

Testing the Waters: New Technical Applications for the Cleaning of Acrylic Paint Films and Paper Supports

ABSTRACT

New techniques for cleaning acrylic emulsion paint surfaces continue to emerge in the practice of contemporary conservation. The discipline is currently in the process of identifying problematic first-generation practices, pursuing improved and alternative treatments, and framing a dialogue to guide future innovations. This paper will present four case studies that illustrate a new aqueous cleaning system for acrylic paint films on paper supports. It will also address this system's potential to treat discolored paper and board.

Driving this evolution in practice is acrylic works' sensitivity to aqueous cleaning methods. Paint film swelling and surfactant or pigment disruption are two primary risks conservators regularly face when cleaning acrylic works of art on paper. The aqueous cleaning system discussed in this paper mitigates these risks by using pH and conductivity meters to test acrylic paint surfaces and to create customized aqueous cleaning solutions—a technique demonstrated at the 2011 Cleaning of Acrylic Painted Surfaces workshop.

Examples of this system will be presented in the treatment of four works. The first case study uses Paula Rego's *In the Garden* (1986), an acrylic painting on paper with embedded dust and dirt. This study will demonstrate the necessity of adapting the cleaning system to diverse pigments and color mixtures, due to their idiosyncratic responses to water. The second case study, *Maquette for Smoking Cigarette Relief* (1983), by Tom Wesselmann, will demonstrate the technique as applied to the removal of active mold growth and associated staining. The final two studies will present successful treatment of stained and discolored paper supports through the use of conductivity and pH adjustment.

TESTING THE WATERS

In 2002, conservators and conservation scientists from the Getty Conservation Institute in Los Angeles, the Tate in London, and the National Gallery of Art in Washington, DC, undertook a groundbreaking collaboration on the study of modern paints. The project was to incorporate three strands of research: assessing analytic methods, studying the physical and surface properties of modern paints, and evaluating cleaning methods for modern paintings.¹ Since 2006, the year of the landmark Modern Paints Uncovered symposium, many more institutions and individual researchers have joined the initiative, contributing numerous technical studies to the subject (Learner et al. 2007).

Throughout this decade of intense study, the conservation community has faced a key challenge: bridging the gap between research and practice (Ormsby and Learner 2009). Many practicing conservators have felt—and continue to feel—unprepared to treat soiled acrylic paint films without a green light from conservation science. On the other hand, scientists are unable to further their investigations without feedback from conservators involved in hands-on treatment. To this end, an investigatory colloquium, Cleaning of Acrylic Painted Surfaces: Research into Practice (CAPS), was held in the summer of 2009 at the J. Paul Getty Museum.

The colloquium incorporated lectures and experimental, hands-on cleaning trials, and was facilitated by several leading figures in the fields of scientific research and paintings conservation. The colloquium has since developed into an annual CAPS workshop. Tiarna Doherty, Tom Learner, Bronwyn Ormsby, Alan Phenix, Chris Stavroudis, and Richard Wolbers have all participated as instructors. Since 2011, the CAPS workshop has introduced greater numbers of conservators to new cleaning systems, while gathering empirical observations in order to further the dialogue between theory and practice.

THE CHALLENGE OF CLEANING ACRYLIC PAINT FILMS

The components of acrylic emulsions are complex and often proprietary, leaving conservators and conservation scientists

Presented at the Book and Paper Group Session, AIC's 41st Annual Meeting, May 29–June 1, 2013, Indianapolis, Indiana.

with an imprecise understanding of their chemical makeup. The ingredients of wet acrylic emulsions typically include water (around 65% volume), acrylic polymer, pigments, surfactants, dispersants, biocides, thickeners, and inorganic components, as well as other materials added by artists (Hayes et al. 2007). Paint composition varies from brand to brand, and even from pigment to pigment. Therefore, colors react differently after aging and during cleaning.

