Hydrothermal Co-carbonization of Sewage Sludge and Organic Waste: chemical and physical properties of hydrochars

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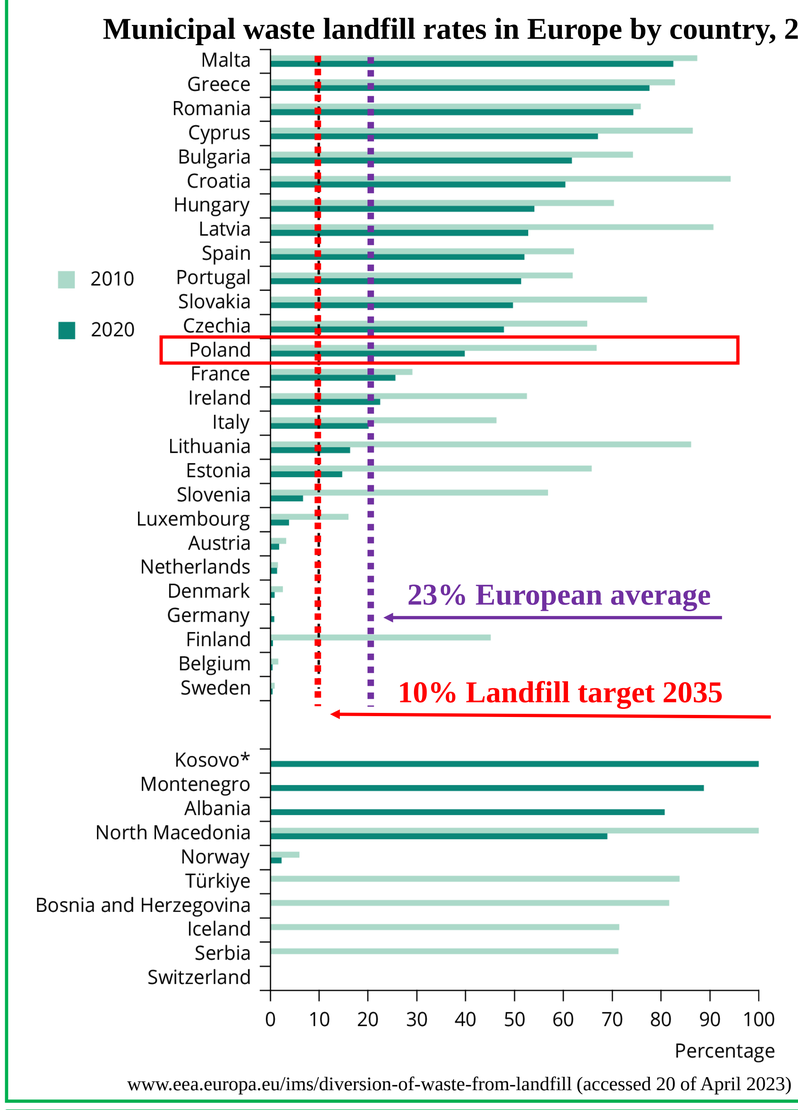
MOTIVATION

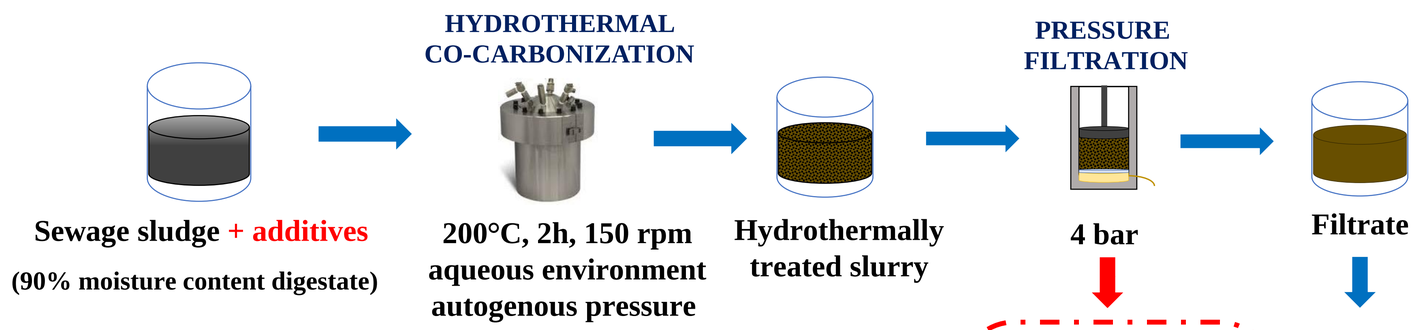


www.eea.europa.eu/ims/diversion-of-waste-from-landfill (accessed 20 of April 2023)

AIM

SEWAGE SLUDGE → „SLUDGE-TO-ENERGY" HYDROTHERMAL CO-CARBONIZATION of SEWAGE SLUDGE and ORGANIC WASTE → IMPROVED FUEL PROPERTIES of HYDROCHAR

MATERIAL and METHODS



ORGANIC WASTE ADDITIVES:

- J – fir, T – straw } lignocellulosic
- W – charcoal
- S – undersieved fraction of municipal solid waste

