8-20-2017

Hydrothermal carbonization of sewage sludge: Char characterization and reference to international legislations

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Introduction

HYDROTHERMAL CARBONIZATION: → Coalification process that converts raw wet biomass into a coal like product

OPERATIVE CONDITIONS: →

- Substrates: organic waste (OFMSW, sewage sludge, wet agricultural residues, algae, etc)
- Moisture: > 75%
- Temperature: 180 – 250 °C
- Pressure: 10 -50 bar (autogenous)
- Residence time: 0.5 – 8 h

AIM OF THE WORK: →

- Apply HTC to different kinds of sludge (thickened sludge, digested sludge and dewatered sludge);
- Apply HTC at different operative conditions to the different feedstocks;
- Characterize the solid produced by the process (ash, carbon, nutrients and heavy metals)
- Compare the hydrochar composition with different soil and biosolid legislations

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Material and methods

FEEDSTOCK: →

Feedstock sampled from WWTP of Trento, Italy

- Primary sludge (after static thickner)
- Digested sludge (after anaerobic digestion)
- Dewatered sludge (after centrifuge)

OPERATIVE CONDITIONS: →

- Dry biomass to water ratio 3% for primary sludge
- Dry biomass to water ratio 3% for digested sludge
- Dry biomass to water ratio 17% for dewatered sludge
- Temperature: 190, 220, 250 °C
- Residence time: 30, 60 min
- Pressure: 10 – 40 bar (function of temperature)

Each test was repeated at least three times

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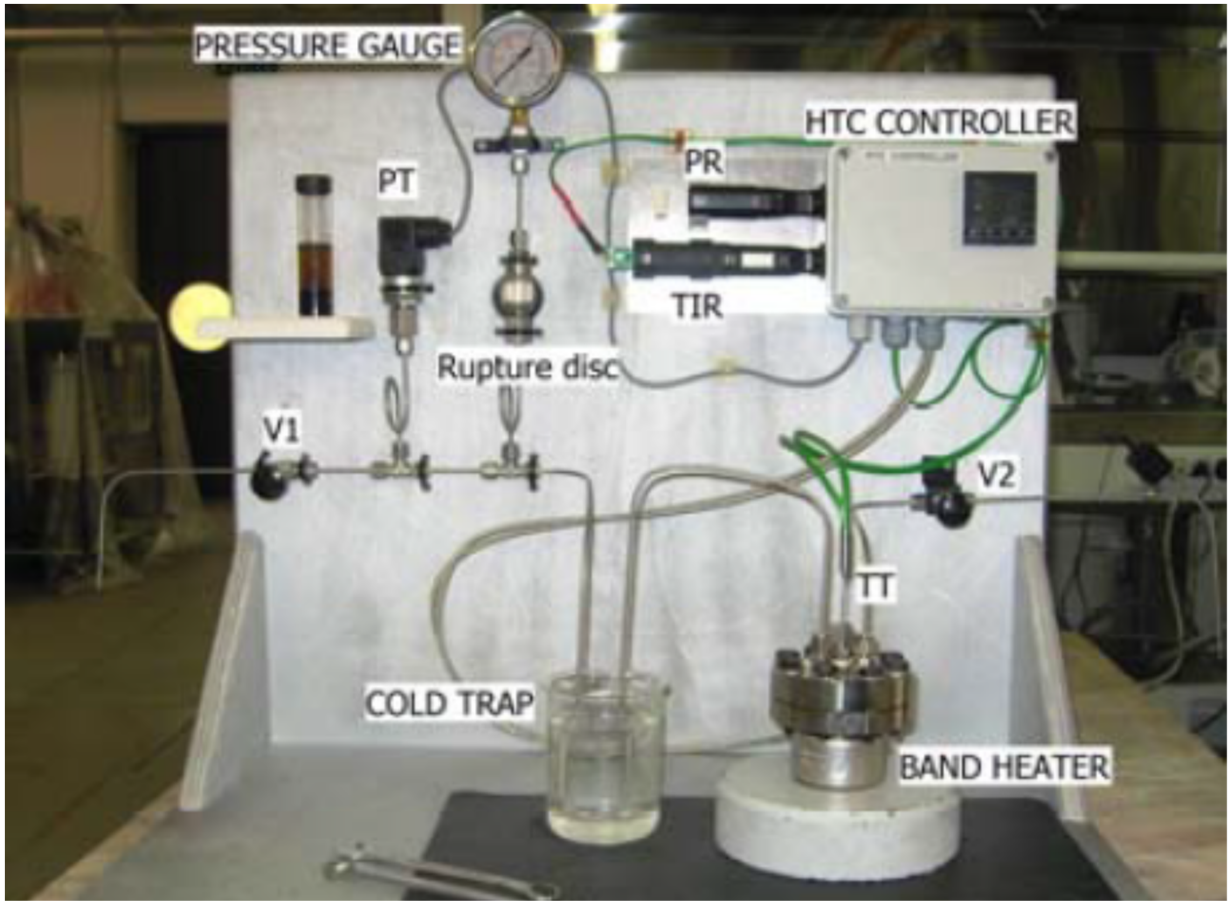
Material and methods



