Detection of inorganic wood preservatives on timber by near infrared spectroscopy

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The recycling of waste wood causes great problems due to the variety of toxic wood preservatives, varnishes and paints used. The fast and reliable distinction and sorting of treated and untreated wood on demolition sites could open new ways of wood recycling, e. g. for the production of chip boards. For this purpose, prepared wood samples treated with inorganic wood preservatives (arsenic, boron, copper salts) were investigated by near infrared-spectroscopy. In most cases, treated wood samples could be distinguished from untreated ones. Furthermore the type of wood preservative could be identified. The observed spectral features are electronic absorption bands and changes in the OH–band due to interaction with salt molecules.

Keywords: NIR-spectroscopy, wood preservatives, used wood disposal, waste management.

Introduction

The eco-toxicologic assessment of waste wood, e. g. from the demolition of houses or from transport or packaging, is an important issue in future waste management. The knowledge of whether and how strong used wood is contaminated with toxic agents opens the way to sorting the wood into streams with different degrees of contamination. Uncontaminated wood can be used for the production of chip boards whereas polluted wood must either be burned under special precautions or deposited in appropiate sites. In Germany, upcoming legislation shall control the recycling and depostion of industrial and municipal waste wood.

Practicable methods for the fast detection of wood preservatives do not exist. Near infrared (NIR) spectroscopy could open the way to a fast and reliable detection of inorganic wood preservatives. Wood used for the construction of houses (e.g. on roof trusses) has often been impregnated under high pressure in liquid concentrations of several percent. The content of toxic (metal) ions in such woods is normally between 500 ppm and 10000 ppm. NIR spectroscopy has already been applied on wood by several authors, mainly to determine chemical parameters such as resin,[1] lignin,[2,3] cellulose[2,4,5] or tannin[6] content, or to determine the physical condition of wood.[7] Other authors applied NIR spectroscopy to the distinction of wood types.[8]

Experimental

A SPEX 270M NIR spectrograph equiped with an extended InGaAs diode array was used for the recording of spectra between 700 nm and 2200 nm. A 70 mm^{-1} grating (blaze wavelength 1500 nm) served as diffracting element. Two 50 W halogen lamps were used as light sources. An F 30 lens collected light from a spot of 2 cm diameter for averaging over the wood surface. The wood pieces were positioned at a fixed distance (20 cm) from the collection lens and the lamps. A teflon disk was used as reference material for the spectrograph. The integration time was 40 ms and 100 spectra were averaged.

The collection optics were coupled to the NIR-spectrograph via a 365 µm low OH silica/silica fibre. The entrance slit width is set to 100 µm. The computer-controlled spectrograph was equiped with a peltier cooled 256-element Extended-InGaAs-array detector (Sensors Unlimited SU256L-2.2TE-100A). The spectral resolution was of about 7 nm, three grating positions (1000 nm, 1500 nm, 2000 nm) each covering a spectral range of about 600 nm were used.

The sample set was provided by the Bundesforschungsanstalt für Forst- und Holzwirtschaft in Hamburg, Germany. It contained samples of Scotch pine impregnated with inorganic wood preservatives in common concentrations: As_2O_3 7150 mg / kg, $B(OH)_3$ 6900 mg / kg, $CuSO_4$ 7000 mg / kg.

Results and discussion

Figure 1 shows a spectrum of spruce (aluminium as reference) with the vibrational overtones observed. The first and second overtone of the CH–stretching vibration are observed at 1800 nm and 1200 nm respectively. Even more important are

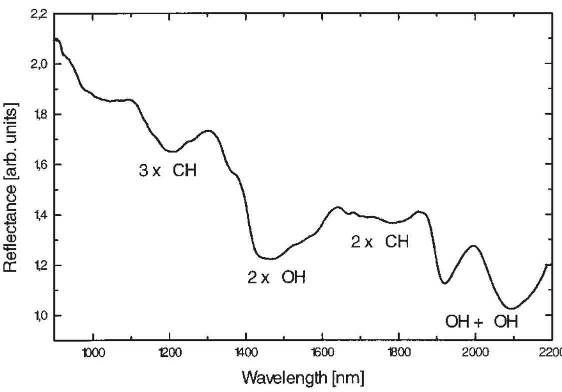

Figure 1. NIR reflectance spectrum of spruce with vibrations observed.

