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CHARCOAL PRODUCTION BY CARBONIZATION OF MUNICIPAL SOLID WASTE

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Abstract

Numerous techniques in treating municipal waste has been studied and applied and they included incineration [1]. Incineration can treat various types of waste (especially waste that hard to be decomposed such as plastic, leather, and rubbers, etc) which can reduce the required area of landfill [2]. However, the secondary pollution from this technique may affect the air quality, along with the high operational cost of the incinerator is quite a disadvantage. Another treatment process was introduced to deal with carbon-rich waste via pyrolysis which draw the attention of researcher from worldwide and Vietnam. This process can simultaneously remove the organic pollutant from the waste at lower operational cost and also create recycled charcoal which can be utilized as a burning fuel or adsorbent in waste treatment. Its basis is to decompose burnable waste at high temperatures in the absence of oxygen [3, 4].

Institute of Environmental Technology had studied the carbonization technology to treat the municipal solid waste of Hanoi city, Vietnam and came up with positive results for the real application [5]. This paper demonstrated the results of the quality and quantity of charcoal products, impact parameters which are temperature (T), burning time (t), charcoal yield (□), total organic carbon (TOC), specific surface area (S). The experiment was conducted at 3 different treatment capacities: 10-20 g/batch, 3-5 kg/batch and 50 kg/batch. The targeted types of waste are papers, woods, plastic, rubbers, and canvas… The results showed that the charcoal yield depends on the carbonization time and temperature. The charcoal yield of wooden waste, plastic, paper, rubber, and cloth were 15÷22; 26÷37; 18÷22; 20÷35 and 24÷29.5 %, respectively. In addition, the TOC content in biochar was also determined, ranging around 52.81÷88.82 %.

Introduction

Research object: Municipal solid waste (MSW), specifically the burnable components such as: woods, plastic, leather, papers, rubbers, and canvas [6].

Purpose of the research: Experiment was conducted to assess the efficiency of carbonization technology for treatment of the solid waste which was hard to be decomposed to determine the optimal condition including burning time, temperature and charcoal yield [7].

The carbonization process was conducted at 3 different capacities: incinerator oven with 20-30 g/batch, the pilot model with 3-5 kg/batch and a large-scale plant with 50 kg/batch.

The carbonization process was described in the following schema:

