

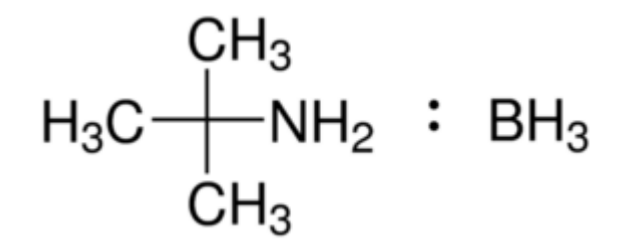
Borane *Tert*-Butylamine Complex: Ageing Properties of Residual Materials Left in Treated Paper Objects



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Introduction

Two main degradation mechanisms contribute to embrittlement and discoloration of paper object: hydrolysis and oxidation of cellulose. Solutions to the problem of oxidation have received less attention, resulting in fewer tools for conservation practice. This project conducted practical research on the use of borane *tert*-butylamine complex for the stabilization and mild bleaching of oxidized cellulose. Samples were treated with different concentrations of the reagent in a rigid aqueous gel and submitted to different rinsing steps before being artificially aged and tested. Results aim to provide guidelines for conservators considering the reagent for the treatment of paper objects.



Borane *tert*-butylamine complex, a stable, mild and selective reducing agent.

Experimental

Samples of Whatman #1 and 1915 newspaper (2.5 x 8cm each) were prepared according to table 1. A total of 20 samples were made for each series, half of which were conditioned at 23°C and 50%RH in the TAPPI paper testing room of the Canadian Conservation Institute (CCI) before being aged in sealed glass tubes for 14 days at 90°C.

Table 1. Experimental Samples Series Preparation

Series number	Type of Paper	Treatment ¹	Rinsing step ²
1	1915 Newspaper	none	no
2	1915 Newspaper	gellan gum only	yes
3	Whatman #1	none	no
4	Whatman #1	gellan gum only	yes
5	1915 Newspaper	0.7% reagent in gel	no
6	1915 Newspaper	0.7% reagent in gel	yes
7	Whatman #1	0.7% reagent in gel	no
8	Whatman #1	0.7% reagent in gel	yes
9	1915 Newspaper	1.4% reagent in gel	no
10	1915 Newspaper	1.4% reagent in gel	yes
11	Whatman #1	1.4% reagent in gel	no
12	Whatman #1	1.4% reagent in gel	yes

¹Treatment of two and a half hours. 2% gellan gum rigid gel used.

²Two hours with a clean 2% gellan gum rigid gel.

