



INVESTIGATION OF EMISSION OF NO_x, SO₂ AND CHLORINE BY BIOMASS-BURNING

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Abstract

It is well known that burning biomass is somewhat CO₂ neutral, but it is not widely known that that process is still a serious environment polluting one. For the investigation of the emission of some biomass material such as energy willow, bamboo, energy cane was burnt and the emission of NO_x, CO, CO₂, SO₂, and Chlorine were measured and analysed. The results show that the generation and emission of SO₂ observed at the beginning of the burning process, while the chlorine is leaving the fire at the end of the process. The emission of NO_x is rather at the middle of the process. The sum of the SO₄²⁻ and the overall chlorine ion are more than those materials in the biomass, indicating that these elements are present in the material in different form.

Keywords: biomass burning, SO₂, NO_x, Chlorine

1. INTRODUCTION

Nowadays one of the most interesting industrial problems is the application of renewable energies, and within this the usage of biomass in energy production. In many cases there are some misbeliefs about the burning of biomass materials especially about the emission of pollutant. It is well known that burning biomass is somewhat CO₂ neutral, but it is not widely known that that process is still a serious environment polluting one. For the investigation of the emission of some biomass materials, such as energy willow, bamboo, energy cane were burnt, and the emission of NO_x, SO₂, and Chlorine were measured and analysed. The results show that the generation and emission of SO₂ observed at the beginning of the burning process, while the chlorine is leaving the fire at the end of the process. The emission of NO_x is rather at the middle of the process.

The pulsed corona discharge process (PCDP) is an effective method to remove hazardous chemicals from exhaust gases. The unipolar corona discharge is a stable, self-maintaining gas discharge, characterized by low gas temperature, and high electron temperature. During the discharge, the free electrons are accelerated by the electric field, and according to the drift they can lose the energy by inelastic collision. The collision of energetic electrons with gas molecules give the formation of chemically active species to initiate chemical reactions, leading to the removal of gaseous pollutants. [1], [2], [3]

2. EXPERIMENTAL ARRANGEMENT

During the experiments energy cane, bio-briquette, and energy willow were burnt, and the electrostatic decomposition of the produced hazardous exhaust gases was examined by gas analyzer.

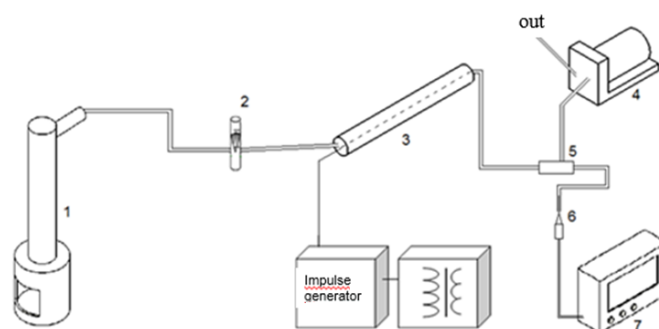


Figure 1 The experimental arrangement

1: oven; 2: flowmeter; 3: reactor; 4: pump; 5: sampler; 6: probe; 7: gas analyzer

The experiments were performed using a cylindrical type reactor, which consists of a grounded steel tube and a tungsten wire of diameter 0.2 mm, placed along its axis. The length of the cell was 120 cm, its diameter was 6 cm.

The high voltage pulses were generated by capacitive circuit (Figure 2) [4]. The pulse capacitor is charged via the charging resistance to direct voltage, and then discharged by rotary spark gap ignition. To achieve the desired impulse voltage, (rise time 50 nsec) the damping resistor was 100

