Assessment of acrylic based textile wastes as energy source

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Abstract. The properties of biochars obtained by the torrefaction of acrylic based textile wastes were investigated. Waste fibres were torrefied at 300-400 °C and the results indicated that acrylic based textile wastes could be converted into biochar with a high mass yield. Resultant biochars had similar properties to bituminous coal.

1. Introduction

Textile fibre consumption continuously increases in parallel with the increase in population, standards of living and fast fashion effects [1-3]. Therefore, millions of tonnes of textile waste are generated annually. Since the re-using and recycling ratio of textile wastes is very low, large amounts of wastes are disposed by landfilling. Moreover, when recycled textile materials are considered, after completion of their primary post-recycling lifetime, a secondary recycling is not generally possible due to the substantial fibre damage. For this reason, recycled textile materials also become waste for disposal. Therefore, rather than disposal, the use of textile wastes for energy conversion will be advantageous in terms of natural resource consumption.

Emissions of greenhouse gases resulting from the use of fossil fuels are causing environmental problems such as global warming, acid rain and air pollution. For a sustainable production, increasing the share of the use of renewable energy sources is of great importance. An important class of renewable energy sources is biomass. Hence, textile wastes have the potential to be utilized as biomass and can be used as energy source. On the other hand, due to being heterogeneous, bulky and porous, energy density of textile wastes are low and it is difficult and problematic to process textile wastes at existing power generation facilities. Therefore, they should be converted into homogeneous, dense and carbon-rich structure to be used as energy source, called biochar. Biochar is a renewable feedstock with reduced CO₂ emissions and is used either for energy output or as carbon source [4]. This study investigates the fuel characteristics of biochars obtained from acrylic based textile wastes through low temperature pyrolysis (torrefaction).

2. Experimental

Textile wastes composed of 100% acrylic fibres (PAC) and their blends with polyester (PAC/PES, 50/50%) and viscose (PAC/CV, 50/50%) were collected. The torrefaction experiments were carried out in a laboratory scale fixed bed reactor in nitrogen stream. Torrefaction temperatures were selected to be 300, 350 and 400 °C. Textile wastes and resultant biochars were characterised through biochar mass yield, elemental analysis, heating value and energy efficiency determination.

Biochar mass yield (MY, %) was calculated as,
\[ M = \left( \frac{M_b}{M_t} \right) \times 100 \]  

(1)

where \( M_b \) is the mass of biochar and \( M_t \) is the mass of textile waste.

Elemental compositions of textile wastes and resultant biochars were tested by using an elemental analyser (Leco CHNS 932). Using elemental analysis results, higher heating value (HHV, MJ/kg) of textile wastes and resultant biochars were calculated as:

\[ HHV = 0.3491C + 1.1783H + 0.1005S - 0.10340O - 0.0151N - 0.0221A \]

(2)

where \( C, H, S, O, N \) and \( A \) denotes the mass ratio of carbon, hydrogen, sulphur, oxygen, nitrogen and ash, respectively [5].

Energy density (ED) and energy yield (EY, %) of resultant biochars were determined by using Equations (3) and (4), respectively,

\[ E = H_b / H_t \]

(3)

\[ E = M \times E \]

(4)

where \( HHV_b \) is the higher heating value of biochar and \( HHV_t \) is the higher heating value of textile waste.

3. Results and Discussion

Elemental analysis, HHV, mass yield, ED and EY values of torrefied acrylic based textile wastes were given in Table 1. Mass yields of acrylic based biochars were obtained in the range of 50-80% depending on the temperature and fibre type. The increase in torrefaction temperature led to a decrease in mass yield. Moreover, the presence of polyester or viscose fibres within acrylic blends decreased the torrefaction mass yield. The HHV (higher heating value) of the resultant biochars were found to be quite high (between 24-30 MJ/kg depending on the blend) and it was found that torrefaction temperature did not have a considerable effect on higher heating value. As shown in Figure 1, O:C and H:C atomic ratios showed that the resultant biochars had similar properties to bituminous coal. On the other hand, acrylic based biochars were high in nitrogen content (12-24%) which will lead NOx emissions during combustion. Therefore, the use of wet scrubbers is recommended to remove NOx emissions from flue gas. On the other hand, nitrogen-rich biochars might be advantageous for the use as soil amendment applications.

Table 1. Properties of acrylic based textile wastes and resultant biochars

| Elemental analysis | HHV, MJ/kg | MY, % | ED | EY, % |
|-------------------|------------|-------|----|-------|
| PAC               | 65.13      | 6.21  | 23.83 | 0 | 4.83 | 29.19 | - | - | - |
| PAC-C300          | 67.84      | 4.86  | 21.88 | 0 | 5.42 | 28.52 | 79.80 | 0.98 | 77.95 |
| PAC-C350          | 70.67      | 4.38  | 20.98 | 0 | 3.97 | 29.10 | 63.46 | 1.00 | 63.26 |
| PAC-C400          | 70.45      | 3.87  | 19.83 | 0 | 5.85 | 28.82 | 57.89 | 0.97 | 56.02 |
| PAC/PES-C300      | 63.02      | 5.10  | 12.19 | 0 | 19.69 | 25.79 | - | - | - |
| PAC/PES-C350      | 66.40      | 4.23  | 13.91 | 0 | 12.57 | 27.66 | 60.02 | 1.07 | 64.38 |
| PAC/CV            | 55.77      | 6.02  | 14.40 | 0 | 23.81 | 23.88 | - | - | - |
| PAC/CV-C300       | 66.40      | 4.63  | 14.95 | 0 | 14.02 | 26.96 | 49.50 | 1.13 | 55.88 |

*calculated by difference
4. Conclusion
Acrylic based textile wastes were converted into biochars by torrefaction with high mass yield. Resultant biochars had high HHV values and had similar properties to bituminous coal. Due to their high nitrogen content, a flue gas scrubber is recommended for combustion applications to remove NOx emissions.

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