Performance of images printed on PET film in Outdoor Settings
Experiences from the AlburyWide 24|7 Project

Dirk HR Spennemann
Performance of images printed on PET film in Outdoor Settings
Experiences from the AlburyWide 24|7 Project

Dirk HR Spennemann

Albury
December 2019
© 2019. All rights reserved by the author. The contents of this publication are copyright in all countries subscribing to the Berne Convention. No parts of this report may be reproduced in any form or by any means, electronic or mechanical, in existence or to be invented, including photocopying, recording or by any information storage and retrieval system, without the written permission of the authors, except where permitted by law.

Preferred citation of this Report

Disclaimer
The views expressed in this report are solely the author's and do not necessarily reflect the views of Charles Sturt University.

Contact
Associate Professor Dirk HR Spennemann, MA, PhD, MICOMOS, APF
Institute for Land, Water and Society, Charles Sturt University, PO Box 789, Albury NSW 2640, Australia. email: dspennemann@csu.edu.au
Abstract
As part of a public art project, 48 images had been digitally printed on polyethylene terephthalate (PET) film with grey block-out backing, were displayed in shopwindows as well as in outdoor settings that were partially or fully exposed to the elements (walls, balcony balustrades and fences).

For the most part the images performed at or above design expectations. Unexpected heavy, wind-driven rain and hail exerted some localised loss of emulsion that did not affect the overall quality of the image, unless viewed at a close range. The images experienced cumulative damage, however, after prolonged exposure beyond the design period.

Introduction
The photography project AlburyWide 24|7 was designed as a public art exhibition in the pedestrian zones of Albury, a regional service centre in southern New South Wales (Australia). AlburyWide 24|7 used environmental portraiture with a 120º distortion-free panoramic camera, to replicate human vision when capturing the community of Albury at work and play. The project was comprised of two discrete components: an intensive 24-hour shoot, photographing subjects in their spaces of work as well as a series of contextual images, of people and settings shot during November 2018 (Spennemann, 2019). The second part was a public art exhibition, with all images (of 1950 x 841 mm size) on public display in pedestrian zones throughout Albury. While the majority was placed in shopwindows, a small number were mounted on walls or suspended from balcony balustrades and fences and therefore partially or fully exposed to the elements. Initially conceptualised as a four-week public exhibition, the project ran from 16 April to 11/16 June 2019 (dates of image removal varied), with some images in shopfronts remaining on display until end of November 2019.

The aim of this document is to place on record the performance of these images in outdoor settings that are partially or fully exposed to the environment.

Design brief
While the majority of the publicly-displayed images was placed in shopwindows, a small number were to be mounted on walls or suspended from balcony balustrades and fences and therefore partially or fully exposed to the elements. The expectation was that printed images had to survive for the duration of the exhibition period of four weeks.

As budget limitations prevented the printing on aluminium panels as initially projected, alternative cost-effective solutions had to be found. Local printing options, however, were limited. The print medium did not matter for the majority of images, as they were to be mounted on the inside of shopwindows. As the exhibition period was conceptualised as four weeks, it was decided to find a printing solution that provided a modicum of weather resistance to those images to be mounted externally, with the understanding that some images might need to be replaced if they deteriorated prematurely. Based on long-term personal experience of local weather, the projected weather events for the projected exhibition period mid-April to mid-May were short-duration to medium-duration rainfall events (Bureau of Meterology, 2019). Extreme downpours and hail events are generally rare.

Images mounted at street level, on fences, or on walls, might be subject to opportunistic vandalism in the form of graffiti, esp. tagging and image modification with felt-tip markers, or of outright destruction (e.g. tearing down an image). This risk was deemed unmitigable and therefore accepted.
Performance of images printed on PET film in Outdoor Settings. Experiences from the AlburyWide 24/7 Project

Literature review

A number of studies have examined the archival quality of inkjet photoprints delivered by a range of printer types on various papers (Burge, 2014; Dobric, Mirkovic, & Bolanca, 2010; J. LaBarca, 2013; J. E. LaBarca, 2010; Venosa, Burge, & Nishimura, 2011; Wilhelm, 2002, 2006; Wilhelm & McCormick-Goodhart, 2000).

