Weather resistance of inkjet prints on plastic substrates

ABSTRACT

The development of wide format inkjet printers made the technology available for large area commercials. Outdoor advertising uses a wide range of substrate including paperboard, vinyl, canvas, mesh; the material of the substrate itself has to endure the physical and chemical effects of local weather. Weather elements (humidity, wind, solar irradiation) degrade printed products inevitably; plastic products have better resistance against them, than paper based substrates. Service life of the printed product for outdoor application is a key parameter from the customer's point of view. There are two ways to estimate expected lifetime: on site outdoor testing or laboratory testing. In both cases weathering parameters can be monitored, however laboratory testing devices may produce the desired environmental effects and thus accelerate the aging process.

Our research objective was to evaluate the effects of artificial weathering on prints produced by inkjet technology on plastic substrates. We used a large format CMYK inkjet printer (Mutoh Rockhopper II, with Epson DX 4 print heads) to print our test chart on two similar substrates (PVC coated tarpaulins) with grammages 400 g/m^2 and 440 g/m^2.

Specimen were aged in an Atlas Suntest XLS+ material tester device for equal time intervals. We measured and calculated the gradual changes of the optical properties (optical density, tone value, colour shifts) of the test prints.

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Introduction

Novel technologies and ideas evolve as the communication landscape is continuously changing, but outdoor advertising is still an effective, colourful and informative way of broadcasting a message to the receptive public. Poster advertising remains an inevitable element of media campaigns. Large format inkjet printing technology has improved in the last few years and has become more stable and more affordable. Inkjet technology allows the use of solvent based, water based and UV curable inks on a wide variety of printing substrates. For outdoor applications plastic substrates are preferred to paper due to their better resistance against the effects of the weather. Weather resistance, a material's ability to hold up against solar radiation, moisture, rain, wind, etc., is a crucial property in case of outdoor prints. In order to incorporate the idea of weather resistance into their products, printers need to know how certain substrate-ink combinations behave exposed to realistic outdoor conditions. The aging process, the irreversible physical and chemical changes of the product occur as a result of the combined effect of heat, moisture and radiation, environmental ionic and gaseous pollutants, microorganisms etc. (Rahauser and Schönlein, 2011). As an alternative to on-site outdoor testing, these effects can be can be simulated in a controlled, laboratory environment. Laboratory testing is faster, it allows for better control of the parameters of weathering. However, artificial aging methods have to be designed carefully to obtain valid results and conclusions (Gates and Grayson, 1999). The resistance of printed materials to the factors of weathering is determined by the substrate and the technology used. Printing inks represent a complex mix-

ture of different components depending on the printing technology. Individual properties and components of ink formulations such as pigment particle size, additives, may contribute at different rate to the light fastness characteristics of prints (Pugh and Guthrie, 2002).
Our research objective was to evaluate the degradation of plastic inkjet prints under the effects of simulated weather factors. In our experiment accelerated aging is interpreted as the long-lasting and continuous exposure to effects, which act for shorter duration but with the same magnitude as in a natural environment. Two canvas substrates were chosen, both of them recommended for outdoor use by the manufacturers. We investigated the objective factors of the apparent loss of visual quality, the changes of the optical parameters of our test prints after equal doses of radiant exposure.