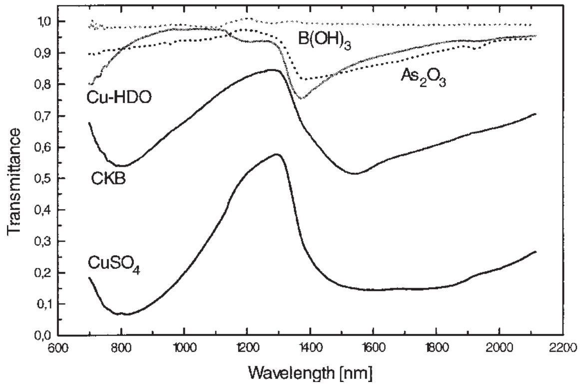

Figure 2. Transmission spectra of wood preservatives solved in water.

the first overtone of the OH–stretching vibration at 1450 nm and the two OH–combination bands at 1900 nm and 2.100 nm.

Transmission spectra of the organic salts solved in water were recorded within a 10 mm cuvette. Pure distilled water was used as reference. The obtained spectra are shown in Figure 2.

Strong absorptions due to electronic transitions can be seen in the spectra of CKB (contains Chrome-, Copper- and Boron-salts, blue) and $CuSO_4$ (blue) around 800 nm and from 1400 nm to 2100 nm. Cu-HDO (light-blue) also shows a weak electronic absorption at the long wavelength edge of the spectrum and another absorption near 1.400 nm (probably an electronic absorption as well). As_2O_3 (colourless) shows spectral changes in the OH-absorption region (1400–1600 nm) which are probably due to an interaction between salt ions and water molecules. Similar changes in the NIR absorption have already been observed with other salt solutions.[9–11] The spectrum of $B(OH)_3$ provides only small spectral changes.

Spectra of different samples of Scotch pine untreated or treated with As_2O_3, $B(OH)_3$, or $CuSO_4$ between 1.200 nm and 1.800 nm are shown in Figure 3. These spectra were range-scaled to show the differences between the differently treated timbers. The most distinct deviation from the untreated wood, observed in the spectra with $CuSO_4$, is due to electronic absorptions. The other two treatments cause spectral changes in the OH–region, which probably result from interactions of the salt ions with OH–groups of

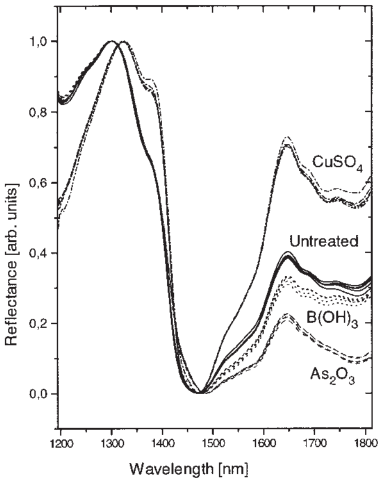

Figure 3. Range-scaled spectra of Scotch pine untreated and treated with As_2O_3, $B(OH)_3$ and $CuSO_4$..

cellulose or adsorbed water molecules. It is surprising that even the boron-treatment shows spectral changes because the transmission spectrum of the boron salt solution did not differ much from that of pure water. It can be seen that a distinction between these four classes is possible.

Conclusions and future developments

It was demonstrated that different kinds of inorganic wood preservatives on wood can be distinguished by using NIR spectra (700 nm to 2200 nm). Some problems, as different humidity of the wood and different surface roughness have to be dealt with in future investigations. They may be overcome by a particular moisture correction and multiplicative scatter correction respectively. The calibration model is also expected to depend on the wood type. Another remaining task is to determine the detection limits of the method.

Acknowledgements

Thanks are due to Mr. Wolfgang Keilholz. This work has been financed by the Deutsche Bundesstiftung Umwelt.

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