Potential for Colorant Transfer Between Adjacent Inkjet Prints During Water Emergencies

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Abstract

The purpose of this experiment was to test and analyze potential colorant transfer to and from adjacent inkjet prints during water emergencies. The relationship between inkjet papers prone to severe ink bleeding ("Bleeders") and those resistant to water damage ("Receivers") was tested. The two types of prints (Bleeder and Receiver) were submerged in different configurations for one hour. After one hour of immersion, prints were removed from the water and placed on a drying rack for 24 hours. Prior to submersion, color measurements were taken on the unprinted borders of each print. Quantitative color measurements were again taken after drying to determine the ΔE (change) in color from before and after submersion, therefore representing consequent color transfer. The experiment was divided into three parts: dye prints, pigment prints, and prints in polyester sleeves. The test configurations included side-by-side (not in contact) and stacked front-to-back. Drying variations included prints separated or unseparated. Prints submerged side-by-side (not in contact) showed little to no cross bleeding from one to the other. It was also found that separating stacked prints from one another at the time at which they are removed from water will minimize colorant transfer between the two. However, the best option to prevent colorant transfer in prints is to store them in polyester sleeves.

Introduction

The purpose of the experiment was to determine if prints that are insensitive to bleed are harmed by adjacent prints prone to bleed during water emergencies. Inkjet printed photographs on fine art papers were examined. This experiment and its results should help institutions responding to a flood or water emergency where there has been accidental submersion of inkjet prints in water. This experiment will also help in the development of proper precautions for print storage prior to water emergencies. If print collections, specifically inkjet, are of mixed characteristics, some could irrevocably damage others depending on their proximities. In water emergencies, prints sensitive to bleed could harm adjacent prints that are not typically sensitive to bleed or colorant transfer. This project examined colorant transfer from dye prints to pigment prints, which is not known to have been done before. Similar research has been done in the areas of: system sensitivity by Daniel Burge and Jessica Scott [2], drying methods by Martin Jürgens and Norbert Schempp [3], and in recovery of water damaged materials by Peter Adelstein, Daniel Burge, and Janette Hanna [1].

Methodology

Test Samples

Two types of samples were used in every part of the experiment: "Bleeders" and "Receivers." The purpose of the experiment was to analyze how colorant transfer from the Bleeder influences the Receiver. A pictorial image was printed on each Bleeder in order to provide colorant for bleed (Figure 1). Originally, a pictorial image was printed on the Receiver as well, but it too bled unexpectedly, confounding the results, resulting in the choice of using a blank Receiver.

Test Configuration

Bleeders and Receivers were placed in different arrangements within different trays filled with either 0.8 Liters (Small Trays) or 1.8 Liters (Large Tray) of room temperature tap water. Samples were removed from the water after one hour. Small stainless-steel screens were placed over the samples as weights, keeping them fully submerged in water. Receivers were arranged in different configurations with respect to the Bleeders in order to illustrate the effects of the Bleeder's bleed on the appearance of both itself and the Receiver.

After one hour of immersion, all prints were removed from their trays to be air dried on a drying rack for 24 hours at 21C/50%RH. The drying rack consists of fiberglass screens with airflow on all sides.

