Changes of Gamut Volume during long-term tests

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Abstract: *The stability of inkjet prints and photographs is influenced by the factors of the surrounding environment. The most harmful factors of environment are the light and the pollutants like ozone. Durability of inkjet prints is besides the ink composition, affected by the type of receiving layer. In this paper will be discussed the lightfastness of inkjet prints and photographs during the long-term ageing tests. Inkjet prints were prepared using both dye-based and pigment-based inks. The samples were exposed to the real conditions. During the test light conditions were precisely monitored. The reflective spectra of samples were measured by spectrophotometer Gretag MacBeth spectrolino. From these data the L*a*b* values were calculated, which were used to gamut visualization as 3D in L*a*b* space. Gamut volume of samples was evaluated by program VolGa, which is a Matlab based utility useful for the monitoring and evaluation of lightfastness of print. VolGa was designed to calculate the Volume of Gamut. This utility currently provides also other features and functions, like gamut visualization, generation of colour difference heat map, calculation of fading rate coefficient, etc.*

Keywords: *inkjet prints, photographs, lightfastness, VolGa, gamut volume*

Introduction

Photographs and inkjet prints are very important component of our lives. Inkjet printing technique has become highly requested reproduction technology and consumers demand stability improvement. These are the reasons, why the durability of inkjet inks and photographs is studied. Their durability is influenced by printing techniques and display/storage environment. There are several ways to determine the light-fastness of prints. First one is accelerating ageing, a method which is quite fast. The simplest way is the exposure of the print to real conditions. This method is time consuming and brings many different problems. On the other hand it gives information about the long-term ageing in real conditions. [1], [2]

In colour reproduction, including computer graphics and photography, the gamut is a certain complete subset of colours. Volume of gamut is one of the options for the monitoring and evaluation of lightfastness of print. It is based on the determination of gamut volume of a freshly printed test chart and subsequent measurement of gamut volume changes during accelerated ageing. Relative gamut volume changes plotted as a function of exposure dose can then be used to determine the fading rate, which can further be used to compare the lightfastness of different media or to predict their lifetime if the end-point criteria are established. This can be used to compare the lightfastness of different types of media or to predict their lifetime if the end-point criteria are established. VolGa is a Matlab based utility designed to calculate the Volume of Gamut. [3], [4]

Methods

The test targets were prepared using two imaging technologies: by inkjet printing technology and by laser light exposure of silver halide photopaper followed by chemical processing (standard process RA-4). Samples were imaging on three various types of media (see Table 1).

Table 1: Overview of used imaging technologies

Sample	Printing technologies	Printer	Inks	Paper
1	RA-4	Noritsu	–	Kodak Royal Digital Paper
2	Dye-based inkjet	HP 500 PS	HP inks	Hewlett Packard
3	Dye-based inkjet	Epson Stylus Photo R220	MIS Associates	Ilford Smooth Gloss
4	Pigment-based inkjet	Epson Stylus Photo R220	MIS Pro	Ilford Smooth Gloss

The prints were let to dry fully. Their reflective spectra were measured by spectrophotometer Gretag MacBeth Spectrolino and they were adjusted to picture frames with glass. In the frame, the photosensitive (TSL235, TAOS) sensor was placed there too. The sensor was connected to digital multimeter UT70B. The frames were situated in a bright sunny corridor. Frequency values collected to a PC from the photosensitive sensor are linearly proportional to the intensity of incident radiation in the range of 5 orders of magnitude, which is sufficient for normal environmental light intensity variations. Humidity and temperature values were automatically measured by humidity and temperature dataloger.

Results and discussion

During long-term ageing of samples the intensities were measured using radiometers (X11 optometer with probe XD-9502 and X97 irradiance meter with probe X9-7). Measurements for each frame took place every week because the results were to certain level dependent on weather. Intensities were measured every month in any atmospheric state. The real condition characterisation was obtained by this way. From these measured values the average monthly intensities were calculated.

Table 2: Values of total radiation dose in UV and VIS spectrum and luminous

Sample	He^{UV} [MJ m^{-2}]	He^{VIS} [MJ m^{-2}]	H [klx h]
1	$1.11 \cdot 10^{-1}$	$2.33 \cdot 10^{2}$	$1.89 \cdot 10^{4}$
2			
3	$1.20 \cdot 10^{-1}$	$2.06 \cdot 10^{2}$	$1.24 \cdot 10^{4}$
4	$1.17 \cdot 10^{-1}$	$1.99 \cdot 10^{2}$	$1.23 \cdot 10^{4}$

The total radiation dose or luminous was obtained by restatement of monthly average intensities. In the table 2 are set particular values of dose of irradiation in UV-A (He^{UV}) and VIS (He^{VIS}) spectrum, and luminous (H). These values are different, because samples were placed in the other frames. The average values of radiation intensities in the UV and VIS spectrum were plotted against months of the years in which the test took place (see fig. 1).