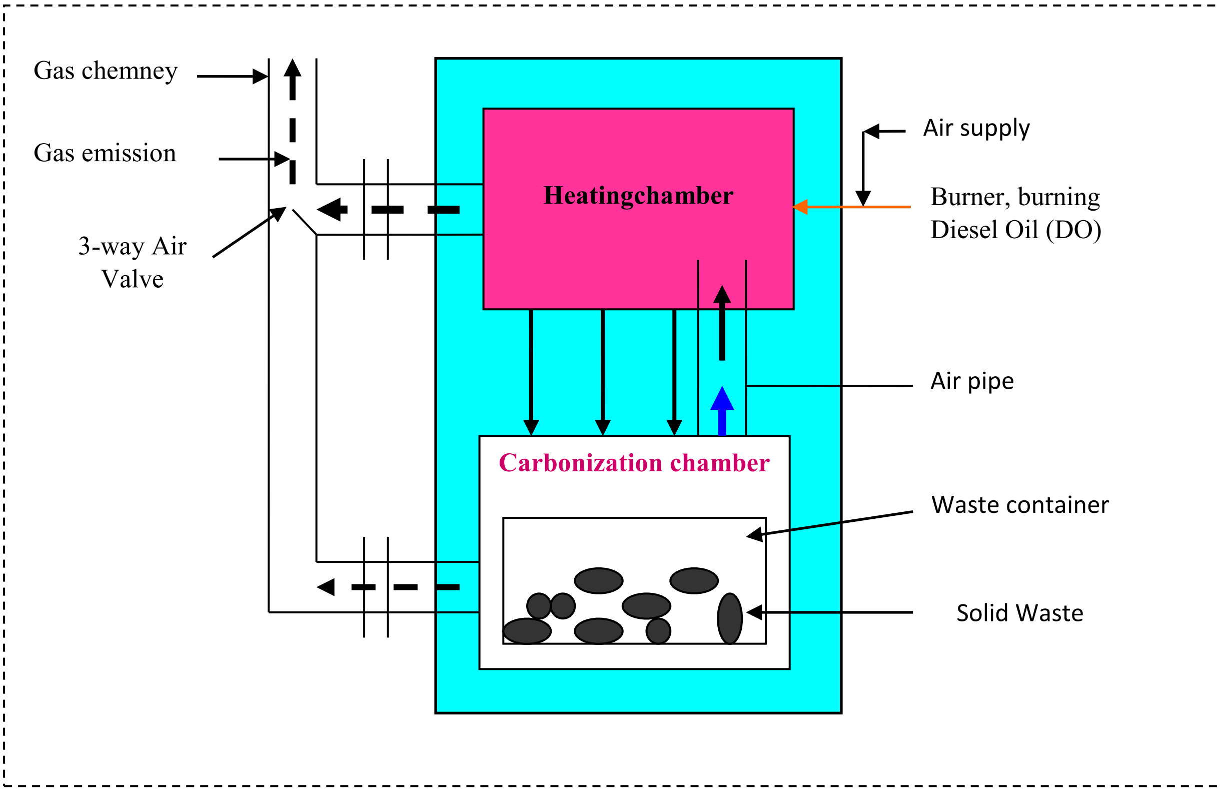

Figure 1. Structure diagram of the pilot model

Experimental description
The Municipal Solid waste (MSW) was taken into the Waste container (Fig. 1), then the door was closed. The air pipe was connected from the top of the waste container to the heating chamber. The synthetic gas from the waste container to the heating chamber had direct contact with the flame from the burner in order to treat the generated emission from the carbonization chamber. The emission was burnt and raised temperature at the Heat chamber, which helped to reduced the fuel - diesel oil (DO) cost for the whole process.

The 3-way-reclining valve can be operated manually or automatically: when the temperature of the carbonization chamber was insufficient then the ir outlet valve would re-direct the heat from the heating chamber to the carbonization chamber. When the temperature reached the optimum level, the air outlet valve would lead the heat directly to the Gas chimney, the Burner was be turn off and the temperature at the Carbonization chamber was maintained stable.

The burner was automatically operated to burn the fuel (Diesel Oil) providing heat for the carbonization process. The temperature in the Carbonization chamber can be controlled by a relay and the 3-way air valve. The temperature was controlled in the range of 300-500 ^oC, the burning time of the carbonization process last for 10-60 minutes.

Analysis parameters:
Analysis methods were performed to determine the characteristic of the recovered charcoal such as specific area, capillary size, heating value of the charcoal, TOC…,

Equipment and devices:
+ Weight measurement: scale 1-gram accuracy AND HV-15KgL – Japan;

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+ Digital scale OHAUS d=0.01g, Switzerland.
+ Total organic carbon in recovered charcoal: TOC analyzer TOC-V_{CPH} TNM1-Shimadzu 4100, Japan.
+ Specific surface area, m^2/g: Automatic Water Vaper Adsorption Apparatus Belsorp-18, Japan; Micromeritic M.
+ Pore structure and density: Scanning Electron Microscope (SEM) (S-4700 Hitachi, Japan);
+ Heating value: DTA-50 Shimadzu, Japan

Results and discussion

Experimental result of paper waste treatment

Experiment was conducted in the carbonization device with the burnable municipal waste including: papers, canvas, rubbers, wood, plastic. Burning time was varied at different durations: 10, 20, 30, 40, 50 and 60 minutes [8, 9].

Experimental results of paper waste carbonization was presented in the Fig. 2.

