FOXY UNDERPANTS: OR THE USE OF CHELATORS, ENZYMES, AND SURFACTANTS TO REMOVE FOXING STAINS FROM LINEN UNDERPANTS

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ABSTRACT—This paper describes a successful treatment to reduce foxing stains on a pair of men's linen underpants ca. 1830 in the collection of the Costume Institute at The Metropolitan Museum of Art. The underpants are ankle length and have a wide corset-like waistband containing 12 baleen stays. Such undergarments are rare in museum collections, yet provide a reminder of the importance of fashionable bodies for men. Foxing stains can be disfiguring on any work of art, but the stains were considered particularly distracting on the underpants.

While foxing stains are a common problem in textile collections, most recent studies have focused on paper collections. Building on research by paper conservators and scientists, this treatment addressed the metals and microorganisms that cause foxing stains. Rather than use bleaching agents, the underpants were wet-cleaned in a series of baths with the chelator ethylenediaminetetraacetic acid (EDTA), a lysing enzyme, and the surfactant sodium lauryl sulfate. An agarose poultice with hydroxybenzyl ethylenediamine (HBED) was used to target an area with dark stains. In both visible and ultraviolet light, the stains showed considerable reduction after the treatment.

RESUMEN—En este trabajo se describe un tratamiento exitoso para reducir las manchas de foxing en un par de calzoncillos de lino para hombres ca. 1830 en la colección del Instituto del Traje en el Museo Metropolitano de Arte. Los calzoncillos llegan a los tobillos y tienen un amplio cinturón similar a un corsé que contiene 12 ballenas. Tales prendas interiores son raras en las colecciones de museos, pero son un recordatorio de la importancia de los cuerpos de moda para los hombres. Manchas de foxing pueden desfigurar cualquier obra de arte, pero las manchas se consideraron particularmente notables en los calzoncillos.

Mientras que las manchas de foxing son un problema común en colecciones de textiles, la mayoría de los estudios recientes se han centrado en colecciones de papel. Basándose en la investigación realizada por conservadores de papel y científicos, este tratamiento se dirigió a los metales y microorganismos que causan el foxing. En lugar de usar agentes blanqueadores, los calzoncillos se limpiaron en una serie de baños con el agente quelante ácido etilendiaminotetraacético (EDTA), una enzima de lisis, y el tensioactivo laurilsulfato sódico. Se utilizó un gel de agarosa con hidroxibencil etilendiamina (HBED) para tratar un área con manchas oscuras. Tanto en luz visible como en luz ultravioleta, las manchas mostraron una reducción considerable después del tratamiento.

1. INTRODUCTION

This paper describes a successful treatment to reduce foxing stains on a pair of men's linen underpants ca. 1830 in the collection of The Metropolitan Museum of Art's Costume Institute. Foxing stains can be disfiguring on any work of art, but the stains were considered particularly distracting on the underpants. The treatment was based on an investigation of published books and articles that included analytic research and case studies. While foxing stains are a common problem in textile collections, most recent conservation studies have focused on paper collections. In addition to details about the treatment, the article includes information about the cultural context and material construction of the underpants. A literature review examines many of the relevant publications. Finally, observations and paths for further research are discussed.

2. MATERIAL CONSTRUCTION AND CULTURAL CONTEXT

The underpants (1999.395.1) are made of linen (note 1) in a balanced plain-weave with approximately 60 threads per inch (fig. 1). They have a wide yoke waistband and tapered ankle-length legs. The waistband is made with a double layer of linen with 12 baleen ribs and closes at center front with four metal buttons and an open fly. Five narrow linen tapes pass through eyelets at center back and wrap crosswise around the body (fig. 2). The tapes terminate at two linen tabs that can fasten to multiple buttons on the front of the waistband, and thus modify the compression. The legs are cut in four pieces; the front pieces are set straight into the waist, while back pieces are cut with considerable fullness at the tops and are pleated at the waistband. At the ankles, there are short openings on the outseams that button closed. The underpants are entirely hand sewn with linen thread, and the long seams are flat felled.