Of all these ingredients, surfactants—which stabilize particles floating in the wet emulsion—have garnered the most attention from conservators and conservation scientists. Surfactants migrate to the surface of aging paint films because their unique structure attracts them to the air-water interface. At the surface, surfactants contribute to the problematic character of porous acrylic paint films by creating a coat that readily attracts and imbibes dirt.² Moreover, the small particle size and ready solubility of surfactants contribute to their easy leaching and removal from the paint film during cleaning (Ormsby et al. 2008). Furthermore, surfactants may leach into absorbent substrates from the verso, possibly altering the physical properties of aging acrylic works on paper. However, the effects of this process on the durability of paint films have not yet been explored.

To date, the majority of scientists agree that there is no apparent long-term implication for the removal of surfactants during cleaning.³ By the time the paint film is dry, surfactants have performed their function—the stabilization of particles floating in wet acrylic emulsion. Still, many conservators are legitimately wary of removing original material. Changes to the film on the microscopic scale after aqueous cleaning have been reported (Zumbuhl et al. 2007). To this end, the CAPS aqueous cleaning system mitigates removal of surfactants and other leachable materials during cleaning.

Primary considerations for the cleaning of an acrylic paint film are either immediate—such as swelling and changes in gloss—or have the potential to manifest as future damage, as in the case of paint embrittlement. Conservators are well equipped to manage immediately visible concerns by testing on a micro-scale. However, it is difficult to predict the long-term results of cleaning treatments, especially wet-cleaning treatments.

According to conservators participating in a self-selected survey, acrylic paintings are commonly cleaned with such tools and solvents as sponges, erasers, saliva, distilled water (with or without added surfactant), and aliphatic and aromatic hydrocarbons (Murray et al. 2002). The CAPS aqueous cleaning system adds a safer, more finely tuned technique to the paper conservator's tool box: a method for adjusting distilled or deionized water to the approximate pH and conductivity of the acrylic's surface in order to alleviate swelling and leaching through the use of an isotonic cleaning solution.

Table 1.

2% (w/v) Agarose gel recipe
100 mL deionized water 2.0 g Agarose Type VII, low gelling temperature 2 drops of the preservative Germaben II (optional)
<ul style="list-style-type: none"> - Heat 100 mL of deionized water to 198°F. - Remove from heat and stir in 2.0 g of agarose powder. - Stir by hand until all powder has incorporated and there are no lumps (roughly 5–10 minutes). Replace on hot plate as needed to keep the temperature constant. - Cool to approximately 140 degrees Fahrenheit, then stir in 2 drops of Germaben II for a longer shelf life. - Immediately pour the mixture into 4 sterilized Petri dishes and allow to cool until gelling is complete, roughly 20 minutes. - For use on paper supports, increase the weight of Agarose to make a 4% or 5% w/v gel. Highly concentrated gel delivers moisture at a significantly reduced rate, consequently mitigating or eliminating the formation of tide lines around the test area.

SAMPLING PH AND CONDUCTIVITY OF ACRYLIC EMULSION PAINT FILMS

In this system, pellets of agarose gel are used to evaluate the surface pH and conductivity of an acrylic emulsion film.⁴ Agarose powder is mixed with pure water over heat, transferred to a Petri dish, and cooled until the liquid forms a gel. The recipe for 2% (w/v) agarose gel is provided in table 1. Cylindrical pellets are then extracted from the cooled gel using a 3 mm biopsy punch, which allows for precise and gentle handling of the pellets.

At room temperature, individual agarose pellets are applied to a paint film and allowed to rest on the surface for 45 seconds (fig. 1).⁵ The pellets imbibe the soluble components of the paint film during contact with the surface of the painting by diffusion and capillary action, which shifts their pH and conductivity closer to that of the paint film. While it is possible to perform the sampling more quickly using a droplet of deionized water, this method often results in aggressive localized swelling at the test site. Slower-acting agarose pellets, however, hold moisture in check and do not cause significant swelling.

Two devices from Horiba Scientific are used to analyze the agarose pellets: the B-171 TWIN conductivity meter and the Laqua pH Tester. These pocket-size, user-friendly meters accommodate sampling through immersion in a solution or by a single drop of liquid placed on a flat sensor. For analysis, the 3 mm pellet of agarose is placed into the well of the conductivity meter using blunt tweezers. Using the tweezers, the pellet must be carefully pushed to the back of the meter to allow direct contact with one of the two black sensors.

