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Feedstock properties' influence on the production of biodiesel from waste urban sludge

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THE PROBLEM:

Safe disposal of sewage sludge is one of the most important (and expensive) phases es in the wastewater treatment cycle

In the European Union, the 2005 sludge production was estimated in 9.4 million tons dry weight, up 54% in ten years, with a 50% increase foreseen by 2020.

Sludge disposal costs may constitute up, and sometimes above, 30-50% of the total cost of operation of a WWTP

CURRENT DISPOSAL SOLUTIONS:

Landfilling: less applicable due to EU legislation mandating recovery of still-exploitable resources from waste streams

Agricultural disposal (only allowed in some Countries, i.e. Italy): limited by local regulations preoccupied by the effects on food chain of the accumulation of heavy metals in soils

Demand of sludge as an “ingredient” (fuel, ashes) in production of construction materials: greatly reduced due to the ongoing economic downturn in most of Europe, creating a weaker market demand for these products.

Exploitation of sludge-embedded resources is becoming a desirable, viable and sensible option for:

-reduction of final waste quantities,

-economic benefit from recovery of resources, either in form of residual nutrients (i.e. struvite recovery) or energy

Domestic wastewater sludge contains energy in different forms:

- intrinsic: embedded within sludge-entrapped wastewater's organics: this is the most direct and most commonly exploitable energy source

Source	Primary Sludge	Secondary Sludge	Anaerobically digested Sludge
Zanoni & Mueller (1982)	15.0	13.5	11.4
Vesilind & Ramsey (1995)			12.6
Shizaz & Bagley (2004)	15.9	12.4	12.7

All values in kJ/g dry weight

-an external energy equivalent which would be required for the production of equivalent amounts of fertilizing elements N and P, (19.3 kWh/kg N by the Haber-Bosch Process and 2.11 kWh/kg P after Gellings and Parmenter)

POTENTIAL ≠ ACCESSIBLE !!!!

due to thermodinamical, technological and process approach limitations

APPLIED TECHNOLOGIES AND PROCESS EFFICIENCIES MUST BE IMPROVED IN ORDER TO FULLY TAP THIS ENERGY SOURCE.

WITH TRADITIONAL WW TREATMENT PROCESS SCHEMES (AEROBIC + ANAEROBOC SLUDGE DIGESTION) WE ARE ABLE TO CAPTURE ONLY A SMALL FRACTION OF THIS POTENTIAL ENERGY

POSSIBLE RECOVERY TECHNOLOGY:

Sludge Pyrolysis: sometimes applied to treatment of sewage sludge from urban WWTPs. From this process, a solid, a gaseous and an oil fractions are produced in variable quantities, either one can be used as a fuel or, in the case of the oil fraction, as a prime material for new chemicals' production.

Microwave-induced pyrolysis (MIP) can be applied for recovery of SSPO (Sewage Sludge Pyrolysis Oil) and Syngas by using a Monomodal Microwave Synthetizer (MMS) as a sole source of heat to the sludge under treatment.

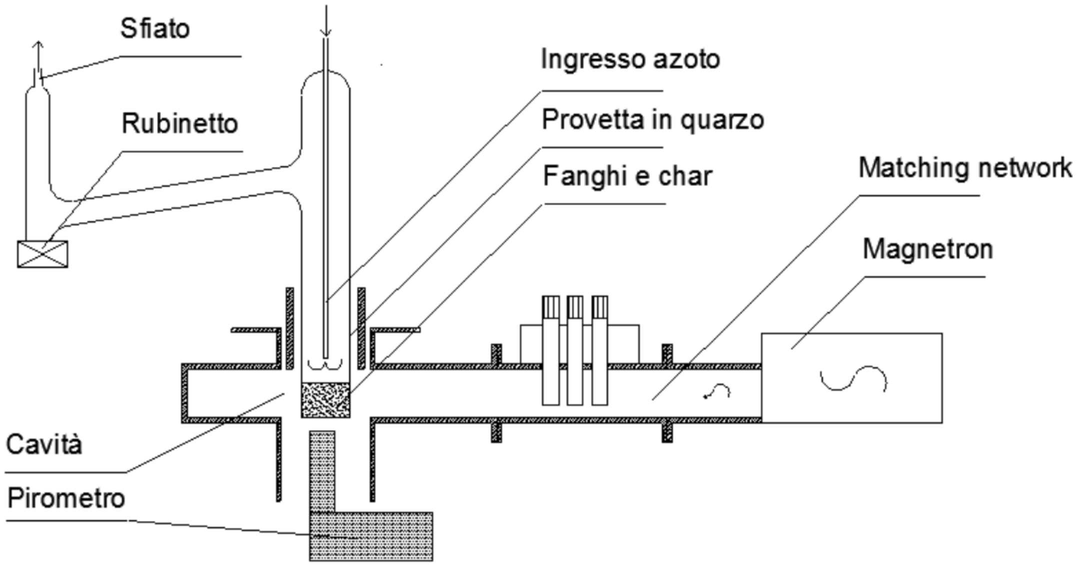
Advantage of MIP are the favourable energetic balance attainable and the possibility of more precise process control.

