BIOCHAR PRODUCTION FROM SEWAGE SLUDGE AND MICROALGAE COMBINATION: PROPERTIES, SUSTAINABILITY AND POSSIBLE ROLE IN A CIRCULAR ECONOMY

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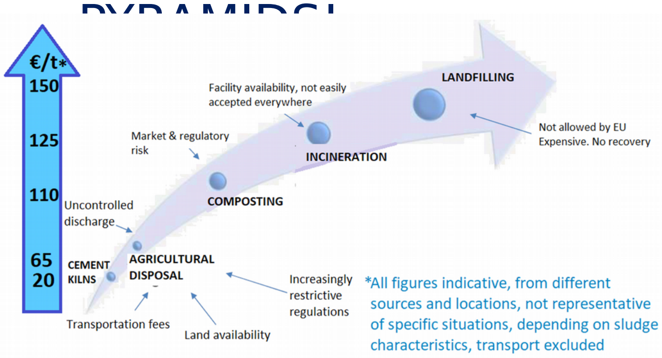
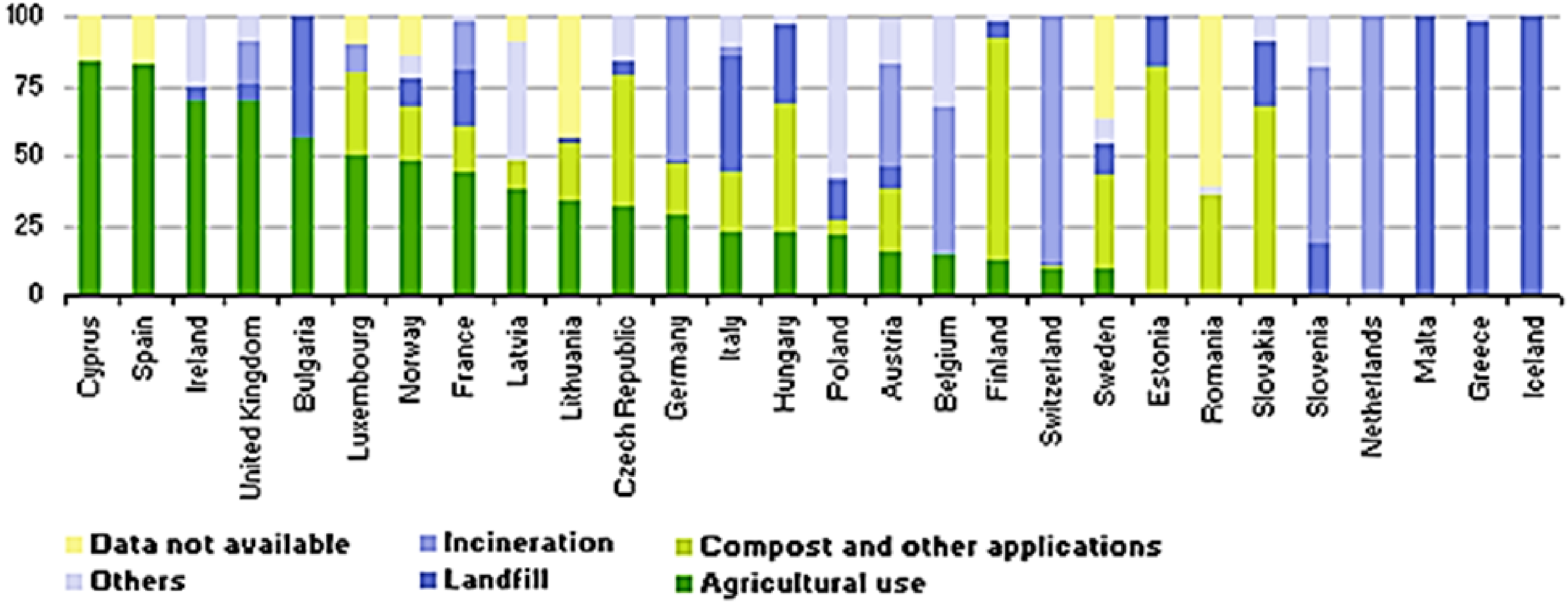
TATEMENT OF PROBLEM -1

Municipal WWTPs excess sludge production expected in 2020 for the entire EU is about 13 Mt.

Assuming a dried sludge water content of 30%, the total volume of sludge to be disposed yearly would be just short of the volume of FOUR Cheope's PYRAMIDS!



