The Generation of Microenvironments from the Differential Decomposition of Buried Textiles in North Central Florida

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Abstract

The analysis of textiles as trace evidence is an important area of focus in the field of forensic science, because enhanced understanding of the decomposition of textiles may point to more accurate methods for estimating the postmortem interval (PMI) of remains found in association with these materials. This study examines the generation of micro-environments from the decomposition of various textile types. This study hypothesized that the decomposition of textiles will generate microenvironments with soil properties distinct from those of the surrounding environment, and that different types of textiles will create different microenvironments as they decompose. Samples of cotton, UV-proofed cotton, polyester, cotton-polyester blended fabric, ripstop, and wool were buried at four sites on a property in North Central Florida for thirteen weeks, with measures of soil temperature, pH, and moisture level, and weather data collected weekly. Following burial, decomposition of each textile type was scored. Data collected were analyzed in R statistical software. Analysis indicated that the level of degradation differed by textile type but not by site. Textile presence, type, and subsequent decomposition significantly impacted soil pH and moisture at all sites but did not have a significant effect on soil temperature. The results of this study demonstrate that the decomposition of textiles can create diverse and unique microenvironments in the soil environment.

Key Words: *Forensic Anthropology; Taphonomy; Postmortem Interval; Textile Decomposition***.**

Introduction

The analysis of textiles as trace evidence is an important area of focus for the larger field of forensic science. Understanding the decomposition of textiles allows forensic scientists to make more accurate and precise estimations of the type of textile material found at a scene and its origin (Northrop & Rowe, 1987; Rowe, 1997). Overall, there is a lack of research in the realm of textiles as associated burial materials in forensic studies.

Additionally, there still exists a need for comparative studies regarding taphonomic decomposition research in different climates across the United States and elsewhere, as no two regions have the same environmental factors (Damann & Carter, 2013).

Decomposition research and analysis is heavily dependent on careful consideration of the environmental factors remains were exposed to, such as temperature, moisture content, depth,

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and pH of a burial environment (Damann & Carter, 2013). These factors may significantly speed up or slow down decomposition rates. Microenvironments, or sub-environments within a region, have been documented and discussed in numerous taphonomic studies and forensic literature and indicate that universal models for decomposition rates are typically inaccurate (Cockle & Bell, 2015; Damann & Carter, 2013; Schultz, 2007; Shean et al., 1993;Wilson et al., 2006). Regionally specific information provides the most accurate estimates of decomposition rates. Microenvironments are typically described in the literature as originating from environmental factors, such as sun exposure and burial depth, and can have a significant impact on decomposition rates. Although taphonomic research on microenvironments have been heavily reported on in archaeological contexts, their analyses and conclusions are often not applicable to forensic work due to the difference in manufacturing between modern and ancient textiles and the extended burial period in archaeological contexts (Gillis & Nosch, 2007; Haglund & Sorg, 2001; Müller et al., 2007; Peacock, 1996; Solazzo et al., 2013). The possibility of microenvironments originating from trace evidence and nonenvironmental factors has not been as heavily investigated.

The need for regionally specific research on textile decomposition and the potential generation of microenvironments from this decomposition becomes clear when considering the fact that only two such studies have been conducted in the state of Florida, each with different methods and findings (Morse & Dailey, 1985; Humbert, 2013). Both of these studies and others conducted outside of Florida have left many questions unanswered regarding textile decomposition.

The Environment of North Central Florida

Florida exhibits unique climates that have differential effects on the decomposition process. The state may be primarily classified as having a Cfa climate (i.e., temperate, without dry seasons, and with hot summers) under the Köppen-Geiger climate classification system (Beck et al., 2018). The generally hot and humid weather typically speeds up decomposition rates. Different flora and fauna throughout the state impact decomposition rates as well (Damann & Carter, 2013). A survey of Alachua county describes the climate of the area as having long, warm summers with fairly uniform temperatures and mild winters highly variable day to day temperatures (Thomas et al., 1985). Humidity in the region is high. Soil in the region is composed of over 50 different soil types, the majority of them being types of sand. Limestone deposits can be found throughout the region. Alachua county has a wide range of flora, including oak and pine trees and perennial and herbaceous grasses, that support a diverse faunal ecosystem. Deer, game birds (e.g., quail), and small to medium sized rodents (e.g., squirrels, possums) are

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prevalent throughout the region.

Two projects have been conducted in Florida concerning fabric decomposition, the first described by Morse et al. (1983) and Morse and Dailey (1985) and the other reported by Humbert (2013). Scientists at Florida State University were the first in the region to study associated burial materials and their rate of decomposition in order to better estimate the PMI, conducting research in southern Georgia and northern and central parts of Florida (Morse et al., 1983; Morse & Dailey, 1985). Results of this study confirmed that of all the environmental variables tested for, temperature played the most critical role for decomposition in Florida. The researchers additionally concluded that the more materials present that can be examined and accurately scored, the more accurate the calculation of time of deposit of remains is. From time of deposit, maximum and minimum thresholds for PMI may be estimated.

Humbert's (2013) research focused exclusively on the decomposition of cotton, cotton/polyester blend, rayon and cotton denim with associated remains. The study found that cotton experienced the most degradation and the other three types of fabric showed very little change over a six-month interval; these findings are consistent with previous studies performed inside and outside the state of Florida. Ultimately, this research also asserts that standardized methodology is essential to creating a useful estimate of PMI from textiles associated with buried remains, and that considering textiles in conjunction with other buried materials will increase the accuracy and precision of the PMI estimate.

Neither study examined textile decomposition separate from remains. Without this, the interactions between the textile samples and the soil environment could not be parsed out from interactions between soft tissue decomposition, the textiles, and the soil environment.

Textile Degradation

Textiles can be divided into three groups: natural (further subdivided into cellulosic, proteinic, and mineral; this third category does not include materials commonly used in clothing production and is not further detailed), semi-synthetic and synthetic (Kadolph & Marcketti, 2014). Cellulosic textiles include such fabrics as cotton and linen. Proteinic textiles are derived from animal or insect-based textiles (e.g., wool and silk). Semi-synthetic textiles are derived from naturally occurring fibers that are then treated with synthetic chemicals, such as rayon (Kauffman, 1997). Synthetic textiles are chemically derived and include fabrics such as polyester and nylon. How the microenvironment interacts with fabric in the ground to break it down is largely dependent on the textile type and properties, including origin, chemical composition, and physical structure (Janaway, 2002; Northrop & Rowe, 1987).