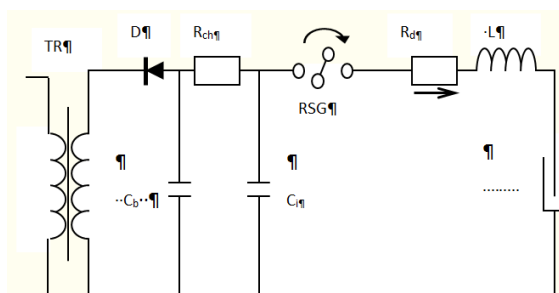


Figure 2 The schematics used to generate fast rising electric pulses

Tr: transformer, D: diode, R_{ch} : charging resistor, R_d : damping resistor, R: reactor, RSG: rotary spark gap, C_b : buffer capacitor, C_i : impulse capacitor, L: inductance

The high voltage pulses were connected to the discharge electrode of the reactor. Because of the high gradient of electric field between the electrodes, a corona discharge is produced at the vicinity of the discharge electrode. If the free electrons gain enough energy from the electric field, they can break the molecular bonds by collision [5],[6],[7]. Figure 3 shows a typical voltage pulse waveform at the discharge electrode.

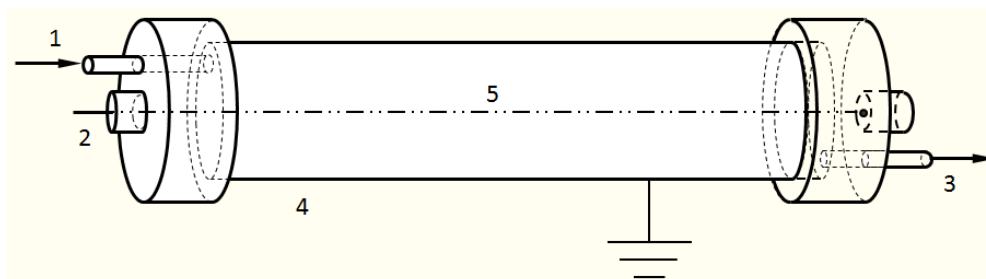


Figure 3 An example of the voltage pulse waveform used

The quantity of the biomass was exactly 100 g in each experiment. The exhaust gas was connected to the reactor through a flowmeter, the purified gas was taken out from the reactor, to the sampler. The concentration of NO, SO₂, Cl₂ components were determined by the ENVIRO 51 gas analyzer, the data were processed by the Envisoft software.

The program recorded the data every 3 seconds, and tabulated them. This was necessary because during the combustion the concentration of the emitted gas mixture was not constant, it changed constantly. By using the table, the concentration-time graphs, were prepared, which are later used for the calculation of the mass of the hazardous gas components.

Several reference measurements were performed in case of off-reactor, in order to calculate the amount of pollutant gas. Finally, the decomposition ratio was calculated as the ratio of the mass of the decomposed gas component and the mass of the total gas component. Since the concentrations were not constant in time, we had to use the mass in the equation.

3. RESULTS

During the measurements the three types of fuels were examined in different points of view. The flow intensity of the exhaust gas was a 100 l/h, the pulse frequency of 100 Hz, the mass of fuel burned was 100 g in each case. The results are presented in each plant in the following graphs.

Energy cane (bamboo)

The decomposition ratio of NO and SO₂ is growing with increasing pulse peak voltage (Figures 4 and 5)

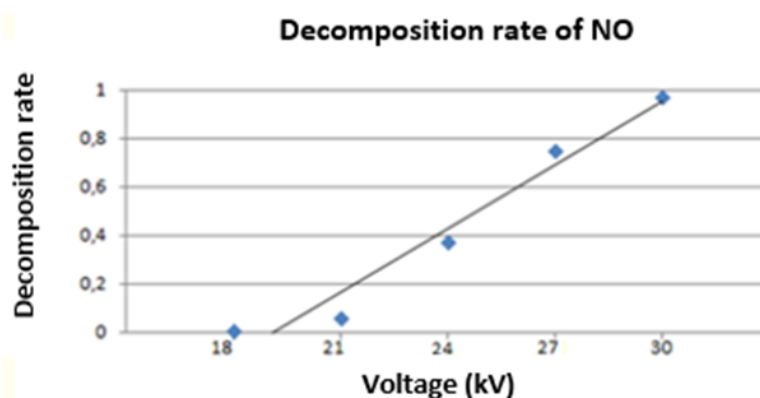


Figure 4 The result of decomposition experiment for NO in the case of energy cane burning