Main sludge disposal options in EU member states



QUESTION: WHAT IS THE MOST SUSTAINABLE OPTION

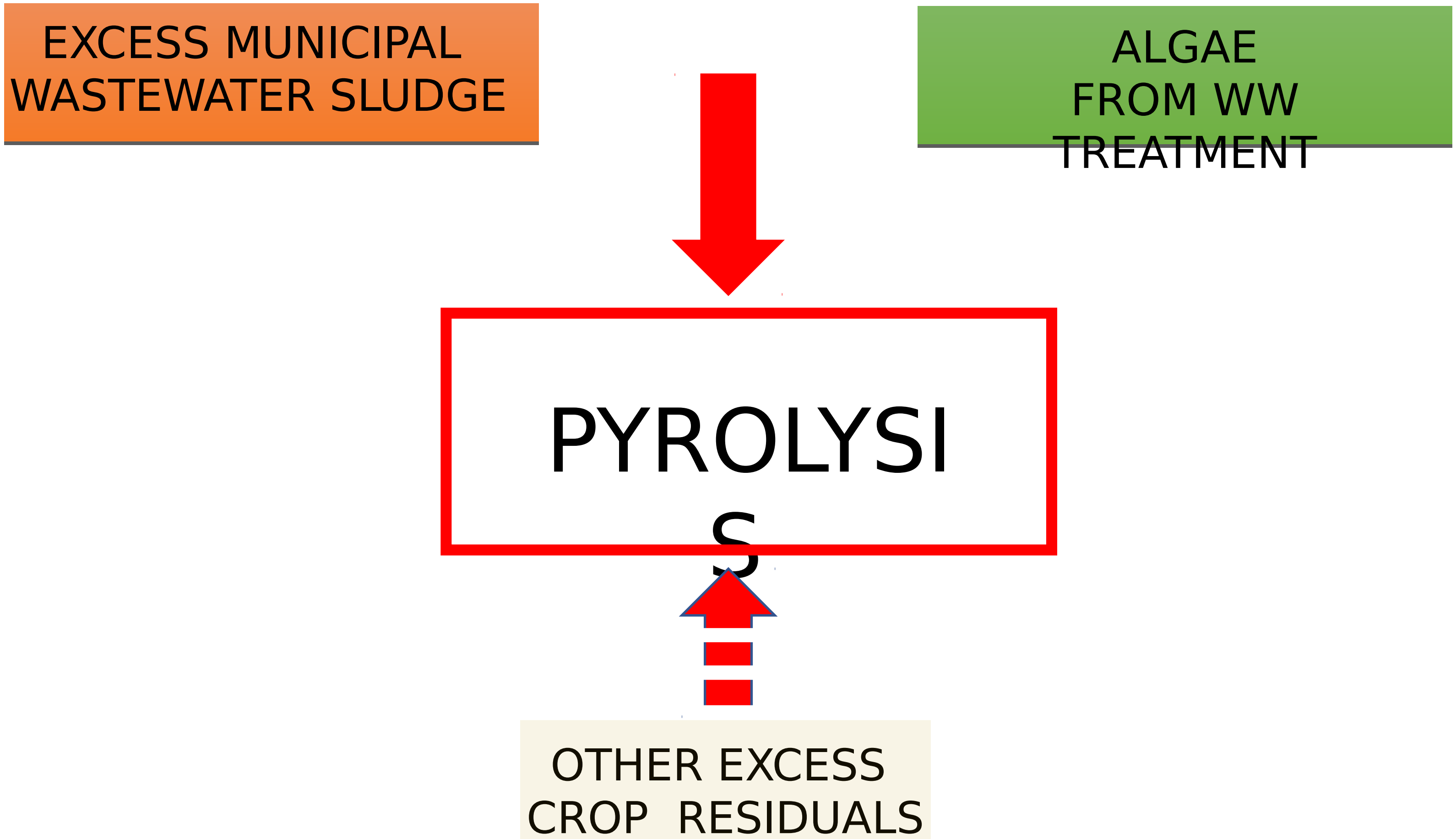
Source: Eurostat, 2016

TATEMENT OF PROBLEM -2

nt technological advances have postulated a paradigmatic change in WW treatm
ologies: example the Almeria (Spain) WWTP where WW is treated by a mixture o
ria and microalgae.

ntages	Disadvantages
(or less) O_2 supply	Need close to 365 sunny days/year
ria remove C	"Sludge" is a mix of m-algae and bacteria
remove N, P and supply O_2	Difficult to dewater
e/algal mix can be digested or converted to fertilizer	May not solve the residuals issue

POSSIBLE SOLUTION



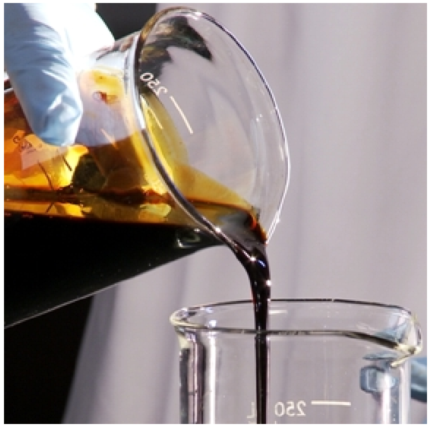
We postulate that co-pyrolys of EMWS, microalgae, and (eventually)
Other excess crop residues (i.e. wine-making residuals, rice straw, roadside grass clippings, etc) is not only effective in

