Identifying Chemical Weapons and Time since Exposure on Suspect Clothing Using a Grading System

The Investigation into Chemical Attacks By using Textile Damage Analysis of Whole Garments

by

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Abstract

There are many published papers surrounding textile damage, which is an important aspect of a criminal investigation. However, there is limited research conducted on chemicals and their effects on garments. Past research has focused on mechanical damage, such as stabbing and abrasions, but there has been less focus towards the science behind chemical damage. This study aims to create a base for a grading system for chemical damage, intended to assist attending officers at crime scenes in identifying the type of chemical weapon used and the time since exposure.

Since 2020, the number of reported chemical attacks in England and Wales have almost doubled every year. In 2020, there were 205 offences reported and the number rose to 1,244 by 2023. The significant resurge in acid attacks calls for more research into investigative tools, in a field where there is limited investigative aid. A chemical attack was reconstructed by applying one of five chemicals (Sulphuric Acid-80%, Sulphuric Acid-40%, Hydrochloric Acid-50%, Nitric Acid-50% and Sodium Hypochlorite-5%), against a garment of fabric types of varying colours and material composition (cotton, acrylic, polyester, denim) and analysing the changing characteristics (colour change, bleaching, dissolving, charring) over a set period (Initial, 5 minutes, 10 minutes, 30 minutes,60 minutes, 24 hours).

Results showed that the white cotton and cream acrylic garment went through the most noticeable changes, both experiencing colour change and high dissolution reactions. The hydrolysis of cellulose by Sulphuric Acid caused polymer chains to break down and degrade cotton fibres, turning the material dark brown. Polyacrylonitrile polymers, found in acrylic garments, can dissolve in Nitric Acid showing substantial dissolution and cause major structural disruption. Different materials exhibit, time dependent degradation and discolouration patterns, such as Nitric acid-50% against cream acrylic or Sodium Hypochlorite-5% on polyester, when exposed to corrosive chemicals. This supports the development of the investigative tool to aid in the identification of chemical weapons and exposure timeline at an acid attack crime scene, contributing to the improvement of the forensic investigative accuracy surrounding acid attacks.

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1. Introduction

1.1 Chemical Attacks

Chemical attacks are a premeditated act of violence of throwing a corrosive substance at a person with the intention of causing them bodily harm or disfiguring them (Masterson and Bleay, 2021). There is a global variation of the demographic of chemical attack victims. Within Western societies, there are higher percentages of male victims compared to women, with England alone having nearly twice as many men as women experiencing injuries in acid attacks (Evans, 2013), a rising cause being UK gang activity. Research completed by Nagarajan *et. al* (2020) showed that in the UK, 27% of attacks were targeted and 28% were associated with theft, robbery or a burglary. A former gang member, Jermaine Joseph Lawlor, explains that an acid attack is seen as "degrading", whereas as a stab wound or scar could in fact give a positive stereotype of creating a "do not mess with me" persona (Farrell, 2017).

Chemical attacks are a form of gender-based violence. The Acid Survivor Trust International (AFIS, 2025) director shares that 80% of victims around the world are women, of which 30% are girls under the age of eighteen. Lewis *et.al* (2020, pp. 213) concluded that outside the UK, the prevalence of attacks has been higher in developing countries due to the patriarchal societies. Tan *et.al* (2015) discusses that in South Asia, women get attacked when a man feels as though their power is being undermined. For example, in Bangladesh, victims are often young women who reject potential suitors and in Pakistan, around 400 acid attacks occur on women annually (Qaisrani ad Liaquat, 2018).

The purpose of an acid attack is rarely to kill the victim, but rather to cause lifelong physical and psychological suffering to the victims (Acid Survivor Trust International, 2025). A review by Sousa (2020) explains how chemical attacks survivors' express unhappiness regarding their appearance, making victims feel inferior to others, leading to social withdrawal and isolation. Damaging a person's face can feel like the equivalent of stripping away one's identity, especially in some cultures where appearance can be the equivalent of status (Sousa, 2020). Few survivors come forward out of shame, but those who have come forward have shared various symptoms, ranging from anxiety and depression. There appears to be no distinct relationship between the severity of a burn injury and the psychological distress reported (Mannan *et.al*, 2006).

1.2 Current UK Legislation

As defined in Section 3A of the Poisons Act (*The Poisons Act 1972*), a person commits an offence if the supplier provides a regulated substance to a member of the public without checking them for a home office license to possess that substance. The UK can regulate the possession and scale of harmful substances, however many of these substances can still be bought over the counter, with the supplier responsible for reporting suspicious behaviour.

With an increase of 228 attacks in 2012 to 601 in 2016, the UK is thought to have the highest rates of recorded corrosive attacks (Lewis *et.al*, 2020). In 2018, amendments to the Act were made: involving the creation of a new offence "carrying a corrosive substance in public", to control the number of substances openly available in the hope of easing the number of attacks (*The Poisons Act (Explosives Precursors) (Amendment) Regulations 2018*).

