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Characteristic of a Solid Carbonaceous Product of Microwave Torrefaction of Sewage Sludge

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Outline:

1. Introduction: disposal of SS, thermal treatment of SS, pyrolysis and microwave torrefaction;

2. Materials and Methods of MT: pretreatment process, full-scale microwave unit, samples of SS, experiments;

3. Results and Discussion: moisture, temperature, yields, heavy metals, calorific value, structure, C_{org} , pH, EC, S_{BET} ;

4. Summarizing: SCP for agricultural use;

1. Introduction

- SS contents hazardous substances:
 - heavy metals (Pb, Cd, Cu, Ni, Hg, Zn, Cr, As);
 - hydrocarbons (AOX, PCB, PAU...);
 - pathogens organisms;
 - organic pollutants (micropollutants);
 - microplastics;
- currently, in the CR, the HMs, hydrocarbon, and pathogens are monitored according to the Czech Regulation No. 437/2016 Sb.;
- new legislation in CR strictly regulates the SS landfilling and direct application in agriculture.

1. Introduction

- Circular Economy Strategy of WW search for new ways of reusing SS for example by thermal treatment: gasification, incineration, hydrothermal carbonisation, torrefaction and pyrolysis;
- based on our previous research MT is suitable solution of SS disposal because it has potential to reduce pathogens, hydrocarbons, organic pollutants and immobilize HMs and depending on temperature;
- products of pyrolysis/torrefaction are:
 - solid carbonaceous product (biochar);
 - pyrolysis oil;
 - pyrolysis gas (Syngas).

1. Introduction

- AdMaS SS research group corporates with several universities:
 - Brno University of Technology,
 - Mendel University in Brno,
 - University of Pavia,
 - Norwegian University of Science and Technology;
- The aim of the AdMaS research:
 - energy production (dried SS, pyrolysis oil);
 - the transformation of SS into new product for agricultural use (biochar or soil amendment).

1. Introduction

Biochar parameters according to IBI

General parameter	Selected parameter	Unit	Guidelines to biochar certification			
			International Biochar Initiative (IBI)		European Biochar Certificate (EBC)	
			Category A	Category B	Premium	Basic
Toxicant assessment, maximum allowed thresholds - HMs	As	mg•kg ⁻¹ dry wt-mass	13	100	13	13
	Cd		1.4	20	1	1.5
	Cr		93	100	80	90
	Cu		143	6 000	100	100
	Pb		121	300	120	150
	Hg		1	10 ^a	1	1
	Ni		47	400	30	50
	Zn		416	7 400	400	400
Other parameters	C _{org}	%	≥60	≥30	≥50	
	pH	pH	Declaration		Declaration	
	Electrical conductivity	dS•m ⁻¹	Declaration		Declaration	
	S _{BET}	m ² •g ⁻¹	-		≥150	

