Synergistic Interactions between Sewage Sludge and Plastics during Co-pyrolysis

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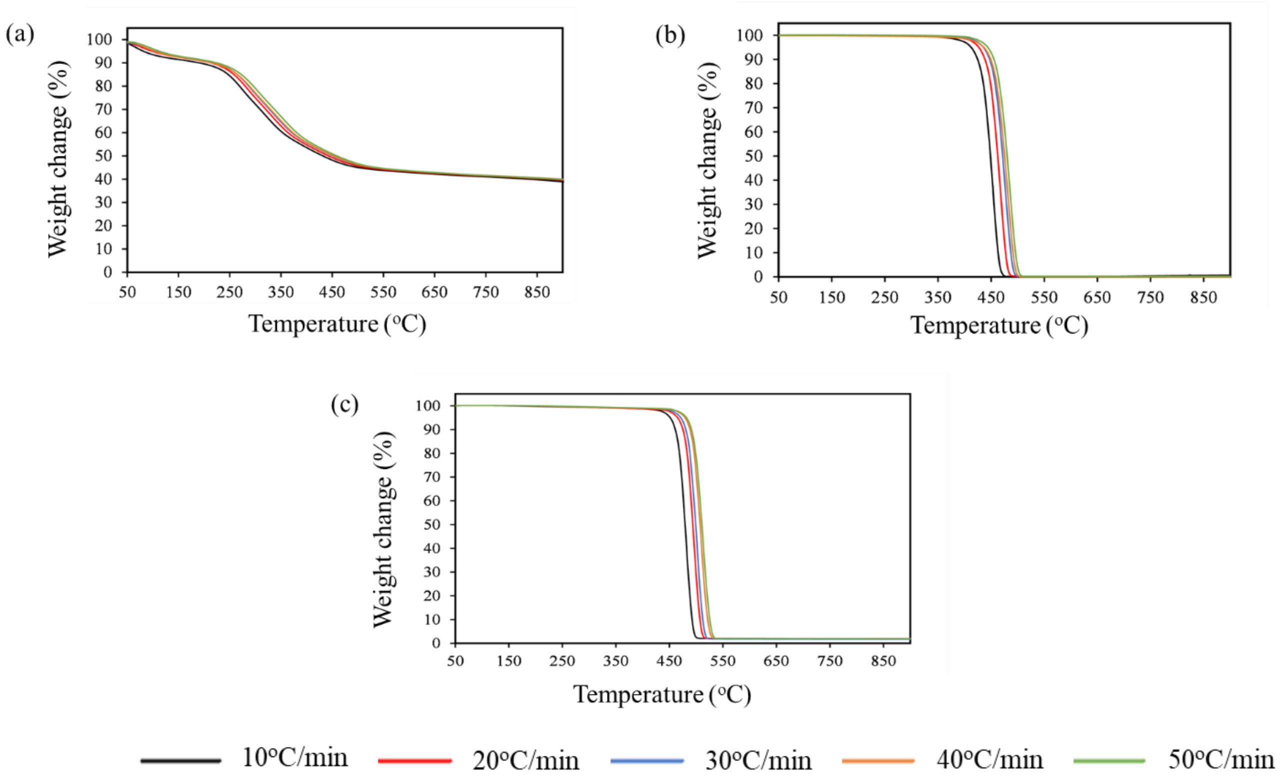
Introduction

