MONITORING OF NO_X EMISSION DEPENDING ON WOOD CHIP QUALITY IN A MEDIUM SIZED BIOMASS COMBUSTION PLANT

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ABSTRACT: The medium combustion plant directive (MCPD) is now being transferred into German law for combustion plants with a thermal heat output from 1 to 50 MW. Within this regulation, flue gas emissions (CO, NO_X and TPM) will be limited to certain values depending on the thermal heat output of the plant. Especially for combustion plants with a heat output from 1 to 5 MW there is a lack of knowledge concerning the variability in the formation of NO_X emissions as caused by the usual variation of fuel properties throughout a complete heating season. The major fuel parameter in focus is the nitrogen content of the fuel. But other important parameters such as moisture content, ash content, bulk density, particle size distribution and chemical composition from elementary analysis are also monitored. The nitrogen content of the fuel as well as the boiler load clearly influenced the NO_X emission.
Keywords: wood chips, quality, emission, medium-scale combustion unit.

1 INTRODUCTION

The medium combustion plant directive (MCPD) is now being transferred into German law by the 44. German Federal Emission Control Act (BImSchV) for combustion plants with a thermal heat output from 1 to 50 MW [1]. In order to gather further data concerning the feasibility of the new emission thresholds in practice extensive flue gas emission measurements were conducted at the combustion plant at TFZ from October 2018 until April 2019. Moreover, every fuel delivery was analysed according to DIN EN ISO 17225-4 [2] by collecting a representative sample during unloading of the trucks. Besides the moisture content, content of fines and ash content also the nitrogen content of the fuel was of special interest, since it mainly influences the formation of nitrogen dioxide (NO_X). The objective of this investigation was to prove the suitability of different wood chip qualities for the combustion plant at TFZ with regard to the formation especially of NO_X. Also the influence of boiler load will be presented.

2 MATERIAL & METHODS

2.1 Fuel sampling and fuel analysis

The combustion plant at TFZ is operated with local untreated wood chips. The assortments are wood chips from stemwood, forest residue, short rotation coppice (poplar) and landscape maintenance. The different fuel assortments were selected by the plant operator without any influence by the researchers in order to obtain objective results regarding a real life related emission behavior. The wood chips were delivered in large trailers with a capacity between 10 to 29 tones on wet basis. During unloading the truck about 10 samples of 10 l each were taken.

Fuel quality of wood chips were analysed regarding moisture content, ash content, net calorific value, bulk density and particle size distribution at TFZ according to international standards for solid biofuels (Table I). Representative samples from each delivery were milled down to a grain size of 0.5 mm for the determination of major and minor elements by an external laboratory (Eurofins Umwelt Ost GmbH in Freiberg) also following international standards.

Table I: International standards to determine the fuel quality of solid biofuels, a.r. – as received, d.b. – dry basis [2]

Parameter	Unit	ISO Standard
Moisture content (a.r.)	w-%	18134-2
Ash content (d.b.)	w-%	18122
Net calorific value (d.b.)	MJ kg^{-1}	18125
Particle size distribution	w-%, mm	17827-1
Bulk density (a.r.)	kg/m³	17828
C, H, N (d.b.)	mg/kg	16948
Main components (d.b.)	mg/kg	16967
Minor element (d.b.)	mg/kg	16968

2.2 Investigated combustion plant

The combustion plant at TFZ consists of two boilers from the manufacturer Müller with a nominal heat output of 650 kW each. The plant was installed in 2006 and is operated only during the heating season between October and April. Depending on heat demand one or two boilers can be operated. During summer time the combustion plant is out of operation. The fuel is fed into a fuel hopper with a size of 140 m³. From there a push floor transports the fuel to a screw conveyer which feeds the fuel into the back of the boiler. From there a moving grate pushes the fuel further to the front of the boiler during combustion. After combustion the ash is removed into the ash collection bin via a stoker. The flue gases pass the heat exchanger unit above the combustion zone and coarse particles are separated by a cyclone.

2.3 Emission measurement methods

The flue gas emissions were sampled every 10 minutes almost continuously over the entire heating period starting from October 2018 until April 2019. All flue gas samples were taken behind the cyclone. Most of the time a Horiba PG 350E was used for the measurement of carbon monoxide (CO), nitrogen dioxide (NO_X), sulfur dioxide (SO_2) as well as oxygen (O_2) on dry basis. Over a period of about four week a FTIR DX4000N by Ansyco GmbH was used. All reported emissions refer to standard testing conditions (STC = dry flue gas at 0 °C and 1,013 hPa) and are based on a volume fraction of 6 % O_2.