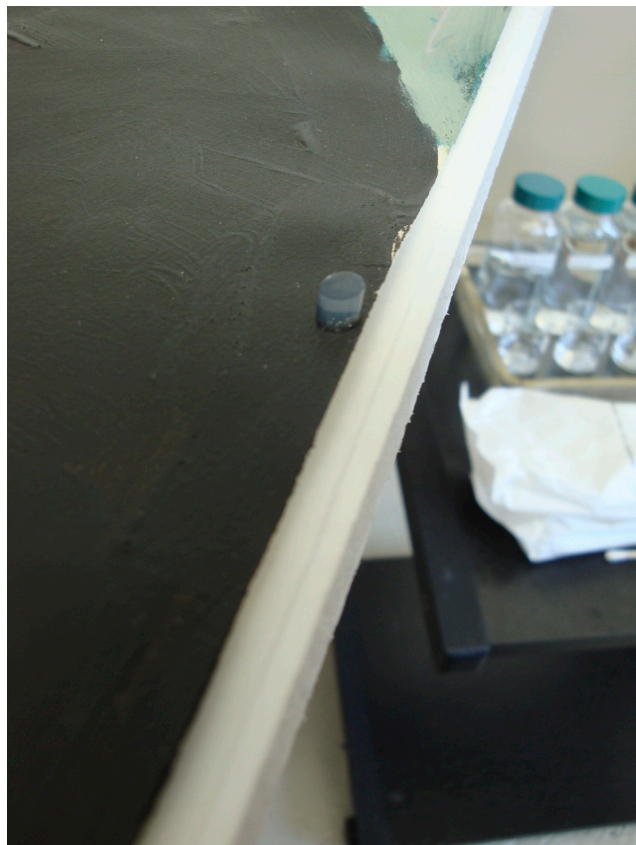


Fig. 1. An agarose pellet resting on the surface of an acrylic paint film

Table 2. pH and Conductivity Readings from *In the Garden* by Paula Rego, July 12, 2012

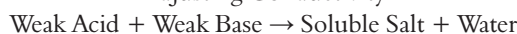
Color	pH	Conductivity ($\mu\text{S}/\text{cm}$)
Control pellet	5.5	40
Deionized water droplet (on black)	6.3	1750
Black	5.6	1330
Dark green	6.2	780
Light green	6.2	130
Red	6.2	380
Orange	6.0	100
Blue	5.8	1120
Brown (A)	6.0	80
Brown (B)	6.0	90

The tweezers must not come in contact with the sensitive glass sensors during this procedure. After placing the pellet, the conductivity may be read and recorded as in table 2. To test pH, the same pellet is then carefully transferred to the pH meter. The pH meter has a different sensor configuration and requires the pellet to be read wet, meaning that a drop or two of deionized water must be added to the well along with the pellet. The deionized water facilitates diffusion—in other words, the release of soluble components into an aqueous solution readable by the Horiba meter. The addition of the deionized water at this stage will not significantly affect the pH of the pellet. After approximately one minute of equilibration time, the pH is read and recorded as in table 2. Ultimately, these readings will be used to formulate isotonic aqueous cleaning solutions.

THE TREATMENT WATERS: CREATING PH- AND CONDUCTIVITY-ADJUSTED AQUEOUS SOLUTIONS

The aqueous solutions presented here consist of three ingredients: deionized or distilled water, glacial acetic acid, and ammonium hydroxide. The CAPS workshop distributed the original recipes for the 12 stock solutions provided in tables 3 and 4. In theory, the formulas are simple, but in practice, they require time and patience to execute. Acetic acid (a weak acid) is first added to deionized water. Then ammonium hydroxide (a weak base), which reacts with the acetic acid to produce a soluble (and volatile) salt, is introduced to set the conductivity. Further addition of ammonium hydroxide raises the alkalinity of the solution to the desired pH.