2. Materials and Methods

Dried SS

Pelletized dried SS



+additives



Noodle
shape dried
SS



MT



MT



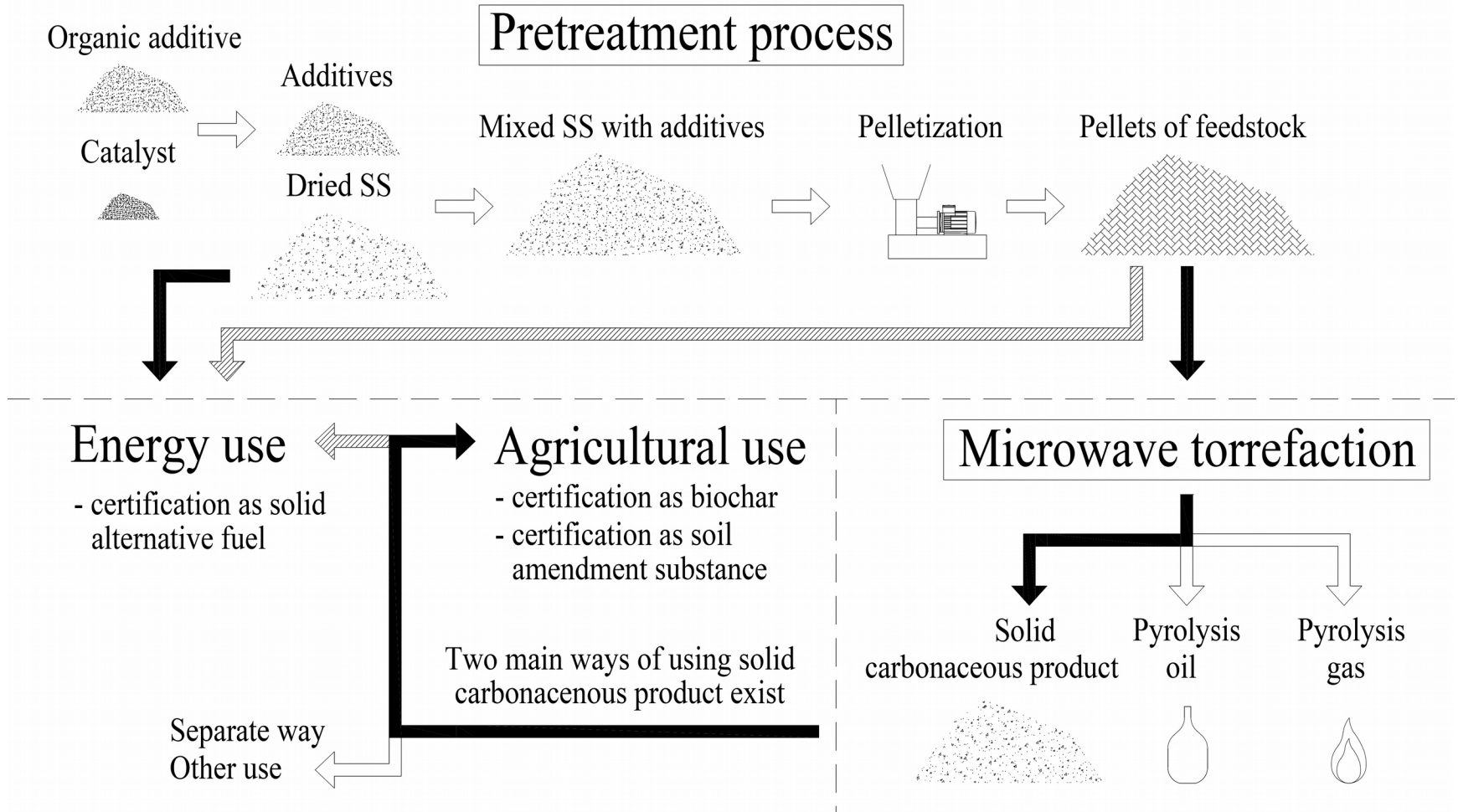
Solid carbonaceous product

Pyrolysis oil
and pyrolysis
gas



2. Materials and Methods

Scheme of pretreatment and MT



2. Materials and Methods

Feedstock mixes for MT: 2 VVWIPs

Additive type		Ratio SS:ADD (%)
-	Dried SS	100:0
Catalyst	Crushed limestone	98:2
	Waste cellulose	95:5
Organic additives	Plastic waste (LDPE)	95:5
	Wooden sawdust	90:10
	Wooden dust	90:10
	Hay	70:30
	Husks	70:30