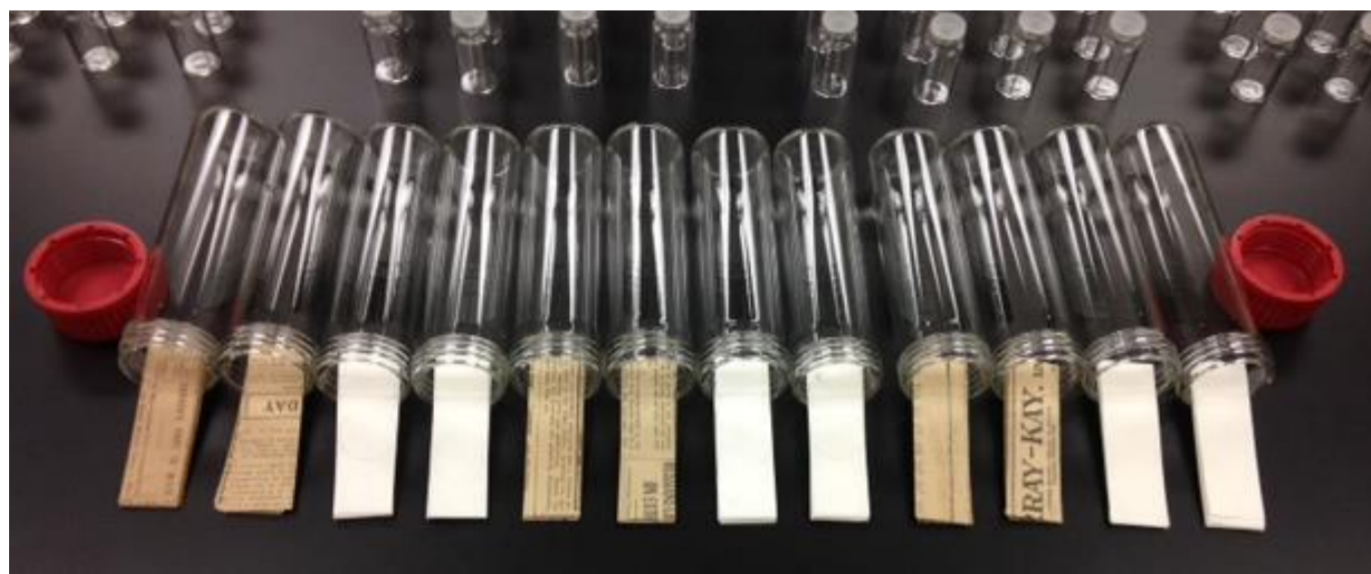


Figure 1. Sample series 1 to 12 being removed from glass tubes after ageing.

CIE L*a*b* colour values, pH and average zero-span tensile strength were measured on aged and unaged samples of each series.

Fourier transform infrared spectroscopy was used to monitor chemical changes throughout the experiment.