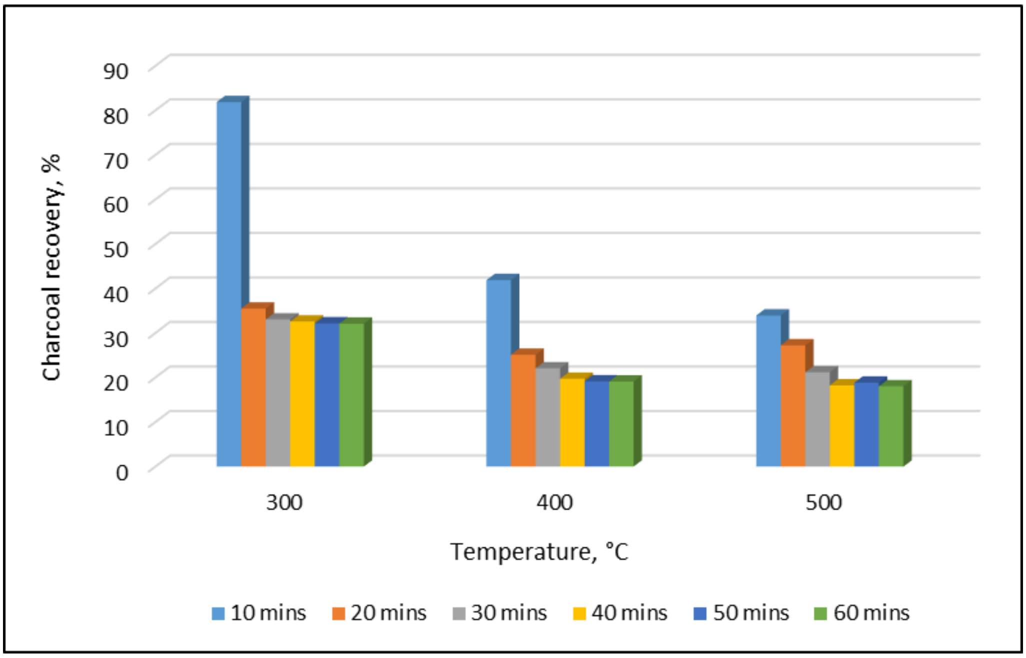

Fig 2. Charcoal yield of the paper

Discussion

- The sample weight decreased rapidly in the first 10 minutes. This phenomenon resulted from the loss of moisture in the waste. After 20 minutes, the moisture was removed completely while the emission started to appear from the carbonization process. From 30 to 60 minutes, the carbonization was quite stable and slowly ealing. The producted obtain was clean charcoal, the charcoal yield of papers carbonization at 300°C was around 32-33%.
- At 400°C, the evaporation of moisture occurred rapidly and emission stared to form in the first 10 minutes. After 30 to 40 minutes, the carbonization process stabilized. The charcoal yield at 400 °C was around 19-22%; at 500 °C was around 18-21%.

Carbonization experiment with plastic waste

Experimental results of plastic waste carbonization was presented in the Fig. 3.

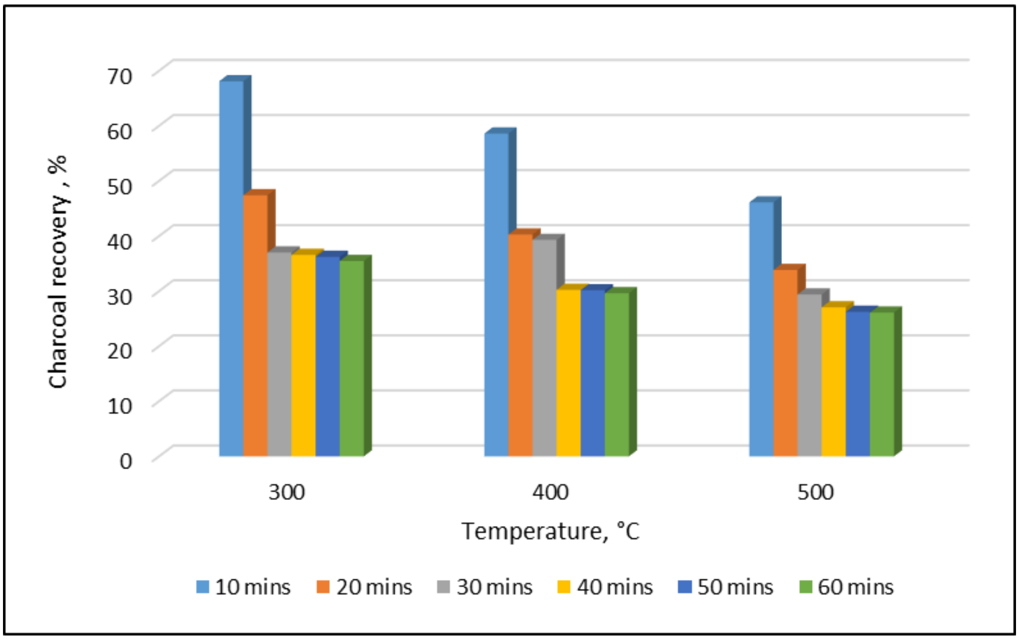

Fig 3. Charcoal yield of the plastic waste

Discussion

- The charcoal yield of plastic was around 35-37% at the temperature of 300°C,
- The charcoal yield of plastic was around 29-30% at the temperature of 400°C,
- The charcoal yield of plastic was around 26-27% at the temperature of 500°C.

Carbonization experiment with other wastes

The experiment was also conducted at the similar condition with other waste components including wood, canvas, leather, bamboo and obtained the following results:

- The charcoal yield of canvas was relatively high around 60-75% at the temperature of 300 and 400°C, but it decreased sharply to 14-59% at the temperature of 500°C.
- The charcoal yield of wood was 15.5-25.2%,
- The charcoal yield of rubbers was 20-35%.