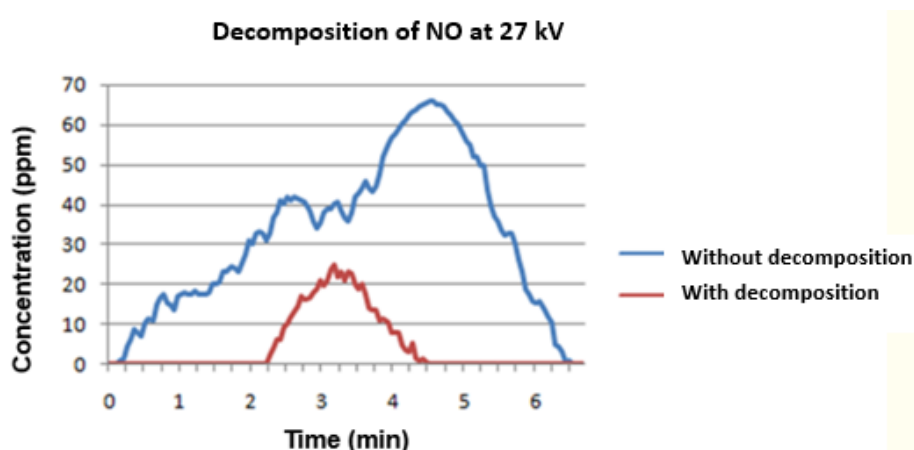


Figure 5 The change of the NO concentration in the case of energy cane

Based on the areas below the graphs, the decomposition ratio can be calculated. In this case the produced NO is 36.84 mg, but only 8.26 mg was released when the PCDP reactor had been operated.

Figure 6 represents the decomposition ratio of SO₂ versus pulse peak voltage.

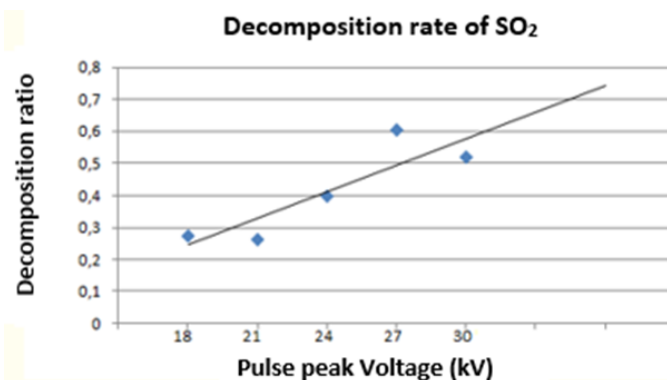


Figure 6 The decomposition ratio of SO₂ versus pulse peak voltage

Figure 7 shows the chlorine concentration in the exhaust gas during the burning of energy cane.

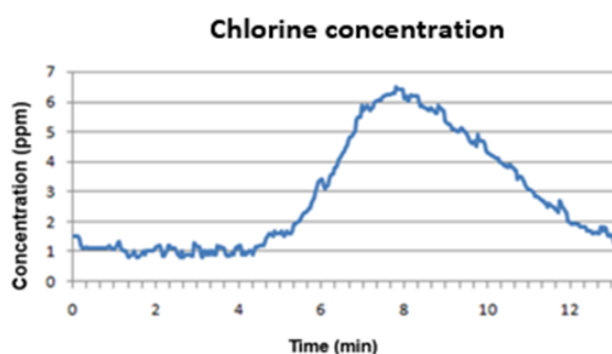


Figure 7 The chlorine concentration versus time

It is clear that its maximum was reached in the second half of the measurement, but the peak value was only 6.5 ppm. A total mass of 7.6 mg of Cl₂ was released during the whole burning.

