The University Of Sheffield.

CO-FIRING & FUEL CHARACTERISATION

The Reuse of Spent Mushroom Compost and Coal Tailings for Energy Recovery

Karen Finney, Jim Swithenbank and Vida Sharifi

Department of Chemical and Process Engineering
University of Sheffield

Overview

- Project aims and objectives
- Reusing wastes as a source of energy
- Typical emissions to the air
- Waste Incineration Directive
- Experimental results:
  - ~ material characterisation
  - ~ pelletisation
  - ~ fluidised-bed combustion of fuel pellets
- Discussion and conclusions

The University Of Sheffield.

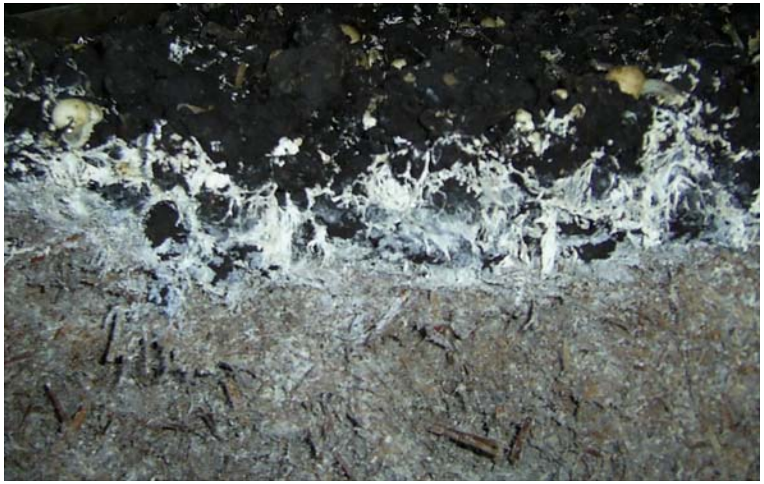
Project Aims and Objectives

- To divert spent mushroom compost from landfill and aid the cleaning of land contaminated by coal tailings by generating a source of renewable, sustainable fuel
- To evaluate ways in which SMC and coal tailings can be utilised to produce energy
- To investigate and characterise the emissions produced from the thermal treatments of these wastes

Wastes as a Source of Energy

- Reusing wastes for energy recovery can mitigate the impacts of unsustainable energy generation and waste management

1. Spent mushroom compost (SMC) – an agricultural waste from mushroom farms



The University Of Sheffield.

Wastes as a Source of Energy

- Reusing wastes for energy recovery can mitigate the impacts of unsustainable energy generation and waste management

2. Coal tailings – an industrial waste produced during coal cleaning processes

Typical Emissions to the Air

- Solid-phase pollutants: ash
- Gas-phase pollutants include:
  - ~ CO and CO_2
  - ~ acid gases – NOx, SOx and HCl
  - ~ dioxins, furans, UHCs, VOCs and PAHs
- Problems: greenhouse gases, ozone depletion, acid rain, photochemical smog, carcinogenic/toxic
- Abatement and control to meet legislation

Waste Incineration Directive

- Waste Incineration Directive – WID
- Concerns the incineration of hazardous and non-hazardous waste
- Outlines limits for various pollutants:
  - ~ solid: flyash
  - ~ gaseous: NOx, SOx and HCl
- The combustion of SMC-coal tailing pellets must comply with this legislation

The University Of Sheffield.

Material Characterisation

ANALYSIS		COAL TAILINGS	SMC SUBSTRATE	SMC CASING
	Moisture (%)	~ 40	65.70	68.56
Proximate Analysis (%)	Ash	41.25	26.89	28.87
	Volatile	20.51	61.80	60.18
	Fixed Carbon	38.24	11.31	10.95
Ultimate Analysis (%)	Carbon	47.87	35.13	35.72
	Hydrogen	2.90	3.59	3.01
	Nitrogen	1.01	2.85	1.11
	Chlorine	-	0.51	0.70
	Sulphur	1.38	2.95	2.16
CV (MJ/kg)	GCV, ar	11.91	4.94	4.33
	GCV, dry	19.85	14.11	12.37

The University Of Sheffield.

