHV_{gas}
- ✓ Carbon conversion efficiency
- ✓ Apparent thermal efficiency

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❑ Materials

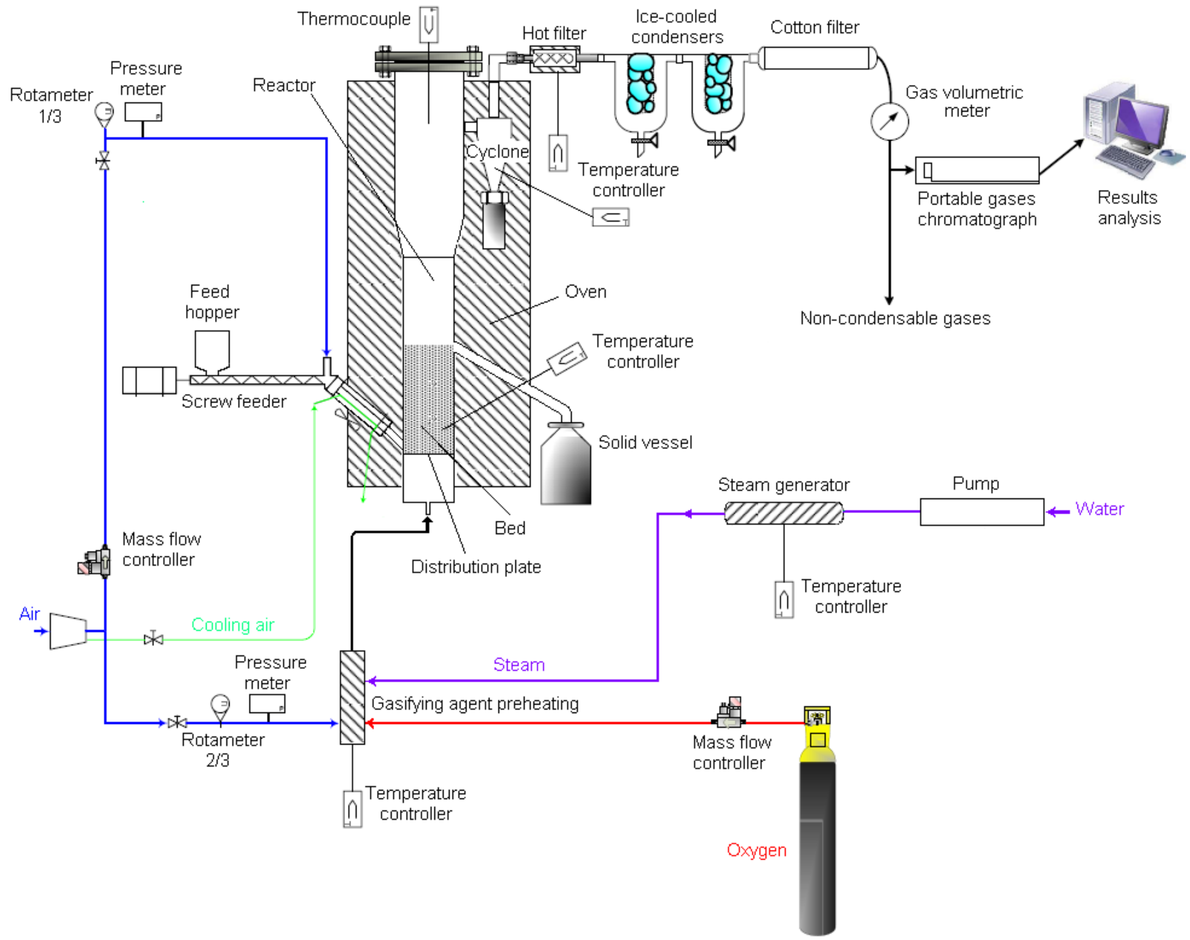
- Anaerobically digested and dried sewage sludge, suplied by a Spanish urban waste water treatment plant (it is ground and sieved to 250-500 µm).

- Char obtained from sewage sludge pyrolysis (530ºC) in fluid bed.