3 RESTULTS AND DISCUSSION

3.1 Fuel assortments and fuel analysis

Wood chips were provided mainly by two suppliers. Only the fuels analysed for emission behavior are considered in this investigation. During Christmas break and after 05th of April no fuel samples were taken. In total 39 deliveries were sampled including 639 tones of wood chips (based on 30 % moisture content) consisting of 28 % stemwood (10 deliveries), 59.2 % forest residue (24 deliveries), 6.6 % poplar (3 deliveries, delivery 3, 27, 28) and 6.2 % landscape maintenance (2 deliveries, delivery 29 and 31).

The moisture content varied between 19 and 51 w-% having a mean value of 35.4 w-%, see Figure 1.The moisture content of supplier 1 was mostly lower than from supplier 2.

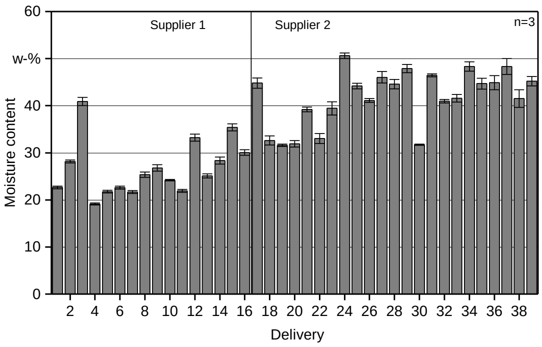

Figure 1: Moisture content for all wood chip samples

The ash content was between 0.2 and 5.8 w-% with a mean value of 1.86 w-%, Figure 2. The lowest ash content was detected for wood chips from stemwood as expected being as low as 0.2 w-%.

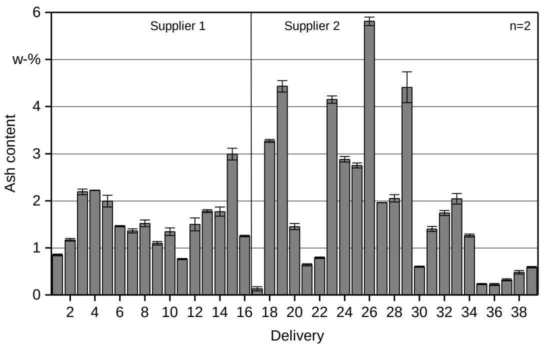

Figure 2: Ash content on dry basis for all wood chip samples

A rather large variation on the content of fines was found ranging between 1.2 and 21.6 w-%.

The bulk density ranged between 142 and 207 kg/m³ (d.b.) with an average value of 178 kg/m³.

The net calorific value varied between 18,024 and 19,755 kJ/kg (d.b.) with an average value of 19,102 kJ/kg.

The most interesting parameter was the nitrogen content in the fuel since it is the main source for the formation of NO_X emission during combustion of woody biomass. The lowest nitrogen content was detected for delivery number 22 being below the detection limit of 0.05 w-% while the highest nitrogen content of 0.44 w-% was found in delivery 23 from supplier 2, Figure 3. For fuel delivery 38 and 39 no values for the nitrogen content are yet available since they are currently analysed..

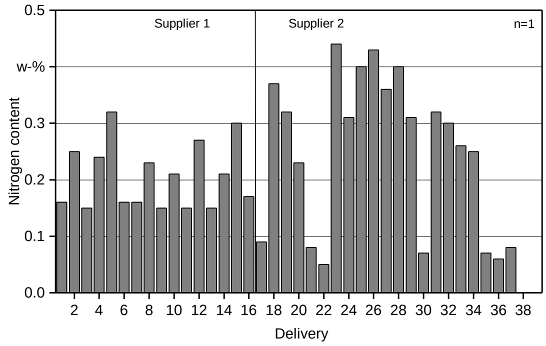

Figure 3: Nitrogen content for all wood chip samples

3.2 Emission behavior of the TFZ plant

Over almost the entire heating season gaseous emissions were recorded. During the first half of the heating season almost the same material of wood chips was delivered by supplier 1 having only a small deviation in the nitrogen content of the fuel between 0.15 and 0.30 w-%. No large variations were observed for NO_X emissions which were most of the time below 370 mg/m³, see Figure 4.

