Changes of Color and Paper Properties in Digital Prints during Accelerated Aging

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Abstract

This paper briefly reports on first part of research in the course of which an attempt was made to evaluate the light fastness of computer prints. An attempt was also made to evaluate the impact of inks and toners used in computer printers on printed paper.

Changes to computer printer colors occurring in the course of exposure in Xenotest 105S were determined by measuring the values of L*, a*, and b* coordinates in the CIELAB color system. Changes were found to be substantial. No substantial influence of computer ink on the pH of the studied papers was established, while the influence on strength properties (tear index and breaking length) was found to vary.

Treating this research as preliminary work, the authors recognize the possibility of greater color light fastness only in the case of black-and-white prints made on the tested laser printer.

Introduction

Computer printing is an extremely fast developing means of generating documents and images. Sometimes it is also a means of creating works aspiring to be works of art. The scale of the trend is sufficiently widespread to influence ways of document storage in libraries and archives

In order to evaluate light fastness of computer prints and the influence of inks and toners used in computer printers on printed paper, suitable accelerated aging tests were conducted. Light fastness of colors was checked by exposing ink jet and laser prints to the xenon lamp, with changes to colors recorded by means of the spectrophotometer Elrepho 2000. The influence of computer printing on paper was evaluated by determining changes to its selected properties occurring in the course of accelerated aging in a climatic chamber. In this paper we report on the first part of research

Preparation of Test Samples

The following two papers were used in the research:

Bodleian, hand-made laid paper made according to the recipe and under the license of the English paper mill Barcham Green & Company (No 2003 in the Anton Glaser catalog, Germany);

Kymlux, machine-made paper for computer laser printers and ink jet printers made by UPM Kymi Paper Mills (Finland).

The choice of the hand-made Bodleian paper used in conservation of paper-based works of art was based on the expected use of the results of this research in a bigger project. This project is devoted to the use of computer printing for reconstruction, which is sometimes used in the course of restoration of historical objects.[1] On the other hand, the Kymlux paper was selected as one of the commonly available papers in the market, which is used for daily printing.

Both papers are high-quality products. They are permanent papers, which means that they meet the requirements of ISO 9706. They do not contain wood pulp or non-bleached cellulose. The Bodleian is made with cotton fiber (75%) and flax fiber (25%), while the Kymlux is made of bleached cellulose. Both papers are neutrally sized and contain an addition of alkaline substances in the amount of at least 2% of $CaCO_3$ (alkaline reserve).

Test samples were prepared by means of one-side printing on both papers with 100% saturated colors making up the main printer colors: yellow, cyan, magenta, and black. Two popular printers were used: Magicolor 2 made by QMS (laser printer) and Color Style 2500 Apple (ink jet printer with ink BCI-21 made by Canon Inc.). Prints were made with the resolution of 600 dpi for the laser printer and 300 dpi for the ink jet printer.

Evaluation of Color Light Fastness

In order to evaluate color light fastness, the test samples as described above on Bodleian paper were exposed to the xenon lamp for 360 hours. Tests were conducted with the use of Xenotest 105S, in which test samples placed on a carousel rotate around the light source, ensuring uniform exposure. Other aging conditions: “open sun” system, with the light reaching test samples filtered through a system of IR and UV filters. Exposure intensity was 1570 W/m^2 (for light wavelength (<800 nm).

For monitoring color changes caused by exposure, measurements of the values of L*, a*, and b* coordinates were used in the CIELAB color system. Measurements were made with the spectrophotometer Elrepho 2000 (made by Datakolor) after 48, 96, 144, 192, 240, and 360 hours of exposure. Measurement parameters were as follows: D.65-10^{o} standard illuminant – observer combination

Table 1 shows changes to the values of L*, a*, and b* coordinates throughout the entire period of exposure. The charts in Figures 1-3 show exposure-related differences in color for different inks, calculated according to the following formula:

$$\Delta E=[(L^*_1-L^*_0)^2+(a^*_1-a^*_0)^2+(b^*_1-b^*_0)]^{1/2}$$

ΔE stands for color difference
L^*_0, a^*_0, b^*_0 stand for values before exposure
L^*_1, a^*_1, b^*_1 stand for values after exposure

Table 1. Changes to values of L*, a*, and b* coordinates for computer colors during 360-hour exposure

	Before aging			After aging		
	L*	a*	b*	L*	a*	b*
Laser:						
yellow	85,6	-5,5	74,3	87,59	0,3	17,2
cyan	59,3	-26,2	-26,2	60,82	-22,9	-19,7
magenta	49,61	53,0	-4,3	49,59	51,6	-2,3
black	33,87	0,7	0,3	33,37	1,3	-1,5
Ink jet:						
yellow	83,73	-0,1	68,3	87,02	1,4	13,0
cyan	55,71	-30,6	-25,0	62,19	-26,8	-10,1
magenta	48,73	56,7	-2,7	88,42	1,5	10,0
black	27,34	3,6	0,3	75,10	5,2	19,0