Environmental factors of heat, humidity and air pollution are known to lead to the decay of digitally printed images (Burge, 2014). While the UV stability of the inks is a major concern for long-term preservation (Burge, 2014; Venosa et al., 2011; Wilhelm, 2006), the main factor influencing the performance of short-term exhibits in outdoor environments is the binder and solvent used in the emulsion. Studies have shown that even minor variations in the chemical composition of the binder will result in substantive changes to image quality and longevity (Zhang, Liu, Cao, & Jing, 2015).

Numerous ink/media combinations have shown to have poor humidity fastness, especially, when stored or displayed in commonly encountered conditions of high relative humidity (let alone outdoors) (Wilhelm, 2002). In situations of high humidity or total immersion, damage to prints tends to greater in instances where coatings are soluble and where ink ‘bleed’ (Jürgens & Schempp, 2010).

Experimental work on short-term (10 min) immersion showed that i) pigment based inks tend to be water-fast, whereas dye-based inks will ‘bleed’ and that “immersion damages swellable coatings, while microporous coatings … on a plastic film … withstood immersion and subsequent drying with hardly any physical changes” (Jürgens & Schempp, 2010). Prints made with solvent-based inks on PVC (polyvinyl chloride) material were the least affected. In addition, movement of the printed medium can aid in the cracking and delamination of the emulsion and subsequent flaking of print surface layers (Burge, 2014).

The prints

All images were printed by OfficeWorks Albury on Charti instant dry white 230 gsm polyethylene terephthalate (PET) film with grey block-out backing (product code CHWPF23061030) using a Canon imagePROGRAF PRO-4000S inkjet plotter. Pigment-based Canon Lucia Pro PFI-1700 inks were used. This film is primarily designed for internal display as banners and poster stands and is marketed as such by the printing section of OfficeWorks. External use was not recommended by the supplier and therefore the application was conducted at own risk.

Pre-testing

As some images were to be displayed externally, it was important to understand how susceptible the prints would be to vandalism and environmental impacts (primarily in the form of rain). Prior to production, an A4-sized test sheet was obtained, cut up into five equally-sized sections (swatches) of 6 x 21 cm, which were subjected to various treatments. One swatch was retained as a control.

In a dry state, the emulsion was found to be moderately scratch resistant (fingernails) but could be damaged with sharp implements (keys). To simulate a short-duration but heavy rain event which is the most common event in Albury, a dry image was exposed to 3 min water treatment with a garden hose with the nozzle set to ‘jet’ pointed at a 90° angle. No impact was observed compared to the control swatch. Two sample swatches were allowed to soak in tap water for 24 hours, and then subjected to similar treatments. In the soaked state, the emulsion was much more prone to physical impact damage (fingernails, keys) but appeared resistant to the waterjet treatment.
Performance of images printed on PET film in Outdoor Settings. Experiences from the AlburyWide 24|7 Project

Fig. 1. Image #7 as mounted on the balustrade.

Fig. 2. Image #8 as mounted on the southern face of a wall.

Fig. 3. Image #12 as mounted on the northern face of a fence.

Fig. 4. Image #31 as mounted on the balustrade.

Fig. 5. Image #36 as mounted on the eastern face of a fence.

Fig. 6. Image #41 as mounted on the western face of a fence.
Display locations

Albury is a rural service centre in southwestern NSW. The six images discussed here were mounted at a number of outdoor locations (Table 1) (for a map of the locations, see Spennemann, 2019, pp. 76–77). Mounting was achieved with plastic cable ties threaded through metal eyelets. On one of the balustrades (#7) the top row of cable ties was anchored with additional adhesive tape to prevent slippage.