Results

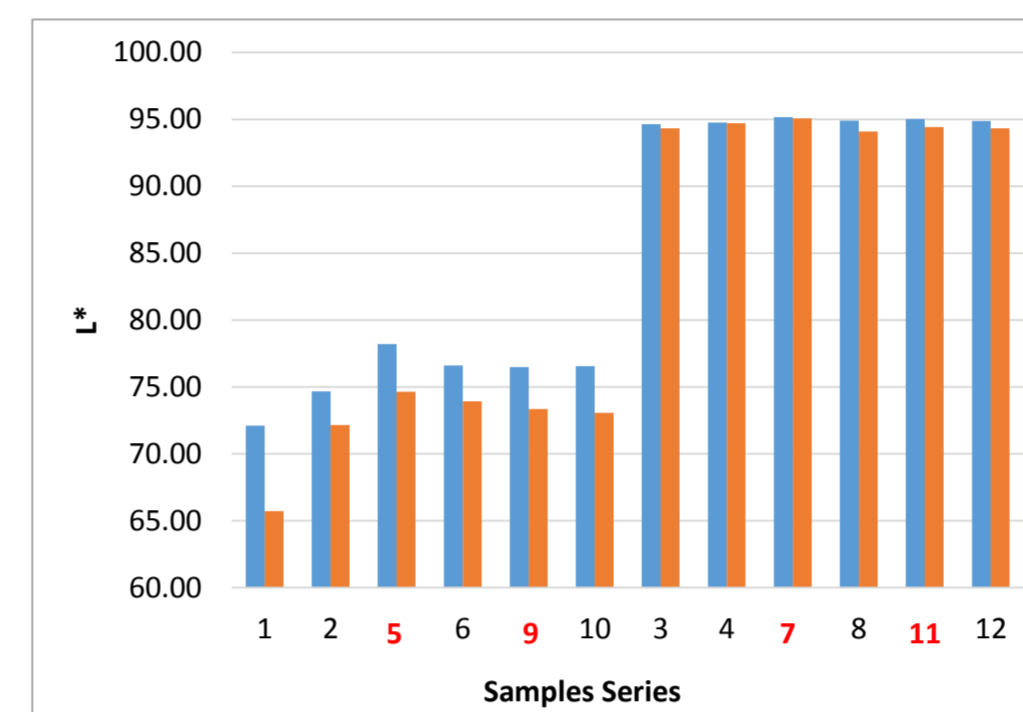


Figure 2a. Average L* values of sample before and after ageing

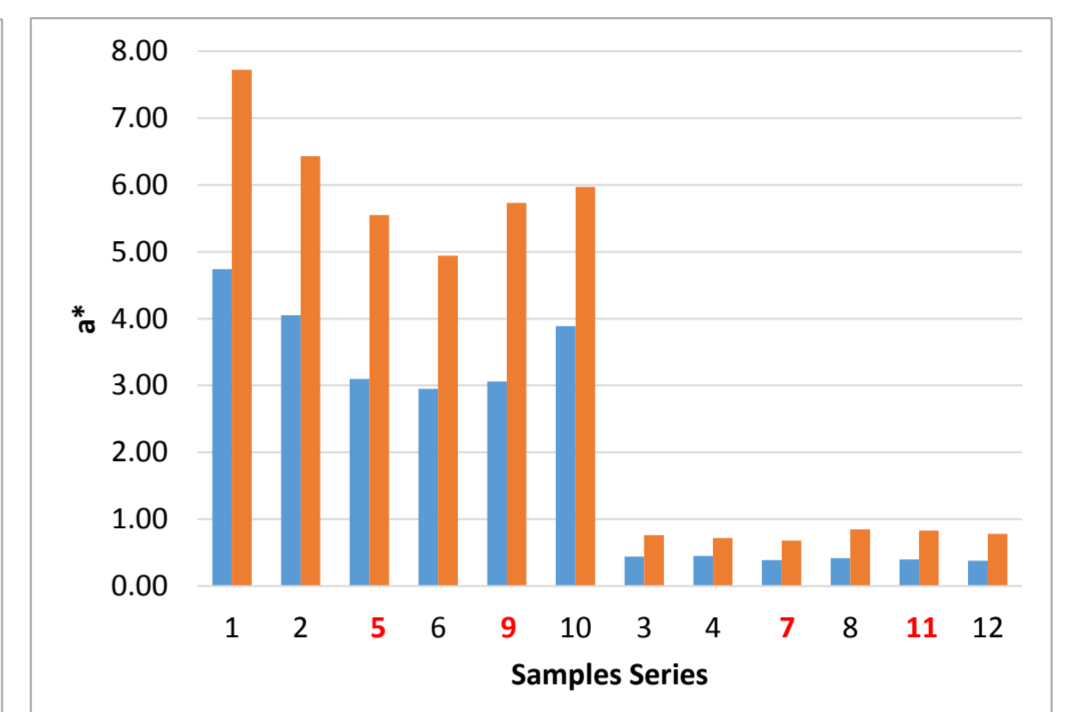


Figure 2b. Average a* values of sample before and after ageing

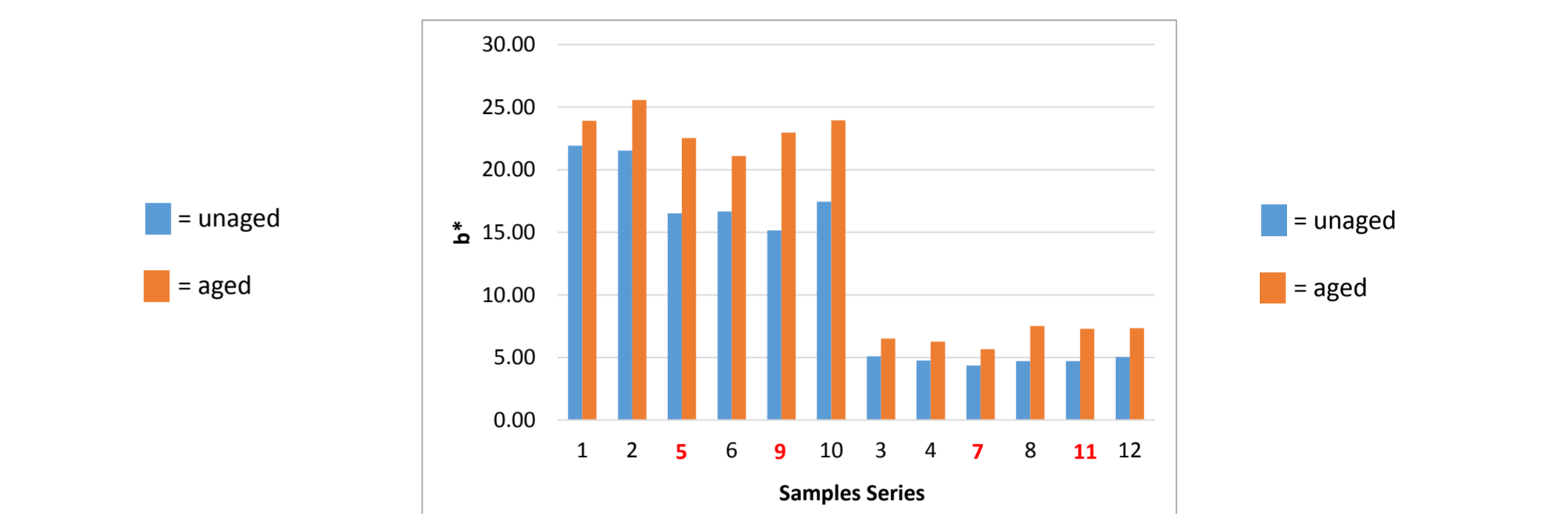


Figure 2c. Average b* values of sample before and after ageing

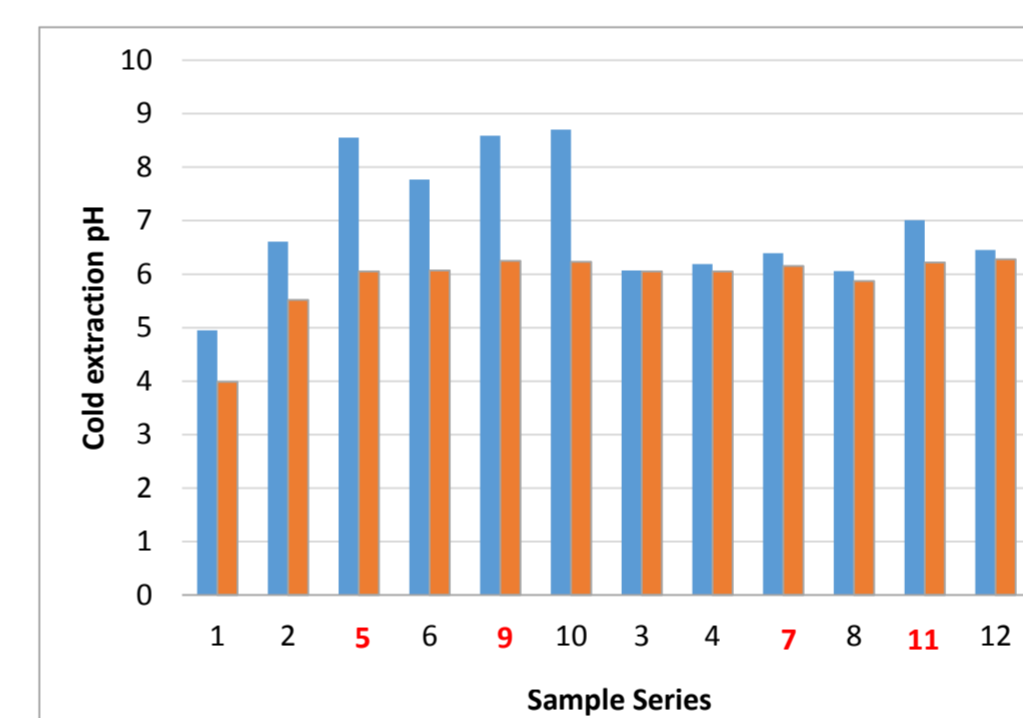


Figure 3. Cold extraction pH of samples before and after ageing

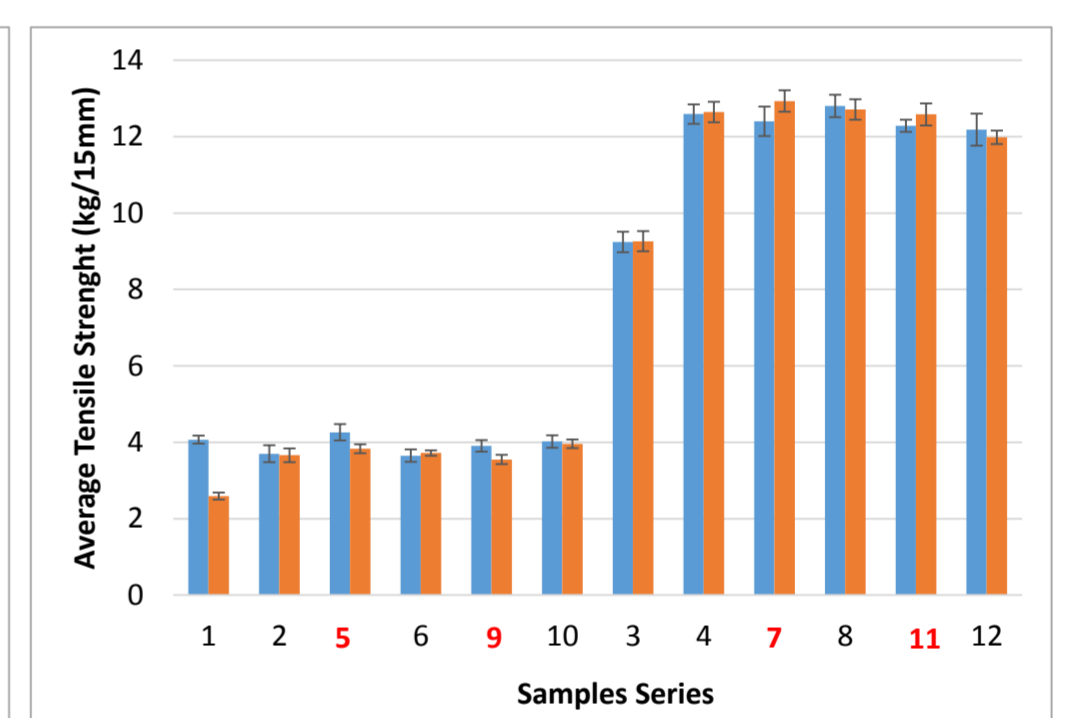


Figure 4. Average tensile strength of samples before and after ageing

Observations

Borane *tert*-butylamine complex can successfully be used in a rigid hydrogel to brighten and stabilize paper samples without pre-treatment. In the current experiment, the use of a 1.4% concentration of reagent did not lead to significant increases in colour change or tensile strength of the tested samples compared to the use of a 0.7% concentration.

Colorimetry (Figures 2a, 2b and 2c)

L*: There is a consistent, observable trend where unrinsed samples of both papers (**series 5, 9, 7, 11**) retain a higher L* value after ageing (second column of each series) than their rinsed counterpart (series 6, 10, 8, 12).