Material Characterisation

ANALYSIS		COAL TAILINGS	SMC SUBSTRATE	SMC CASING
Moisture (%)		~ 40	65.70	68.56
Proximate Analysis (%)	Ash	41.25	26.89	28.87
	Volatile	20.51	61.80	60.18
	Fixed Carbon	38.24	11.31	10.95
Ultimate Analysis (%)	Carbon	47.87	35.13	35.72
	Hydrogen	2.90	3.59	3.01
	Nitrogen	1.01	2.85	1.11
	Chlorine	-	0.51	0.70
	Sulphur	1.38	2.95	2.16
CV (MJ/kg)	GCV, ar	11.91	4.94	4.33
	GCV, dry	19.85	14.11	12.37

Material Characterisation

ANALYSIS		COAL TAILINGS	SMC SUBSTRATE	SMC CASING
Moisture (%)		~ 40	65.70	68.56
Proximate Analysis (%)	Ash	41.25	26.89	28.87
	Volatile	20.51	61.80	60.18
	Fixed Carbon	38.24	11.31	10.95
Ultimate Analysis (%)	Carbon	47.87	35.13	35.72
	Hydrogen	2.90	3.59	3.01
	Nitrogen	1.01	2.85	1.11
	Chlorine	-	0.51	0.70
	Sulphur	1.38	2.95	2.16
CV (MJ/kg)	GCV, ar	11.91	4.94	4.33
	GCV, dry	19.85	14.11	12.37

The University Of Sheffield.

Pelletisation of Wastes

PELLETISATION PARAMETER	OPTIMUM
Moisture Content	10-11 %
Minimum Pressure	2500 psi / 17 MPa
Maximum Pressure	6000 psi / 41 MPa
SMC:Coal tailing Ratio	50:50 wt%
Binder	Starch
Amount of Binder	1 wt%
Temperature	45-75 °C
Length of Steam Conditioning	5 mins

