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# The effect of weathering on the forensic comparison of disposable gloves

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BOSTON UNIVERSITY  
SCHOOL OF MEDICINE

Thesis

**THE EFFECT OF WEATHERING ON  
THE FORENSIC COMPARISON OF DISPOSABLE GLOVES**

by

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Submitted in partial fulfillment of the  
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Master of Science

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**THE EFFECT OF WEATHERING ON  
THE FORENSIC EXAMINATION OF DISPOSABLE GLOVES**

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Boston University School of Medicine, 2013

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**ABSTRACT**

Disposable gloves are often used by the perpetrators of a crime to prevent the deposition of fingerprints and epithelial cells at a crime scene. When removed and discarded at the scene, these items of evidence are often analyzed by a Trace Evidence Unit. By evaluating basic physical and chemical characteristics, a comparison to a known glove can be made. However, it is unclear whether temperature and weather conditions at a crime scene can alter the characteristics of the glove, and have a detrimental effect on this evidence comparison.

In this study, a variety of disposable gloves made of nitrile rubber, natural rubber latex, and polyvinyl chloride were studied to assess the relationship between environmental conditions and polymer characteristics. Samples were placed in evidence envelopes or immersed in distilled water at three different temperatures, and were analyzed after 0, 3, and 6 weeks. Analysis included thickness measurements, stereomicroscopy, and Fourier-Transform Infrared Spectroscopy (FTIR).

Results demonstrate that disposable gloves are susceptible to physical changes when exposed to various conditions. A majority of gloves exhibited an increase in thickness measurements at a variety of temperature and moisture conditions. Several gloves — spanning all types and different brands — displayed subtle changes in surface texture and spectral data.

Analysis was complicated by the fact that no glove is 100% polymer, but instead contains a variety of additives, including stabilizers, plasticizers, and dyes. Additional characterization with a quantifiable separatory method, such as Pyrolysis-Gas Chromatography/Mass Spectrometry, is therefore recommended to further elucidate the changes that can occur.

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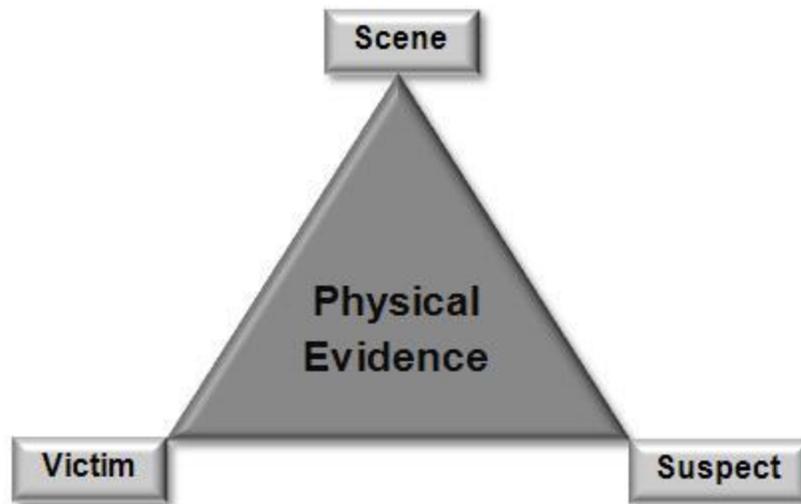
## LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ATR	Attenuated Total Reflectance
°C	degrees Celsius
C	Carbon
CDS	Chemical Data Systems, LLC
Cl	Chlorine
DEHP	di(2-ethylhexyl)phthalate
DOP	dioctyl phthalate
DSC	Differential Scanning Calorimetry
et al.	et alia ( <i>and others</i> )
FTIR	Fourier-Transform Infrared (Spectroscopy)
GC/MS	Gas Chromatography/Mass Spectrometry
H	Hydrogen
IR	Infrared
mm	millimeters
n	Polymerization Index
N	Nitrogen
O	Oxygen
PVC	Polyvinyl chloride
Py-GC/MS	Pyrolysis-Gas Chromatography/Mass Spectrometry
S	Sulfur

SWGMA	Scientific Working Group for Materials Analysis
TD-NMR	time-domain nuclear magnetic resonance
T <sub>g</sub>	Glass Transition Temperature
TGA	Thermogravimetric Analysis

## 1. Introduction

In the course of a criminal investigation, forensic science is used to analyze physical evidence, which has the valuable ability to connect people and places. This physical evidence can be collected during crime scene processing, collected from the victim, or obtained from the suspect's possession in the execution of a search warrant. Figure 1 demonstrates this relationship between elements of a crime, in what is called the Evidence Linkage Triangle.



**Figure 1. Evidence Linkage Triangle**

Often, physical evidence of unknown origin can be connected back to a known source by analyzing its physical characteristics and chemical properties. For example, a disposable glove discarded at a crime scene (the unknown object) could be linked back to a box of gloves located in a suspect's home (the known source). This association between known and unknown items is common

across all forensic disciplines, including DNA analysis, firearms analysis, and explosives analysis.[1]

It has been hypothesized that exposure to various weather and temperature conditions can inherently change the physical and chemical characteristics of evidence. This can complicate linkage comparisons: if the properties of the unknown evidence are inherently changed by weather degradation, the association to the known source can be misinterpreted. As explained by Causin[2]:

“In the development of an analytical method focused on the structural characterization, the effect of weathering must always be taken into account because the structure of polymers is sensitive... The possible effect of weather should be considered also when interpreting the chemical information included in spectral data. For example, suppose that the IR spectrum of a questioned item differs from that of its possible source object by the presence of a carbonyl band due to oxidation at around  $1700\text{ cm}^{-1}$ . The analyst should determine if that oxidation can be due to the crime scene environment, rather than to the history experienced by the object during its life until the commitment of the crime. In other words, for a significant and probative result, the influence of the crime scene environment on shaping the structure and morphology of the trace item must be ruled out, either by tests simulating the effect of the crime scene conditions on a similar plastic item or by analysing [sic] the circumstances of that case.”

Valerio Causin, “Polymers on the crime scene: How can analytical chemistry help to exploit the information from these mute witnesses?”

## 1.1 Polymer Structure and Properties

Polymers, more commonly referred to as “plastics” or “rubber,” are ubiquitous in everyday life. Polymers are essential to the manufacturing of packaging, apparel, electronics, and other consumer products. As a result, the plastics industry is one of the largest materials industries in the United States.[3] Consequently, there is a great propensity of these items to appear as evidence at a crime scene, including synthetic fibers, duct tape, plastic bags, condoms, and disposable gloves.[2]

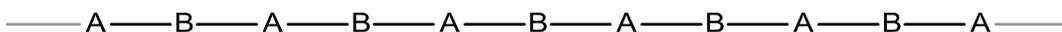
A polymer is a molecule comprised of repeating sub-units called monomers. These monomers are connected to each other by chemical bonds to form the polymer macromolecule. The number of monomers is referred to as the polymerization index, and is denoted as “n”. N can often range from 100 to 100,000; as a result, polymers are large macromolecules with masses in the kiloDalton range.[4] The large polymer molecules interact with each other by van der Waal’s forces. While individual van der Waal’s forces are relatively weak, the large surface area of the macromolecule results in many interactions, increasing the overall strength of the intramolecular force. The result is a polymeric material, which is a chemically inert solid at room temperature.[5]

A polymer comprised of the same repeating monomer is called a homopolymer, and is shown in Figure 2. In this example, the monomer is A, and would be represented in text as  $(A)_n$ , where n is the polymerization index.



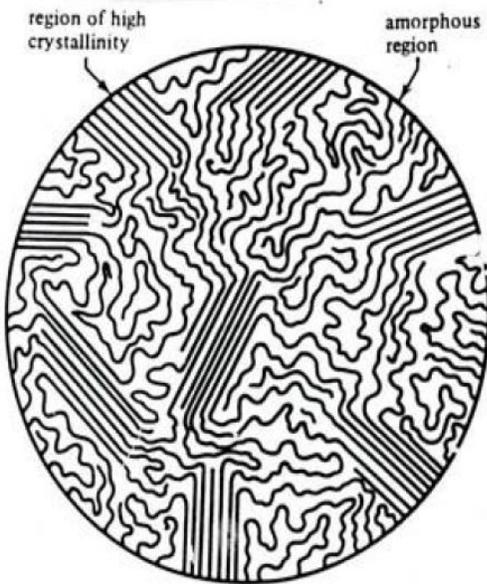
**Figure 2. Homopolymer of repeating subunit “A.”**

Polymers can also include more than one type of monomer. In that conformation, it is referred to as a copolymer. An example of a simple alternating copolymer is shown in Figure 3. This would be represented in text as  $(AB)_n$  or A-c-B.



**Figure 3. Copolymer of alternating “A” and “B” subunits.**

Polymers are generally amorphous solids, yet they can display areas of order called partial crystallization zones.[4] These zones can be seen in Figure 4. Crystallization is the energetically favorable alignment of the polymer chain into organized folds called lamellae. Crystallization is a temperature-dependent process that increases bond density and strengthens the material. The uniformity of homopolymers imparts a propensity for crystallization, while the nature of copolymers disfavors partial crystallization. The presence of crystallization zones also affects the mechanical properties of the polymer. A polymer with a greater degree of crystallinity has a stiffer, more brittle texture. A polymer with less crystallinity has a more elastic texture.

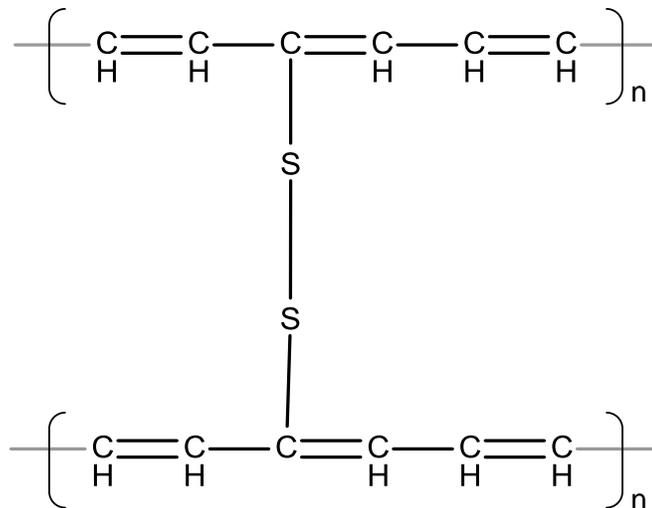


**Figure 4. Partially crystallized polymer.[5]**

The elasticity of a polymeric material is temperature-dependent. The glass transition temperature, or  $T_g$ , is the temperature above which sections of the polymer chain exhibit motion and flexibility. Below its  $T_g$ , a polymer is brittle and inelastic. Above the  $T_g$ , the material exhibits elasticity and deformability. A glass transition is not a phase transition like crystallization, but rather a measure of how the polymer chains exhibit motion depending on the material's use temperature.[5], [6]

Polymers with linear chain architecture can undergo a process called crosslinking, in which covalent bridges are created between individual polymer molecules.[7] Sulfur is often used as a spacer atom between the two linked chains because of its tendency to form strong covalent bonds, as shown in Figure 5.[4] This disulfide crosslinking allows for great flexibility and strength in

the material, and therefore imparts elasticity. When the material is deformed, it can return to its original shape because of the covalent sulfur bond.[8] Another word for an elastic polymer is an elastomer.



**Figure 5. Disulfide crosslinking between two polymers.**

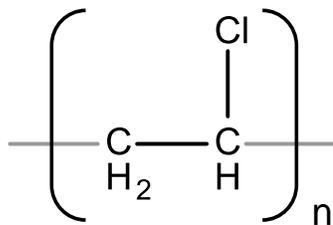
## 1.2 Introduction to disposable gloves

Disposable gloves are manufactured as protective barriers, used in the medical field to protect against the transmission of pathogens.[9] Disposable gloves can also be manufactured for household use to protect hands against paint and cleaning supplies. These gloves are made from polymers because of the materials' elasticity and strength. The most commonly encountered gloves are latex, nitrile, and vinyl.[10]

Natural rubber latex, or "latex," is comprised of 1,4-cis polyisoprene, as shown in Figure 6. The individual isoprene monomers are joined at the 1,4



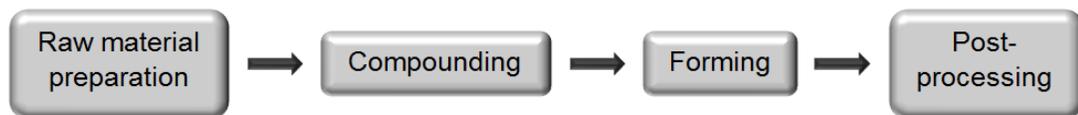
Polyvinyl chloride (PVC), commonly referred to as “vinyl,” is a homopolymer of vinyl chloride, as shown in Figure 8.[15] Unplasticized PVC is a rigid, brittle plastic.[14] The addition of plasticizers during manufacturing is essential in imparting elasticity. Vinyl is, however, not as resistant to breakage as nitrile and latex.[16]



**Figure 8. Structure of polyvinyl chloride.**

### 1.3 Glove Manufacturing

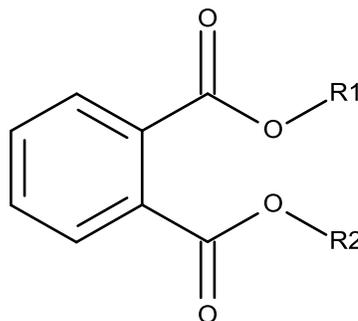
A general schematic for the manufacturing of disposable gloves can be seen in Figure 9.



**Figure 9. Disposable glove manufacturing**

Latex is a naturally-occurring material and is obtained from the sap of *Hevea brasiliensis* trees.[12] The natural rubber latex is centrifuged to obtain a latex concentrate. Conversely, nitrile and vinyl are formed by chemical synthesis, by polymerization of the original monomer. This is done by an “addition process,” usually under the application of heat in the presence of a catalyst.[4]

The starting polymer is placed in a large vat to facilitate the manufacturing process. The polymer is then compounded, and the result can be referred to as a polymer composite. Compounding is the process of mixing in additives to alter mechanical properties to exact specifications. These desired characteristics include less tackiness, improved plasticity, and degrees of opacity.[7] Plasticizers enhance the plasticity of the material, which allows it to be more easily molded to a desired shape. The most common kinds of plasticizers are phthalates.[15] Figure 10 shows a generic phthalate structure, where R1 and R2 represent any functional group, most often a linear alkane chain of at least six carbons.



**Figure 10. General phthalate structure.**

A vulcanization accelerator can be added, which is essentially a catalyst that increases the vulcanization reaction rate.[17] This is most commonly a dithiocarbamate, such as zinc diethyldithiocarbamate or dibutyldithiocarbamate.[18] Other additives include antioxidants, stabilizers, and dyes.[7]

Once compounded, the polymer composite is formed into gloves by the use of molds called formers. These hand-shaped structures are often made of

porcelain, but can sometimes be made from a thermally stable plastic.[7] The formers are initially dipped into a coagulant, often a calcium salt such as calcium carbonate or calcium nitrate. This facilitates the removal of the glove from the former at the end of the manufacturing process. The former is then dipped into the polymer composite. This results in the deposition of a thin film on the former, in the shape of a glove. The amount of coagulant, and the length of time during which the former is dipped determine the thickness of the polymer film. The polymeric material is allowed to cool, and is then peeled, or “beaded” off.