Stainless steel lab batch reactor (50mL) capable to withstand high pressure (140 bar) and temperature (300 °C) was used. Temperature and pressure were measured with a Thermocouple and a pressure transmitter, respectively.

A copper gasket was used to ensure perfect sealing

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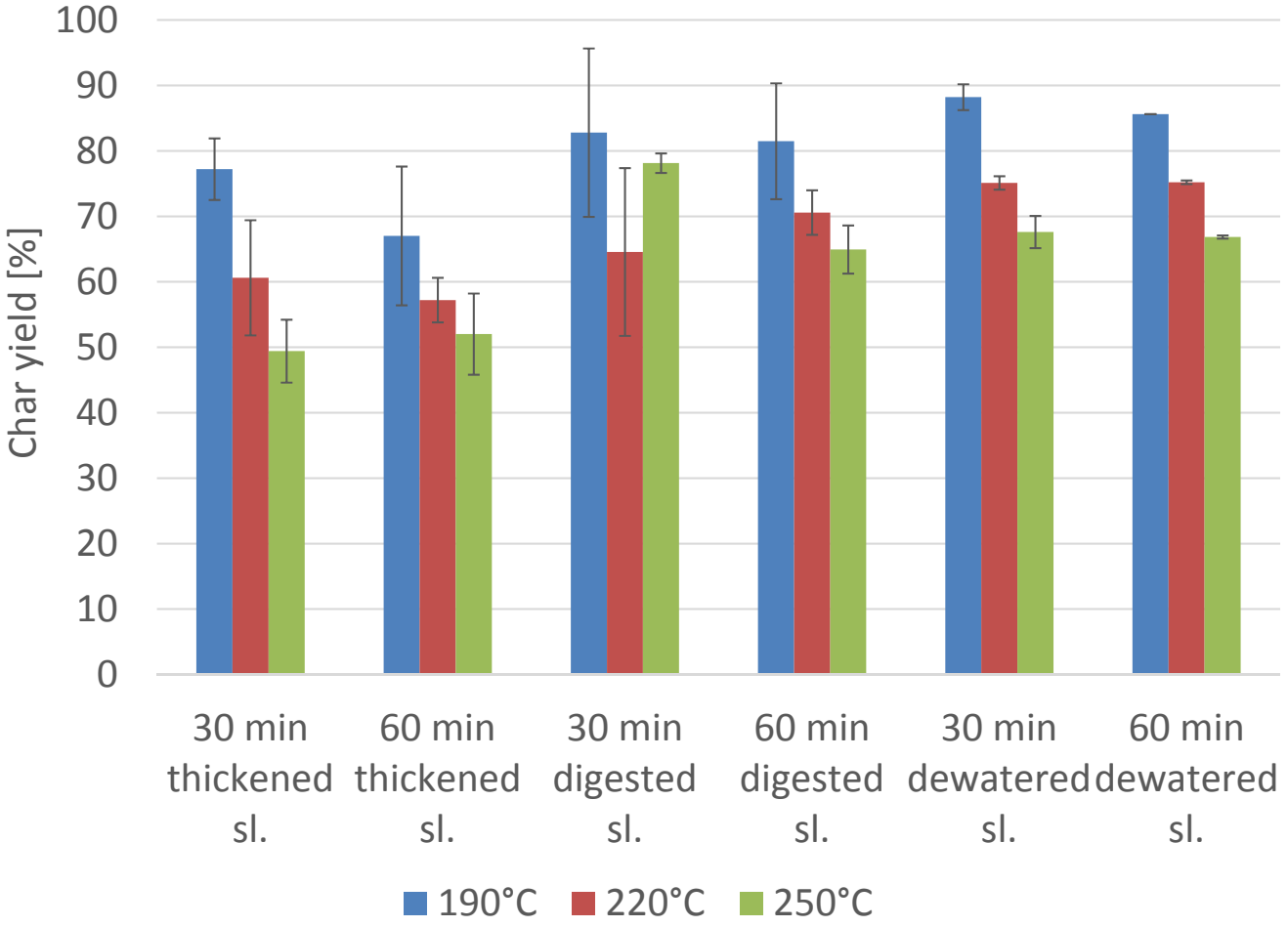
Results: char yield