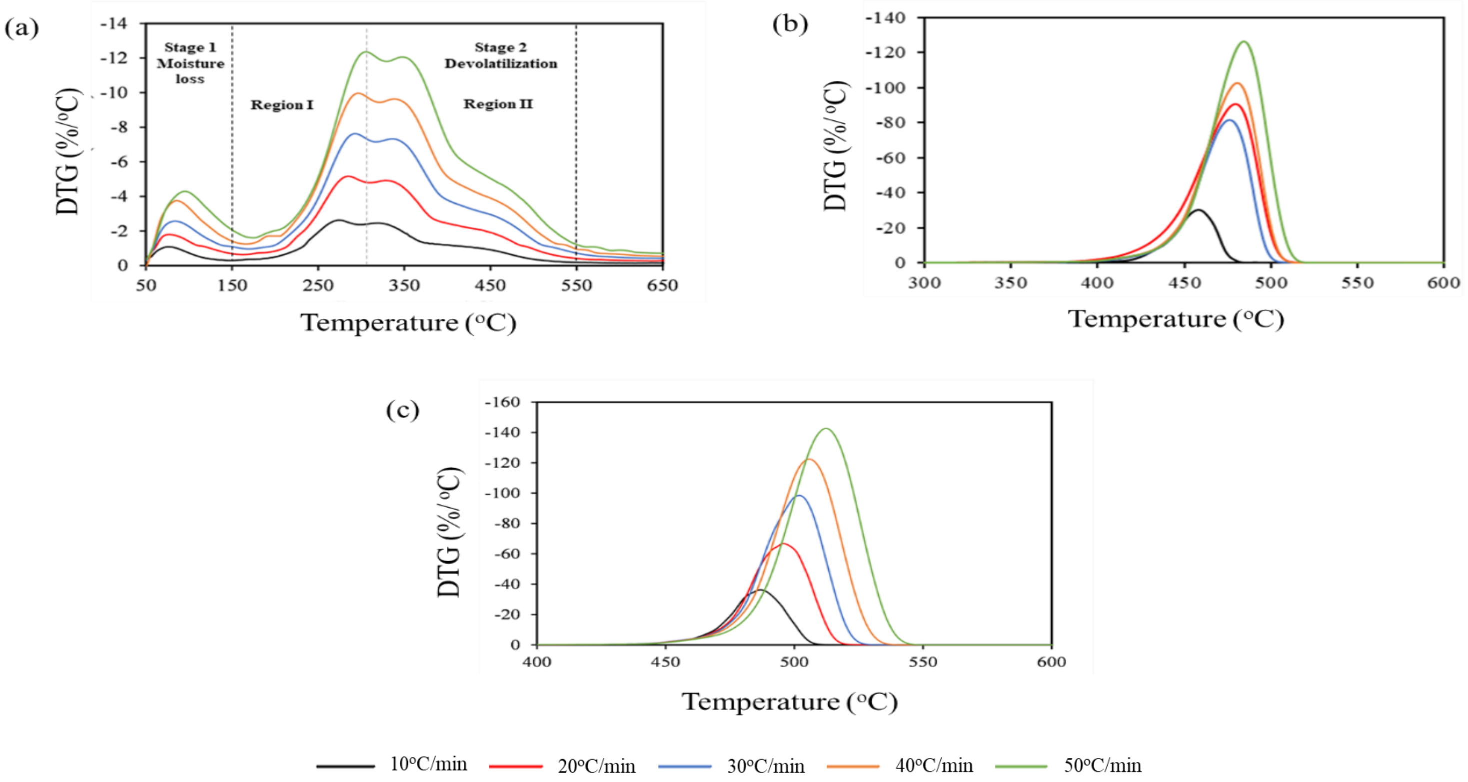
- **Sewage sludge (SS) is a heterogeneous mixture of organic and inorganic constituents, produced as a by-product of wastewater treatment processes.**
- **While pyrolysis of SS would reduces waste going to landfill and greenhouse gas emission, effective energy recovery from SS is hindered by its low bio-oil composition.**
- **During co-pyrolysis, 2 or more materials are mixed and pyrolyzed together, which interacts to affect overall product composition and distribution.**
- **Polyolefins, such as polypropylene (PP) and high-density polyethylene (HDPE), have high H content in its polymeric structure.**
- **Hence, co-pyrolysis of PP and HPDE with SS is studied to elucidate synergistic effects on activation energy and product distribution.**

Thermogravimetric curves



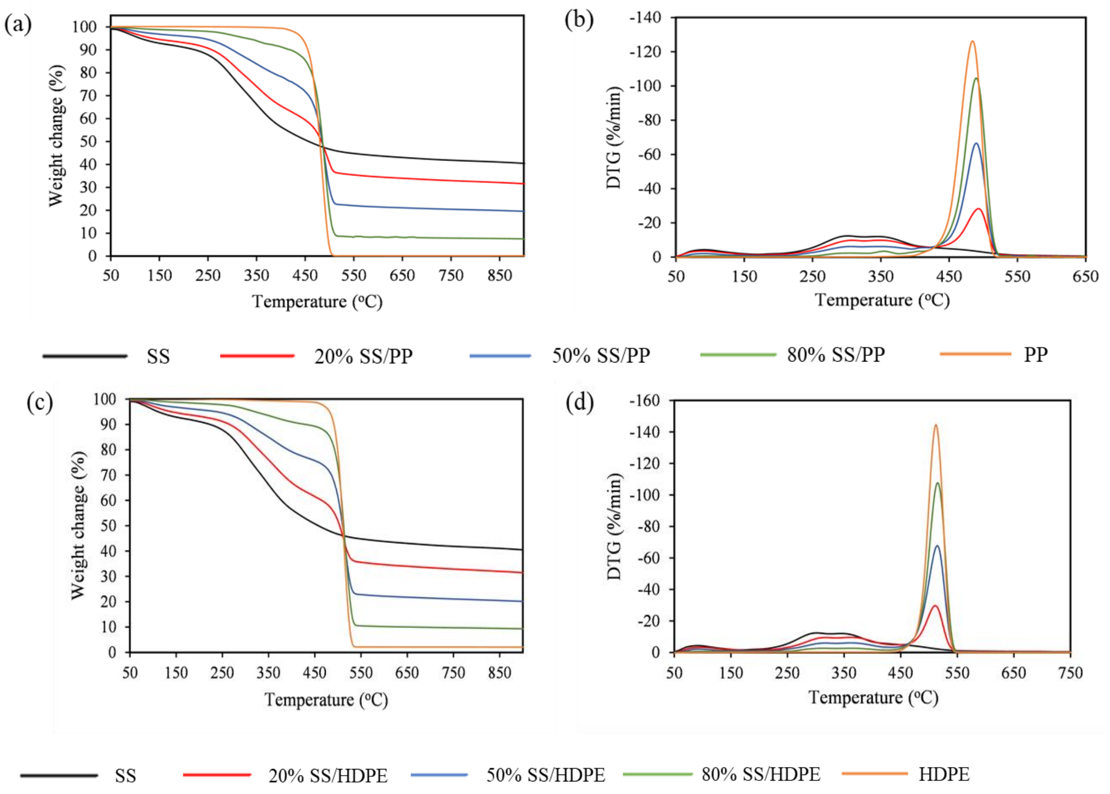
Thermogravimetric curves of (a) SS, (b) PP and (c) HDPE between 50 – 900°C at heating rates 10, 20, 30, 40, 50°C/min under constant N_2 flow (100 mL/min)