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In soil, natural textiles are degraded primarily by microbes and fungi. In low oxygen conditions, it is pH that plays a more essential role since lower oxygen contributes to less abundant microbiota populations (Janaway, 2002). The more acidic conditions are, the faster that cellulosic fibers will rot. On the other end of the spectrum, alkaline environments will slow the decomposition of cellulosic fibers. Proteinic fibers respond in an opposite manner to acidic and alkaline environments; they will break down slower in acidic environments and faster in more alkaline conditions. Another large factor contributing to the quick degradation of natural fibers is their high absorbency and ability to retain moisture (Janaway, 2002). The presence and abundance of moisture accelerates the decay process. Conversely, drier conditions generally tend to preserve associated burial materials (Janaway, 2002).

Synthetic and semi-synthetic fibers are much less susceptible to environmental breakdown than natural textiles (Brinsko et al., 2016; Janaway, 2002; Szostak-Kotowa, 2004). Some synthetic textiles, such as nylon, are naturally resistant to microbiota and fungi (Janaway, 2002). Synthetics also possess water wicking properties which preserves them significantly longer compared to natural and proteinic fabrics. Wicking is a fabric's ability to efficiently move liquid through its weave to eventually be evaporated into the air. Wicking contributes to a much lower absorbency of moisture in synthetics like nylon and polyester. In fact, nylon has been observed holding remains in place in the grave because it is so resistant to decay (Janaway, 2002). Acrylic and rayon have also been found to be intrinsically rot-proof (Morse et al., 1983;Morse & Dailey, 1985).

Previous forensic studies have yet to fully examine the influence of textile type on the generation of differential microenvironments within graves. This study seeks to examine soil microenvironments created by decaying textiles. More specifically, this study is focused on the effects of differential decomposition of various types of textiles on the pH, temperature, and soil moisture levels of shallow graves that exist in the context of North Central Florida's unique climate. This study hypothesizes that the decomposition of textiles over time will generate microenvironments with properties that differ from the surrounding soil. Furthermore, this study hypothesizes that different types of textiles will create microenvironments that differ from one another due to their varied properties and material compositions.

Methods

Textiles Sampled

Cotton, UV-proofed cotton, polyester, cotton-polyester blend (60% cotton, 40% polyester), ripstop (100% nylon) and roving yarn wool were used in this study. These samples were selected due to their common use in clothing as well as being representative of the broad range of types of textiles that can be produced (**Table 1**). Cotton was expected to degrade quickly because of its intrinsic

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properties like high moisture absorption and susceptibility to microbes and fungi (Szostak-Kotowa, 2004). UV-proofed cotton was thought to likely decay similarly to cotton, but possibly slower as some fabric treatments have been shown to deter the penetration of soil and other particulates through their weave (Kawar et al., 1978). Wool was predicted to have a high level of degradation as it, like cotton, has high absorbency properties and is very susceptible to microorganism breakdown (Szostak-Kotowa, 2004). Polyester, the cotton-polyester blend fabric and ripstop are all inherently more resistant to degradation due to their partial to full synthetic makeup and it was anticipated they would show little-to-no degradation (Szostak-Kotowa, 2004). Though polyester has wicking properties, it is not uncommon to observe pitting of the fabric after coming in contact with moisture (Sanders & Zeronian, 1982).

All textiles except for wool were machine-washed with cool water and detergent and dried prior to being cut into 31 by 15-centimeter rectangles. UV-proofed cotton was treated with ForceField UV SunBlock™ spray using bottle directions following washing and drying but prior to cutting. More specifically, the fabric was misted with the spray and left to dry for six hours. This spray is

Figure 1: Starting from upper left and moving clockwise: Site 1, Site 2, Site 3, and Site 4.

Table 1: Type, composition, and relevant properties of textiles used in this study (Kadolph & Marcketti, 2014).

Textile	Type	Composition	Properties
Cotton	Natural (cellulosic)	100% cotton	Good Abrasion Resistance Poor Thermal Retention Poor Resiliency Medium Absorbency
Wool	Natural (proteinic)	100% wool	Moderate Abrasion Resistance Excellent Thermal Retention Excellent Resiliency High Absorbency
Polyester	Synthetic	100% polyester	Excellent Abrasion Resistance Excellent Thermal Retention Excellent Resiliency Low Absorbency
Ripstop	Synthetic	100% nylon	Excellent Abrasion Resistance Good Thermal Retention Excellent Resiliency Medium Absorbency

primarily composed of synthetic isoparaffinic hydrocarbon (75-95%), which can experience between 7-29% biodegradation by microorganisms after 29 days (U.S. EPA, 2008). Wool samples measuring 31 by 15-centimeters were hand-knitted using 13-gauge needles and 100% wool roving yarn. These were not washed to prevent possible shrinkage or felting of the material. Photographs of each textile type, showcasing the weave of each textile, were taken prior to burial for subsequent comparison for examination of differential decomposition.

Site Descriptions and Burial

Samples were buried at four separate sites on a farm property in Archer, Florida for thirteen weeks spanning November 2019 through February 2020 (Autumn through Winter in this region; **Figure 1**). These sites differed in their environmental conditions. Soil at the farm property is primarily a Jonesville-Cadillac-Bonneau complex with 0 to 5 percent slopes (**Table 2**; Soil Survey Staff). The soils are heavily intermixed, with Jonesville comprising 45-55% of the area, Cadillac making up 25-35% of the area, and Bonneau making up 5-10% of the area (Soil Survey Staff; Thomas et al., 1985). The parent material of this region is sandy and loamy marine deposits with some limestone. The first two horizons of the soil are typically fine sand, followed by a mixture of sandy clay loam and fine sandy loam, and finally bedrock. The soil is well-drained with low water capacity, non-saline to very slightly saline, and has a maximum content of 5 to 15% calcium carbonate.

Within the burial sites, little to no organic material was found below surface level. What organic material was

Table 2: Horizons and properties of the three main components of soil at the research site (Soil Survey Staff).