Table 1. Details of location and display conditions of the images discussed in this report

<table>
<thead>
<tr>
<th>Nº</th>
<th>Location</th>
<th>Co-ordinates</th>
<th>Substrate</th>
<th>Cover</th>
<th>Facing</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>#7</td>
<td>CSU campus</td>
<td>-36.038083, 146.991200</td>
<td>balustrade</td>
<td>partial</td>
<td>north</td>
<td>Fig. 1</td>
</tr>
<tr>
<td>#8</td>
<td>Cardo Drive</td>
<td>-36.032592, 146.951614</td>
<td>wall</td>
<td>full</td>
<td>south</td>
<td>Fig. 2</td>
</tr>
<tr>
<td>#12</td>
<td>Mitchell St</td>
<td>-36.076776, 146.913950</td>
<td>wire mesh fence</td>
<td>none</td>
<td>south</td>
<td>Fig. 3</td>
</tr>
<tr>
<td>#31</td>
<td>David St</td>
<td>-36.077331, 146.921318</td>
<td>balustrade</td>
<td>partial</td>
<td>east</td>
<td>Fig. 4</td>
</tr>
<tr>
<td>#36</td>
<td>Thurgoona St</td>
<td>-36.075182, 146.909255</td>
<td>wire mesh fence</td>
<td>none</td>
<td>east</td>
<td>Fig. 5</td>
</tr>
<tr>
<td>#41</td>
<td>Victoria St</td>
<td>-36.076871, 146.913832</td>
<td>wire mesh fence</td>
<td>none</td>
<td>west</td>
<td>Fig. 6</td>
</tr>
</tbody>
</table>

Meteorological conditions encountered during the exhibition period

Albury experiences an average annual rainfall of 700 mm and average seasonal temperatures average daily minima of 2.7°C in winter (recorded minimum -4.0°C) and daily maxima 31.2°C in summer (recorded maximum 44.6°C). The closest weather station with climatic data for the exhibition period 16 April to 11/16 June 2019 was Albury Airport (station nº 072146) (Bureau of Meterology, 2019). The recorded daily maximum and minimum temperature (read at 3 pm), as well as rainfall data (9 am to 9 am) have been plotted in Fig. 8. The grey shaded area indicates the exposure beyond the four-week ‘design period.’ The temperature dropped from the high 20s in April, to the high 10s in May and the mid-10s in June. The average daily temperature fluctuation during the total exhibition period was 12.0±3.9°C (range 3.9–19.7°C) (Fig. 9).
Fig. 8. Meteorological conditions encountered during the exhibition period, showing daily maximum and minimum temperature, as well as rainfall (dots). The grey area indicated the exhibition period beyond the initially projected period.

Fig. 9. Daily temperature fluctuation and rainfall (dots) during the exhibition period. Also shown is the average daily temperature with one standard deviation (shaded area).
Rainfall was patchy, with half of the days having no rainfall and only 19.4% of the days having rainfall greater than 2 mm. Four major rainfall events occurred, on 21 April (16 mm), 2 May (52 mm), 10 May (17.4 mm), and 12 June (12.6 mm). The major rainstorm that occurred on 2 May was a high localised, prolonged and heavy downpour, accompanied by up to 40 km/h winds. During this event a short-duration (<5 min) hail event occurred with hailstones of less than 5 mm in size.

The short-duration rainfall event in the afternoon of May 10 was accompanied by a major hailstorm with hail pellets larger than 5 mm, accumulating up to 10 mm of hail on the ground in selected areas of Albury’s CBD (Pohlner, 2019a, 2019b).

**Performance—Effects of Rain and Hail**

The combination of saturation and subsequent softening of the emulsion, combined with the physical impact of heavy rain and/or hail on a softened emulsion caused some damage that accelerated as time went by. The image mounted on a wall and protected, to a certain extent, by the waves, was largely unaffected. This does not apply to two of the images that had been fence-mounted (images #12 and #41) and the two that had been mounted on balustrades (images #7 and 31).