Thermal Treatments

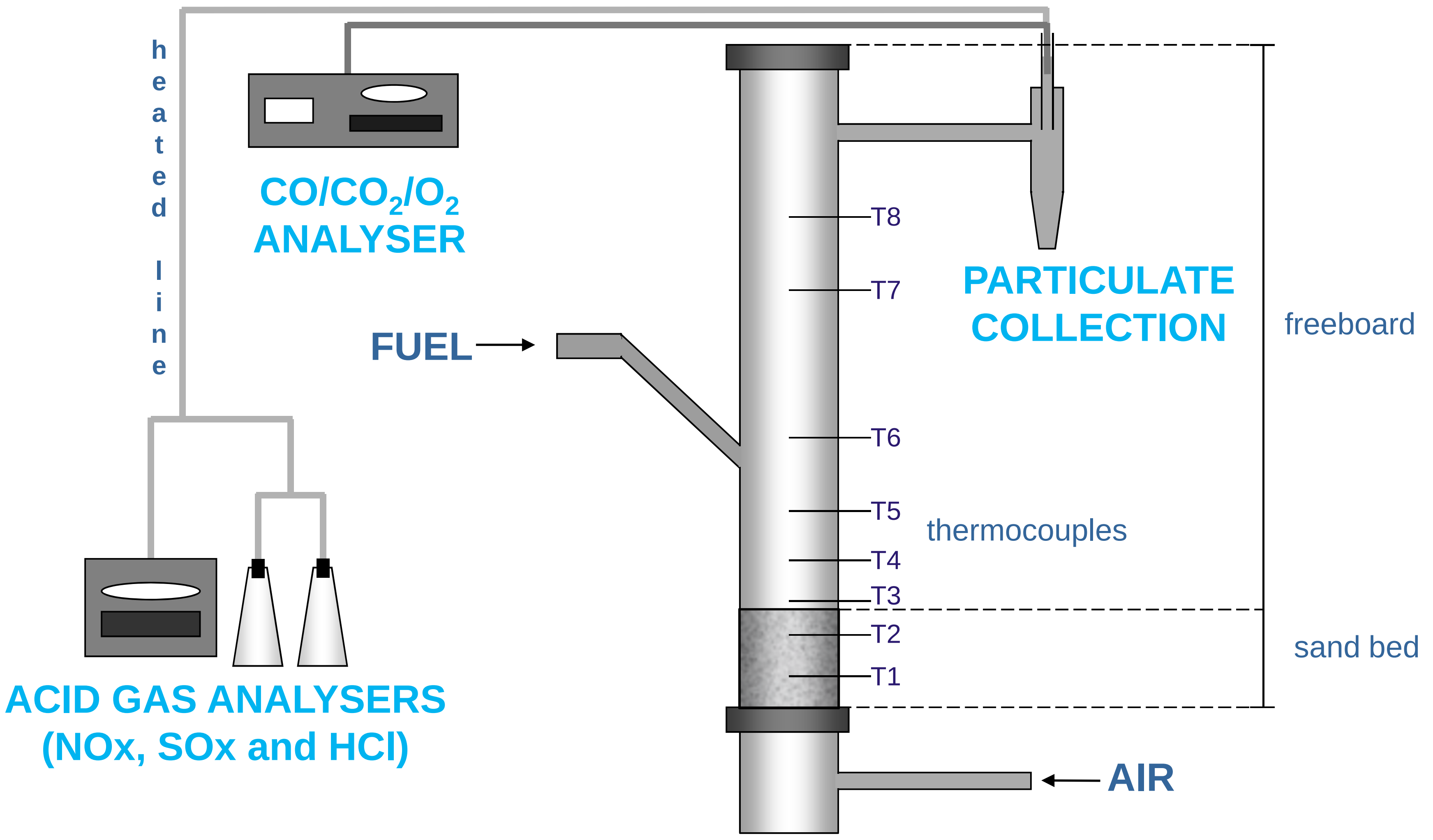
EXPERIMENTS

- Combustion tests in a laboratory-scale fluidised-bed and a packed-bed:
  - ~ combustion of SMC-coal tailing pellets
  - ~ combustion of raw, dried SMC
- Gasification and pyrolysis of SMC