Methods

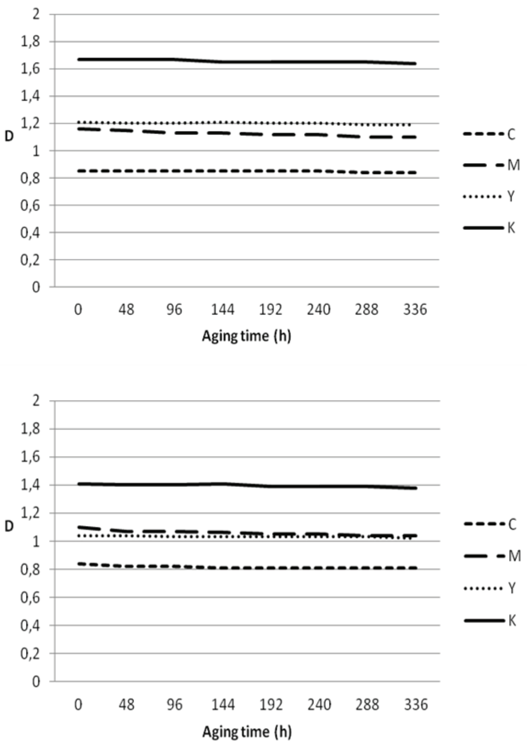
We have chosen two types of PVC tarpaulin substrates ('standard': grammage: 400g/m^2, count: 1000x1000 DIN and 'blockout': grammage: 440g/m^2, count: 800x800 DIN) for the artificial aging experiment. A large format CMYK inkjet printer, Mutoh Rockhopper II, with Epson DX 4 print heads and eco-solvent ink set recommended for outdoor by the manufacturer were used to produce our test prints. For the light fading of the test specimen we used a xenon material tester, Atlas Suntest XLS+. The settings of the test complied with the ISO 4892-2 Method B6 without wetting. Irradiance on the sample was 45 W/m^2 in the 300 nm – 400 nm spectral range, the temperature of the test chamber was 24°C – 65°C during the tests. Individual tests ran for 48 hours, radiant exposure of the specimen was approximately 7776 KJ/m^2 (table 1.), the discontinuous test allows for sample cooling, introducing additional thermal and humidity induced chemical effects between each run. After each 48 hour test run optical characteristics (optical density, tone value increase, colour tri-stimulus values) of the samples were measured, and the colour gamut was determined. Optical properties were measured by X-Rite SpectroEye spectrophotometer and an Eye-One IO automated scanning table.

Table 1
Operating time (t) and the corresponding radiant exposure (H) values on the sample plane of the test chamber after 48 hour steps of aging

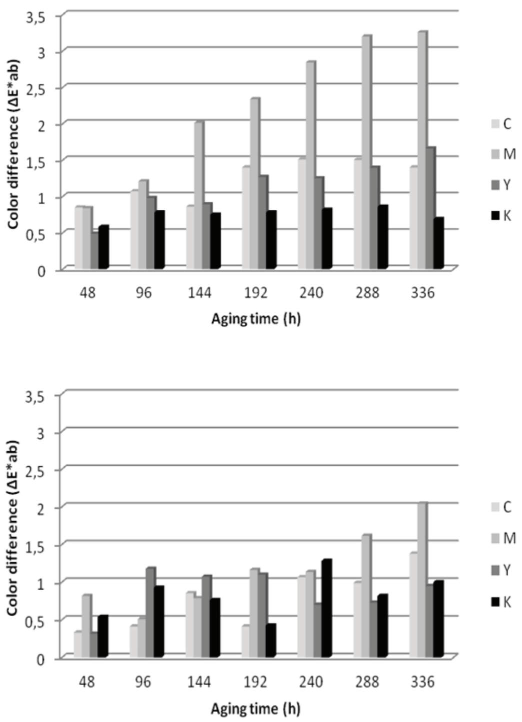
t (hours)	0	48	96	144	192	240	288	336
H (kJ/m²)	0	7776	15552	23328	31104	38880	46656	54432

Results and discussion

Measured optical density values were slightly decreasing with radiant exposure (figure 1.). The visual magnitude of the fading is not predictable by these density values only.



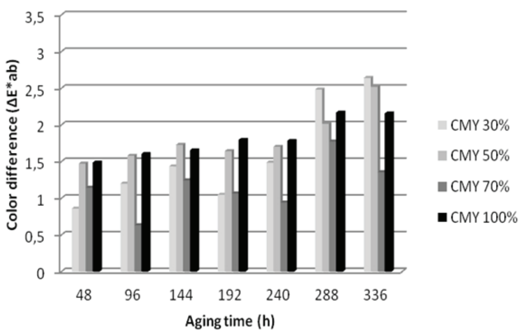
» **Figure 1:** *Optical density values of process colours (C, M, Y, K) during the 336 hours aging process. The diagrams show test prints on substrate 1 (above) and substrate 2 (below)*

