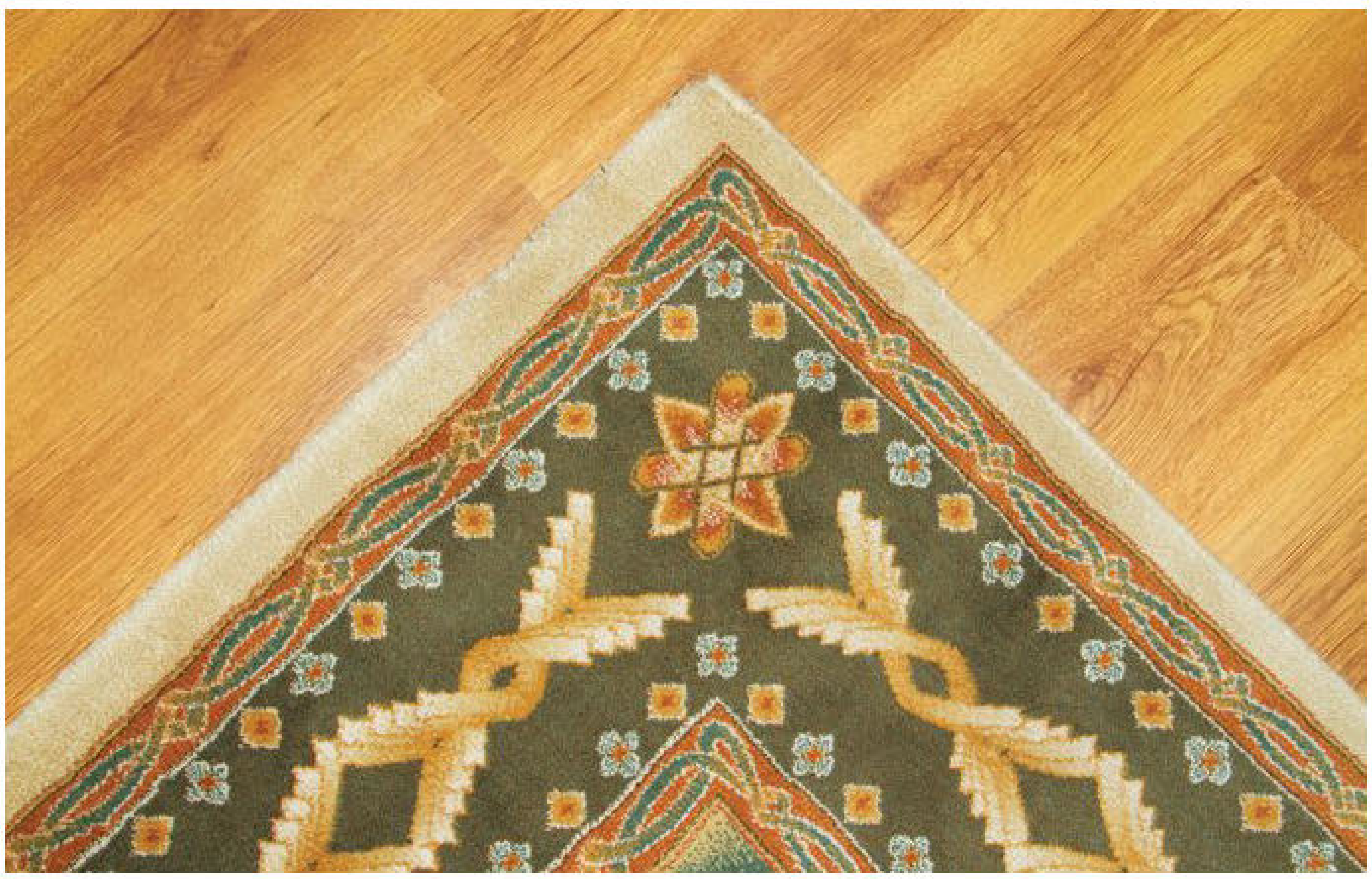
The Effect of Disinfectants, Cleaning and Drying Practices on Oriental Rugs Flooded with Contaminated River Water

The author shares the methodology and results of his doctoral dissertation which focused on measuring the effectiveness of cleaning, disinfection and drying of Oriental rugs immersed in Category 3 floodwater.

>> by Daniel Bernazzani Ph.D.



Oriental rugs

contaminated with Category 3 floodwater potentially harbor environmental bacteria known to be human pathogens. River water inoculated with three species of gram-positive and gram-negative environmental bacteria (*Escherichia coli, Enterococcus faecalis, Pseudomonas aeruginosa*) were used to assess the effectiveness of disinfectant type, cleaning methodology and drying practices by examining the survival rates of bacteria.

Rug sections were immersed for one hour in contaminated water, saturated in one of three EPA-registered disinfectant products (phenol, quaternary chloride and thyme oil) or tap water as a control, followed by cleaning and drying. The results showed that all disinfectants reduced the overall microbial load better than tap water. Two applications of disinfectants were slightly more effective than one application, which, in combination with drying in 24 hours or less, produced an effect that notably reduced microbial counts. These results provide in-plant rug cleaners the ability to assess the benefits of different products and drying procedures, and demonstrate significant reductions of potentially pathogenic bacteria in Oriental rugs contaminated with Category 3 water.

