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COPING WITH ARSENIC-BASED PESTICIDES ON TEXTILE COLLECTIONS

JAE R. ANDERSON, NANCY ODEGAARD, MARTINA DAWLEY, DELANA JOY FARLEY, WERNER ZIMMT

ABSTRACT

This article discusses the development of a protocol for testing and removing arsenic pesticide residues from textiles. This research was conducted by a team at the Arizona State Museum Conservation Laboratory and with funding from a National Center for Preservation Training and Technology (NCPTT) grant that partially supported the purchase of equipment, supplies, and a stipend for a graduate student assistant. A procedure for the survey of toxic metal pesticides on textiles and a methodology for a treatment to remove arsenic-based pesticides from textiles were created.

The project included the following activities.

- Scholars of Navajo (Dinè) textiles and Navajo weavers were consulted as the project was developed.
- The entire collection of Navajo textiles was surveyed with a portable x-ray fluorescence instrument (pXRF). A protocol for the testing procedure was developed to make this task both (1) efficient in sometimes difficult storage access conditions and (2) useful for the development of an arsenic removal method.
- A protocol for arsenic removal was based on testing of a series of arsenic-treated samples (doses based on typical amounts found during the survey on ASM collections). The samples were pXRF tested before and after variations in washing technique including time, temperature, pH, and agitation. Wash water from the samples was also tested for arsenic.
- Three museum textiles were successfully cleaned of arsenic pesticide residues.

1. INTRODUCTION

Traditional conservation care of historic textiles is a tiered system of conservation treatments. No treatment is preferred, considering any degree of handling induces irreversible effects; however, circumstances may require some form of treatment, which should be minimal. Removing arsenic through wet cleaning is highly invasive; nevertheless, the benefit may be necessary to reduce potential health risks for cultural, occupational, or scholarly handling of these contaminated materials.

The removal of arsenic-based pesticides on textile collections is a complex conservation issue. A grant from the National Center for Preservation Training and Technology (MT 2210-11-NC-07) was awarded to the Arizona State Museum (ASM) at the University of Arizona to develop guidelines for the use of portable x-ray florescence spectroscopy (pXRF) instruments for both the survey of pesticide residues on historic textiles and their removal through an aqueous conservation treatment using technically sound methodologies.

The removal process leads to post-wash arsenic solutions, which need to be legally and safely disposed of as nonhazardous arsenic waste, <5 mg/L or <5 parts per million (ppm) (U.S. Environmental Protection Agency 2009). Research into water treatment of arsenic for safe drinking water standards offers various filtration methods, which may be beneficial.

2. BACKGROUND

After a longer history in environmental conservation, the pXRF has become a common and powerful tool in museum conservation. The study described here combined the growing standardization and versatility of pXRF technology with ASM's knowledge and extensive experience in pesticide residue studies. Portable XRF technology has evolved significantly over the past 10 years. Notable manufacture changes include the move from sealed radioactive sources which, depending on the half-life of the source, have varying life-use expectancies, to the use of x-ray tube sources; the ability to detect and differentiate a broader range of elements including light elements; and improved analytical software that allows for batch processing of data. X-ray tube source pXRFs are being used for pesticide surveys; however, new guidelines have not been published, and reporting is inconsistent. NCPTT funding permitted ASM to obtain an up-to-date x-ray tube source pXRF analyzer and to use it to develop survey guidelines on the basis of a documented collection. It has also allowed us to develop guidelines for treatment evaluation on the basis of removal methods developed.

Navajo textiles provided an excellent material type for this case study as they have a uniform format, density, and consistent use of wool yarns. They are secular and distributed throughout the United States in private and institutional collections. They were often treated with pesticides to prevent or arrest insect damage. ASM has over 600 Navajo textiles. These items are well documented and curatorial expertise at ASM is foremost in the world. This project considered the links in pesticide residue type and distribution with other historic details of the collection. This study provided broader information for the ASM collection, and we anticipate there is a potential to predict the presence of pesticide residues in other institutional collections.

3. EXPERIMENTAL METHODOLOGY FOR TEXTILE COLLECTIONS SURVEY

A systematic and efficient approach to conduct a complete survey of the entire collection of Navajo textiles was developed using the handheld x-ray florescence (XRF) spectrometer. The pXRF analyzer was efficient and easy to use in the storage rooms, where textiles of varying sizes are housed in cabinets and shelving units as seen in figure 1.

Fig. 1. Storage of ASM Navajo Textiles (Courtesy of Martina Dawley)

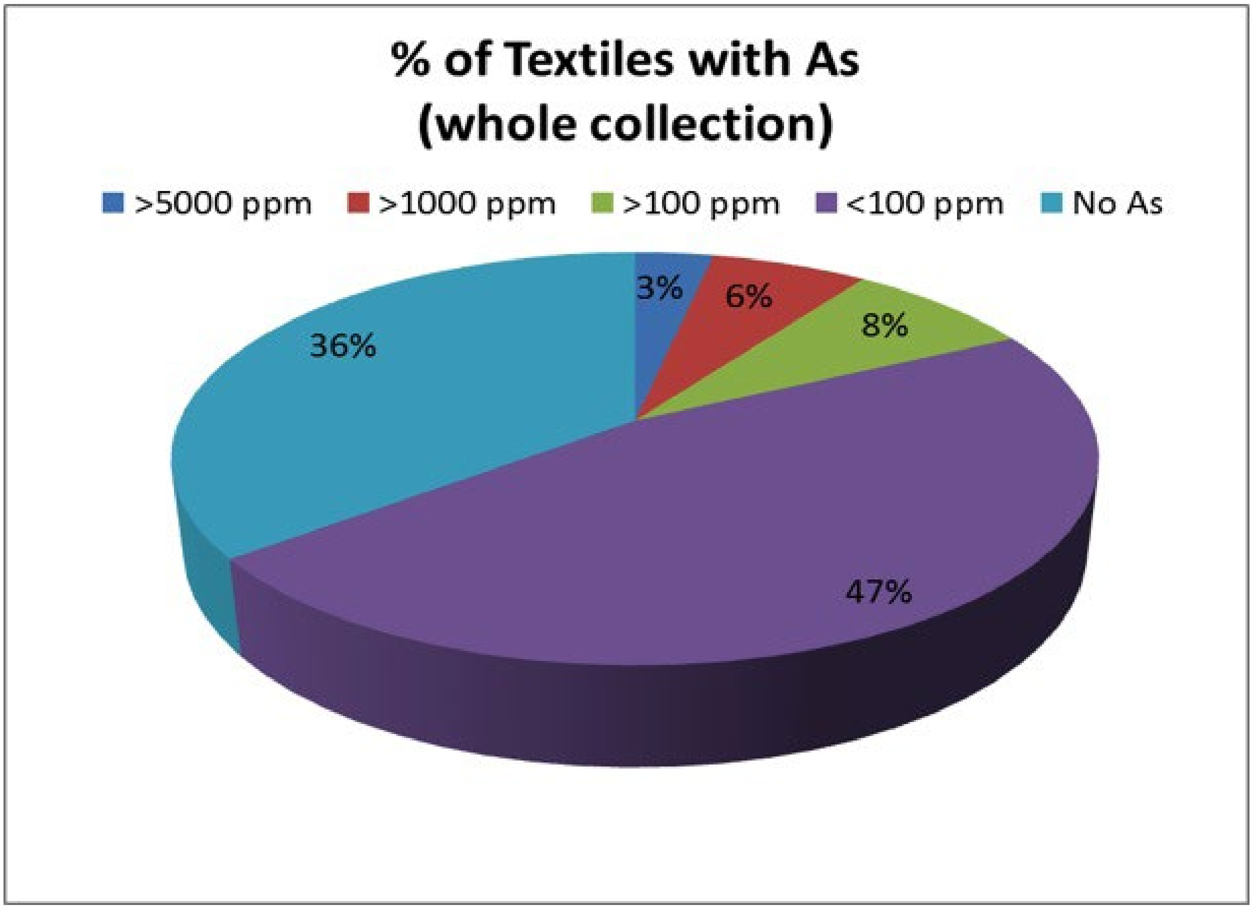


Fig. 2. Percentages of arsenic levels (Courtesy of Martina Dawley)

The Navajo textiles were tested for the presence of toxic metal pesticide residues (As, Zn, Hg, and Pb). Arsenic levels were organized into the following categories: No As, <100 ppm, 100–1000 ppm, 100–5000 ppm, and >5000 ppm as seen in figure 2.

The highest reading was 29,105 ppm. Ultimately, textiles with high levels of arsenic correlated with a particular time period, creating a time line for arsenic-based pesticides used in collections from early museums and private collectors.

