Characterization of Gaseous Emissions from a Small-Size Industrial Plant for Thermal Wood Modification by GC/MS

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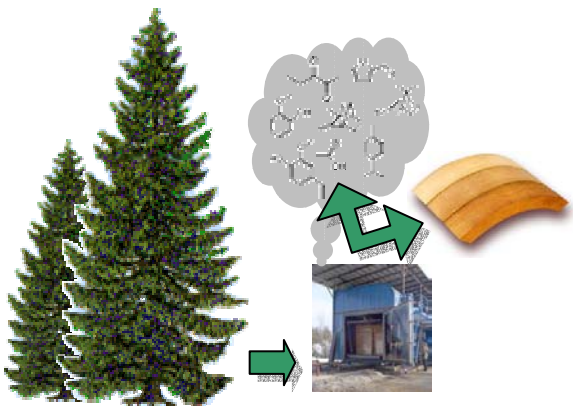
INTRODUCTION

Heat treatment of wood has lately grown in interest as a modification method for several reasons: there are already well established processes, no chemicals are applied during the treatment and there is a positive influence on different wood properties (e.g. reduced swelling and shrinking, better resistance against fungal attack/decay, color change of treated wood welcome as an important style element, easy to handle at end of lifetime, etc.) (Militz, 2002). Besides elevated temperature in a range of about 180-220 °C other important process parameters are: pretreatment, duration of high-temperature interval, atmosphere within the reactor, post treatment. All these have a significant influence on the chemical reactions within wood. Many of the reaction mechanism and the changes in the chemical composition of heat treated wood are already well investigated (Viitaniemi et al., 2001). However, there is only limited data available on the volatile organic compounds, which are released during the heat treatment of wood.

The aim of our work is the characterization of these emissions, and focuses on the condensable gases emitted by a wood treatment plant. It is intended to determine, if the emissions contain compounds considered to be valuable products and if they could be obtained in amounts, which are sufficient for an economically viable recovery.



MATERIALS AND SAMPLING METHOD

The wood material treated in the monitored industrial process was air-dried (moisture content around 20%) and bark free European spruce (*Picea abies*). The treatment was carried out in a small-size Austrian plant equipped with a heating chamber with a maximum capacity of 15 m³ of wood per treatment. Together with the regular load of wood, 8 small wooden boards (400 x 200 x 10mm) were treated to determine mass loss. Emission samples where taken directly from the chambers' flue-gas line by means of a small testing tube. Compounds were collected through condensation in a condenser followed by a gas-trap. After each sample collection the condenser and the gas trap were carefully washed with acetone. Washing solutions were collected for successive analyses.

ANALYTICAL METHODS

The volatile organic compounds in the liquid, aqueous phase collected from condensation were extracted with dichloromethane (CH_2Cl_2) while acetone samples from washing were used without further treatment. Analyses of both was carried out by GC/MS. For interpretations, the obtained mass spectra were matched with data from a comprehensive electronic database. The total organic carbon (TOC) and the pH – values of the samples were also determined. Average mass loss was measured by drying (105 °C, 24 h) and weighing 8 small wooden boards before and after heat treatment.

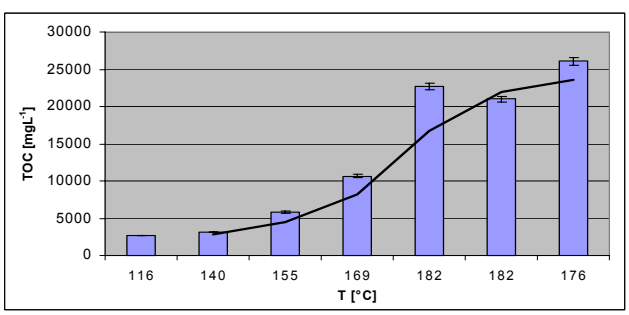


Figure 1: TOC-values versus temperature at sampling

RESULTS

TOC values raise corresponding to increasing temperature and remain almost constant at the temperature plateau (180 °C), which shows the strong influence of temperature on degradation and emission of volatile organic compounds (VOC) in wood (figure 1). pH – values decrease slightly in the range of 2.7 to 2.4 from samples 1 - 7, which is in accordance with the increasing amounts of acids found in later samples. Mass loss of treated spruce was determined at 2,6% of initial dry substance (DS). This is in good accordance with comparable data from literature (Alén *et al.* 2002).