	Sewage sludge	Char from sewage sludge pyrolysis
Ultimate analysis (wt. % as received)		
Moisture	6.6	1.7
Ash	41.3	74.2
Volatiles	46.1	15.0
Fixed carbon	6.0	9.1
Elemental analysis (wt. % as received)		
C	27.7	15.5
H	4.4	1.0
N	3.9	1.9
S	0.8	0.4
Lower Heating Value		
LHV (MJ/kg)	10.80	4.96

❑ Experimental plant

- Fluidized bed reactor (atmospheric pressure)
- $u_f/u_{mf} \approx 6$
- Continuous feed of solids and continuous removal of ash



Operational conditions

- Gasifying agent → mixtures of steam and enriched air with different H_2O/O_2 molar ratios: 1 or 3.
- Gasifying agent ($H_2O + O_2$) to biomass ratio: 1.1 kg H_2O+O_2/kg biomass *daf* (dry and ash free).
- Bed temperature: 820 or 860ºC

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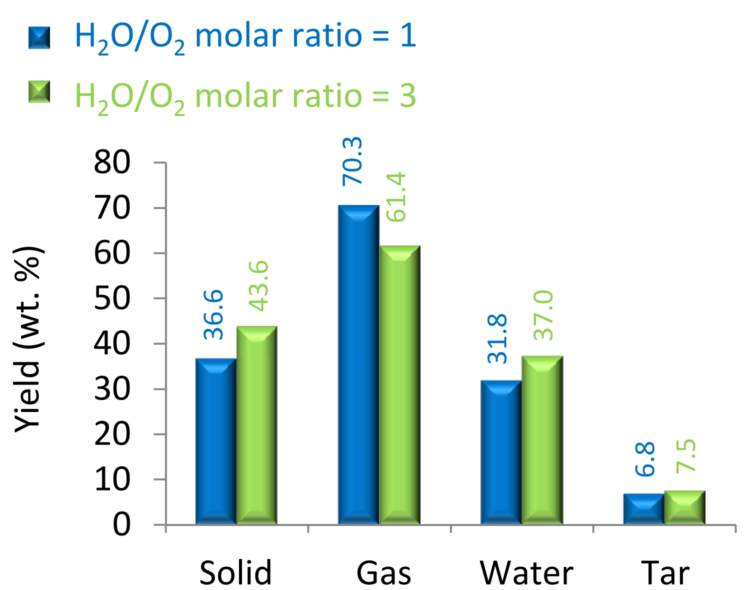
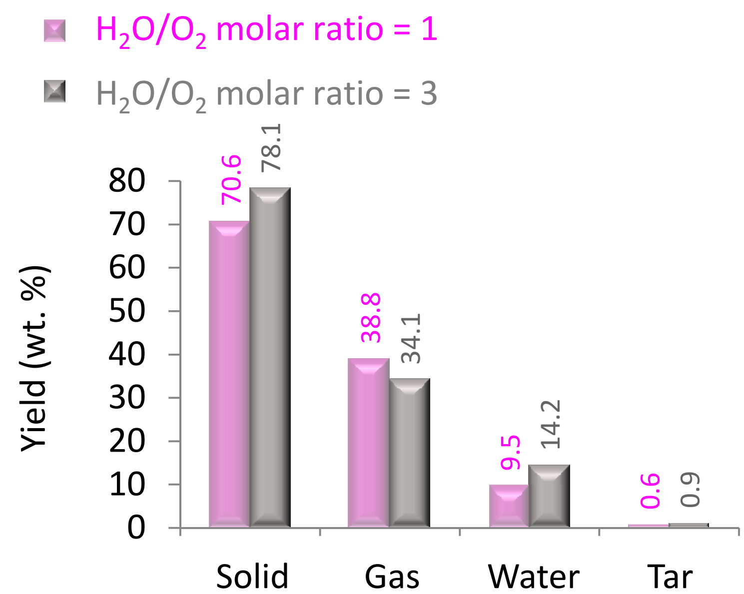
❑ Effect of H_2O/O_2 molar ratio used as gasifying agent (I)