Curators at the Los Angeles County Museum of Art (LACMA) requested the underpants for inclusion in their 2016 exhibition, *Reigning Men: Fashion in Menswear, 1715–2015*. Clarissa M. Esguerra, assistant curator of Costume and Textiles at LACMA, noted that the underpants are similar to a woman's corset from the same time period that is in the LACMA collection (M.63.54.7). In addition to similar construction, both the corset and the underpants contribute to an hourglass shape for the body, which was fashionable for both men and women during the 1830s.

Fig. 1. Linen underpants, ca. 1830 (MMA, Costume Institute Benefit Fund, 1999, 1999.395.1) with linen shirt, 1820s (MMA, Gift of Douglas Robbins, 1958, C.I.58.27.1), front view. Courtesy of MMA.

Fig. 2. Linen underpants with shirt, back view. Courtesy of MMA.

Many suits from the 1830s included cutaway coats that were waist-length in front, and worn with flat-front trousers with tapered legs—a style that placed emphasis on the abdominal area. Satirical cartoons provide evidence that male bodies that failed to conform to fashionable standards could be ruthlessly ridiculed.

3. FOXING RESEARCH

While the underpants are beautifully crafted and are a significant artifact of fashion history, the pervasive foxing stains compromised their appearance (fig. 3) and a treatment was needed to reduce the stains before exhibition. The development of a treatment proposal required extensive research to better understand the composition of foxing stains, as well as advantages, limitations, and risks of different treatment options.

The term "foxing" is difficult to define without resorting to descriptions of what it is not. The *Getty Art & Architecture Thesaurus* defines foxing simply as "pale, brownish, diffuse spots that appear on paper or other surfaces."

The etymology is equally intriguing and unclear. Paper conservators have compared the rusty red color of some foxing stains to the color of foxes, and dated the term's use to the mid-19th century (Lydenber and Archer 1931; Meynell 1979). The stain's name may reference Reynard the Fox—an anthropomorphic trickster character appearing in medieval European tales. This connection is supported by definitions of "fox" in the *Collins Dictionary*, which include: to perplex or confound; to cause paper to become discolored with spots; to trick or deceive. Certainly, foxing has foxed conservators and scientists for many years.

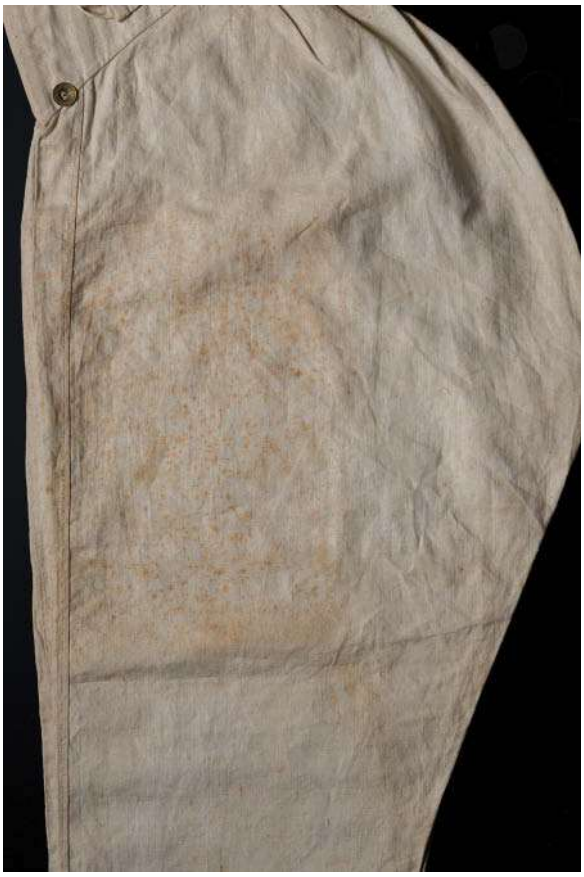

Fig. 3. Detail of underpants on back proper left leg, before treatment. Courtesy of author.