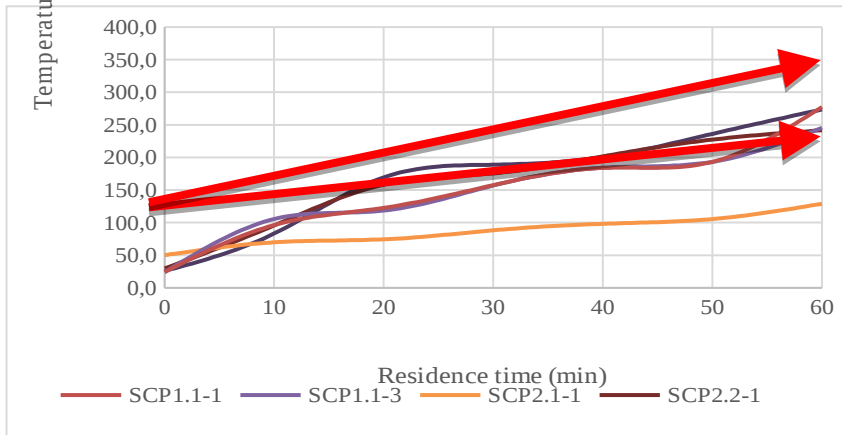


3. Results and

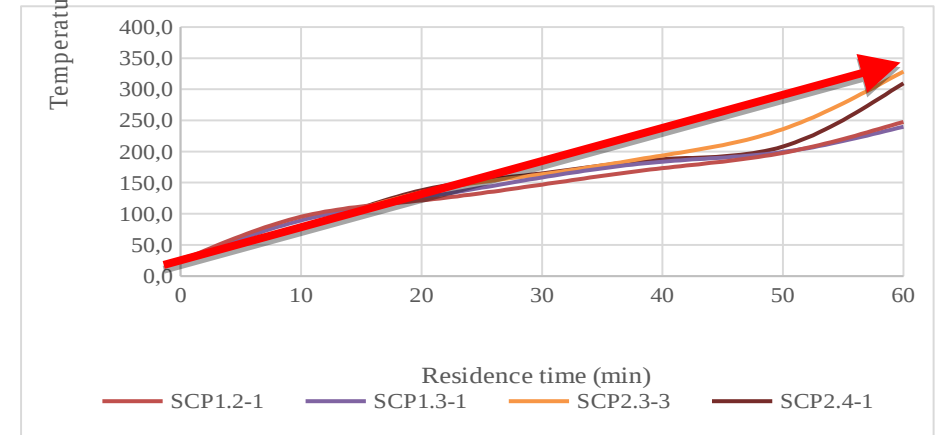
Parameters: temperature, yields

Additive type		Ratio SS:ADD (%)	Sample ID	Maximum temperature (°C)	Yields (%)			Calorific value
					SCP	Pyrolysis oil	Pyrolysis gas	(MJ•kg ⁻¹)
-	Dried SS	100:0	SS2.1	-	-	-	-	13,49
			SCP2.1	129	86,6	5,2	8,2	14,30
Catalyst	Crushed limestone	98:2	FS2.2	-	-	-	-	12,63
			SCP2.2	242	65,5	15,6	18,9	11,64
				245	57,1	10,1	32,8	9,32
				274	56,2	9,8	34,0	9,68
Organic additives	Waste cellulose	95:5	FS2.3	-	-	-	-	12,61
			SCP2.3	291	60,3	6,4	33,3	9,30
				324	57,4	9,6	33,0	10,01
		329	56,6	9,8	33,6	9,72		
	Plastic waste (LDPE)	95:5	FS2.4	-	-	-	-	14,68
			SCP2.4	310	54,8	5,0	40,2	12,01
				274	56,7	7,5	35,8	-
		250	55,8	6,6	37,6	-		
	Wooden sawdust	90:10	FS2.5	-	-	-	-	13,60
			SCP2.5	176	59,6	12,9	27,5	12,69
				225	57,7	15,3	27,0	12,56
		273	46,6	14,3	39,1	9,46		
	Wooden dust	90:10	FS2.6	-	-	-	-	13,49
			SCP2.6	296	45,2	12,5	42,3	10,01
				263	46,1	9,5	44,4	11,19
		313	62,1	8,3	29,6	-		
	Hay	70:30	FS2.7	-	-	-	-	13,49
			SCP2.7	278	45,2	15,9	38,9	12,76
				246	64,5	12,3	23,2	11,06
				259	53,2	7,2	39,6	12,66
	Husks	70:30	FS2.8	-	-	-	-	13,89
			SCP2.8	281	47,5	9,9	42,6	11,72
				276	48,2	7,5	44,3	12,67
				268	45,9	11,2	42,9	11,10