A good example of the rain effects is an image that had been mounted externally to the first floor balustrade of the Albury Townhouse Motel, facing East (Fig. 4). The image had been fastened with plastic cable ties but given the nature of the faux-cast iron railing, the one corner of the mounted print had marginally slipped over time, sufficient to causing a small bulge at the bottom right quarter of the image (Fig. 22). It is that sloping section on the upper side of the curvature which was most exposed to the impact of rain drops and shows exfoliation of the emulsion, whereas the other parts of the image are unaffected (Fig. 23). At this location both longitudinal striations and point impact were observed (Fig. 30b). The emulsion in this section exhibited flaking (Fig. 30c) as well as craquelure of the emulsion. The remainder of the image was largely unaffected.
Following the heavy rainfall event on 2 May, the images placed outdoors were inspected for damage. The wall-mounted and balustrade-mounted images exhibited no visible impact, while two fence-mounted images showed limited damage (Fig. 12, Fig. 24), mainly in the form of small circular impact points (Fig. 15, Fig. 17, Fig. 26). This spatially very confined loss of emulsion was caused by the oblique-angled high velocity impact of wind driven rain droplets and, to a lesser degree, hail pellets. At that point in time, there was little discernible difference of decay between the west-facing image (image #41) and the north-facing image (#12).

Image #12 was reassessed a day after the hail-storm event of 10 May (Fig. 13). The image showed considerable loss of emulsion, in particular along the upper sections (Fig. 21). The physical impact of the hail pellets caused localised peeling of the emulsion (Fig. 20). That decay differentially impacted primarily the lighter shades whereas the black, fully saturated parts of the image were much less affected (Fig. 21). It can be surmised that the previous days’ rainfall has caused parts of the emulsion to swell and thus make it more susceptible to physical impact.

Re-assessment and re-photography of the two fence-mounted images after six weeks of exposure (on 30 May) showed considerable damage on the west-facing image (image #41) with a vertically aligned loss of emulsion (Fig. 25). This damage was not uniform, but differentially impacted primarily the lighter shades (Fig. 27), whereas the black, fully saturated parts of the image were much less affected. This is well exemplified by the selective loss of the light shaded emulsion in the QR codes (Fig. 34). The north-facing image (#12) on the other hand showed a near total loss of light shaded areas and also an extensive loss of the darker shaded areas (Fig. 14, Fig. 17, Fig. 19). The contrast between the state of preservation of this image at 3 May and 30 May is stark (compare Fig. 15 with Fig. 17, compare Fig. 18 with Fig. 19; all images photographed while mounted on the fence).

The condition of the images at the end of the observation period (after 9 weeks) showed extensive deterioration throughout (Images #7, #12, #31m $1, Fig. 28–Fig. 30). Similar effects were noted on the other images (Fig. 28a–b; Fig. 29a). Adhesive failure of the emulsion was well developed (Fig. 28c–g; Fig. 29d–g) with the light shades differentially more affected.

It can be surmised that the continual expansion and contraction cycles both led to a fractionation of the originally homogenous emulsion layer and to a loss of adherence to the PET film base. This is well exemplified in Fig. 28g. In addition, the resulting lack of adhesion can be demonstrated with physical impact on a dry surface. The heavy rain and the resulting raindrops running down the image cause incremental erosion of the surface, leading to the observed vertical striations. Moreover, while images that had never undergone wetting and drying cycles subsequent to the original printing are fully touch and moderated scratch resistant (see p. 2), even gentle rubbing of the fractionated surface (Fig. 30e) led to abrasion of the residual emulsion, in particular the light toned sections (Fig. 30f), while the dark sections showed more resistance (Fig. 30g). As the emulsion would have been uniformly applied during the manufacturing process, it can be speculated that ink penetrating the emulsion affects the binder’s ability to adhere to the smooth surface of the PET film, even after repeated hydration and dehydration cycles.