HTC allows sludge reduction: yield of Chars was 49-88% in function of temperature, residence time and kind of sludge.

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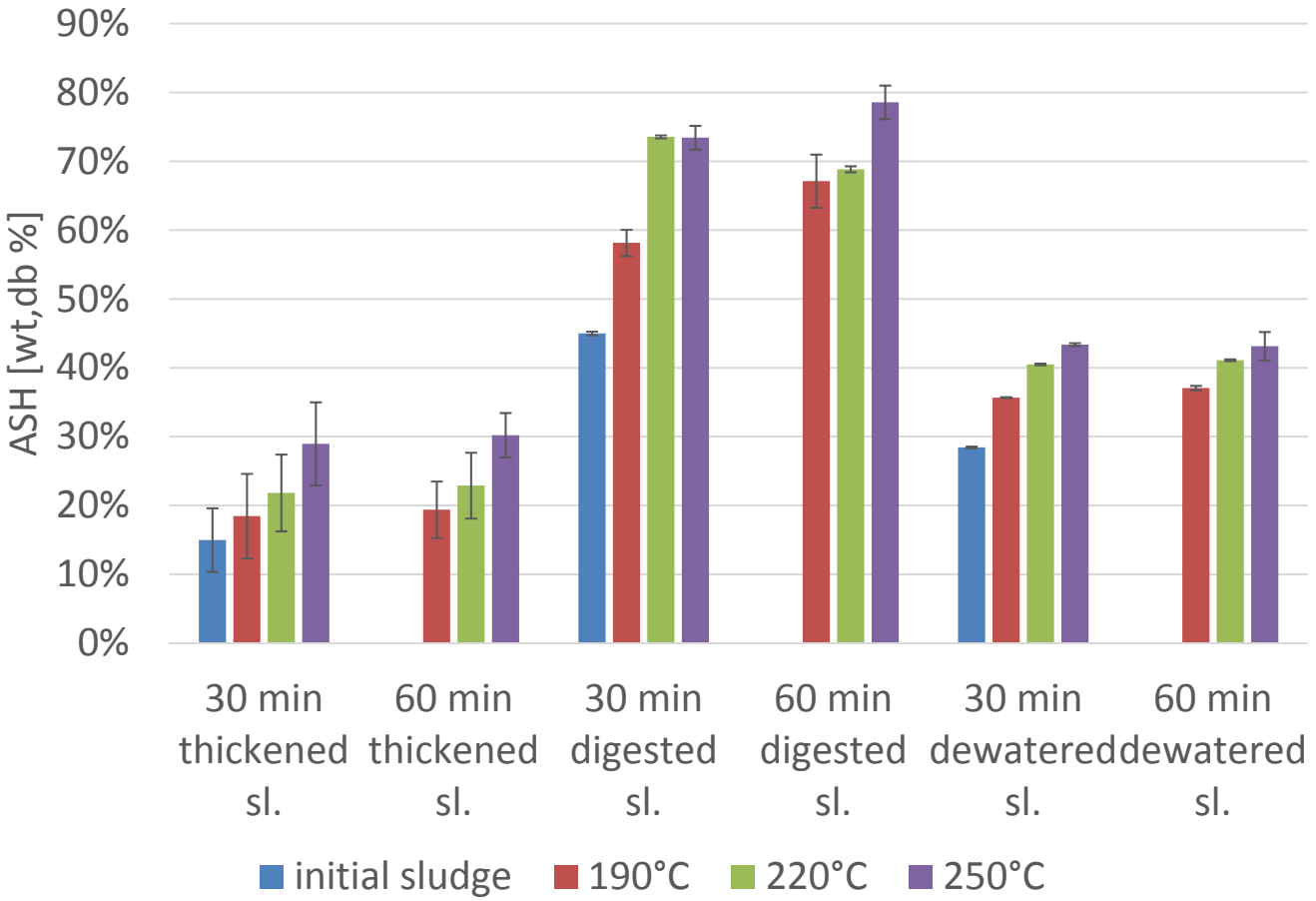
Results: ash



Ash content always increased after HTC and the phenomenon is strongly affected by temperature.