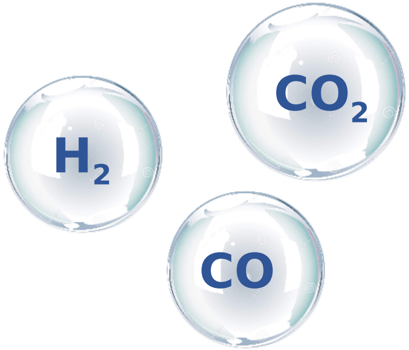
PYROLYSIS PRODUCTS

BIO-OIL

BIOCHAR

SYNGAS



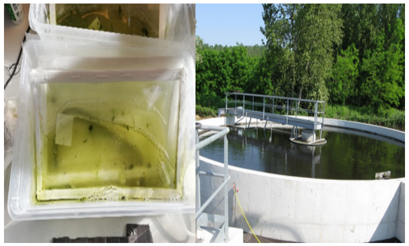


HIGH C CONTENTS & LONG-TERM STORAGE

LIMITED RELEASE OF HEAVY METALS

AMPLE APPLICATON POSSIBILITIES

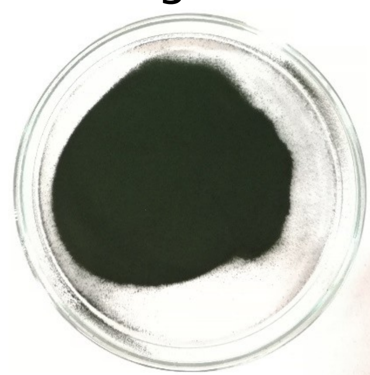
EXPERIMENTAL SETUP



TYPE “A” SAMPLE Mix (B+D)

