# VOC reduction of lignin containing materials

*Improvement of the strength properties and reduction of the emission of volatile organic compounds by enzymatic modification of lignin containing biopolymers and composites*

**Partners involved in the VOC reduction of lignin containing materials project**

*Project coordinator*

Prof. C. Wilhelm
Saxon Institute for Applied Biotechnology - Germany

*Project leaders*

Dr. M. Moreira
University of Santiago de Compostela – Spain

Dr. M. Penninckx
Université Libre de Bruxelles – Belgium

Dr. Ing. W. Nendel
Chemnitz University of Technology – Germany

Dr. Ing. A. Pfriem
Technische Universität Dresden – Germany

Prof. E. Dobrowolska
Warsaw University of Life Sciences – Poland

Dr. T. Tamminen
VTT Technical Research Centre – Finland

**Contact information**

Prof. Dr. Christian Wilhelm
Deputy Dr. Gerhard Kerns
Institution SIAB - Saxon Institute for Applied Biotechnology
Germany
+49-341-2352078
+49-341-9736870
siab@rz.uni-leipzig.de
cwilhelm@rz.uni-leipzig.de

The main objective of the project was the degradation of volatile organic compounds (VOC) in lignin. Due to their toxic effects and their bad smell, VOCs limit the production of biopolymers from lignin composites. To develop biotechnologically feasible strategies for VOC elimination from lignin, the following investigations were carried out:

(i) the development of enzyme complexes for the efficient degradation or polymerisation of lignin-based and hemicellulose-based compounds, which are responsible for emissions of VOC; (ii) the development of methods to modify lignin, aimed at reducing its odour and improving its ability to bind with the reinforcement fibres in composites; (iii) the analysis of different lignin composites with regard to their chemical characteristics; (iv) investigations into the injection moulding of composites from lignin; and (v) the physical-mechanical investigation of composites from modified lignin.

For this purpose, different enzymes with a specific spectrum of lignin-oxidising activities were characterized, produced and investigated for lignin modification. A laccase from Cerrena unicolor was produced up to pilot scale in a 150-L bioreactor and a manganese peroxidase from Bjerkandera adusta sp. R1 up to 30-L scale. For the enzymatic incubation, methods were developed both in small lab-scale and in pilot scale with 1.5 kg of lignin. The incubations were carried out in aqueous solution with different enzymes. The effect of treatments on VOC reduction was determined both by sensing and by chemical analysis. The sensing was supported by gas chromatography–olfactometry (GC–O). Modification with the Cerrena unicolor laccase resulted in VOC reduction, whereas manganese peroxidase had no effect. Laccases with an alkaline pH-optimum therefore seem to be favoured for lignin modification. The VOC´s of the starting lignin were determined by GC/MS.

Kraft lignin shows 5 different phenolic components, which induce the odour; the main component is guaiacol. Different types of lignin were characterized; this involved elementary analysis, determination of the content of functional groups, IR spectroscopic analysis and pyrrolysis GC-MS.

The highest differences were found in the carbonyl content, which is inversely related to the methoxy content.

Injection moulding as well as press moulding was used for the production of composites. Moulded samples based on modified and unmodified lignin were tested in terms of their mechanical and physical properties. The results show that the material properties are primarily influenced by the type and the amount of fibre and additive used for the compound, whereas the lignin has less influence. For example, higher strength/hardness and reduced water swelling/absorption can be achieved by the use of lignin with hemp shives and shellac as additives.

The reduction of lignin VOC´s by enzymatic modification prior to the compounding and moulding process has proven to be challenging. A significant reduction of lignin-based VOC emissions was achieved up to a level of 93%. However, the odour reduction was smaller, because of the extremely low odour threshold. To solve this problem, the utilization of lignin of a different origin appears to be promising. During the project, it was shown that a Natural Pulping lignin based on wheat straw seems to increase the likelihood of low VOC, because of its structure. The present project was the starting point for continuing collaboration between several partners in a new ERA-IB project 'Products from lignocellulose', which includes the use of lignin from annual plants, such as wheat straw or maize straw.

The advantage of the project is the opportunities it presents for the synergistic sharing of work between the partners. This involves, for example, the exchange of strains for enzyme production between USC, ULB and SIAB, and the exchange of methods for enzyme assay and VOC between VTT, SIAB and TUD. The lignin modification is investigated in SIAB, while the preparation and investigation of composites takes place at TUD. The injection moulding is performed at TUC and the mechanical testing at SGGW.

After cellulose, lignin is the second most common renewable substance. A target application for lignin is its use in the production of biopolymers. Currently, the largest part of lignin production, which is a by-product of the pulp and paper industry, is burned for energy supply in the energy-intensive papermaking process. The annual output of pulp is about 133 million tons, which results in the formation of about 70 million tons of lignin. It is expected that this quantity will increase with the production of ethanol from lignocellulosic substrates.

Only a small fraction of lignin is used for material utilization. Some products are manufactured from sulfite lignin, based on its binding and adhesive properties. However, the lignin produced by the predominant Kraft process is usually burned. Nevertheless, in recent times there has been an increase in research activities in the utilization field. In addition to research into the possible utilization of lignin for the production of biopolymers, investigations relating to its utilization for the production of basic chemicals have also increased.