Introduction

Oriental rugs contaminated with floodwater may contain many kinds of pathogenic microorganisms.[1] Therefore, it is essential that the cleaning process has not only a cleaning effect but also an antimicrobial effect.[8] Because human beings may be susceptible to infection from contact with them after contamination (e.g. young children, the elderly, those whose systems are immunocompromised), it is recommended that the best practices available be used in disinfecting flood-damaged Oriental rugs. For almost 150 years, chemical disinfectants have been used to kill microorganisms that cause human disease.[8] However, complications with disinfection have occurred since the mid-1800s when Joseph Lister began developing techniques used in medical procedures.[14] Inappropriately disinfected textiles are a possible reservoir for potentially pathogenic organisms and their components (fragments and toxins) that may become aerosolized and thus present an inhalation exposure risk.[1]

Since 1994, the Institute of Inspection, Cleaning and Restoration Certification (IICRC) *S500 Standard and Reference Guide for Professional Water Damage Restoration* has included qualitative and descriptive disinfection definitions and procedural guidelines on their use.

This study was initiated to further define whether disinfectant products, cleaning and drying achieve together substantial reductions in bacterial activity, and to provide minimum recommendations for professional cleaners, restorers and flood victims who may attempt to clean flood-contaminated Oriental rugs.

Materials and Methods

In order to determine the potential for disinfecting contaminated textiles, the following experiment was performed with two used Oriental rugs of undetermined age in visually good condition, knotted with 100% wool face yarns. Prior to the test, each rug was cleaned by submersion method using a neutral detergent and dried at Bon Ton Rug Cleansers, Watertown, Massachusetts. Two hundred (200) sections (approximately 8.75 cm in diameter) 22.8 g (±1.5g) were cut from each rug using a stainless steel template and razor blade. Each sample was numbered for identification and placed in sterile bags.

Three randomly selected rug samples, x, y, and z, were used as controls and analyzed to determine levels of indicator organisms present prior to immersion in Category 3 water. IICRC defines Category 3 water as water that is grossly contaminated and can contain pathogenic, toxigenic or other harmful agents. Bacterial suspensions for use on selected test samples were prepared: bacterial stock cultures grown for 24 hours on tryptic soy agar (TSA) plates (Hardy Diagnostics, Santa Maria, CA) in an incubator at 37°C (98.6°F). After 24 hours the plates were removed from the incubator and resultant growth was quantified. Before immersion in contaminated river water, the mean bacterial colony-forming units (CFU) for three control samples was quantified at 307 CFU/ml (x=190 CFU/ml, y=370 CFU/ml, and z=360 CFU/ml).

Sixteen samples were randomly selected from rug number 1, an Indo Hariz tied with symmetrical knots oftentimes referred to as Ghiordes or Turkish knots (Figure 1). This type of knot is commonly used for attaching face yarns because it is the most secure for pile rugs.[6] Sixteen additional samples were randomly selected from rug number 2, an Indian design tied with asymmetrical knots (Figure 2), also referred to as a Persian or Sehna knot, used by Eastern weavers.[6] These knots provide an even distribution of pile over the surface of the rug. Asymmetrical and symmetrical knots can be densely packed and are among the most common knots found in hand-knotted woven Oriental rugs.[12]