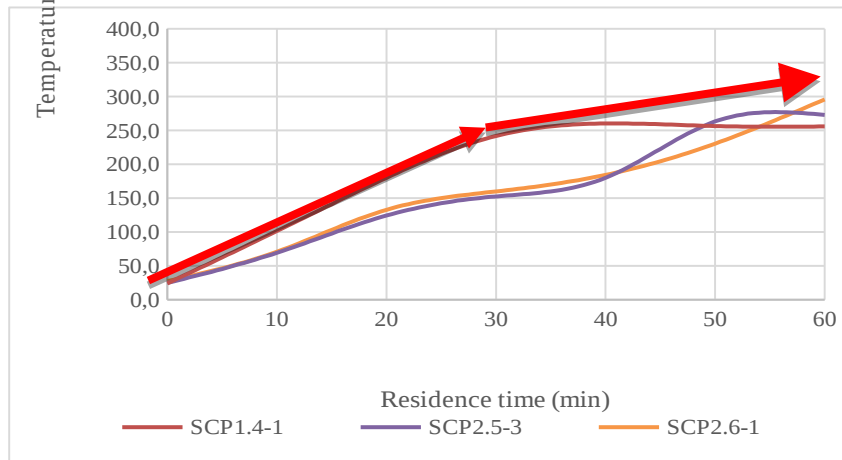
Without additives; with 2% catalyst



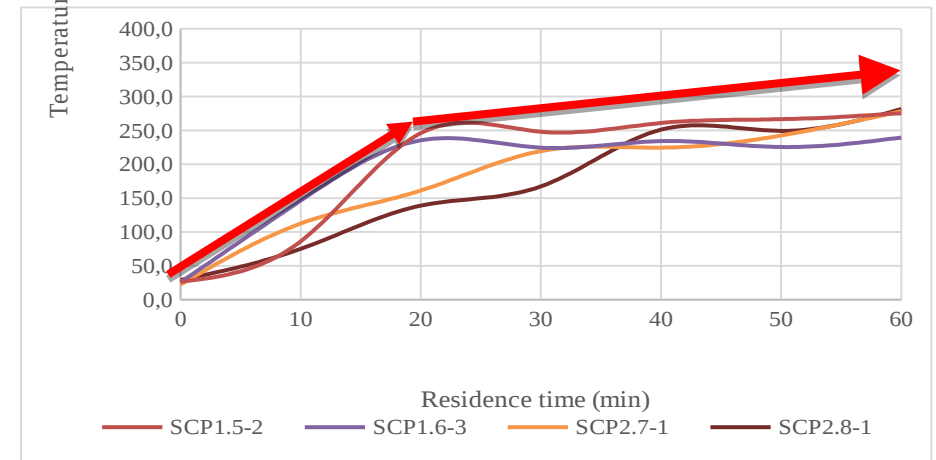
With 5% organic additives



With 10% organic additives



With 30% organic additives



3. Results and Discussions

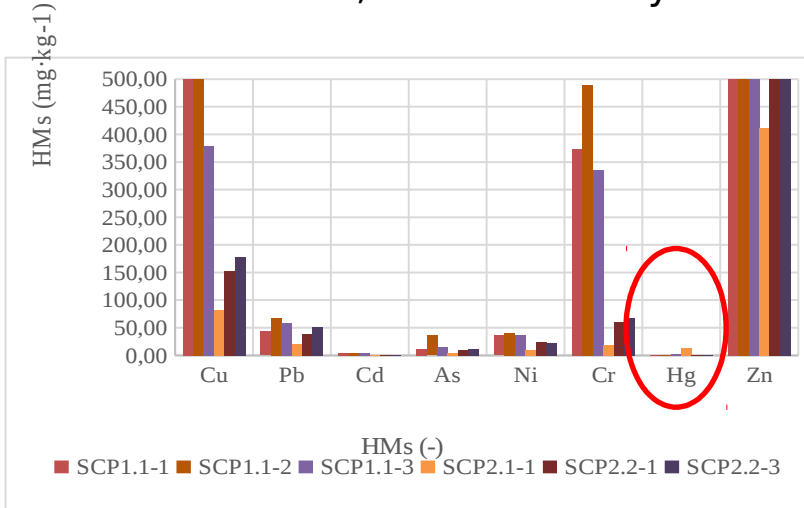
3. Results and

Parameters: C_{org} , pH, EC & Discussions

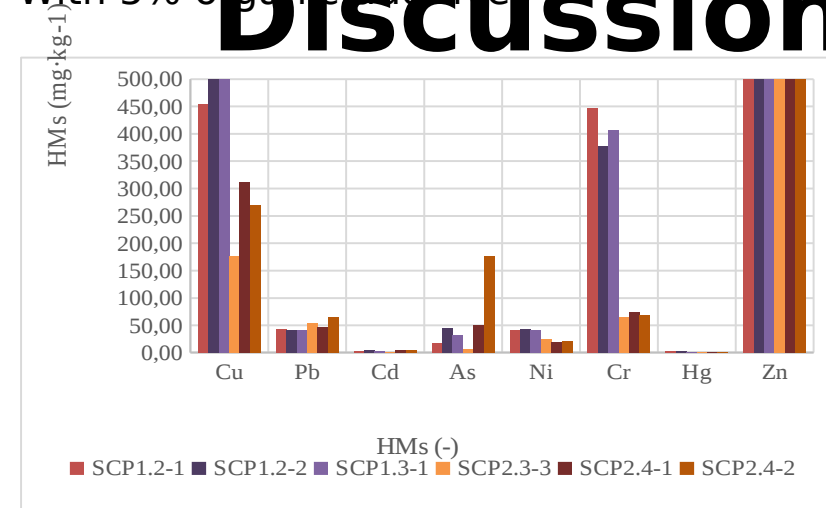
			Selected agricultural parameters			
Additive type		Ratio SS:ADD (%)	C_{org} (%)	pH (-)	EC ($\mu S \cdot cm^{-1}$)	S_{BET} ($m^2 \cdot g^{-1}$)
-	Dried SS	100:0	32,59	9.005	3150	-
			35,18	9.039	1929	-
Catalyst	Crushed limestone	98:2	33,15	7.381	4950	-
			32,51	7.587	388	-
			-	7.677	277	-
			-	7.661	365	-
			-	7.272	4050	-
Organic additives	Waste cellulose	95:5	31,46	7.272	4050	-
			36,64	7.665	450	3,329
			-	7.704	273	-
			-	7.150	138	-
			-	7.498	5370	-
	Plastic waste (LDPE)	95:5	38,71	7.498	5370	-
			33,95	7.546	226	-
			-	7.477	244	-
			-	6.990	458	-
			-	7.701	4620	-
	Wooden sawdust	90:10	33,59	7.701	4620	-
			32,19	8.012	656	-
			-	7.820	480	-
			-	7.707	348	-
			-	7.347	4570	-
	Wooden dust	90:10	35,00	7.347	4570	-
			33,69	7.632	308	-
			-	7.598	351	-
			-	7.875	526	-
			-	5.490	1965	-
	Hay	70:30	37,65	7.262	1960	-
			33,29	7.955	795	-
			-	8.160	843	1,516
			-	6.530	5050	-
			-	7.405	423	-
	Husks	70:30	33,59	7.405	423	3,147
			33,97	7.520	332	-
			-	7.535	371	-
			-	-	-	-
			-	-	-	-