Adjusting Conductivity



Trials have indicated that these recipes are not 100% reproducible. Factors including the shelf life and potency of the component chemicals will affect the necessary quantity of ammonium hydroxide. To achieve the most accurate values, the pH and conductivity of the solution should be measured after completing the first two steps, and then adjusted as needed. The ammonium hydroxide will likely need to be added in 0.5 mL increments or dropwise until the desired pH is achieved. To maintain accuracy, the Horiba meters must be powered off and rinsed after each reading. By diluting the final solutions 1:1 with deionized water, the conductivity will be halved without a significant change in pH. Large quantities of the solutions will last for several weeks if stored in a refrigerator in sanitized, airtight containers—or if a drop of Germaben II, a preservative, is added to the batch. The solutions should be discarded when they begin to exhibit mold growth.

Recently, these aqueous solutions have been added to various microemulsions, effectively minimizing contact between the aqueous solution and paint film through the addition of an aliphatic hydrocarbon.⁶ The following case studies, however,

Table 3. Recipes for pH-Adjusted Water at 1,000 $\mu\text{S}/\text{cm}$

pH	Recipe
5.0	<ul style="list-style-type: none"> • Drop 0.5 mL glacial acetic acid into 0.5 L of DI H₂O • Set pH to 5.0 by adding approximately 5 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
5.5	<ul style="list-style-type: none"> • Drop 0.5 mL glacial acetic acid into 0.5 L of DI H₂O • Set pH to 5.5 by adding approximately 8 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
6.0	<ul style="list-style-type: none"> • Drop 0.5 mL glacial acetic acid into 0.5 L of DI H₂O • Set pH to 6.0 by adding approximately 9 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
6.5	<ul style="list-style-type: none"> • Drop 0.5 mL glacial acetic acid into 0.5 L of DI H₂O • Set pH to 6.5 by adding approximately 10 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
7.5	<ul style="list-style-type: none"> • Drop 0.5 mL glacial acetic acid into 0.5 L of DI H₂O • Set pH to 7.5 by adding approximately 12 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity

are limited to the application of variable pH and conductivity waters, which are more broadly applicable to paper conservation practices.

CASE STUDY I: PAULA REGO, *IN THE GARDEN*

In the Garden (1986; fig. 2) is a large acrylic painting on paper by Paula Rego (born 1935). Despite having been framed for decades under acrylic glazing, the painting had collected a significant layer of dirt and dust. For this work, Rego used heavily diluted Liquitex acrylic emulsion paint to achieve watercolor-thin washes of color, in addition to thick applications of Liquitex paint to achieve moderate impasto. The thickly painted passages were more significantly affected by the dusty accumulation, manifesting in decreased gloss and saturation across the majority of the painting.

Three primary goals were established for the cleaning of this painting: to reduce surface dirt and dust, to minimize swelling and pigment extraction, and to avoid undesirable changes in surface sheen. An initial attempt to reduce surface dirt by dry cleaning with minimally abrasive, nonlatex cosmetic sponges revealed the following two issues: 1) significant



Fig. 2. Paula Rego, *In the Garden*, 1986, 156.9 x 127.6 cm, acrylic on paper lined to canvas. Image reproduced courtesy of the artist

Table 4. Recipes for pH-Adjusted Water at 6,000 $\mu\text{S}/\text{cm}$

pH	Recipe
5.0	<ul style="list-style-type: none"> • Drop 1 mL glacial acetic acid into 100 mL of DI H₂O • Set pH to 5.0 by adding approximately 6–7 mL 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
5.5	<ul style="list-style-type: none"> • Drop 1 mL glacial acetic acid into 100 mL of DI H₂O • Set pH to 5.5 by adding approximately 10 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
6.0	<ul style="list-style-type: none"> • Drop 1 mL glacial acetic acid into 100 mL of DI H₂O • Set pH to 6.0 by adding approximately 11 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity
6.5	<ul style="list-style-type: none"> • Drop 1 mL glacial acetic acid into 100 mL of DI H₂O • Set pH to 6.5 by adding approximately 12 mL of 10% ammonium hydroxide • Test pH and conductivity • If necessary, add 10% ammonium hydroxide in 0.5-mL increments to raise the pH • Dilute with DI H₂O to reduce conductivity

amounts of surface dirt were embedded in the acrylic paint film and 2) specific colors were sensitive to abrasion.