Post-processing encompasses a variety of manufacturing processes, including vulcanizing and rinsing. Vulcanization is a process in which the disulfide cross-linking occurs.[19] Vulcanization occurs in an oven. The application of sulfur reagents, called curatives, and heat increases the elasticity of the final product. In some instances, additional post-processing can include detergent washes and hot water rinses, to remove any residual chemicals that remain from the manufacturing process. Sometimes, a polyacrylate or polyurethane coating is added to the inside of the glove to improve the ease of donning.[7] Alternatively, gloves can be powdered to improve ease of donning and reduce tackiness. The powder is deposited onto the glove surface by dipping the finished glove products in a powder slurry, and allowing them to dry. The powder most often used is cornstarch. [20]

The manufacturing process and the types of additives can differ depending on the glove material and desired end product. In nitrile gloves, di(2-

ethylhexyl)phthalate (DEHP) is often used as a plasticizer, and a variety of phenols can be used as antioxidants.[21] The elasticity and mechanical strength of plasticized vinyl is known to deteriorate over time.[22] Therefore, metal carbonates, most commonly calcium, barium, or zinc, are added into the vinyl formulation to improve stability, strength, and elasticity. In addition to carbonates, organic stabilizers can be added, most commonly dioctyl phthalate (DOP). [23]

Each batch of manufactured gloves is assigned a lot number.[7]

Numerous boxes of gloves can belong to the same batch. The ability for variation between batches is plausible. Possible contamination can occur within the vat of polymer composite, in addition to varying ratios of additives, or degradation of the composite within the vat.[6] In addition, because rubber latex comes from a natural source, there is a potential for variation among the quality of the rubber tree from which the latex is derived.[24] It is therefore potentially feasible to trace back a glove to a certain batch, but not practical to link a glove back to an individual box.

#### **1.4 Forensic Analysis of disposable gloves**

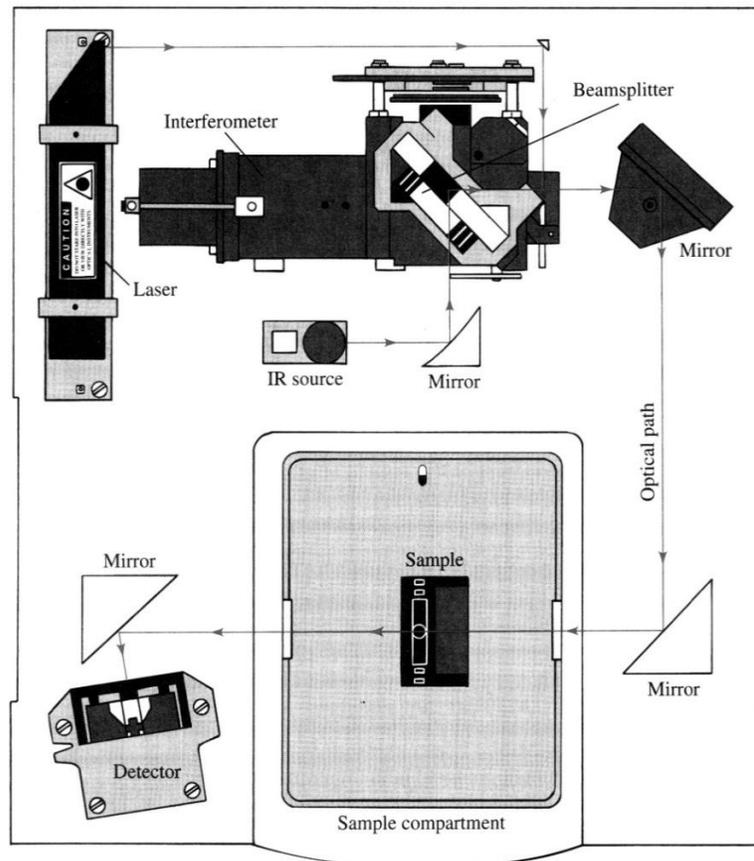
Disposable gloves are often used by perpetrators of a crime as a forensic countermeasure, to prevent the deposition of fingerprints or epithelial cells on surfaces.[2] They can also prevent contact between the perpetrator's and the victim's bodily fluids. There are currently no methods with discriminatory power sufficient enough for individualization to a particular box of gloves; however, the

evaluation of class characteristics is an important step in creating linkages between suspect, victim, and scene.

A visual examination by the criminalist is initially performed to assess the item of evidence. This involves laying the glove on clean butcher paper and noting its color, shape, and any apparent defects or markings. The dimensions of the glove are measured with a ruler, often cuff to fingertip and thumb to little finger. The thickness of the gloves is then measured with digital calipers. It is essential that when comparing knowns and unknowns, the thickness measurement is taken at the same relative location on each glove, as thickness can vary from fingertips to palm. The color of the glove can be classified through the use of Munsell color charts, a color identification system that determines the hue, darkness, and gloss of a material. Alternatively, a microspectrophotometer can be used for color information in spectral form.[25]

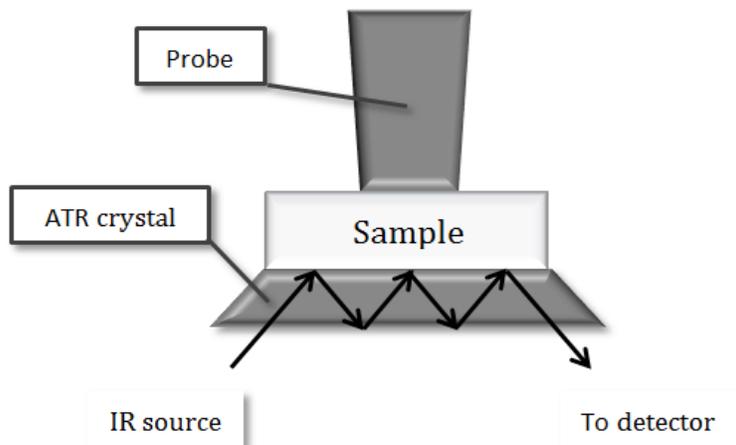
A microscopic examination of the evidence is then performed. The gloves are analyzed under a stereomicroscope. A stereomicroscope is an optical microscope with great depth of field and low magnification power, typically 10–100x. The microscope contains two objective lenses and two separate optical paths, giving a three-dimensional image when viewed under the binocular eyepiece.[1] Under the stereoscope, general observations about the texture of the glove material can be made. The presence of powder can also be determined; if present, the powder can be further analyzed under polarized light microscopy.

Ultimately, a chemical analysis of the glove material is performed to determine the identity of the polymer. Fourier-Transform Infrared Spectroscopy, or FTIR, is a technique that identifies the vibrational modes of molecules. A diagram of a typical FTIR instrument setup is shown in Figure 11. The sample is subjected to varying wavelengths of infrared light, which induces various vibrational modes within the molecule. The presence of a vibrational mode requires a change in dipole moment in the molecule. These vibrational modes include stretching, bending, scissoring, rocking, and twisting, and result in changes in absorbance.[26] This data is represented in a plot called an FTIR spectrum. Because different molecules have different bond strengths, different component atoms, and different vibrational modes, a molecular structure can be elucidated from the FTIR spectrum. FTIR is not, however, a separatory technique. Therefore, when analyzing a mixture, the final spectrum observed is a sum of the individual spectra of each compound within the material (polymer, plasticizer, stabilizer, etc.). The result is a unique spectral “fingerprint.” [2]



**Figure 11. Schematic of FTIR instrumentation. [26]**

Attenuated Total Reflectance, or ATR, is a sampling technique for FTIR spectroscopy that minimizes the need for sample preparation.[27] The technique uses a high refractive index crystal, called an internal reflection element. The sample is pressed against the crystal with a probe, as shown in Figure 12. The infrared light source enters the crystal and undergoes internal reflection, extending slightly into the sample in an evanescent wave. The penetration depth of the evanescent wave depends on the wavelength of light.[28] The light is then collected by the IR detector, which transduces it into an electrical signal.[26]



**Figure 12. Attenuated Total Reflectance.**

FTIR is a well-established technique for the analysis of polymers.[2], [27], [29] First, the general polymer type can be deduced. Identifying the functional groups from the spectral data can identify the elastomer constituting the principle structure of the material. Secondly, the presence of additives can be determined by their contributing peaks. Lastly, very slight changes in the polymer's microstructure can be determined by FTIR. These include changes in cross-linking, crystallinity, and degrees of hydrogen bonding. These subtle changes can be represented by the presence of new peaks, and band intensity changes.[29]

Another method of polymer analysis is Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS).[30] This method has the added advantage of separating and identifying individual compounds within the glove material.[31–33] Because of their high molecular weight, most polymers are not amenable to traditional GC/MS methods, which require the analyte to be

sufficiently volatile. The application of pyrolysis allows the components of a polymeric structure to be analyzed. When the sample is pyrolyzed, the material enters the gaseous phase, and is amenable for GC/MS analysis. The components, or pyrolysates, are separated in gas chromatography by their differential affinities between the mobile gas phase and a stationary phase column. The separated components are then fragmented and ionized, which allows them to be detected by a mass analyzer. The mass analyzer measures the components by their mass-to-charge ratio, and each component can be identified. This is a quantitative technique. Py-GC/MS has been used to analyze latex and synthetic rubber for the past 60 years.[34–37] Chemical Data Systems, (CDS) LLC, an industry leader in the manufacture of pyrolysis systems, has demonstrated the use of Py-GC/MS in the analysis of latex gloves.[38] They were able to identify the presence of plasticizer, anti-mold paraffins, and monomers of isoprene.

Current literature on the forensic analysis of disposable gloves is limited. One published method for differentiating latex gloves was thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC).[39] These two techniques detect the changes in properties that occur when a sample is subjected to changes in temperature. Causin et al. compared 28 samples of latex gloves by use of these thermal techniques, and successfully differentiated 99.5%.[39] Similarly, Mauri et al. compared 20 different latex gloves by 1(H) time-

domain nuclear magnetic resonance (TD-NMR).[40] This non-destructive technique successfully differentiated 88% of the latex gloves studied.

However, neither TGA/DSC nor NMR are instrumental techniques commonly found in standard forensic laboratories, which are usually limited to analysis by GC/MS and FTIR. There are several examples in the literature of the use of ATR-FTIR in the forensic comparison of other polymers, including condoms, tape backings and plastic bags.[41–43] Causin et al. used ATR-FTIR, thickness measurements, and DSC to characterize and discriminate plastic polyethylene bags.[42] There have been multiple applications of FTIR to the forensic analysis of pressure-sensitive tapes. [43–45]

While the current literature on forensic analysis of polymers is limited, there is a multitude of polymer research conducted in other arenas. In the field of biomedical safety, gloves are extensively studied to optimize barrier performance against the transmission of pathogens.[46–48] In occupational health and safety, barrier performance against hazardous chemicals is also the focus of much research.[49–51] In addition, the prevalence of latex allergies has resulted in many publications comparing the dexterity, barrier performance, and shelf life of different kinds of disposable gloves.[8], [13], [24] In the fields of polymer science, chemical engineering, and materials science, topics include the leaching of polymer additives, determination of polymer blend ratios, and the weathering of polymers in industrial applications.[15], [52], [53]

## 2. Materials and Methods

### 2.1. Materials

**Table 1. List of glove samples and their assigned numbers.**

	Brand	Name	Material	Powdered
1	CVS	"Durable Nitrile Exam Gloves"	Nitrile	No
2	CVS	"Disposable, Powdered Latex Exam Gloves"	Latex	Yes
3	CVS	"Latex-Free Gloves: Powder-free Clear Vinyl"	Vinyl	No
4	CVS	"Latex Exam Gloves: Powder Free, Aloe Vera"	Latex	No
5	Fisherbrand	"Powder-Free Nitrile Exam Gloves"	Nitrile	No
6	Fisherbrand	"Powder-Free Aloe Latex Exam Gloves"	Latex	No
7	up&up	"Vinyl exam gloves: latex free, powder free"	Vinyl	No
8	evercare	"Disposable latex gloves"	Latex	Yes
9	WestChester	"Nitrile Disposable Gloves"	Nitrile	Yes
10	WestChester	"Vinyl Disposable Gloves"	Vinyl	Yes
11	WestChester	"Latex Disposable Gloves"	Latex	Yes
12	WestChester	"Vinyl Disposable Gloves"	Vinyl	Yes
13	Grease Monkey	"Disposable Black Nitrile Gloves"	Nitrile	Yes

2.1.1. Gloves. "Durable Nitrile Exam Gloves," "Disposable, Powdered Latex Exam Gloves," "Latex-free Gloves: Powder-free Clear Vinyl" and "Latex Exam Gloves: Powder Free, Aloe Vera" were purchased from CVS/pharmacy. "Powder-Free Nitrile Exam Gloves" and "Powder-Free Aloe Latex Exam Gloves" were purchased from Fisher Scientific. "Vinyl exam gloves: latex free, powder

free” and “Disposable latex gloves” were purchased from Target. “Nitrile Disposable Gloves,” green “Vinyl Disposable Gloves,” “Latex Disposable Gloves,” clear “Vinyl disposable gloves,” and “Disposable black Nitrile gloves” were purchased from Home Depot. These gloves were assigned numbers 1–13 for ease of record-keeping, and are listed in Table 1.

Gloves #11 and #12 were neither advertised as “powdered” nor “powder-free.” For these two samples, a clean razor blade was used to lightly scrape the surface of the glove. The presence of a fine white powder was observed, and these gloves are therefore classified as “powdered.”

2.1.2. Water. Deionized water was used as a water source.

## **2.2. Methods**

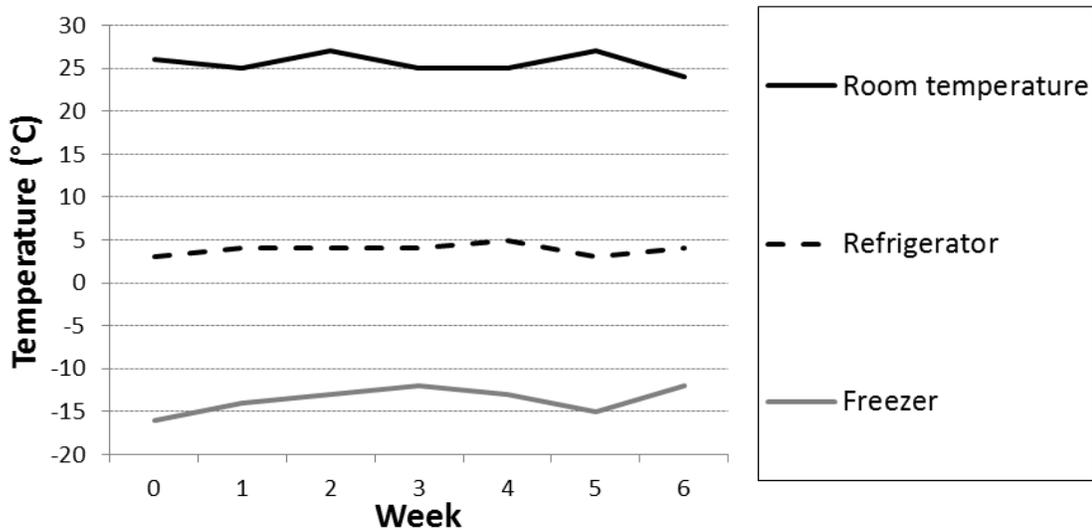
The gloves were cut into 1 cm squares for ease of handling. These cuttings were taken from the palmar surface of the glove, to avoid any variability in thickness and spectral characteristics between different areas on the glove. For the wet samples, gloves were placed in a 20 mL Wheaton Scintillation vial, and 15 mL of deionized water was added. The vials were then stored either in the laboratory at room temperature, in a refrigerator, or in a freezer. The room temperature samples were placed in a cardboard box to prevent exposure to light. All samples were handled with tweezers that were cleaned with an alcohol wipe in between samples.

For the dry samples, gloves were cut into 1 cm squares for ease of handling, as described above. Samples were placed in a 3" × 5" coin envelope. The envelopes were then placed in the laboratory, in a refrigerator, or in a freezer.

The temperature of the environment was recorded once a week and is shown in Table 2 and Figure 13. Each environmental condition was repeated in triplicate.