A typical total ion chromatogram (TIC) of a high temperature sample is shown in figure 2. The identified main components from the GC/MS analyses in the condensed gas samples are: acetic acid, furfural, dimethylglyoxal, hydoxyacetone, toluene and various terpenes (mainly α-pinene). Levels of acetic acid and hydroxy-ketones continually rise from sample 4 to 7. As for the acetone samples the identified main components are: various terpenes (mainly α-pinene, but also limonene, β-pinene and δ-carene), 4-hydroxy-4-methyl-pentanone, acetic acid and furfural.

Significant levels of various terpenes emitted throughout the process (mainly found in acetone phase) indicate that their emission takes place continuously over the whole process.

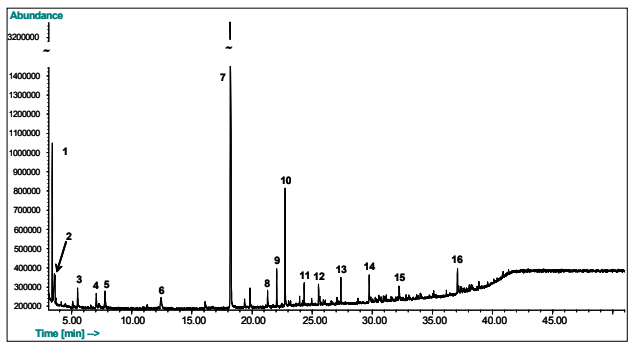


Figure 2: TIC of high temperature sample (CH_2Cl_2 – phase)

Table 1: Composition of emission sample

ID	t_R [min]	Peak area [%]	Identified compound	CAS#
1	3,40	7,67	2,3-Butanedione	431-03-8
2	3,58	4,80	Acetic acid	64-19-7
3	5,51	1,96	1-Hydroxy-2-propanone	116-09-6
4	7,06	1,33	2,3-Pentanedione	600-14-6
5	7,78	2,04	3-Hydroxy-2-butanone	513-86-0
6	12,45	2,14	Toluene	108-88-3
7	18,25	54,55	Furfural	98-01-1
8	21,31	1,24	1-(2-Furanyl)ethanone	1192-62-7
9	22,06	2,60	α-Pinene	80-56-8
10	22,76	6,67	5-Methyl-2-furancarboxaldehyde	620-02-0
11	24,35	1,22	Limonene	138-86-3
12	25,55	1,11	2-Methoxyphenol	90-05-1
13	27,39	1,37	(-)-α-Terpineol	98-55-5
14	29,75	1,44	2,6-Dimethoxyphenol	91-10-1
15	32,24	1,46	Homovanillic acid	306-08-1
16	37,10	1,54	Cembrene	1898-13-1

CONCLUSIONS

The aim of this study was to get information on the emissions of an industrial-plant heat treatment process. A first qualitative study of the emitted components was carried out successfully. The data offers information on the composition of the emissions during the whole process. Compounds emitted reflect the complex chemical degradation reactions of wood constituents taking place during wood heat treatment. The identified compounds are interesting products for various industrial uses and therefore should be considered as valuable by-products.

REFERENCES

Alén, R., Kotilainen, R., Zaman, A. (2002) Thermochemical behaviour of Norway spruce (Picea abies) at 180 – 225 °C. Wood Science Technology, 36(2), 163-171.

Militz, H. (2002) Heat Treatment Technologies in Europe: Scientific Background and Technological State-of-Art. In: The international research group on wood preservation, prepared for 33rd annual meeting, Cardiff, Wales. IRG Secretariat, SE – 100 44 Stockholm, Sweden.

Viitaniemi, P. et al (2002) Reaction mechanisms of modified wood. Final Report Finnish Forest Cluster Research Programme - Wood Wisdom, ed. Leena Paavilainen. Helsinki, Finland, pp 185-195. Tammer-Paino Oy, Tampere.

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