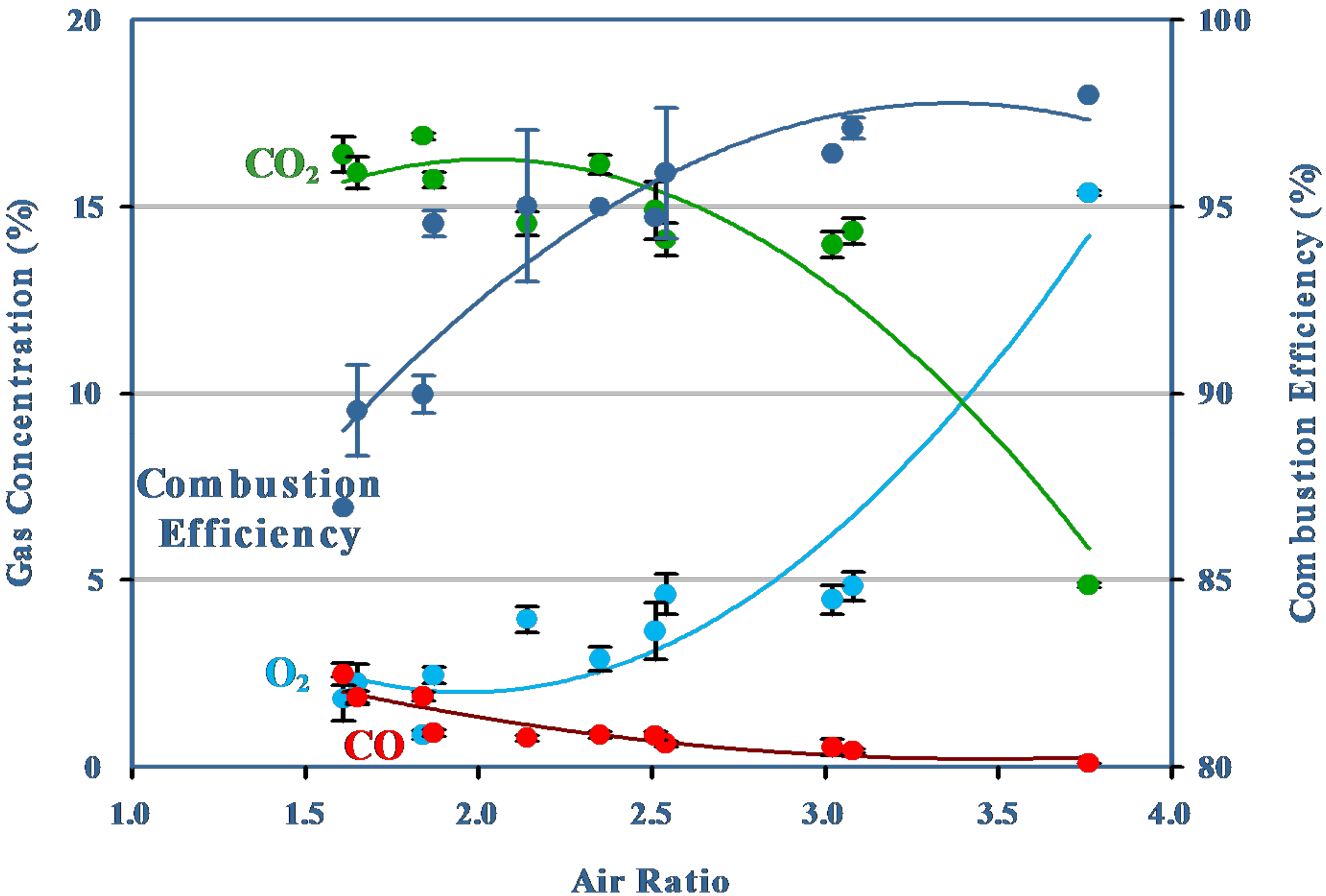
RESULTS

- Pellet combustion performed better
- Fluidised-bed combustion was more efficient than in both cases
- Fluidised-beds are better suited for high ash-content fuels

Fluidised-bed Combustor



The University Of Sheffield.



Evaluation of Combustion

- Small-scale nature of the reactor meant inherent inefficiencies
- Scale-up of the reactor
  - ~ a deeper bed can be used whilst maintaining a bed-depth-to-diameter ratio of 1
  - ~ increase efficiency
- Secondary air jets
  - ~ high-speed, turbulent secondary air to optimise fuel-oxidiser mixing to complete burnout of fuel and residual gases
  - ~ lower CO, prompt NOx and combustible material

The University Of Sheffield.

Gaseous Emissions

	NOx	SOx	HCl
Range	2.1 - 58.4 ppm	2.35 - 41.69 ppm	0.88 - 16.88 ppm
Average	10-20 ppm	12 ppm	5.3 ppm
Maximum	91 mg/m^3	123 mg/m^3	25 mg/m^3
WID Limits	200-400 mg/m^3 (~257 ppm)	50 mg/m^3 (~19 ppm)	10 mg/m^3 (~6.7 ppm)
Ash	N not abundant in the ash – N_2O?	S concentrated in ash – 15,000 mg/kg	Cl concentrated in ash – 535 mg/kg

Particulate Pollutants

COMPONENT (mg/kg)	FUEL PELLETS	FLYASH
Flyash as % of Ash in Pellets	-	78.95
Alkali Index (kg-alkali/GJ)	-	0.235
Al	2500	45000
Fe	5604	37250
K	8364	20625
Na	1123	3750
P	3121	5237.5
S	11702	15300
Si	1487	3137.5
Ash Fusion Temperatures (°C)	-	1272

Discussion and Conclusions (1)

- Fluidised-bed combustion is the best way to recovery energy from these wastes, after drying and pelletisation
- Combustion efficiency could be high (up to 98 %) using appropriate conditions
- Efficiency could be further improved by:
  ~ using turbulent secondary air to aid mixing
  ~ an industrial-scale reactor with a deeper bed
  ~ reduce CO, prompt NOx and unburned material

Discussion and Conclusions (2)

- Characterisation identified potential pollutants
- NOx, SOx and HCl were minimal compared to the initial concentrations of N, S and Cl
  - ~ NOx emissions were below regularity limits
  - ~ SOx and HCl did **not** conform to WID
- Flyash removal needed to comply with WID
  - ~ alkali metal oxides = slagging and fouling
  - ~ Al, Fe, Si and Cl = ash agglomeration
  - ~ temperatures lower than those of ash fusion

Acknowledgements

- Prof. Jim Swithenbank and Prof. Vida Sharifi
- Engineering and Physical Science Research Council
- Veolia Environmental Trust
- Maltby Colliery
- Dr John Burden and Monaghan Mushrooms Ltd.