**Table 2. Temperatures of sample conditions.**

Week	Temperature (°C)		
	Room	Refrigerator	Freezer
0	26	3	-16
1	25	4	-15
2	27	4	-13
3	25	4	-12
4	25	5	-13
5	27	3	-14
6	24	4	-12
<i>average</i>	26	4	-14

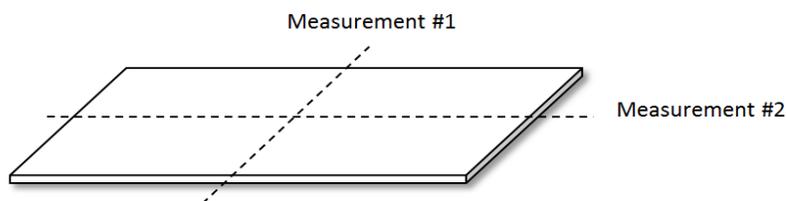


**Figure 13. Recorded temperature conditions**

For all samples, the gloves were removed from the coin envelope or vial and placed on plain butcher paper for 30 minutes, allowing them to equilibrate with room temperature and for the water to evaporate. The samples were then analyzed. Once analyzed, the samples were placed in new coin envelopes, and stored in a paper bag at room temperature.

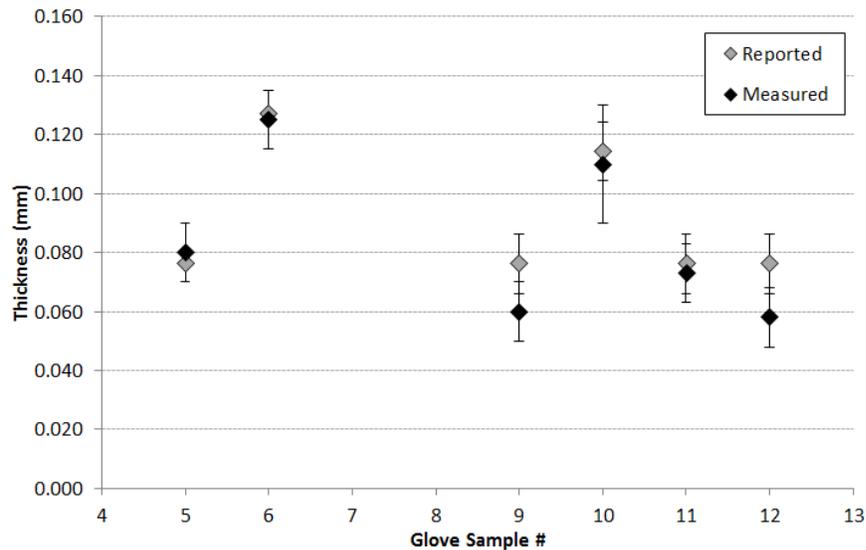
### 2.2.1. Thickness.

ASTM (American Society for Testing and Materials) D 3767-03: “Standard Practice for Rubber – Measurement of Dimensions” was used as a guideline for the measurement of the thickness of each glove sample.[54] Thickness was measured with Fisher Scientific Digital Calipers by pressing the calipers tightly closed, allowing the material to relax for 5 seconds, and then recording the value. This procedure is recommended for determining accurate dimensions of elastic products. Thickness was measured across both axes of the sample, as shown in Figure 14, to account for any variability. Measurements were recorded in Microsoft Excel. Statistical analyses performed included averaging, calculation of standard deviation, and calculation of 95% confidence interval.



**Figure 14. Diagram of thickness measurements**

Several of the glove manufacturers advertised a value for palm thickness on the specification sheet for each product.[55–59] These values were compared to the initial (Week 0) measured thicknesses of the glove samples. This was performed as a quality control measure to ensure the accuracy of the measurement technique. Figure 15 shows the results of this comparison. Samples 1–4, 7, and 8 are not depicted because this information was not provided by the manufacturer.



**Figure 15. Comparison of reported and measured glove thicknesses.**

The error bars for the measured data represents a 95% confidence interval. The error bars for reported thickness of gloves 9–12 represent the advertised range. Manufacturers of gloves 5 and 6 did not include a range of error and these data points subsequently have no error bars. The figure shows sufficient agreement between the reported and measured values to ensure accurate measurements.

### 2.2.2. Stereomicroscope

Samples were viewed under the stereoscope prior to spectroscopy so the compression of the material with the ATR probe would not complicate analysis of surface texture. The samples were analyzed under a Nikon SMZ1000 stereomicroscope. Gloves were examined for overall surface texture at 10x magnification. Images of both the interior and exterior of each sample were acquired with a SPOT™ Idea digital camera and SPOT™ 5.0 imaging software. If any aberrations were noted — such as defects in the glove structure, or aggregates of powder — they were magnified to 40x and an image was acquired. All images shown are 10x unless otherwise specified.

### 2.2.3. FTIR Spectroscopy

FTIR spectra were acquired on a Nicolet 6700 FTIR with SmartOrbit ATR attachment. 64 scans were acquired for each sample from 4000 to 400  $\text{cm}^{-1}$ , with a resolution of 4.0. Between different glove samples, the ATR surface was swabbed with an alcohol wipe, dried with a KimWipe, and a new background spectrum was obtained. Spectra of both the interior and exterior of each sample were acquired.

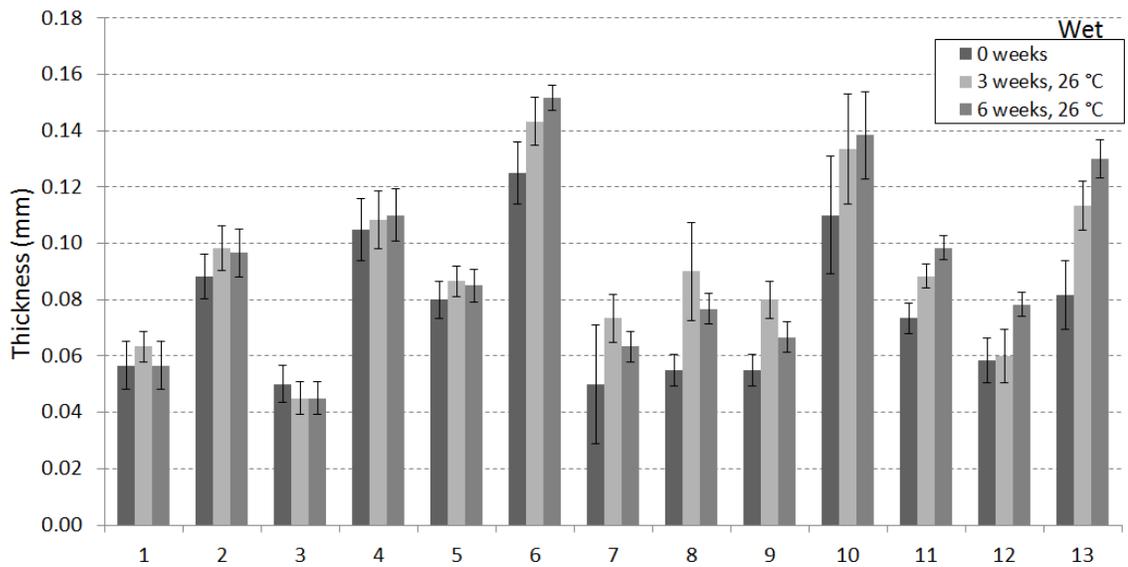
Spectra were analyzed using ThermoScientific OMNIC Software and Microsoft Excel. Triplicate spectra were averaged using the Statistical Spectra function in the OMNIC Software.

### 3. Results and Discussions

#### 3.1 Thickness measurements

##### 3.1.1. Wet Samples

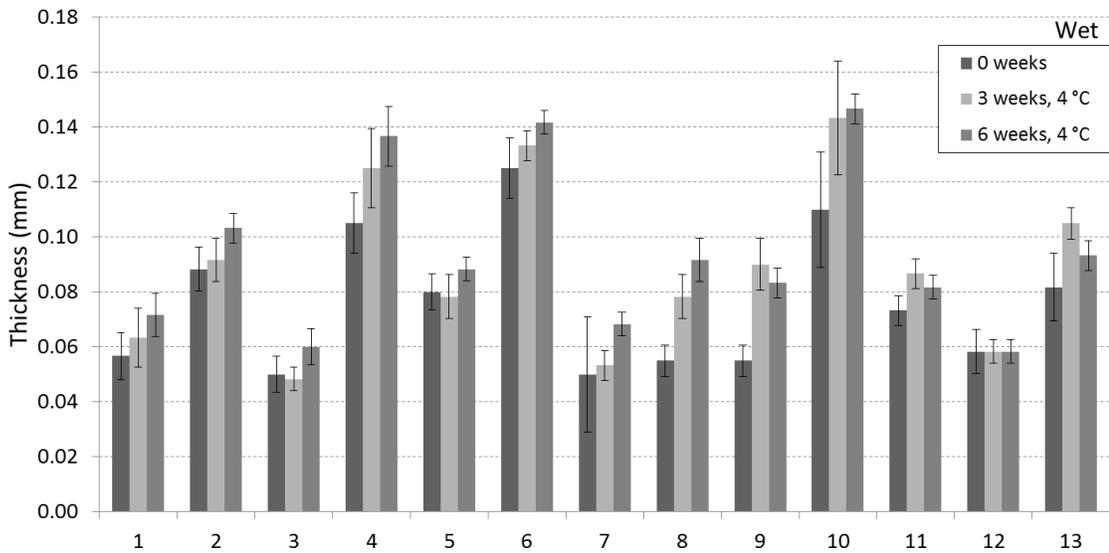
The thickness of the wet glove samples are shown in Figures 16–18. The y-axis represents thickness in millimeters and the x-axis represents the sample number. The error bars represent the confidence interval calculated with 95% confidence t-values. These error bars allow for the differentiation between statistically significant and statistically insignificant changes in thickness. The majority of samples did not show significant changes from week 0 to week 3 or week 3 to week 6, but showed significant overall changes from week 0 to week 6.



**Figure 16. Thickness measurements for wet 26 °C samples.**

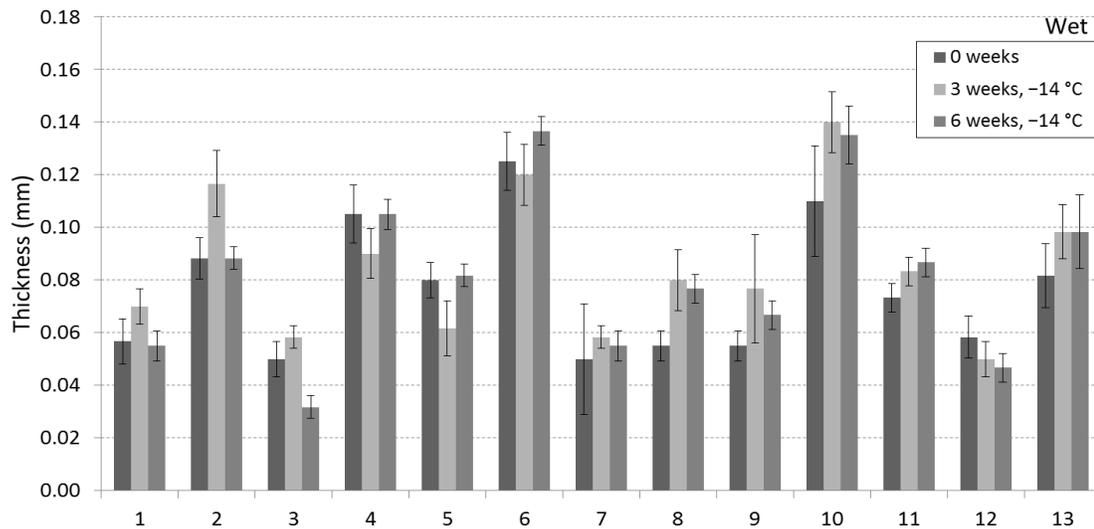
For the wet 26 °C samples, shown in Figure 16, there are significant increases in thickness over time for samples 6, 11, 12, and 13. These gloves are,

respectively, latex, latex, vinyl, and nitrile. The remaining gloves show insignificant variations in thickness.



**Figure 17. Thickness measurements for wet 4 °C samples.**

For the wet 4 °C samples, shown in Figure 17, there are increases in thickness over time for samples 2, 4, 6, 8, and 10. These gloves are all latex, except for #10, which is vinyl. The remaining gloves show insignificant variations in thickness.



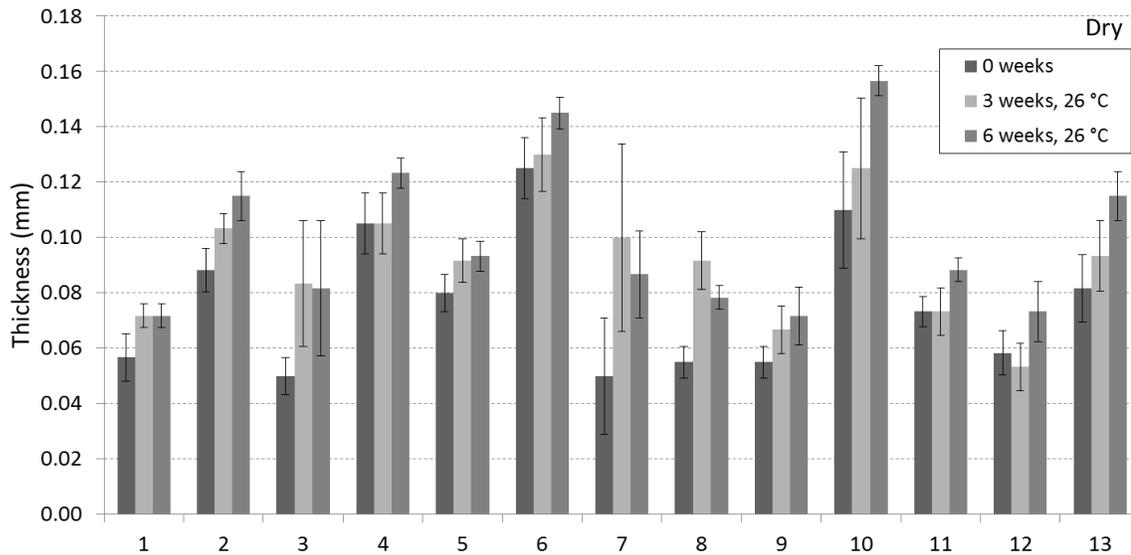
**Figure 18. Thickness measurements for wet -14 °C samples.**

For the wet -14 °C samples, shown in Figure 18, there are increases in thickness over time for samples 8 and 11. These gloves are both latex. There was a decrease in thickness for sample 3, a vinyl glove. The remaining gloves show insignificant variations in thickness.

7 of the 11 wet glove samples that exhibited an increase in thickness over time were latex. This represents a majority of those samples. Samples #8 and #11, both latex gloves, exhibited changes at more than one temperature condition. There is no noticeable trend regarding the increase in thickness at various temperatures. Only one sample, vinyl glove #3 at -14 °C, showed a significant decrease in thickness.