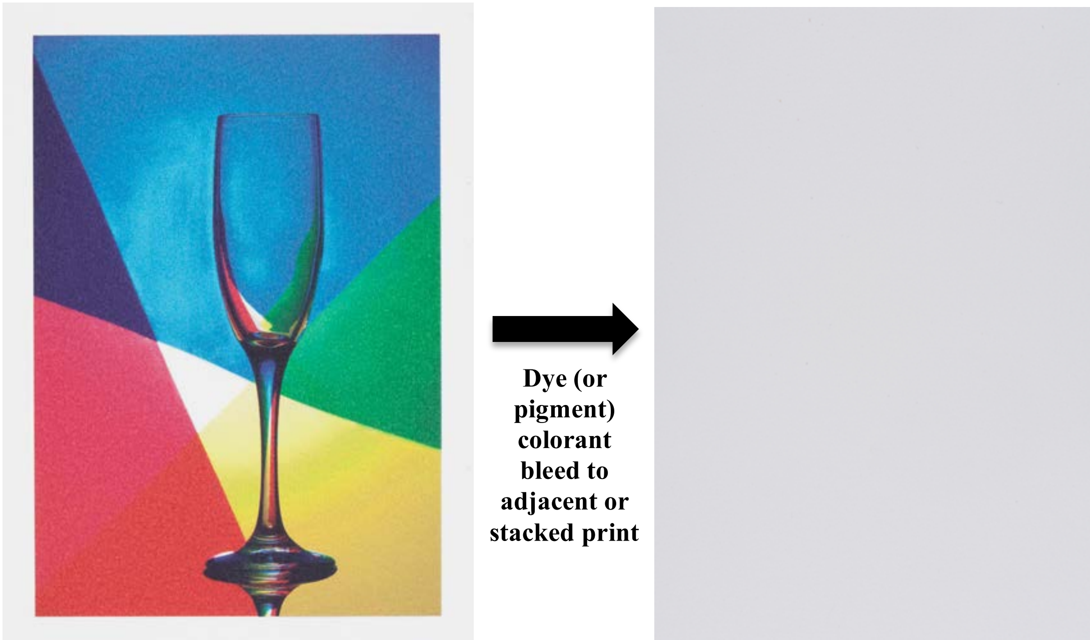
Measurements

Quantitative color measurements were taken for all three parts of this experiment. Prior to initial submersion, color measurements were taken on each border of every print at Dmin (minimum density; unprinted, whitest area). A Gretag Spectrolino spectrophotometer was used to measure these values. Colors were measured in terms of the L*a*b* color space (a 3D color-opponent space). L* is the luminance (brightness) value, measured on a scale of 0-100 (0 being black, 100 being white), a* is measured on a scale of -100 to +100 (negative values being green and positive values red) and b* is measured on a scale of -100 to +100 (negative values being blue and positive values yellow). The ΔE value represents the change in overall color based off these three values from before to after immersion and 24 hours drying. The smaller the ΔE, the fewer color changes occurred.

Measurements were taken on each border of each individual print, meaning that if the bleed was only present on one edge, the averaged Delta E value may not fully reflect the color change in that print. However, simultaneous visual assessments would prevent inappropriately drawn conclusions. Each print, both Bleeders and Receivers, measured to be 4x5.5 inches overall, each with ¾ inch border.

Part I: Dye Prints

Part I involved putting two different print types ("Receivers" and "Bleeders") into multiple configurations in water, and analyzing change after 24 hours of drying. A matte-coated fine art inkjet paper was used as the "Receiver." A dye ink on uncoated fine art inkjet paper was used as the "Bleeder," as these are known to bleed immediately and heavily upon contact with water. A pictorial image (See Figure 1) was printed on the same paper.



Dye Bleeder *Unprinted Receiver*

Figure 1: Relationship of Bleeders to Receivers

Table 1, Figure 2, and Figure 3 explain and illustrate the configurations of samples for Part I. For Part I:

- Dye Bleeder is always uncoated fine art
- Unprinted Receiver is always matte coated fine art

Table 1: Part I Sample List

TRAY #	SAMPLE TITLE	CONFIGURATION
1	Dye Bleeder	Alone (Individual trays) Removed from water after 1 hour Dried for 24 hours
2	Unprinted Receiver	Alone (Individual trays) Removed from water after 1 hour Dried for 24 hours
3	Dye Bleeder, Unprinted Receiver	Indirect Contact (Side by Side) Removed from water after 1 hour Dried for 24 hours
4	Dye Bleeder, Unprinted Receiver	Stacked front to back Removed from water after 1 hour Separated and dried for 24 hours
5	Dye Bleeder, Unprinted Receiver	Stacked front to back Separated after 24 hours of drying stacked