Energy willow

In case of energy willow the decomposition ratio of NO is also rises with increasing voltage. The results clearly show that the ratio of NO destruction increases with voltage, but the curve is not so steep as in case of energy cane. The measured results show that the destruction ratio changes between 0.3 and 0.7 depending on the voltage. Figure 8 shows the destruction of SO₂ versus time for willow. The decomposition ratio is also growing as expected with increasing voltage. The measuring points are scattered, but the regression straight line indicates relation between the decomposition and the pulse peak, As in case of NO, the results here also varied between 0.3 and 0.72.

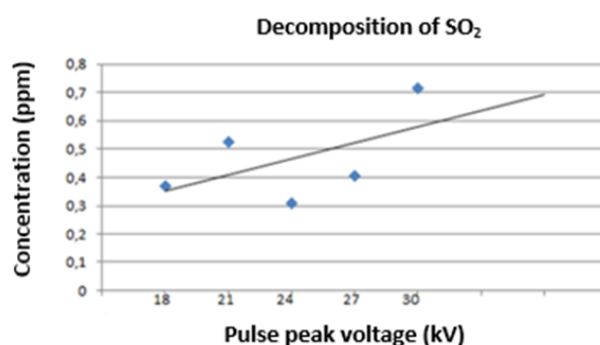


Figure 8 The decomposition ratio of SO₂ versus pulse peak voltage

Biomass-briquette

Biomass briquettes, mostly made of green waste and other organic materials, are commonly used for electricity generation, heat, and cooking fuel. These compressed compounds contain various organic materials, including rice usk, bagasse, ground nut shells, municipal solid waste, and agricultural waste. Environmentally, the use of biomass briquettes produces much fewer greenhouse gases, specifically, 13.8% to 41.7% CO₂ and NO_x. There was also a reduction from 11.1% to 38.5% in SO₂ emissions when compared to coal. The chlorine emission was also examined for biomass briquette; the results are shown in the Figure 9.

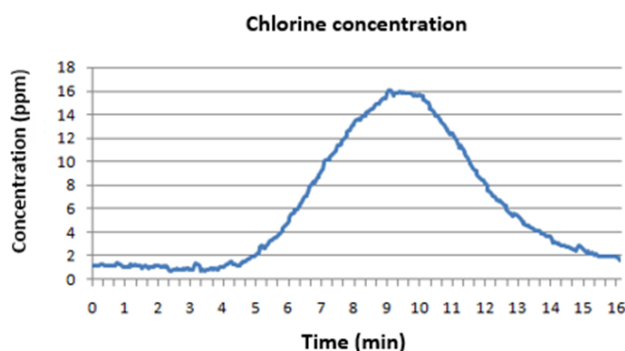


Figure 9 The concentration of emitted chlorine for burning of biomass briquette.

Compared to the chlorine emissions of the briquette to the emissions of the other two energy plants, it is clear that the chlorine concentration peak is the highest in case of briquette. It is 16 ppm, which is almost twice as much as for willow. All chlorine emissions were also the highest, 19.87 mg.

The temperature in the combustion chamber was also measured as a function of time. Figure 10 shows these data.

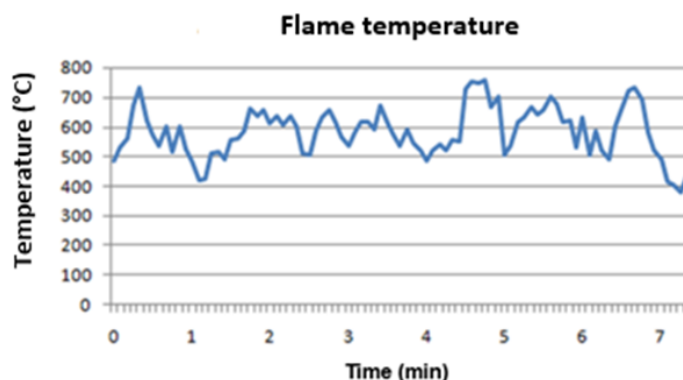


Figure 10 The temperature in the combustion chamber of the oven vs. time

During the combustion, the temperature has been irregularly changed between 400 and 750°C. The NO gas appears at the temperature of 800°C during combustion, so if the material is heated at a higher temperature, than probably much more NO would have been generated in the flue gas.