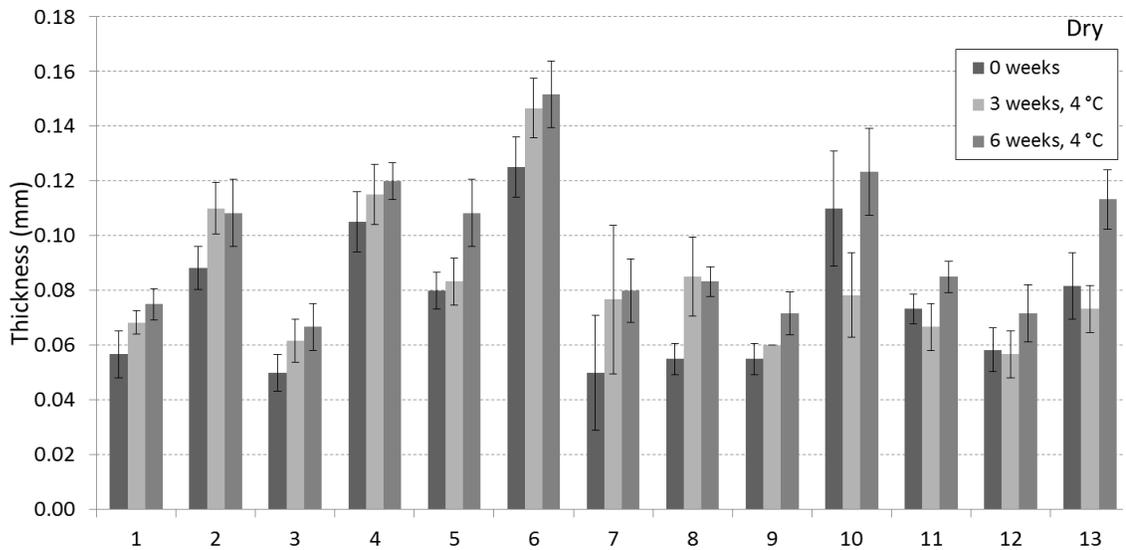
### 3.1.2 Dry Samples

The thickness of the dry glove samples are shown in Figures 19–21



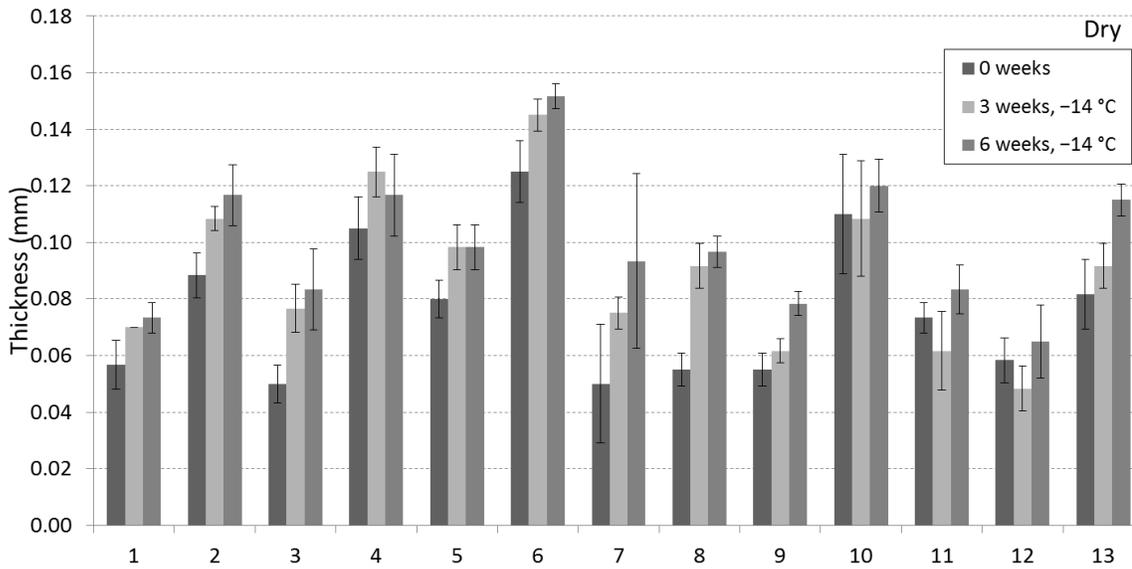
**Figure 19. Thickness measurements for dry 26 °C samples.**

For the dry 26 °C samples, shown in Figure 19, there are increases in thickness over time for samples 1–6, 8–11, and 13. That includes all 4 nitrile glove samples, 2 vinyl glove samples, and all 5 latex samples. The remaining gloves show insignificant variations in thickness.



**Figure 20. Thickness measurements for dry 4 °C samples.**

For the dry 4 °C samples, shown in Figure 20, there are increases in thickness over time for samples 1–9, and 13. That includes all 4 nitrile glove samples, 2 vinyl glove samples, and 4 latex samples. The remaining gloves show insignificant variations in thickness.



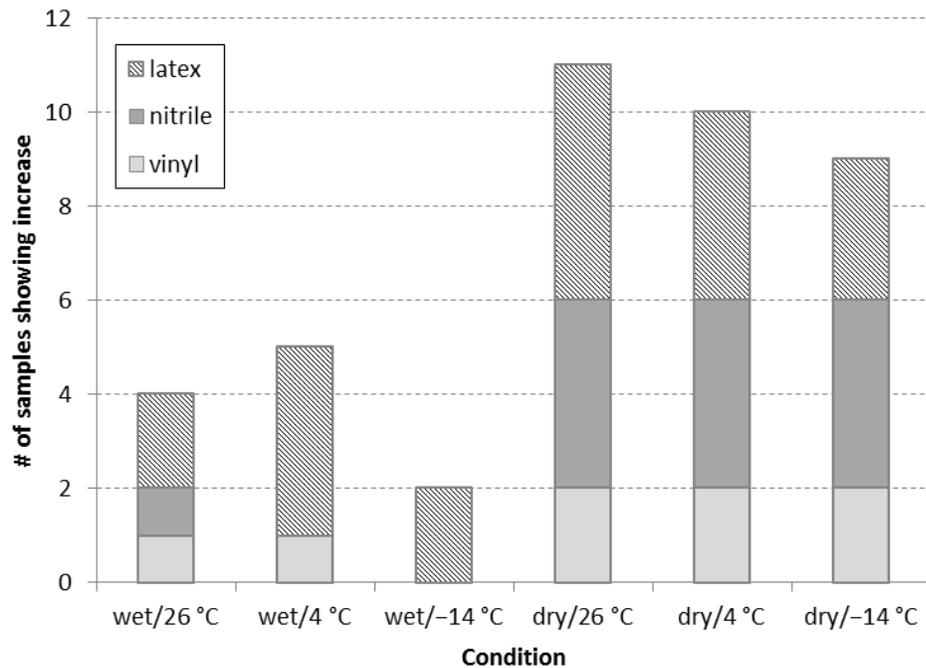
**Figure 21. Thickness measurements for dry -14 °C samples.**

For the dry -14 °C samples, shown in Figure 21, there are increases in thickness over time for samples 1–3, 5–9, and 13. That includes all 4 nitrile glove samples, 2 vinyl glove samples, and 3 latex samples. The remaining gloves show insignificant variations in thickness.

### 3.1.3. Discussion

The number of gloves that exhibited increases in thickness across all temperature conditions is not evenly distributed among the three material types. Of the 30 samples that showed changes, 12 were nitrile, 6 were vinyl, and 12

were latex. The number of gloves that showed an increase in thickness across all conditions is represented in Figure 22.



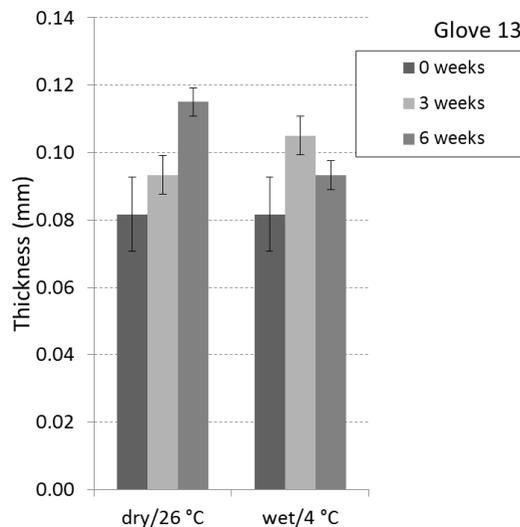
**Figure 22. Samples showing increase in thickness across all conditions.**

It is evident that exposure to water affected a greater number of latex gloves than vinyl or nitrile. Conversely, exposure to dry conditions affected approximately the same distribution of each glove material. This graph manifests that a significantly higher number of gloves were affected by dry conditions than by wet conditions, regardless of temperature. Among all samples and conditions, only one sample showed a decrease in thickness. This sample was vinyl.

The most likely reason for the increase in thickness is a lack of elasticity. When a sample is measured with the calipers, it is compressed on either side of the material. The amount to which the caliper pads can compress the material is

measured as thickness. When the sample loses its elasticity — due to an increase in the number of crystallization zones, or leaching of plasticizer — it becomes brittle and unyielding. The pads of the calipers can no longer compress, and the measured thickness is greater. In addition, degradation of polymer, such as chain scission and oxidation, results in structural differences that could contribute to changes in thickness observed.

The significance of these results is evident when considering them in the context of a crime scene environment. For instance, a disposable glove tossed in a river after the commission of a crime would be subjected to wet and possibly cold conditions. The source of the glove — a box of similar gloves in the perpetrator’s vehicle — would be subjected to milder, dry conditions. Figure 23 shows how the thickness measurements of these initially comparable samples change over time.



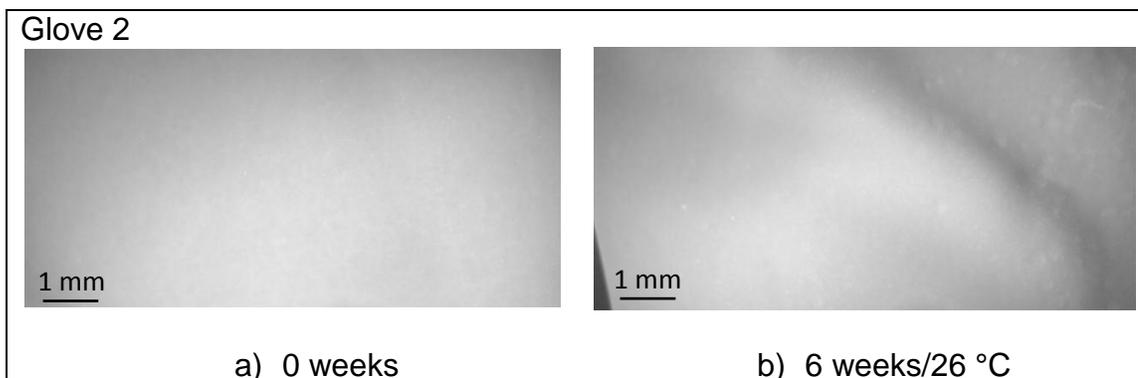
**Figure 23. Comparison of thickness measurements (Glove #13).**

In an attempt to link an unknown to the known, the physical characteristics of the gloves would be measured and recorded, including: size, condition, color, and thickness. Depending on the length of time in which the gloves were subjected to their respective environments, an analyst may exclude the known box of gloves as being the source of the unknown glove. While there are no clear, simple trends regarding the relationship between thickness and these variables — time, temperature, water exposure — it is clear that knowledge and context of the crime scene should aid the analyst in proper interpretation of data. Knowledge of exposure to extreme temperature conditions could result in less stringent guidelines for exclusions, because of the possible variations that arise.

### 3.2 Stereomicroscope images

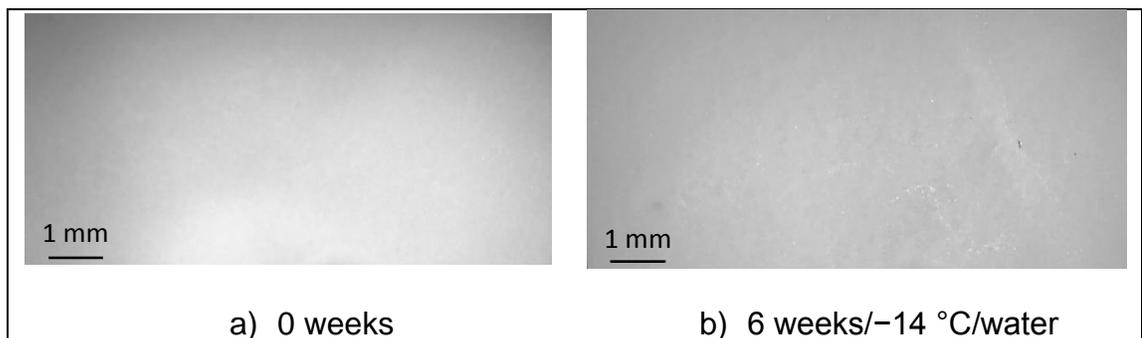
#### 3.2.1. Latex

Glove #2 exhibited changes in surface texture when exposed to both wet and dry conditions.



**Figure 24. Surface changes on Glove #2, dry conditions.**

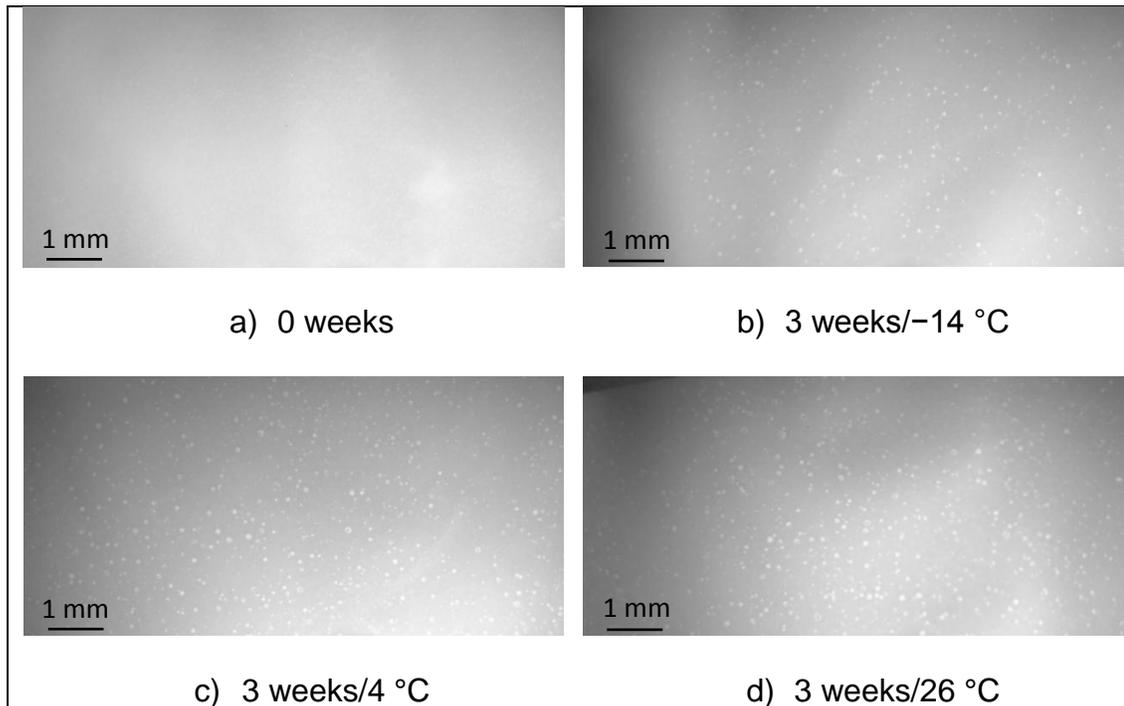
Figure 24a shows the originally smooth surface of the glove. Figure 24b shows the presence of depressions on the surface that create a pitted texture. Similarly, Figure 25a shows the initial smooth surface while Figure 25b shows what appear to be striations or scratches on the surface after the material was exposed to water.



**Figure 25. Surface changes on Glove #2, wet conditions.**

Gloves #4 and 6 showed no appreciable change in surface characteristics under the stereomicroscope.