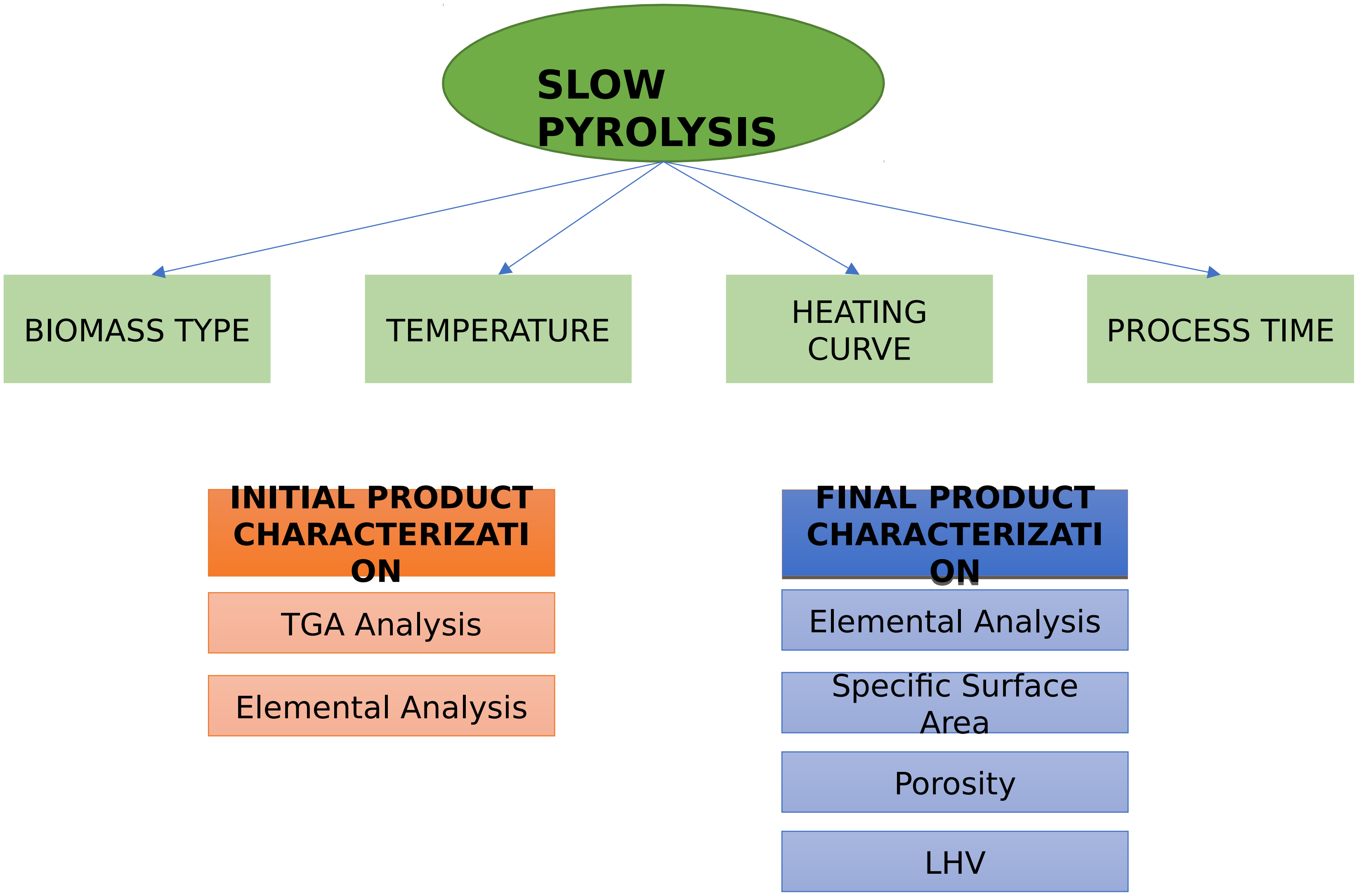
TYPE “B” SAMPLE Lab-grown algae

TYPE ‘C’ SAMPLE Commercial Algae



TYPE ‘D’ SAMPLE EMWS

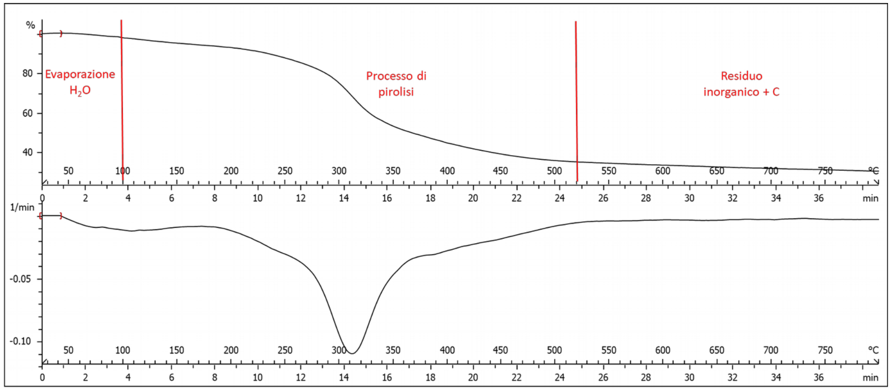
BIOCHAR PRODUCTION



INITIAL CHARACTERIZATION

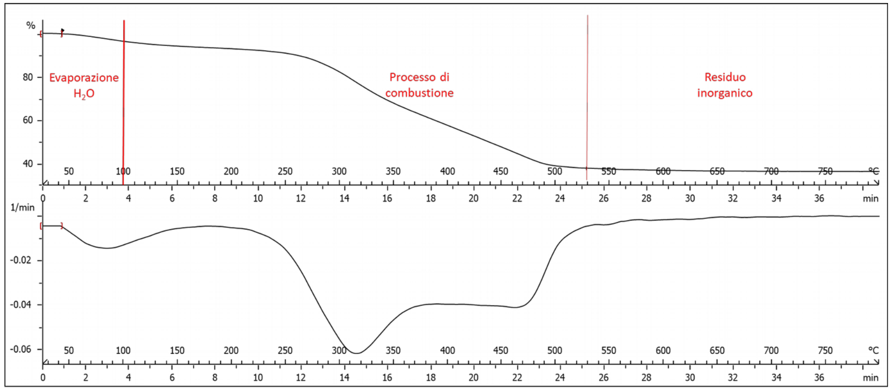
N - TGA

- Humidity content
- Pyrolysis Temperature

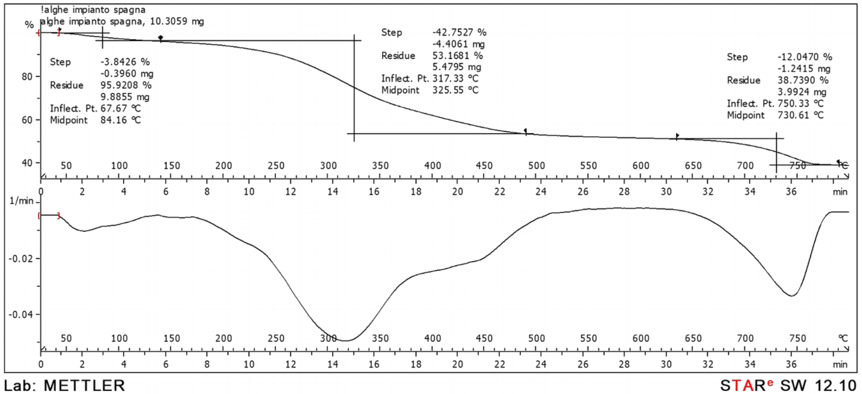


AIR TGA