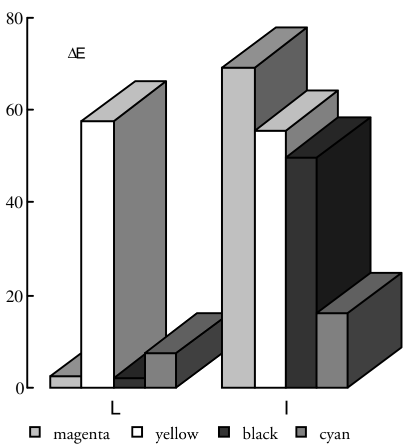

Figure 1. Color difference (ΔE) for computer prints after exposure with xenon lamp for 360 hours

Changes to several inks and toners used in computer printers are substantial. This observation especially applies to the yellow for both printers and the magenta for the ink jet printer (Table 1, Figures 1 and 2).

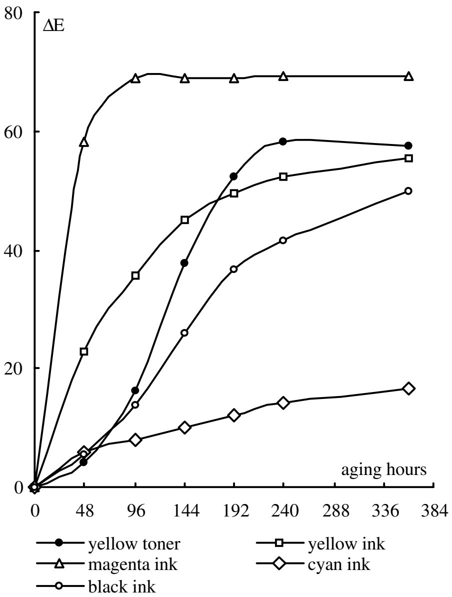

Figure 2. Dependence of color difference (ΔE) on exposure time for least fast computer colors

On the other hand, changes to the black color during exposure are significantly smaller. This observation is especially evident for laser printing for which the color changed slightly during exposure (Figures 1 and 3). This points to good color light fastness during long-term storage of black-and-white prints made on the laser printer.

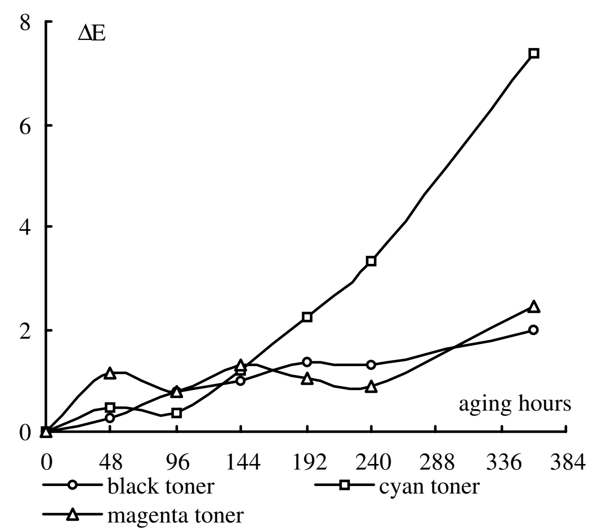

Figure 3. Dependence of color difference (ΔE) on exposure time for most fast computer colors

Table 2. Influence of printing on Ph of paper during accelerated aging (24 hours, 65% RH, 80 C degree)

Samples	pH		
	Before aging	After aging	Difference
Bodleian paper			
Non printed	9,12	9,06	0,06
laser: yellow	9,15	9,12	0,03
cyan	9,06	9,01	0,05
magenta	8,91	8,88	0,03
black	8,96	8,94	0,02
Ink jet: yellow	9,07	9,05	0,02
cyan	9,09	8,97	0,12
magenta	9,02	8,99	0,03
black	9,04	8,93	0,11
Kymlux paper			
Non printed	8,97	8,83	0,14
laser: yellow	8,89	8,77	0,12
cyan	8,99	8,94	0,05
magenta	9,10	8,95	0,15
black	8,91	8,63	0,24
Ink jet: yellow	8,92	8,59	0,33
cyan	8,96	8,84	0,12
magenta	8,59	8,58	0,01
black	8,80	8,73	0,07

Table 3. Influence of printing on tear index during accelerated aging (24 hours, 65% RH, 80 C degree)