b*: The same unrinsed samples retain a lower b* value after ageing.

a*: No consistent trend is observed for the variation in a* values during ageing.

The observed differences are small, however unrinsed samples seemingly resist yellowing and darkening better during ageing. Further ageing on the samples and experimentation on other substrates could assist in confirming the trends.

Measured pH values, average tensile strength and Fourier transform infrared spectroscopy.

The pH values of unaged samples shown in figure 3 indicate that treatment with the complex leads to a strong increase pH of the newspaper samples and a slight increase for the Whatman #1 paper samples. During ageing, samples treated with the reagent show a similar decrease in pH values which suggests that borane *tert*-butylamine has a buffering action on the materials.

Most unrinsed samples retain a higher average zero-span tensile strength after ageing compared to their rinsed counterparts. This is seen in figure 4 by higher aged values for series **5, 7** and **11** when compared with series 6, 8 and 12. Stronger statistical evidence for this is required and could be obtained from additional ageing of the samples or from more repeats.

Monitoring using FTIR spectra did not allow for observation of new peaks due to reagent residues or the formation of new chemical functions.

Conclusion

There is evidence to suggest that residual reagent in the treated samples does not lead to significant unwanted colour changes or loss of tensile strength. In fact, rinsing samples after treatment seemingly decreases their ability to resist discoloration and loss of tensile strength during ageing. Additional ageing on the samples studied and further experimentation with other paper substrates is recommended to support and better understand the observed trends. Research on the used of the complex on different materials prone to oxidation such as canvas and other textiles is also suggested.

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