3.1. FOXING CAUSES AND CLASSIFICATIONS

Foxing is typically used as an umbrella term to include stains with a wide variety of colors, shapes, and sizes that can be further classified according to their visual characteristics and by analysis of their compositions.

The "Great Foxing Debate," to borrow the title of a paper by Schaefer (1993), is focused on the causes of foxing stains. The two sides of this historical debate are biological microbial activity or chemical metal-induced degradation, with a third option proposing both systems working simultaneously or sequentially.

Foxing stains are most typically identified by examination under visible and UV lights. UV lights may reveal areas of fluorescence that do not appear stained in visible light. Rebrikova and Manturovskaya (2000) suggest that fungal foxing stains are most luminescent during their early stages. A few authors have found discrepancies in fluorescence and caution against reliance on this type of analysis (Florian 2000; Greve 2000; Zotti et al. 2011). Other analytic methods to distinguish between microbial and metal causes include binocular microscopy, SEM, FTIR, and energy dispersive XRF (EDX). However, these analyses are not always available or possible to make without destructive sampling.

One classification system for foxing stains is included in a chapter in *The Paper Conservation Catalog* (Derow and Owen). Published in 1992, this comprehensive source is still widely referenced by conservators. The chapter describes different types of foxing stains using four terms created by Cain and Miller (1982) based on shape, color, and UV fluorescence. The two most common types are bullseyes and snowflakes (fig. 4). Bullseyes are small and round; these stains have metal cores that do not fluoresce in UV light. Snowflakes are larger with irregular edges; these stains often show microbial activity and have white fluorescence in UV light.

Other conservators have suggested alternative classifications. Florian is the most cited expert on fungal deterioration and has published widely on the subject; her book *Fungal Facts: Solving Fungal Problems in Heritage Collections* (2002) provides extensive information. In a 2000 article, Florian listed nine types of stains, each described according to visual observation, stereoscopic microscopy, and light microscopy as well as SEM and EDX analyses. The two most common types in this system are irregularly shaped fungal fox spots

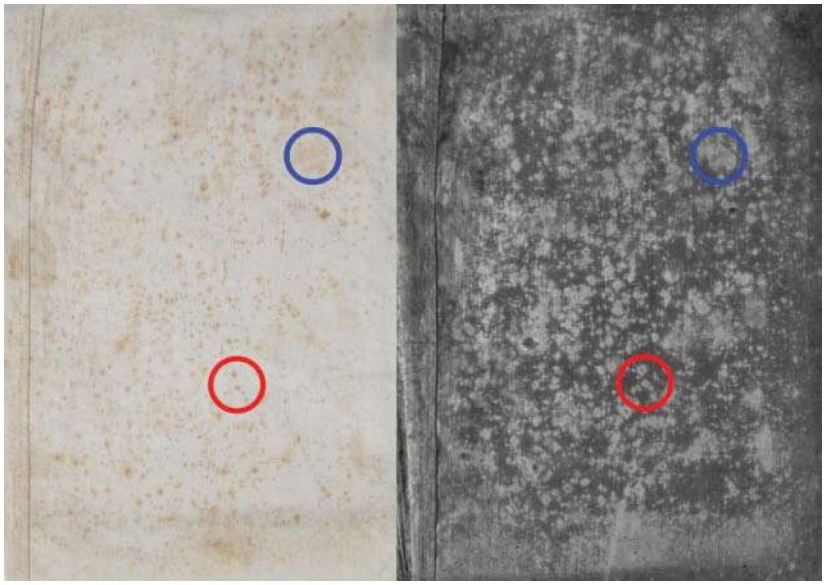

Fig. 4. Back view of underpants before treatment in visible light (left) and UV light (right). Bullseyes are marked with red circles and snowflakes with blue circles. Courtesy of MMA.

and corroded iron spots. These are roughly analogous to snowflakes and bullseyes, respectively. Some conservators use a modified version of Florian's system and reserve the term foxing exclusively for fungal stains.