Differential thermogravimetric (DTG) curves



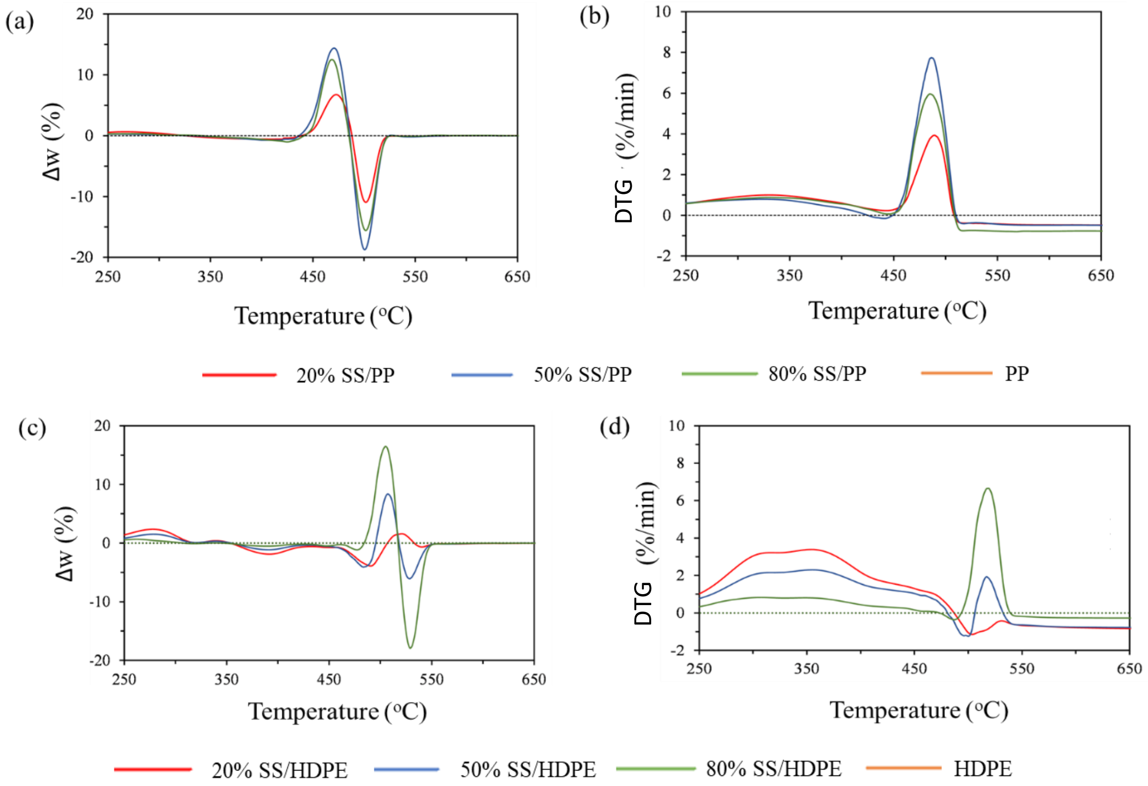
Differential thermogravimetric (DTG) curves of (a) SS, (b) PP and (c) HDPE between 40 – 900°C at heating rates 10, 20, 30, 40, 50°C/min under constant N_2 flow (100 mL/min)