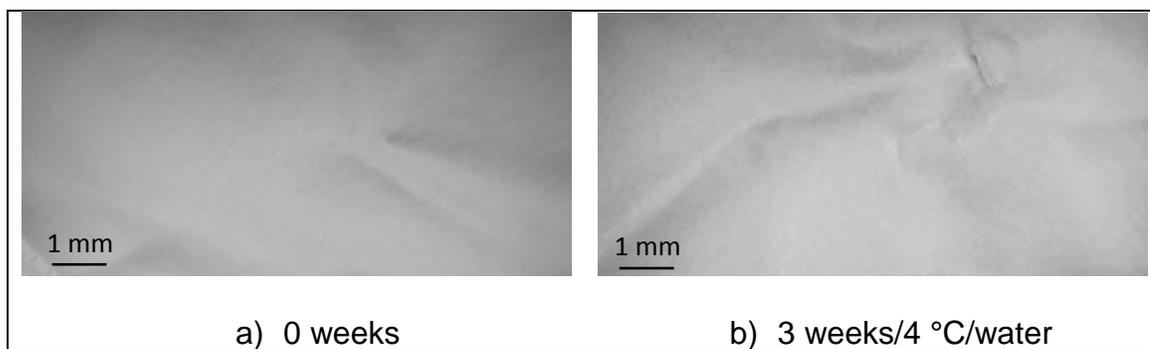
Glove #8, a non-powdered latex glove, showed the formation of bubbles on the exterior surface of all gloves exposed to dry temperature conditions. These defects are shown in Figure 26. These defects were not present on the Week 0 controls, and were not observed in any of the wet samples. The defects were more densely populated on the gloves exposed to higher temperatures.



**Figure 26. Stereomicroscope images of Glove #8, dry conditions.**

### 3.2.2. Nitrile

Samples of Glove #1 exposed to cold temperature showed slight defects in the surface of the material. Figure 27 shows one of the defects.

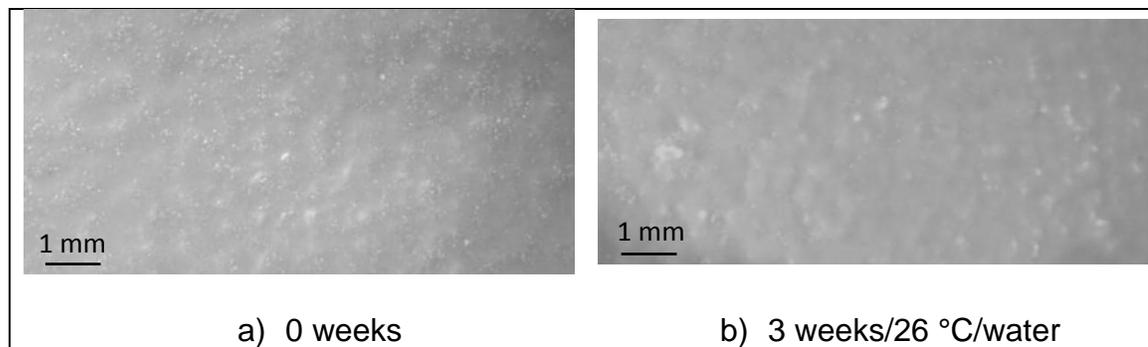


**Figure 27. Defect observed on Glove #1 after exposure to 4 °C for 3 weeks**

Defects were also present in the following samples: 3 weeks/24 °C/water, 6 weeks/4 °C/water, 3 weeks/-14 °C/water, and 6 weeks/-14 °C/water.

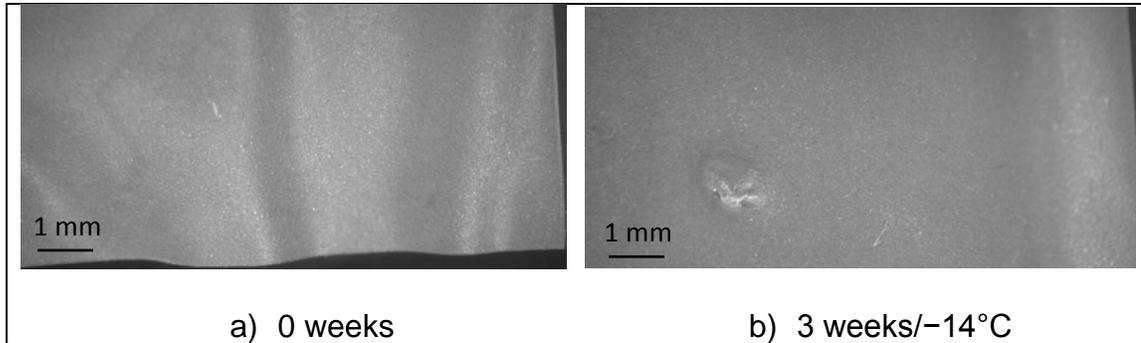
This defect is most likely caused by the handling of the glove with tweezers. A cold polymer exhibits more partial crystallization zones, and is therefore more brittle and less plastic.[5] Additionally, the phthalates compounded with the polymer could have leached into the water, resulting in a loss of plasticity.[60]

An observation regarding the powdered gloves #9 and #13 was the disturbance and loss of powder when submersed in water. The initial samples showed an even distribution of fine powder across the interior surface of the glove. Submersion in water resulted in the dislocation of the powder from the glove's surface. When removed from the water and dried, the powder was once again stuck to the surface, but instead of being evenly distributed, it was present in larger aggregates. This pattern was observed in all powdered glove samples exposed to water, and an example is shown in Figure 28.



**Figure 28. Powder dispersion in Glove #5 after exposure to water.**

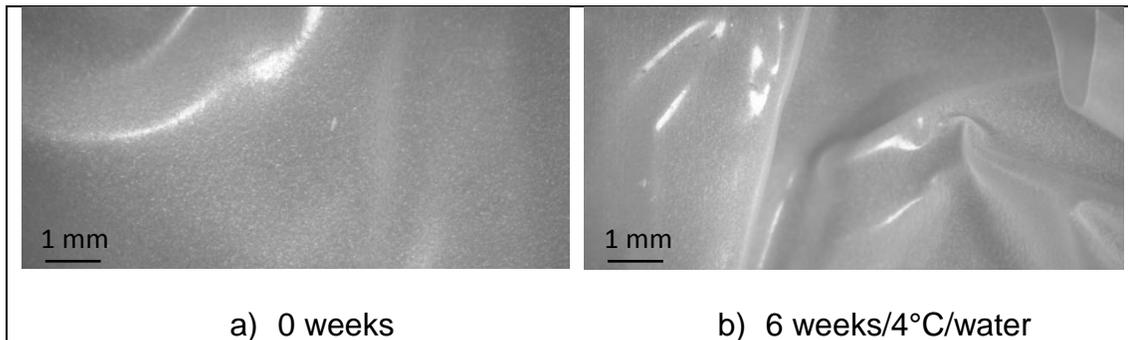
### 3.2.3. Vinyl



**Figure 29. Defect in Glove #3 after exposure to -14 °C for 3 weeks**

Exposure of vinyl gloves to colder temperatures resulted in defects similar to those observed in nitrile gloves. This can similarly be explained by the brittle nature of the glove under low temperature. Figure 29b shows such a defect.

Defects were also present on the following samples: 3 weeks/4°C, 6 weeks/-14°C, and 6 weeks/4°C

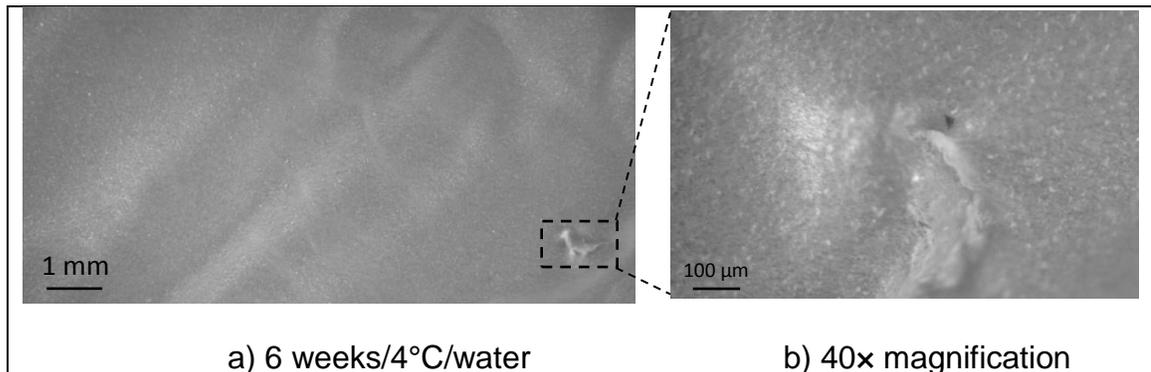


**Figure 30. Deformation of Glove #3 shape after exposure to water.**

All of the vinyl gloves exposed to water withered. Figure 30 shows the change in overall shape from an initially smooth surface to a wrinkled surface.

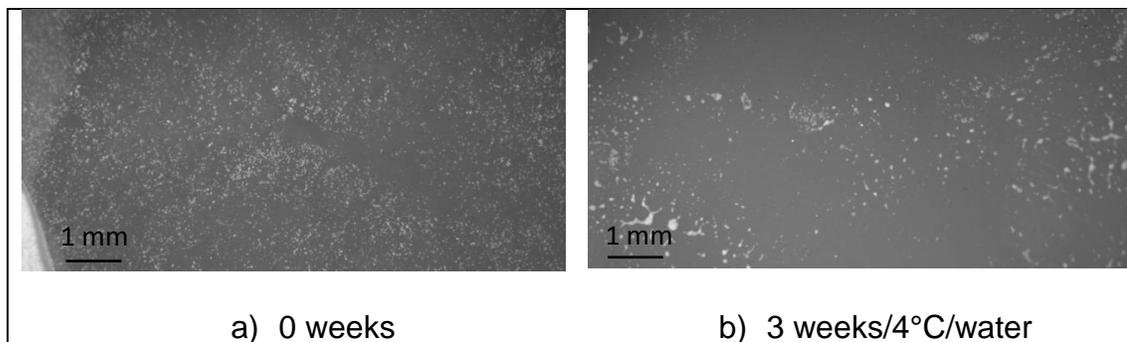
This deformation of sample shape was also observed in the following samples: 3





**Figure 33. Defect in Glove #7 after exposure to cold water.**

As noted with the nitrile gloves, the powdered vinyl gloves exposed to water also displayed changes in powder dispersion.

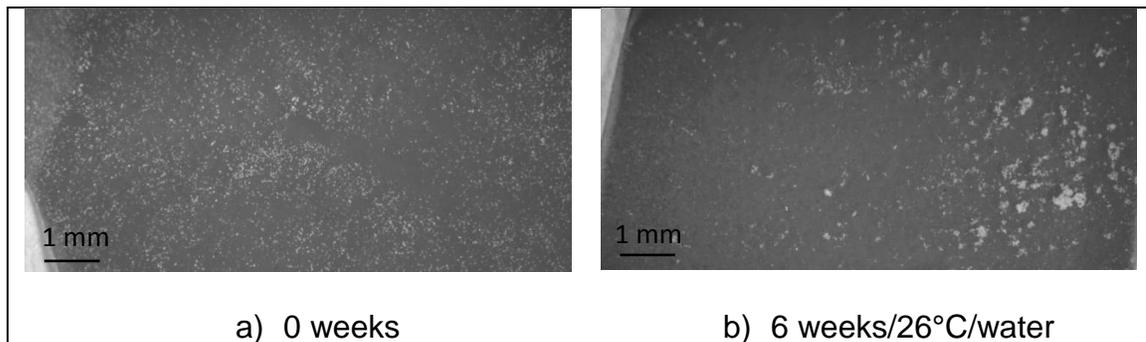


**Figure 34. Changes in powder in Glove #10 after exposure to water.**

Figure 34a shows the initial surface of glove #10, with powder evenly distributed across the interior surface of the glove. Figure 34b shows the interior surface of glove #10, after exposure to water. These powder changes were observed in both gloves #10 and #12.

In addition to changes in powder, Glove #10 showed slight changes in the surface texture. When initially examined at Week 0, Glove #10 had a very smooth, even surface, as shown in Figure 35a. After exposure to cold water for 6

weeks, there was a marked increase in surface texture, evidenced by the pitting and bubbling shown in Figure 35b.



**Figure 35. Surface changes on Glove# 10, wet conditions.**

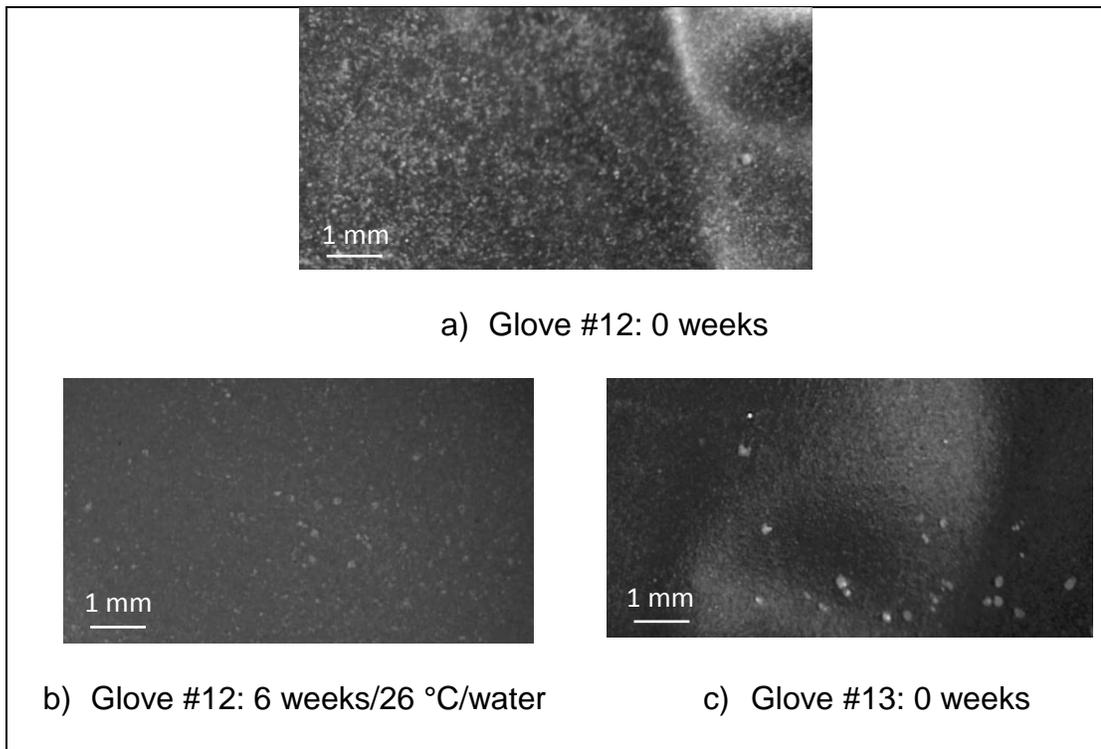
#### 3.2.4 Discussion

Exposure of the glove material to a variety of conditions resulted in several changes in surface characteristics, viewable under the stereomicroscope. The most likely explanation is that changes to the glove material on a chemical level result in susceptibility to tears, holes, and changes in texture. For the dry samples, exposure to atmospheric oxygen can break the polymer chains through an oxidation reaction.[34] For wet samples, exposure to water results in a hydrolysis reaction, where the addition of water breaks chemical bonds. The breakage of chemical bonds results in loss of chain length. Shorter chain lengths lead to decreased strength, which makes the material prone to surface defects.

In addition to polymer chain degradation, the loss of additives can lead to changes in texture. Phthalate plasticizers have been shown to leach into water after prolonged exposure.[61] Phthalates can also slowly volatilize, or dissipate

into the gaseous phase, over time.[60] Loss of plasticizers results in a brittle polymer texture that is more susceptible to cracking and breaking.