3.1 SURVEY PREPARATION

Preparations for the survey included an ASM Navajo Textile Analysis Workshop, which was open to the general public with priority registration given to grant personnel, Friends of ASM Collections, ASM's membership group, and Tucson's Textile Study Group. In addition, University of Arizona's required radiation and chemical lab safety training courses ensured proper safety practices such as personal protective equipment as shown in figure 3.

Additional research was conducted in areas of arsenic in museums, arsenic in the natural environment (ground and water), safety precautions on how to handle toxic materials, care and handling of Navajo textiles, and Navajo textile makers, collectors, and trading posts. The research constructed a time line of arsenic use in collections from early museums and private collectors up to the mid-1900s as seen in figure 4. This time line helped determine which textiles were most likely to be contaminated.

Fig. 3. Personal protective equipment worn while conducting pXRF testing on textiles (Courtesy of Gina Watkinson)

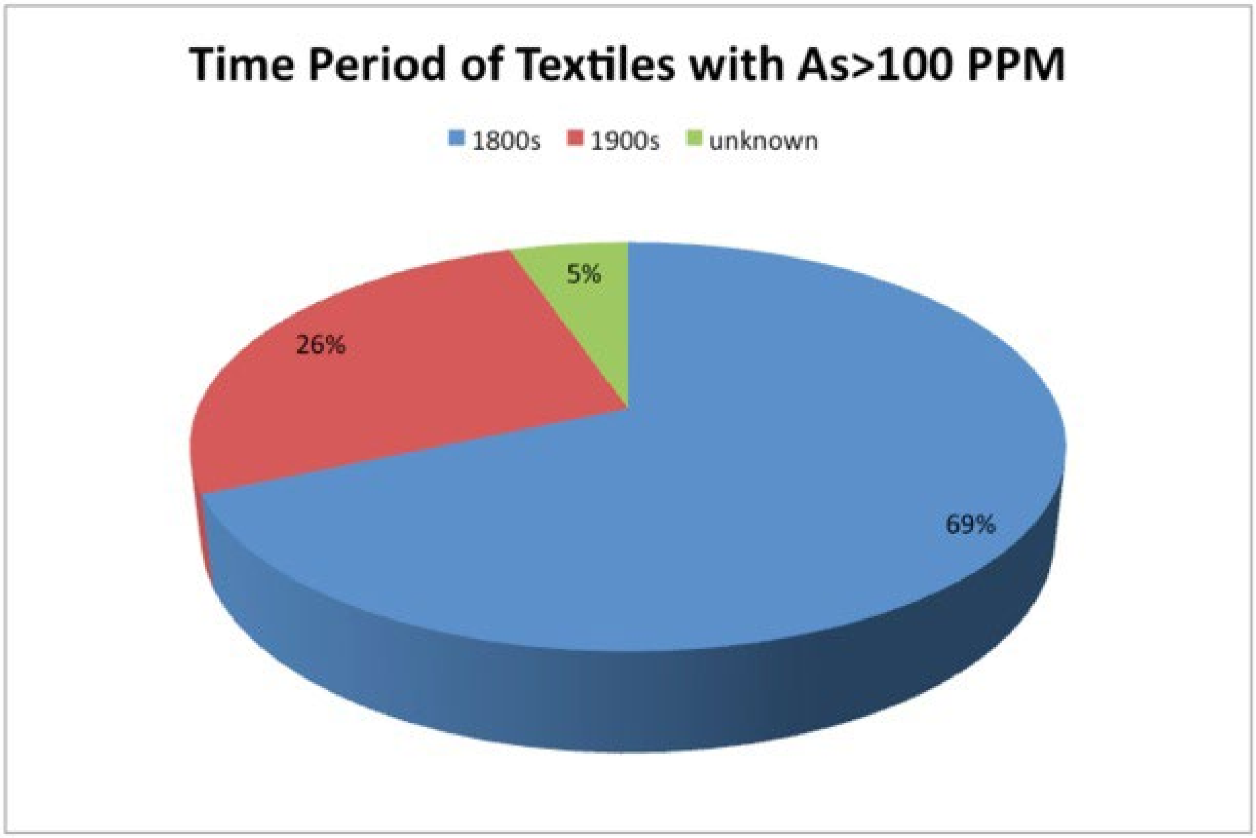


Fig. 4. Arsenic use in ASM collections based on date (Courtesy of Martina Dawley)

3.1.1 Goal Set for Survey

A list of goals to conduct the survey was as follows:

1) test all Navajo rugs for pesticides (As, Zn, Hg, and Pb);
2) create Excel spreadsheet to compile data;
3) organize by highest readings of arsenic;
4) consider size of rug for pesticide removal to fit lab sink;
5) find the highest occurrence of arsenic by collector and organize by region, location of highest occurrence, organize by time period of highest occurrence;
6) organize into schematic of very high to very low arsenic levels.

3.2 PROTOCOL DEVELOPMENT FOR THE SURVEY

The methodology for this project included use of an instrument log sheet, and after each day of testing, data were downloaded onto a computer and stored. The testing procedure evolved somewhat over time. Each textile was laid out flat as shown in figure 5, and a printed photo was used to record the exact area tested.

The catalog label was used to determine the orientation of the test areas on the textile. Label side was recorded as *recto label* and the reverse as *verso label*. The area tested started with the label side up. The first reading was done directly above or below the label (depending on how the label is oriented). This procedure was used for the first 50 textiles resulting in 5 to 10 readings taken on the recto and verso for each textile. Preliminary data from this group showed that if a textile has less than 100 ppm of arsenic from the first reading, then the textile will most likely have subsequent readings below 100 ppm.

Fig. 5. Textile laid flat for pXRF testing (Courtesy of Martina Dawley)

Likewise, if the first pXRF reading contained more than 100 ppm of arsenic then the textile will most likely have subsequent readings above 100 ppm.

After the first 50 textiles were tested, the protocol was modified. Each rolled textile was first read directly above or below its catalog label. If the pXRF reading was above 100 ppm then the textile was unrolled and tested in two to three more random areas recto and verso the label. If large textiles were over 100 ppm, they were partially unrolled and read once more verso the label.

4. EXPERIMENTAL METHODOLOGY FOR WET CLEANING

Developing a wet treatment procedure to remove arsenic, a toxic substance, from a textile requires a systematic approach in a controlled environment to ensure the safety of individuals and objects. The approach first observed the properties of test materials with deionized water to determine the best technique to efficiently fabricate arsenic test samples. The process then proceeded to pXRF instrument calibration of cotton and wool arsenic test samples. Arsenic test samples correlated with common arsenic levels from the Navajo textile survey. Traditional textile conservation wet cleaning variables were considered in the testing of conditional effects relating to time, temperature, agitation, and pH. Each conditional effect used the same concentration of arsenic, which related to arsenic levels on potential Navajo textile candidates. Supplementary analysis examined the post-wash water for arsenic.

4.1 TEST SAMPLE PREPARATION

Initial test samples consisted of unbleached cotton interlock knit and wool jersey knit (55 mm diameter) with a dry mass of approximately 0.4 g. The selected fabrics were acquired from a previous textile study and appropriately reflected fibers associated with Navajo textiles. The wetting properties of the fabrics and application techniques were evaluated with de-ionized water to devise a method to produce homogenous arsenic test samples. Preparation of samples included a progression of application techniques that started with a dropper, transitioned to more traditional pesticide treatment methods such as spraying, and ended with a dipping process.

The hydrophobic effects of each fabric prevented ideal homogenous arsenic test samples. A drop of Triton X-100, a nonionic surfactant, was added to approximately 400 mL of deionized water with a glass micropipette, which improved wetting properties of both fabrics. Wetting of the wool test sample resulted in a curling effect when saturated with deionized water, causing nonhomogenous dry arsenic samples. The wool test sample was substituted with a thicker undyed handwoven Chimayo wool fabric, which also directly correlated with historic Navajo textiles. Homogeneous absorption was visually confirmed by adding dark food coloring such as green or blue to the solution as shown in figure 6.

4.2 ARSENIC TEST SOLUTIONS

Arsenic is a chemical element, atomic number 33, derived from natural and anthropic sources, which presents worldwide environmental and health concerns. The element exists naturally as organic or inorganic compounds, with the inorganic form considered more abundant and toxic. Arsenite (As[III])

Fig. 6. Homogeneous absorption into cotton sample: deionized water, Triton X-100, and McCormack food coloring (Courtesy of Jae R. Anderson)

and arsenate (As[V]) are two species of inorganic arsenic compounds, with As[III] specified to be 25–60 times more toxic than As[V] (Vasudevan et al. 2012). Arsenous acid (As_2O_3) and sodium arsenite ($NaAsO_2$) were primarily used as traditional preservation pesticide treatments on artifacts by museums and collectors (Odegaard et al. 2005).