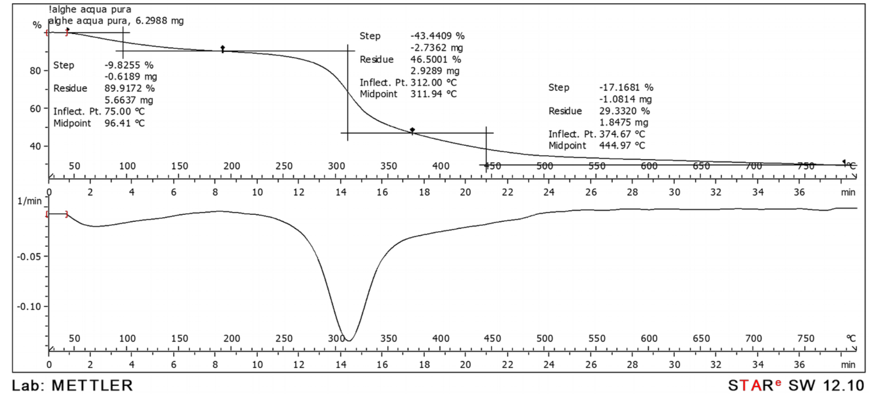
- Humidity Content
- Ash Content



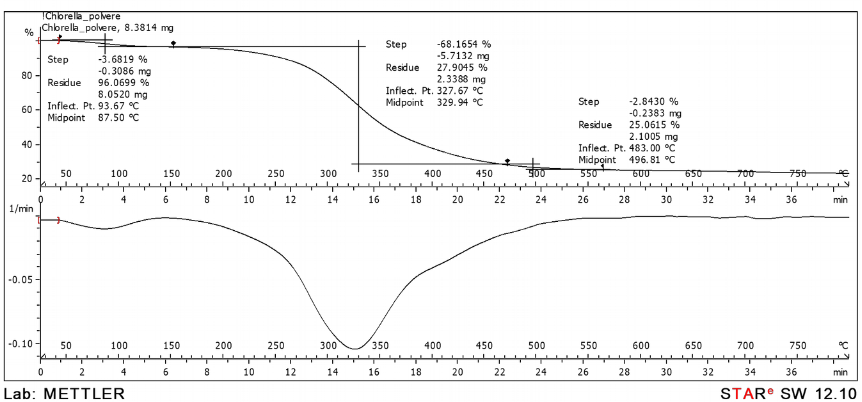
INITIAL CHARACTERIZATION



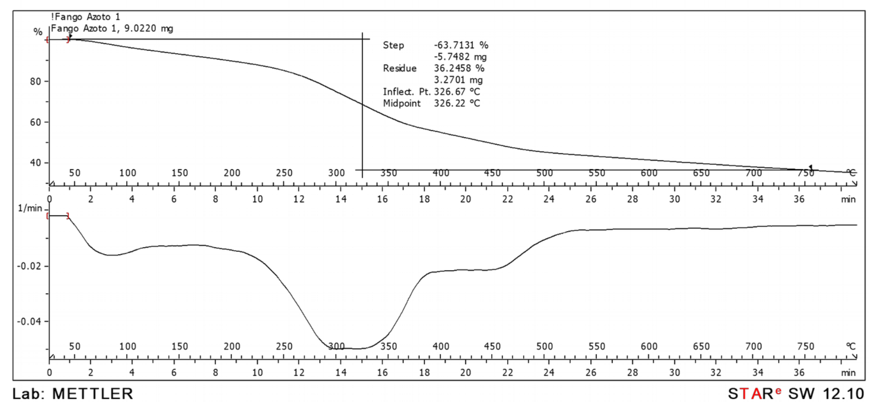
SAMPLE A, Mix



SAMPLE B, Algae grown in lab



SAMPLE C, Commercial Algae

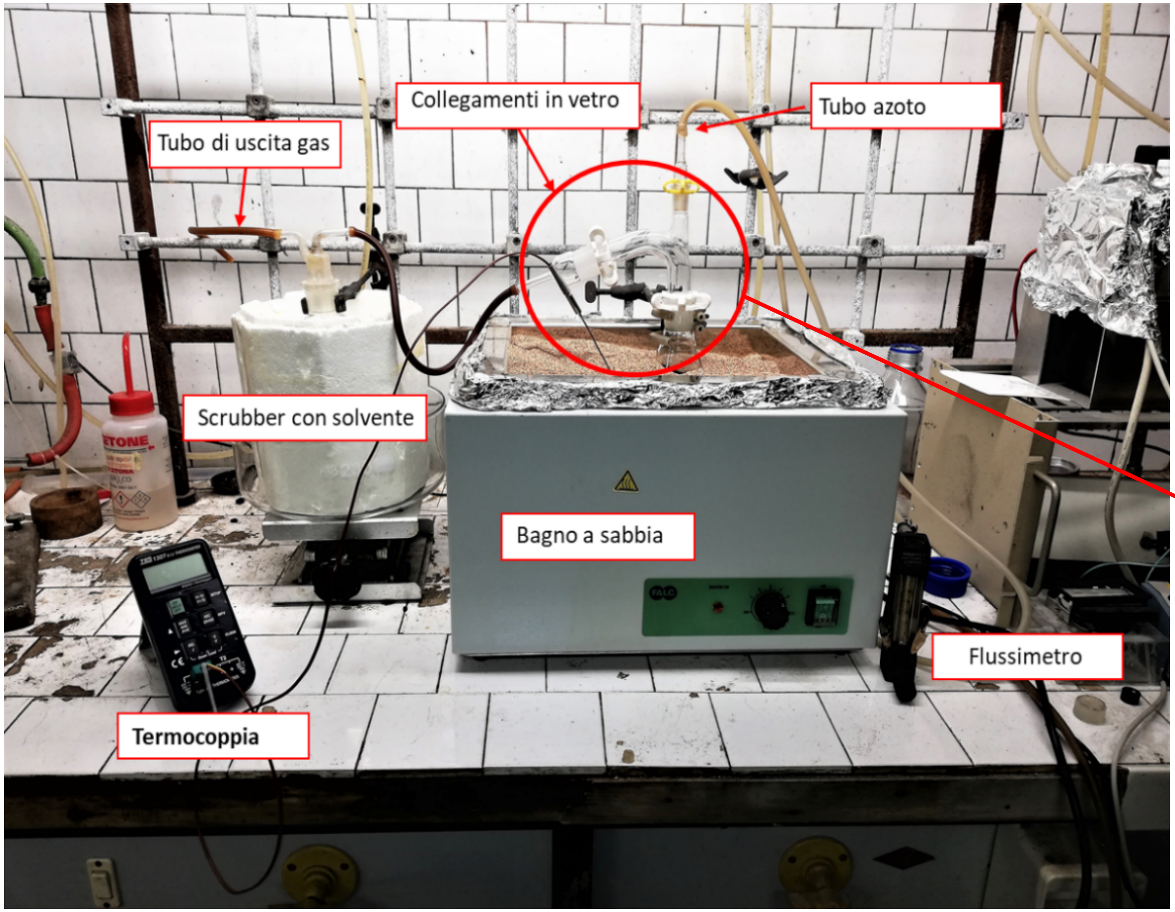


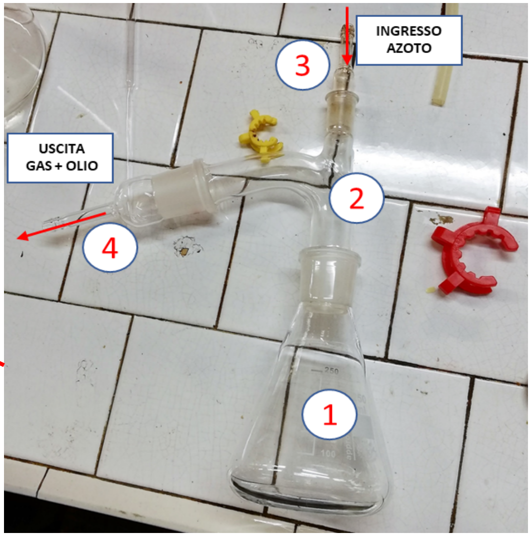
SAMPLE D, UMWS

