Slow Pyrolysis of Municipal Wastes

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Introduction

Energy recovery from municipal wastes

- Most of combustible materials in wastes are bioderived (green house gas neutral)
- Energy recovery from wastes after segregation (material recovery) is a key part of energy policy as well as waste management.
- Incineration is dominant in industry but pyrolysis and gasification processes are also available.

Pyrolysis of Municipal Wastes

- Thermal decomposition into char, tar (liquid) and gas at elevated temperatures.
- Pyrolysis for energy conversion from waste/biomass: as a separate process for feedstock production or integrated process with gasification.
- Advantages
  - Storable feedstock (char and liquid) with various industrial purposes including energy recovery.
  - Compact process suitable for small scale applications complementary to incineration.

Research Advantages

- To provide fundamental data on pyrolysis products from key waste materials.
- To assess the use of pyrolysis for a fraction of waste materials that are not economically reused or recycled.

Material Characterisation

Materials: Cardboard, Waste wood and Textile residues

Properties	Waste wood	Cardboard	Textile Residues
Moisture (%wt)	6.9	2.7	3.6
Volatile matter (%wt)	71.7	80.4	89.0
Fixed carbon (%wt)	18.5	11.2	6.9
Ash (%wt)	2.9	5.7	0.5
Carbon (%wt)	44.9	41.7	43.3
Hydrogen (%wt)	6.7	6.4	6.2
Oxygen* (%wt)	38.6	43.5	46.4
Gross calorific value (MJ/kg)	16.0	15.7	16.0
Particle size and shape	20mm cube	5x20x20mm	30x50mm
Bulk density of bed (kg/m³)	308	76	90


Waste wood

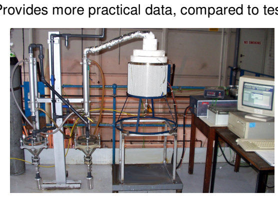

Cardboard

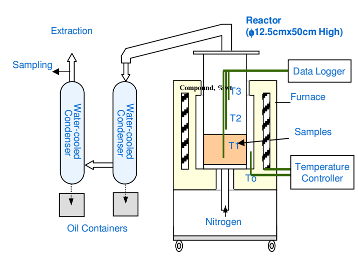

Textile residues (cotton ~95%, polyester ~5%)

Experimental Methods

Pyrolysis Reactor

- Stainless steel reactor (ID 125mm x H 500mm) seated in a electrically heated furnace
- Provides more practical data, compared to tests with a very small amount of sample such as TGA





Pyrolysis Conditions

- Final temperature: 350-700ºC
- Heating rate: 10ºC/min
- Nitrogen: 2 l/min
- Initial sample weight: ~200g
- 1hr at the final temperature

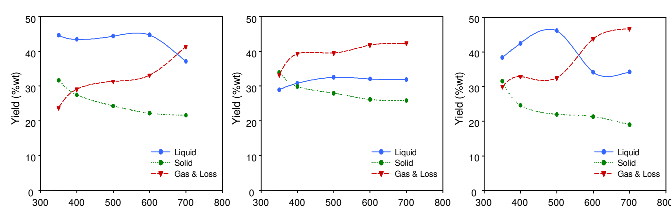
Characterisation of Products

- Standard fuel analyses (proximate, ultimate and calorific value) for raw material, char, liquids
- Gas composition: CO/CO2/O2 analyser, GC
- Elemental composition of raw material, char and liquids
- Liquid compounds: GC-Mass

Experimental Results: Pyrolysis Products

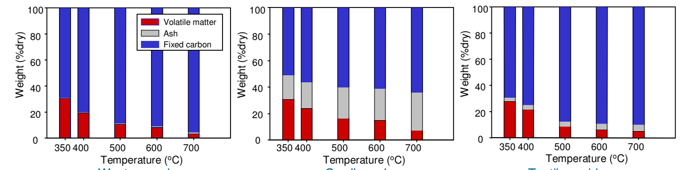
Product Yield: approximately equal mass yields for each product

- Char yield gradually decreases as pyrolysis temperature increases.
- Liquid yield drops by effect of thermal cracking at high temperatures over 600oC.
- Gas yield gradually increases as pyrolysis temperature increases