The brown and dark-green pigments were particularly sensitive to abrasion during dry surface cleaning. However, after a few gentle strokes of the sponge, a threshold of pigment loss would be reached, beyond which pigment particles were no longer dislodged from the surface. It was determined that a percentage of pigment particles were not bound permanently within the acrylic polymer matrix during drying, and therefore remained as a surplus on the surface.

After dry cleaning, seven colors were selected for pH and conductivity testing using 2% (w/v) agarose pellets. While time constraints prevented sampling of all surfaces, the colors chosen were representative of 80% of the pure colors and color mixtures within the painting. The results were used to develop a practical range of pH and conductivity parameters for cleaning the remaining areas.

As an experimental control, pH and conductivity readings were also performed on a blank 2% agarose pellet that had not been previously applied to any area of the Rego painting (table 2). Likewise, to compare the performance of the agarose gel to that of pure water, a droplet of deionized water applied directly to the surface of black paint at the right of the painting was analyzed for pH and conductivity. The readings obtained from the deionized water droplet were significantly greater than those obtained with an agarose pellet applied to

an adjacent location of black paint, confirming that the water droplet acted more quickly and aggressively on the surface of the paint film than the pellet.⁷ Finally, multiple readings were taken from different areas of the same color to confirm accuracy and reproducibility of the readings. Note that the readings from two nonadjacent areas of brown paint (A and B) are very similar.

Cleaning trials began using the premixed stock solutions of pH- and conductivity-adjusted waters. Based on the methodology of Chris Stavroudis and others, a number of specific stock solutions were selected to match the pH and conductivity of the readings taken directly from the surface of the Rego painting. By choosing an aqueous cleaning solution that harmonizes with the paint film, near chemical equilibrium may be achieved at the surface, thus avoiding leaching materials from, or depositing them into, the paint film (Stavroudis and Doherty 2013). Without fail, the solutions whose conductivity and pH most closely matched that of the colors on which they were applied resulted in the least swelling and pigment transfer while maximizing cleaning efficiency. There was no practical difference in cleaning efficacy or swelling when using solutions within a few tenths of the pH reading, and within approximately 500 μS of the conductivity reading, demonstrating that the pH and conductivity need not precisely match. It is usually less disruptive to err on the side of



Fig. 3. Detail of *In the Garden*. Right: embedded dirt and dust are visible despite dry cleaning. Left: dirt and dust significantly reduced after aqueous cleaning

higher conductivity when selecting an aqueous solution to clean an acrylic paint film (Wolbers et al. 2013).

Cleaning of *In the Garden* proceeded for several weeks. Three to four passes with a lightly dampened (preblotted) cotton swab provided just enough moisture for the acrylic paint surface to release its hold on embedded dirt and dust (fig. 3). Hand-rolled cotton swabs were used during this cleaning for their softness and variability in size. Though cotton swabs are not appropriate for all acrylic surfaces, the paint surface was carefully monitored for abrasion during cleaning.

Aqueous cleaning reduced the dusty film that obscured the color and sheen of this acrylic painting. After cleaning, the work appeared more balanced, fresh, and lively. To further refine the understanding of this aqueous cleaning system, it is necessary to experiment with different methods of application and materials such as nonabrasive sponges or brushes.

CASE STUDY II: TOM WESSELMANN, *MAQUETTE FOR SMOKING CIGARETTE RELIEF*

Upon arrival in the studio, *Maquette for Smoking Cigarette Relief* (1983) by Tom Wesselmann (1931–2004) was covered in extensive mold growth (fig. 4). Fluffy, bright yellow mold covered most of the sculpture, its paper-covered wooden base, and the clear acrylic box in which it was displayed.

A soft-bristle brush attached to a HEPA vacuum was used to remove the dry surface mold, but stubborn circular yellow stains remained, marring Wesselmann's flat acrylic emulsion paint surface (fig. 5). The mold stains were embedded in the paint film and appeared matte in comparison to the slight gloss of the surrounding unaffected areas. Initial testing to remove these stains, which included local treatment with triammonium citrate (TAC) and diammonium citrate (DAC), proved unsuccessful.