The final products of a pyrolysis process are influenced by its operating conditions (heating rate, final temperature and HART of volatiles).

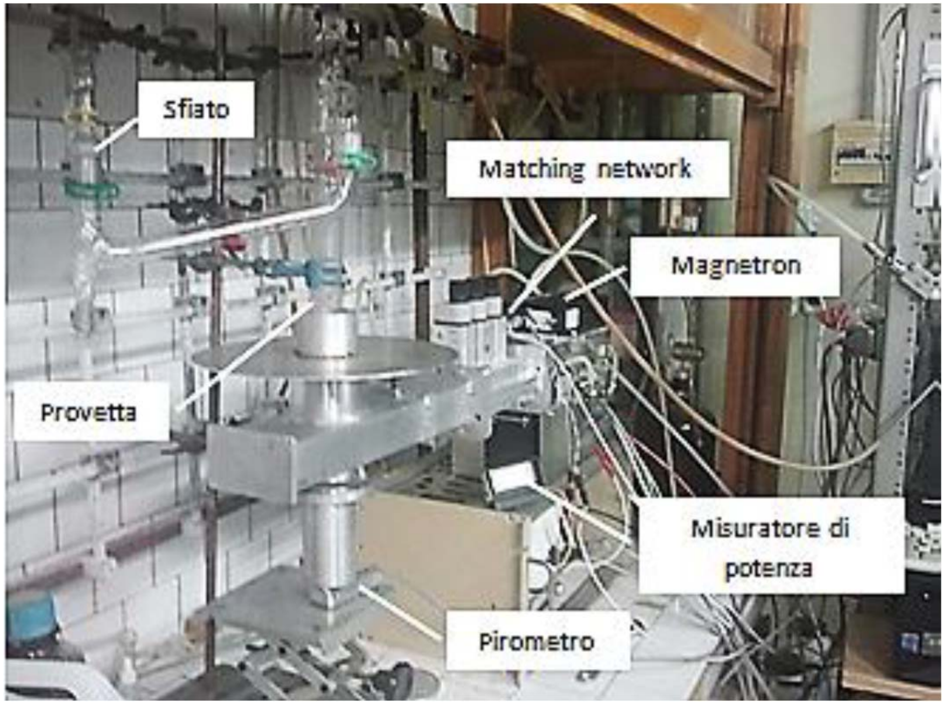
MIP can be optimized to maximize the production of the most desirable fractions. It has been observed that combining pyrolysis and microwave heating, the production of more desirable oil and gas fractions is increased, and the residual solid fraction decreases.

By properly tuning the microwave energy intensity to the load characteristics (i.e. humidity) more energy can be recovered in the form of SSPO and syngas than that spent for the process (up to 240% more).