Experimental results from the pilot models: 3-5kg/batch and 50kg/batch

After 2 months of operation of the carbonization system with the municipal waste sample, the results were obtained as follow:

- Time to reach the optimum temperature: 10-15 minutes;
- Temperature at Heat chamber: 600-800 °C;
- Temperature at Carbonization chamber: 300-500 °C;
- Carbonization time: 30-60 minutes;
- The charcoal yield of papers: 30-40%; of wood: 30-32.5%; of bamboo: 25-35.5%; rice husks: 35-37%; of cob: 30-40%.

Recovered charcoal quality from the carbonization process

TOC content

The product was expected to be an alternative fuel for industrial application and adsorbent for wastewater treatment. In order to be used as burning fuel, the product shall generate significant heat which was a result of high TOC content.

TOC measurement was performed at product samples from carbonization at the temperature from 300 to 500°C from different periods of time from 10 to 50 minutes and results were presented as follow:

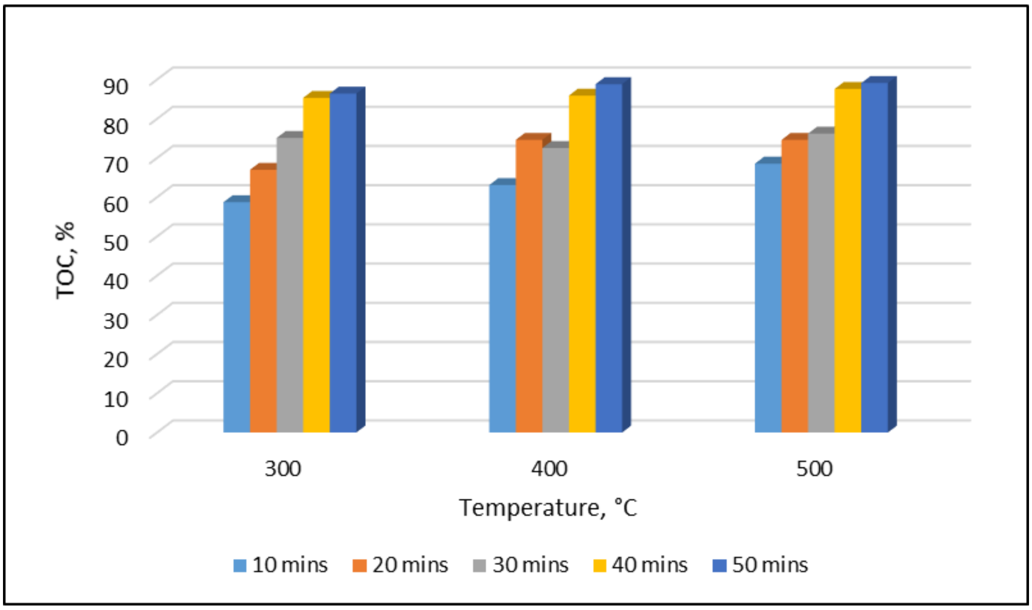

Fig 4. TOC of wood

Discussion

- TOC level increased over carbonization time and varied around 60-90%. This value could be enhanced if the product was well-preserved from moisture.
- Highest TOC level was around 88-89 %,
- However, if the recovery efficiency was taken to prior, the carbonization process shall last between 30-50 minutes.

Table 10 demonstrated the TOC results of products from carbonization process from other waste components.

Table 10. TOC of recovered charcoal

Type of charcoal	TOC, %
Bamboo	86,77
Wood	88,82
Papers	52,81
Leather	57,58
Cob	79,35
Rice husk	68,15

Charcoal from bamboo, wood, and cob was noticed to have considerably high TOC percentage around 80-90%. The results pose a prospect of application for carbonization technology to treat waste and produce charcoal for clean energy.

The pecific surface area of recovered charcoal

The objective of determining specific surface area was to assess the product potential to be used as bio-media in pollution treatment.

The SEM images showed that charcoal product from wood waste and bamboo was suitable to act as material in pollution treatment because of its capillary size and specific surface area of 10-150µm.

