Imperial College London

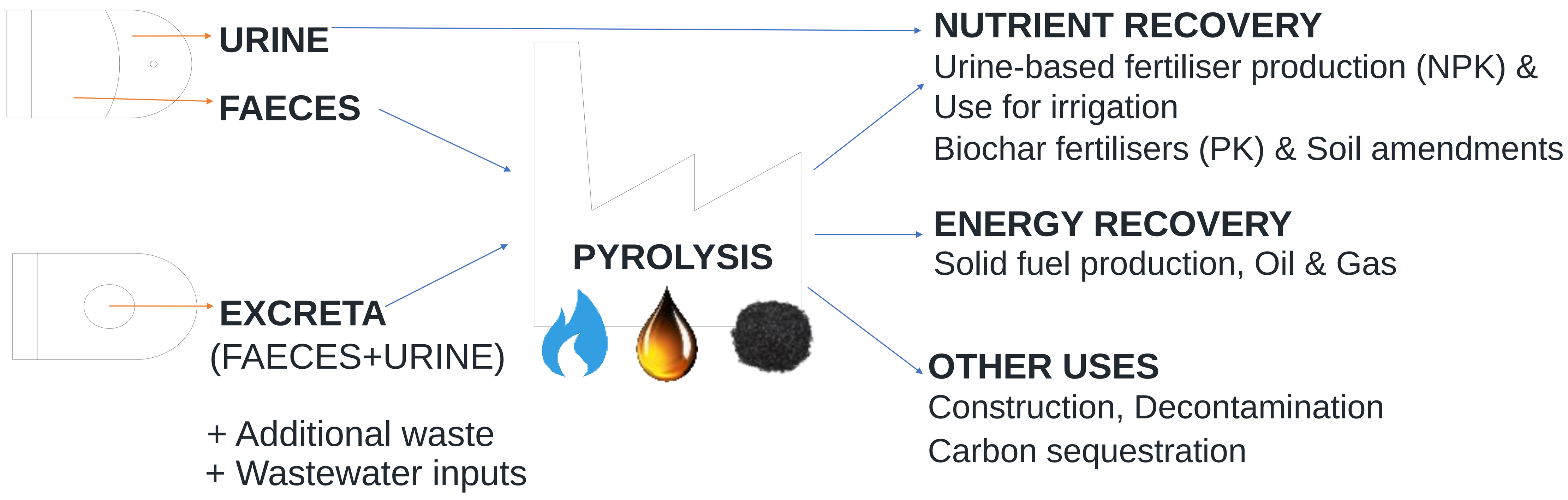
Source-separation of human excreta as a driver for optimised resource recovery via pyrolysis

M.E. Koulouri[1], M. R. Templeton[1], G.D. Fowler[1]

[1]Department of Civil and Environmental Engineering, Imperial College London, UK, SW7 2AZ
Presenting author e-mail: maria.koulouri17@imperial.ac.uk

1 Introduction

- **Faecal sludge (FS)** is the material that accumulates in on-site sanitation facilities and consists of human excreta with or without additional waste and wastewater inputs [1].
- The FS reaching treatment plants is very variable in composition and ensuring consistent **quality of recovered products** is challenging.
- There is a need to understand how FS composition impacts resource recovery and identify ways to improve recovery rates through **source-control**.
- **Source-separation of faeces and urine** at source has been reported to be beneficial for resource recovery but its effects on feedstock and product characteristics cannot easily be quantified based on existing knowledge.



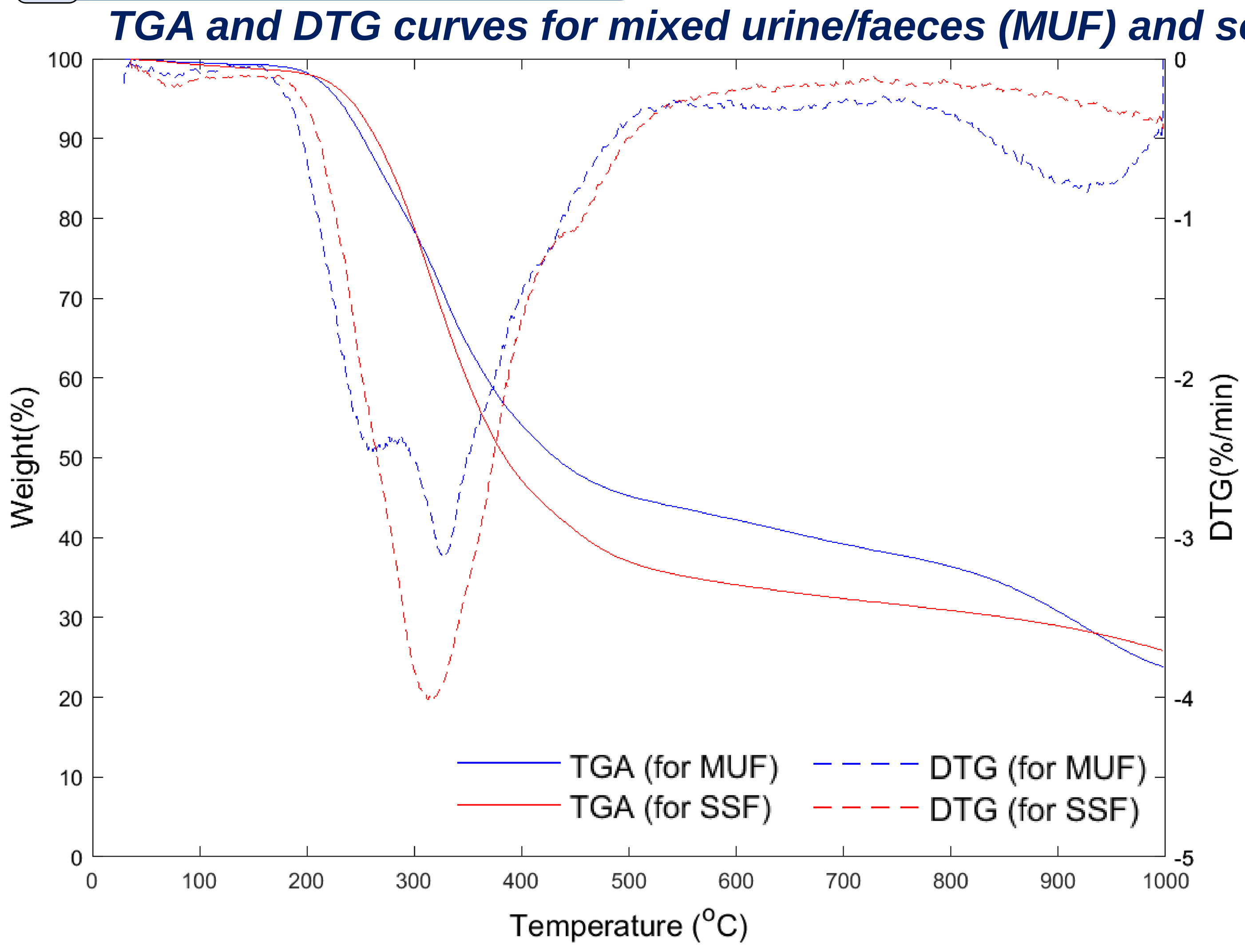
Objective: quantifying the effects of source-separation on faecal sludge characteristics to inform resource recovery via pyrolysis.