Temperature = 820ºC

Sewage sludge gasification



Char gasification

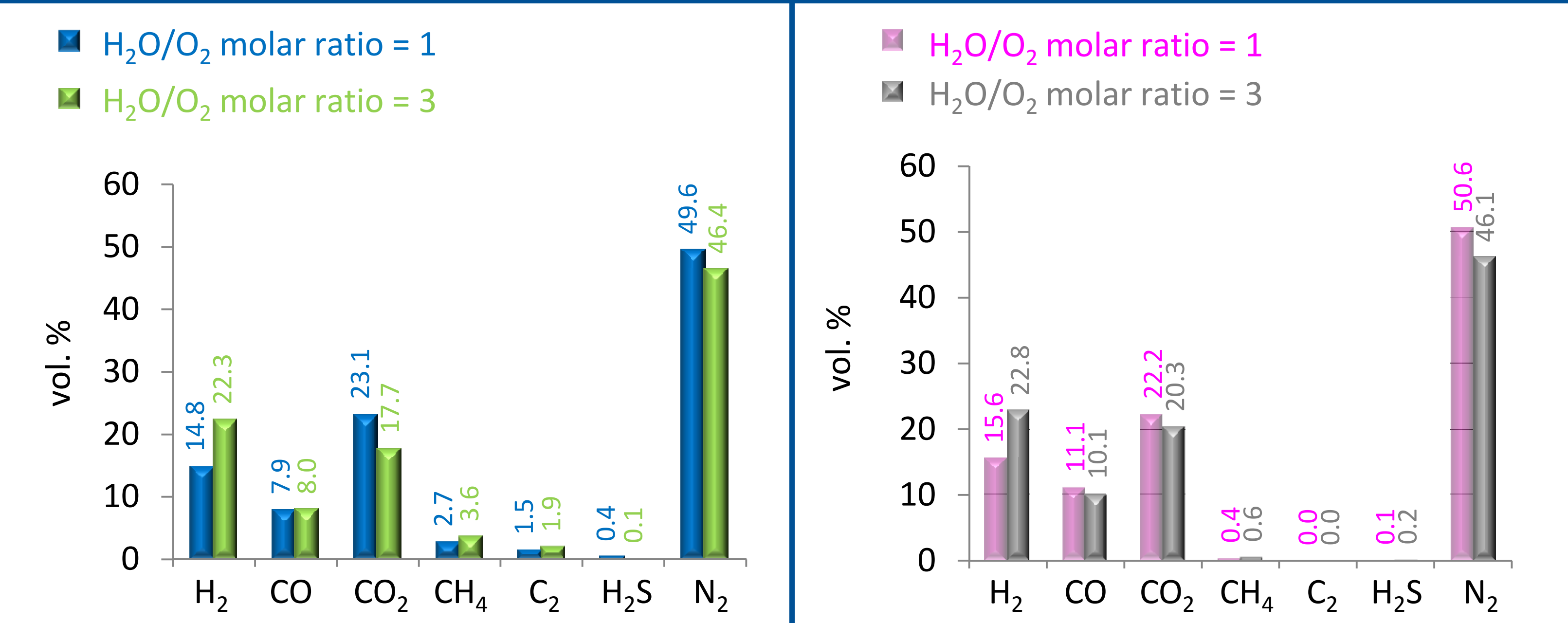


- ↑ steam proportion → ↓ gas yield; ↑ solid, water and tar yields.
- The main product obtained in sewage sludge gasification was the gaseous product, while solid was the main product in char gasification.

❑ Effect of H_2O/O_2 molar ratio used as gasifying agent (II)

Temperature = 820°C

Sewage sludge gasification	*Char gasification*



- ↑ steam proportion → ↑ H_2 and light hydrocarbons; ↓ CO_2.
- vol. % of CH_4 and C_2 were lower in the gas obtained in char gasification than in those obtained in sewage sludge gasification.

❑ Effect of H_2O/O_2 molar ratio used as gasifying agent (III)

Temperature = 820ºC

	Gas LHV (MJ/Nm^3)	Carbon conversion efficiency (%)	Apparent thermal efficiency (%)
	Sewage sludge gasification		
H_2O/O_2 molar ratio = 1	4.55	83.83	49.72
H_2O/O_2 molar ratio = 3	5.87	75.67	64.30
	Char gasification		
H_2O/O_2 molar ratio = 1	3.25	76.18	42.85
H_2O/O_2 molar ratio = 3	3.97	66.12	49.40

$$\text{Carbon conversion efficiency (\%)} = \frac{\text{kg C in gas produced}}{\text{kg C in biomass fed}} * 100$$

$$\text{Apparent thermal efficiency (\%)} = \frac{Nm^3 \text{ gas produced} * LHV_{gas}\left(\frac{MJ}{Nm^3}\right)}{\text{kg biomass fed} * LHV_{biomass}\left(\frac{MJ}{kg}\right)} * 100$$

- ↑ steam proportion → ↑ LHV_{gas} (↑ vol. % of H_2, CH_4 and C_2); ↓ carbon conversion efficiency; ↑ apparent thermal efficiency.
- LHV_{gas}, carbon conversion efficiency and apparent thermal efficiency are lower in char gasification than in sewage sludge gasification.