	Jonesville	Cadillac	Bonneau
A Horizon	0-7 inches fine sand	0-7 inches fine sand	0 to 9 inches fine sand
E Horizon	9-29 inches fine sand	7 to 52 inches fine sand	9 to 29 inches: fine sand
Bt Horizon	29-33 inches: sandy clay loam	52 to 76 inches: sandy clay loam	Bt1 - 29 to 38 inches: fine sandy loam Bt2 - 38 to 84 inches: sandy clay loam
C Horizon	N/A	76 to 99 inches: clay	N/A
R Horizon	33-37 inches: unweathered bed-rock	N/A	N/A
Parent Material	Sandy and loamy marine deposits over limestone	Sandy and loamy marine deposits	Sandy and loamy marine deposits
Depth to Water table	Over 80 Inches	Over 80 Inches	42 to 60 inches
Drainage Class	Well drained	Well drained	Moderately well drained
Runoff Class	Low	Negligible	Very Low
Calcium Carbonate	Maximum 5%	Maximum 15%	N/A
Maximum salinity	Nonsaline to very slightly saline (0.0-2.0 mmhos/cm)	Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)	Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity	Very low (about 2.0 inches)	Low (about 4.1 inches)	Low (about 5.7 inches)

present primarily included roots of surrounding trees and smaller plants. Site 1 for this study was a pine barren next to the fence line of the property. This site received heavy shade due to the surrounding trees and was laden with a layer of pine needles and leaves. The soil at this site had few large roots present and abundant earthworm activity. Site 2 was located adjacent to the home on the farm property, a fire pit, and an underground pipeline. Soil at this site is slightly darker than that at Site 1, likely due to an increased presence of moisture in the soil. Beetle grubs, increased earthworm activity, and limestone rocks were heavily present at this site. Site 3 was located in an open area that lacked any tree coverage, giving it direct sunlight at all times of day. Below the layer of grass, the soil in this site was mostly devoid of moisture and earthworm activity was limited. A gopher tortoise burrow was located nearby the site. Site 4 was situated between two palmetto plants in a forested area on the property, lying approximately 4.7 meters from a walking trail. The site was shaded by both the palmettos and larger trees within the area. The soil visually appeared to be more moist than at Site 3 but less moist than that at Site 2. Leaf detritus was present at the site but insect and earthworm activity were minimal.

Sites were laid out as one and a half meter squares with a depth of twenty centimeters using shovels and trowels. This depth only reached the first or second horizon of the soil, both comprised of the same fine sand, at each site. Sites were subdivided into sequentially numbered plots measuring approximately twenty-five by thirty centimeters. This produced five rows and six columns at each site. Site 1 consisted of plots one through 30, Site 2 plots 31 through 60, Site 3 plots 61 through 90, and Site 4 plots 91 through 120. Textile samples were folded in half to measure fifteen by fifteen centimeters and were placed into individual plots. The samples were folded to better represent materials typically found at forensic recoveries (e.g., clothes and personal effects with internal and external surfaces). Sites were organized with each column representing one textile type, so that the first five plots at each site represented UV-proofed cotton, followed by wool, polyester, ripstop, cotton-polyester blended fabric, and finally cotton fabric (**Figure 2**). Sites were staked

Figure 2: The layout of each site, using Site 1 as an example. From left to right the textiles present are: UV-proofed cotton, wool, polyester, ripstop, cotton-polyester blended fabric, and cotton.

and roped off following burial to deter animal and human activity through the sites. Rope was marked to denote the boundaries of each plot. The week of burial was designated as week zero for this study. Data were collected following methods described below after burial at all sites was completed.

Data Collection

Soil pH, temperature in degrees Fahrenheit, and moisture level were measured weekly using a General brand Soil Moisture Meter 9V. The user's guide states that the meter can measure a temperature range of 16 degrees Fahrenheit to 122 degrees Fahrenheit at one-degree intervals with an error range of +/- 1.8 degrees F. Temperature data were subsequently converted to Celsius scale. The meter can detect a pH of 3.5 to 9.0 at 0.5 intervals with an error range of +/- 0.5 pH units. Soil moisture is classified by the meter with the designations Dry (<5%), Dry Plus (5-10%), Normal (10-20%), Wet (20-30%) and Wet Plus (>30%). Qualitative soil moisture values were subsequently converted to ordinal data with five levels. To collect data, the meter was inserted twenty centimeters, the maximum length of the meter's probe, deep into the center of each plot for thirty seconds. Data were collected between 1100 and 1300 hours every Sunday for the thirteen weeks, starting at Site 1, plot one and continuing in numerical order. All data were recorded in a Google spreadsheet at the time of collection. Control data were collected by inserting the soil probe at each site's upper left corner, outside of the perimeter of each site prior to data collection at the plots at each site weekly. Only one control plot was designated for each site.

Excavation and Sample Processing

Samples were excavated on week thirteen of this study following data collection. Researchers and volunteers excavated textile samples by digging down to just above the floor of each site with shovels, and finishing excavation with trowels to ensure samples were not destroyed or moved during the process. Samples were removed in numerical order consistent with plot numbers and placed into labelled resealable plastic bags. Samples were immediately transported from the site, removed from their respective bags underneath a fume hood, and brushed to remove loose soil and debris that obscured observation of the textile surfaces. The effect of brushing and its possible damage were considered but the textile surfaces could not be examined clearly without removal of adherent soil. In cases where the samples were too wet or delicate for brushing upon removal from the collection bag, which most often occurred with wool samples, they were dried under the fume hood for 2-4 days and then the excess dirt was removed by careful brushing. Samples were brushed until the weave could be clearly seen on at least a one by one inch patch, and were then re-bagged with bags left open and stored in a fume hood until photos were taken for analysis.

Data Analysis

Sample deterioration was scored using modified methods from Humbert (2013) to assign a numerical score for percent of sample loss based on area estimation. Humbert (2013) created a transparency sheet that was overlaid over each fabric swatch to trace the area of the fabric; this area was then transformed into simple shapes (triangles, squares, and circles), and area was calculated.

Degradation was calculated based on overall areal decrease and areal weakness (the size of regions deterioration in the fabric) was calculated as well from these shapes. A condition score from 0 to 11 was then assigned based on the level of degradation.