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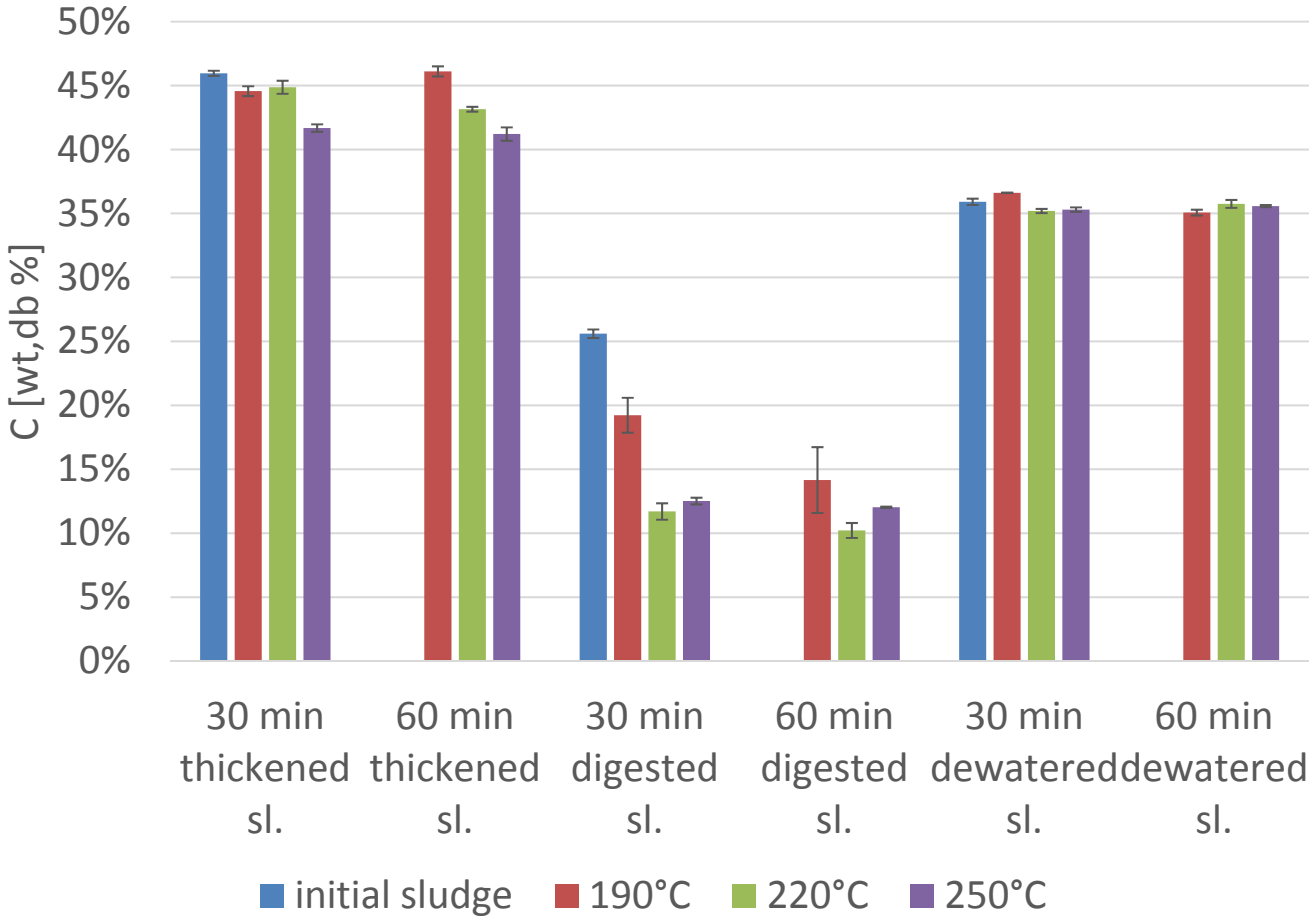
Results: C



Carbon content increases only in two cases. This is due to high ash content and mass reduction caused by the degradation of the organic fraction during the HTC process.

