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Can alkaline reserve be harmful? In-depth studies into aging behavior of paper after mass deacidification

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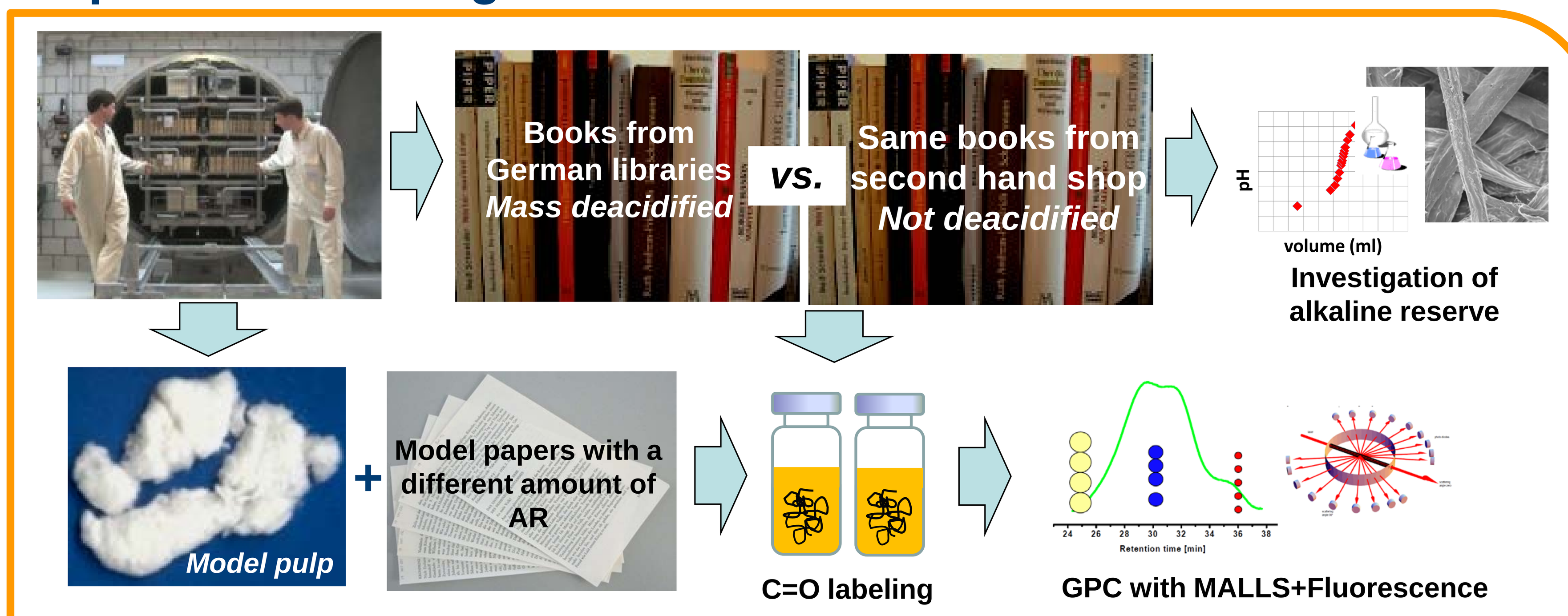
Introduction

Mass deacidification processes have been applied to library collections in order to neutralize acids present and to deposit an alkaline reserve. Book papers which have undergone natural aging for up to 150 years have been subjected to mass deacidification with a possible risk of alkali-induced degradation. The extent of β-elimination-type degradation reactions as well as stabilisation of cellulose against acid hydrolysis was investigated by comparing deacidified library books that were treated in the 1990s to their identical non-deacidified counterparts. An artificially oxidized model pulp was also deacidified in a mass scale process and compared to the book papers. The long-term effect of mass deacidification was studied after applying accelerated aging.

Multi-detector gel permeation chromatography coupled with selective carbonyl group fluorescence labelling allowed for a closer look into the molecular structure of the celluloses, especially the extent of oxidation in different molecular weight regions.