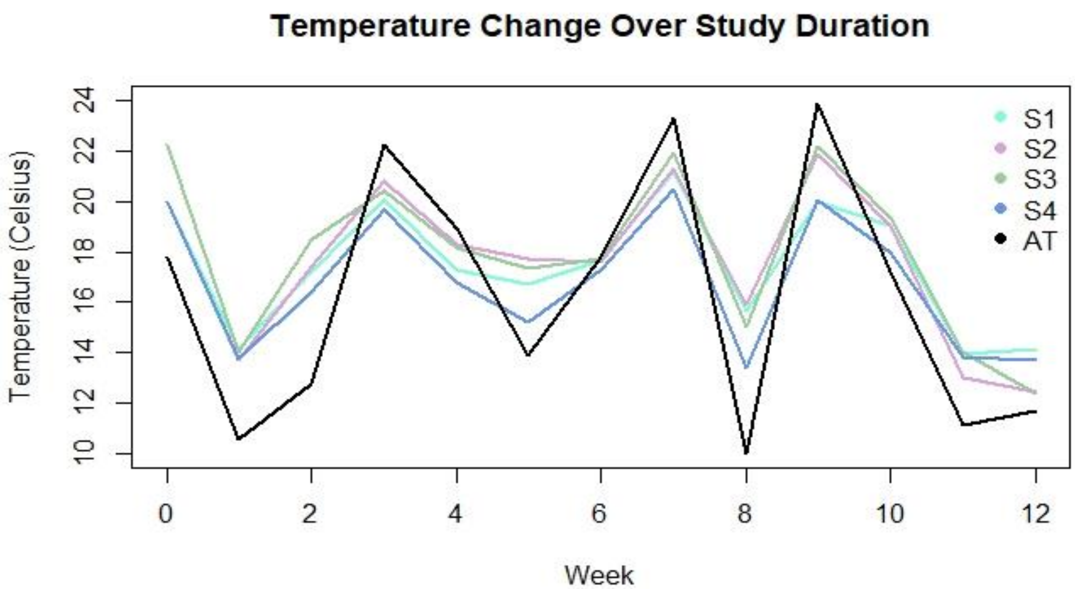
For this study, estimation of area was made by cutting a 31 by 15-centimeter rectangle of paper and laying each sample flat on top of this piece of paper. A score from 0 to 11 was then estimated by the researchers by comparing the overall area of the unearthed textiles to the original area of the sample, as represented by the paper. To score the textiles, one sample was chosen to be the representative standard of each numeric score. All other samples were scored by comparison to these standards. Chi-square tests were performed using score data to determine if percent loss varied between site and textile type respectively.

Samples were photographed with a DinoLite 2.0 Digital Microscope at 9.9x magnification to examine detailed changes in weave pattern, reflected as weakening in Humbert (2013). Both surfaces of each sample were examined. Sample photos were then labelled according to their individualized sample number. Soil environment data were analyzed to investigate the relationship between the differential decomposition of the study textiles, site effects, and environmental variables recorded during the thirteen weeks of data collection. Weather data on average ambient temperature and humidity were collected for every day during the study period from information provided by the National Weather Service, which was then aggregated into weekly averages. Spearman rank correlation tests were performed to examine the strength of those relationships.

To test whether textile presence had a significant impact on the microenvironment of individual plots, plot data at each site were scaled by control data for the respective site. Control values were subtracted from each plot value for each week that data were collected. One-sample Wilcoxon signed rank tests were then performed for each dependent variable on the scaled data pooled together, examining deviations in soil temperature, pH, and soil moisture values from the corresponding control values. The tests were performed to determine if the distribution of the scaled data indicated a systematic deviation from zero, which would indicate that the presence of textiles affected soil environment.

Weather conditions varied significantly over the study period, as is common for North Central Florida during winter months (Soil Survey Staff; **Figure 3**). In order to control for the effect of weather over time, grand means for each of the soil environmental variables (temperature, pH, moisture) were calculated, pooling sites and textile types for each week. In addition, weather data (average ambient temperature and humidity) were averaged for each week. Scaled environmental variables were calculated as arithmetic deviations from the grand mean for that week to minimize ambient effects. Grand mean scaling was used due to the presence of nested variable levels (i.e., data collected, textile type, site). When analyzing multilevel models such as this study, grand mean centered models typically produce correct estimates of the effects of the varied levels, while other centering methods may produce incorrect estimates where variables

Figure 3: Temperature change over the duration of the study. S1 = Site 1, S2 = Site 2, S3 = Site 3, S4 = Site 4, and AT = Ambient Temperature. Temperature fluctuated greatly over the duration of the study period. Site temperature fluctuated primarily in response to changes in ambient temperature.



are folded into the wrong levels (Wu & Woodridge, 2005).

In order to test how soil environment varied across the four test sites, MANOVA testing was conducted using the scaled environmental variables (model: env_variables ~ Site). To test the combined effects of site and textile type, a second MANOVA was used (model: env_variables ~ Site * Textile). Post hoc ANOVAs and Tukey's honestly significant difference tests were used to identify the variables that had significant effects on scaled soil environment. MANOVA assumes the normal distribution of dependent variables to accurately model variance. Nonparametric two-way ANOVAs using Aligned Rank Transform (ART) (Wobbrock et al., 2000) were used to confirm the results of the MANOVA for variables that violated that assumption. All data analysis and was performed using R Statistical Software using the dplyr, readxl, and ARTool, packages (R Core Team, 2019).

Visualizations of all results were also performed in R Statistical Software using the ggpubr, ggplot and cowplot packages (R Core Team, 2019). Balloon plots were created to display the number of samples displaying each level of textile degradation for each textile type and site, respectively. Boxplots were created to examine the results of the post hoc ANOVAS on scaled environmental variables, site, and textile type, although not on impacts of the interaction term. These enabled the researchers to better examine clustering and differences between the variables examined in relation to the factors that might impact variance. Histograms were created displaying the scaled environmental variables pooled by both site and week to view the magnitude of the effects of the various textiles in the study.