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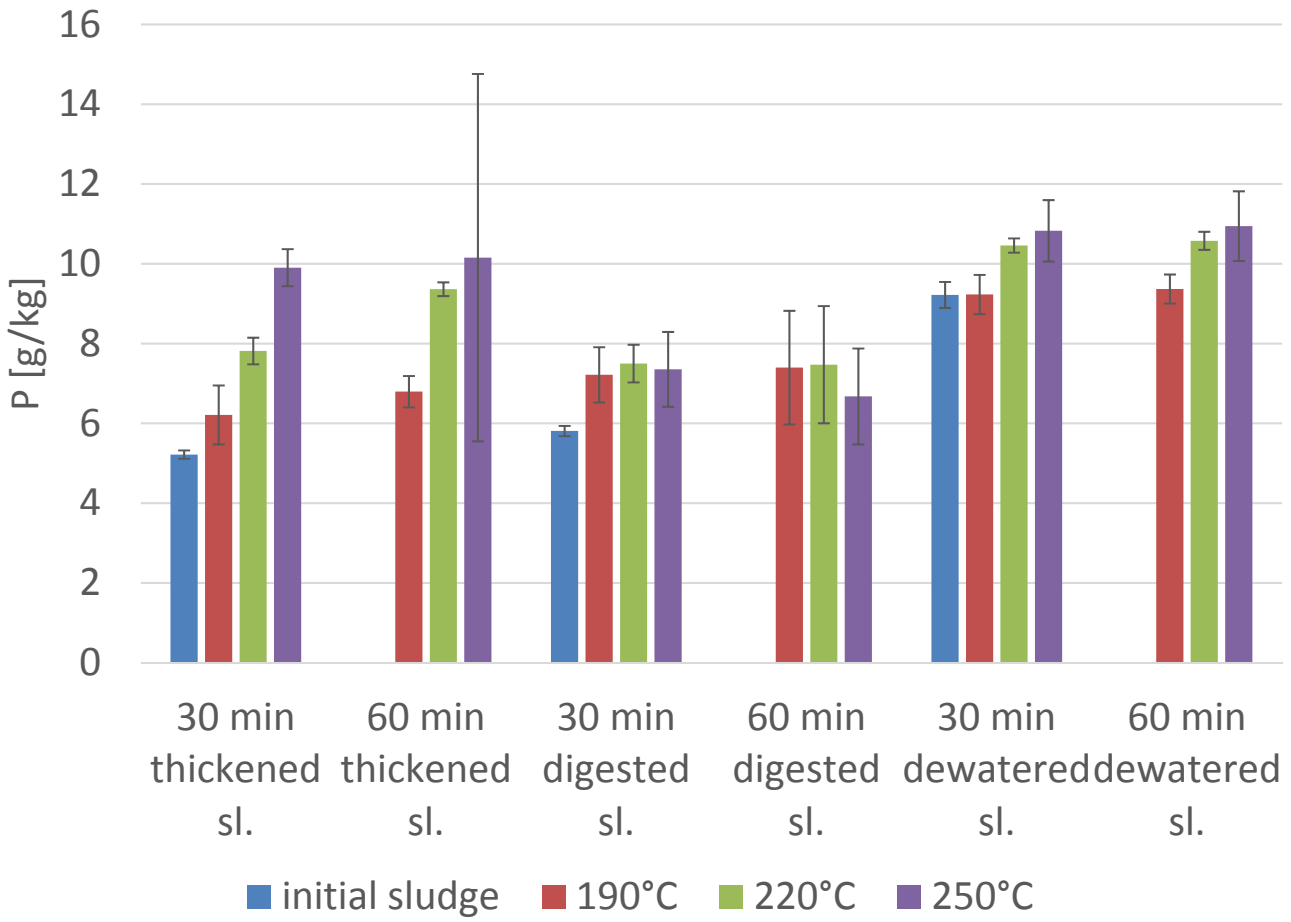
Results: P



Phosphorus increased in char after HTC. the phenomenon is strongly affected by temperature and to a lesser extent by the residence time.