AIR TGA RESULTS

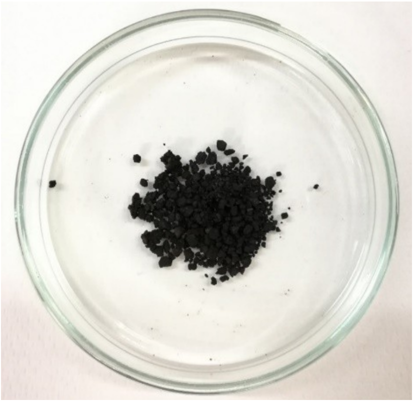
SAMPLE	ASH CONTENT
A, Mix	24 %
B, Lab grown Algae	14 %
C, Commercial algae	5 %
D, UMWS	30 %

PYROLYSIS TESTS





PYROLYSIS PRODUCTS



SAMPLE A (MIX) 500°C, Uniform Granulometry, black

SAMPLE D 500°C, Uniform granulometry, black

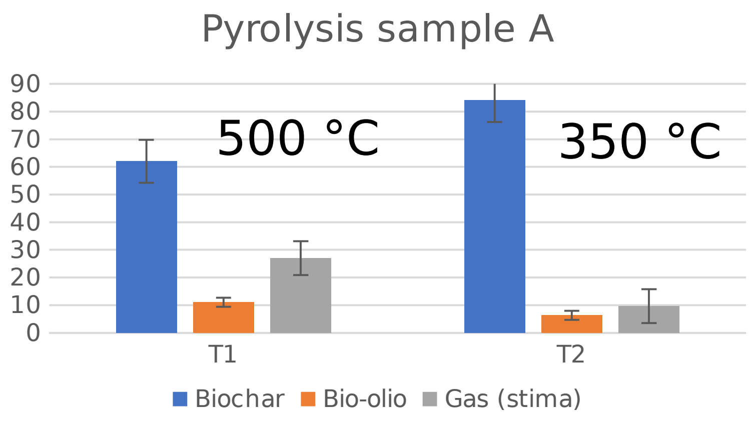
SAMPLE C 500°C, Varied granulometry, black