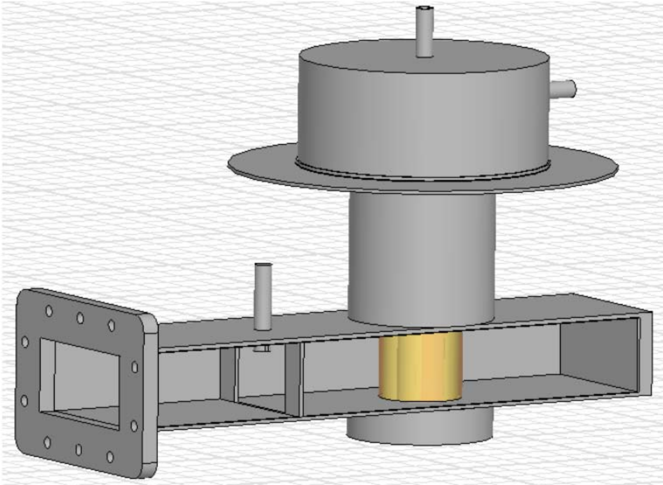
TECHNOLOGY

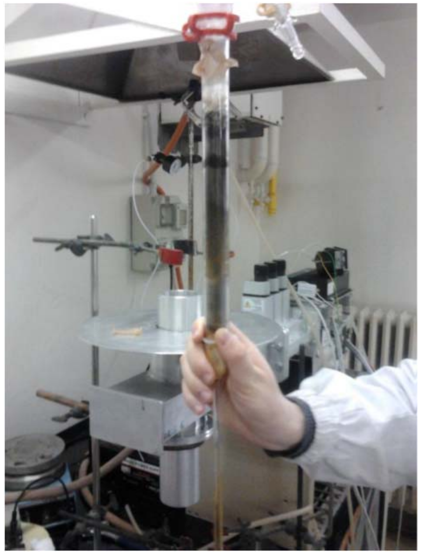


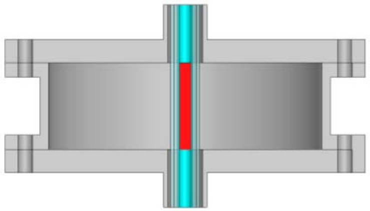
Sfiato
Rubinetto
Ingresso azoto
Provetta in quarzo
Fanghi e char