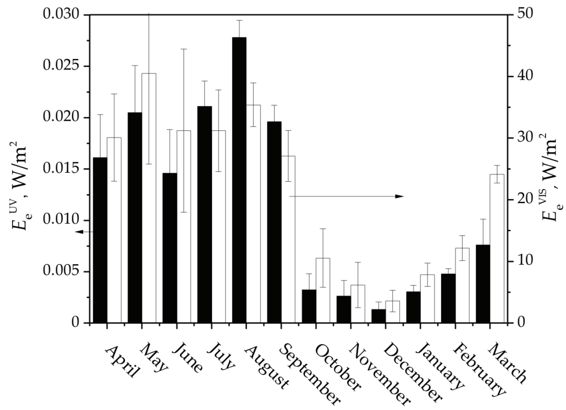
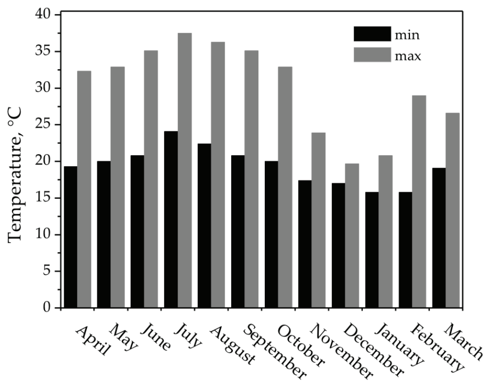


Figure 1: Irradiance in UV and VIS spectrum depending on month

Data of relative humidity and temperature were collected to the dataloger during the whole test. At the left side of figure 2 are illustrated the minimum and maximum values of temperature depending on month. Relative humidity was plotted against months of the years in which the test took place (Fig. 1 right).



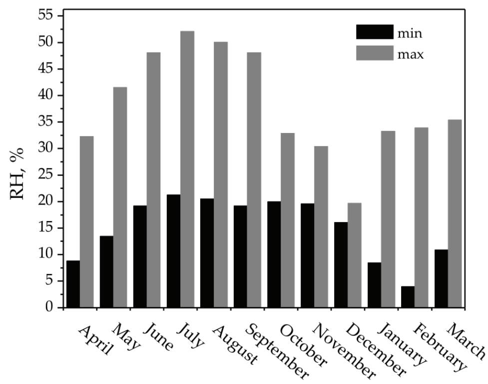


Figure 2: Values of temperature (left) and relative humidity (right) depending on month

During test the reflective spectra of samples were measured. From these spectra the Lab values were calculated. Volumes of colour gamut were calculated from Lab values using program VolGa.

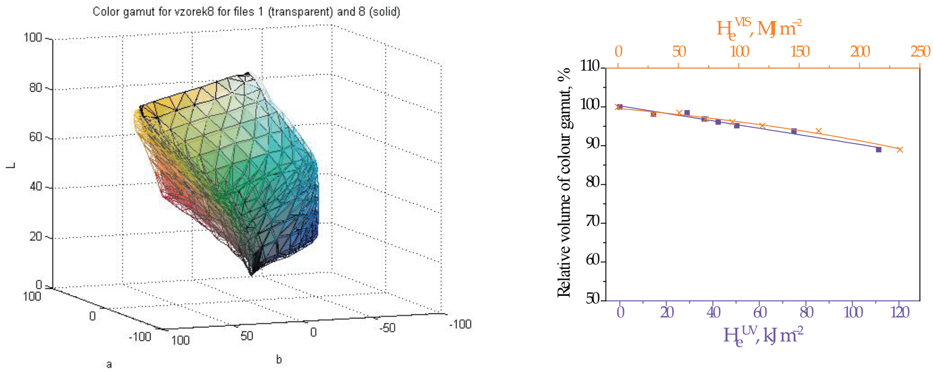


Figure 3: Left is the colour gamut volume change of sample 1. Before exposure (grid); after exposure (full volume). Right: decrease of relative volume of colour gamut depending on radiation dose in UV and VIS spectrum.

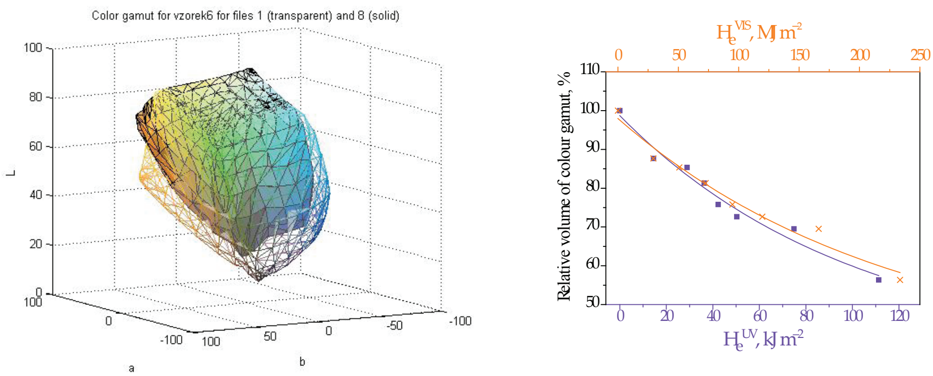


Figure 4: Left is the colour gamut volume change of sample 2. Before exposure (grid); after exposure (full volume). Right: decrease of relative volume of colour gamut depending on radiation dose in UV and VIS spectrum.