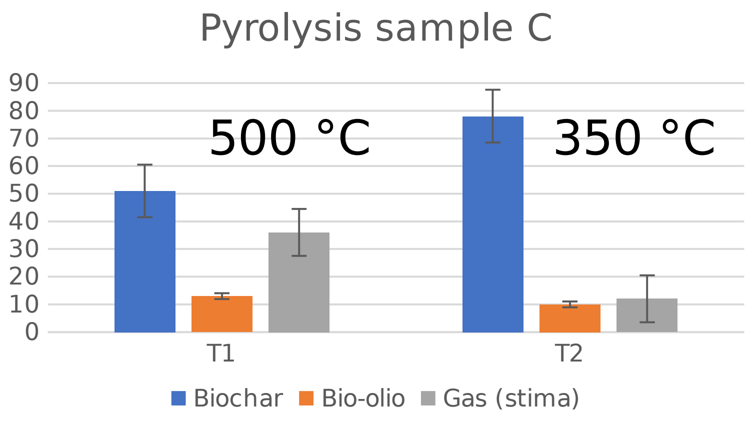
SAMPLE A (MIX) 350°C, Uniform granulometry, brown

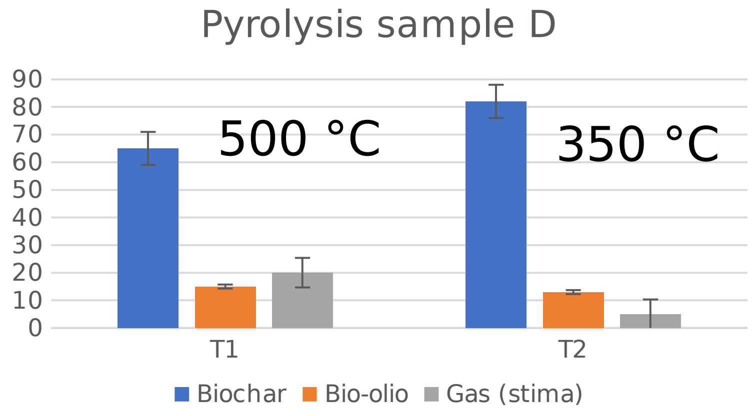
SAMPLE D 350°C, Uniform granulometry, brown

SAMPLE C 350°C, Varied granulometry, black

PRODUCTS


Pyrolysis sample A
90
80
70
60
50
40
30
20
10
0
500 °C
350 °C
T1
T2
Biochar
Bio-olio
Gas (stima)


Pyrolysis sample C
90
80
70
60
50
40
30
20
10
0
500 °C
350 °C
T1
T2
Biochar
Bio-olio
Gas (stima)


Pyrolysis sample D
90
80
70
60
50
40
30
20
10
0
500 °C
350 °C
T1
T2
Biochar
Bio-olio
Gas (stima)

PYROLYSIS PRODUCTS SUMMARY

SAMPLE		T (°C)	% Biochar	% Bio-oil	% Gas	% H_2O
Sample A	1	500	63	15	22	5
		500	62	8	30	
		500	62	13	25	
	2	350	81	4	15	
		350	85	6	9	
		350	82	7	11	
Sample C	3	500	50	15	35	5
		500	50	14	36	
		500	52	11	37	
	4	350	82	11	7	
		350	80	10	10	
		350	72	10	18	
Sample D	5	500	64	12	24	9
		500	61	18	21	
		500	69	14	17	
	6	350	87	12	1	
		350	79	13	8	
		350	80	14	6	

BIOCHAR CHARACTERIZATION

TEST	PURPOSE
TGA in air	Determine ash content
TGA in nitrogen gas	Verification of pyrolysis completion
IR	Chem. Bounds Variation after pyrolysis
Calorimetry	Determine HCC

SAMPLE	HCC (MJ/kg)
1	16
2	17
3	17
4	16
5	29
6	27

RESULTS DISCUSSION

1. UMWS PYROLYSIS

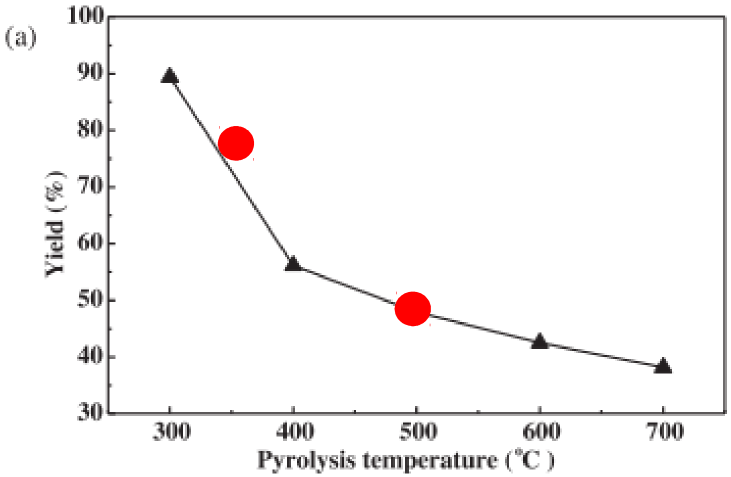
SAMPLE	REACTOR	T °C	GAS	INITIAL WEIGHT	REFERENCE
UMWS	Quarts, fluidized bed	350, 450, 550, 950	He	30 g	(Domı et al., 2009)
UMWS	Tubular fluidized bed	300, 400, 500, 700	Nitrogen	264 – 273 g	(Hossain et al., 2011)
UMWS	Sand bed	350, 500	Nitrogen	20	This work