Results

Analysis of Textile Decomposition

Following excavation, UV-proofed cotton samples removed from relatively moist Sites 2 and 4 were heavily stained and degraded. UV-proofed cotton samples removed from Sites 1 and 3 were somewhat less degraded than their untreated cotton counterparts (**Figure 4A-B**). Wool samples were notably less decayed than cotton samples, which is consistent with results documented in prior studies (**Figure 4C-D**; Janaway, 2008). The weave of the samples following excavation appeared flattened and compressed. Polyester samples were primarily intact, although heavily soil-stained, pitted, and root-etched with some roots present in the textile's weave. (**Figure 4E-F**). Pitting on these samples is caused by exposure to moisture (Sanders & Zeronian, 1982). Ripstop samples were intact with minimal degradation or soil staining but did have root etching present. (**Figure 4G-H**). Cotton-polyester blended fabric samples were heavily soil stained with significant moisture absorbance, but minimal fraying and degradation (**Figure 4I-J**). Cotton samples were observed to be heavily soil stained and degraded, especially at Sites 2 and 4 which had relatively moist soil (**Figure 4K-L**). No difference in staining and degradation was found between the 'internal' and 'external' surfaces of each sample. Degradation counts can be viewed in **Table 3**.

Chi-square testing using textile type as the independent variable and degradation score as the dependent variable indicated that textile type did have a significant effect on level of degradation ($X^2 = 136.29$, $p < 0.001$; **Figure 5A**). Synthetic and semi-synthetic textiles - the cotton-polyester blended fabric, polyester, and ripstop – all exhibited minimal degradation while the natural textiles in this study showed varying degrees of loss. Chi-square testing using site as the independent variable and degradation score as the dependent variable indicated that site did not have a significant impact on degradation ($X^2 = 37.408$, $p = 0.2738$; **Figure 5B**).

Analysis of Microenvironment Generation

Spearman rank correlation tests indicated that soil temperature had a significant and strong relationship with ambient temperature (rho = 0.85, $p < 0.0001$). Soil pH had a significant but very weak relationship with ambient humidity but soil moisture did not have any significant relationship with ambient humidity (rho = -0.4, $p < 0.0001$; and rho = 0.02, $p = 0.3519$, respectively). **Figure 3** illustrates the average weekly soil temperature by site, relative to the average ambient temperature, suggesting that the soil creates an insulating effect relative to ambient temperatures.

One-sample Wilcoxon signed rank tests on the pooled data, scaled for site-specific controls, found that the estimated median of the data distribution significantly differed from zero for soil temperature and moisture but not for soil pH ($p < 0.0001$, $p<0.0001$, and $p=0.4721$, respectively). The null hypothesis, that textile presence did not affect the soil environment, was rejected for soil temperature and moisture.

Figure 4. Pictures of textile samples prior to burial (left column) and following excavation (right column). Colors are true for all samples except those of the cotton-polyester blended fabric, where lighting differed between the two images. ***(A and B)*** *UV-proofed cotton. The after picture is of sample 3.* ***(C and D)*** *Wool. The after picture is of sample 9.* ***(E and F)*** *Polyester. The after picture is of sample 11.* ***(G and H)*** *Ripstop. The after picture is sample 19* ***(I and J)*** *Cotton-polyester blended fabric. The after picture is sample 24.* ***(K and L)*** *Cotton. The after picture is sample 29.*