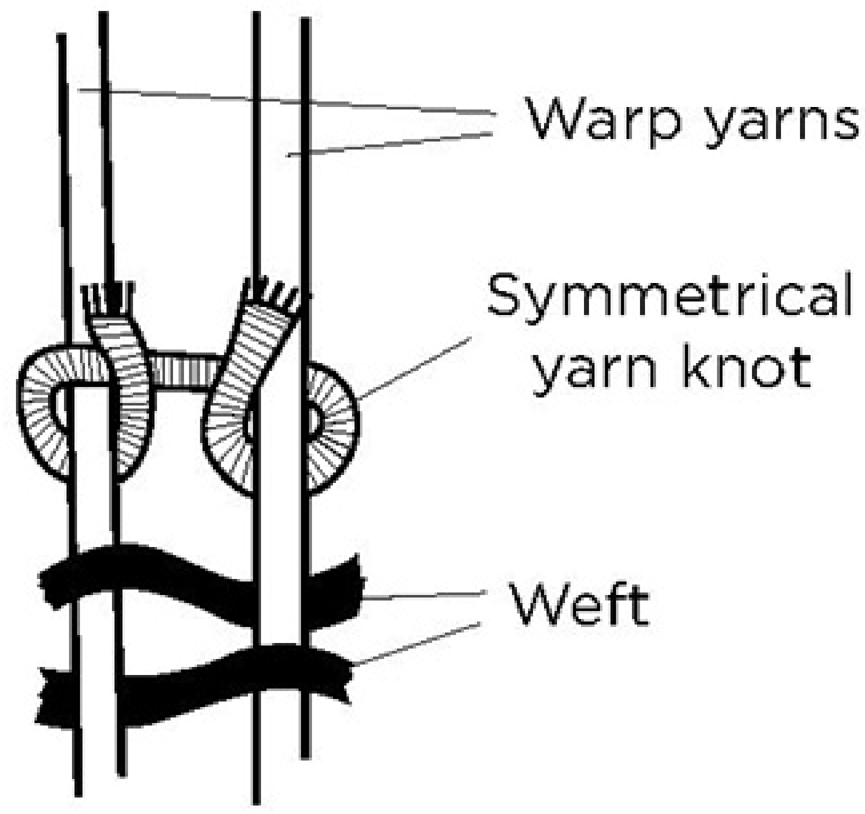


FIGURE 1
Symmetrical knot, ©Adam Costa

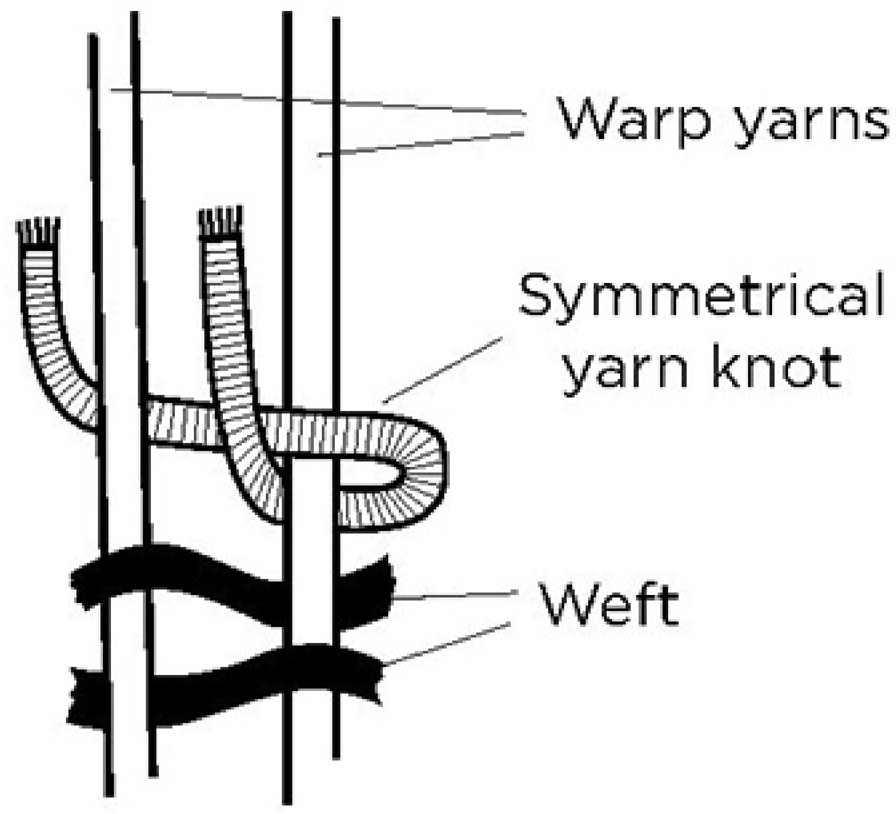


FIGURE 2
Asymmetrical knot, ©Adam Costa

To determine the efficacy of the selected disinfectant products and procedures, the following gram-positive and gram-negative bacteria, originating from environmental sources such as soil and sewage, were carefully chosen and used as representative potential pathogen species for the research project: NLML 1B70 *Escherichia coli* (gram negative), NLML 2B41 *Enterococcus faecalis* (gram positive), NLML 2B33 *Pseudomonas aeruginosa* (gram negative). All strains were maintained by Natural Link Mold Lab, Inc., Reno, Nevada.

Category 3 floodwater (e.g. contaminated water, sewage, rising water from rivers and streams) was collected from four points along the Connecticut River following three days of torrential rain, and kept under refrigeration. These collection sites included farm land in New Hampshire and Vermont and residential and commercial areas in Massachusetts and Connecticut. The water was characterized prior to introducing representative species as shown in Table 1. The collected river water was analyzed by Hub Testing Laboratory, Waltham, Massachusetts for total coliform bacteria, *Pseudomonas aeruginosa*, pH, total dissolved solids, total suspended solids and turbidity.

Contamination, Cleaning and Disinfection of Rug Samples

To examine the efficacy of disinfectant products and application rates (one time versus twice), a standardized cleaning protocol based on *ANSI/IICRC S100 Standard and Reference Guide for Professional Carpet Cleaning*, 2011 was employed. One half of the samples (16) were randomly selected for one-time disinfectant application for each of the disinfectants or the tap water control (A: tap water, B: thyme oil, C: phenolic, and D: quaternary chloride) and cleaning; while the remaining 16 samples had the disinfectant process repeated a second time.

The Oriental rug samples were contaminated by immersing each sample in an inert plastic tray containing approximately 1.0 liter of contaminated river water (8.5 x 10^7 bacterial CFU/ml) at approximately 21.1°C (70°F) for one hour of contact and saturation.

Following one-hour saturation in the contaminated river water, the 16 rug samples selected for a single application of disinfectant were individually removed from the contaminated river water using stainless-steel hooks attached to the top of each sample and placed into one of four inert plastic trays containing either approximately one liter of three disinfectant products: phenolic, quaternary chloride, thyme oil, or tap water (as a control), at approximately 21.1°C (70°F) for 20 minutes. After 20-minutes dwell time, each rug sample was rinsed and cleaned per the following protocol:

1. Sample was removed from the tray.
2. Sample was rinsed by holding with a stainless-steel hook under a faucet with approximately three liters of tap water at approximately 21.1°C (70°F) for 30 seconds.
3. Sample was vacuum-extracted using a portable carpet extractor.
4. Approximately 40 ml of a neutral detergent (pH 7) was applied to each sample.
5. A light tamping action was applied to sample with a nylon brush to provide uniform distribution of the neutral cleaning agent.
6. Twenty minutes of dwell time was allowed for sample.
7. Sample was removed and again rinsed with tap water for 30 seconds in the manner described above.
8. Sample was vacuum-extracted in the manner described above and hung to dry using the stainless-steel clip.