Another excellent overview of foxing research is the article "Foxing on Paper: A Literature Review" (Choi 2007). Choi notes that none of the proposed classification systems for foxing stains have achieved widespread use, and that this contributes to a gap between scientific research and practical applications. Since research for this article included many different definitions and descriptions, the term "foxing" will be used with the broadest definition for simplicity's sake.

3.1.1. Metals

A few researchers have focused on metals in foxing stains. Cain and Miller (1982) used SEM and XRF to identify iron, copper-mercury, and copper-zinc. Both iron (II) and copper (I) are transition metal ions that can catalyze cellulose oxidation. Rebrikova and Manturovskaya (2000) describe this process and note that the formation of free radicals contributes to the degradation. Daniels and Meeks (1994) used EDX and SEM to analyze foxing stains; they found corroded brass (copper and zinc alloy), and noticed that dark spots contained copper (I) sulfide.

3.1.2. Microbes

A much larger group of researchers has analyzed foxing stains that contain fungal activity. Many conidial fungal strains and their amino acids have been identified in publications by Montegut et al. (1991), Aranyank (1995), Arai (2000), and Florian (2000). Typical strains include *Aspergillus* and *Penicillium* groups. Florian describes these as the "most widespread and destructive agents of decay on earth" (2002, 25). These authors mention that identification of specific genera or species can be challenging or impractical.

The dark colors of these foxing stains are related to pigments, including melanin, found in the fungal cell walls (Florian and Purinton 1995; Nieto-Fernandez et al. 2003). Fungal cell walls are distinctly different from those of plants. Fungal cell walls contain beta-glucan and chitin instead of cellulose. Chitin is also found in insect exoskeletons, so it is unsurprising that fungal stains are not water soluble.

Several researchers have documented the process of microbial damage on cellulosic fibers. Once small colonies of fungi form on a fiber surface, they begin feeding through their hyphae. These externalized stomachs can depolymerize fibers as they secrete enzymes that convert cellulose to glucose and soluble sugars (Montegut et al. 1991; Mandels and Reese 1999). Microbes can feed on surface micro-dust and damage textiles even before their hyphae target fibers. The feeding process produces organic and amino acids. As glucose reacts with these amino acids, brown spots are formed in the Maillard reaction (Florian 1993; Arai 2000). In addition, beta-glucan in fungal cell walls can brown as the fungi age and die (Florian 2000, 2002).

3.1.3. Multiple Causes

With the exception of a few authors including Arai (2000), Florian (2000), and Nunes et al. (2015), most studies suggest that foxing stains include metal and microbial components. While *Fungal Facts* rejects labeling metal-induced stains as foxing, it describes the process by which fungal cell walls seek trace elements and chelate with iron, copper, and zinc.

Recently, Sullivan et al. (2014) analyzed foxing stains with fungal and iron components. This study used a fluorescent staining protocol to confirm the presence of chitin, and XRF to confirm that iron levels within stains were higher than in unstained areas.

The foxing stains on the underpants were examined in visible and UV light (fig. 4). Based on areas with fluorescence, it appeared that most of the foxing was related to microbial activity. UV photographs revealed

Table 1. pH and Conductivity Readings

Stain type (Three areas of each type were tested)	**pH**		**Conductivity**	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Dark stains	4.6–4.8	5.9–6.0	140–310 μS	65–135 μS
Light stains	4.7–5.2	5.8–5.9	120–230 μS	24–52 μS
No visible stain	5.7–6.0	5.7–5.8	50–180 μS	11–24 μS

many fluorescent areas that did not appear to have foxing stains in visible light, which might indicate less advanced microbial activity. The area on the back proper left with the darkest spots appeared to have metal components based on fluorescent patterns characteristic of bullseye stains.

The pH of areas with and without foxing stains was tested using small disks of 4% w/v agarose gel made with deionized water. The gels were left in contact with the linen for 30 minutes and then placed in a pH meter (note 2). The foxing stains were more acidic than the unstained areas, and the darkest foxing stains were the most acidic (see table 1).