Arsenic test solutions were created using sodium meta-arsenite ($NaAsO_2$), deionized water, and Triton X-100. Approximately 400 mL of deionized water was pretreated using a glass micropipette to add a drop of Triton X-100. A measured amount of sodium arsenite was dissolved into the deionized water and surfactant solution to generate a 100 mL arsenic solution with a concentration of 10,000 ppm. Five 50 mL arsenic solutions were prepared by diluting 10,000 ppm to produce concentrations of 5000 ppm, 2500 ppm, 1000 ppm, 500 ppm, and 100 ppm.

4.3 HANDHELD PXRF CALIBRATION

A pXRF arsenite calibration curve was constructed for both cotton and Chimayo wool textile as seen in figures 7 and 8. A total of 15 wool samples were contaminated with known arsenic concentrations. A concentration set consisted of three wool samples immersed in one of five prepared arsenic solutions: 5,000 ppm, 2,500 ppm, 1,000 ppm, 500 ppm, or 100 ppm. Each contaminated wool sample was pXRF tested wet and dry, in five different areas to ensure uniformity and quality of concentration. Each pXRF reading was conducted in the manufacturer's "soil" mode for a period of 90 seconds with beam settings at 40 kV for 60 seconds and 15 kV for 30 seconds. This generated a total of 150 measured pXRF wool readings partitioned into five controlled concentration sets. The process was repeated with 15 samples of cotton.

The detection of arsenic on dry Chimayo wool nearly doubled from wet samples. A quick study doubling the thickness of a thinner dry cotton sample by folding it in half and pXRF testing nearly

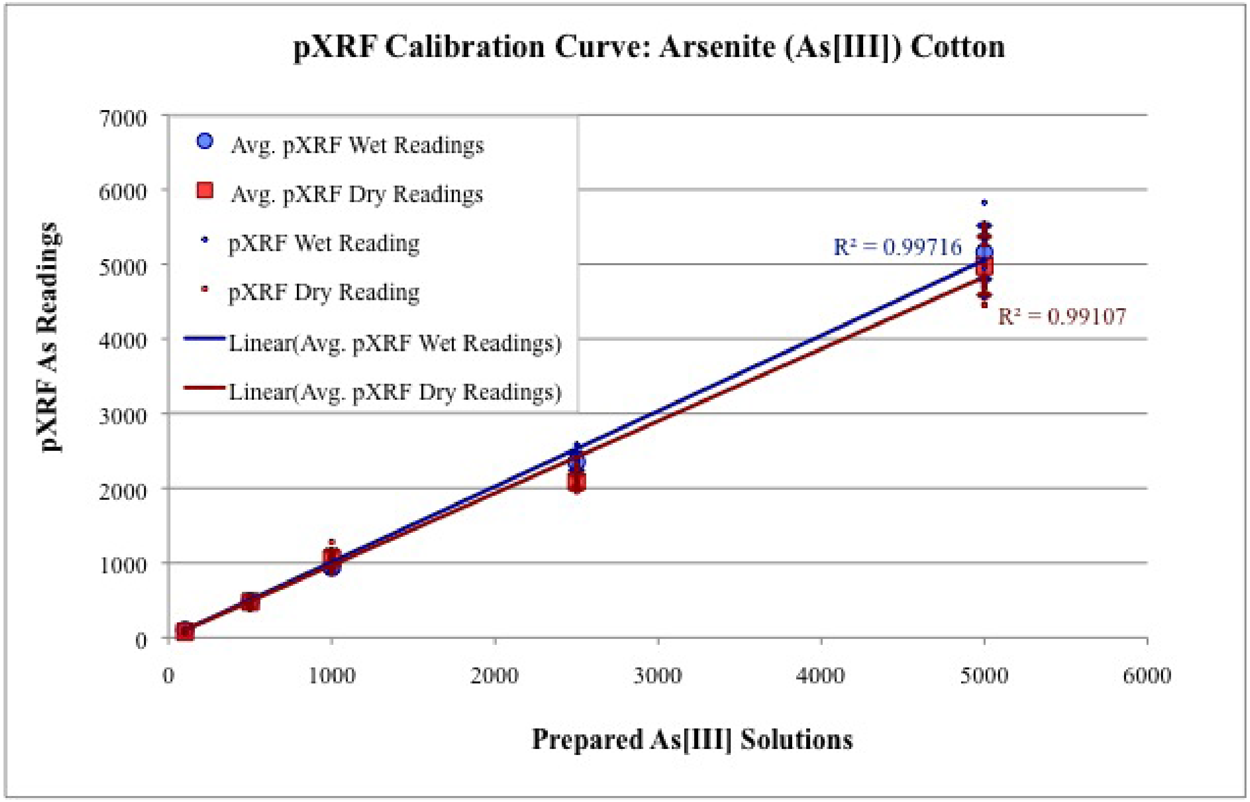


Fig. 7. pXRF cotton calibration curve (Courtesy of Jae R. Anderson)

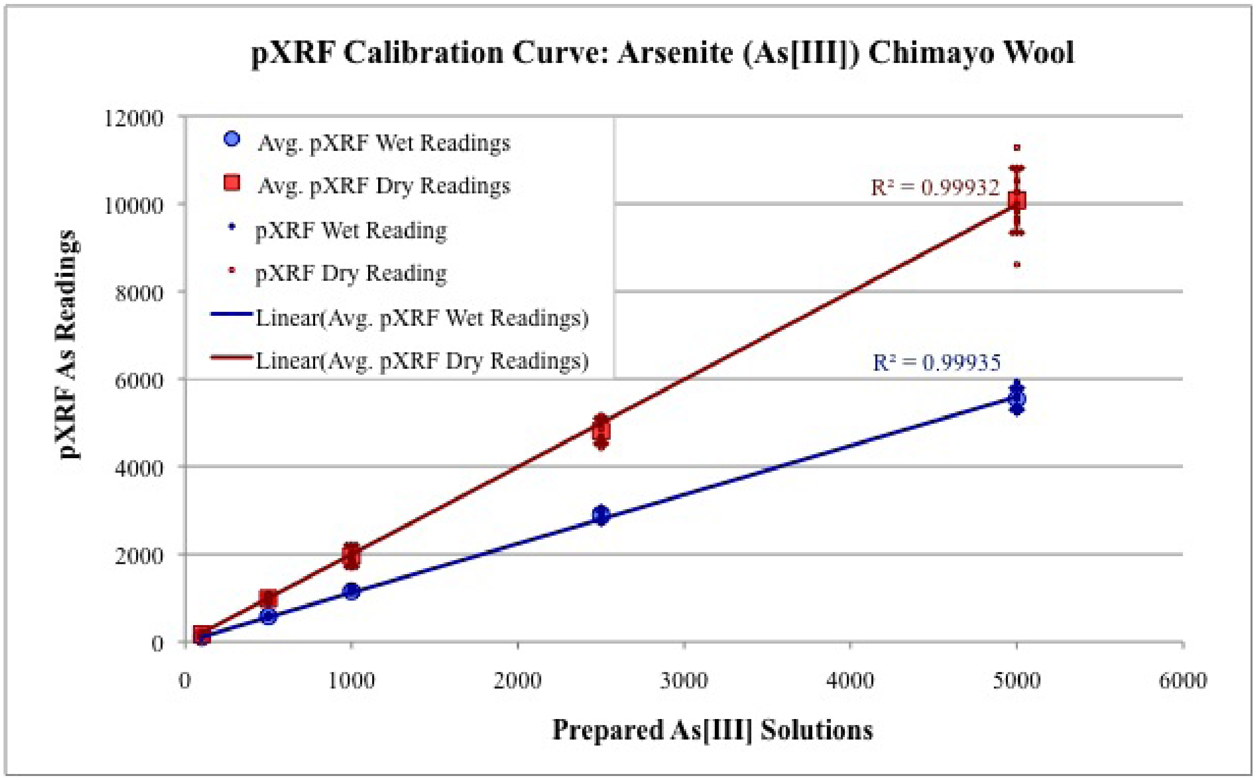


Fig. 8. pXRF Chimayo wool calibration curve (Courtesy of Jae R. Anderson)

doubled the detection of arsenic. The calibration curves display corresponding detection levels of arsenic on wet samples regardless of thickness or fiber; thus, the thickness of a dry fabric sample is significant in the detection of arsenic, which is likely due to efflorescence, but is a topic for further investigation. The conditional effects for removing arsenic from cotton are also a topic for further research.