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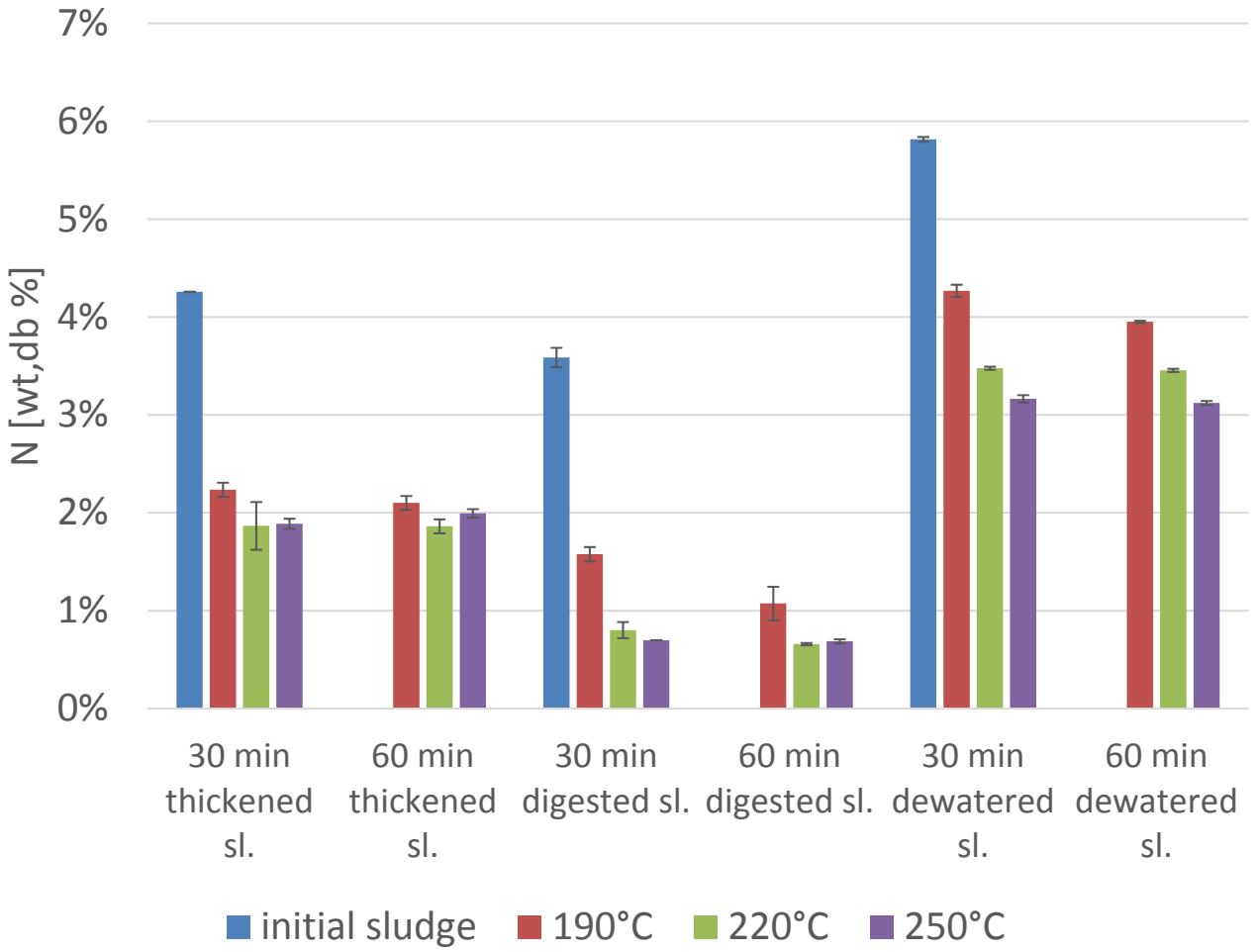
Results: N



N always decreases after HTC for all feedstocks and operative conditions. The phenomenon is strongly affected by temperature and to a lesser extent by the residence time.