FRACTION	(Domı et al., 2009)		(Hossain et al., 2011)		This work	
	350 °C	550 °C	300 °C	550 °C	350 °C	500°C
% char	52	49	72.3	57.9	82	65
% oil	10	9	-	-	13	15
% gas	20	21	-	-	5	20

RESULTS DISCUSSION

2. MICROALGAE PYROLYSIS

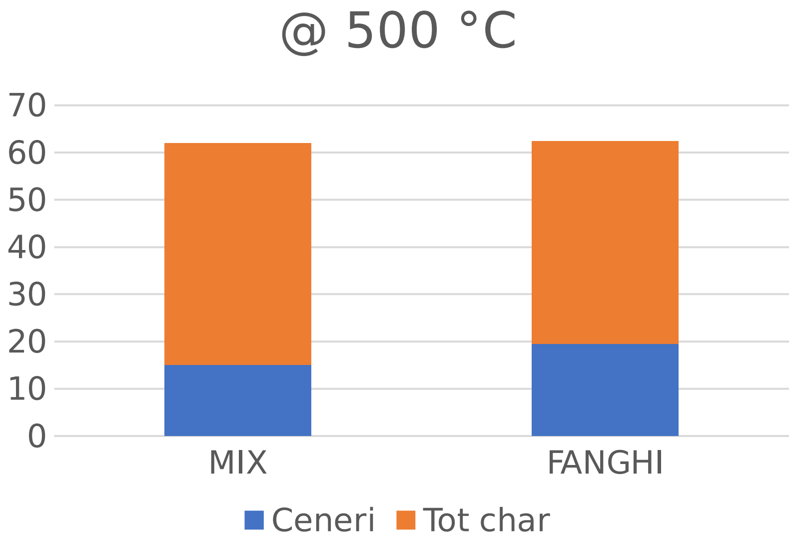
SAMPLE	REACTOR	T °C	GAS	HEATING RATE	INITIAL WEIGHT	REF.
Chlorella	Sand bed	350, 500	Nitrogen	5 °C/min	20 g	This work
Chlorella-based residuals	Tubular, fluidized bed	300, 400, 500, 700	nitrogen	10 °C/min	0,2 g	(Chang et al., 2015)

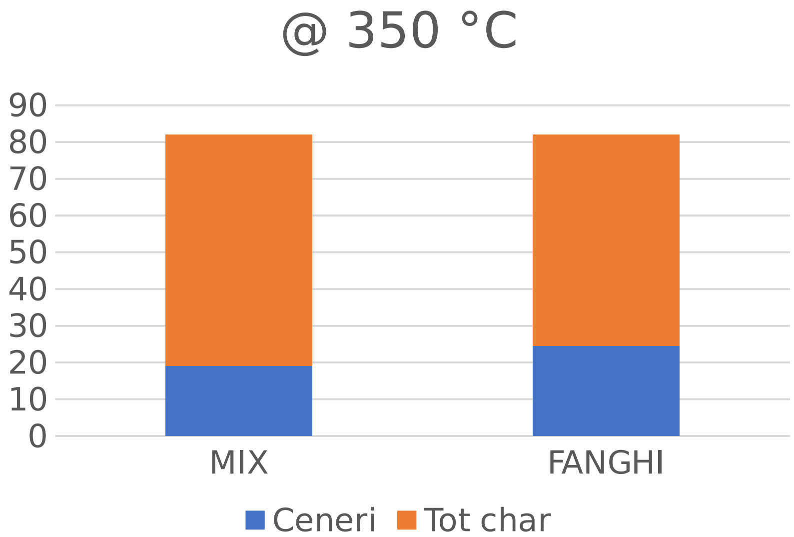


T °C	YIELD BIOCHAR (%)
350	78
500	50

DISCUSSION

3. CO-PYROLYSIS OF UMWS and MICROALGAE





BIOCHAR APPLICATIONS

SOIL AMMENDANT

INORGANIC & ORGANIC POLLUTANTS ADSORBENT

TREATAMENT OF INDUSTRIAL WASTE WATER

ANODIC MATERIAL (MFCs)

FUEL

CONCLUSIONS

- ✓ UMWS and algae co-pyrolysis is a sustainable solution to the disposal issue
- ✓ Production of solid residue with multiple applications
- ✓ Determination of ideal ratio UMWS/algae to maximise biochar production

THANK YOU!!! … and, remember: save th date

https://iwa-network.org/events/15th-iwa-specialist-conference-on-water-basin-and-river-management/