Determination of the quantity of chloride and sulfate ion in the dry matter

Other measurements were also made to detect the harmful content of plants. Before and after the combustion, the chloride ion and sulphate ion content were determined (Figures 11, 12). The chloride content was measured by photometer and the sulphate content by wet mass determination.

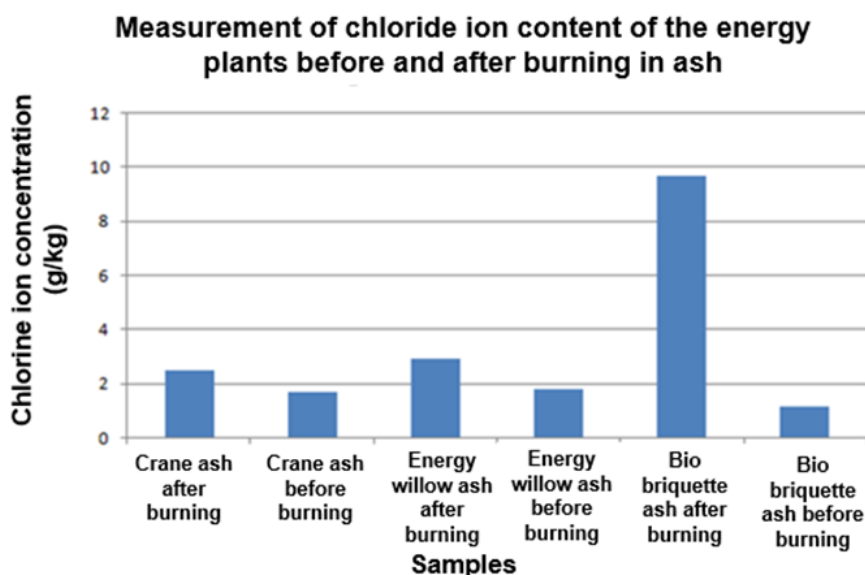


Figure 11 The chloride ion content of different plants before and after burning

The Figure shows clearly, that the burned ash of the biomass briquette contained the highest concentration of chlorine; this concentration was lowest before combustion.