Experimental design



Original book papers vs. Oxidized model pulp

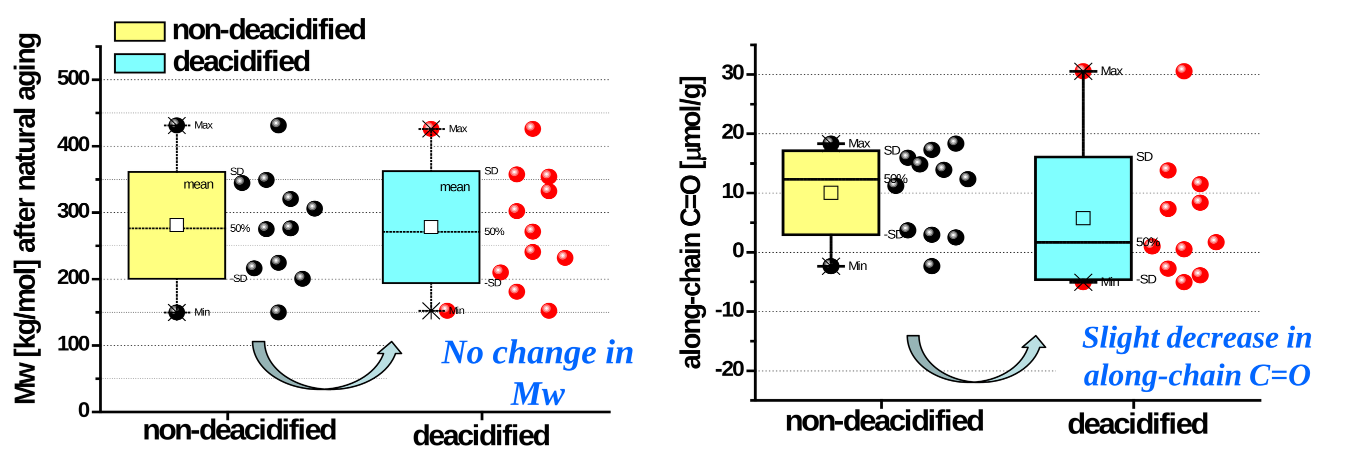


***Fig. 1**:*
Left: Box plots of Mw of deacidified papers and their non-deacidified duplicates.
Right: Box plots of along-chain C=O contents of the same sets of samples.

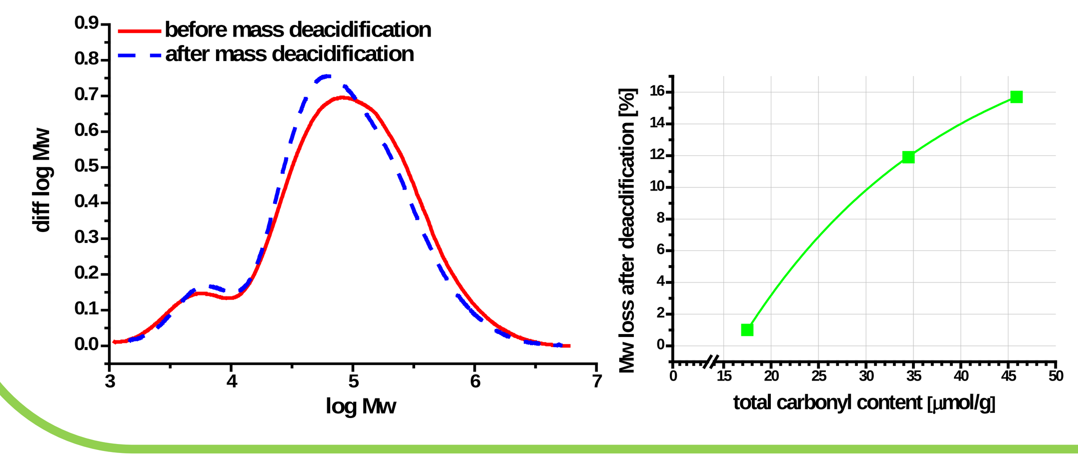
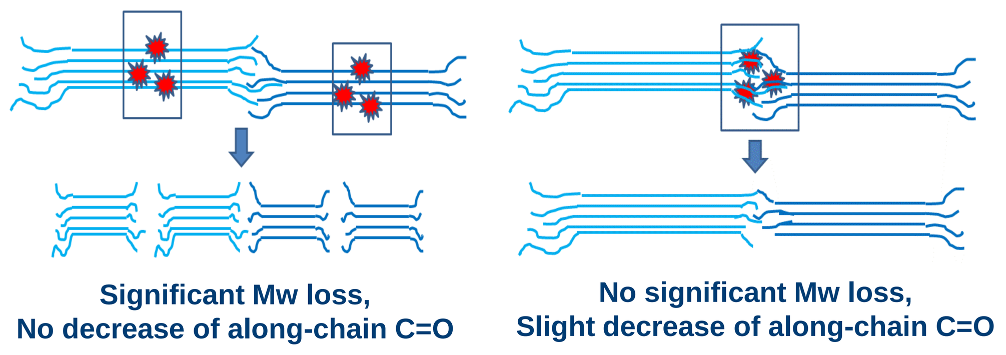