3.2. FOXING TREATMENT OPTIONS

Interventive treatment options researched for this project include: surfactants, pH- and conductivity-calibrated solutions, bleaches, chelators, and enzymes.

The use of detergents is not typically effective in the reduction of foxing stains since they are not water soluble, but Montegut et al. (1991) recommend washing treatments to remove acidic oxidative byproducts. A study by Mandels and Reese (1999) found that anionic detergents significantly inhibited microbial activity.

Many paper publications, and all those for textiles, recommend bleach treatments to remove foxing stains. The generally preferred treatment for paper involves a sequenced process: the chelator EDTA targets metal components, followed by a reducing bleach such as sodium dithionite (Burgess 1991; Derow and Owen 1992). Burgess (1991) notes that without a chelator, incompletely removed iron material may re-oxidize, causing the stains to reappear.

In *The Textile Conservator's Manual* (1998, 72), Landi recommends "an oxidizing or reducing agent to remove [the stain] fully." *Chemical Principles of Textile Conservation* (1998) by Tímár-Balázsy and Eastop does not specifically address foxing stains, but does suggest bleaches and chelators for mold and rust stains, respectively. In the more recent *Changing Views of Textile Conservation* (2011, 386), an article by Ringgaard recommends the reducing bleach borohydride to remove "smaller brownish spots known as foxing."

Solutions with calibrated pH and conductivity levels are increasingly utilized for stain reduction treatments. Keynan and Hughes (2013) successfully removed mold from a paper-covered sculpture using an aqueous solution adjusted to match the conductivity and pH of an area with mold stains.

Other studies have explored the potential for enzymes to treat foxing stains. Nieto-Fernandez et al. (2003) experimented with two different ligninases, but noted that the treatment produced some distortions on the test papers. Other conservators have also tested the potential of enzymes, but with limited success (Edmonds and Horton-James 1991; Florian 2000; van Dyke 2003).

A recent successful treatment to reduce foxing stains on paper is described in Sullivan et al. (2014). Sullivan tested the combination of the chelator HBED (N,N'-Di(2-hydroxybenzyl)ethylenediamine-N,N'-diacetic acid monohydrochloride) and a lysing enzyme (Glucanex) to reduce foxing stains. HBED is a strong chelator for iron. Glucanex is a proprietary lysing enzyme containing β-glucanase, cellulase, protease, and chitinase activities. Chitinases, glucanases, and peptidases are referred to as wall-associated enzymes because they target and break down fungal cell walls (Bowman and Free 2006).

Sullivan measured test areas with XRF and colorimetry as well as visible and UV photography. While the post-treatment visible-light photographs show considerable reduction in foxing stains, the other measurements are more impressive. The XRF data shows a significant decrease in iron, and the UV photography shows substantial reduction in fluorescence. These analyses indicate that the improved appearance was achieved by removing the causes of the foxing stains.

4. TREATMENT STEPS

All of this research was considered during the development of a treatment proposal for the underpants. While aesthetic improvement through stain reduction was a primary goal, the treatment proposal focused on methods that directly addressed the causes; bleaching was rejected in favor of chelators and enzymes. The system used by Sullivan was the most closely aligned with the analysis and goals for the underpants. This protocol was translated from a poultice spot treatment for paper to an immersion bath for a textile garment.

It was not feasible to conduct physical tests due to the lack of surrogate test material and the short time available for treatment. The decision to perform a treatment without physical tests was not undertaken lightly; however, the literature research suggested that the proposed treatment would have a high chance of success with minimal likelihood to cause damage.

4.1. TREATMENT PREPARATION

Since the foxing stains appeared in all areas of the underpants, a full-immersion bath was chosen rather than spot treatments. This required the removal of all buttons and stays. The placement of stitches was documented, and minimal stitches were clipped to remove the stays.