The second 16 contaminated rug samples, which had been randomly selected for a second application of disinfectant products, were removed from the contaminated river water, immersed in the disinfectant solutions, then rinsed and cleaned following the identical process and protocol described above for the first 16 samples. After the initial disinfectant application process and rinse/clean protocol was completed, it was repeated a second time.

The Effect of Drying Time on Microbial Growth

To examine the effect of drying time, the rug samples were evaluated by placing equal, randomly selected sets of 16 in different drying conditions. One set of 16 rug samples were allowed to dry at approximately 22.1°C (71.8°F) ambient air and approximately 29.9 percent relative humidity for 24 hours. These rug samples reached their initial dry state temperature of 22.1°C (71.8°F), as indicated with a Thermo Imaging Camera (Flir I7), within 24 hours. The remaining 16 samples were selected for a process that involved drying in warm, wet conditions: 32°C (87.8°F) ± 0.2° and >90 percent relative humidity. Samples placed in warm wet conditions did not dry in 24 hours and supported the growth of the test organisms.

At 24 hours of drying, each rug sample (16 not dry and 16 dry) was placed in an individual sterile bag containing approximately 40 ml of sterile water, aggressively shaken for ten seconds followed by collection of rinse water and plating of the collected water. A series of tenfold dilutions of the water samples were made to 10^{-6} and used for enumeration of bacterial contents using TSA plates. After 24 hours, the plates were removed from the incubator and growth was quantified.

As previously described, three randomly selected control samples, x, y, and z, were analyzed to determine levels of indicator organisms present prior to immersion in Category 3 water. Preparation of bacterial suspensions for use on selected test samples: Bacterial stock cultures were grown for 24 hours on TSA plates in an incubator at 37°C (98.6°F). After 24 hours the plates were removed from the incubator and growth was quantified.

Results and Discussion

- The results of this study have shown the successful development of a new methodological approach to the quantitative assessment of disinfection, cleaning and drying of flooring textiles contaminated with Category 3 river water. It is important to note that while this study was grounded in the use of Category 3 water, the results are not meant to imply that sewage-saturated textiles would exhibit the same or similar results using the restorative approach described here. A definitive assessment of such an approach with sewage-saturated textiles, or the necessary modification of that approach to show effectiveness in terms of sanitary and hygienic acceptability, would necessitate an additional study using raw sewage in conjunction with the methodology developed in this study.
- Under the conditions described, the disinfection process led to lower microbial burden than when treated with water alone, and when combined with a drying time of 24 hours or less, substantial decreases in microbial burden were observed. Rug samples dry in 24 hours decreased microbial contamination levels from 8.5 x 107 CFU/ml to as low as 3.2 x 102 CFU/ml. These data confirm that rapid drying (24 hours or less) efficiently reduces growth of microorganisms or resuscitation of sub-lethally damaged microbes. Overall, the microbial burden was reduced by 99.4% with water alone and 99.9% or greater using disinfectant products (Table 2).
- The effect of two applications of disinfectants combined with cleaning and drying in 24 hours or less provided acceptable results for sanitizing flood-contaminated Oriental rugs (Table 2). I observed that microbiocidal activity is improved when disinfectants are used on previously cleaned and disinfected surfaces. These data support the practice and recommendations of the IICRC that two applications of disinfectant products are the minimum needed to reliably kill flood-related bacteria. In comparing one application with two applications of disinfectant products, two applications reduced test organ-

isms better than a one-time application, resulting in a reduction from 8.5 x 107 CFU/ ml to as low as 3.2 x 102 CFU ml (Table 3).

- In comparison with water treatment alone as the control disinfectant, a substantially higher number of test organisms were found when compared with disinfectant application (Table 3).
- In comparison with the rug samples that dried in 24 hours, the microbial burden in samples that were not dry in 24 hours increased from 8.5 x 107 CFU ml to as high as 3.4 x 108 ml. In terms of reduction of test organisms, all rug samples dry in 24 hours led to significant reductions of microbial growth. These drying differences had a dramatic effect on results, as evidenced by the significant decrease of test organisms in the samples that were dry in 24 hours.
- The results of this research support a recently published study on bacterial amplification in flooded flooring textiles and the need for rapid remediation[9], and demonstrate that one of the most important factors in the success of disinfecting contaminated water-damaged textiles is a drying time of 24 hours or less to significantly improve sanitation efficacy. However, the selection of appropriate disinfecting agents, as well as the number of applications, should be taken into consideration because it is a combination of all of these factors that successfully kill microorganisms. These findings also confirm that a botanical disinfectant can have considerable disinfection effect on textiles without fiber degradation.