Figure 4A

Figure 4B

Figure 4C

Figure 4D

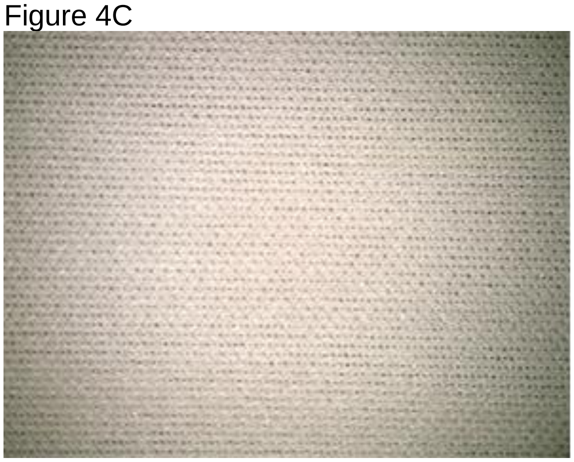


Figure 4E

Figure 4F

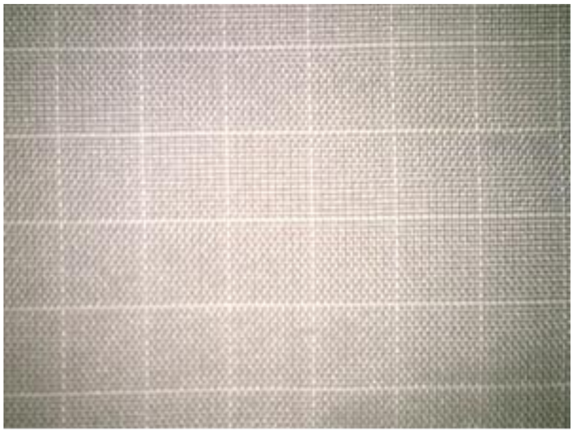


Figure 4G


Figure 4H

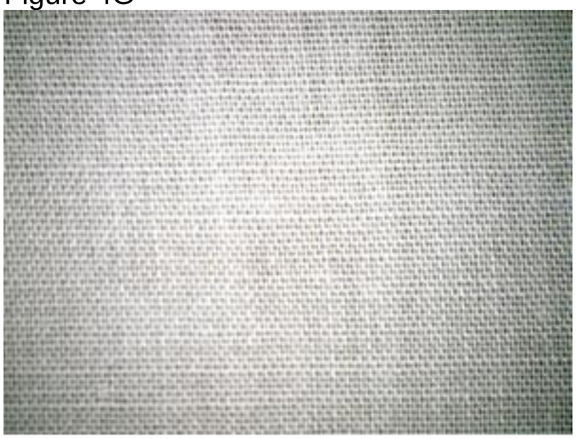


Figure 4I


Figure 4J


Figure 4K


Figure 4L

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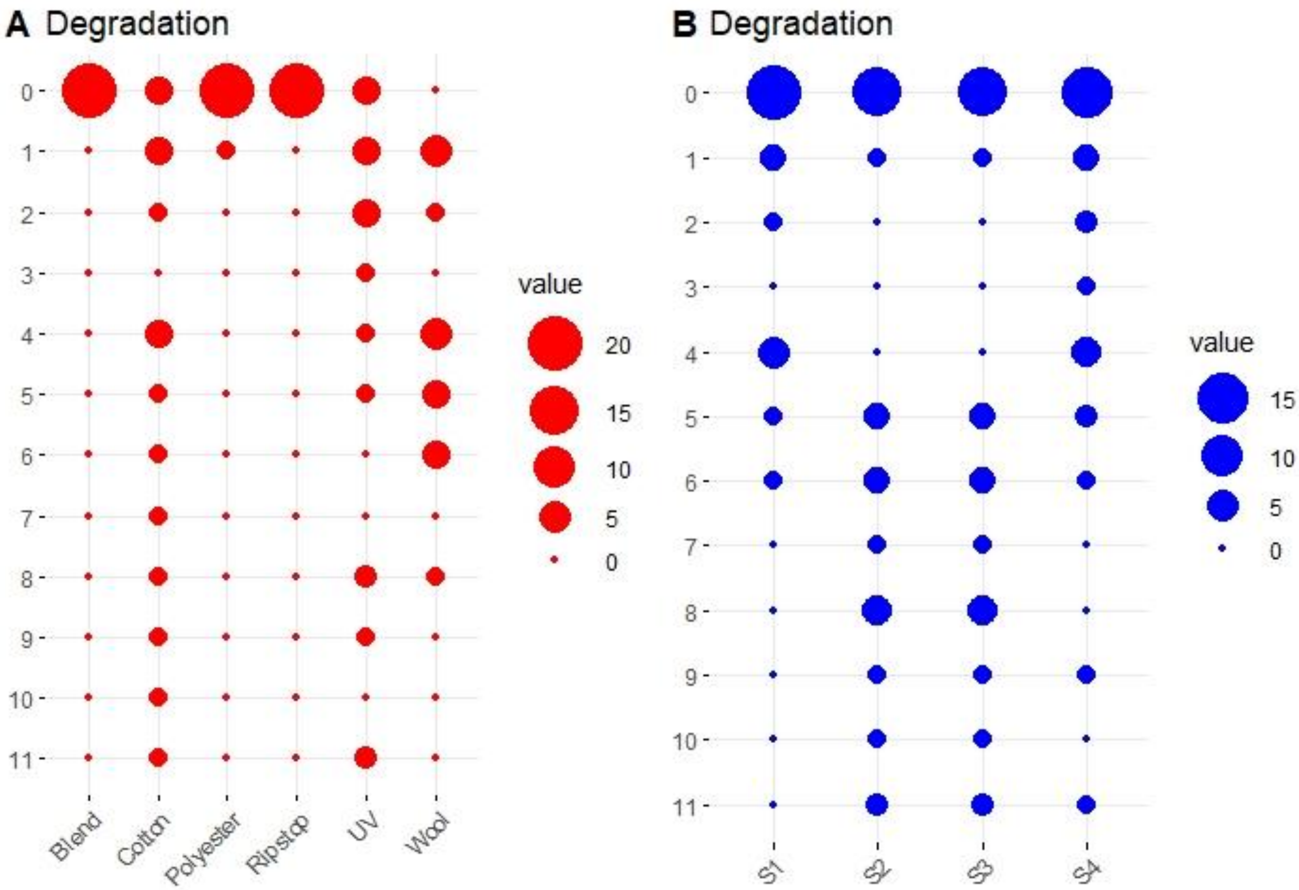
Table 3: Degradation scores for samples, reported by site and textile type. Counts are listed for each score value.

Site	Fabric	Deterioration Score and Count											
		0 0%	1 >0-10%	2 >10-20%	3 >20-30%	4 >30-40%	5 >40-50%	6 >50-60%	7 >60-70%	8 >70-80%	9 >80-90%	10 >90-<100%	11 100%
1	Cotton	1	1	1	0	2	0	0	0	0	0	0	0
	UV-Proofed Cotton	3	2	0	0	0	0	0	0	0	0	0	0
	Wool	0	0	0	0	3	1	1	0	0	0	0	0
	Cotton-polyester blend	5	0	0	0	0	0	0	0	0	0	0	0
	Polyester	5	0	0	0	0	0	0	0	0	0	0	0
	Ripstop	5	0	0	0	0	0	0	0	0	0	0	0
2	Cotton	0	0	0	0	0	1	1	1	1	0	1	0
	UV-Proofed Cotton	0	0	0	0	0	0	0	0	2	1	0	2
	Wool	0	0	0	0	0	2	2	0	1	0	0	0
	Cotton-polyester blend	5	0	0	0	0	0	0	0	0	0	0	0
	Polyester	4	1	0	0	0	0	0	0	0	0	0	0
	Ripstop	5	0	0	0	0	0	0	0	0	0	0	0
3	Cotton	3	1	0	0	1	0	0	0	0	0	0	0
	UV-Proofed Cotton	1	2	2	0	0	0	0	0	0	0	0	0
	Wool	0	4	1	0	0	0	0	0	0	0	0	0
	Cotton-polyester blend	5	0	0	0	0	0	0	0	0	0	0	0
	Polyester	5	0	0	0	0	0	0	0	0	0	0	0
	Ripstop	5	0	0	0	0	0	0	0	0	0	0	0
4	Cotton	2	0	0	0	1	0	0	0	0	1	0	1
	UV-Proofed Cotton	0	0	2	1	1	1	0	0	0	0	0	0
	Wool	0	1	0	0	2	1	1	0	0	0	0	0
	Cotton-polyester blend	5	0	0	0	0	0	0	0	0	0	0	0
	Polyester	5	0	0	0	0	0	0	0	0	0	0	0
	Ripstop	5	0	0	0	0	0	0	0	0	0	0	0