4.4 CONDITIONAL EFFECTS

Conditional effects were based on variables in traditional textile conservation wet cleaning practice. Time, temperature, agitation, and pH were investigated in the removal process of arsenic from Chimayo wool textiles. Each investigation utilized a 2-L Tupperware Square Pick-A-Deli Container with a measured volume of deionized water (200 mL or 400 mL), and 1000 ppm arsenic samples. Two lift-up strainers of different dimensions assisted in retaining a fixed sample position during deionized water submersion and extraction as seen in figure 9. Samples were extracted from deionized water and immediately wet tested with the pXRF instrument on a nonabsorbent glass surface, then retested on the same glass surface after being air-dried.

4.4.1 Time

The investigation of time was considered the most straightforward test since temperature (23°C), agitation (none), and pH level (~7.0) were all held constant. Published research established a minimum and maximum range of time for a textile to be in an aqueous solution (Rice 1972; Cross 2007). A total of 15 wool samples were divided into five sets of three samples. Each sample set was immersed in 200 mL of deionized water at a respective time interval of 1, 5, 10, 15, or 20 minutes. Samples were pXRF tested wet and dry, and results plotted as seen in figure 10.

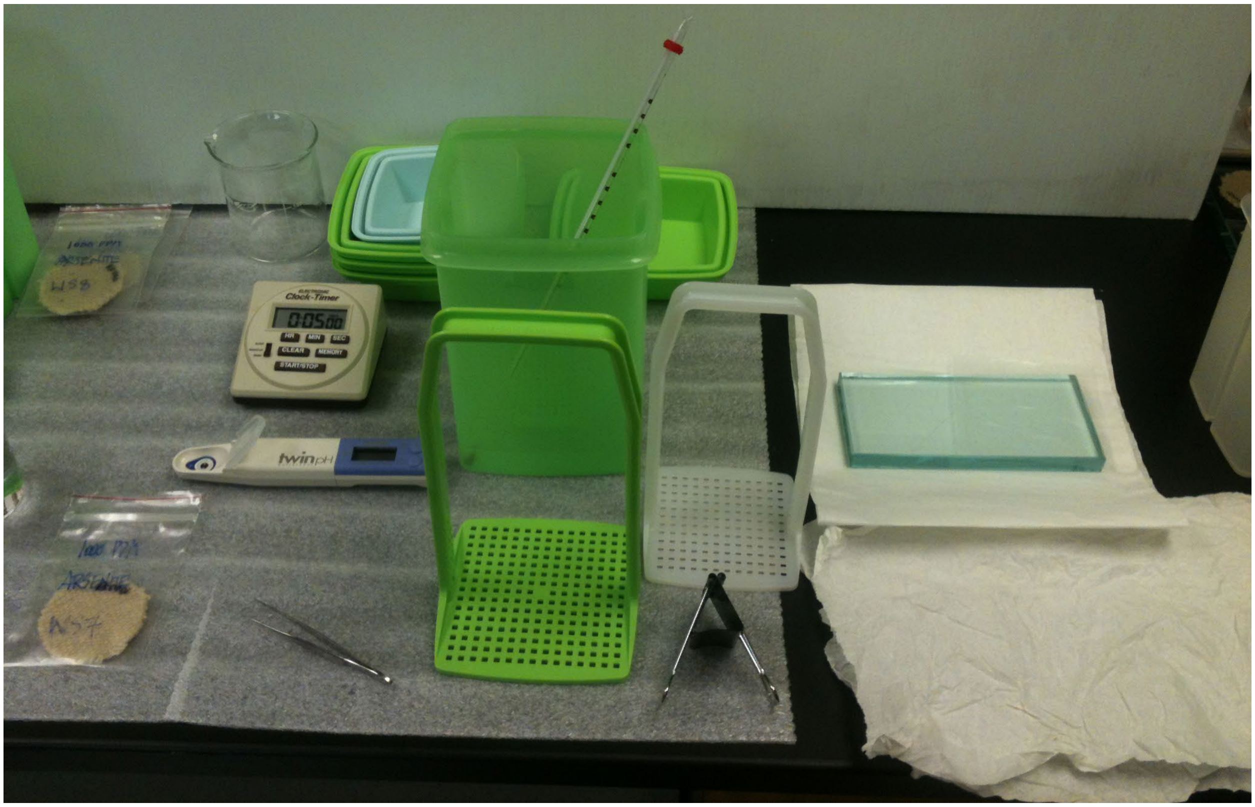


Fig. 9. Conditional effects testing setup (Courtesy of Jae R. Anderson)

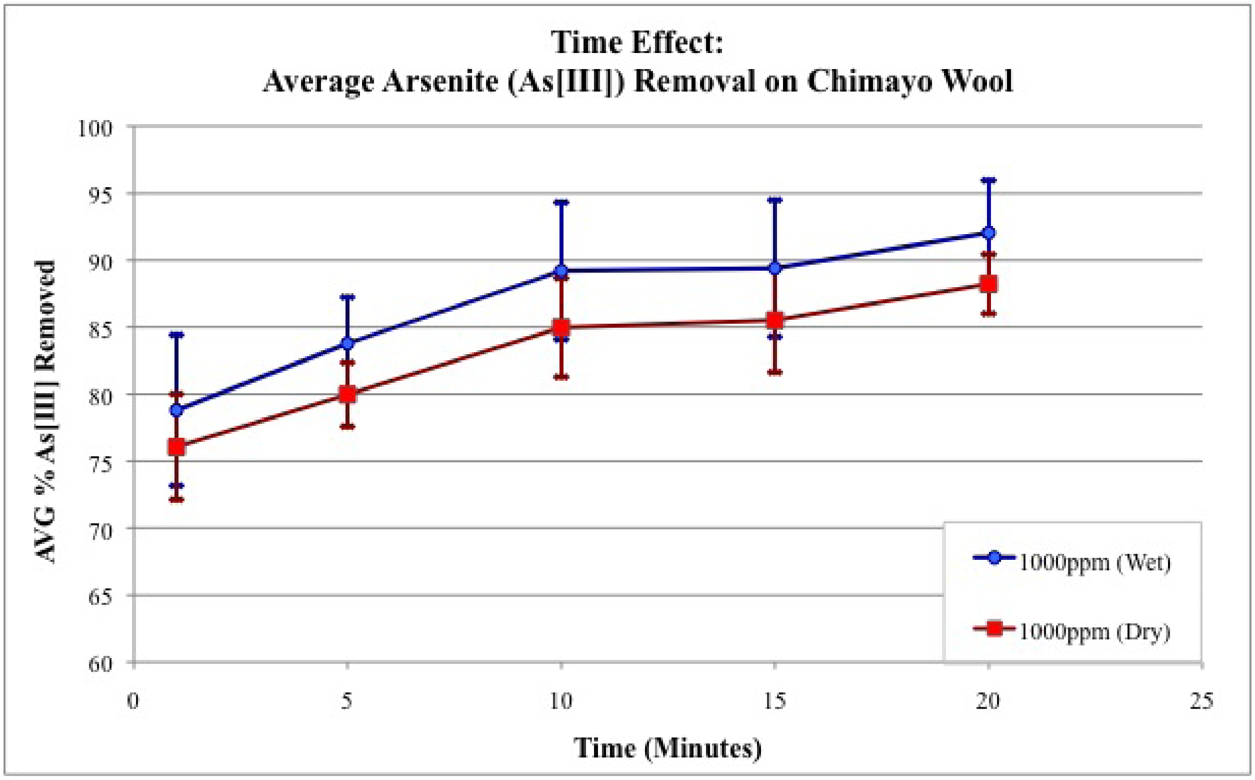


Fig. 10. Effects of time (Courtesy of Jae R. Anderson)

4.4.2 Temperature

The effects of temperature were evaluated with time (15 minutes), agitation (none), and pH (~7.0) held constant. Published research established an upper temperature limit to minimize potential structural damage of the wool (Rice 1972).

A bench top combined stirrer and hot plate were employed to slowly increase the temperature of the water to 30°C and 40°C. The Tupperware container was filled with 200 mL of deionized water and placed into a larger pool of water to maintain the desired temperature for duration of the test as seen in figure 11.