Matching network
Magnetron
Cavità
Pirometro

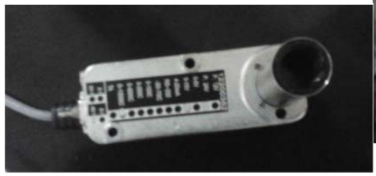


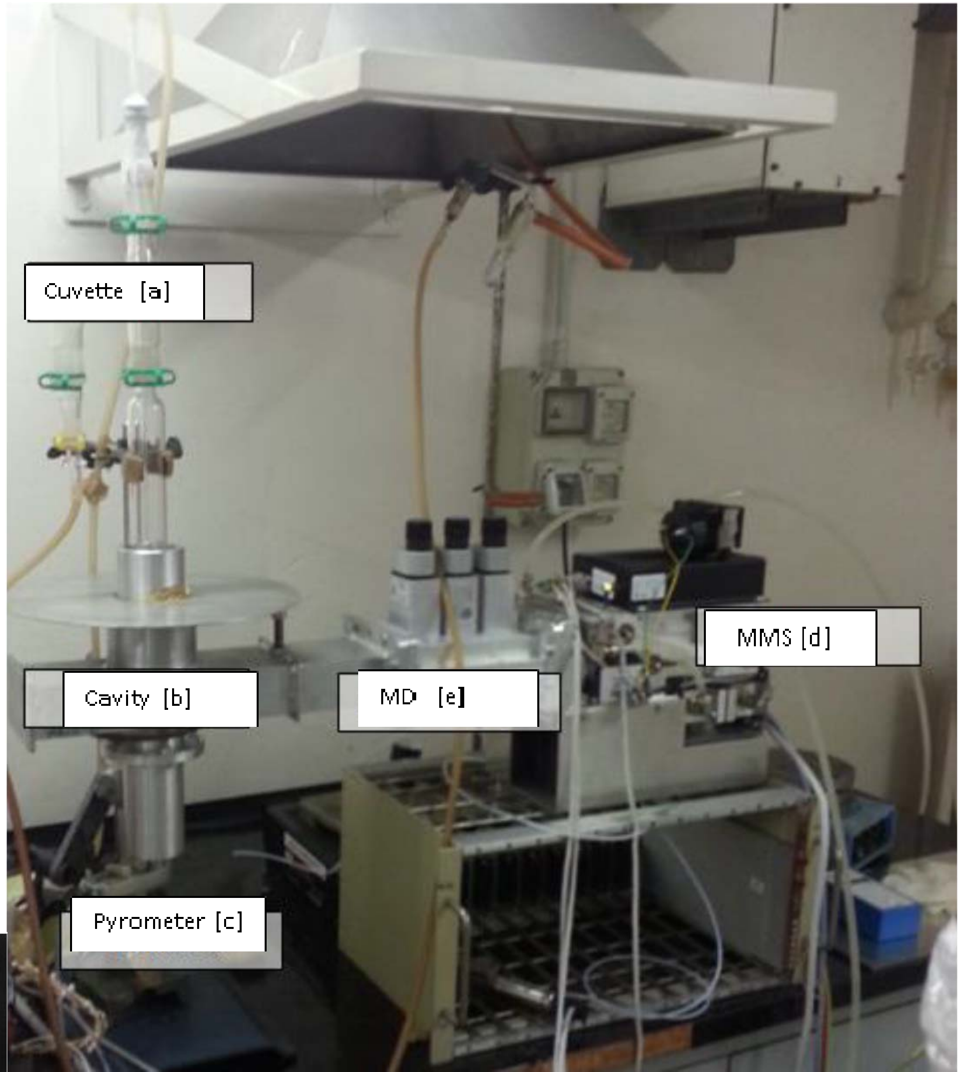
Sfiato
Matching network
Magnetron
Provetta
Misuratore di potenza
Pirometro