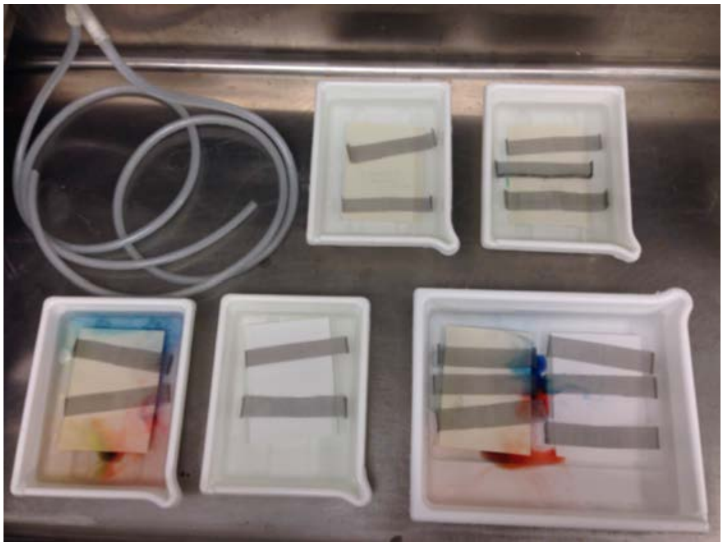


Figure 2: Image of Sample Configurations Upon Immersion

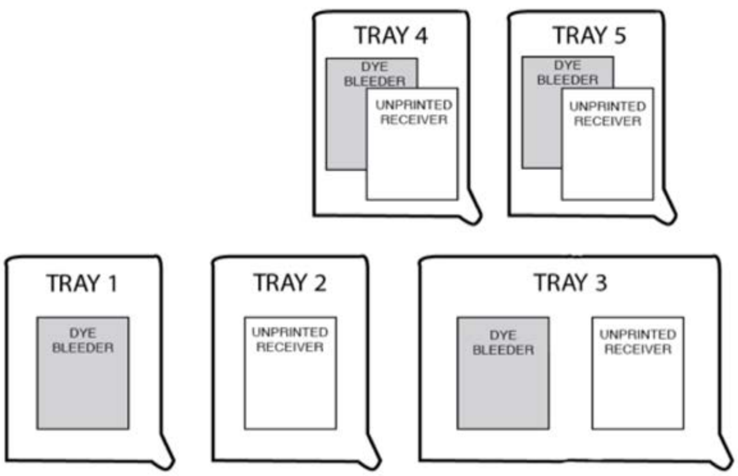


Figure 3: Corresponding Diagram of Part I and Part II Sample Configurations

All prints were placed face down to prevent the stainless-steel screens from damaging the surfaces of the prints. Tray 1 held one copy of the Bleeder and Tray 2 held one copy of the Receiver (Figure 3) for control. Tray 3 held one Bleeder and one Receiver side by side to demonstrate transfer between adjacent non-contacting prints.

The print configurations of both trays 4 and 5 were identical in submersion arrangement, but differed in drying methods. In both Trays 4 and 5, the pictorial image printed on the front side of the Bleeder was placed against the uncoated backside of the Receiver. This front to back configuration mimics the most common method of storing photographic prints in stacks. The Dye Bleeder and Unprinted Receiver in tray 4 (Table 1) were removed from the water after one hour and separated in order to dry as individual prints. The Dye Bleeder and Unprinted Receiver in tray 5 were also removed from the water after one hour, but were left in direct contact with one another until twenty-four hours after immersion.

Part II: Pigment Prints

In Part II, pigment ink on matte-coated fine art inkjet paper was used as the "Bleeder" and unprinted matte-coated fine art inkjet paper was used as the "Receiver." This allowed for the little bleed typically caused by this print type to be assessed in the same configurations as with dye above. Similarly to Part I, pictorial images were printed on the front side of each Bleeder. Part II of this experiment included the same sample list, configurations, and drying times as Part I.

For Part II:

- Both the Pigment Bleeder and the Unprinted Receiver utilized matte-coated fine art paper.

Part III: Dye and Pigment Prints in Enclosures

Four samples were used in Part III: two Bleeders, and two Receivers. The first Bleeder was a dye pictorial image on uncoated fine art inkjet paper. The Unprinted Receiver (matte-coated fine art inkjet paper) was placed in a polyester sleeve to protect it from the bleeding dye print. No pictorial image was printed on the Receiver. The Dye Bleeder was stacked front to back with the polyester sleeve holding the Receiver.

In the second case, both the Bleeder and Receiver were matte coated fine art inkjet paper. This "Pigment Bleeder" included a pictorial image and the Receiver was blank. The Receiver was again placed within a polyester sleeve to protect it from bleed.

Results/Discussion

Part I: Dye Prints

Control (Trays 1 & 2)

The control (Figure 4: Unprinted Receiver) did not visually change as a result of immersion. The Delta E value (change in color from before and after immersion) for the Unprinted Receiver was only 1 (Table 2), a minute change that is insignificant and likely unnoticeable to the human eye. On the other hand, the Delta E for the Dye Bleeder was much larger and noticeable.