The significance of powder dispersion arises when performing comparisons between known and unknown samples. Consider an unknown glove sample that had been submerged in water and was found in the execution of a crime scene search, and a second glove found in the possession of a suspect. An initial examination of surface texture under the stereomicroscope would show the markedly different surface characteristics. The clumping of the powder on the unknown sample could be misconstrued as larger powder size. The questioned sample would appear inconsistent with the known.



**Figure 36. Interpretation complications between Gloves #12 and #13.**

An example of this potential for misinterpretation is shown in Figure 36. Figure 36a shows the original stereomicroscope image of Glove #12, with fine powder dispersed evenly across the surface. Figure 36b shows the same glove after exposure to water; the powder has aggregated into large clumps. Figure 36c shows the original powder dispersion of a different glove, #13. The powder of glove #13 consists of large crystalline particles. This series of images shows how environmental conditions can alter a glove's appearance, complicating the linkage between image a and b, while creating a potential false linkage between image b and c.

In addition, the disturbance of surface powder can indicate that the sample was submerged in water. When it is evident that the sample in question has been exposed to water, this added information can help explain other characteristics of the glove in question.

### 3.3. FTIR spectroscopy

#### 3.3.1 Latex

Figure 37 shows a latex spectrum and Table 3 shows peak assignments for a latex sample.[62]

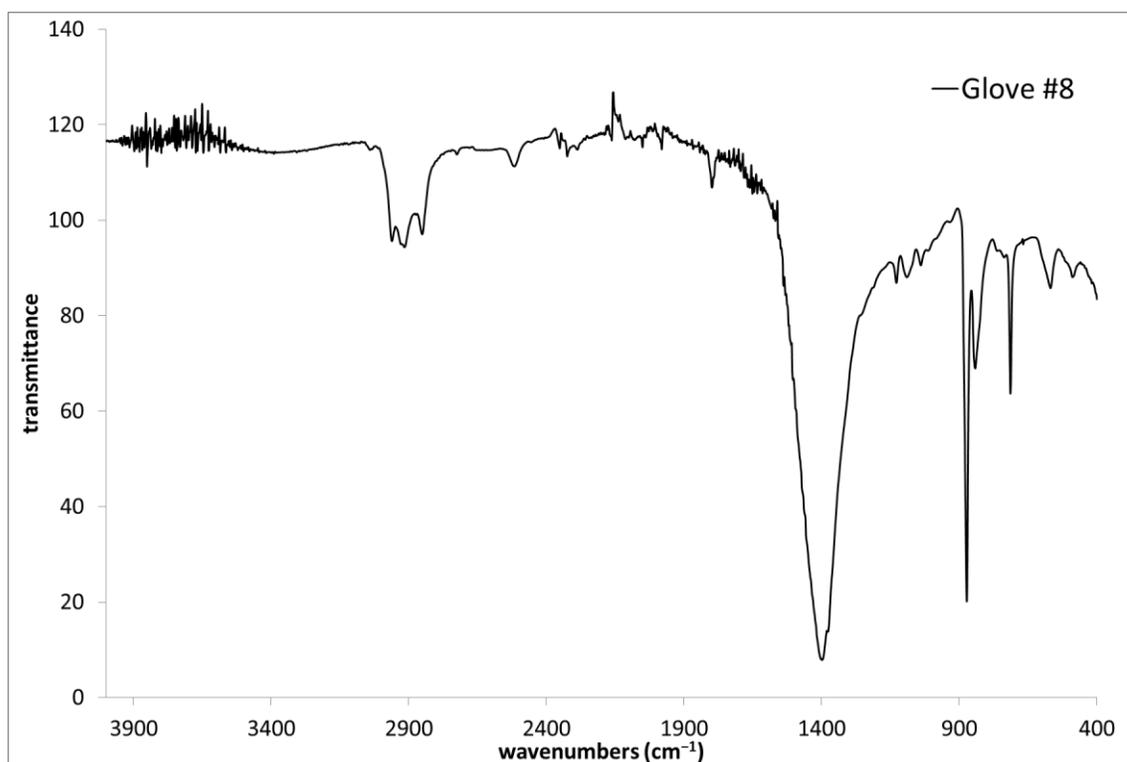
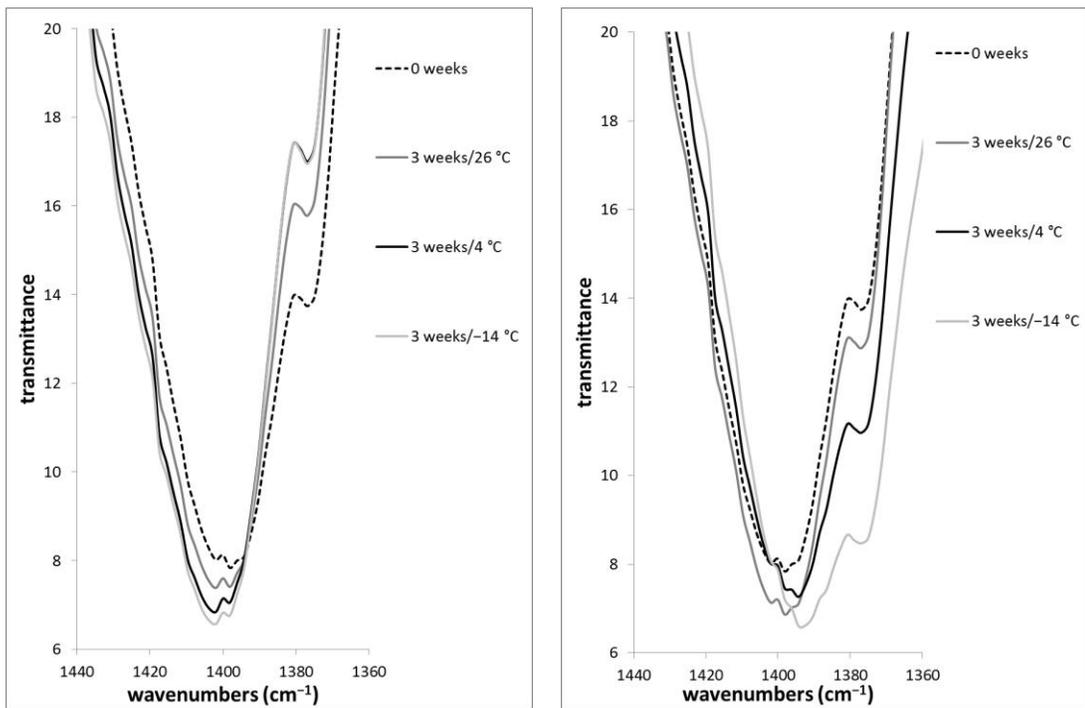


Figure 37. Infrared spectrum for latex (Glove #8).

Table 3. Infrared peak assignments for latex (Glove #8).

Wavenumber (cm <sup>-1</sup> )	Assignment
2956.3	Methyl C–H asymmetric stretch
2910.1	Methylene C–H asymmetric stretch
2846.4	Methyl C–H symmetric stretch
1398.1	C–H deformation
871.7	C–H wag
838.9	=C–H bend
713.5	C–H rock

Glove #8 showed changes in the peak position of C–H deformation for samples exposed to various dry temperatures. These changes did not occur for the wet samples. Figure 38 shows the C–H deformation shifts for the 0 week and 3 week samples under each environmental condition, which are tabulated in Table 4. The most significant shifts were the dry 4 °C and –14 °C samples. These shifts are most likely brought about by subtle changes in the polymer microstructure.[29]



a) Glove #8, wet

b) Glove #8, dry

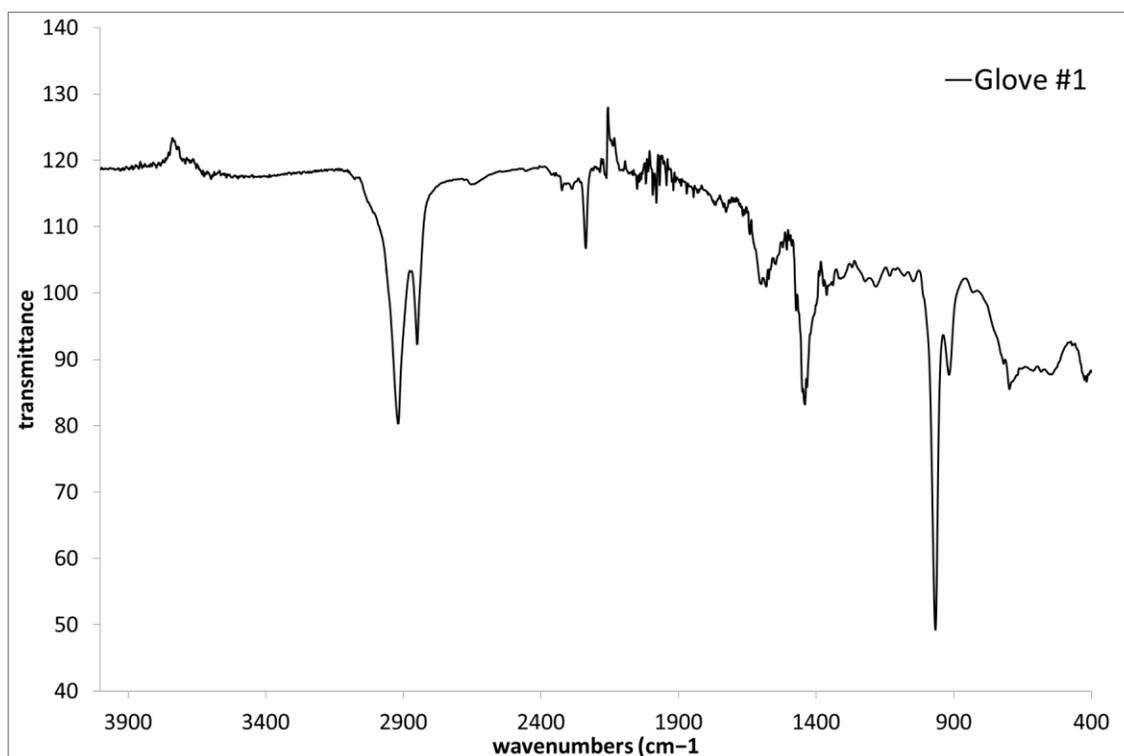
**Figure 38. Differences in 1360–1440cm<sup>-1</sup> range for Glove #8.**

**Table 4. Peak position of C–H deformation in Glove #8.**

Sample	Wavenumber (cm <sup>-1</sup> )
0 weeks	1398.1
3 weeks/26 °C/wet	1400.1
3 weeks/4 °C/wet	1398.1
3 weeks/-14 °C/wet	1400.1
3 weeks/26 °C/dry	1398.1
3 weeks/4 °C/dry	1394.2
3 weeks/-14 °C/dry	1394.3

### 3.3.2 Nitrile

Figure 39 shows a nitrile spectrum and Table 5 shows basic peak assignments for a nitrile sample.

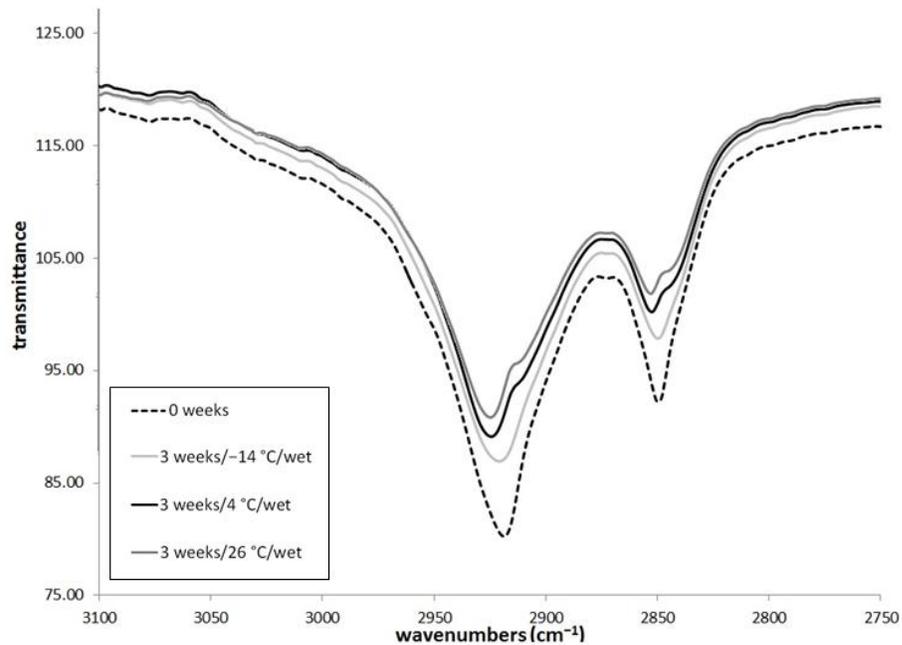


**Figure 39. Infrared spectrum for nitrile (Glove #1).**

**Table 5. Infrared peak assignments for nitrile (Glove #1).**

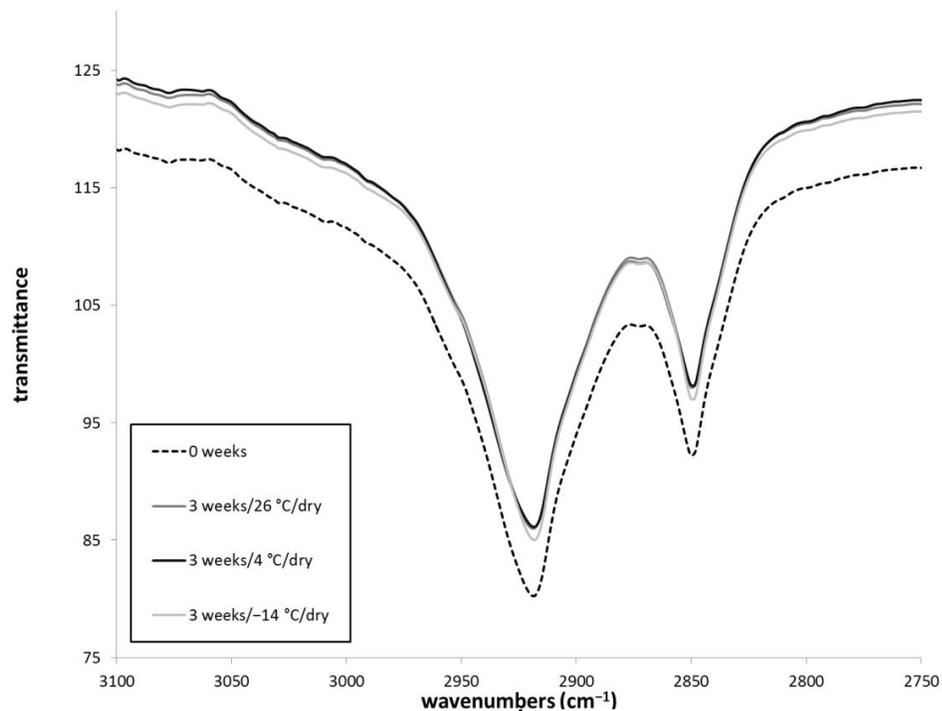
Wavenumber (cm <sup>-1</sup> )	Assignment
2915.8	Methylene C–H asymmetric stretch
2848.4	Methylene C–H symmetric stretch
2237.0	C≡N stretch
1440.6	C–H bend
966.2	=C–H bend

In Sample #1, changes to the aliphatic C–H stretches were observed and are shown in Figure 40. These changes occurred in the samples exposed to water, and were seen in both the 3- and 6-week samples. The changes observed are the slight shift and shouldering of the stretches. The peak change was temperature dependent; 26 °C samples experienced the most significant changes, 4 °C samples had less pronounced changes, and –14 °C samples had no significant changes.



