Insights into the effects of operating conditions on waste polypropylene and polystyrene co-pyrolysis oil production

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Contents:

I. Introduction: plastic waste issue

II. ANN-GA coupled with a central composite design

III. Optimization for WPP/WPS co-pyrolysis product yields

V. Optimization for WPP/WPS co-pyrolysis oil fractions

VI. Conclusions
I. Introduction: plastic waste issue

- Nearly 25% of plastic waste ends up in landfills.
- Plastic waste accumulates rapidly due to the low environmental degradability.

- Waste polypropylene (PP) and polystyrene (PS) are a considerable proportion of plastic types found in municipal solid waste (MSW), accounting for 16% and 9%.
I. Introduction: plastic waste issue

Figure 3. High-quality oil production from waste PP and PS co-pyrolysis.
The pyrolysis experiments were performed in a 200 mL bench-scale semi-batch reactor. Waste PP and PS were provided from a Plastic Recycling & Development Base. It was recycled from municipal solid waste (MSW) and cut into about 3 mm pellets.
The effects of temperature, PS mass fraction, and carrier gas flow rate were investigated.

Through a central composition factorial design, an empirical model with a series of independent variables (temperature, PS mass fraction, carrier gas flow rate) was studied to establish liquid fuel yield.

A total of 23 sets of experiments were carried out, including R1–17 for the ANN training set and R18–23 for the ANN testing set.
II. ANN-GA coupled with a central composite design

- An artificial neural network (ANN) was utilized to establish the mathematical expressions between the independent (PS mass fraction, temperature, and carrier gas flow rate) and dependent variables (pyrolysis product yields and oil fractions).
- GA was adopted to obtain the optimal co-pyrolysis product yields and oil fractions.

![Diagram showing the flow of data from inputs to output through ANN and GA]

Figure 5. The demonstration of ANN-GA for WPP/WPS co-pyrolysis oil production’s evaluation.
The experimental oil, gas, and char yields varied from 60.0 wt% to 71.8 wt%, from 11.1 wt% to 20.8 wt%, and from 14.0 wt% to 16.5 wt%, respectively.

The R-squared values between the experimental and ANN predicted co-pyrolysis product yields were 0.9986 in the training set and 0.9988 in the testing set.

ANN predicted co-pyrolysis product yields are accurate.
• Evaluating the WPP/WPS co-pyrolysis product yields

- The ANN has established **mathematical expressions** to determine the WPP/WPS co-pyrolysis product yields by the PS mass fraction, temperature, and carrier gas flow rate.
- The parameters have **complicated interactions** on the co-pyrolysis product yields.

![Figure 7](image)

**Figure 7.** Interactive effects of operating conditions on (a) oil yield at 0 mL/min, (b) gas yield at 10 wt% PS, and (c) char yield at 425 °C.
• Optimization of product yields by ANN-GA

- The highest oil yield of **71.90 wt%** was obtained at **478 °C**, **30 wt% PS**, and **0 mL/min**.
- The highest gas yield of **20.75 wt%** was achieved at **525 °C**, **10 wt% PS**, and **60 mL/min**.
- The highest char yield of **16.54 wt%** was recovered at the lowest temperature of **425 °C**, the lowest PS mass fraction of **10 wt%**, and the highest carrier gas flow rate of **60 mL/min**.

![Figure 8. ANN-GA optimized (a) oil yield, (b) gas yield, and (c) char yield.](image)
IV. Optimization for WPP/WPS co-pyrolysis oil fractions

- The experimental light (C7-C11), middle (C12-C20), and heavy fractions (>C20) varied from 5.20% to 25.21%, from 26.48% to 52.02%, and from 34.30% to 63.35%, respectively.

- The R-squared values between the experimental and ANN predicted co-pyrolysis oil fractions were **0.9747** in the **training** set and **0.8775** in the **testing** set.

Figure 9. Experimental and ANN predicted co-pyrolysis product yields.
• Evaluating the WPP/WPS co-pyrolysis oil fractions

- An increase in temperature leads to a decrease in light and middle fractions and an increase in heavy fraction.
- Higher carrier gas flow rates can enhance the light fraction in oil.

![Figure 10](image)

**Figure 10.** Interactive effects of operating conditions on (a) light fraction at 0 mL/min, (b) middle fraction at 0 mL/min, and (c) heavy fraction at 0 mL/min.
- Optimization of oil fractions by ANN-GA

- The highest **light** fraction of 23.71% was achieved at 425 °C, 30 wt% PS, and 0 mL/min.
- The highest **middle** fraction of 52.02% was obtained at 425 °C, 10 wt% PS, and 0 mL/min.
- The highest **heavy** fraction of 62.34% was recovered at the highest temperature of 525 °C, the highest PS mass fraction of 30 wt%, and the non-sweeping atmosphere of 0 mL/min.

Figure 11. ANN-GA optimized (a) light fraction, (b) middle fraction, and (c) heavy fraction.
V. Conclusions

- ANN-GA coupled with a central composite design was adopted to evaluate the WPP/WPS co-pyrolysis oil production.
- ANN-GA was qualified to optimize the oil yield and fractions.
- The highest oil yield of 71.9 wt% was obtained at 478 °C, 30 wt% PS, and 0 mL/min by ANN-GA.
- The highest light fraction of 23.71% was achieved at 425 °C, 30 wt% PS, and 0 mL/min; and the highest middle fraction of 52.02% was obtained at 425 °C, 10 wt% PS, and 0 mL/min.