TABLE 1
Characterization of Connecticut River water

Parameter	Results
Total Coliform Bacteria	4 CFU/ml
Pseudomonas aeruginosa	0 CFU/ml
pH	7.5 pH units
Total Suspended Solids	7 ppm
Total Dissolved Solids	66 ppm
Turbidity	0.8 NTU

TABLE 2
Reduction after immersion in disinfectant

	Disinfectant Two Applications			
	CFU per ml Start	CFU per ml After dry	Log Reduction	% Reduction
Water	8.5×10^7	5.5×10^5	2 log	.994
Thyme oil	8.5×10^7	1.8×10^4	3 log	.999
Phenol	8.5×10^7	3.2×10^2	5 log	.9999
Quaternary	8.5×10^7	1.7×10^3	4 log	.9999

TABLE 3
Average plate counts after immersion in category 3 water at 8.5 x 107 CFU ml for 1 hour

	Disinfectant One Application		Disinfectant Two Applications	
At 24 hrs.	CFU per ml 1 x Not Dry	CFU per ml 1 x Dry	CFU per ml 2 x Not Dry	CFU per ml 2 x Dry
Water	3.4×10^8	1.5×10^6	1.3×10^8	5.5×10^5
Thyme oil	2.3×10^8	1.2×10^5	6.5×10^7	1.8×10^4
Phenol	2.3×10^8	4.6×10^3	1.8×10^8	3.2×10^2
Quaternary	1.8×10^8	3.1×10^2	1.7×10^8	1.7×10^3

Tactile and Visual Cleanliness

After drying, 24 individual Oriental rug samples used in the study were assessed by eight expert rug cleaning professionals. The expert participants were not informed about which samples were used as controls or which samples were immersed in the various disinfectant solutions. Additionally, no information was provided to the experts regarding drying times. The following subjective score was used to describe the degree of change in texture and color:

#1 indicates no detectable change from the control.
#2 indicates little change.
#3 indicates moderate detectable change.
#4 indicates substantial change.
#5 indicates highest detectable change.

These tests were conducted blind without participants being aware of which samples received which treatment (Figure 3).

As a final assessment of visual changes in fibers following drying, micrographs were obtained on a scanning electron microscope (SEM) located at Northeastern University Electron Microscopy Center, Boston, Massachusetts. Samples were randomly selected from those used in the disinfectant immersions for examination by Northeastern microscopy technician William H. Fowle.

The fibers examined with the SEM indicate that fiber degradation (e.g. color, texture, hand) occurred in both the phenol-based (Figure 7) and quaternary ammonium chloride-based treatments (Figure 8), while the thyme oil (Figure 6) showed no degradation, which was equivalent to the control fiber not used in the test (Figure 4) and the fiber using water as a control for the disinfectant (Figure 5).

The SEM images were especially important because the results of the tactile tests findings observed by the