Co-pyrolysis TGA and DTG curves



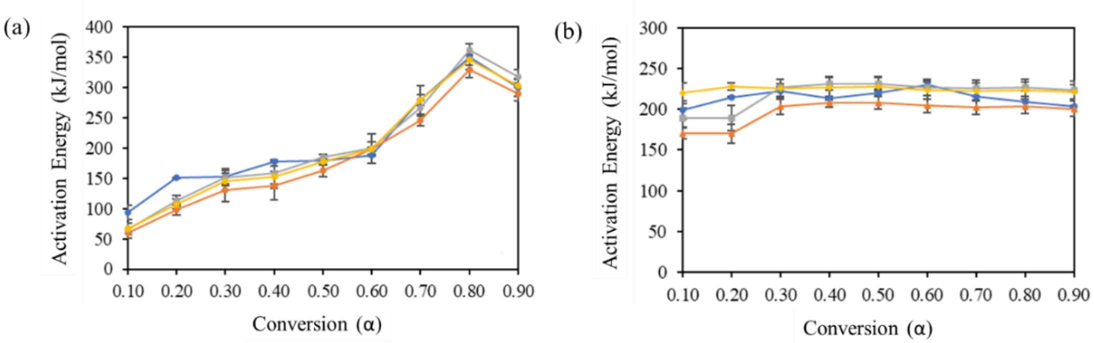
Co-pyrolysis TGA and DTG curves of 20%, 50%, and 80% SS/PP and SS/HDPE

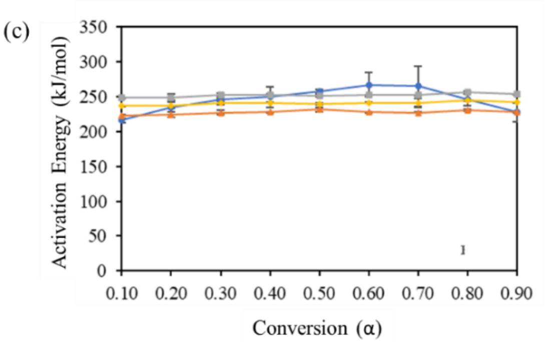
Synergistic analysis of overall volatile conversion and rate of devolatilization



Synergistic analysis of overall volatile conversion and rate of devolatilization during SS/PP (a, b) and SS/HDPE co-pyrolysis

Activation energies of SS, PP, and HDPE



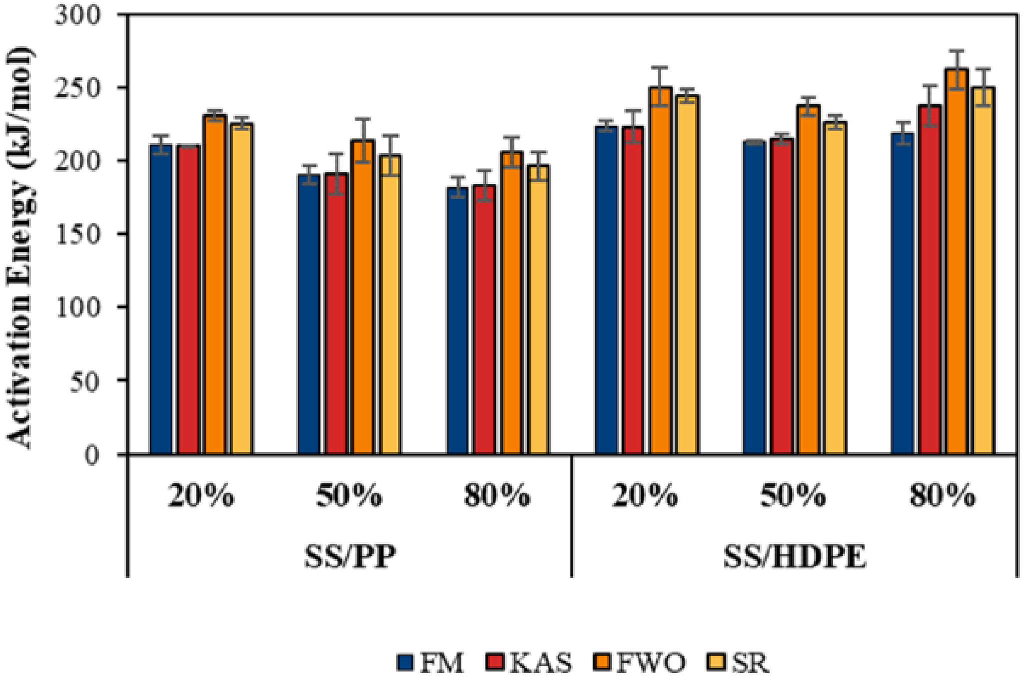


Average activation energies for PP and HDPE

	FM	KAS	FWO	SR
PP (kJ/mol)	201.35	192.46	217.18	204.79
HDPE (kJ/mol)	246.66	227.72	252.26	240.74

Activation energies (kJ/mol) of SS, PP, and HDPE pyrolysis as determined by iso-conversional model-free methods: Friedman (FM), Flynn-Wall-Ozawa (FWO), Kissinger-Akarhira-Sunose (KAS), and Starink (SR).