3. Results and Discussions

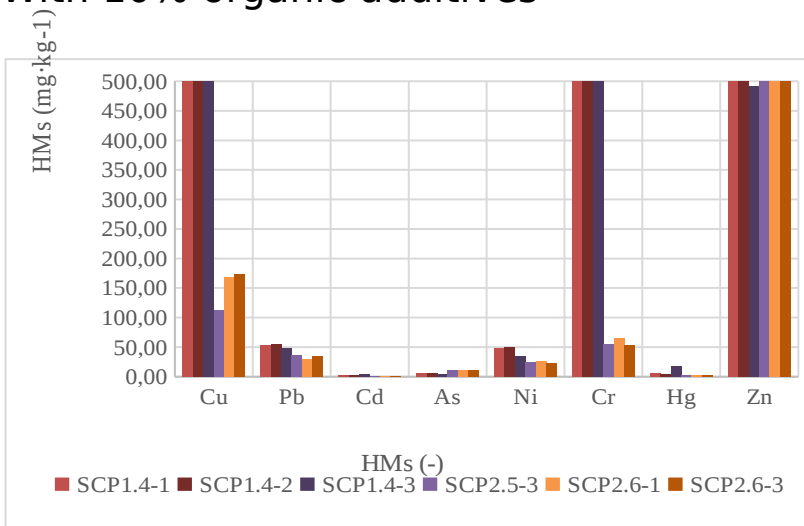
Without additives; with 2% catalyst



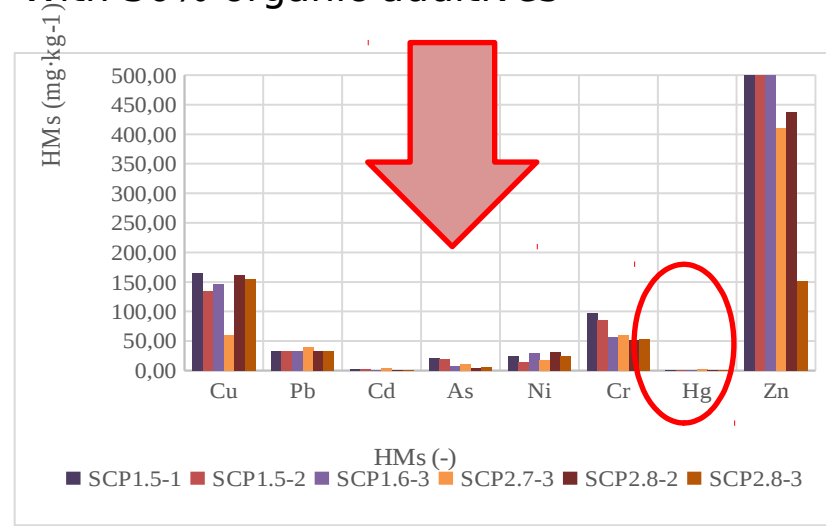
With 5% organic additives



With 10% organic additives



With 30% organic additives



4. Summarizing

- According IBI guidelines biochar category B, SCP with 30% organic additives complies with the limits of the selected parameters: HMs;
- mixing and pelletizing process improve the FS qualitative parameters for the certification of biochar or the soil amendment substances;
- sample without additive represents only further drying (high C_{org} , calorific value);
- sample with 2% crushed limestone catalyst achieved high temperature and high SCP yield;
- samples with 30% organic additives achieved rapid temperature rise, high pyrolysis gas yield, and immobilization HMs.

5. Conclusion

- Our tests have proved that SS treated MT mixed with additives yields SCP/biochar can be certified;
- feedstock with organic additive and feedstock with crushed limestone catalyst after MT have shown acceptable characteristic for biochar certification;
- combination of organic and catalyst may lead to further improvement;
- future research: HMs fixation, organic pollutants, S, N, P, K

Thank you for your attention

Questions???