Fig. 11. Temperature test setup (Courtesy of Jae R. Anderson)

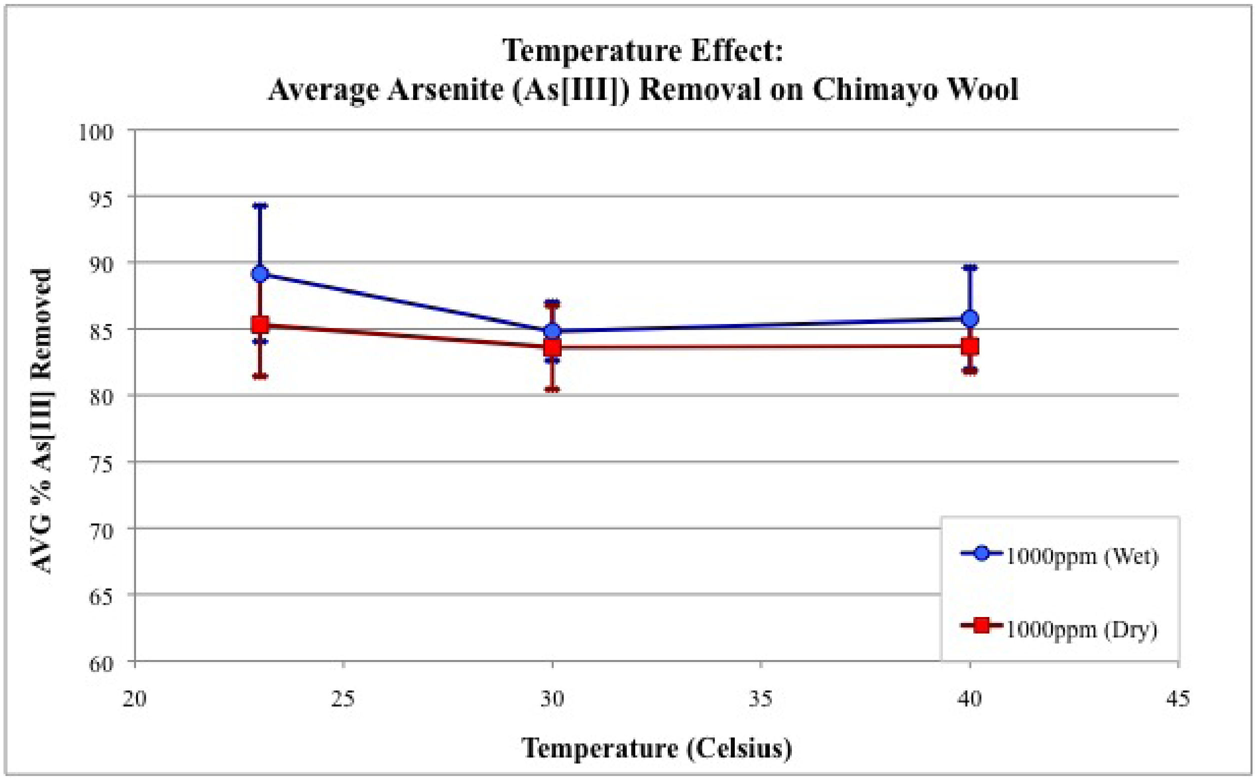


Fig.12. Effects of temperature (Courtesy of Jae R. Anderson)

Samples were placed in the water bath when the temperature of the larger pool of water and the measured water within the Tupperware container reached equilibrium. Data were analyzed and plotted as seen in figure 12.

4.4.3 Agitation

Initial tests with minimal constant agitation were carried out to determine whether investigation of higher agitation speeds would be necessary. If arsenic removal increased over time with minimal agitation, then an elevated level of agitation would be tested and evaluated. Temperature (23°C) and pH (~7.0) were both held constant.

A bench top combined stirrer and hot plate generated constant agitation. A stirring bar, 4 cm in length, was centered at the bottom of the plastic Tupperware container, with four rubber stoppers placed in corners to generate space between the stirring bar and sample testing apparatus as seen in figure 13. A volume of 400 mL of deionized water was used to account for the added height of the testing apparatus.

Low agitation was created with the Corning instrument's stirring dial set to 2.5 notches, which resulted in minimal movement of the water surface. A total of 12 samples were divided into four sets of three samples. Each set was tested at respective time intervals of 1, 5, 10, or 15 minutes. The pXRF data were analyzed and plotted as seen in figure 14.

High agitation was created with the Corning instrument's stirring dial set to 4 notches, which resulted in a more aggressive movement of the water surface. A total of 12 samples were divided into four

Fig. 13. Agitation testing setup (Courtesy of Jae R. Anderson)

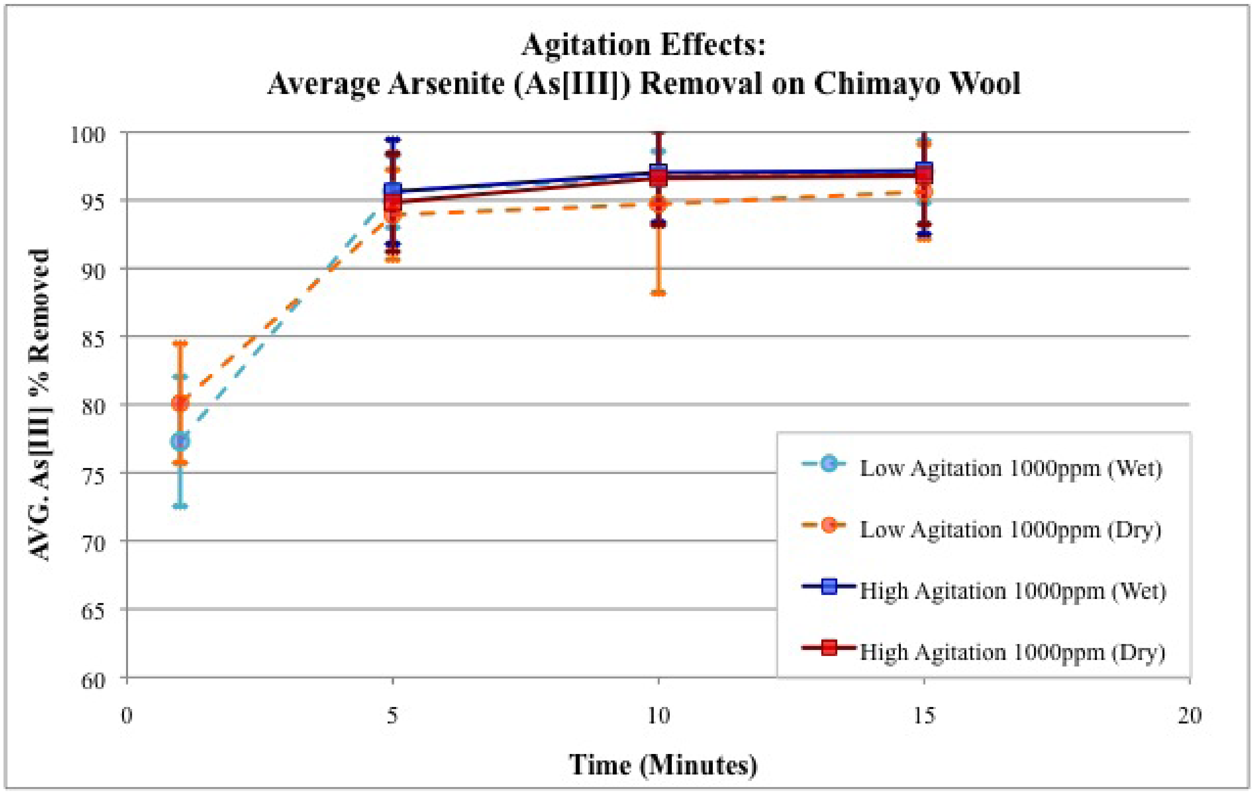


Fig.14. Effects of agitation (Courtesy of Jae R. Anderson)

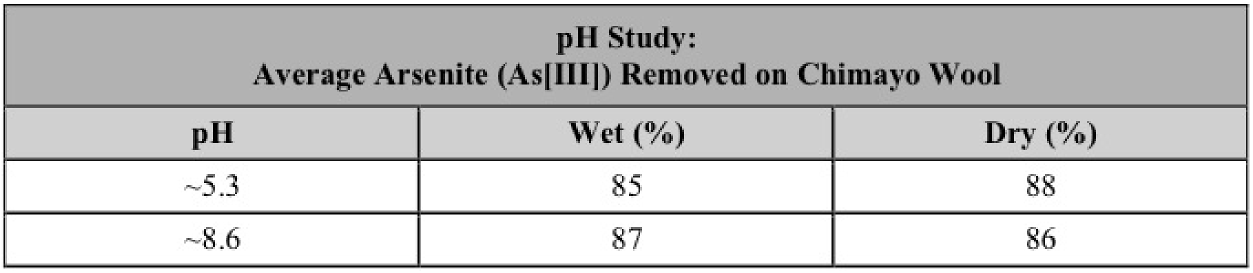
sets of three samples. Each set was tested at a respective time interval of 5, 10, or 15 minutes. The pXRF data were again analyzed and plotted, also seen in figure 14.

4.4.4 pH

The pH effect was a single case study with time (15 minutes), temperature (23°C), and agitation (none) held constant. One wool sample was tested in an acidic solution with a pH level ~5.3. A second sample was tested in a basic solution with a pH level ~8.6. The effects of pH on arsenite removal from wool initially indicated no significant changes as shown in figure 15.