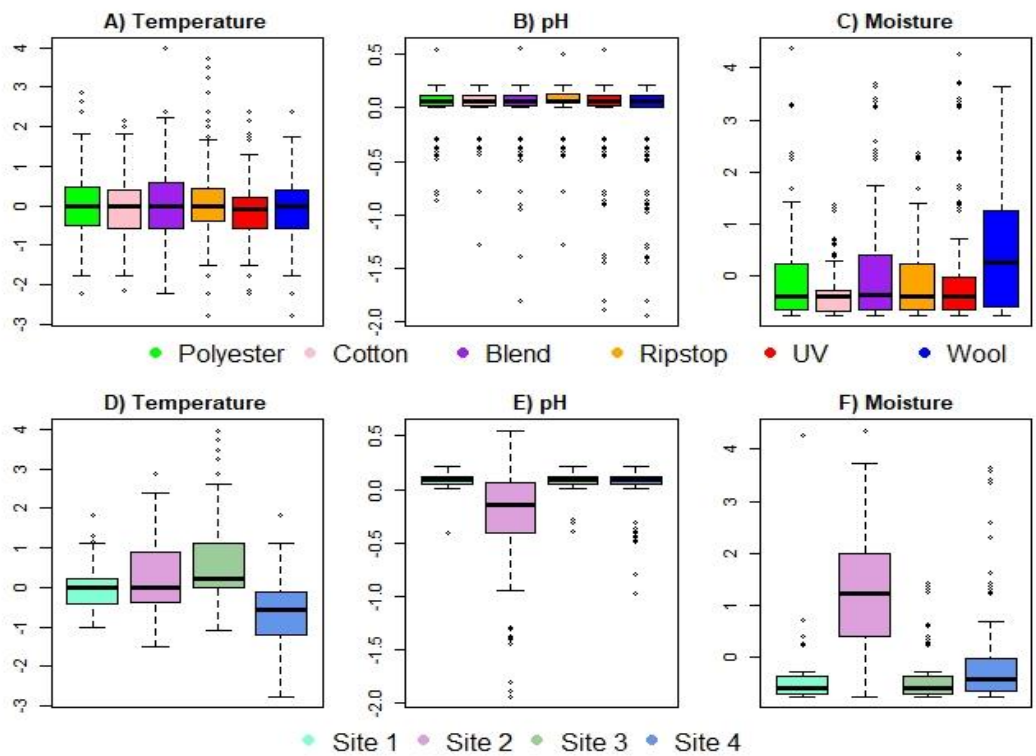
*Figure 5: Results of chi-square tests using **(A)** textile type as the independent variable and **(B)** site as the independent variable. The y-axis represents degradation scores for samples. Plots on the graphs represent count data for each degradation score.*



The MANOVA on the matrix of soil environment variables scaled by the weekly grand means was followed by two-way ANOVA on each environmental variable. These tests demonstrated that site, textile type, and the interaction of these main effects all had a significant effect on soil pH and moisture level but textile type did not have a significant effect on soil temperature ($p < 0.0001$ for all significant effects; **Figure 6A-F**). The scaled environmental variables violated the assumption of normality. In particular, pH was left-skewed, and moisture was right skewed. For this reason, the nonparametric test using ART was used to confirm results in three post hoc ANOVAs for each environmental variable. These results were consistent with the parametric MANOVA, except that there were no significant effects of site or textile type on soil temperature. Only the effects on soil pH and moisture are discussed further.

Tukey's honestly significant difference tests examining textile type confirmed that textile type did not impact soil temperature but did impact soil pH and moisture levels. More specifically, when examining effects on soil pH, the impact

Figure 6: Plots A through C display the ANOVA results of the tests using textile type as the independent factor. Textile type did not have a significant effect on temperature, but did have significant effects on pH and moisture. Effects on moisture are most noticeable. Plots D through F display ANOVA results of the tests using site as the independent factor. Site had a significant on temperature, pH, and moisture.



of wool differed from those of all other textiles but UV-proofed cotton, and UV-proofed cotton and ripstop differed from one another. When examining effects on soil moisture levels, it was found that the impacts of wool differed from those of all other textiles, and that polyester and cot ton differed from one another. Wool appeared to decrease soil pH but increase soil moisture. Histograms were generated to visualize the strength of impact of each textile type on the scaled data throughout the duration of the study (**Figure 7**). Tukey's honestly significant test results examining site effects again confirmed results of the nonparametric ANOVAs. Site effects on soil pH differed between Site 2 and all other sites. Site effects on moisture level differed between all sites except for Sites 1 and 3.