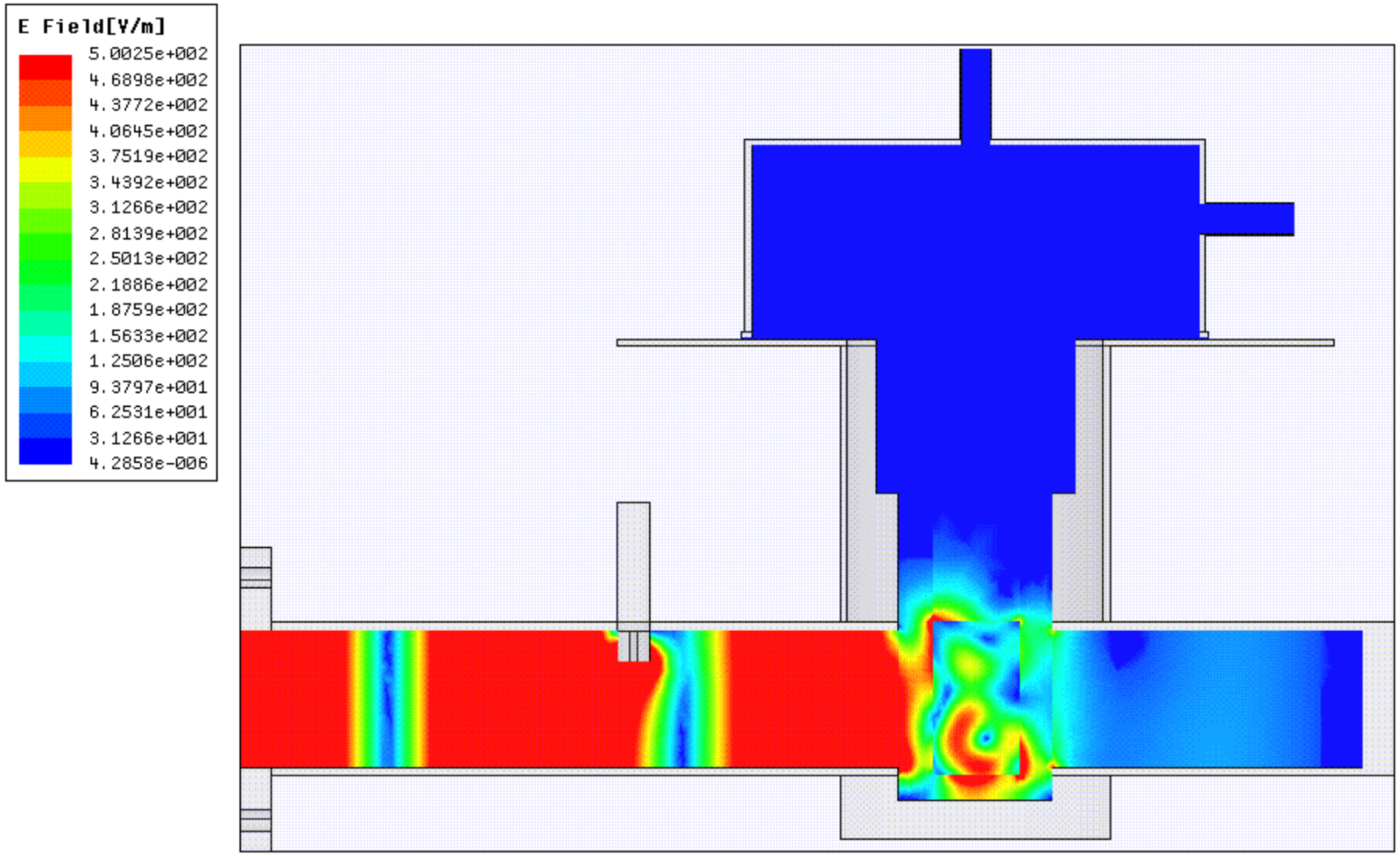





Cuvette [a]
Cavity [b]
MD [e]
MMS [d]
Pyrometer [c]


DUMMY

Energy Field simulation in the apparatus



Sludge samples from waste sludge from the municipal WWTP, already subject to anaerobic digestion process, from which biogas (methane and CO_2) had already been produced.

Samples were desiccated at 60°C for 24 hours.
Dry sludge was ground to fine powder.

Sample	Dry fraction	Humidity	Volatile fraction
Desiccated sludge at 60°C/24 hrs	26.10%	73.87%	
Dried sludge at 105°C/24 hrs	85.38%	14.62%	
Dried sludge at 600°C/3 hrs	53.60%		46.40%