4.5 ARSENIC POST-WASH STUDY

Approximately 10 mL of post-wash water for each conditional effect test was preserved to conduct a supplementary analysis with an arsenic paper test. The study confirms desorption of arsenic


pH Study:
Average Arsenite (As[III]) Removed on Chimayo Wool

pH	Wet (%)	Dry (%)
~5.3	85	88
~8.6	87	86

Fig. 15. pH preliminary results (Courtesy of Jae R. Anderson)

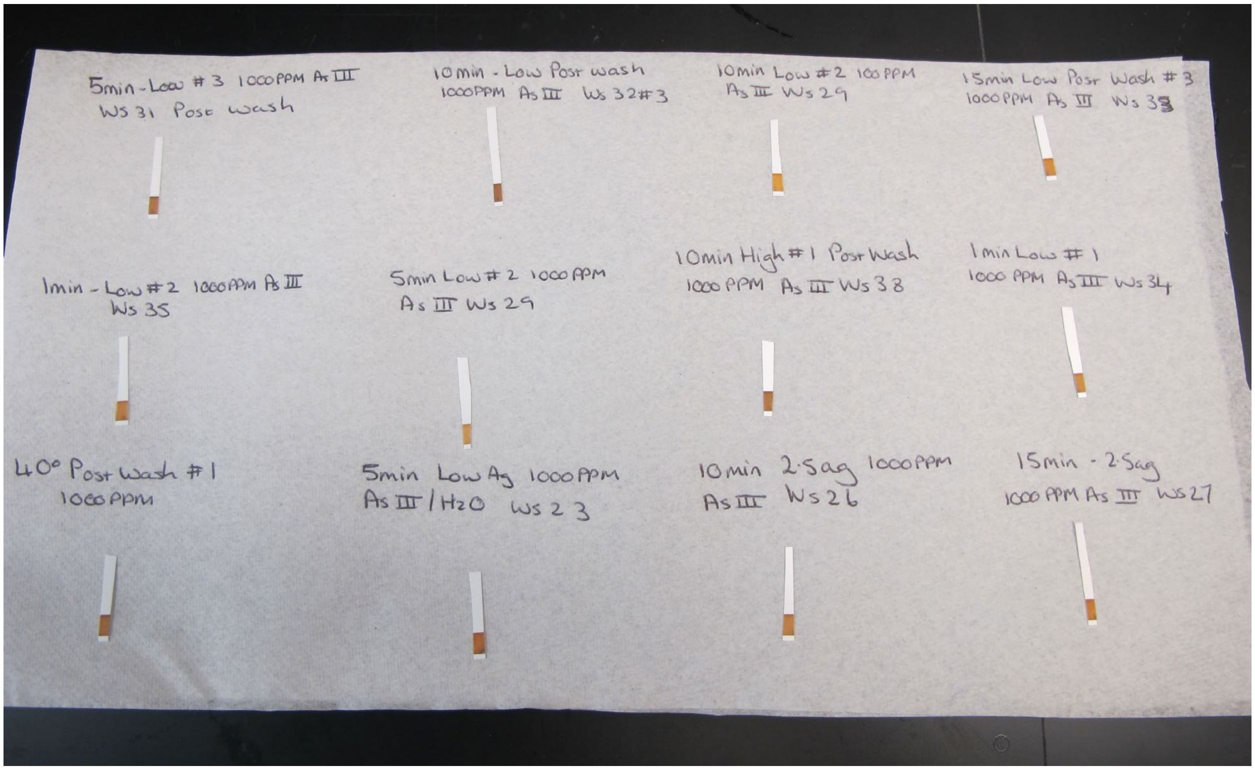


Fig. 16. Arsenic post-wash paper test (Courtesy of Jae R. Anderson)

from the wool textile into deionized water; however, the results from the arsenic paper test were not sensitive enough to provide reliable quantitative data to the arsenic concentration in the post-wash solution as seen in figure 16.

Dr. James Farrell, Department of Chemical and Environmental Engineering, University of Arizona, subsequently recommended inductively coupled plasma optical emission spectrometry (ICP-OES) as a secondary analytical technique for arsenic detection in post-wash solutions. The instrument is a powerful tool used to detect metals in a variety of matrices such as arsenic in an aqueous solution. The instrument has the potential to provide quantitative data of post-wash arsenic solutions.

5. ARSENIC REMOVAL ANALYSIS ON ASM NAVAJO TEXTILES

Three late 19th and early 20th century ASM Navajo textiles were selected on the basis of overall size (small) and arsenic presence results from the textile survey conducted as part of this study. Prewash investigation for each textile consisted of documentation of physical properties (dimensions and mass), a colorfastness test to determine potential reactions of dyes with deionized water, and thorough pXRF testing of both sides of the textile. Experimental research established preliminary guidelines that suggested submersion of the wool textile in deionized water at room temperature (23°C) for at least 10 minutes with constant mechanical agitation. The washing conditions predicted approximately 95% of arsenic could be removed from the textile.

5.1 WASHING TREATMENTS

The first washing treatment was performed on an Early Rug Period (ca. 1910–1915) Double Saddle Blanket, Rug (ASM catalogue #3917) approximately 0.55 × 1.15m. A tapestry weave used

Fig. 17. Wash treatment #1 of ASM catalog no. 3917 (Courtesy of Gina Watkinson)

handspun sheep's wool (wefts) and string cotton (warps) to produce a design of two serrated diamonds. A red synthetic dye outlined diamonds with the colors of gray, blue, black-brown, and white. Gray serrations on a white background flanked the diamond designs. The textile contained an arsenic concentration approximately 44 ppm, which is considered low for the scope of this study.

A shallow tub (1.40 × 0.56 × 0.11m) was used to submerge the textile in a minimal volume of deionized water (~13 L). The textile was placed between vinyl fiberglass screens to provide support in handling. A plastic grid screen was placed at the bottom of the tub as a spacer. A constant gentle hand agitation was applied as seen in figure 17. The textile was removed from the aqueous bath, wet-tested with pXRF, and blotted with terry cloth towels. After air-drying at room temperature, the textile was retested on documented prewash test locations.

A Transitional Period (ca. 1880–1890) sheep's wool blanket (ASM catalog no. 8423) measuring 0.66 × 0.59 m was selected for the second washing treatment. A plain weave used synthetic dyes to create a banded design of yellow and orange on a red-orange background. The second textile contained a higher arsenic concentration of approximately 1000 ppm.

Fig. 18. Wash treatment #2 of ASM catalog no. 8423 (Courtesy of Gina Watkinson)

The first washing treatment did not produce anticipated results on the basis of the investigations into conditional effects. Before the second treatment, a larger volume of deionized water was calculated on the basis of experimental measurements: mass of the dry wool fabric divided by the measured volume of water; however, time and the size of the Nalgene container (0.91 × 0.61 × 0.61 m) limited the volume of water to approximately 70 L.

Vinyl fiberglass screens were again used to support immersion of the textile into the Nalgene container as seen in figure 18. A plastic grid was used in conjunction with the vinyl fiberglass screens to create agitation by vertical movements of the textile. The textile was removed from the aqueous bath with noted minimal bleeding of the red-orange dye. The textile was quickly pXRF wet-tested, and blotted with terry cloth towels to arrest further bleeding of the dye. The textile was air-dried at room temperature, and pXRF dry-tested on prewash test locations.

The third washing treatment involved a Transitional/Early Rug Period (ca. 1880–1910) Rug (ASM catalog no. 2322) measuring 0.82 × 1.29m. A tapestry weave used cotton (warps) and sheep's wool (wefts) to create a concentric and outlined serrated diamond shape design. The multicolored design