To further reduce the staining, the work was cleaned using the CAPS aqueous cleaning system. One agarose pellet was



Fig. 4. Tom Wesselmann, *Maquette for Smoking Cigarette Relief*, 1983, acrylic on paper board. Courtesy of the Estate of Tom Wesselmann, licensed by VAGA, New York, NY



Fig. 5. Detail of embedded mold growth. Courtesy of the Estate of Tom Wesselmann, licensed by VAGA, New York, NY



Fig. 6. After cleaning with pH- and conductivity-adjusted water. Courtesy of the Estate of Tom Wesselmann, licensed by VAGA, New York, NY

placed on a discolored area for 60 seconds, then pH and conductivity readings were obtained from the surface of the acrylic paint using the method described above. The results were then used to formulate a pH- and conductivity-adjusted aqueous solution to match the test site. Light swabbing with the appropriately adjusted water removed all the embedded mold stains, resulting in a surface that agreed with the color, texture, and sheen of its surroundings (fig. 6).

CASE STUDY III: HURRICANE SANDY WATER DAMAGE ON PAPER SUPPORTS

Since late October 2012, many conservators have contended with works of art on paper damaged during Hurricane Sandy. These treatments are often very complex and challenging due to the unusual composition of the storm water. (The development of treatments to reduce extensive, widespread damage is a topic unto itself.) However, the CAPS aqueous cleaning system, adapted for paper supports, has the potential to improve treatment results in situations ranging from localized stain removal to overall washing. Of course, there are several variables to be considered when designing an aqueous treatment—pH, chelator, and application method to name a few—but the conductivity of the treatment water has proven to be a decisive influence in each of the following cases.

Internal tide lines that fluoresce bright blue are present within the supports of many Hurricane Sandy-damaged artworks.⁸ Often the affected area does not appear stained to the naked eye, but strong tide lines become visible under ultraviolet (UV) radiation. These tide lines are very difficult and sometimes impossible to remove using standard procedures. While treatment methods utilizing deionized water, calcified and ammoniated water, etc., often reduce visible tide lines, under UV, the blue fluorescence remains unaffected—or has merely shifted along the paper fibers. The source of the blue fluorescence is unclear, though indications suggest that the unusual fluorescence may be caused by residual antibiotics found in the flood waters (Wolbers 2013).

The efficacy of pH- and conductivity-adjusted waters was tested prior to treatment, using a technique modified from the CAPS aqueous cleaning system. Instead of using pure water to formulate the agarose gel, premixed pH- and conductivity-adjusted solutions were used—thereby yielding pH- and conductivity-adjusted agarose. Three test pellets representing different conductivities were applied to a tide line stain and left to rest for 2 to 10 minutes while imbibing the soluble components of the discoloration (fig. 7). The tests were carried out using pellets at 1000 $\mu\text{S}/\text{cm}$, 5000 $\mu\text{S}/\text{cm}$ and 10,000 $\mu\text{S}/\text{cm}$, following recipes shared by Richard Wolbers. For the testing and treatment of paper supports, the adjusted agarose gels may be formulated in concentrations ranging from 2% to 5% (w/v). High concentrations of agarose (4–5%) will yield semi-rigid gels with small pore formation and stronger capillary force.



Fig. 7. The tide line with local tests using conductivity-adjusted agarose pellets. From left to right: 1,000 $\mu\text{S}/\text{cm}$, 5,000 $\mu\text{S}/\text{cm}$, and 10,000 $\mu\text{S}/\text{cm}$

