

The Effect of Alum and Metals on Paper Aging

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ABSTRACT

The papers in preserved books and archives experience aging which was affected by a variety of factors. Thus, the studies concerning impacts of those factors on paper aging are required. In this research, a simulation of a short-time accelerated paper aging was conducted in order to examine the effects of acid and metals (alum, copper (II) sulfate, copper (II) chloride, and iron (III) chloride) on the natural paper aging for a long time. As a result of experiments, it is found that both acid and metals have impacts on paper aging. Alum resulted in the significant decrease of pH, brightness, folding endurance, and viscosity of paper. Both copper (II) chloride and iron (III) chloride also resulted in the decrease of brightness, folding endurance, and viscosity of paper. In more detail, paper aging by iron (III) chloride showed much more significant than that by copper (II) chloride. The paper aging in case of copper (II) sulfate coexisting sulfate ion, where metal absorbed moisture was higher than in case of paper treated only by alum. This result indicated that metal catalyzes paper aging by acid. Based on these results, it was revealed that both alum and metal are the major factors in paper aging. In particular, paper aging was far more accelerated in case when acid and metals existed in paper at the same time.

Keywords : Alum, metal, copper (II) sulfate, copper (II) chloride, iron (III) chloride, accelerated aging

1. Introduction

Long-time preservation leads books and archives to discoloration or the reduction of folding endurance of paper, which curtail their life span. Discoloration occurs more frequently in paper which was particularly produced from mechanical pulp (1). Aging rate even in acidic paper increases so that its possible preservation span is, at most, 50 years or so (2).

Previous studies show that the major cause of paper deterioration is the acid-catalyzed hydrolysis of cellulose by the acid that exists in paper fiber (1, 3). However, many other factors as well as the acid can also have effects on paper deterioration (1). Specially, among other factors, interests on the impact of metals on paper aging are growing (4).

Lindström (5) reported that metals accelerate degradation of cellulose with oxygen, particularly at

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high temperature. In his experiment, it is revealed that injection of SO_2 and SO_3 into the paper treated by iron, copper, and manganese accelerates paper aging.

In this research, the impacts of alum on paper aging, which is the major cause component of acidic compounds in paper, is compared with the impacts of metals such as iron and copper. Furthermore, the impacts on paper aging, when both metals and acid exist in paper, are examined.

2. Experimental

2.1 Materials

As paper sample, the Whatman Filter paper was employed so as to test the magnitude of paper deterioration. The chemicals treated into paper are alum, copper (II) sulfate, copper (II) chloride, and iron (III) chloride. In addition, to analysis the ICP and IC, the standard solution, such as copper, iron, aluminum, sulfate, and chloride, and HCl was used. (CED) was used with purpose of testing their viscosity.

2.2 Methods

2.2.1 Additives treatment

Paper samples have been deposited for a period of time in 0.02 M of alum solution and 0.01 M of copper (II) sulfate, copper (II) chloride, and iron(III) chloride solutions respectively. After those samples are flattened by the size press, they are desiccated in the cylinder dryer, and then treated by additives.

2.2.2 ICP and IC analysis

The measurement of ICP and IC was conducted to know the amount of accumulated metals, sulfate, and chloride ion. The measurement of ICP and IC concerning quantity of copper, iron, aluminum, sulfate, and chloride showed results as follow (Table 1).

2.2.3 Accelerated aging of paper

Paper samples, which was treated by additives,

Table 1. The contents of copper, iron, aluminum, sulfate, and chloride in the whatman filter paper

	Alum	Copper(II) Sulfate	Copper(II) Chloride	Iron(III) Chloride	(Unit: ppm/g)
Cu	-	21.767	22.600	-	
Fe	-	-	-	14.533	
Al	21.500	-	-	-	
SO_4^{2-}	95.751	13.439	-	-	
Cl^-	-	-	11.768	11.471	

carried out a accelerated aging, in the condition that 90°C of temperature and 50% of relative humidity for 3 and 6 days.

2.2.4 Properties

The aging ratio of each sample, by measuring their pH, brightness, MIT folding endurance, and viscosity before and after aging, was compared.

3. Results and Discussion

3.1 The effect of acid and metals on pH during accelerated aging of paper

The magnitude of paper aging significantly varies depending on the existing acid in paper. Thus, it is necessary to investigate the pH variation in the process of paper aging. Fig. 1 shows the initial pH and changed pH values due to paper aging. Initial pH are different in each sample so that the decreasing rate of pH in the process of aging is measured for comparison of each case (Fig. 2).

The graph in Fig. 2 shows that the decreasing rate of pH of paper treated by copper (II) sulfate is the highest and that iron (III) chloride (II), copper (II) chloride, and alum orderly lead to the high decreasing rate.