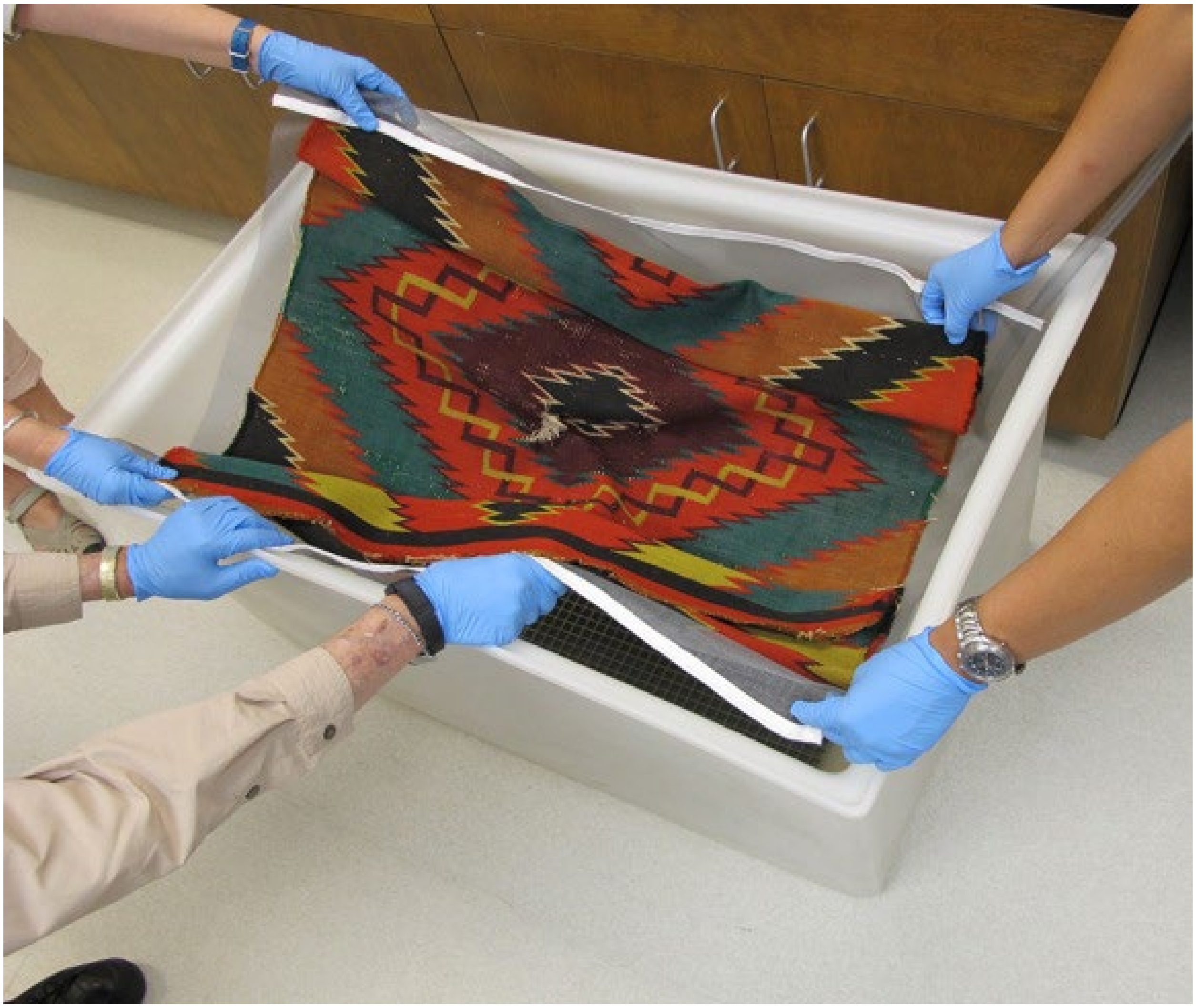


Fig. 19. Wash treatment #3 of ASM catalog no. 2322 (Courtesy of Gina Watkinson)

used natural white with black, brown, green-blue, yellow, and red synthetic dyes. Prewash testing detected a concentration of arsenic approximately 44 ppm.

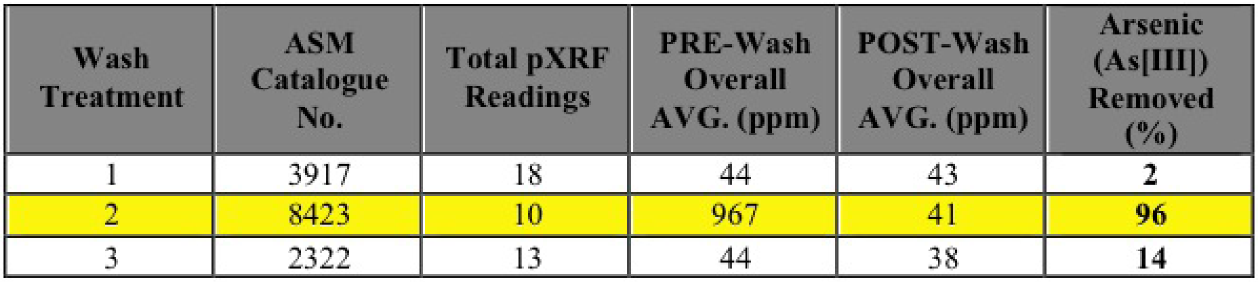
The devices, volume of deionized water (~70 L), and washing from the second washing treatment were kept identical. The textile ends were loosely rolled because of container size restraints. The washing process developed in the second washing treatment was implemented for the final washing treatment as shown in figure 19.

5.2 RESULTS

The wet treatment of wool-based experimental textiles and three historic Navajo textiles from the ASM collection provided positive preliminary results. The experimental test sample aqueous washing treatment correlated with one Navajo textile washing treatment.

5.2.1 Experimental Aqueous Washing Methodology

Calibration of handheld pXRF analyzer strongly correlates observed wet and dry pXRF readings with known arsenic test samples. Testing of wet fabric samples appears to be independent of fabric



Wash Treatment	ASM Catalogue No.	Total pXRF Readings	PRE-Wash Overall AVG. (ppm)	POST-Wash Overall AVG. (ppm)	Arsenic (As[III]) Removed (%)
1	3917	18	44	43	**2**
2	8423	10	967	41	**96**
3	2322	13	44	38	**14**

Fig. 20. ASM wash treatment results (Courtesy of Jae R. Anderson)

thickness considering observed pXRF readings are consistent with known arsenic concentrations. This conveys a liquid quantification, opposed to dry samples, which is viewed as a solid quantification. The difference between dry cotton and wool pXRF readings is associated with fabric thickness. This was confirmed by observing the detection of arsenic nearly doubling when the cotton thickness was doubled.

Each conditional effect resulted in removing a certain percentage of arsenic from wool samples with an initial concentration of ~1000 ppm. Time indicates the greatest percentage of arsenic is removed within the first 10 minutes. Increasing temperature does not increase the percentage of arsenic removal for a washing period of 15 minutes. Agitation significantly increases the removal of arsenic within the first 5 minutes and increasing agitation moderately improves arsenic removal. Increasing or decreasing pH does not increase the effectiveness of arsenic removal.

5.2.2 ASM Navajo Textile Aqueous Washing Treatments

The following results for arsenic-based pesticide residues on historic Navajo textiles are considered preliminary as shown in figure 20. The first and third wash treatments removed minimal amounts of arsenic. The second water treatment removed approximately 96% of arsenic, which directly correlated with experimental results.

5.3 DISCUSSION

Approximately two years of research coincided with the Navajo textile pXRF survey to engineer a cost-effective and conservation conscious aqueous washing treatment for wool-based textiles. The Navajo textile pXRF survey identified a range of arsenic concentrations associated with the ASM collection, and identified three Navajo textiles for wet treatment. Survey data provided significant institutional knowledge of the collection leading to introduction of labeling, handling, or storage protocols to reduce potential health risks.

Each washing treatment was a unique experience and reinforced a necessary collaborative effort to safely manage and assess various elements of a hazardous arsenic removal process. Experimental research of conditional effects utilized an effective liquid (200 mL) to solid (1.6 g) ratio that removed a high concentration of arsenic (~1000 ppm), which was used to calculate a larger volume of water needed for a larger textile, as conducted in the second Navajo washing treatment. Sufficient space, time, and assistance are key elements when undertaking a potential wet treatment to remove arsenic from larger textiles.

Preliminary testing of low arsenic concentrations (<100ppm) on prepared samples was not achieved due to time constraints. However, the third washing treatment of ASM #2322 indicates a low concentration of arsenic (~44ppm) is not affected by an increase of water volume. This warrants further investigation as a low concentration of arsenic may be irreversibly bonded to the wool fibers. Therefore, treating textiles with very low levels of arsenic may be futile and should probably be avoided.

Attempting to remove a high arsenic concentration (~1000ppm) from a textile produces an arsenic post-wash solution substantiated by the arsenic paper test. Initial arsenic concentrations, volume of water, and textile mass were determined to be significant components for approximate arsenic concentration in post-wash solutions:

$$[\text{As detected on dry textile (ppm)} \times \text{Mass of textile (g)}] \div 10^6 = \text{As on textile (g)}$$

$$[\text{As on textile (g)} \div \text{Volume of deionized water (L)}] = \text{As in post-wash solution (g/L)}$$

Arsenic water treatment is a prevalent worldwide concern to ensure safe drinking water. Treatments encompass a variety of effective methods to remove arsenic levels below 10 parts per billion (ppb), the maximum contaminant level set by the U.S. Environmental Protection Agency; however, non-hazardous arsenic waste levels are determined to be <5 mg/L or 5 ppm (U.S. Environmental Protection Agency 2009). Ideally, drinking water standards need to be attained if post-wash arsenic solutions are to be disposed of in public drainage systems.