Dye Bleeder
Tray 1

Unprinted Receiver
Tray 2

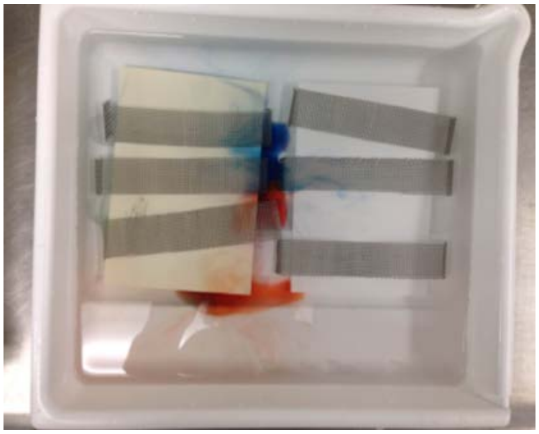
Figure 4: Controls (Trays 1 and 2)

Table 2: Delta E of Controls

SAMPLE	**ΔE**
Dye Bleeder	20
Unprinted Receiver	1

ADJACENT PRINTS (TRAY 3)

When a print prone to bleed was placed in indirect contact with one that does not bleed, the appearance of the non-bleeding sample (Receiver) was not noticeably altered. The Dye Bleeder and Unprinted Receiver were placed in the same tray in indirect contact (Figure 5). As expected, there is visible, overt bleed coming from the Bleeder. The Dye Bleeder, similarly to the control Dye Bleeder discussed previously, lost significant colorant and detail due to bleed. The Delta E for the Dye Bleeder was 12, while the Delta E for the Unprinted Receiver was only 1 (Table 3).



Dye Bleeder and Unprinted Receiver
1 Hour of Immersion

Dye Bleeder *Unprinted Receiver*

Figure 5: Tray 3 Samples (Adjacent)

Table 3: Delta E of Tray 3 Adjacent Prints

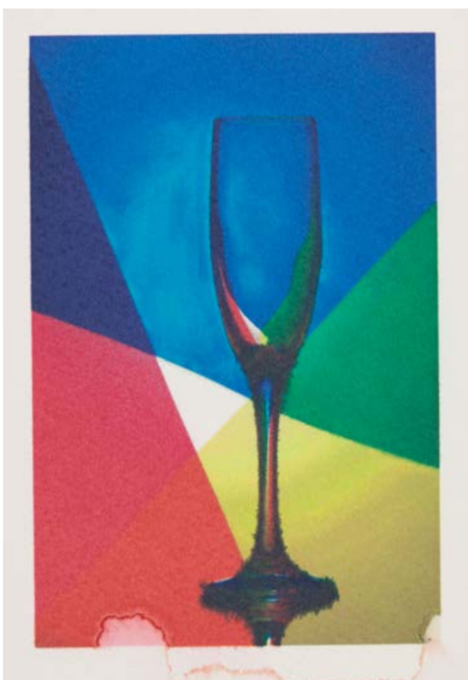
SAMPLE	**ΔE**
Dye Bleeder	12
Unprinted Receiver	1

STACKED AND IMMEDIATELY SEPARATED (TRAY 4)

In this configuration, the Dye Bleeder and Unprinted Receiver were stacked front to back during immersion. After one hour of immersion, they were removed from the water and separated to dry individually. The Dye Bleeder did not bleed significantly as a result of the immersion. This is extremely important due to the fact that previous research suggested that prints once thought to be unrecoverable might actually be salvageable. Separating stacked prints immediately after they have been removed from water has a significant, positive impact on prints prone to bleed. When the control Bleeder (Figure 4) was immersed without being stacked, its appearance was severely degraded, further indicating that the stacked configuration can minimize image bleed. The colors of the original pictorial image printed on the Bleeder also became visibly darker as a result of immersion (Compare figures 1 and 6). Due to immersion, the image-forming dots of dye on the Bleeder, which make up the pictorial image, spread to fill in the intermediary white spaces. As a result, the color appears darker and detail is lost (Figure 6A). There was noticeable but little bleed onto the backside of the Receiver.

The bleed also did not reach the front of the Receiver. The stacked configuration, however, allowed for color transfer to the back of the Receiver.