The decreasing rate of pH of pure paper sample without treatment by additives is higher than that of paper sample added by alum. This may be attributable

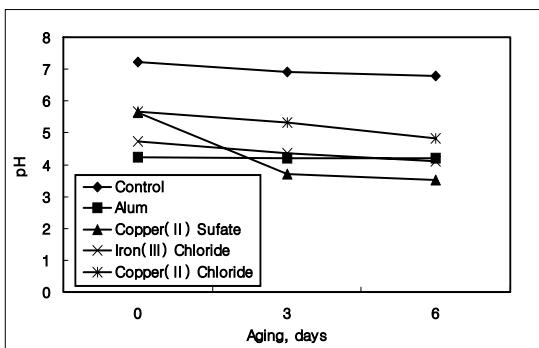


Fig. 1. The effect of acid and metals on pH during the accelerated aging of paper.

to the lower initial pH shown as Fig. 1.

3.2 The effect of acid and metals on brightness during accelerated aging of paper

The effect of each additive on paper brightness in the process of paper aging is examined. As results, the brightness of paper sample treated by copper (II) sulfate decreases the most significantly and, in the order of alum > iron (III) chloride, copper (II) chloride > control (without additives) respectively, the decreasing magnitude of brightness of paper samples is smaller (Fig. 3 and Fig. 4). The brightness of sample paper treated by alum may decrease due to acid produced by reaction of sulfate ion in alum with H₂O.

The lower initial brightness of paper sample treated

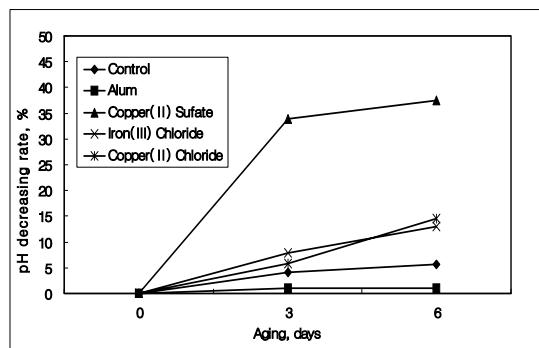


Fig. 2. The effect of acid and metals on the decreasing rate of pH during the accelerated aging of paper.

by iron (III) chloride compared with other additives may be attributed to heat used for desiccation paper sample after flattening paper sample, when the paper samples are produced.

3.3 The effect of acid and metals on MIT folding endurance during accelerated aging of paper

The effect of each additive on MIT folding endurance of sample papers in the process of paper aging is examined.

As shown in Fig. 4 and Fig. 5, copper (II) sulfate results in the most significant decreasing rate of MIT folding endurance of paper. Following copper (II) sulfate, alum > iron (III) chloride, copper (II)

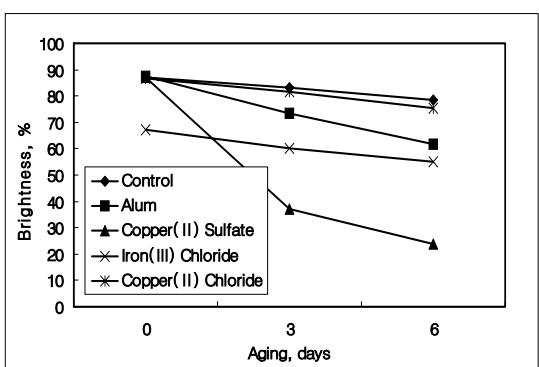


Fig. 3. The effect of acid and metals on brightness during the accelerated aging of paper.

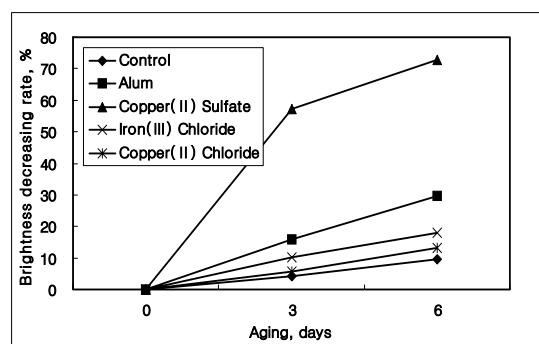


Fig. 4. The effect of acid and metals on the decreasing rate of brightness during the accelerated aging of paper.

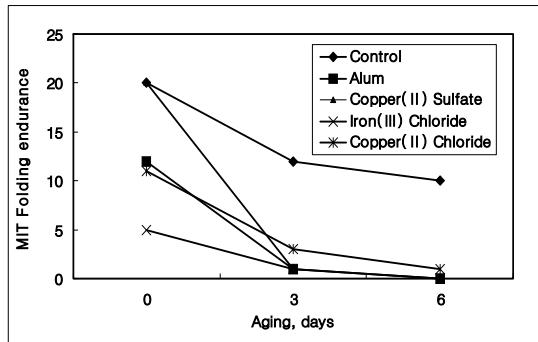


Fig. 5. The effect of acid and metals on MIT folding endurance during the accelerated aging of paper.