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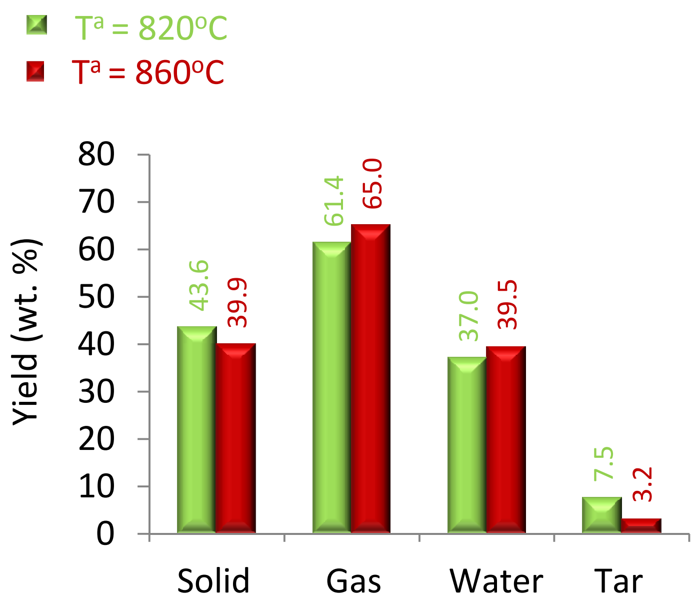
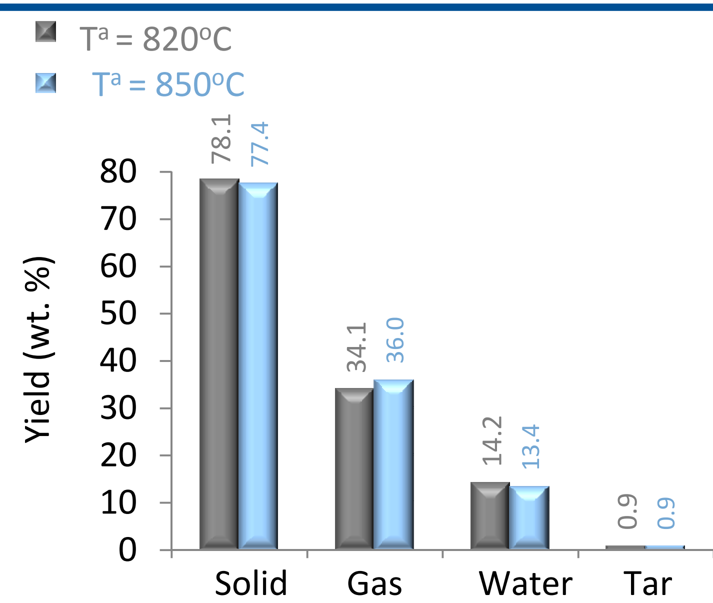
❑ Effect of temperature (I)

H_2O/O_2 molar ratio = 3

Sewage sludge gasification	*Char gasification*





- ↑ temperature → ↑ gas yield; ↓ solid yield; ↓ tar yield in sewage sludge gasification, but this difference was not significant in char gasification.