Average activation energy of co-pyrolysis determined with model-free methods



Average activation energy (kJ/mol) of co-pyrolysis determined with iso-conversional model-free methods: Friedman (FM), Flynn-Wall-Ozawa (FWO), Kissinger-Akarhira-Sunose (KAS), and Starink (SR).

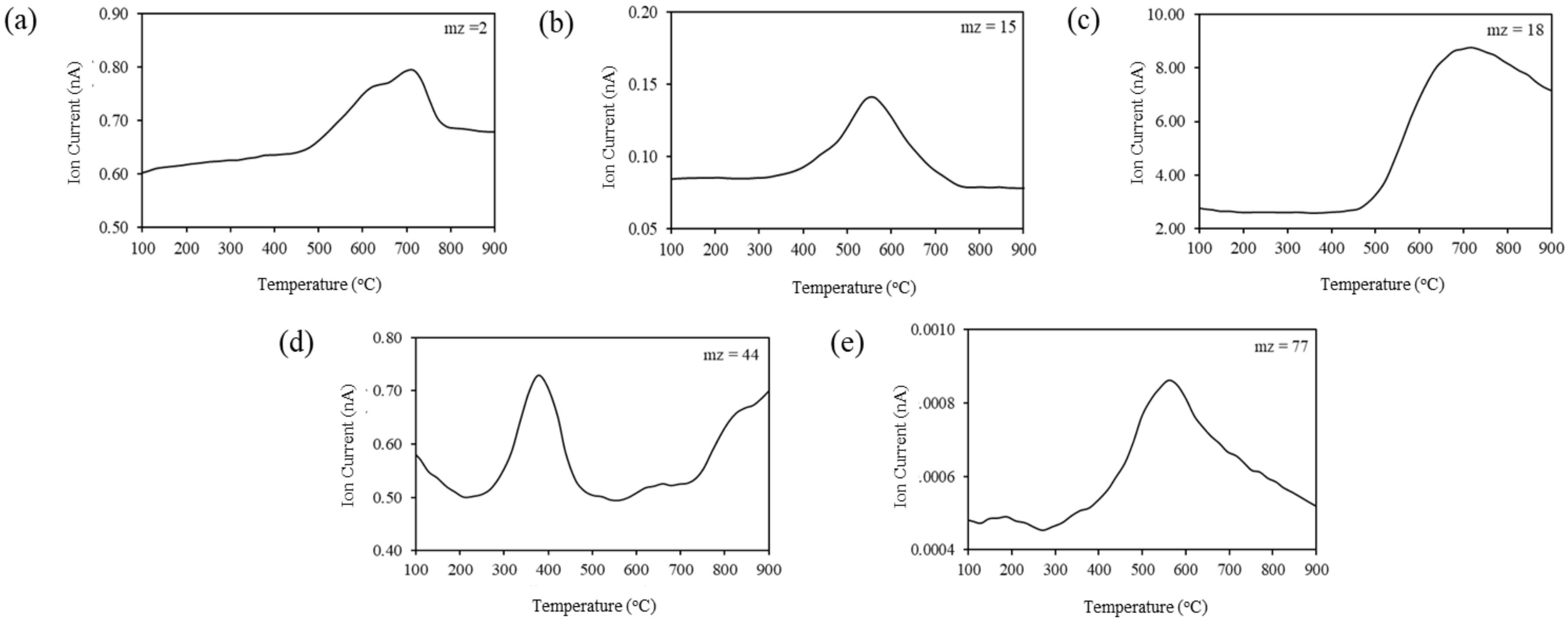
Activation energies of co-pyrolysis determined with model-free methods

	Friedman (FM)	Kissinger-Akahira-Sunose (KAS)	Flynn-Wall-Ozawa (FWO)	Starink (SR)
	E_A (kJ/mol)	E_A (kJ/mol)	E_A (kJ/mol)	E_A (kJ/mol)
SS/PP				
20%	211.39 ± 6.14‡*	210.87 ± 0.05‡	230.89 ± 3.26‡	225.62 ± 4.34‡
50%	190.71 ± 6.51‡*	191.16 ± 13.89‡	213.36 ± 14.62‡	203.62 ± 13.95‡
80%	181.95 ± 6.59‡*	182.99 ± 10.56‡*	205.76 ± 10.50‡	196.36 ±10.01‡*
SS/HDPE				
20%	223.65 ± 3.25	223.24 ± 11.07‡	250.46 ± 13.15‡	244.50 ± 4.65‡
50%	213.05 ± 1.00‡*	214.90 ± 3.89‡	237.25 ± 6.15‡	226.33 ± 4.72‡
80%	218.91± 7.85‡*	237.69 ± 13.71	262.09 ± 12.76	250.08 ± 12.14