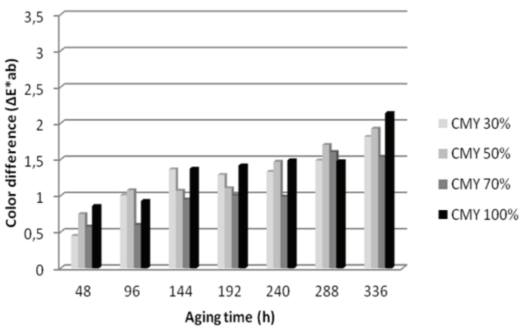


» **Figure 2:** *Colour differences in ΔE*ab units of solid patches of process colours (C, M, Y, K) at 48 hour steps of aging in case of test print on substrate 1 (above) and substrate 2 (below)*

Tone value increase was also measured, they were determined using the Murray-Davis formula which is based on optical density data. We found no considerable changes in the TVI values during the experiment, the most affected was the black process colour with both substrates.

Density values do not provide information on the magnitude of the visually perceivable changes. Therefore we measured the CIELAB values of the colour samples of the test chart and calculated colour differences between the original and the aged specimen in CIE 1976 ΔE*ab units. The results are shown in figure 2 for the four process colours (C, M, Y, K) and figure 3 for the chromatic greys (CMY 30%, 50%, 70%) and black on the two substrates. The magnitudes were in the range of small, but visible colour differences for both substrates. In case of the second substrate the colour shifts of the process colours remained around the threshold (just noticeable) level even after 7 steps of aging. The fade resistance of chromatic greys at different tone levels were also tested, the individual full tones and combinations of the process colours showed colour shifts in the same range. In our previous experiments we encountered visible, large colour differences on coated paper substrates at lower levels of radiant exposure (Borbély et al., 2012).





» **Figure 3:** *Colour differences in ΔE*ab units of chromatic grey and black (CMY 30%, 50%, 70% and full tone) at 48 hour steps of aging in case of test print on substrate 1 (above) and substrate 2 (below)*

Reproducible colour gamut is a useful indicator of print quality. The range of reproducible colours can be calculated by sampling the colour solid (gamut) obtained for a standard colour management profile. We generated printer profiles with X-Rite i1 Profiler software for both test prints based on a built-in CMYK chart with 400 patches, using-Rite EyeOne Pro measurement device together with an i1 iO scanning table. Profiles were created after each step of exposure and loaded to a gamut visualization software, which also estimates the dimensions of the printable gamut in CIELAB colour space volume units. The algorithm searches for the centre of mass of the gamut, which becomes the origin of a cylindrical coordinate system. Then its samples the gamut at uniformly spaced longitudinal and latitudinal angles and stores the lengths of the vectors pointing to the maximum saturation points in the actual direction, and finally interpolates the missing points to get the total volume (Imatest, 2008).

Gamut volumes were expected to decrease with the loss of optical density and colour saturation. Table 2 shows these gamut changes in percentages of the initial gamut volume. The initial gamut sizes of the prints were 33% (substrate 1) and 25% (substrate 2) relative to the standard sRGB gamut.

Table 2
Relative gamut volume as a function of aging time (t) for both substrates

Aging time (h)	Substrate 1	Substrate 2
0	100%	100%
48	98%	96%
92	97%	94%
144	96%	93%
192	95%	92%
240	95%	92%
288	94%	91%
336	93%	91%

Conclusion

In our discontinuous light fading experiment we tested PVC coated tarpaulin substrates printed by wide format inkjet technology. The specimen received 54432 kJ/m^2 radiant exposure in 7 equal doses, optical properties were determined after each period of irradiation with typical instruments and measurement setup. We found no considerable changes in optical density values or in parameters based on optical density. We encountered near and above threshold level colour differences during the colorimetric evaluation of the aged specimen of the set of process colours and chromatic gray mixtures. We experienced a gradual decline of the gamut volume, the cumulative decrease after the 7 stages was within 10% of the initial size.

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