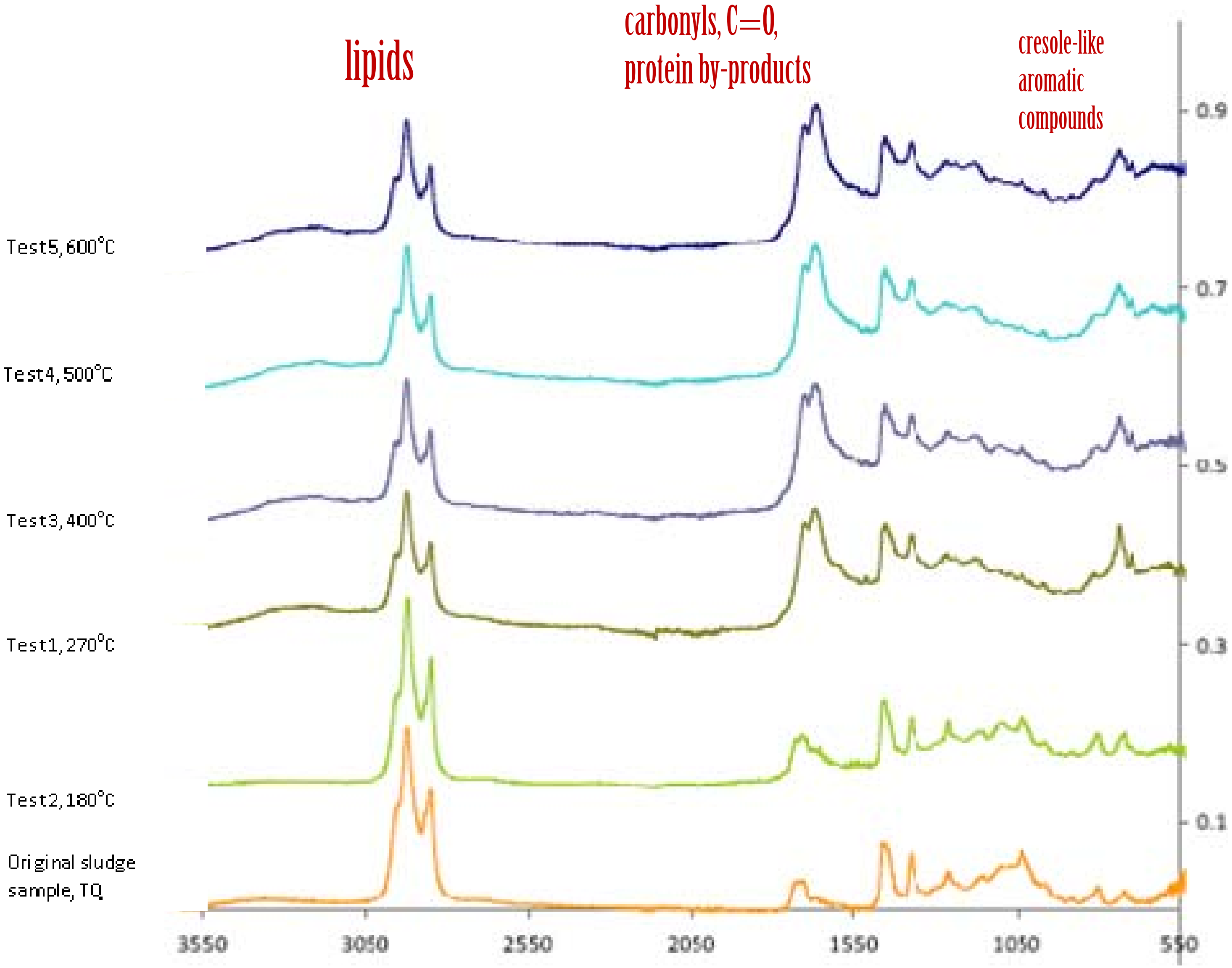
oils were extracted with solvent using a Soxhlet extractor, desiccating the extract with a vacuum rotating evaporator (rotavapor)

	Max Temp. ºC	Time at T_{MAX} [min]	Total process Time [min]	% oil to total sludge	% oil to sludge org. fraction
TQ	60	=	=	3.57*	7*
TEST 1	270	20	55	9.68	19
TEST 2	180	28	50	3.30	7
TEST 3	400	5	55	8.64	17
TEST 4	490	1	54	10.25	21
TEST 5	600	3	56	8.71	17
TEST 6	400	6	46	11.79	24
TEST 7	500	9	51	7.63	15
TEST 8	650	-	60	7.38	15
TEST 9	280	2	8	12.52	25
TEST 10	400	2	18	10.77	22