Waste wood — Cardboard — Textile residues

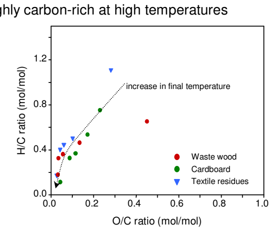
Char: Proximate Analysis



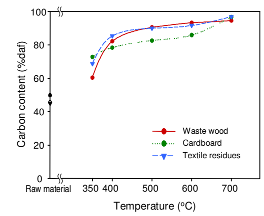
Waste wood — Cardboard — Textile residues

Char: Elemental Composition

- Highly carbon-rich at high temperatures



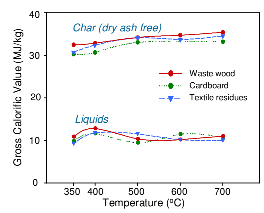
Van Krevelen diagram of char



Carbon content in char

Calorific Value of Pyrolysis Products

- Char: over 30MJ/kg-daf due to high carbon content
- Liquid: 10-13 MJ/kg (containing large amount of water)
- Gas: typically 17 MJ/m³-dry for pyrolysis temperature of 700ºC



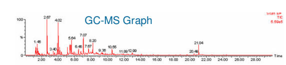
Gross calorific value of char and liquids

Element	Waste wood	Cardboard	Textile Residues
C	60.71	42.345	43.81
H	11.37	8.24	7.90
O*	27.99	50.71	47.95
Empirical formula	$C_{5.06}H_{11.37}O_{1.75}$	$C_{3.53}H_{8.24}O_{3.17}$	$C_{3.65}H_{7.90}O_{2.30}$
GCV (MJ/m³-dry)	27.87	17.00	16.95

Elemental composition and calorific value of gas products integrated up to 700ºC

Liquid Products: Composition and Compounds

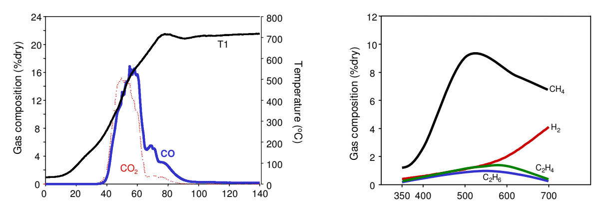
- Over 70 compounds identified in pyrolysis liquids
- Mainly oxygenated compounds


GC-MS Graph

Material / Temperature (ºC)	Waste wood			Cardboard			Textile Residues		
	350ºC	500ºC	700ºC	350ºC	500ºC	700ºC	350ºC	500ºC	700ºC
Alcohols	12.3	13.0	4.9	12.4	19.7	7.5	8.6	10.0	3.2
Acids	17.7	16.6	8.2	9.2	11.8	7.0	4.9	6.0	0.9
Furans	14.3	10.7	16.6	18.4	25.4	19.0	34.2	24.5	30.0
Pyrans	0.4	3.0	2.2	1.8	3.1	1.4	0.8	0.9	1.41
Anhydroglucosans	3.3	12.8	2.6	22.1	11.6	23.1	14.9	27.4	3.45
Phenols	7.3	9.1	13.2	10.2	5.1	8.8	8.9	11.4	17.6
Guaicols	36.2	24.7	27.6	13.4	9.3	14.4	20.7	9.2	21.9
Syringols	1.1	0.6	1.8	0.7	0.8	1.6	0.7	0.5	0.8

Gas Composition

- Mainly CO and CO_2 in the early stage of pyrolysis
- H2, CH4 and heavy hydrocarbons increase with pyrolysis temperature



Gas composition from waste wood for pyrolysis temperature of 700ºC

Conclusions

- **Pyrolysis for segregation residues can be a viable way of energy conversion complementary to incineration.**
- **Char from segregation residues having low ash contents is a good quality fuel for various industrial uses.**
- **Liquids can be transported to and converted to energy in large-scale power plants.**
- **Gas can be directly consumed in order to provide energy required for pyrolysis.**
- **No significant benefits for pyrolysis at over 500ºC**

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More Information on SUWIC can be found at our websites: http://www.suwic.group.shef.ac.uk/

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