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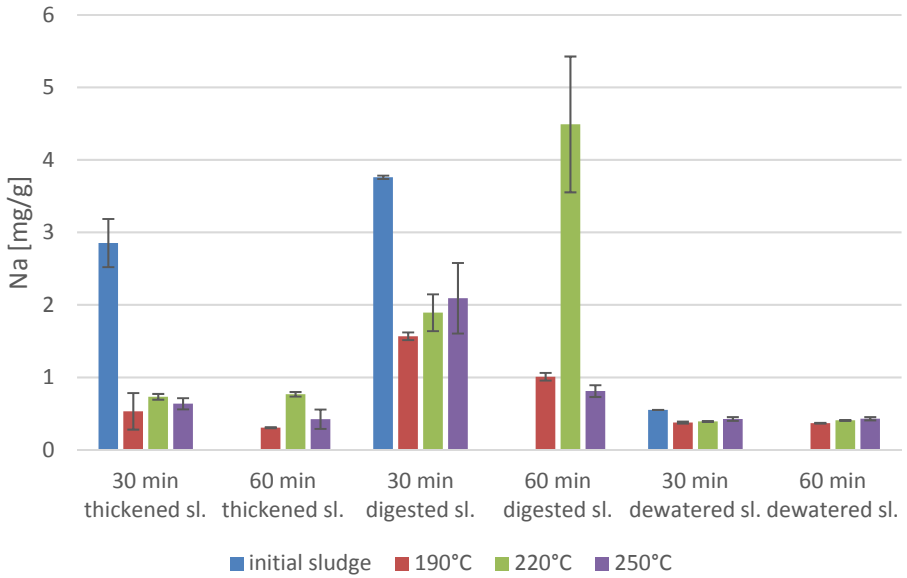
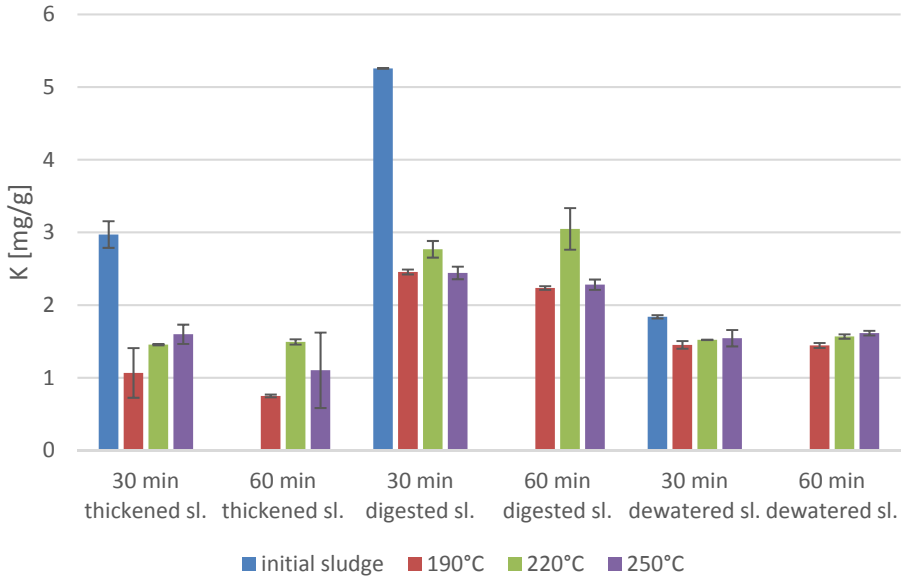
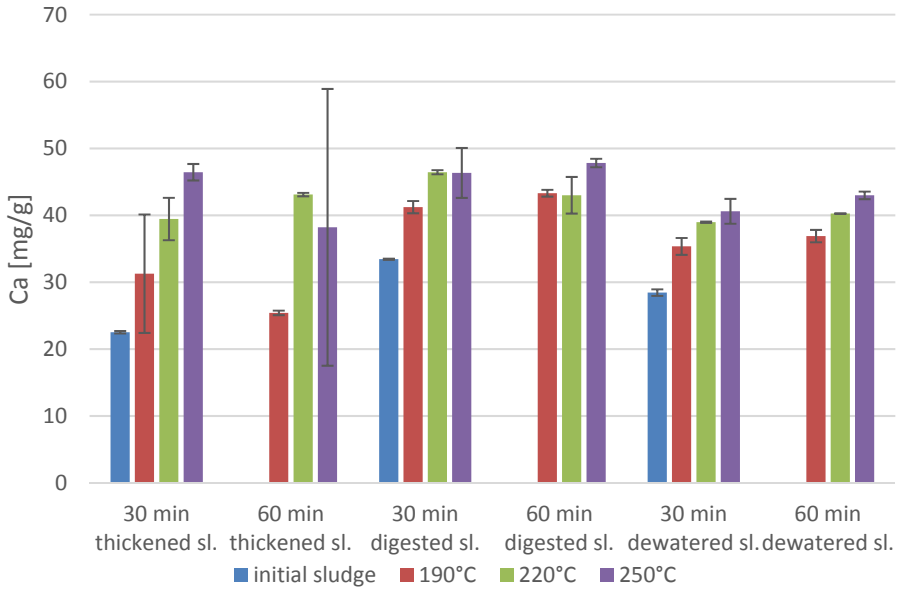
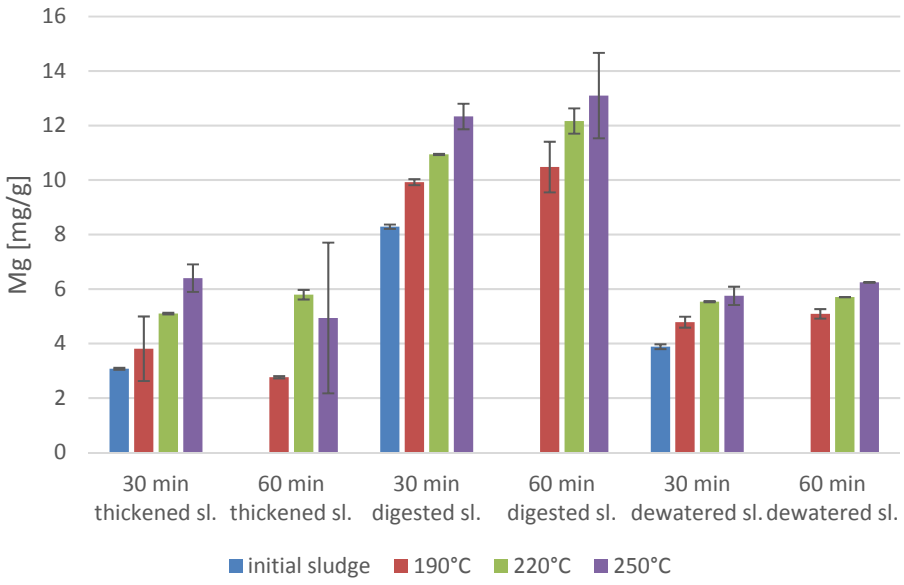
Results: Na, K, Mg, Ca