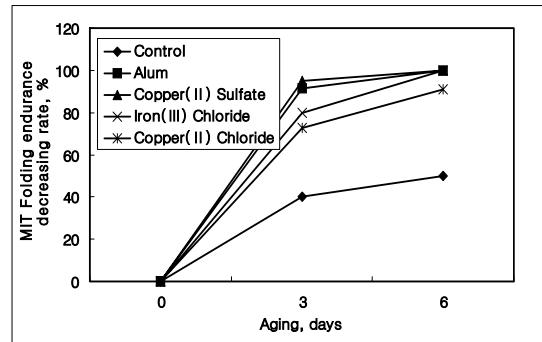


Fig. 6. The effect of acid and metals on the decreasing rate of MIT folding endurance during the accelerated aging of paper.

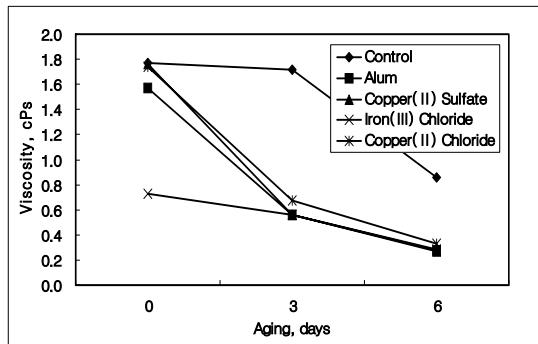


Fig. 7. The effect of acid and metals on viscosity during the accelerated aging of paper.

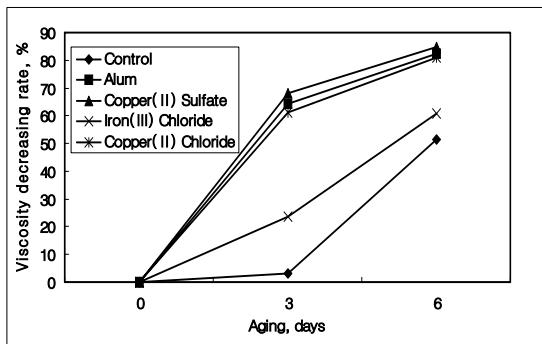


Fig. 8. The effect of acid and metal on the decreasing rate of viscosity during the accelerated aging of paper.

chloride > control contribute to the decrease of MIT folding endurance of paper.

Copper may accelerate paper aging more significantly, according as the MIT folding endurance of paper treated by copper (II) sulfate, which contain both copper and sulfate ion, decreases more than that added by alum, where only sulfate ion exists. In addition, iron may be more effective on paper aging than copper, based on the result that MIT folding endurance of paper sample treated by small amount of iron (III) chloride is much more significantly reduced than that by copper (II) chloride (Table 1).

3.4 The effect of acid and metals on viscosity during accelerated aging of paper

When it comes to impacts on viscosity of paper, the viscosity of paper sample treated by copper (II) sulfate is the most noticeably reduced. In the following order of alum > copper (II) chloride > iron (III) chloride > control, the decreasing rate of viscosity of paper is getting smaller (Fig. 7 and Fig. 8).

By contrast with MIT folding endurance, the viscosity of paper treated by iron (III) chloride is lower than that by copper (II) chloride, attributable to its lower initial viscosity. This may be caused by oxidation by heat as discussed in the previous section.

4. Conclusions

The experiments conducted in this research proved

that acid and metals had significant effect on paper aging. In particular, the contribution of iron to paper aging was much more significant than that of copper. Iron, through oxidation, leads to the lower initial brightness, viscosity, and MIT folding endurance of paper, compared with other additives. In addition, paper aging seems to be accelerated much more actively, in the case that, as the major causes of paper aging, sulfate and metal exist together in paper. Based on these results, it is revealed that metals accelerate paper aging with acid

Literature Cited

1. Byung-Ho Yoon, Preservation and Aging of paper, Paper Technology No.4:1-14, KNUV, Korea (1995).
2. Byung-Ho Yoon, Preservation and Aging of paper (II)-Deacidification technology, Paper Tech-nology No.8:1-13, KNUV, Korea (1996).
3. W. A. Kindler, Jr. and P. Battin, Collection Preservation;The Practical Choices, Paper Preservation, Philip Luner (ed.), TAPPI Press, Atlanta, pp. 35-39 (1989).
4. Chandru J. Shahani and F.H. Hengemihle, Effect of Some Deacidification Agents on Copper-Catalyzed Degradation of Paper, Library of Congress, USA (www.loc.gov/preserv/).
5. T. Lindström, Discussion Contribution: "Slow Fires-It's Paper Chemistry, Physics and Biology", Paper Preservation, Philip Luner (ed.), TAPPI Press, Atlanta, pp. 74-75 (1989).