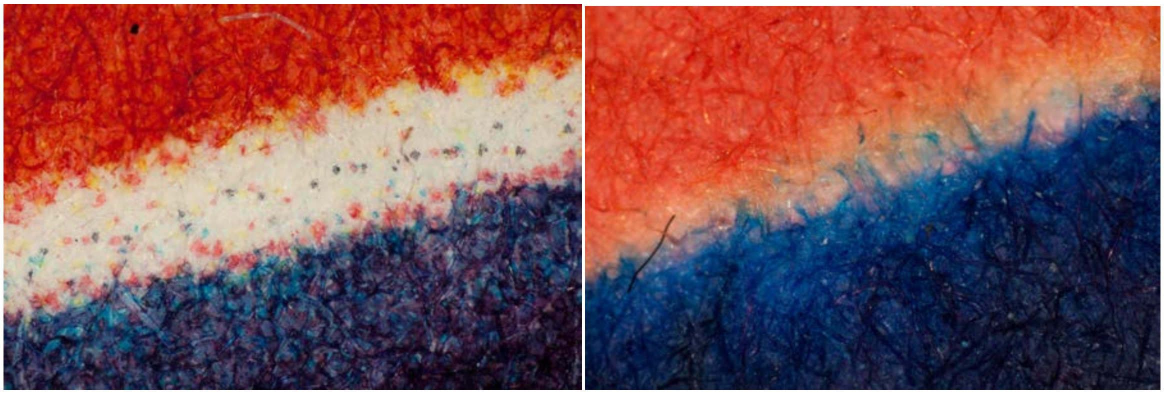
Finally, the Delta E for both the Dye Bleeder and the Unprinted Receiver was 3 (Table 4), meaning that there was color change for both samples, but it was not significant.



Dye Bleeder

Unprinted Receiver

Figure 6: Tray 4 Samples (Stacked; Immediately Separated)



Before Immersion *After Immersion*

Figure 6A: Micro View of Colorant Spread in White Areas due to Immersion.

Table 4: Delta E of Tray 4 Stacked Prints (Separated Immediately)

SAMPLE	**ΔE**
Dye Bleeder	3
Unprinted Receiver	3

STACKED AND SEPARATED AFTER 24 HOURS (TRAY 5)

The Dye Bleeder and Unprinted Receiver were again stacked front to back during immersion; however, the two samples were left to dry for 24 hours in the same stacked configuration in which they were immersed. As a result of this drying method, the colorant transfer from the Dye Bleeder was glaring and significantly changed the appearance of the verso of the Unprinted Receiver (Figure 7). The Delta E values corresponding to the Dye Bleeder and Unprinted Receiver further reflect this major change.

Visual differences due to the two different drying techniques utilized by the tray 4 samples versus that of the tray 5 samples are illustrated in Figure 8. The most colorant transfer of all experiment configurations occurred in the case of the tray 5 samples, which were left to dry in contact with one another.

Dye Bleeder *Unprinted Receiver*

Figure 7: Tray 5 Samples (Stacked; Separated After 24 Hours)

Table 5: Delta E of Tray 5 Stacked Prints (Separated After 24 Hours

SAMPLE	**ΔE**
Dye Bleeder	8
Unprinted Receiver	19

Figure 8: All Samples 24 Hours After Immersion (See diagram below).