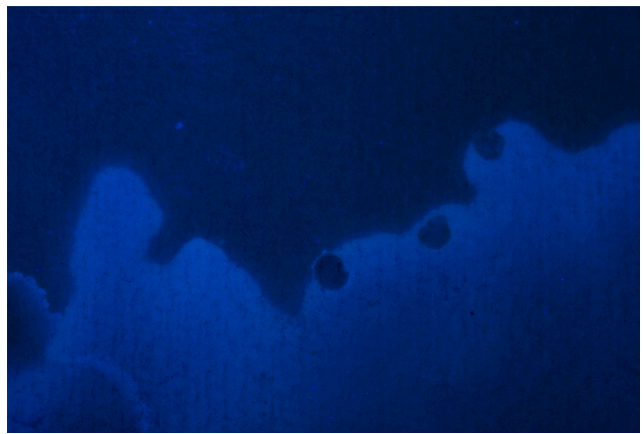


Fig. 8. The same test areas under UV illumination

In all three test cases, the tide line was no longer visible under UV illumination after testing with the adjusted agarose pellets (fig. 8). Furthermore, the test areas differed enough in both visible light and under UV to indicate that 5000 $\mu\text{S}/\text{cm}$ was the most effective approximate conductivity for stain reduction. The local stain removal was performed using fumed silica poultices dampened with a 1% TAC solution. One-percent TAC is a buffered solution with a pH of approximately 7.5 and a conductivity of 4,300 $\mu\text{S}/\text{cm}$, placing it within the conductivity range called for by the agarose test pellets. A barrier solvent (D5 silicone solvent, cyclopentasiloxane) was then applied to avoid the formation of new tide lines while the work was being cleaned with the aqueous solution.⁹ As a result of these preliminary tests, the final treatment removed the tide line, including external and internal fluorescent blue staining.

CASE STUDY IV: REDUCING DISCOLORATION AND STAINING FROM PAPER AND BOARD

Removing staining and discoloration, especially from boards, is uniquely problematic. Treatment is often limited by the board's moisture threshold—that is, the amount of moisture that may be introduced before distortions, delamination, or adulterant migration from the board core begin to occur. By increasing ionic activity at the stain site via appropriate water adjustment, paper swelling is limited and absorbency controlled. The end result offers more efficient stain reduction.

In order to demonstrate the effects of various adjusted waters, a sample of naturally aged two-ply card was dry surface cleaned to prepare for aqueous testing. Three cotton swabs were prepared, each dampened with a different aqueous solution: water at pH 5.5 with a conductivity of 14,000 $\mu\text{S}/\text{cm}$, water at pH 6.6 with a conductivity of 6000 $\mu\text{S}/\text{cm}$, and deionized water (fig. 9). Three light passes were subsequently performed on the card with each of the swabs.

The card surface was delicate, with a fine texture, and fibers were vulnerable to disruption during surface cleaning. The swab dampened with deionized water proved to clean the least effectively, and unevenly at that, altering the surface topography most significantly. The swab with the pH 6.6, 6,000 $\mu\text{S}/\text{cm}$ water glided more easily on the surface, offered more even cleaning results, and felt easily controllable during swabbing. The swab with the pH 5.5, 14,000 $\mu\text{S}/\text{cm}$ water gave the most effective cleaning (perhaps too effective, as three passes were unnecessary). A hypertonic, very high conductivity solution such as 14,000 $\mu\text{S}/\text{cm}$ will swell the paper surface. Swelling facilitates cleaning and the release of discoloration, but swelling can also result in alteration of the paper texture. After drying, the cleaned areas were tested again for pH and conductivity, and all gave similar readings despite having been cleaned with different solutions. By

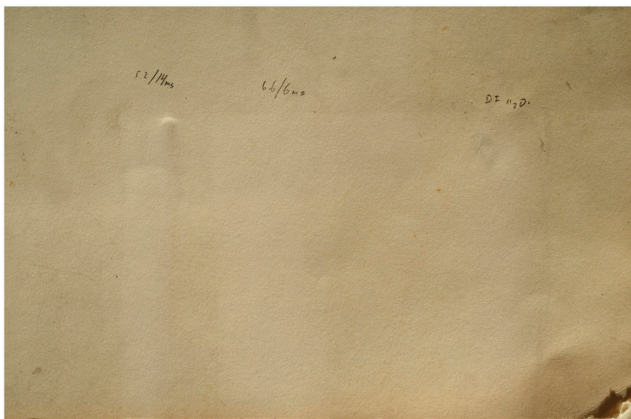


Fig. 9. Test sample of naturally aged 2-ply board, swab-cleaned using three waters. From left to right: water at pH 5.5 with conductivity of 14,000 $\mu\text{S}/\text{cm}$, water at pH 6.6 with conductivity of 6000 $\mu\text{S}/\text{cm}$, and deionized water

using adjusted waters when reducing discoloration on board, satisfactory results may be achieved with less repetition, less wetting out of the substrate, reduced loss of surface texture, and reduced planar distortion.