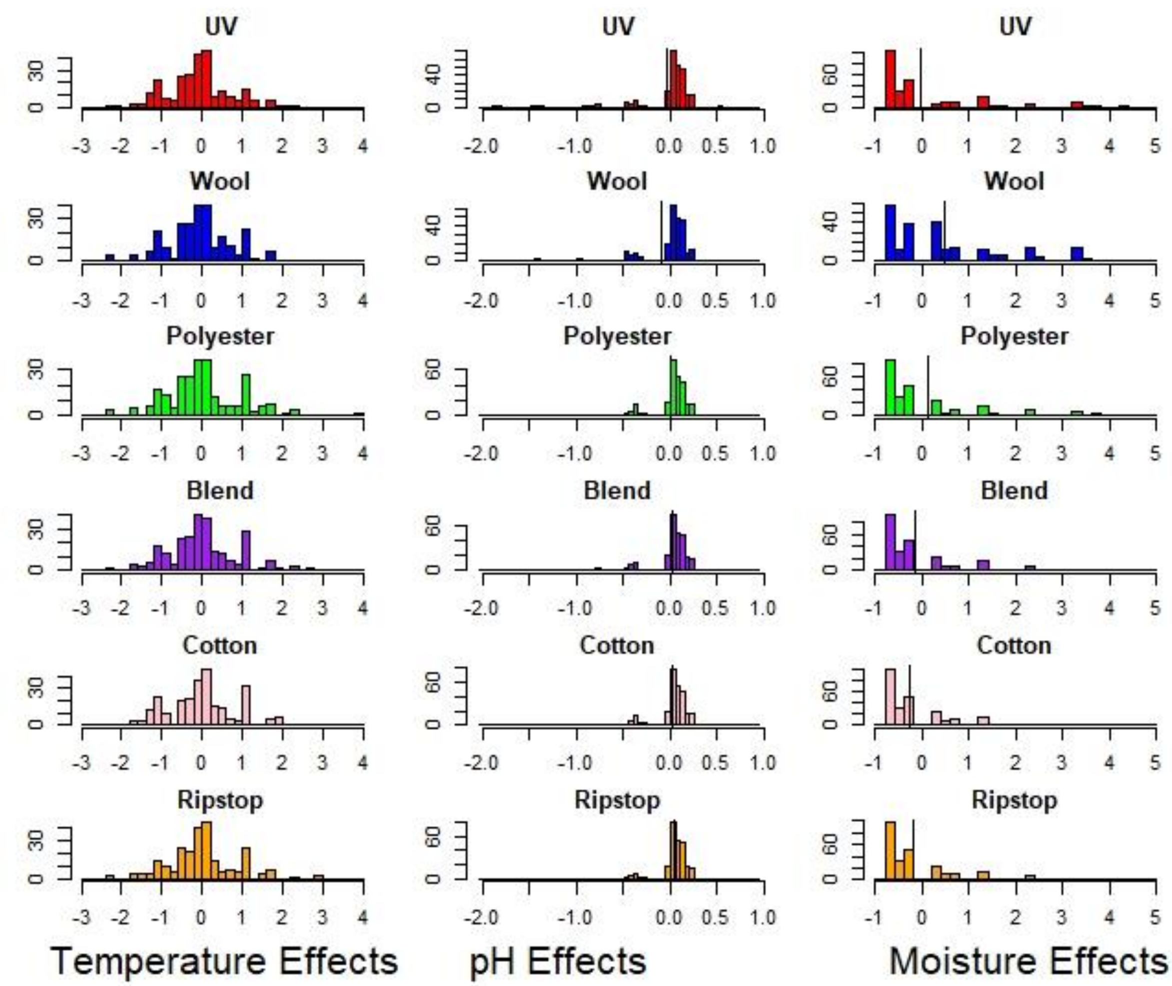
Discussion

The hypotheses proposed in this study may be accepted given the results found. The results of the chi-square testing reinforce the validity of some properties of textiles that were already known and corresponded to results found in other studies (Janaway, 2008; Li et al., 2010; Mitchell et al. 2012; Szostak-Kotowa, 2004). Level of degradation varied based on textile type but did not vary based on site. Synthetic textiles appeared to best hold up to the external environment, exhibiting minimal degradation while natural textiles had higher and more varied degradation scores. These results mirror those found in Humbert (2013).

Spearman rank correlation testing suggested that ambient temperature drove much of the changes in soil temperature over the data collection period of this study, as evinced by the high correlation between the two. Despite a known relationship between ambient humidity and soil pH and moisture level in established research, there appeared to be little-to-no relationship between these conditions in this study (Leelamanie, 2010; Natural Resources Conservation Service, 2014). The strength of these relationships may be climate dependent, and heavily affected by burial depth and environmental factors intrinsic to the soil or the presence of the textile samples.

The results of the one-sample Wilcoxon signed rank tests bolster the argu-

Figure 7: Histograms of plot data scaled by the grand means, pooled by site and week. Ablines on the pH and moisture graphs mark means for each plot. All temperature plots demonstrate comparable distributions around the plot means, and indicate that the mean



ment for the impact of textile samples on the generation of plot microenvironments, demonstrating that textile presence did have a significant impact on soil temperature and moisture, although not on soil pH. Although textile presence cannot account for all differences found between ambient conditions, control environments, and the experimental plots. These results demonstrate that the presence of textiles in a burial environment does generate microenvironments with properties that differ from the surrounding soil.

Results of the MANOVA and subsequent nonparametric tests on scaled variables indicated that different types of textiles do create microenvironments that differ from one another due to their varied properties and material compositions. These microenvironments primarily vary in terms of soil pH and moisture level rather than soil temperature. That is, while the general presence of textiles did impact soil temperature, different types of textiles did not impact the temperature of the soil differently. The MANOVA additionally revealed site effects on all data collected, as well as site-textile type interaction effects on all data collected except for temperature. The significant effects of site-textile type interactions on soil pH and moisture level had no discernable pattern. The lack of patterning of this interaction may complicate estimation of textile decomposition rates.

Regarding site effects, Site 4 and Site 2 were the most different in terms of soil temperature and soil pH changes respectively. The significant difference in mean soil temperature and temperature range at Site 4 could be caused by confounding variables that exist in the environment surrounding this site. On average, Site 4 was significantly cooler than the other three sites and had a small range of overall values. This could have been caused by the large canopy made up of the two palmetto trees shading the site and many larger oak trees overhanging and providing shade and protection from the sun. The thick layer of leaf detritus that blanketed the site may have also inhibited sunlight from penetrating into the ground twenty centimeters to reach the grave environment, preventing significant temperature change. The soil pH of Site 2 was significantly more acidic than the other sites. Moisture levels at Site 2 were non-significantly higher than those of the other sites, which might in part cause the acidification of the site's soil (Leelamanie, 2010; Natural Resources Conservation Service, 2014). Increased human and animal activity at the site, impacted by its location, may have also affected the soil pH.

Post hoc Tukey's honest significant difference test results confirmed the results of the MANOVA and clarified the sources of variance in terms of the effects of different types of textiles. Wool appeared to be the textile with the most diverse effects on soil pH and moisture level in comparison to the other sample textiles. It is not surprising the wool retained such a high amount of moisture based on its intrinsic properties (Janaway, 2002; Kadolph & Marcketti, 2014). The high amounts of moisture trapped in the wool fibers also likely sped along the processes of breakdown, further increasing wool's effects, and decreasing the pH of the plots in comparison to plots holding other textiles (Natural Resources Conservation Service, 2014).

This study demonstrated that the decomposition of buried textiles leads to the generation of microenvironments with properties that differ from the surrounding soil. This study additionally demonstrated that the decomposition of different types of textiles created microenvironments that differed from one another. The results of this study highlight the importance of recognizing the presence of microenvironments in taphonomic research and the factors that may create them, calling forth textiles as a factor that must be further investigated. Additional research is required on the creation of burial microenvironments, the interaction of different textile types with decomposing remains to determine the strength of their effects on modifying decomposition rates, and the inclusion of textile analysis in the estimation of the postmortem interval. To enhance further research, future studies should incorporate textiles made specifically for experimental studies, to ensure that all factors regarding the composition of the textile are known, and lay out samples in a randomized system to prevent the possibility of row or column effects. Furthermore, future studies may better detail the effects of textiles on the surrounding environment through the use of a continuous data logging system, rather than the probing method used in this study. Finally, to be able to incorporate the analysis of textiles in PMI estimation, studies must be performed that examine the effects of different types of textiles on human remains.

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