The underlying decay process appears to be the following continuous cycle: hydration (direct via rain or indirect via high humidity) > softening and subsequent swelling of the emulsion > drying > shrinking of the emulsion > differential contraction > structural failure including craquelure of the emulsion and separation from PET film > hydration.

The mere cycle of hydration-dehydration, however, does not fully account for the observed decay, as the wall mounted image #8 attests. Although sheltered from direct rain and hail impact by an overhanging eave, the image was exposed to the same humidity cycles yet exhibited no macroscopically visible craquelure or other damage to the emulsion.
Decay caused by physical impact of rain droplets and hail pellets on a rehydrated and swollen emulsion manifests itself in the form of discrete point impact. The observed craquelure has to be attributed to mechanical forces, i.e. flexing of the PET substrate during the dehydration process. The likely cause of the observed adhesion failure is the cumulative effect of differential rates of expansion and contraction of the emulsion versus the PET film.

**Fig. 11. Schematic representation of decay cycle and external influences**

**Performance—Effects of Wind**

The high winds on 2 May in particular, affected two of the three images mounted on fences. A corner of image #12 (with an eyelet) tore from the rest of the image. The image could be repaired with backing tape. Image #41, mounted on a fence at a right angle to image #12 (Fig. 7) survived the wind event without damage. Image #36 on the other hand was completely shredded (Fig. 37, Fig. 38) and had to be replaced.

The ability of the wind to push unfettered against the back of a fence-mounted image caused the mounted print to move (flap), weakening the eyelets (in the case of #12) and eventually, due to extensive movement, tear the PET film (#36). Even though during initial mounting on the fence care had been taken to tighten the cable ties to the maximum extent (in order to minimise bowing of the image), a chain link (‘cyclone mesh’) fence inevitably exhibits movement that creates some slack and slippage and therefore movement of the mounted image occurred.

Once the image #36 had been torn, the partly detached sections flapped in the wind, causing the PET film to be chafed (Fig. 40), scratched (Fig. 41), and creased (Fig. 42). The damage, while spatially extensive, was limited to a plethora of minor scratches, with the exception of creasing, where larger sections of the emulsion were affected.

**Performance—Functionality of the QR codes**

A QR code had been added to the bottom left corner of each image, to provide passers-by with a link to the project website that contained, inter alia, a map (both an interactive and a printable version) to all display locations. Fig. 31 to Fig. 36 show different stages of degradation of the emulsion at the end of the observation period. The image mounted on an external wall (image #8, Fig. 31) showed
virtually no macroscopically visible deterioration (Fig. 32), while the image mounted on a western-facing fence (image #41, Fig. 33) showed the loss of the light coloured areas, with the dark-pigmented areas largely unaffected (Fig. 34). The QR code was still functional at this state of decay. The damage was much more extensive on the north facing image (image #12) which exhibited extensive loss of emulsion (Fig. 35) including much of the deep black sections (Fig. 36). At this state of decay, the QR code was no longer functional.

**Performance—Graffiti**

Contrary to the artist’s expectations, none of the images were graffitied or otherwise vandalised.

**Conclusions**

The images exposed to the environment experienced a gradual decay of the emulsion caused by continual hydration–dehydration cycles. The nature of environmental exposure, primary governed by the type of mounting, influenced the degree of decay. Wall-mounted images showed the least decay as they were sheltered from both direct rain and hail (being under the eaves) and experienced no wind-induced flexing. Balustrade-mounted images were exposed to impact from both direct rain and hail and experienced some flexing which resulted in some loss of emulsion during the drying cycle. Fence-mounted images performed the worst, as they were exposed to direct rain and hail impact and also experienced extensive flexing which resulted in extensive loss of emulsion during the drying cycle.