After removing the buttons and stays, the underpants were mechanically cleaned with a Nilfisk vacuum. Next, the underpants were sandwiched between two pieces of soft nylon net. Basting stitches around the perimeter of the underpants stabilized them between the net layers. This allowed conservators to lift, fold, and flip the underpants during wet-cleaning by holding the net.

The Costume Institute's wet laboratory has deionized water on tap, but no wash table. A container for the wash bath was made out of a corrugated plastic box with a small hole cut at one short end. The box was lined with polyethylene sheeting that was secured to the sides with binder clips. A slit in the polyethylene aligned with the hole in the box, and a stopper was made with a small piece of polyethylene and a glass weight. To fit in the wash box, the underpants were folded at the center with one leg was on top of the other (fig. 5). This allowed the fabric in the seat area to spread out with minimal folds. The box was placed on a table to make it level with the sink. With one short end of the box extending over the sink, it was possible to fill and drain the wash box using existing plumbing.

Fig. 5. Underpants in wash box. Courtesy of Glenn Petersen.

4.2. WET-CLEANING TREATMENT STEPS

The underpants were given a series of baths, and a timeline helped keep everything on track during a treatment that lasted about 11 hours. The sequence of baths was designed to escalate from less to more aggressive solutions, and to make the most effective use of the costly enzyme and chelator components. The treatment steps are detailed in table 2.

Table 2. Treatment Steps

Treatment	Duration	Notes
Day 1		
Glucanex bath prep—in pot on stove, add enzyme to pH adjusted water and heat	45 minutes	• 25g in 5 L for 0.5% w/v bath • pH = 6.0
Soak bath—deionized water	45 minutes	• pH = 7.3 • Conductivity = 1 μS
Calibrated bath 1—pH and conductivity	30 minutes	• pH = 6.3 • Conductivity = 300 μS • Water adjusted with citric acid and sodium citrate
Wash bath 1—with sponging, then soak with HBED poultice	40 minutes sponging 1 hour poultice	• 0.5% w/v Orvus, 1% w/v EDTA, 0.5 g/L SCMC • Each side was sponged for ~7 min • HBED poultice applied to back proper left rectangle
Rinse 1—deionized water	1 hour	• Rinse with deionized water poured slowly around HBED poultice for first 30 minutes

Table 2. Treatment Steps (*Continued*)

Treatment	Duration	Notes
Calibrated bath 2—pH for enzyme	30 minutes	• pH = 6.0 • Water adjusted with citric acid and sodium citrate
Glucanex soak	3 hours	• Flip every 30 minutes • Enzyme solution and underpants in plastic sling clipped to short ends of basin, water bath with warm tap water running in basin to maintain warm temperature (about 30°C) for enzyme
Wash bath 2—with sponging, 2nd soak with HBED poultice	30 minutes sponging 1 hour poultice	• Each side was sponged for ~7 minutes
Rinse bath 2—DI water	1 hour	• Rinse with DI water poured slowly around HBED poultice for first 30 minutes
Press with towels	15 minutes	
Unstitch net sandwich and pad underpants with dry net	15 minutes	
Dry with heat guns on low	1 hour	• Left to dry overnight with fans providing gentle air flow
Day 2		
Glucanex soak	2 hours	• Flip every 30 minutes • Enzyme solution and underpants in plastic sling clipped to short ends of basin, water bath with warm tap water running in basin to maintain warm temperature (about 30°C) for enzyme
Wash bath—with sponging, soak with HBED poultice	30 minutes sponging 1 hour poultice	• Each side was sponged for ~7 minutes
Rinse—deionized water	1 hour	• Rinse with deionized water poured slowly around HBED poultice for first 30 minutes
Press with towels	15 minutes	
Unstitch net sandwich and pad underpants with dry net	15 minutes	
Dry with heat guns on low	1 hour	• Left to dry overnight with fans providing gentle air flow

After a soak bath in deionized water, the underpants were soaked in deionized water calibrated to a pH and conductivity close to that of the darkest foxing stains. This was followed with a wash bath using the anionic surfactant Orvus WA Paste (sodium lauryl sulfate), sodium carboxymethyl cellulose (SCMC) as a suspension aid, and EDTA. During the first part of the bath, each of the four sides of the underpants was repeatedly pressed with natural sea sponges (fig. 6). The last rotation left the proper left back leg face up. A poultice of 0.5% w/v HBED in 2% w/v agarose was placed on the area with the darkest foxing stains and left for 30 minutes. The poultice was partially submerged in the shallow bath.