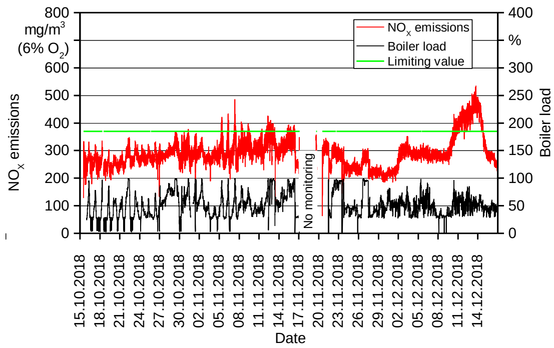

Figure 4: NO_X emissions and boiler load during October to December 2018 at the combustion plant at TFZ

But during the second half of the heating season (January to April 2019) a large spectrum of different fuel qualities was delivered ranging from wood chips made of stemwood to landscape maintenance. The combustion of stemwood was characterized by NO_X emissions below 200 mg/m³, see Figure 5 at the end of January 2019. This low level of NO_X emission was repeated during the beginning of March as well as during April 2019, Figure 5. The nitrogen content of the fuel was below 0.1 w-%.

During the combustion of wood chips from forest residue (e.g. during February 2019) higher values for NO_X emissions above 370 mg/m³ were observed as seen in Figure 5. During this period fuel deliveries 23 to 26 were combusted in the combustion plant with nitrogen content between 0.3 and 0.44 w-%.

Both deliveries from landscape maintenance (29 and 31) had a comparable nitrogen content of 0.32 and 0.31 w-%, respectively. The only difference between both deliveries was that the second one was screened before delivery which reduced the content of fines as well as the ash content. This improvement on fuel quality led to slightly lower NO_X emissions on around the 10^{th} of March compared to values at the end of February 2019, Figure 5. The same influence of the content of fines on NO_X emissions was found in [3,4]. Unfortunately, no flue gas monitoring was performed during the combustion of poplar due to failure of the equipment.

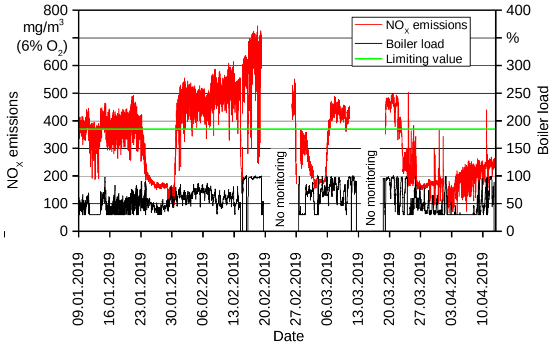

Figure 5: NO_X emissions and boiler load during January to April 2019 at the combustion plant at TFZ

Finally the dependency of fuel nitrogen and boiler load on the formation of NO_X is summarized in Figure 6. It can be clearly seen that for fuels with a low nitrogen content (mainly for stemwood) the NO_X emissions were below 270 mg/m³ for all boiler loads. Up to a nitrogen content of about 0.2 w-% the future limiting value will not be exceeded for almost all boiler loads. With a further increase in nitrogen content in the fuel the NO_X emissions will be above 370 mg/m³ at all boiler loads for the combustion plant at TFZ, Figure 6.

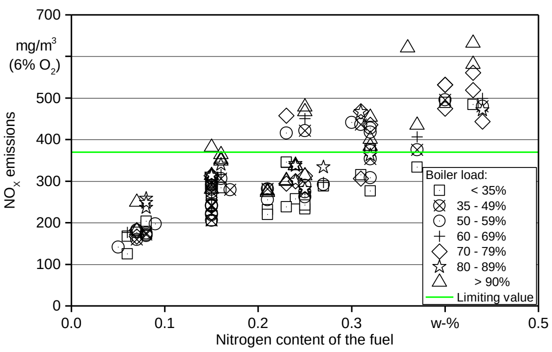

Figure 6: Influence of fuel nitrogen and boiler load on the NO_X emissions at the combustion plant at TFZ

4 SUMMARY AND CONCLUSION

During the extensive monitoring phase of the combustion plant at TFZ clear correlations between nitrogen content of the fuel and NO_X formation were found. If stemwood was combusted low NO_X emissions were detected for all boiler loads. In case of a higher nitrogen content in the fuel (above 0.3 w-%) the NO_X emissions were above the upcoming limiting value claimed by the 44. BImSchV for all boiler loads. During fuel delivery it is difficult to estimate the nitrogen content of the fuel, which makes it impossible to predict the NO_X emission behavior during combustion. But in general it can be stated that bright wood chips or slightly darker wood chips with a low fraction of fines may help to fulfill also the upcoming limiting value of 370 mg/m³.

5 REFERENCES

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