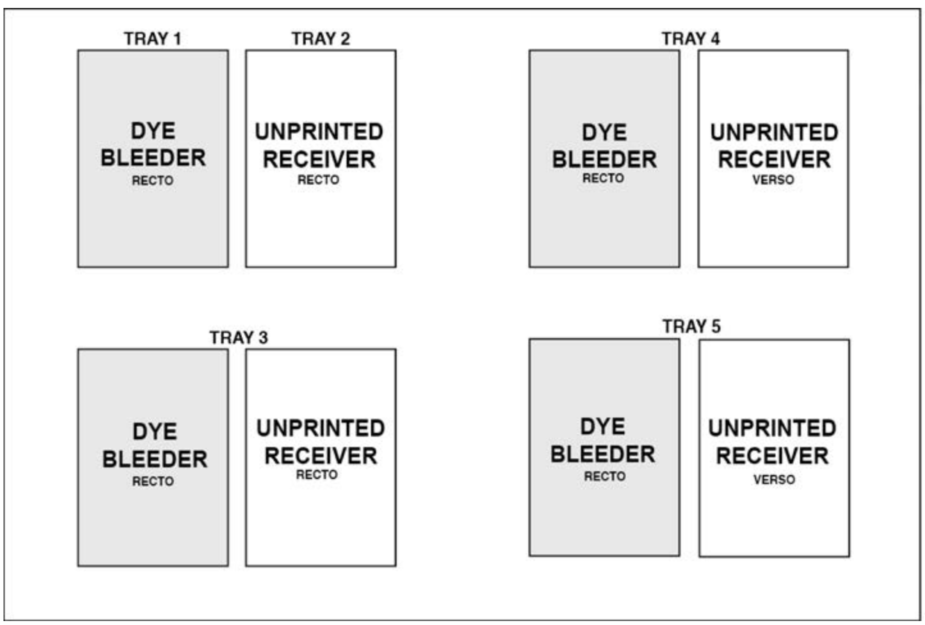


Figure 9: Corresponding Diagram of Sample Types.

PART II: PIGMENT INKJET

Matte-coated fine art inkjet paper was used as both the Unprinted Receiver and the Pigment Bleeder. The same immersion configurations, measurements, and drying methods from Part I were utilized in Part II.

CONTROL (TRAYS 1 & 2)

Each sample had it's own tray and was immersed on its own. The Pigment Bleeder was just barely altered (Delta E of 1) (Table 6) as a result of immersion. The control (Unprinted Receiver) did not bleed or suffer from colorant transfer, as it was not in any type of contact with a Bleeder during immersion. (Figure 10)

Dye Bleeder
Tray 1

Unprinted Receiver
Tray 2

Figure 10: Controls (Trays 1 and 2)

Table 6: Delta E of Controls

SAMPLE	ΔE
Pigment Bleeder	1
Unprinted Receiver	1

ADJACENT PRINTS (TRAY 3)

Pigment Bleeder *Unprinted Receiver*

Figure 11: Tray 3 Samples (Adjacent)

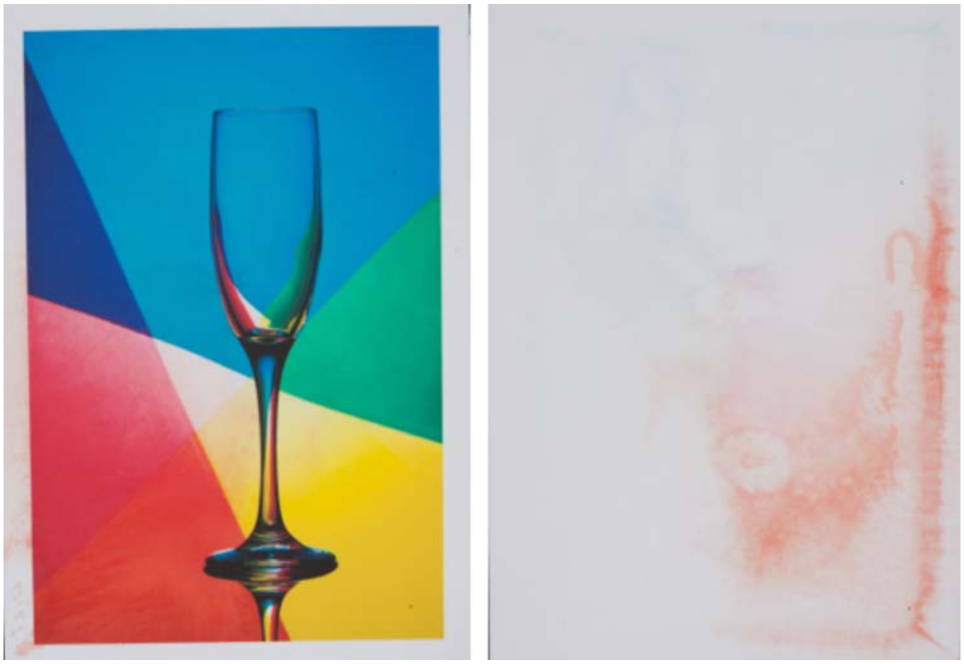
Table 7: Delta E of Tray 3 Adjacent Prints

SAMPLE	ΔE
Pigment Bleeder	1
Unprinted Receiver	2

When two matte-coated fine art samples, a Pigment Receiver and an Unprinted Receiver, were immersed in the same tray in indirect contact with one another, no major colorant transfer occurred. No visible bleed was present 24 hours after drying (Figure 11). The Delta E values for both samples further indicate that little to no noticeable change in color occurred for either samples (Table 7).