COMBUSTION PERFORMANCE:

1. Ultimate and proximate analysis
2. Higher heating value determination
3. Combustion behaviour and key combustion parameters based on TGA data

RESULTS

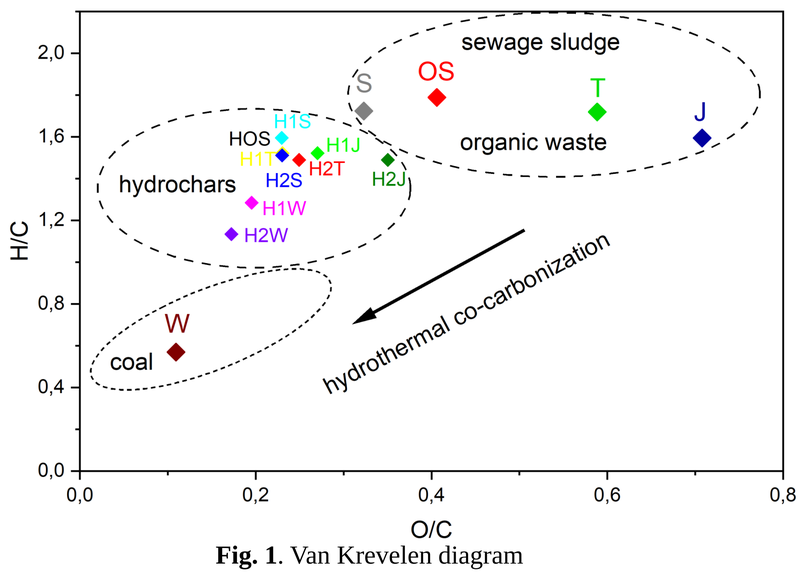


Fig. 1. Van Krevelen diagram

Table 1. Chemical and physical properties of feedstocks and hydrochars, db

		C, %	H, %	N, %	S, %	O, %	FC, %	Ash, %	VM, %	FC/VM	HHV, MJ/kg	SSA, m^2/g
Sewage sludge	OS	36.9	5.50	5.99	1.57	19.98	8.52	28.04	61.42	0.14	15.78	0.63
Organic waste additives	J	47.5	6.31	0.39	0	44.83	17.59	0.97	81.44	0.22	17.66	0.72
	T	39.8	5.70	2.43	0	31.23	9.25	16.71	69.91	0.13	15.86	-
	W	77.8	3.69	0.66	0.06	11.35	66.07	3.14	27.49	2.40	30.49	0.42
	S	43.3	6.22	1.23	0	18.65	6.63	30.6	62.77	0.11	17.29	1.44
Hydrochar without additive	HOS	35.3	4.69	3.36	1.23	10.81	9.21	44.61	46.18	0.20	15.84	15.25
Hydrochars with additives 1 – 10% 2 – 20%	H1J	36.5	4.63	3.53	1.19	11.22	13.35	40.99	45.66	0.29	16.33	15.02
	H2J	37.3	4.63	3.52	1.16	12.40	14.92	35.97	49.11	0.30	17.09	14.72
	H1T	36.5	4.63	3.53	1.19	11.22	10.89	42.93	46.18	0.24	15.96	13.22
	H2T	37.3	4.63	3.52	1.16	12.40	11.40	40.99	47.61	0.24	16.14	13.80
	H1W	41.1	4.40	3.27	1.14	10.71	18.09	39.38	42.53	0.43	17.37	13.22
	H2W	**45.6**	**4.31**	**3.08**	**1.09**	**10.47**	**25.92**	**35.44**	**38.64**	**0.67**	**18.83**	**13.66**
	H1S	35.3	4.69	3.36	1.23	10.81	9.21	44.61	46.18	0.22	16.05	12.46
	H2S	36.7	4.62	3.29	1.15	11.26	10.15	42.98	46.87	0.21	16.32	12.16