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Results: heavy metals

	As [mg/kg]	Cd [mg/kg]	Co [mg/kg]	Cr_{tot} [mg/kg]	Cu [mg/kg]	Pb [mg/kg]	Hg [mg/kg]	Ni [mg/kg]	Zn [mg/kg]
Austria - Compost [1]		4		150	400	500	4	100	1000
Belgium - Compost [1]		1		70	90	120	0.7	20	280
Denmark - Compost [1]		1.2				120	1.2	45	
France - Compost [1]		8				800	8	200	
Germany - Compost [1]		1.5		100	100	150	1	50	400
Spain - Compost [1]		40		750	1750	1200	25	400	4000
Italy - Compost [2]		1.5			230	140	1.5	100	500
USA - Biosolid [1]	75	85			4300	840	57	420	7500
Italy - soil law (residential) [3]	20	2	20	150	120	100	1	120	150
Italy - soil law (industrial) [3]	50	15	250	800	600	1000	5	500	1500
Char from Primary Sludge	1-2	0-1	0-2	23-39	417-1098	30-51	19-33	14-29	642-1104
Char from Digestate	0-1	0-1	2-3	35-48	630-749	54-108	11-18	23-39	680-906
Char from Dewatered Sludge	4-5	0-1	1-2	25-29	317-1340	40-50	-	16-21	794-992

[1] Libra, J. A, Ro, K.S., Kammann, C., Funke, A., Berge, N.D., Neubauer, Y., Titirici, M.-M., Fühner, C., Bens, O., Kern, J., Emmerich, K.-H., 2011. Hydrothermal carbonization of biomass residuals: a comparative review of the chemistry, processes and applications of wet and dry pyrolysis. Biofuels 2, 71–106. doi:10.4155/bfs.10.81
[2] Italian Law 152/2010, Norms concerning fertilizers
[3] Italian Law 152/2006, Norms concerning the environment

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Conclusions:

The resulting chars have:

- ash content between 18 and 79 %
- C content between 10 and 46 %
- N content between 2 and 7 %
- P, Mg, Na, K and Ca content of several g/kg
- Pb, Cd, Ni, Zn, Cu, Hg, Cr, As and Co content of the order of mg/kg
- The HTC process tends to concentrate P, Mg and Ca and reduce K and Na content in the hydrochar in respect to the initial dry sludge.

Acknowledgement

Financial support from Atzwanger s.p.a. is greatly acknowledged

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THANKS YOU FOR YOUR ATTENTION