Samples	Tear index ($mN*m^2/g$)		
	Before aging	After aging	Difference %
Bodleian paper			
Non printed	1,0380	0,9958	4,07
laser: yellow	0,9088	0,8925	1,79
cyan	0,9188	0,9020	1,83
magenta	0,9246	0,8830	4,50
black	0,9431	0,9205	2,40
Ink jet : yellow	0,9535	0,9407	1,34
cyan	0,9865	0,9498	3,72
magenta	0.9820	0,9411	4,47
black	0,9894	0,9413	4,86
Kymlux paper			
Non printed	0,6930	0,6519	5,93
laser: yellow	0,6388	0,5936	7,08
cyan	0,6402	0,5803	9,36
magenta	0,6431	0,5791	9,95
black	0,6410	0,5681	11,37
Ink jet: yellow	0,6760	0,6261	7,38
cyan	0,6704	0,5958	11,13
magenta	0,6698	0,6478	3,28
black	0,6762	0,6611	2,23

Table 4. Influence of printing on breaking length during accelerated aging (24 hours, 65% RH, 80 C degree)

Samples	Breaking length (m)		
	Before aging	After aging	Difference %
Bodleian paper			
Non printed	4085	4429	8,4
laser: yellow	4067	4154	2,1
cyan	3710	3972	7,1
magenta	3844	4099	6,6
black	3886	4338	11,6
Ink jet: yellow	3602	3866	7,3
cyan	3783	4196	10,9
magenta	3584	3983	11,1
black	3861	4364	13,0
Kymlux paper			
Non printed	4085	4429	8,4
laser: yellow	4067	4154	2,1
cyan	3710	3972	7,1
magenta	3844	4099	6,6
black	3886	4338	11,6
Ink jet: yellow	3602	3866	7,3
cyan	3783	4196	10,9
magenta	3584	3983	11,1
black	3861	4364	13,0

Evaluation of Influence of Printers Toners and Inks on Paper

In order to evaluate the influence of computer printing on paper, test samples of printed Bodleian and Kymlux papers were subjected to accelerated aging in a climatic chamber at 80 degrees Celsius and 65% relative humidity for 24 days. Non-printed paper samples were aged together with printed paper samples for comparative purposes.

The results of accelerated aging evaluated by comparing various properties marked in aged and non-aged papers. Three of these properties are discussed in this paper, including the pH of cold water extract and strength properties, such as breaking length and the tear index.

The pH results are shown in Table 2. The examination of the pH confirmed the alkaline nature of both papers meeting the requirements of ISO 9706, while a comparison of the results before and after accelerated aging indicates that the pH is not substantially affected by the inks and toners used in the tested printers. After aging, all the samples continued to be clearly alkaline, with their pH not lower than 8.5. For the hand-made Bodleian paper, the revealed differences should in fact be considered insignificant, falling within the margin of analytical error.

Tables 3 and 4 present strength parameters of the studied papers shown as average values for both directions.

Based on the results, it is not possible accurately and unequivocally assessing the impact of computer colors on durability properties of the studied papers. Printing alone causes the deterioration of the two investigated properties, with the impact in some cases seeming fairly substantial.

However, for the highest quality paper (i.e., the Bodleian paper made with flax and cotton fibers) we did not observe such changes to deepen during accelerated aging. The tear index for the printed Bodleian paper during artificial aging falls more slowly than for the non-printed paper. Breaking length for both types of paper increases during accelerated aging, with the influence more clearly evident for the cellulose-based Kymlux paper.

Resistance to breaking is connected with the type of glue used for paper sizing. Aquapel 30X was used in the case of the Bodleian paper, and Raisafob in the case of the Kymlux paper. Both glues belong to the AKD (alkyl ketene dimer) group, which with maturation on heating increase paper resistance to breaking. It is also during natural aging during long-term storage that papers sized in such a manner as well as books and magazines made with such papers undergo the same, only much longer, process.

Conclusion

The observations based on the results of this research must be treated as preliminary in nature. Nevertheless, it is clear that it should not be assumed that color computer printouts made on the tested materials and equipment could be stored on a long-term basis. With exposure to light, such printouts are affected by substantial color changes. Therefore, such objects should be stored without exposure to light.

On the other hand, light resistance of black-and-white printouts, especially made by the tested laser printer, seems to be considerable.

Next step is to relate accelerated aging effects to natural aging.

The prerequisite for forecasting the feasibility of long-term storage of computer printouts is the necessity for prints to be made them on high quality papers, which – apart from a high alkaline reserve and neutral sizing – have a good fiber structure. Naturally, we mean the so-called permanent papers meeting the requirements of ISO 11108.

References

1. N. Pauler, Optyka papieru, Instytut Celulozowo-Papierniczy, Lodz 1999, pg. 52-54.

Biography

Marzenna Ciechanska is an art conservator and researching in the field of paper conservation. She is Lecturer at Academy of Fine Arts in Warsaw, Department of Paper Conservation. She obtained an MA degree in art conservation from Academy of Fine Arts in Warsaw, Faculty of Conservation and Restoration of Object of Art in 1990. Now she is conducting project "Digital technology in paper conservation, digital reconstruction of object of art"

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