**** Lower than individual feedstock***

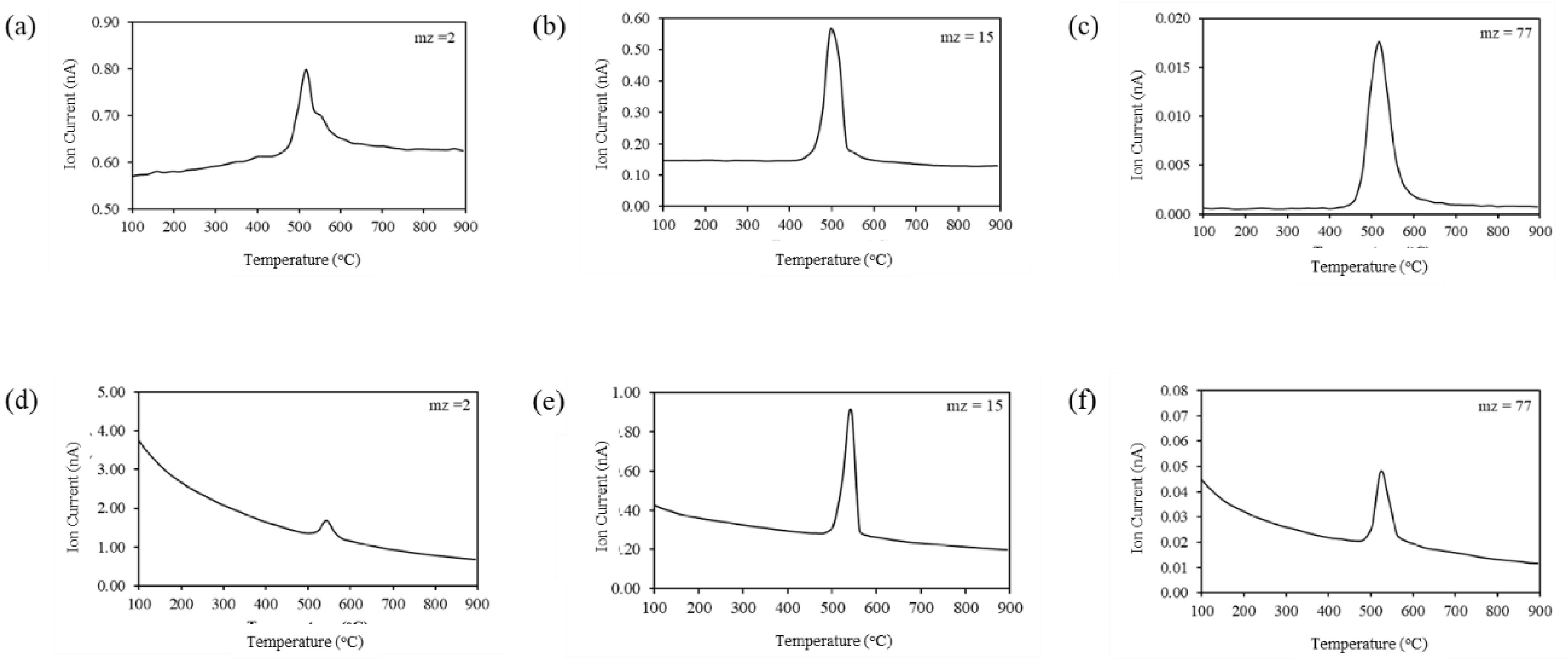
‡ Lower than weighted average

Evolved gas analysis during pyrolysis of sewage sludge (SS)



Evolution of (a) hydrogen (H_2, m/z = 2), (b) methane (CH_4, m/z = 15), (c) water (H_2O, m/z = 18), (d) carbon dioxide (CO_2, m/z = 44) and (e) benzene (C_6H_6, m/z = 77) during SS pyrolysis monitored with thermogravimetric analysis-mass spectrometry (TGA-MS).