FIGURE 3
Tactile change observed by Oriental rug experts

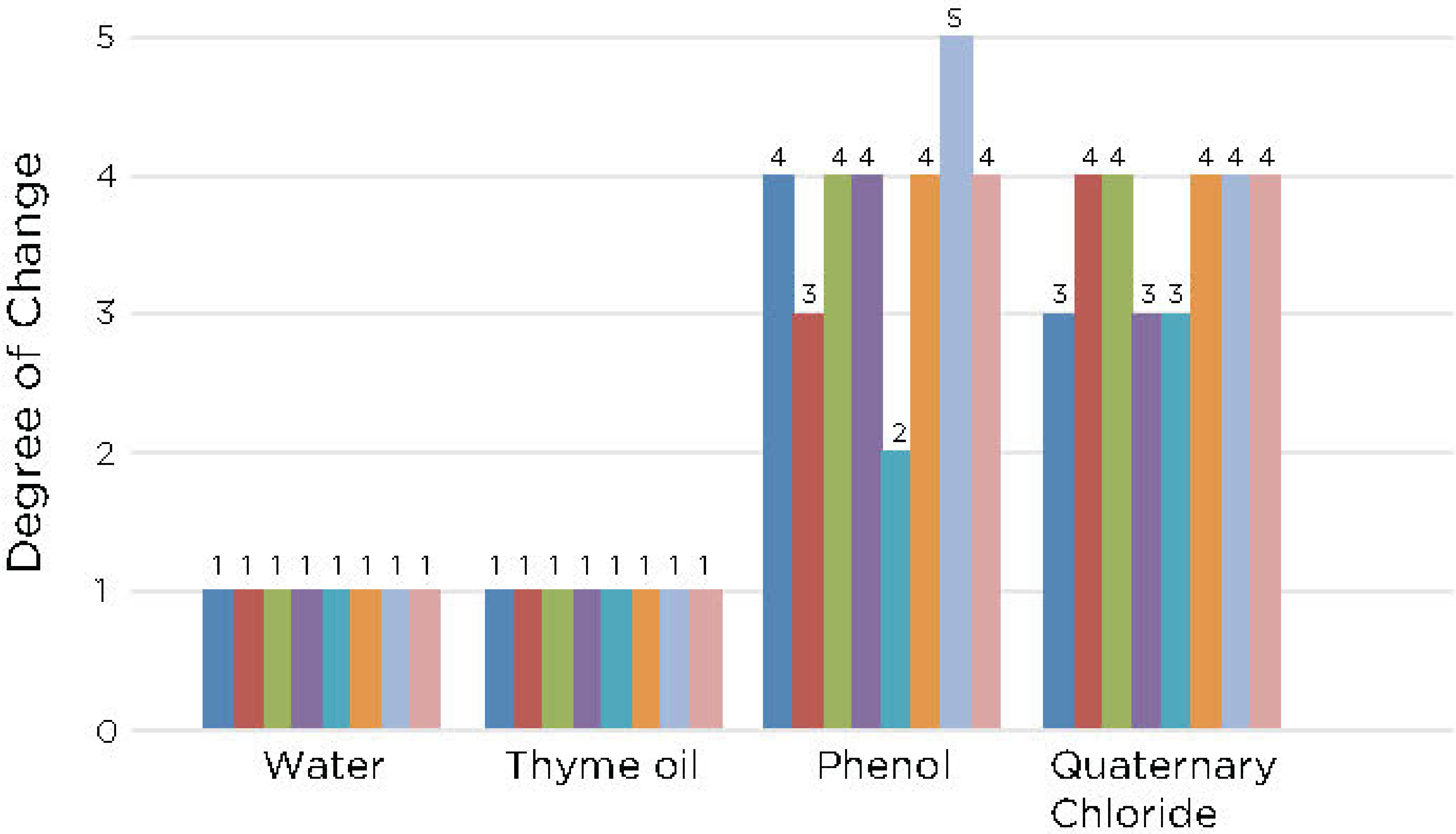
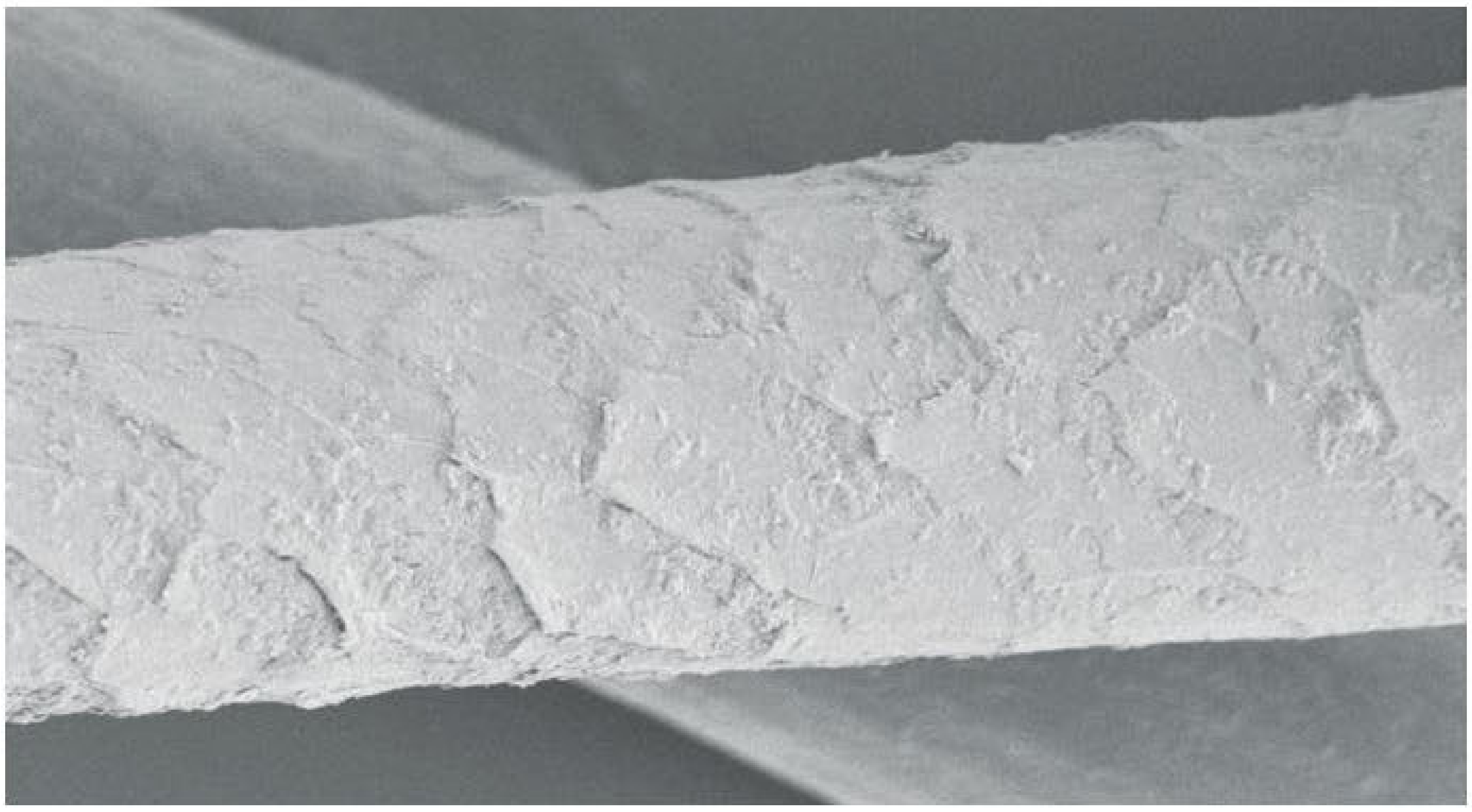


FIGURE 4
Control fiber not used in test



rug experts, along with the SEM images, allows me to state my conclusions much more strongly. The tactile tests and SEM images interpretations provide a strong correlation of damage to textile fibers given the specific disinfecting treatment.