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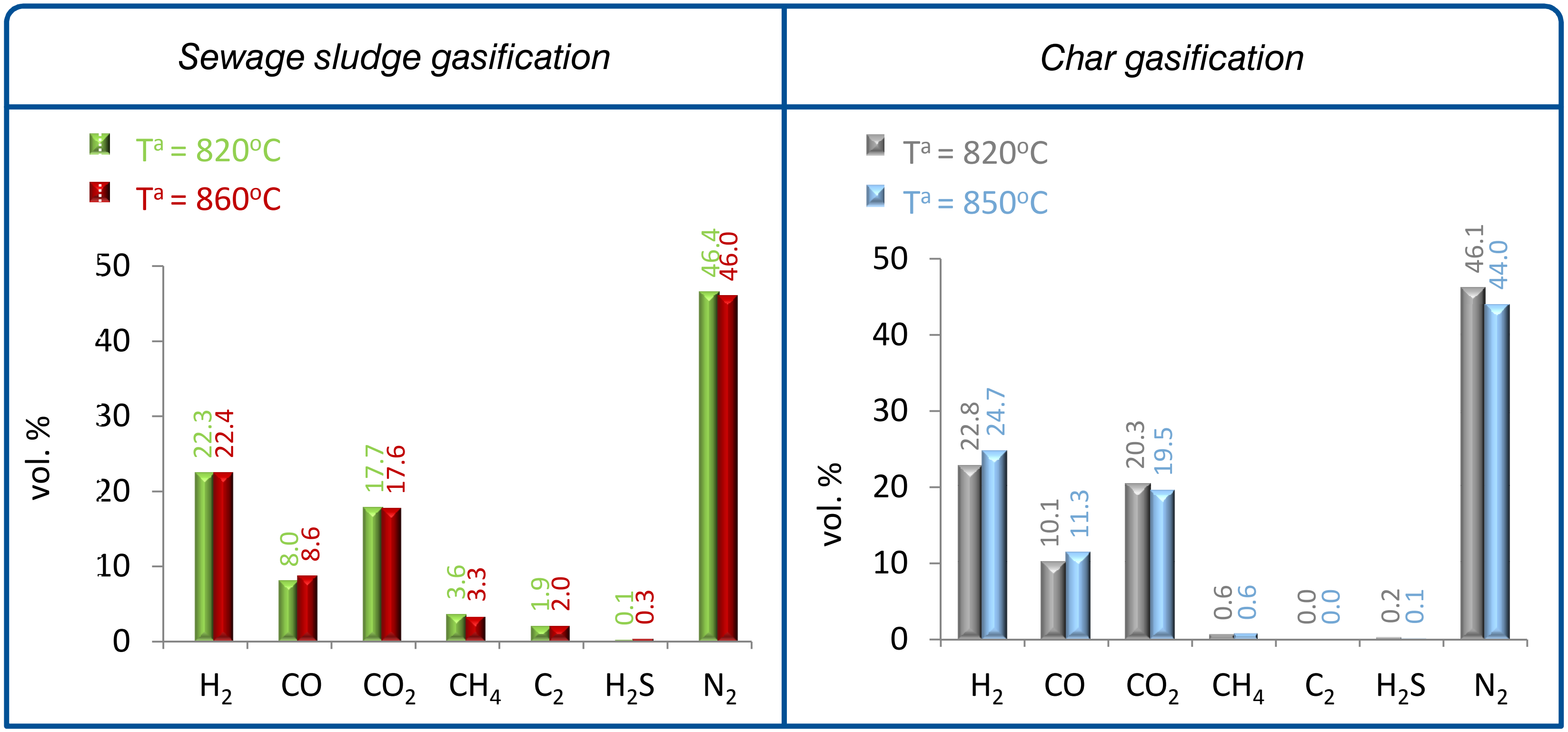
❑ Effect of temperature (II)

H_2O/O_2 molar ratio = 3



➢ Gas composition was hardly influenced when temperature was increased in both sewage sludge and char gasification.

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❑ Effect of temperature (III)

H_2O/O_2 molar ratio = 3

	Gas LHV (MJ/Nm^3)	Carbon conversion efficiency (%)	Apparent thermal efficiency (%)
	Sewage sludge gasification		
T = 820ºC	5.87	75.67	64.30
T = 860ºC	5.88	79.96	67.50
	Char gasification		
T = 820ºC	3.97	66.12	49.40
T = 850ºC	4.32	70.90	56.98

- ↑ temperature → LHV_{gas} was hardly influenced; ↑ carbon conversion efficiency; ↑ apparent thermal efficiency.

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CONCLUSIONS

- The H_2O/O_2 molar ratio used as gasifying agent had a significant effect on gasification process of both, sewage sludge and sludge derived char.
  - ↑ H_2O/O_2 molar ratio → ↓ gas yield but ↑ LHV_{gas} and ↑ apparent thermal efficiency; ↑ H_2 formation.
  - ↑ H_2O/O_2 molar ratio → ↑ H_2/CO molar ratio in gas product (above 2).
- ↑temperature → ↑ gas yield; gas composition and LHV_{gas} were hardly influenced.
- Char gasification yielded a gas with a very low LHV, being the advantage the low tar content.

FUTURE WORKS

- To analyze the influence on tar composition
- To deepen into the gas cleaning process

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