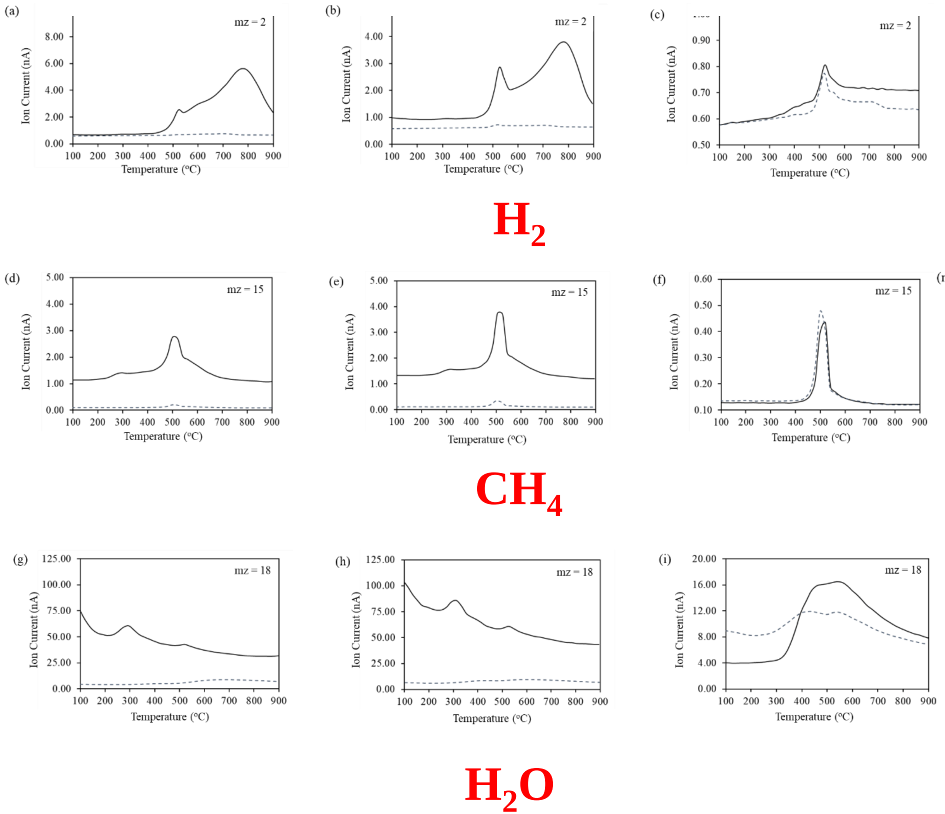
Evolved gas analysis during pyrolysis of PP and HDPE

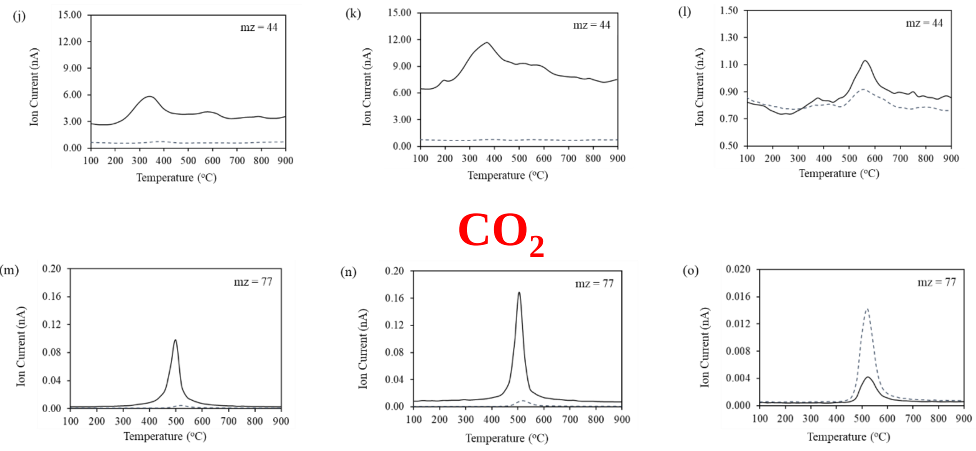


Evolution of hydrogen (H_2, m/z = 2), methane (CH_4, m/z = 15) and benzene (C_6H_6, m/z = 77) during (a-c) PP and (d-f) HDPE pyrolysis monitored with thermogravimetric analysis-mass spectrometry (TGA-MS)..