Due to time constraints for the long treatment, the rinse time overlapped with the poultice time; non-poulticed areas were rinsed first while the poultice was still in place. After the poultice was removed, the entire garment was rinsed with deionized water. Next, a second calibrated bath brought the pH to 6 in preparation for the lysing enzyme Glucanex (note 3). The underpants were then lifted from the wash box, and placed on a polyethylene sling that was somewhat tautly stretched over the wash box and secured with binder clips. The wash box was filled with warm running water to create a bain marie at 25–27°C (77–80.6°F) and maintain the temperature needed for enzyme activity (fig. 7). The Glucanex solution was added to the sling with the underpants. A space heater in the wet laboratory helped to maintain a warm temperature.

After two hours soaking in the enzyme solution, the underpants were removed from the bain marie and returned to the wash box. A second wash procedure was conducted, repeating the same wash solution and poultice steps. Finally, the underpants were thoroughly rinsed with deionized water.

To dry the underpants, they were first blotted between cotton towels. The net sandwich was removed, and nylon net padding was inserted into the legs and waist area. The underpants were dried using three hairdryers on cool settings, and left overnight with two fans positioned to provide gentle airflow.

The underpants were visually examined the next day, and the foxing stains were much reduced. The stains were still visible however, and additional treatment was desired. Two additional solutions were tested on some of the darkest foxing stains. These solutions were chosen based on recommendations from other conservators and immediate availability of materials. The first test of sodium borohydride (0.1% w/v) and EDTA (2% w/v)

Fig. 6. Wet-cleaning the underpants. Courtesy of Glenn Petersen.

Fig. 7. The underpants and enzyme solution warmed in the bain marie. Courtesy of Glenn Petersen.

Fig. 8. Front view of underpants in visible light before treatment (left) and after treatment (right). Courtesy of MMA.

Fig. 9. Back view of underpants in visible light before treatment (left) and after treatment (right). Courtesy of MMA.

had minimal effect. The second test utilized citric acid (1% v/v); this had less effect on the stain than on the area adjacent to it. Each solution was brushed on a small stain and left for one hour. After each test, the treated area was rinsed with deionized water on a suction platen. Both solutions were rejected for this treatment.

Since contact time is a significant factor for treatments with chelators and enzymes, it was decided to re-treat the underpants with an abbreviated repetition of the first day's treatment. They were again stitched between pieces of nylon net. This treatment started with the enzyme bath, followed by another wash bath with chelator poultice. Finally, the underpants were rinsed and dried. The repetition of wash baths did provide a noticeable but small difference.

5. DISCUSSION

The use of chelators and enzymes to reduce foxing stains on the linen underpants proved very successful. The general appearance of the underpants was greatly improved (figs. 8, 9), UV light showed dramatically decreased fungal presence (figs. 10–12), and the pH of areas with foxing was less acidic (table 1).

Fig. 10. Front view of underpants in UV light before treatment (left) and after treatment (right). Courtesy of MMA.

Fig. 11. Back view of underpants in UV light before treatment (left) and after treatment (right). Courtesy of MMA.