CONCLUSION

The pH of water has long been adjusted for various uses by paper conservators. By developing a more acute awareness of conductivity, and practicing conductivity measurement and adjustment, we may begin to take full advantage of the properties of our treatment waters. The resulting treatments will be better tailored to the needs of our materials.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the CAPS workshop instructors and participants. Daria Keynan would like to particularly thank Richard Wolbers for his help and guidance with artworks damaged during Hurricane Sandy. Amy Hughes gratefully acknowledges support for the presentation of this paper: a George Stout Grant from the Foundation of the American Institute for Conservation of Historic and Artistic Works, and the New York University Institute of Fine Arts Conservation Center's 50th Anniversary Fund.

NOTES

1. See the Getty's website for more information: www.getty.edu/conservation/our_projects/science/modpaints/ (accessed 07/14/13).
2. Jablonski et al. provide an excellent literature review and summation of acrylic emulsion paints, including the composition of the paint films, their aging properties, and an explanation of the reasons why they attract and imbibe dirt: Elizabeth Jablonski, Tom Learner, James Hayes, and Mark Golden, 2003, "Conservation concerns for acrylic emulsion paints," *Reviews in Conservation* 4: 3–12.
3. Tom Learner, 2013, personal communication, Getty Conservation Institute, Los Angeles.
4. Measurements should be conducted at a constant temperature because pH and ion electrodes are sensitive to temperature differences.
5. For further readings on the use of agarose in conservation see Jeffrey Warda et al., 2007, "Analysis of agarose, carbopol, and lap-onite gel poultices in paper conservation," *Journal of the American Institute for Conservation* 46: 263–279, and Paolo Cremonesi, "Rigid gels and enzyme cleaning," in *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politécnic de Valencia and Museum Conservation Institute*, ed. Marion F. Mecklenburg et al.: 179–183.
6. Anthony Lagalante, Richard Wolbers, and Amanda Norbutus presented on the use of these microemulsions during the 2013 AIC conference. A. F. Lagalante, R. W. Wolbers, and A. J. Norbutus, "Mass spectrometric imaging of acrylic emulsion paint films: Engineering a microemulsion-based cleaning approach," presented at the 41st

National Meeting of the American Institute for Conservation of Historic and Artistic Works (AIC), Indianapolis, IN, May 29–June 2, 2013.

7. It is important to keep in mind that testing and cleaning methods should cohere in degree of restraint. In this case, the slower-acting agarose pellet is a more appropriate method for testing when used in concert with gentle, damp swab cleaning.

8. The examples used in this case study must remain unspecified to observe legal confidentiality requirements.

9. D5 is a low-polarity, volatile, silicone-based solvent. For more information see Ray A. Cull and Stephen P. Swanson, 2001, “Volatile methylsiloxanes: Unexpected new solvent technology,” in *Handbook for Critical Cleaning*, ed. Barbara Kanegsberg, Boca Raton: CRC Press, pp. 147–156.

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SOURCES OF MATERIALS

- *Glacial Acetic Acid*: Sigma Aldrich #27225-1L
- *Ammonium Hydroxide*: Sigma Aldrich #320145-500ml
- *Agarose*: Sigma Aldrich #A4018-10G -or- Benchmark Scientific #A1701
- *Germaben II*: Personal Formulator #PA005B
- *Horiba Laqua Tester*: Cole Parmer #EW-05754-10
- *Horiba B-171 TWIN Conductivity Meter*: Cole Parmer #EW-05751-10
- *Biopsy Punch*: Harris Uni-Core 3.0 tip Biopsy Punch, www.tedpella.com #15078
- *Disposable Graduated Pipettes*: Grainger #21F249
- *Large Vessel ~2,000ml*: Sigma Aldrich Pyrex Graduated Beaker #CLS100326

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