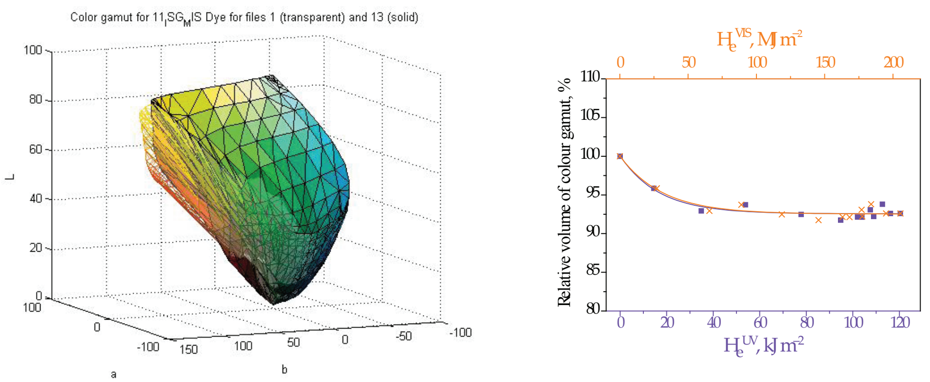


Figure 5: Left is the colour gamut volume change of sample 3. Before exposure (grid); after exposure (full volume). Right: decrease of relative volume of colour gamut depending on radiation dose in UV and VIS spectrum.

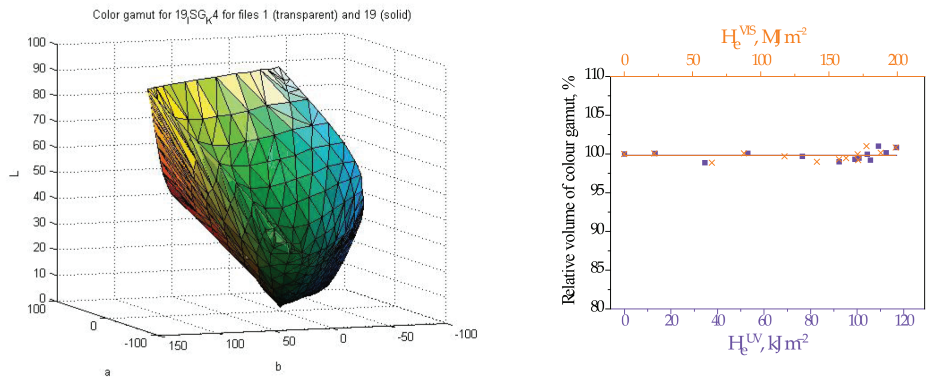


Figure 6: Left is the colour gamut volume change of sample 4. Before exposure (grid); after exposure (full volume). Right: decrease of relative volume of colour gamut depending on radiation dose in UV and VIS spectrum.

At the left side of figures 3–6 are illustrated the changes of gamut volumes before and after exposure. In the case of sample 1, prepared by laser light exposure of silver halide photopaper followed by chemical processing, the rate of degradation of cyan, magenta and yellow dye was approximately the same. The most stable during whole test was sample 4, which was prepared by pigment–based inkjet (Fig. 6 left). On the other hand sample 2, prepared by dye–based inkjet on Hewlett Packard paper, was the most unstable from all of these. In this case magenta and yellow dyes significant faded. Long-term ageing of sample 3 influenced by light led to the degradation of yellow and magenta dye too.

These results are confirmed at the right side of figures 3–6 too. There is the decrease of relative volume of colour gamut depending dose of irradiation in UV and VIS spectrum of sample 1–4. As you can see, decrease of gamut volume caused by light of sample 1 was about 11 %. The most significant changes occurred on sample 2, where gamut volume decreased about 45 %. The degradation of sample 3 had the different continuance. The most significant decrease of gamut volume occurred only at the beginning of exposure, than the degradation process took place very slow. Changes of gamut volume on sample 4 can be considered within the measurement error. These samples were very stable during the whole test.

Conclusion

Light condition analysis showed that the maximum value of UV radiation was very low 4.41±0.79 μW lm^{-1}. In the experimental conditions VIS radiation has the greatest impact on the dye degradation. Mostly long-term ageing influenced by light led to the degradation of yellow and magenta dye. Result is a significant reduction of colour gamut volumes especially in the case of dye–based inkjet technology. We can say that the samples prepared by pigment–based inkjet technology are the most stable. According the data, the sample 4 was much more stable than sample prepared by laser light exposure of silver halide photopaper.

Acknowledgement

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