***Fig. 2**:*
Left: MWD of the oxidized sulphite model pulp before and after mass deacidification.
Right: Initial total C=O content of the oxidized model pulp vs. Mw loss (%) after mass deacidification.

Natural aging

Deacidified book papers with more than 10 years of natural aging did not show significant cellulose degradation compared to their non-deacidified duplicates, reflecting that no severe chain cleavage was induced by the treatment (Fig. 1, left). In contrast, an artificially oxidized model pulp deacidified in a same way, showed significant Mw loss (%) upon the treatment (Fig. 2). The extent of Mw loss (%) corresponded to the initial value of C=O content (Fig. 2, right).



The outcome of *β*-elimination reaction in dependence on the carbonyl position is shown in the left scheme.

β-elimination will not affect Mw significantly if carbonyl groups are located in chain ends, which we may see from the naturally-aged book papers after mass deacidification (Fig. 1, right).

The profile of carbonyls relative to the MWD was significantly different for the model pulp and the naturally aged papers. A predominant oxidation at short chains for the naturally aged papers, mainly at HO-C3 and HO-C2 of the anhydroglucose units, also resulted in no significant Mw loss, but in reduction of along-chain carbonyl groups due to *β*-elimination.

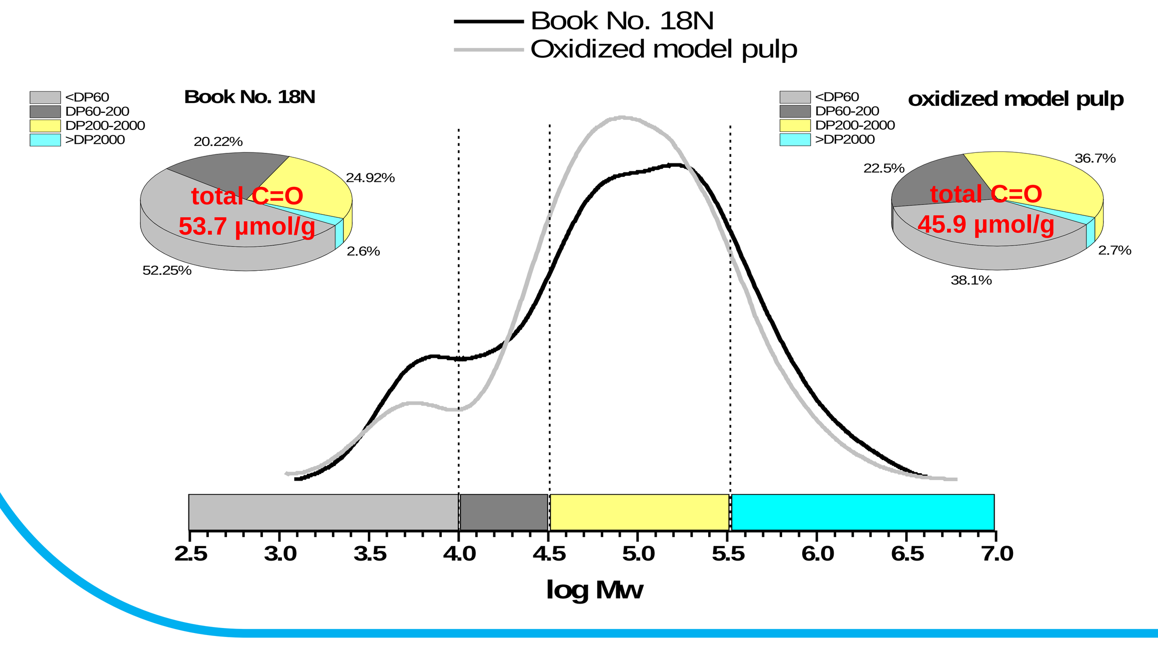


***Fig. 3**: Distribution of total C=O within different areas of the MWD of an example book (No. 18N) and an oxidized model pulp. Pie charts show percentages of total C=O in the respective DP regions, with similar MWD.*