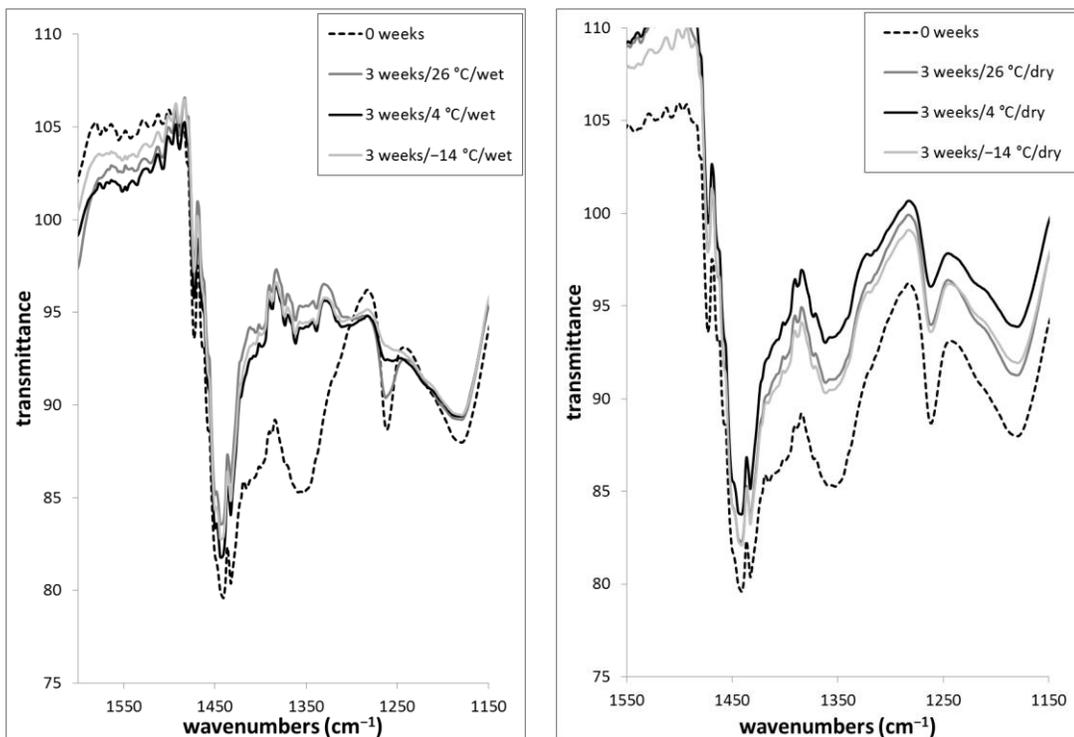
**Figure 40. Differences in 2750–3100cm<sup>-1</sup> range for Glove #1, wet conditions.**

Figure 41 shows the corresponding data for the dry samples. None of those samples experienced changes to the C–H stretch; they are all consistent with the original 0 week sample. This shows that exposure to temperature alone did not significantly alter the stretch, but submersion in water resulted in changes.



**Figure 41. Differences in 2750–3100 $\text{cm}^{-1}$  range for Glove #1, dry conditions.**

Both samples #5 and #9 showed changes to peaks in the 1300–1400  $\text{cm}^{-1}$  region when exposed to water. There were no changes observed for the dry samples. Samples exposed to water exhibited absorbance decreases for the 1344  $\text{cm}^{-1}$  peak, as seen in Figure 42a. For samples exposed to dry conditions, absorbance decreased slightly, but the main peak shape was retained, as seen in Figure 42b.

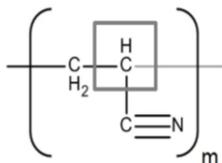


c) Glove #5, wet

d) Glove #5, dry

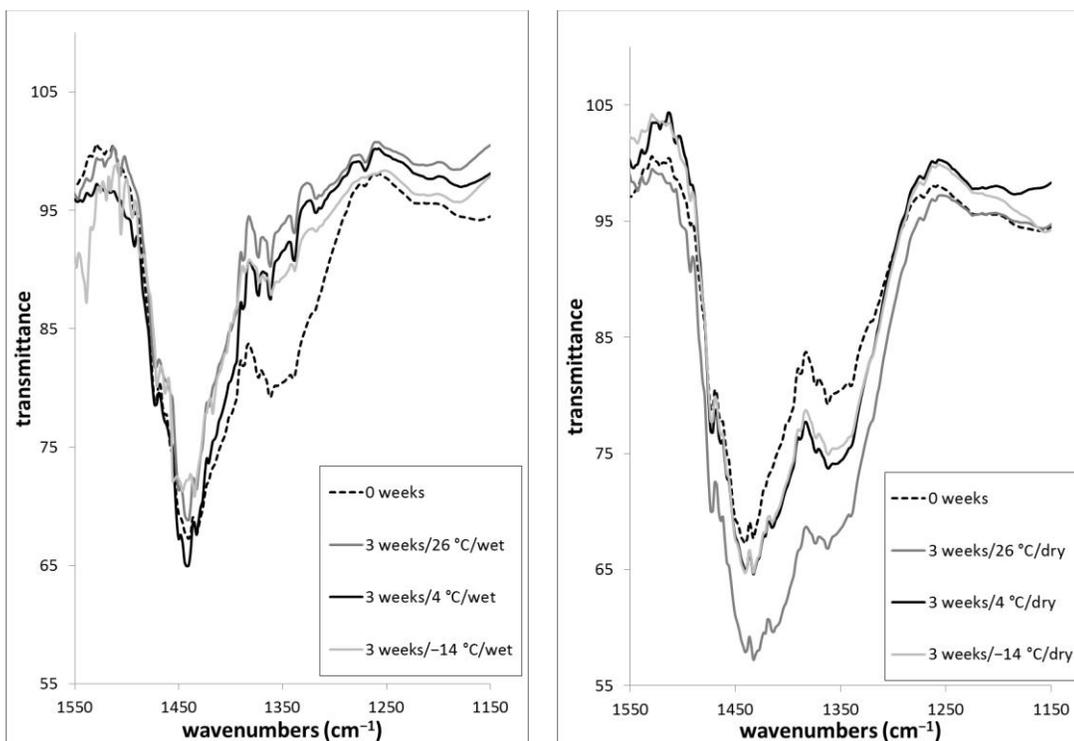
**Figure 42. Differences in 1150–1550 $\text{cm}^{-1}$  range for Glove #5.**

The identity of the peak in question is not clear, because of the complications that arise when interpreting a spectrum collected from a mixed sample. It could be a bend of the C–H bond highlighted in Figure 43. The literature reports these bends having absorbance in the frequency range of 1350–1330  $\text{cm}^{-1}$ . [62]



**Figure 43. Acrylonitrile monomer, showing carbon bonded to hydrogen.**

Alternatively, the band could be caused by a carboxylate ester, such as is present in phthalates and any number of additives. The carboxylic ester functional group has reported frequencies of  $1420\text{--}1300\text{ cm}^{-1}$ . [62] The band could have decreased in absorbance after exposure to water because of the leaching of plasticizer from the polymer compound.



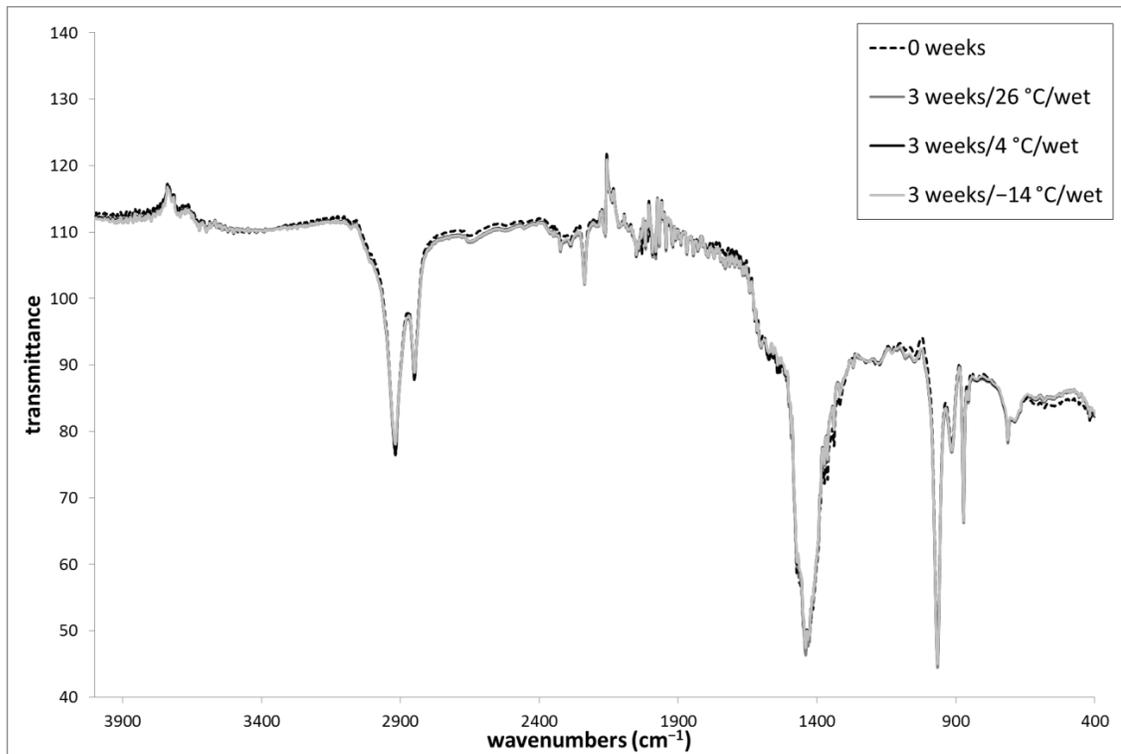
a) Glove #9, wet

b) Glove #9, dry

**Figure 44. Differences in  $1150\text{--}1550\text{ cm}^{-1}$  range for Glove #9.**

As shown in Figure 44, Glove #9 showed changes identical to Glove #5. Similarly, there were no major decreases in absorbance for the gloves exposed to dry temperature conditions.

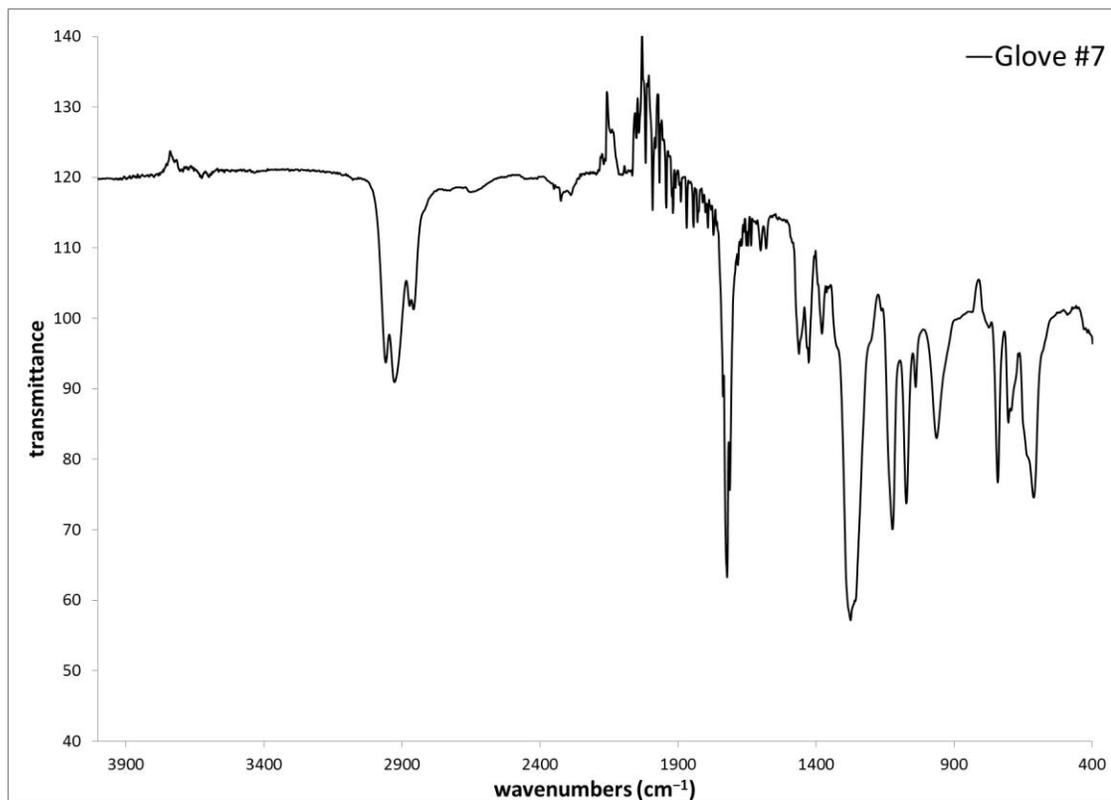
Glove #13 showed no significant changes to the infrared spectrum throughout all temperature, time, and moisture conditions. An example of the consistency of these spectra is shown in Figure 45.



**Figure 45. Infrared spectrum of Glove #13, wet conditions.**

### 3.3.3 Vinyl

Figure 46 shows a vinyl spectrum and Table 6 shows peak assignments for a vinyl sample.



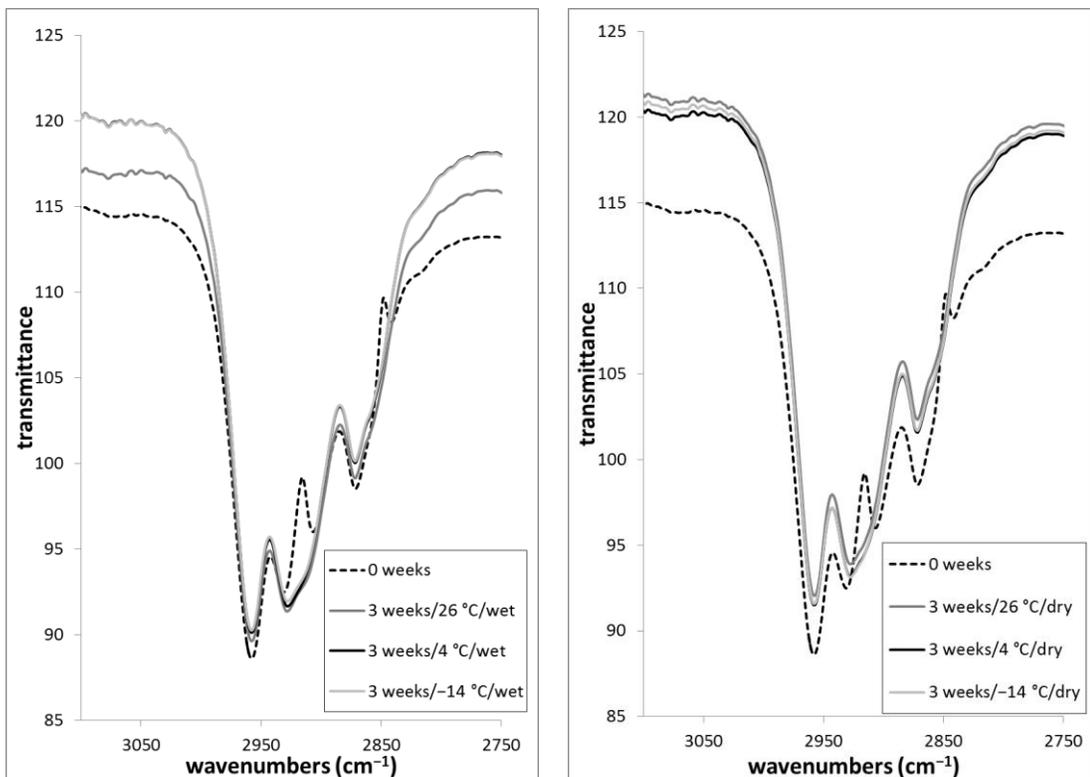
**Figure 46. Infrared spectrum for vinyl (Glove #7).**

**Table 6. Infrared peak assignments for vinyl (Glove #7).**

Wavenumber (cm <sup>-1</sup> )	Assignment
2954.4	Methyl C–H asymmetric stretch
2917.8	Methylene C–H asymmetric stretch
2859.5	Methyl C–H symmetric stretch
2854.1	Methylene C–H symmetric stretch
1722.1	C=O stretch
1276.6	Cl–CH <sub>2</sub> wag
740.5	C–Cl stretch

Sample #10 showed changes in bands associated with aliphatic C–H stretches. As illustrated in Table 6, polyvinyl chloride has four bands in this region: The symmetric and asymmetric stretches associated with the H–C–H bonds, and the symmetric and asymmetric stretches associated with the H–C–Cl

bonds. For Sample #10, the initial week 0 sample had four bands. However, all gloves exposed to all temperature and moisture conditions only exhibited three bands in the aliphatic C–H stretch region. This is shown in Figure 47.