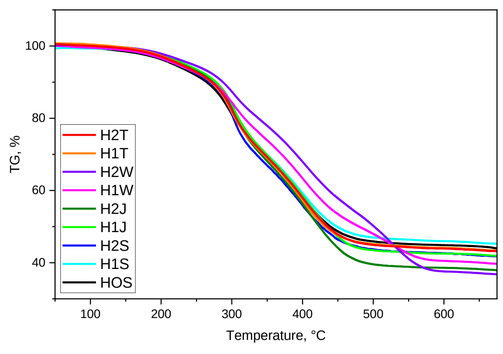


Fig. 2. TG of hydrochars with and without additives

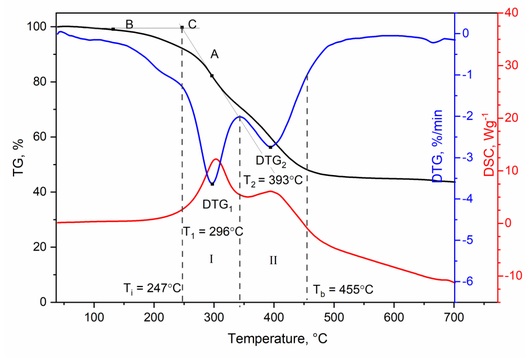


Fig. 4. TGA for HOS without additive

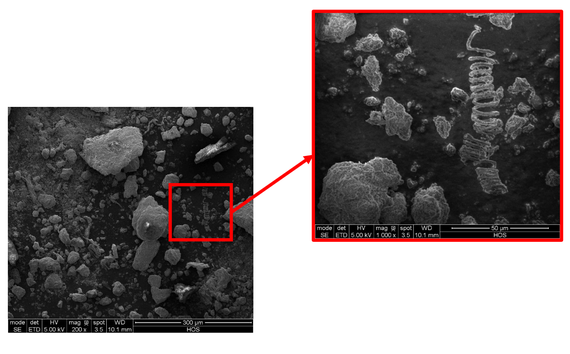


Fig. 6. SEM for HOS without additive

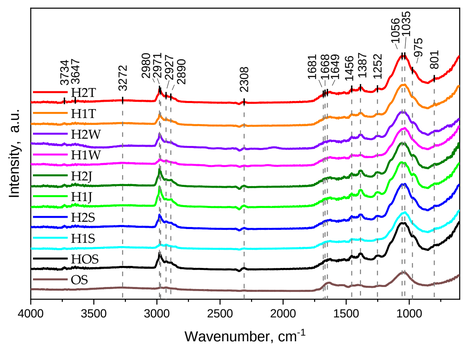


Fig. 8. FTIR of hydrochars

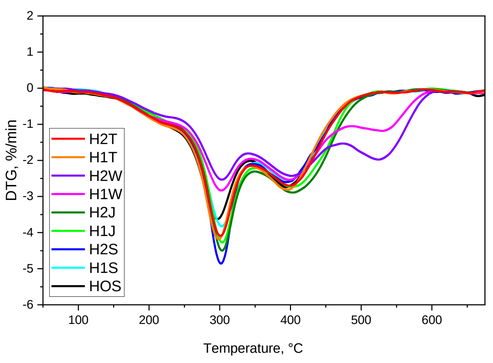


Fig. 3. DTG of hydrochars with and without additives

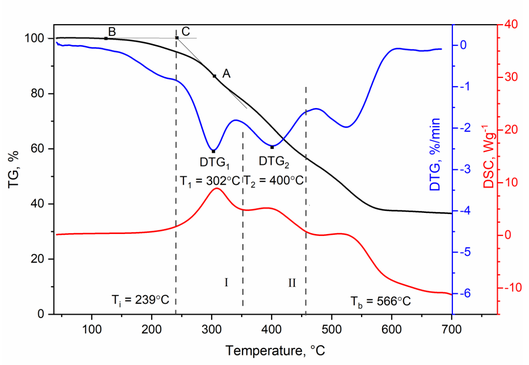


Fig. 5. TGA for H2W with 20% of charcoal additive

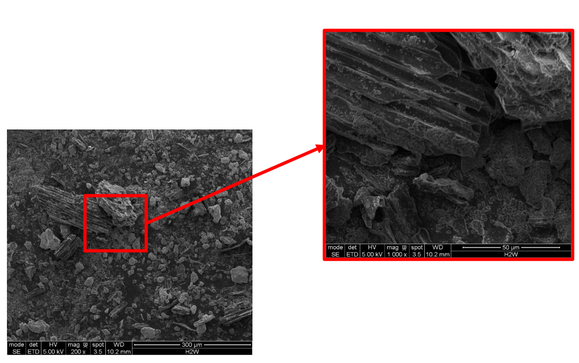


Fig. 7. TGA for H2W with 20% of charcoal additive

Table 2. Key combustion parameters

	T_i, °C	T_b, °C	D_i, %·min^{-3}	S, %·min^{-2}·°C^{-3}	H_f, %·min·K^{-2}
HOS	247	455	0.0048	$11 \cdot 10^{-8}$	1048
H1J	258	470	0.0057	$13 \cdot 10^{-8}$	1075
H2J	257	473	0.0060	$12 \cdot 10^{-8}$	1100
H1T	244	453	0.0059	$14 \cdot 10^{-8}$	1072
H2T	238	566	0.0059	$12 \cdot 10^{-8}$	1080
H1W	239	547	0.0037	$7 \cdot 10^{-8}$	1074
H2W	239	566	0.0033	$6 \cdot 10^{-8}$	1080
H1S	239	455	0.0053	$13 \cdot 10^{-8}$	1060
H2S	**252**	**456**	**0.0072**	$\mathbf{16 \cdot 10^{-8}}$	**1092**

CONCLUSIONS

1. **Hydrothermal co-carbonization of sewage sludge and organic waste improved fuel properties of hydrochars when compared to sewage sludge.**
2. **An addition of 20% of charcoal to sewage sludge led to an increase in hydrochars with the highest values of HHV, C and FC, but prolonged the time of combustion.**
3. **Combustibility indexes confirmed slightly easier and more stable combustion to hydrothermally treated sludge without an additive giving the most optimal results for organic waste additives such as undersieved fraction of municipal solid waste.**
4. **FTIR, BET and SEM analyses confirmed changes of hydrochar structures.**

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