For the most part, however, the images performed at or above design expectations. The heavy, wind-driven rain and hail that was experienced during the initial four-week exhibition period was outside the design parameters. These events exerted some localised loss of emulsion which affected the overall quality of the image when viewed at close range (at 3 m distance or less). It did not significantly affect the overall image when viewed from a distance beyond 3m. Thus balustrade-mounted images as well as street level, fence-mounted images (if seen across the street or a from a passing car) performed well, even though the environmental conditions were outside the design parameters. The images experienced cumulative, image degrading damage, however, after prolonged exposure beyond the design period.
Fig. 12. Image #12 as mounted on the fence 3 May.

Fig. 13. Image #12 as mounted on the fence 11 May.

Fig. 14. Image #12 as mounted on fence 30 May.
Performance of images printed on PET film in Outdoor Settings. Experiences from the AlburyWide 24/7 Project

Fig. 15. Image #12 as mounted on fence 3 May (detail).
Image taken 18 days after exposure to the environment and one day after the heavy rainfall event of 2 May.

Fig. 16. Image #12 as mounted on fence 11 May (detail).
Image taken 25 days after exposure to the environment and one day after the heavy hail event of 10 May.

Fig. 17. Image #12 as mounted on fence 30 May (detail).
Image taken 45 days after exposure to the environment.
Fig. 18. Image #12 as mounted on fence 3 May (detail).
Image taken 18 days after exposure to the environment and one day after the heavy rainfall event of 2 May.

Fig. 19. Image #12 as mounted on fence 30 May (detail).
Image taken 45 days after exposure to the environment.

Fig. 20. Detail of image #12 as mounted on fence 11 May (detail).
Image taken 25 days after exposure to the environment and one day after the heavy hail event of 10 May.
Fig. 21. Detail of Image #12 as mounted on the fence 11 May. Image taken 25 days after exposure to the environment and one day after the heavy hail event of 10 May.
Performance of images printed on PET film in Outdoor Settings. Experiences from the AlburyWide 24/7 Project

Fig. 22. Image #31 as mounted on the balustrade at the end of the observation period.

Fig. 23. Image #31 as mounted on the balustrade (detail).

Fig. 24. Image #41 as mounted on the fence 3 May.

Fig. 25. Image #41 as mounted on fence 30 May.

Fig. 26. Image #41 as mounted on fence 3 May (detail).

Fig. 27. Image #41 as mounted on fence 30 May (detail).
Fig. 28. Detachment and deterioration of the emulsion at the end of the observation period. Images #7 (left column) and #12 (right column)
Fig. 29. Detachment and deterioration of the emulsion at the end of the observation period. Image #41
Fig. 30. Detachment and deterioration of the emulsion at the end of the observation period. Image #31
Fig. 31. Image #8, full QR code.

Fig. 32. Image #8, detail of QR code.

Fig. 33. Image #41, full QR code.

Fig. 34. Image #41, detail of QR code.

Fig. 35. Image #12, full QR code.

Fig. 36. Image #12, detail of QR code.
Fig. 37. Image #36. Wind damaged print as mounted on the fence 4 May 2019.

Fig. 38. Image #36. Reassembled wind-damaged print.

Fig. 39. Image #36. Wind-damaged print (detail).

Fig. 40. Image #36. Wind-damaged print (detail).

Fig. 41. Image #36. Wind-damaged print (detail).

Fig. 42. Image #36. Wind-damaged print (detail).
Endnotes

1. The product description states “Charti Instant Dry Bright Glossy White Polyester Film is a 7ml [sic] thick high glossy PET film with grey block-out backing which delivers exceptional high quality poster and photographic images with super high colour gamut. This media is ideal for high quality advertising prints such as trade show graphics, photographic prints, graphics for retractable roll up display stand, retail point of sale poster prints, pop-up graphics and mount onto any adhesive panels. This polyester film can be un-laminated. For longer lasting result, hot or cold lamination is recommended.” (CHARTI, 2019).


3. The QR code linked to this web page:

References