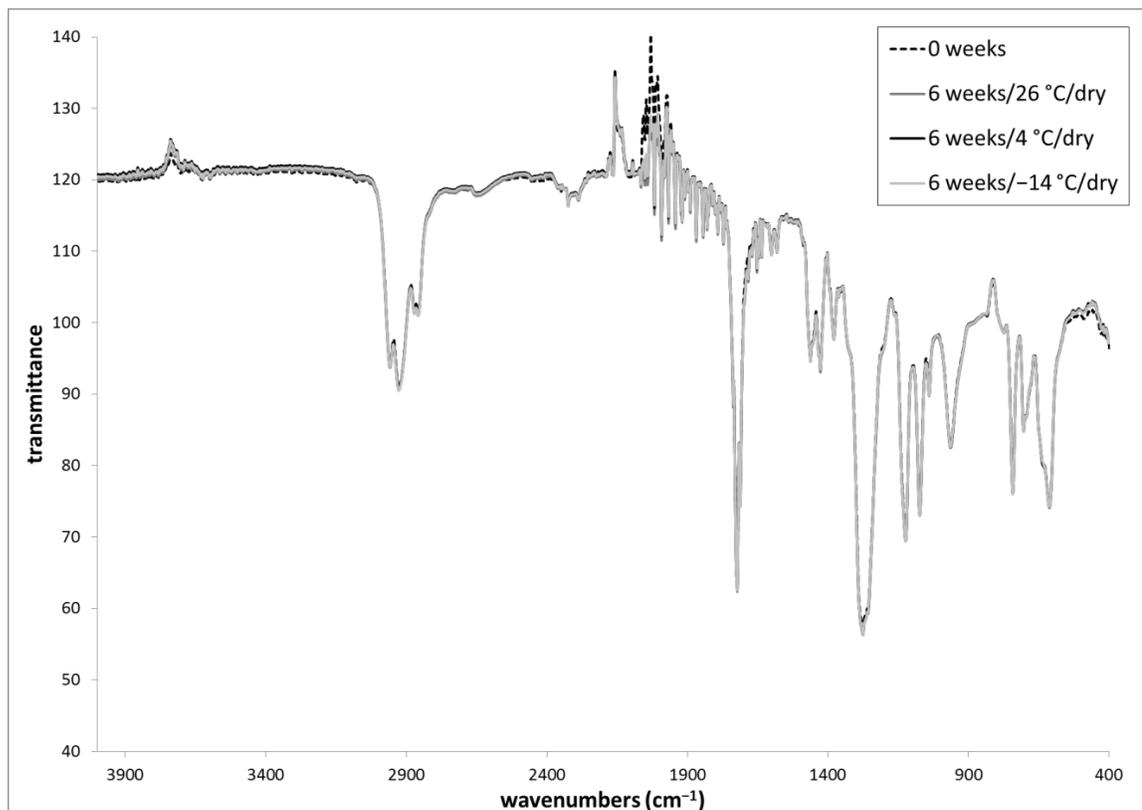
a) Glove #10, wet

b) Glove #10, dry

**Figure 47. Differences in 1150–1550 $\text{cm}^{-1}$  range for Glove #10.**

Because vinyl gloves are heavily plasticized, it is highly likely that phthalates contributed to the C–H stretches in this region. Changes in the number of peaks could be caused by a variety of reasons.

The remaining vinyl samples had insignificant differences in their spectra. An example of this consistency is shown in Figure 48.



**Figure 48. Infrared spectrum of Glove #7, dry conditions.**

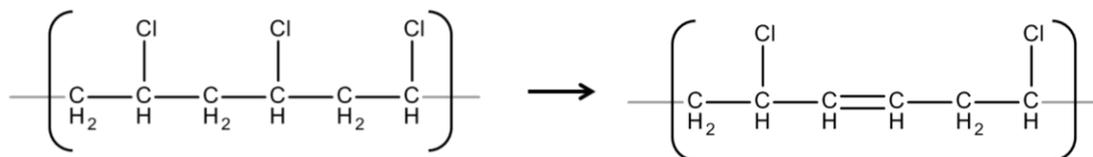
### 3.3.4. Discussion

One explanation for the changes observed in the infrared spectra is the loss of plasticizer that occurs over time. There is a multitude of research available regarding the leaching of phthalates.[60] The diffusion of phthalates from a polymer substrate into water is most often studied for environmental health reasons, in the context of plastic water bottles and food containers. However, because disposable gloves are heavily plasticized with phthalates, these studies can be applied to the weathering of disposable gloves. For example, Xu et al. studied the migration of several different phthalates from food containers into water. The level of dioctyl phthalate in the water reached 20

ng/mL after only 10 days.[61] In addition, phthalates with short chain length are relatively volatile, and can diffuse out of a polymer structure and volatilize when exposed to air. While the migration rate depends on a variety of factors, including phthalate chain length, temperature conditions, and the nature of the polymer, it is evident that significant changes in gloves could result from a loss of phthalates.

While phthalates are a common plasticizer and can account for up to 40% of the bulk of a polymer composite, there are a number of other additives that could contribute to the IR spectra. These include dyes, antioxidants, stabilizers, other plasticizers, and polyurethane coatings. It is entirely possible for any number of these additives to leach into water or volatilize into the atmosphere, resulting in subtle changes in the infrared spectrum.

Another explanation for changes in the FTIR spectra is the changes in polymer structure that occur with degradation. The degradation of polyvinyl chloride is a dehydrochlorination reaction, as illustrated in Figure 49.[63]

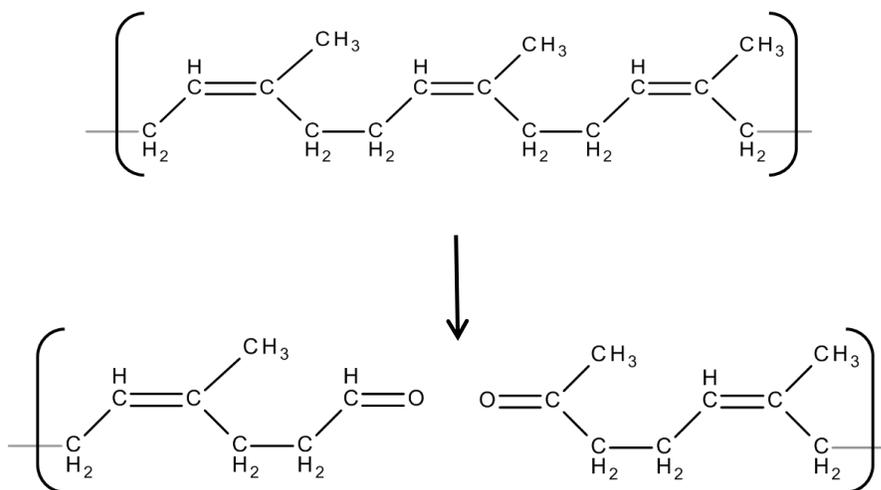


**Figure 49. Degradation mechanism of PVC.**

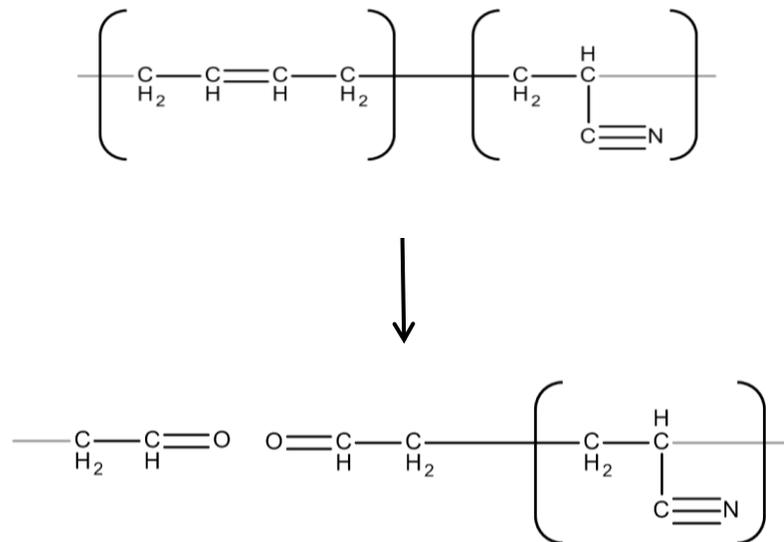
In addition to the formation of a double bond, the high electronegativity of the chlorine atom significantly affects the vibrations of adjacent C–H bonds.

Therefore the presence or absence of the chlorine atom results in changes in the FTIR spectrum.

Both latex and nitrile rubber degrade by an oxidative chain scission mechanism,[64] as shown in Figures 50 and 51. In nitrile rubber, the scission occurs in the butadiene monomer; the acrylonitrile monomer has proven to be rather robust and there is no disruption of the  $C\equiv N$  stretch, even under extreme temperature conditions.[65]



**Figure 50. Oxidative degradation of polyisoprene chain.**



**Figure 51. Oxidative degradation of butadiene monomer.**

The emergence of a strong band associated with the C=O stretch can be seen in the FTIR spectrum. However, this strong band may be masked by other C=O contributors, including glove composite additives such as phthalates and stabilizers.

Lastly, changes in the FTIR spectra can occur due to subtle changes in polymer microstructure. Changes in the amount of crosslinking between chains, chain orientation, degrees of crystallization and folding of the chain are all defects that affect the chain symmetry and bonds. These subtle changes can lead to new bands, shifts of bands, or changes of absorbance in the FTIR spectrum. [29] It should be noted that the analysis and conclusions drawn from slight wavelength shifts is dependent on the instrument's resolution. While the spectra in this study were taken in triplicate, and these changes were consistently observed, they may not be considered statistically significant.

#### 4. Conclusions

Subtle changes to various characteristics of disposable gloves were observed after exposure to various time, temperature, and moisture conditions. Those changes are summarized in Tables 7–9.

**Table 7. Overview of nitrile gloves that experienced changes.**

	Material	Powdered	Color	Thickness		Texture		FTIR	
				wet	dry	wet	dry	wet	dry
1	Nitrile	No	Blue		✓	✓		✓	
5	Nitrile	No	Blue		✓	✓		✓	
9	Nitrile	Yes	Light-blue		✓	✓		✓	
13	Nitrile	Yes	Black	✓	✓	✓			

**Table 8. Overview of latex gloves that experienced changes.**

	Material	Powdered	Color	Thickness		Texture		FTIR	
				wet	dry	wet	dry	wet	dry
2	Latex	Yes	Off-white	✓	✓	✓	✓		
4	Latex	No	Green	✓	✓				
6	Latex	No	Pale Yellow	✓	✓				
8	Latex	Yes	Off-white	✓	✓		✓		✓
11	Latex	Yes	Off-white	✓	✓				

**Table 9. Overview of vinyl gloves that experienced changes.**

	Material	Powdered	Color	Thickness		Texture		FTIR	
				wet	dry	wet	dry	wet	dry
3	Vinyl	No	Clear		✓	✓	✓		
7	Vinyl	No	Clear		✓	✓	✓		
10	Vinyl	Yes	Dark green	✓	✓	✓		✓	✓
12	Vinyl	Yes	Clear	✓		✓			

(✓= Changes seen under these conditions)

There were no major differences observed between the 3- and 6-week samples for any temperature condition, so it can be concluded that these

changes take place over the course of days, not weeks. A distribution of glove types and brands showed changes, with several discernible trends. Wet conditions affected the characterization of surface texture and FTIR spectra for nitrile gloves, while dry conditions affected thickness measurements. Both wet and dry conditions affected thickness for latex gloves, while the other characteristics examined showed few changes. Vinyl gloves showed no apparent trends in changes.

It is evident that when analyzing glove evidence that has been subjected to cold temperatures, a criminalist must interpret with caution. While the Scientific Working Group for Materials Analysis (SWGMA) does not have a guideline for analyzing glove evidence, the guideline for analyzing tape by FTIR can be adapted.

8.1.2.2 For spectra to be considered indistinguishable, the position of the absorption bands should have reasonable agreement with each other. A rule of thumb is that the positions of corresponding peaks in two or more spectra being compared should be within a few wavenumbers of each other, depending on whether the peak is sharp or broad. For sharp absorption peaks one may use tighter constraints and with broad peaks the variation may be slightly greater.

8.1.2.3 For spectra to be considered indistinguishable, the shape of the absorption bands should be consistent between comparison samples. The peak width and the symmetry of each peak should be evaluated. Sample thickness may affect the peak width and resolution.

8.1.2.4 For spectra to be considered indistinguishable, the relative intensities of respective absorption bands should be similar between comparison samples. The relative intensity may be affected by the heterogeneity of the sample. [66]

When comparing a known and unknown glove, changes in physical characteristics and spectral data due to the environment can distort consistencies between two gloves from the same source. It is therefore important for the analyst to have knowledge of the conditions in which the evidence was located.

Due to the variety of components contained within a glove, it is recommended that Py-GC/MS be utilized to completely comprehend the changes a glove sample can undergo in an environment. Quantification of the various components of the polymer composite over time could clarify the complex process of polymer degradation.

In addition to the implementation of Py-GC/MS, future studies would include the further evaluation of various conditions. These considerations could include: exposure beyond 6 weeks to determine long-term changes to the gloves; sampling more frequently (one week intervals) to further understand when changes occur; exposure to conditions warmer than room temperature to simulate different environmental conditions; exposure to soil and varying degrees of salinity to analyze buried gloves; and photodegradation studies to analyze samples exposed to sun light.

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- Jan. 2013 **Boston University School of Medicine** Boston, MA  
M.S. degree (Biomedical Forensic Sciences)
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#### RELEVANT EXPERIENCE

- 2012 **Boston University** Boston, MA  
Graduate Teaching Assistant – Prepare laboratory sessions for Instrumental Analysis course, communicate with instructor and students, review students' written reports.
- 2010 **Wellesley College Chemistry Department** Wellesley, MA  
Chemistry Prep Technician – Maintained the laboratories for Wellesley College chemistry courses, prepared reagents, and supervised seven student workers.
- 2008–09 **Wellesley College Chemistry Department** Wellesley, MA  
Part-Time Prep Technician – Prepared reagents for Wellesley College chemistry courses, and kept inventory of laboratory supplies.
- 2007–10 **Wellesley College Chemistry Department** Wellesley, MA  
Undergraduate Research – Investigated the temporal stability of gold nanoparticle thin films on glass substrates.
- 2006-07 **University of Connecticut Chemistry Department** Storrs, CT  
Research Assistant – Implemented research on the morphology of nickel hydroxide nanoparticles.

#### PUBLICATIONS AND PRESENTATIONS

- 2010 The Temporal Stability of Gold Nanoparticle Thin Films  
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- 2008 3D Flowerlike  $\alpha$ -Nickel Hydroxide with Enhanced Electrochemical Activity  
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Xu, L; Ding, YS; Chen, CH; Zhao, L; Rimkus, CL; Joesten, R; Suib, SL. *Chem. Mater.*, 2008, 20 (1), 308-16