Accelerated aging

The accelerated aging study of the books also resulted in no significant alkali-induced degradation of cellulose, and retardation of acid hydrolysis was profound. The extent of decrease of acid hydrolysis was highly dependent on the amount of alkaline reserve deposited and fine homogeneous distribution of alkaline reserve into the paper matrix as well as on the surface.

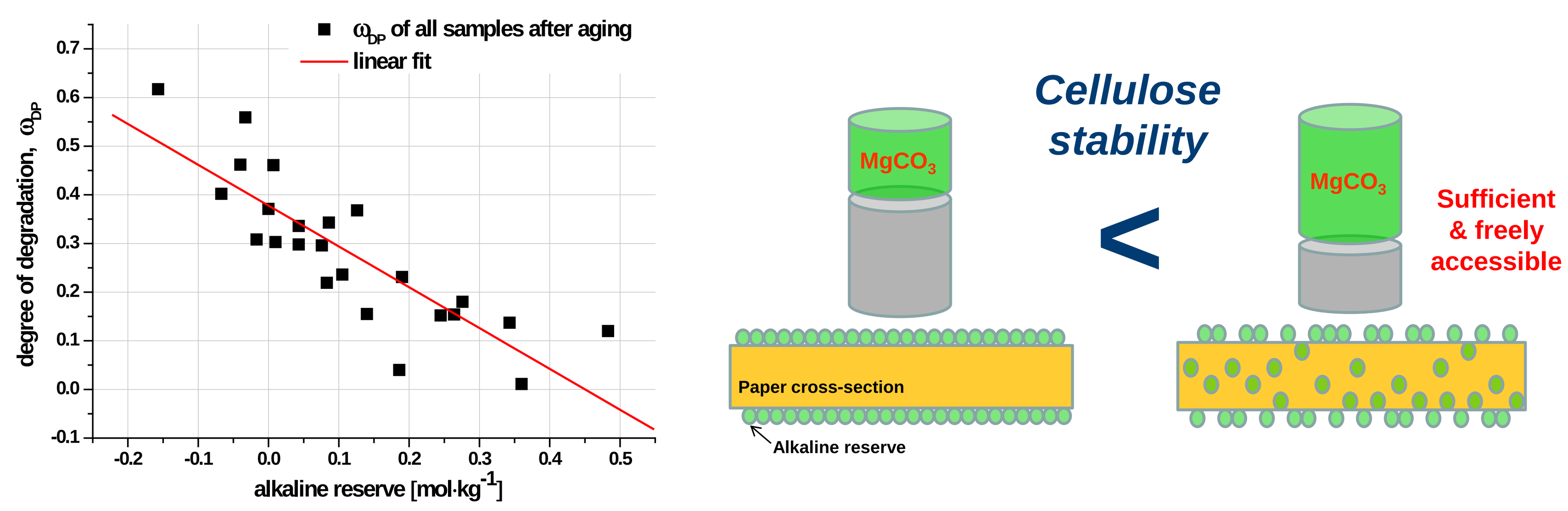


***Fig. 4**: Correlation between degree of degradation (% Mw loss) of original book papers after accelerated aging vs. the amounts of alkaline reserve introduced by mass deacidification. Right image shows schematic description of more effective deposition of alkaline reserve to enhance cellulose stability.*

Conclusions

According to the data presented, *β*-elimination is not a threat in the mass deacidification of naturally-aged book papers thanks to predominant oxidation at chain ends and short chains. Retardation of acid hydrolysis of cellulose after mass deacidification depends on the parameters of alkaline reserve left in the paper.

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