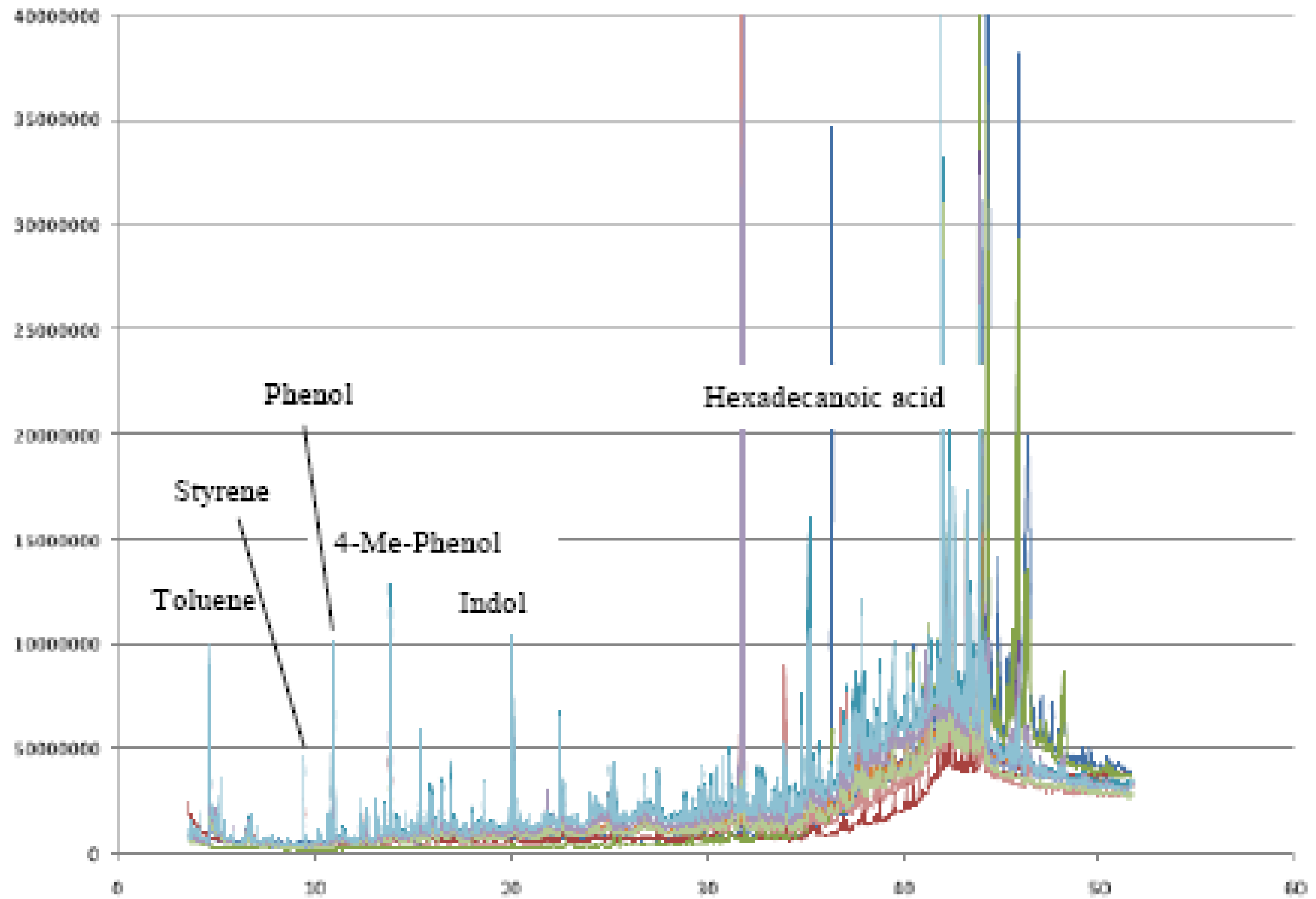
-greatest oil yields were observed between 270 and 500C

-oil yield increases in inverse proportionality to test duration

ATR-IR spectroscopy analysis of oil samples



GC-MC analyses on diluted samples



Energetic balance summary of tests conducted

Test no./ Temp. ºC	Emitted Energy [kJ]	Reflected energy [kJ]	Absorbed Energy [kJ]	Oil yield [g]	Recoverable Energy [kJ]	Process Efficiency Gross [%]	Process Efficiency Net [%]
1/ 270	49.36	13.96	35.40	1.7164	56.6	114.67	159.89
2/ 180	65.94	23.82	42.11	1.7894	59.1	89.63	140.35
3/ 400	47.22	25.08	22.14	1.5621	51.5	109.06	232.61
4/ 490	76.07	31.85	44.22	1.0775	35.6	46.80	82.54
5/ 600	44.09	21.53	22.56	1.1365	37.5	85.05	166.22
6/ 400	90.64	62.7	27.94	1.8413	60.8	67.09	217.61
7/ 500	60.19	18.79	41.40	1.022	33.7	55.99	81.40
8/ 650	94.51	33.31	61.20	0.86221	28.4	30.05	46.40
9/ 280	92.99	19.17	73.82	1.4137	46.7	50.22	63.26
10/ 400	134.62	33.34	101.28	1.4077	46.6	34.61	46.01

Gross Efficiency incorporates energy losses due to reflected energy in the irradiation system, indicating that a process overall efficiency was achieved "as was" during the experiments if its value is greater than 100