2 Materials & Methods

Samples of faeces and urine, collected from 12 volunteers in the UK, were prepared and categorised as **source-separated** and **mixed human excreta** samples at Imperial College London. Comparative analysis of sample groups was conducted via: proximate analysis, thermogravimetric analysis, calorific value measurements, CHNS analysis and elemental composition analysis via ICP-OES.

3 Results & Discussion

TGA and DTG curves for mixed urine/faeces (MUF) and source-separated faeces (SSF) (under N_2 50ml/min, 10°C/min) (on a dry basis).



Three thermal stages observed within the typical pyrolysis temperature range (200-700°C):

200-400°C: Decomposition of protein, hemicellulose, cellulose and other carbohydrates [2,3]. Around 50% weight loss occurs for both sample groups, although the decomposition behaviour differs. This may be attributed to the prevalence of proteinic compounds' degradation in urine-containing excreta sources.

400-550°C: Completion of lignin decomposition reactions and cracking of oil & grease [2]. Forming a shoulder on the DTG curve, until the completion of main pyrolytic reactions by 550°C. This shoulder appears to be more distinct for source-separated faeces, possibly due to faecal fat excretion.

>550°C: Continued carbonisation with slow weight loss. Further weight loss occurs >700°C due to the decomposition of inorganic compounds. Notably, this occurs at a significantly higher rate for urine-containing excreta sources, due to the high presence of inorganic salts in urine [4].

Source-separated faeces are a **more energy-dense** feedstock.
22.5% increase in calorific value & 34% decrease in ash content with source-separation.

Higher **essential nutrients (NPK)** values when urine is present.
N volatilisation during pyrolysis **minimised** by source-separation & **opportunity to increase N retention** when directly recovered from urine. P and K retained in both fractions.

Capturing more carbon per kg of feedstock treated.
35% increase in fixed carbon content with source-separation.

Effects of source separation on feedstock characteristics and elemental composition (on a dry basis). HHV = Higher Heating Value

	Volatile matter (%)	Fixed carbon (%)	Ash (%)	HHV (MJ/kg)	C (%)	H (%)	N (%)	S (%)	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)
Mixed excreta	70.0	11.2	18.9	17.8	41	5.3	6.8	2.1	32.2	28.5	17.7	8.7
Source-separated faeces	72.5	15.1	12.5	21.8	50	6.8	4.9	1.3	22.4	12.9	23.2	8.8

4 Conclusions

- **Source-separation** followed by separate treatment of urine and faeces, is a promising way to **increase resource recovery from human excreta**.
- Source separated faeces are more suitable for treatment via pyrolysis, while urine is more suitable for non-thermal methods with the objective of nutrient recycling.
- Quantifying the added value of source-separation can inform the **design of circular sanitation systems** and create financial **incentives for increased sanitation coverage** through human waste valorisation.

References

[1] Velkushanova, K. et al., 2021. Methods for Faecal Sludge Analysis. IWA Publishing.

[2] Krueger, B.C. et al., 2021. Faecal sludge pyrolysis: Understanding the relationships between organic composition and thermal decomposition. Journal of Environmental Management 298, 113456.

[3] Somorin, T., Parker, A., McAdam, E., Williams, L., Tyrrel, S., Kolios, A., Jiang, Y., 2020. Pyrolysis characteristics and kinetics of human faeces, simulant faeces and wood biomass by thermogravimetry–gas chromatography–mass spectrometry methods. Energy Reports 6, pp. 3230-3239.

[4] Rose, C. et al., 2015. The Characterization of Feces and Urine: A Review of the Literature to Inform Advanced Treatment Technology. Crit Rev Environ Sci Technol 45, pp. 1827–1879.

The authors would like to thank the Department of Civil and Environmental Engineering of Imperial College London for the donation of a scholarship and the Society of Chemical Industry (SCI) for financially supporting this work. Approvals and permissions for the collection of human excreta samples were obtained via the Imperial College Research Governance and Integrity Team (RGIT) and the Imperial College Healthcare Tissue Bank (ICHTB).