Recent exploration into the post-wash issue has garnered interest from The University of Arizona Department of Chemical and Environmental Engineering. As mentioned earlier, Dr. Farrell and his team have expertise in arsenic sorption systems and have communicated the capability to quantitatively measure post-wash arsenic concentrations using an ICP-OES. Collaborating on devising a closed-loop sorption system would be beneficial on several levels. Theoretically, constant filtering of arsenic from the water would limit the volume of water needed to conduct a wet treatment on any textile size. Further, safe levels of arsenic in post-wash water could be achieved and properly disposed of. The process of treating the water while conducting a wet treatment is a positive initiative to the arsenic textile removal issue, and needs to continue.

Overall, the attempt to remove arsenic from a historic textile was a preliminary success, with further work needed to refine and enhance the wet treatment removal process. Conducting a wet treatment to remove arsenic on a historic textile is complex and needs to be fully evaluated in terms of space, time, and resources.

6. CONCLUSIONS

The ASM Conservation Laboratory demonstrated successful preliminary results for a method to remove arsenic-based pesticides from a wool-based textile via an aqueous cleaning treatment. A complete pXRF survey of ASM's Navajo textile collection provided knowledge of potential arsenic-based residues, identified trends relating to time period and collector, and created a foundation for further experimental research. Preliminary experiments showed that when arsenic is at high concentrations, approximately 95% of arsenic was removed from wool within the first 10 minutes by submersion in deionized water at room temperature with constant agitation. Experimental washing guidelines were implemented on three ASM Navajo textiles with low (< 100 ppm) and high (~1000 ppm) arsenic concentrations. Textiles with arsenic levels <100 ppm had minimal arsenic removal through washing. Approximately 96% of arsenic was removed from the high-concentration textile. Our results suggest that the concentration of arsenic, the mass of textile, and the volume of deionized water used are key factors to the aqueous treatment process and that it is unlikely that all arsenic can be removed.

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REFERENCES

Cross, P. S. 2007. Aqueous alpha-lipoic acid solutions for removal of arsenic and mercury from materials used for museum artifacts. PhD diss., University of Arizona, Tucson.

Odegaard, N., A. Sadongei, and Associates. 2005. *Old poisons, new problems: a museum resource for managing contaminated cultural materials.* New York: AltaMira Press.

Rice, J. W. 1972. Principles of fragile textile cleaning. In *Textile conservation*, ed. J. E. Leene. Washington, D.C.: Smithsonian Institution Press. 64–5.

U.S. Environmental Protection Agency. 2009. Hazardous waste characteristics: a user friendly reference document. www.epa.gov/osw/hazard/wastetypes/wasteid/char/hw-char.pdf (accessed 10/26/14).

Vasudevan, S., J. Lakshmi, and G. Sozhan. 2012. Studies on the removal of arsenate from water through electrocoagulation using direct and alternating current. *Desalination and Water Treatment* 48(1–3): 163–4.

FURTHER READING

Cullen, W. R. 2008. *Is arsenic an aphrodisiac? The sociochemistry of an element*. Cambridge: Royal Society of Chemistry.

De Graaf, A. J. 1982. Tensile properties and flexibility of textiles. In *Conservation and restoration of textiles: international conference: Como 1980*, ed. Francesco Pertegato. Milan, Italy: Centro Italiano per lo Studio della Storia del Tessuto. 53.

Gelya, F. 2011. The transactional relationship between occupation and place: Indigenious cultures in the American southwest. *Journal of Occupational Science* 18 (1): 3–20.

Gilbert, S. G. 2009. *A small dose of toxicology: the health effects of common chemicals*. 2nd ed. Seattle: Healthy World Press.

Hewett, R. T. 2011. Case study of the effectiveness of removal of arsenic from textiles prior to exhibit. *ICOM Committee for Conservation Preprints.* 16th Triennial Conference, Lisbon. Lisbon, Portugal: ICOM. 1–9.

Hofnek de Graaf, J. H. 1980. Cleaning ancient textiles. In *Conservation and restoration of textiles: international conference: Como 1980*, ed. Francesco Pertegato. Milan, Italy: Centro Italiano per lo Studio della Storia del Tessuto. 62.

James, G. W. 1920. *Indian blankets and their makers*, ed. E. E. Farnsworth. Chicago: A. C. McClure and Company.

Landi, S. 1998. Cleaning. In *The textile conservator's manual*, ed. A. Oddy et al. 2nd ed. Woburn, MA: Butterworth Heinemann. 79.

Love, G. W. 1981. *The use of chemicals for weed control*. Honolulu, Hawaii: Soil Conservation Services, United States Department of Agriculture.

Madden, O., J. Johnson, and J. R. Anderson. 2010. Pesticide remediation in context: toward standardization of detection and risk assessment. In *Pesticide mitigation in museum collections: Science in conservation*, eds. A. E. Charola and R. J. Koestler. Washington, D. C.: Smithsonian Institution Scholarly Press. 1–6.

Mandal, B. K. and K. T. Suzuki. 2002. Arsenic round the world: A review. *Talanta* 58(1): 201.

Mohan, D. and C. U. Pittman Jr. 2007. Arsenic removal from water/wastewater using adsorbents: A critical review. *Journal of Hazardous Material* 142(1–2): 1.

National Park Service, U.S. Department of the Interior. National NAGPRA. www.nps.gov/nagpra/ (accessed 10/26/14).

Odegaard, N., D. R. Smith, L. V. Boyer, and J. Anderson. 2006. Use of handheld xrf for the study of pesticide residues on museum objects. *Collections Forum* 20(1): 42–8.

Odegaard, N. Some comments on the care of Navajo textiles. Arizona State Museum. www.statemuseum.arizona.edu/preserv/navajo_txtl.shtml (accessed 05/25/14)

Olympus Corporation. 2011. *Delta handheld xrf for research and discovery configuration guide*. www.gwm-engineering.fi/Delta_R.pdf (accessed 10/26/14).

Olympus Corporation. 2014. Delta professional handheld xrf analyzers. www.olympus-ims.com/en/xrf-xrd/delta-handheld/delta-prof/ (accessed 04/20/14).

Parascandola, J. 2012. *King of poisons: A history of arsenic*. Dulles, VA: Potomac Books, Inc.

Rathore, H. S. 2010. Introduction. In *Handbook of pesticides: methods of pesticide residues analysis*, eds. L. M. L. Nollet and H. S. Rathore. Boca Raton, FL: CRC Press. 1.

Shackley, M. S. 2011. An introduction to x-ray fluorescence (xrf) analysis in archaeology. In *X-Ray Fluorescence (XRF) Spectrometry in Geoarchaeology*. New York: Springer. 7.

Shackley, M. S. 2012. Portable x-ray fluorescence spectrometry (pxrf): The good, the bad, and the ugly. *Archaeology Southwest Magazine* 26(2).

U.S. Environmental Protection Agency. 2007. *Inorganic arsenic TEACH chemical summary*. www.epa.gov/teach/chem_summ/Arsenic_summary.pdf (accessed 10/26/14).

U.S. Government Printing Office. 2014. U.S. electronic code of regulations. www.ecfr.gov/cgi-bin/text-idx?type=simple;c=ecfr;cc=ecfr;sid=abefc428407c704d63fef71637939827;idno=43;region=DIV1;q1=NATIVE%20AMERICAN%20GRAVES%20PROTECTION%20AND%20REPATRIATION;rgn=div=;view=text;node=43%3A1.1.1.1.10#43:1.1.1.1.10.3.90.3 (accessed 06/03/14)

Whitaker, K. 2002. *Southwest textiles: weavings of the Navajo and Pueblo people.* Seattle, WA: University of Washington Press.

World Health Organization. 2014. Arsenic fact sheet. www.who.int/mediacentre/factsheets/fs372/en/ (accessed 05/07/14).

SOURCES OF MATERIALS

McCormick & Co., Inc.
18 Loveton Circle
Sparks, MD 21152
800-632-5847
www.mccormick.com

Ortega's Weaving
53 Plaza Del Cerro
Chimayo, NM 87522
877-351-4215
http:/ortegasweaving.com/

EM Science Division of EM Industries Inc.
480 Democrat Rd.
Gibbstown, NJ 08027
856-423-6300

Sigma-Aldrich
3050 Spruce St.
St. Louis, MO 63103
800-325-5052
www.sigmaaldrich.com/united-states.html

Conservation Materials Ltd.
1395 Greg St., Suite 110
Sparks, NV 89431
702-331-0582

Testfabrics, Inc.
415 Delaware Ave.
West Pittston, PA 18643
570-603-0432
www.testfabrics.com/

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