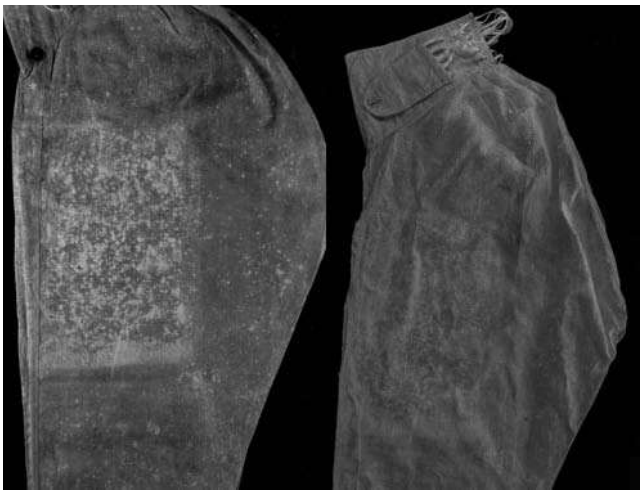

Fig. 12. Detail of underpants on back proper left leg in UV light before treatment (left) and after treatment (right). Courtesy of MMA.

Two circumstances specific to this treatment deserve special mention. The HBED poultice in agarose failed to form a rigid gel, but maintained a thick, pudding-like texture as it cooled. The gel appeared to be compromised by heating the HBED and agarose together in solution. This contradicted the experiences of multiple conservators making smaller batches of poultices with the same materials. While the texture of the poultice was acceptable for use in combination with an immersion bath, it would have made removal problematic in a spot treatment. In addition, the underpants came into the collection highly starched. The treatment assumed that the foxing stains occurred after the underpants were starched, and thus the starch was not a cover layer over the stains; however, the presence of starch undoubtedly impacted the treatment. A significant amount of starch was removed during treatment, but some remains on the underpants.

6. CONCLUSIONS

The success of this treatment would not have been possible without access to the many excellent research articles and case studies published by conservators and scientists. Just as this paper built on the work of others, it is hoped that this process will continue and future papers will share ongoing research and treatments.

Many additional research paths could inform future treatments. A better understanding is needed regarding the impact of pH and conductivity calibrated solutions on textiles. Another avenue for study is an analytic comparison of chelators, enzymes, and bleaches on textiles with foxing stains. While chelators and enzymes successfully reduced the foxing stains by targeting their causes, a bleach treatment might further diminish the stains. Perhaps the most effective treatment will include a sequence of all three.

NOTES

1. Fiber identification with visible and polarized light microscopy.
2. Conductivity and pH tests utilized small plugs of 4% w/v agarose made with deionized water. The gels were in contact with the textile for 20–30 minutes. Measurements were taken with Horiba Laquatwin B-771 compact conductivity meter and B-71X compact pH meter.

3. Glucanex has maximum activity at 45°C and pH 4.5. Its active ranges are 25–60°C and pH 3.5–7.5 (Prieto et al. 2011; Sigma Aldrich 2014).

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SOURCES OF MATERIALS

Agarose, molecular biology grade
- Benchmark Scientific
- PO Box 709
- Edison, NJ 08818
- Tel: (908) 769-5555
- www.benchmarkscientific.com

Citric acid
- Pro Chemical & Dye
- 126 Shove St.
- Fall River, MA 02724
- Tel: (800) 228-9393
- https://prochemicalanddye.net/

EDTA
- Alfa Aesar
- 26 Parkridge Rd.
- Ward Hill, MA 01835
- Tel: (800) 343-0660
- Fax: (800) 322-4757
- www.alfa.com

Glucanex
- Sodium citrate
- Sigma-Aldrich Corp.
- St. Louis, MO
- Tel: (314) 771-5765
- Fax: (314) 771-5757
- www.sigmaaldrich.com

HBED

Santa Cruz Biotechnology
10410 Finnel St
Dallas, TX 75220
Tel: (800) 457-3801
Fax: (214) 358-6070
www.scbt.com

Orvus WA Paste

Sodium borohydride
Conservation Support Systems
PO Box 91746
Santa Barbara, CA 93190
Tel: (800) 482-6299
Fax: (800) 605-7503
www.conservationsupportsystems.com

Sodium carboxymethyl cellulose

Talas
330 Morgan Ave.
Brooklyn, NY 11211
Tel: (212) 219-0770
www.talasonline.com

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