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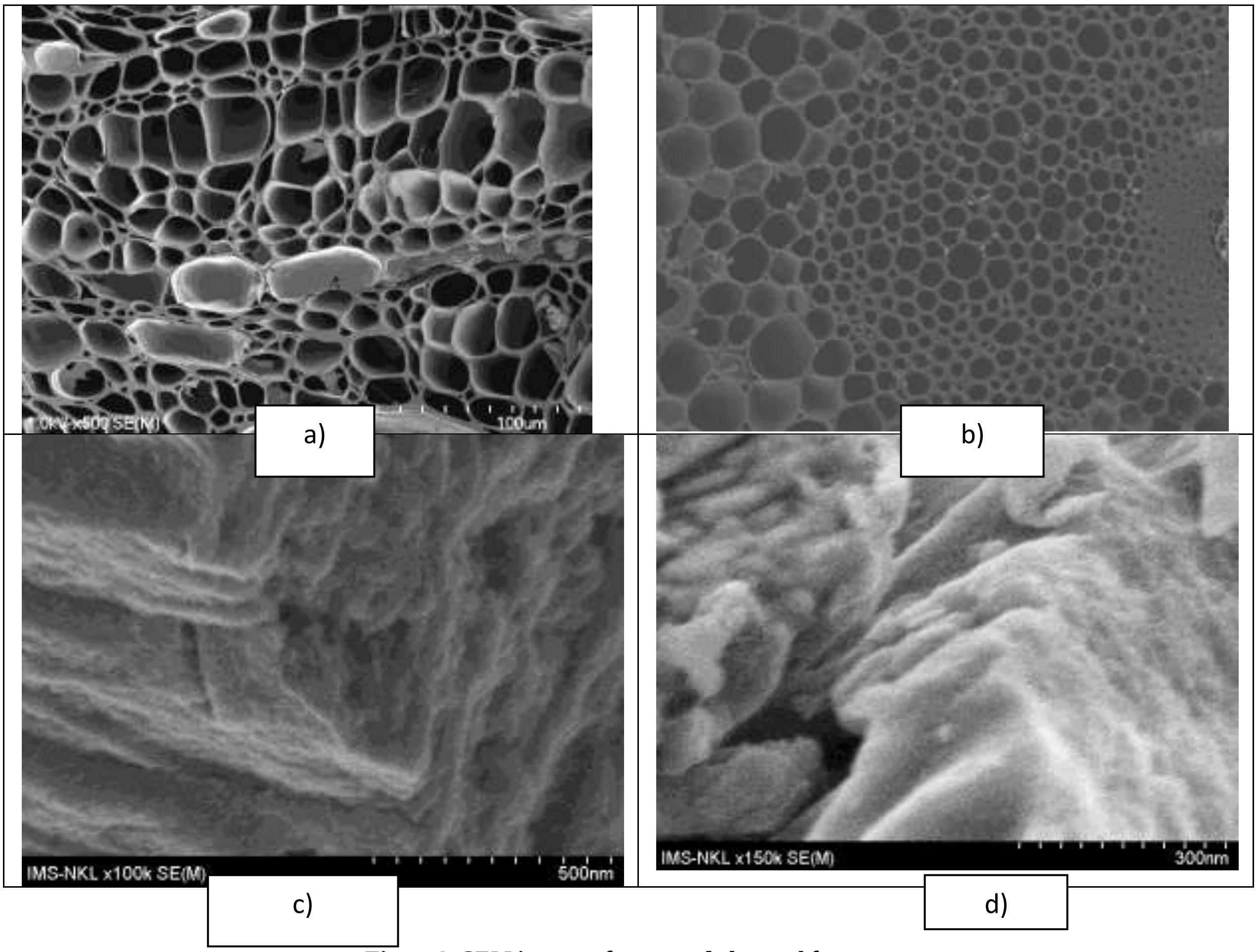

Figure 3. SEM images of recovered charcoal from:
a) wood; b) bamboo; c) canvasand d) papers.

The results of pore size and specific surface area were presented in the following table

Table 11. Pore sizes and specific surface area results from Micromeritics M of charcoal from waste components

Types of charcoal	Pore size	Specific surface area, m^2/g
Canvas	Very small, mostly around 1-2nm	60-70
Papers	Small size, 1-2nm	50-70
Bamboo	10-20μm (around 90%)	300-400
Wood	50-150μm	100-300

Conclusion

- Carbonization is a potential treatment technique because of its numerous benefit such as lower operational cost than incinerator, emission controllable and preservable for heating when it compares to other methods.
- Experiments were conducted in 3 different scales of carbonization system: 2-20g/batch; 3-5kg/batch and 50 kg/batch.

- The charcoal recovery efficiency was determined for different waste components at various carbonization time from 10-60 minutes and various temperature at 300, 400 and 500ºC. In particular, the charcoal yield of paper was 22-30%; of plastic was 25-39%; of canvas was relatively high around 60-75% at the temperature of 300 and 400ºC, but it decreased sharply to 14-59% at the temperature of 500ºC; the charcoal yield of wood was 15.5-25.5%; of rubbers was 20-35%.
- The parameters related to the quality and heating value of the product were determined. The TOC concentration of the recovered products was considerably high around 80-90%. The results of pore size and the specific surface area also described the potential of recovered charcoal to be adsorbent. However, other experiment on adsorption capacity and mechanical resistance should be studied further.

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