Discussion

Much attention is devoted to cleaning flood-contaminated textiles for appearance; I developed this study grounded in cleaning for health. Currently, the subject of textile cleaning following pollution with flood-borne fecal material causes concern among those employed in the fields of carpet and rug cleaning, water damage restoration, and mold remediation. Since 2008, in the course of testing sewage-contaminated Oriental rugs, I discovered that hidden and viable microbes remained when they were presumed to have been removed during the cleaning process. This raised a critical question: If we could detect organisms imbedded in textiles after careful and professional cleaning, what organisms remain when Oriental rugs are cleaned by flood victims themselves?

My research focused on studying the efficacy of killing and removing microbes from textiles after exposure to floodwaters containing fecal matter. My interest has motivated me to conduct this research specifically on Oriental rugs, because of the complexity of their construction, as well as their intrinsic value. However, the results of this study may influence the cleaning methods of other textiles as well.

I have developed minimum recommendations that provide safe, effective methods for cleaning, disinfecting and drying Oriental rugs that effectively remove microorganisms from textiles. This research will help to evolve and advance our understanding of cleaning contaminated Oriental rugs and disinfection efficacy by considering the effects of two independent factors: applying disinfectants and prompt drying.

I am committed to the continued development of safe techniques for cleaning textiles of historic or artistic value. My objective encompasses the advancement of "green" cleaning and recognizes the contribution that cleaning makes to good health. Cleaning procedures must be designed for the physical preservation of yarns and their structure, with the aim of minimizing damage to materials, and most importantly, contributing to a healthful indoor environment. The act of cleaning contaminated rugs is complicated by the difficulty of removing microorganisms trapped between complex yarn structures without degrading the textile or diminishing its historic, artistic, or monetary value.

Recommendations

In order to protect human health, I recommend that all flood-contaminated Oriental rugs be removed from homes and cleaned by the immersion method to protect the health of workers and flood victims. Every contaminated rug should be rinsed, immersed in a disinfectant with at least twenty minutes dwell time, cleaned and have the process repeated a second time, followed by rapid drying in 24 hours or less. The drying of wet Oriental rugs following cleaning and disinfection requires a dry air stream to evaporate the water vapor from the surface. Increasing temperature at low humidity will accelerate drying. Efficacy testing should be performed following drying with involvement of an indoor environmental professional for post-restoration testing to ensure complete decontamination.[1]

The aim of this study was to determine the actual reduction of microbial burden from Category 3 floodwater via the application of disinfectants, cleaning and rapid drying. This study did not include an investigation of possible influences from sea water, dwell time of Category 3 water for longer periods of time or temperature of the floodwater. My focus centered on results of Oriental rugs dry in 24 hours, however, research is needed on desiccation of microorganisms as time progresses after drying to determine what effect time will make in the final analysis.