STACKED AND IMMEDIATELY SEPARATED (TRAY 4)

The two samples were stacked front to back, and were detached from one another after one hour of immersion to dry separately. Noticeable colorant transfer occurred between the Pigment Bleeder and the Unprinted Receiver (Figure 12). Migration of the colorant is present in the red and white areas of the Bleeder, which was unexpected given that pigment is not normally prone to bleed. The red and blue areas from the Bleeder also transferred onto the backside of the Unprinted Receiver. The appearance (as further indicated by the Delta E of 10) (Table 8) of the verso of the Unprinted Receiver changed significantly as a result of being stacked with the Pigment Bleeder. More colorant transfer occurred toward the edges of the Receiver than throughout the rest of the print.



Pigment Bleeder *Unprinted Receiver*

Figure 12: Tray 4 Samples (Stacked; Separated Immediately)

Table 8: Delta E of Tray 4 Samples (Separated Immediately)

SAMPLE	**ΔE**
Pigment Bleeder	3
Unprinted Receiver	10

Stacked and Separated After 24 Hours (Tray 5)

Pigment Bleeder *Unprinted Receiver*

Figure 13: Tray 5 Samples (Stacked; Separated After 24 Hours)

Table 9: Delta E of Tray 5 Samples (Stacked; Separated Immediately)

SAMPLE	**ΔE**
Pigment Bleeder	6
Unprinted Receiver	2

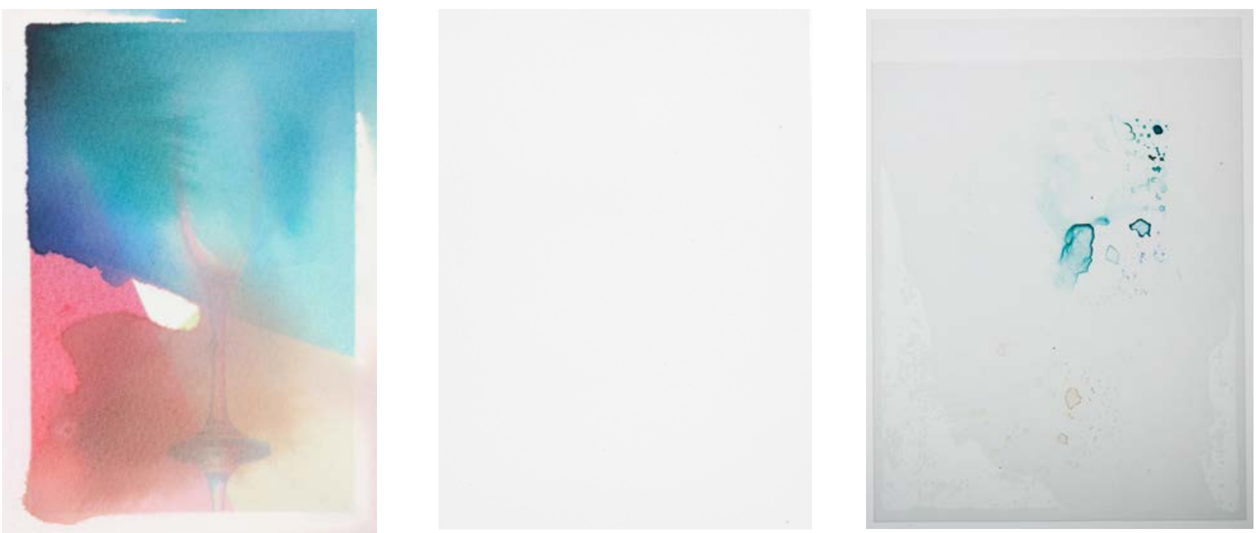
When a matte-coated fine art Pigment Bleeder and Unprinted Receiver were stacked front to back during immersion and left in that same configuration to dry, colorant transfer in the reds and blue areas occurred (similarly to the case of the tray 4 adjacent prints which were separated immediately). The amount of colorant transfer that occurred in between these two tray 5 samples compared to the case of the tray 4 samples is arguably not much different (Figures 12 and 13). The Delta E value for the tray 5 Unprinted Receiver is significantly less than that of the tray 4 Unprinted Receiver due to the fact that color measurements were taken on the outer edges of each print (Tables 8 and 9). However, visual assessments showed the opposite, as there is more visible bleed on the tray 5 Receiver than on the tray 4 Receiver.