Evolved gas analysis during co-pyrolysis of SS and PP

20% SS/PP	50% SS/PP	80% SS/PP	20% SS/PP	50% SS/PP	80% SS/PP





benzene

Thermogravimetric analysis-mass spectrometry (TGA-MS) of evolved gases of H_2, CH_4, H_2O, CO_2 and benzene for 20%, 50%, and 80% SS/PP during co-pyrolysis between 40°C – 900°C heated at 50°C/min

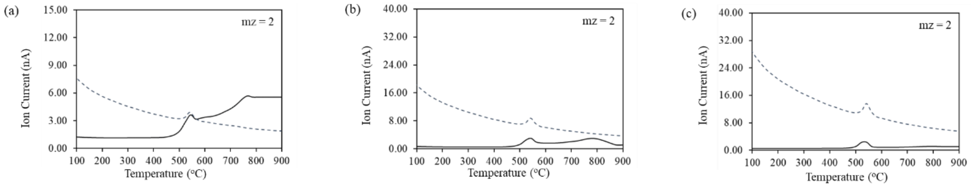
Actual —— Weighted Average - - - -

$$W_{wt\ avg.} = X_{SS}W_{SS} + X_pW_p$$

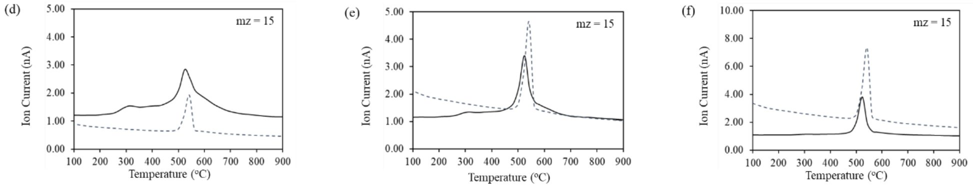
where X_{SS} and X_P refer to the mass percentage of sewage sludge and plastic in the mixed sample respectively

Evolved gas analysis during co-pyrolysis of SS and HDPE

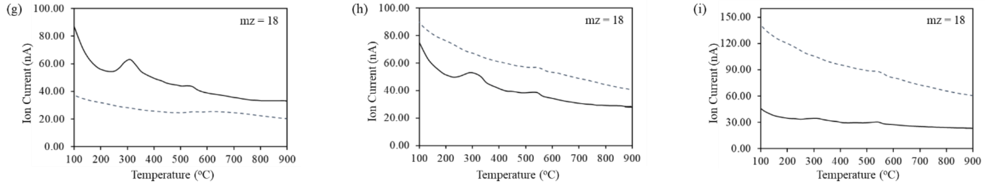
20% SS/HDPE | 50% SS/ HDPE | 80% SS/ HDPE | 20% SS/ HDPE | 50% SS/ HDPE | 80% SS/ HDPE



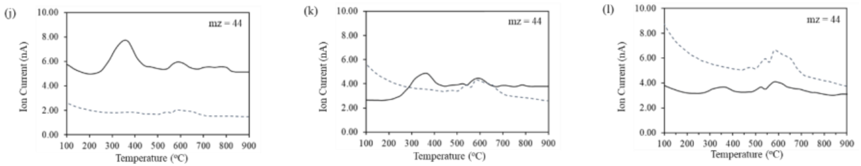
H_2



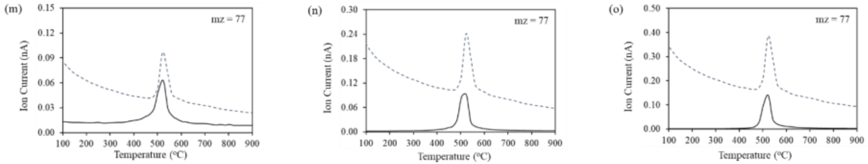
CH_4



H_2O



CO_2



benzene

Thermogravimetric analysis-mass spectrometry (TGA-MS) of evolved gases of 20%, 50%, and 80% SS/HDPE during co-pyrolysis between 40°C – 900°C heated at 50°C/min

Actual — Weighted Average

$$W_{wt\ avg.} = X_{SS}W_{SS} + X_pW_p$$

where X_{SS} and X_P refer to the mass percentage of sewage sludge and plastic in the mixed sample respectively

Summary

- Co-pyrolysis of sewage sludge (SS) with polypropylene (PP) and high density polyethylene (HDPE) were studied
- Synergistic reductions in activation energy were observed during co-pyrolysis
- Co-pyrolysis increased volatile conversion for SS/PP, and only some volatile components for SS/HDPE.
- Different interactions occurred during co-pyrolysis of sewage sludge with different plastics

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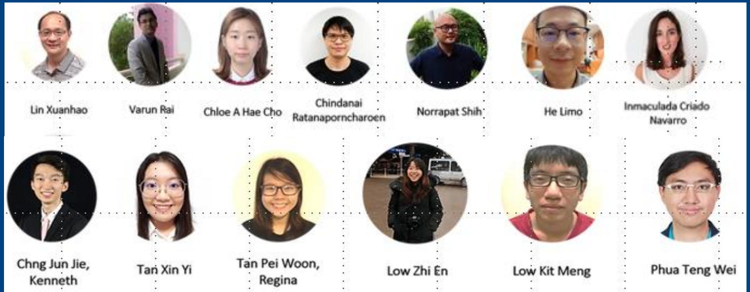

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THANK YOU!