FIGURE 5
Fiber selected for immersion in water as control for disinfectant

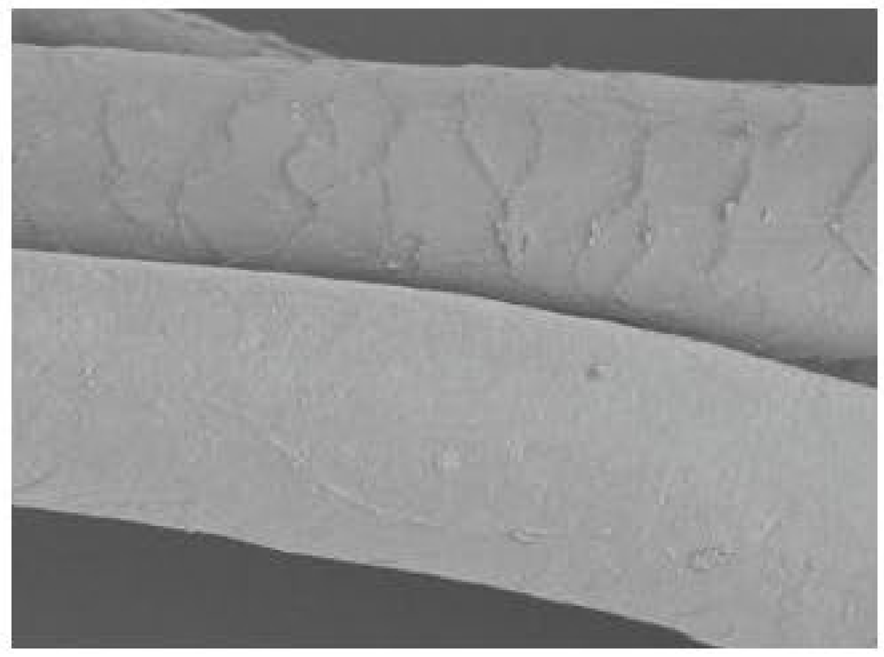


FIGURE 6
Fiber selected for immersion in thyme oil

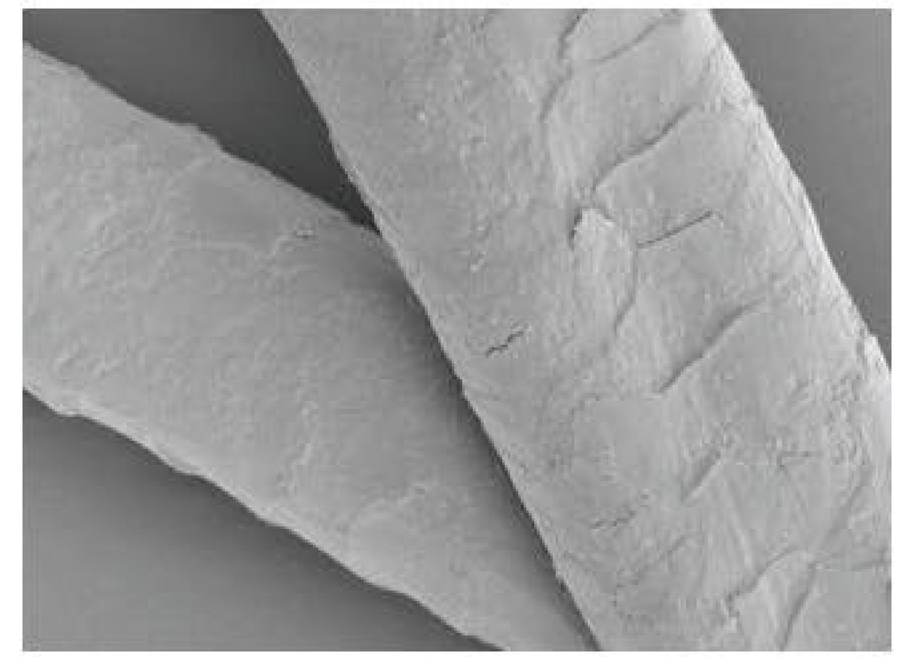


FIGURE 7
Fiber selected for immersion in phenol

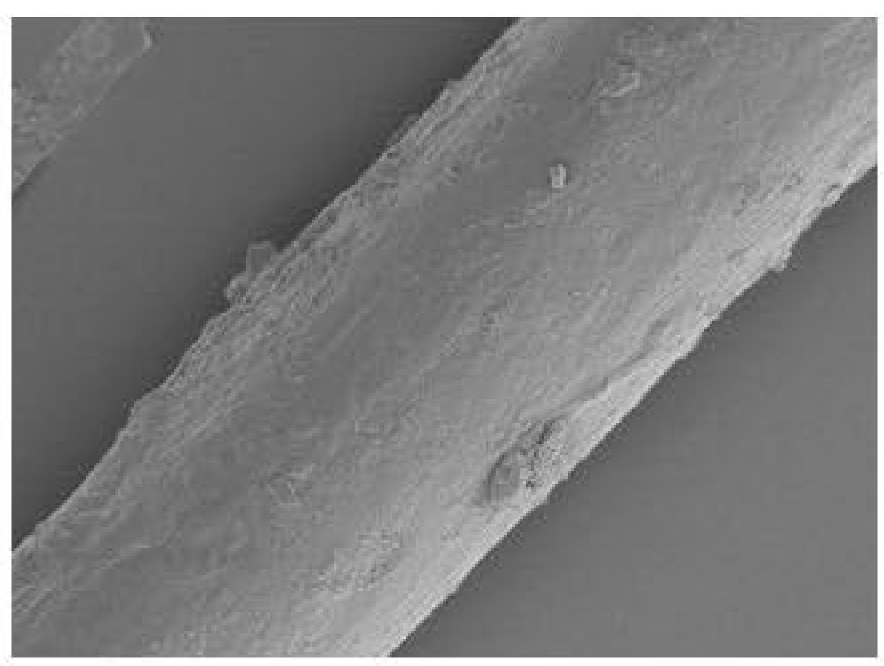
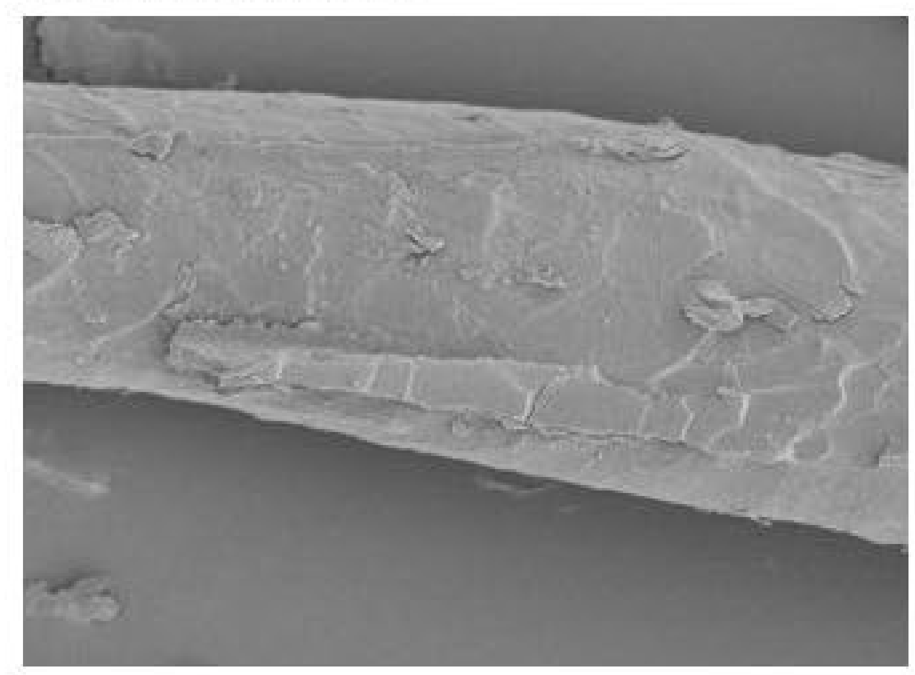


FIGURE 8
Fiber selected for immersion in quaternary ammonium chloride



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