PART III: DYE AND PIGMENT PRINTS IN ENCLOSURES

In both configurations of Part III, Bleeders and Receivers were stacked front to back during immersion. Receivers were stored within Polyester Sleeves to protect from bleed. All samples were left in their original immersion configurations (stacked) until after 24 hours of drying. The purpose of Part III was to illustrate the potential for polyester sleeves to prevent colorant transfer between prints in water emergencies.

CONFIGURATION 1: DYE BLEEDER

Configuration 1 of Part III included a Dye Bleeder (uncoated fine art paper), an Unprinted Receiver (matte-coated fine art paper), and a polyester sleeve holding the Receiver. In this first configuration, the dye print bled significantly after being submerged in water. However, there was no change in visual appearance or Delta E for the Unprinted Receiver, which was contained within a polyester sleeve (Table 10). The colorant from the Dye Bleeder can be seen to have transferred onto the Polyester sleeve (Figure 14), but the Receiver was not affected due to the protection of the sleeve. Storing the Unprinted Receiver in a polyester sleeve prevented colorant transfer from occurring.



Dye Bleeder — *Unprinted Receiver* — *Polyester Sleeve Holding Unprinted Receiver*

Figure 14: Polyester Sleeve Configuration 1 (with Dye Bleeder)

Table 10: Delta E for Configuration 1 Samples

SAMPLE	**ΔE**
Dye Bleeder	10
Unprinted Receiver	0

CONFIGURATION 2: PIGMENT BLEEDER

Pigment Bleeder

Unprinted Receiver

Polyester Sleeve holding the Unprinted Receiver

Figure 15: Polyester Sleeve Configuration 2 (with Pigment Bleeder)

Table 11: Delta E for Configuration 2 Samples

SAMPLE	**ΔE**
Pigment Bleeder	1
Unprinted Receiver	0

The Pigment Bleeder and Unprinted Receiver, both matte-coated fine art, were organized in the same configuration as Configuration 1. While there are noticeable tidelines on the Pigment Bleeder, and some bleed is visible on the outside of the Polyester Sleeve, no colorant transfer occurred and the Receiver remained unaffected.

Conclusions

- Inkjet print response to water emergencies can be variable due to multiple factors such as a type of print, type of contact, and/or presence of enclosures.
- Dye Inkjet Prints are more at risk when exposed individually than in stacks.
- Pigment prints are more at risk when stored in stacks than individually.
- Polyester barriers between prints can minimize colorant transfer between adjacent or stacked prints.
- In order to minimize colorant transfer, inkjet prints that are stuck together should be gently separated immediately upon being removed from water.
- Prints in enclosures should be removed after a water emergency to minimize damage such as the tidelines on pigment prints in polyester sleeves.
- Prints in contact with one another that are often considered to not be salvageable could actually be salvageable due to the protective effect of stacking.
- Prints should always be dried individually and laid flat on a drying rack.

References

[1] Adelstein, P. D. Burge, and J. Hanna. 2006. Recovery of water-damaged digital and traditional prints. *Proceedings of the Third International Conference on Preservation and Conservation Issues Related to Digital Printing and Digital Photography*, ed R. Thompson, A. Manning, and J. Townsend. London: Institute of Physics. 64-67

[2] Burge, D. J. Scott. 2012. Resistance of digitally and traditionally printed materials to bleed, delamination, gloss change, and planar distortion during flood. The Journal of the American Institute for Conservation 51. 139-152.

[3] Jürgens, M., N. Schempp. 2010. Freeze-drying wet digital prints: An option for salvage? *Proceedings of the Fourth International Conference on: Preservation and Conservation Issues Related to Digital Printing and Digital Photography. Journal of Physics Conference Series* 231(1):012005

Biography

Meghan Connor recently finished her second year of undergraduate studies in the Photographic Sciences Department at RIT, where she is majoring in Imaging and Photographic Technology and minoring in Imaging Systems Management. Her interests include color management and reproduction, camera technology, and image quality analysis. She is currently serving as a student co-op at the Image Permanence Institute.