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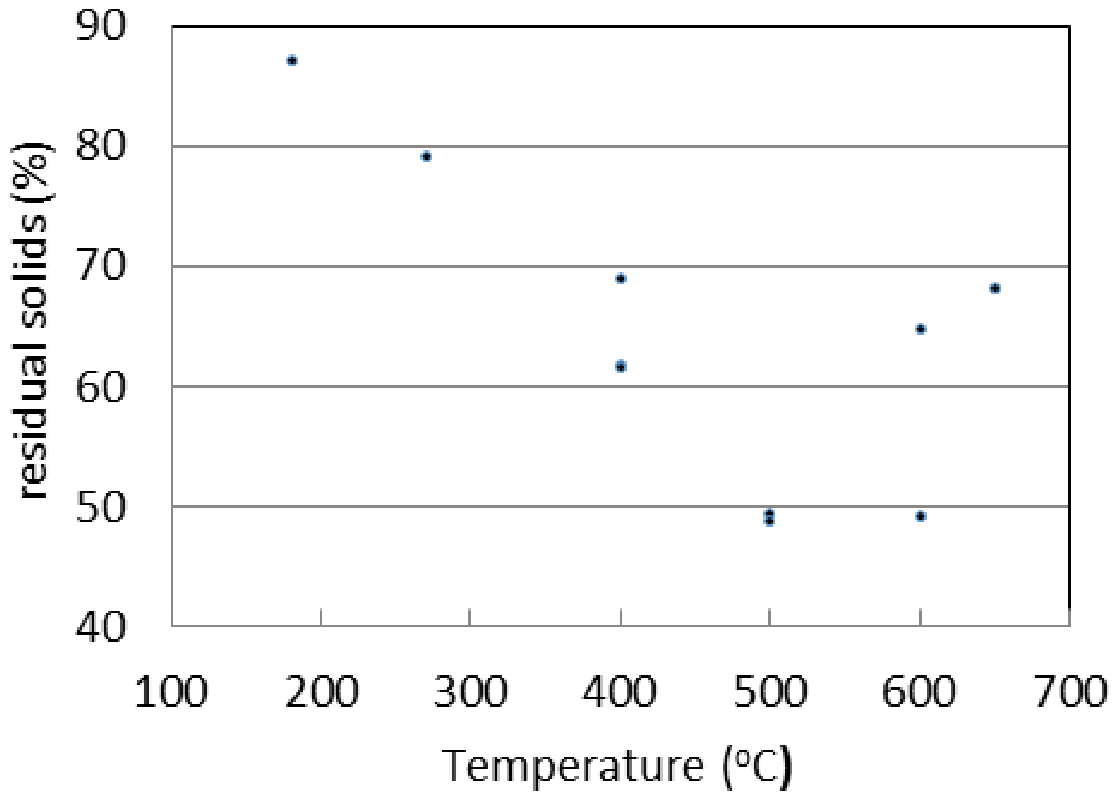
Solids residuals as a function of temperature



CONCLUSIONS

Sewage Sludge Pyrolysis Oils (SSPOs) were produced through microwave-assisted pyrolysis of municipal waste sludges with different preprocessing.

Undigested sludges have, as expected, higher specific yields (at equivalent conditions) than digested sludges.

Addition of different organic waste materials (agricoltural biomasses, microalgae) to sludge has shown to improve yields of energy recovery as SSPOs.

Process yield varies according to operating conditions and depends on a good tuning between MMS and sludge samples.

Obtained oil composition is similar to that reported by other authors and not dissimilar

CONCLUSIONS

Process yield varies according to operating conditions and depends on a good tuning between MMS and sludge samples.

Obtained oil composition is similar to that reported by other authors and not dissimilar to that of biodiesel obtained from common feedstock crops, with a slightly lower calorific value.

CONCLUSIONS

Overall, microwave-induced pyrolysis can be an interesting process for production of bio-oils and syngas from a waste component such as sewage sludges, since it may allow energy-positive recovery of resources on one side, and at the same time reduce the original sludge volumes, consequently reducing disposal costs.

The process may become more popular should energy and sludge disposal cost continue to rise at the current rates.


Thank you for your attention !

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