Evolved gas analysis on peat pyrolysis catalyzed by fire-extinguishing agents and sodium carbonate salts

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1. Introduction

Peat is a type of charcoal formed in the soil by the deposition of undecomposed organic matter. In Indonesia, where there are approximately 200,000 km^2 of peatlands, large-scale fires in peatlands frequently occur, resulting in haze. Mixing fire-extinguishing agents (FEAs) consisting of sodium carbonate and/or sodium silicate salts into the extinguishing water can promote penetration into the ground and cooling, thereby increasing the firefighting effectiveness.

Previous studies have shown that adding of FEA to peat increases the amount of volatile organic compounds (VOCs) generated by pyrolysis. This is because sodium carbonate, the main component of the FEA, acts as a catalyst in the pyrolysis of biomass such as cellulose and lignin in peat, thereby promoting the generation of VOCs. It is well known that alkali metals such as sodium have a catalytic effect on biomass pyrolysis. There is a concern that FEAs with sodium carbonate as a main ingredient may increase VOCs emission. It is necessary to understand in detail the effects of the FEAs on the gases evolved during combustion and pyrolysis of peat.

The aim of this study is to understand the effect of a FEA and its main component, Na_2CO_3, on VOCs generation during peat pyrolysis. The FEA and sodium carbonate were added to peat, respectively, and the evolved gases from pyrolysis were analyzed using direct-injection chemical ionization mass spectrometry (DI-CIMS).

2. Experimental

As peat samples, we used ground and dried peat soil collected from Kalimantan Island, Indonesia. FEA and Na_2CO_3 were added to 1 mg of peat sample at 10-100 wt% each and analyzed. Methane was used as the reagent gas for the chemical ionization method, and the ion source temperature was set to 200 ℃. After each sample was injected directly into the ionization chamber, it was heated to 150 ℃ and held for 30 min to remove moisture from the sample. The temperature was then raised to 500 ℃ at a heating rate of 80 ℃/min. During the measurement, the ionization chamber was vented, creating anoxic conditions like the ground in a peat fire.

3. Results and Discussion

Figure 1 shows the ratio of ion current values for peat samples alone and peat samples with 10-100 wt% FEA in DI-CIMS. Also shown in Fig. 1 are the ion current ratios in total ions and selected ions such as m/z 69 (isoprene), 85 (2-furanone), 95 (phenol), 97 (furfural), 163 (levoglucosan). Figure 2 shows the ion current ratios of the peat samples with 10-100 wt% Na_2CO_3 as in Fig. 1 above. When FEA was added (Fig. 1(b)), the generation of all selected ions increased. In the case of Na_2CO_3 addition (Fig. 2(b)), an increase in ion generation was observed only at 10 wt% addition rates, while selected ions such as levoglucosan were found to decrease at addition rate above 20 wt%.

According to a review by Yu et al. [1], pyrolysis of biomass such as cellulose and lignin in peat first produces gases such as CO, and at temperatures above 180 ℃, the residual solids (char) decompose further to produce soot components and VOCs called tar, such as levoglucosan and phenol. On the other hand, when CO_2 and H_2O coexist with biomass, not only the pyrolysis of char but also the further pyrolysis of tar is accelerated, producing low-molecular-weight organic matter and gas species. From the above, in

the process of pyrolysis of peat, if the char pyrolysis-promoting effect of Na in Na_2CO_3 is greater than the tar pyrolysis-promoting effect of CO_2 and H_2O generated from Na_2CO_3 and peat, respectively, the amount of tar such as levoglucosan generated will increase and vice versa. From the experimental results, when the addition rate of FEA to the peat sample is 10-100 wt%, the amount of tar generated was higher due to the greater effect of Na in promoting char pyrolysis. On the other hand, in the case of Na_2CO_3 addition, the addition rate of 10% increased the amount of tar generation due to the greater effect of Na in promoting char pyrolysis, while the addition rate of 20 % or more decreased the amount of tar generation due to the greater effect of CO_2 and H_2O in promoting tar pyrolysis.

4. Conclusions

This study showed that the use of sodium carbonate salt as a FEA in firefighting against peat fires may increase the emission of VOCs. Depending on the composition of FEAs and the amount of water used, it is possible to reduce VOC emissions by using FEAs. It is necessary to quantify the effect of Na, CO_2, and H_2O, which are derived from FEA and catalyze the pyrolysis of peat, on the amount of VOCs generated.

References: [1] J. Yu et al. Fuel Processing Technology, 214, 106723 (2021).

Keywords: Peat fire, Haze, Biomass pyrolysis, Alkali metal catalyst, Direct injection chemical ionization mass spectrometry

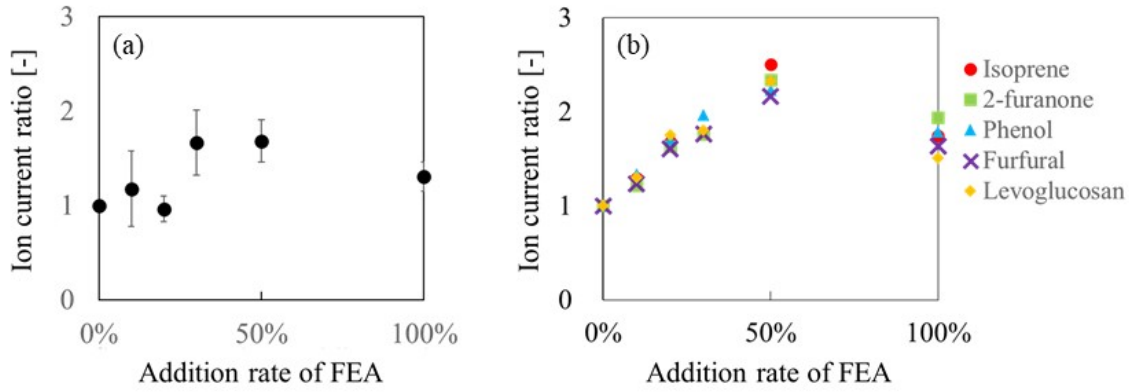

Fig. 1 Ion current ratio in DI-CIMS for peat with fire-extinguishing agent; (a) Total, (b) Selected ion

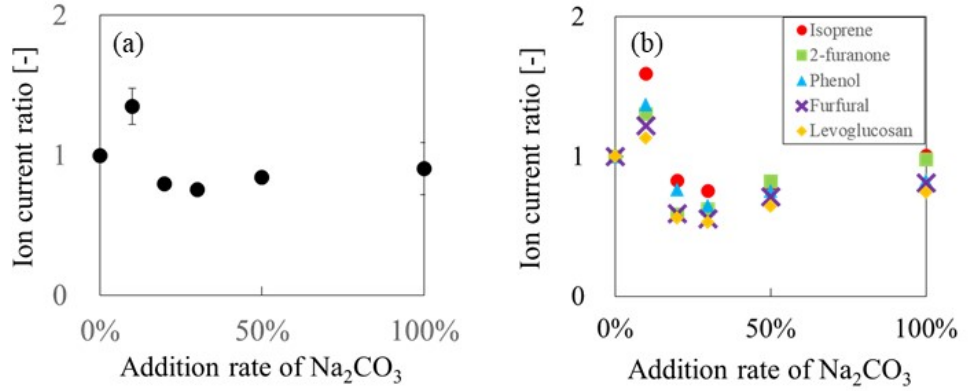

Fig. 2 Ion current ratio in DI-CIMS for peat with Na_2CO_3; (a) Total, (b) Selected ion