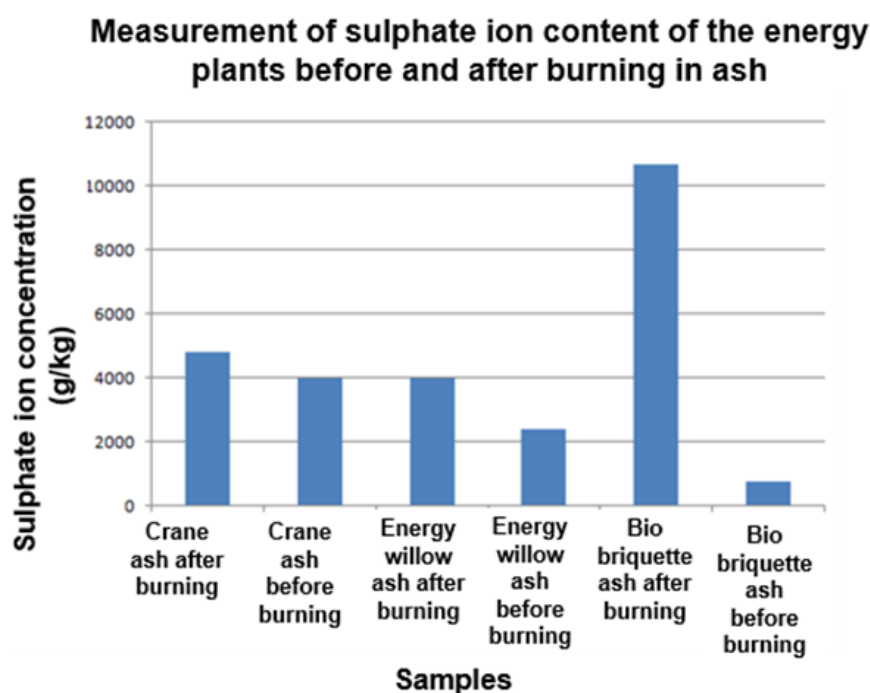


Figure 12 The sulphate-ion content of different plants before and after burning

The concentration of sulphate ion in plants is similar to that of chloride ions. Here the concentration of sulphate ion is the highest in the in the ashes of the burned bio-briquette and also in the pre-combustion bio-briquette.

Conclusion

Our measurements show and the related literature also reveals that the energy plants contain a significant amount of sulfur and chlorine. This is mentioned in the literature, but unfortunately it does not known in public. People did not realize that the burning of energy

plants is also pollute the environment, and apart from the NO, sulfur dioxide and chlorine are released into the air. Nitrogen oxide appears at each combustion because in the presence of oxygen, and the nitrogen is oxidized in the air. The photometric measurement showed that, post-combustion ash has a higher concentration of chloride than before combustion at each plant. There are several reasons for this. It is obvious that, 80-90% of the material was removed during the combustion, and a significant amount of chlorine remained in the ash, so concentrations increased. In case of determining the sulfate ion, the concentration in the ash is higher after combustion than before. The explanation is the same, sulfur was in a form that could not be detected by the available methods.

However, it is not necessary to give up the use of energy plant, there is a technology to decompose these air pollutant gases, to purify the flue gas generated by combustion. By using the pulsed corona discharge technology, 70-99% of the resulting nitrogen oxide and 50-70% of the sulfur dioxide can be decomposed so that air pollution can be significantly reduced. According to our results, the efficiency of the method increases with increasing peak voltage of the corona pulses, so the appropriate reactor can be designed and dimensioned for combustion of energy plants. This technology can be used not only for domestic heating system, but also in the energy industry and the exhaust gas of thermal power plants can be efficiently cleaned.

The research was supported by EFOP 3.6.2-16/2017-00018.

REFERENCES

- [1] Kiss I., Suda J., Szedenik N., Berta I.: New Results in ESP Modelling, *Electrostatics*, 1999. Proceedings of the 10th International Conference Cambridge, 28-31 March 1999. pp. 299-305.
- [2] Luigi Civitano: Industrial Application of Pulsed Corona Processing to Flue Gas *NATO ASI Series, Vol. G. Part B*, Springer – Verlag Berlin Heidelberg 1993
- [3] E. Kiss, M. Nifuku, M. Sato, M. Horváth, I. Jenei, G. Hajós, M. Brendel: "Removal of NO from Flue and Exhaust Gases Using Nonthermal Plasma Technology 6th International Conference on Electrostatic Precipitation, Budapest, Hungary, 18-21 June, 1996. Proceeding, pp. 574-579
- [4] Jen-Shih Chang, Arnold J. Kelly, Joseph M. Crowley: *Handbook of Electrostatic Processes*, Marcel Dekker, Inc. 270 Madison Avenue, New York 10016 (1995)
- [5] Horváth M., Kiss E: Kinetic Model of Hazardous Gas Decomposition by Pulsed Corona Discharge *Pollack Periodica* Vol. 2, No. 1. 2007, pp.51-61
- [6] Yan P., Fujiwara M., Zhou Y., Ishida M.: Investigation on luminescence and NO_x removal by pulsed corona discharges *Journal of Electrostatics* Vol. 51-52, 2001, pp.260-271
- [7] Chang J. S., Masuda S.: **Mechanism of pulse corona induced plasma chemical process for removal of NO_x and SO₂ from combustion gases** *Industry Applications Society Annual Meeting, 1988, Conference Record of the 1988 IEEE* Vol.2(7), 1988, pp.1628-1635

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