In 2018, the UK Government Modernising Defence Programme stated that they will focus on chemical, biological, radiological, and nuclear (CBRN) threats. To work towards this goal, a £48 million investment was put towards chemical analysis laboratories, followed by an £11 million investment in March 2019 towards new technical capabilities for substance analysis (Christie and Spragg, 2019).

1.3 Common Chemicals in Chemical Assaults

Any corrosive substance can be used as a weapon in an assault case (Tan *et.al, 2015*). Acids have accounted for 98.7% of injuries in reported chemical assaults, with Sulphuric and Nitric Acids being some of the most used corrosive substances in acid attacks in London (Lin *et. al,* 2011). Whilst these chemicals, alongside Hydrochloric Acid, are common in the UK, alkali-based chemicals with a pH level over 11 can also be highly corrosive to skin, likewise being used in chemical attacks (Milner, 2023).

The main alkali involved in chemical assaults is Sodium Hydroxide, but it is less accessible for the public to purchase. However, in the UK, there are certain common cleaning household products that can contain corrosive substances in smaller concentrations (Lin *et. al,* 2011). Due to the increasing number of under eighteen years old accessing these substances, the UK has added these products to be a subject of the Challenge-25 age restriction policy (Middlesbrough Government, 2025). The similarity between all these chemicals, acid or alkali, is that they are corrosive in nature (Stewart *et.al*, 2019).

1.4 Current research in the scope of Chemical Attacks

With the growing scale of acid attacks, there is no reported increase in work surrounding investigative aid being completed. According to the review of Moffatt and Rhimes (2020), the evidence base surrounding deliberate corrosive substance attacks is limited in the UK setting. Most work is currently leaning towards victim care and policies, not so much investigative tools (Hopkins and University of Leicester Institute for Policy, 2025). Analytical processes, such as gas chromatography - mass spectroscopy (GC-MS), and advanced chromatography techniques have been enforced to present chemical impurity profiles, helping distinguish specific chemical samples from bulk sources (Hoggard *et al.*, 2010). However, there is not enough on on-site detection.

1.5 Textile Damage

1.5.1 Textile damage analysis

Textile damage analysis observes ways textiles are damaged to provide contextual information about the circumstances surrounding a crime (Carr, 2017). Textiles go through natural damage throughout their lifecycle but can also go through a degradation process: this includes hydrolysis, oxidation, photodegradation, biodegradation, abrasion, tearing, and cutting (Smith and Thompson, 2017). This main degradation pathway is typically observed with textiles involved at crime scenes, where textiles go through much harsher treatments, usually with the intention of them being destroyed.

1.5.2 Methods for assessing textile damage

Scanning Electron Microscopy (SEM), a tool utilised to observe morphological changes and fibre surface impurities, is the most common microscopy technique used for observing textile damage in forensic cases (Mahall, 2012). SEM and optical microscopy enable detailed observations of chemical and mechanical degradation on different fabric types, including synthetics, cottons and more, aiding in showing damage caused by any external agents (Ziogos *et.al*, 2023).

Currently, issues are still being raised in laboratory settings regarding scoring answers towards the level of textile damage observed. Williams (2018) highlights this need for more robust interpretational framework to reliably distinguish chemical damage from other forms of textile wear or degradation. Current laboratory tests look at various methods including stabbing, shooting, cutting, burning, and heating (Schumann, 2018). Scoring these categories is subjective in nature, requires practitioners to have a broad understanding of the complex mechanisms and damage formations to formulate a reliable conclusion (Sloan *et.al*, 2018). Imaging techniques support the interpretation of damage, which is a step up towards standardisation in the forensics field (Sloan *et.al*, 2022).

1.6 Aim

The aim of this study is to investigate the macroscopic effects of a variety of chemical types against garments. This study also aims to reconstruct the action of chemicals being deposited onto garments during an acid attack to create a grading scheme for chemical damage. This grading system is intended to be used by attending officers at crime scenes to aid in the identification of chemical weapons and when they were used. It should not be used as official identification but act as a guide. The data should also help lab technicians figure out what chemical they will be further investigating when analysing the fabric and fibre level of the garment.

1.7 Objectives

1. Analyse and document the effect of chemical components on various material sample squares.
2. Create a replicable grading system for chemical damage
3. Investigate and explain colour change levels in garments as a consequence of chemical interactions over a 24-hour period.
4. Investigate and explain bleaching levels in garments as a consequence of chemical interactions over a 24-hour period.
5. Investigate and explain dissolution levels in garments as a consequence of chemical interactions over a 24-hour period.
6. Investigate and explain charring levels in garments as a consequence of chemical interactions over a 24-hour period

2. Method

2.1 Samples

2.1.1 Chemical Preparation

For this study, individual chemical substances are examined rather than branded household products, which are presented in Table 1. This is except for the *Domestos* branded bleach where the main active ingredient is Sodium hypochlorite which is part of other and non-branded bleaches.

Table 1: List of chemicals and the concentrations used

Chemical	**Concentration**
Battery Acid (Diluted Sulphuric Acid)	40%
Domestos branded Bleach (Active ingredient = Sodium hypochlorite)	5%
Hydrochloric Acid	50%
Nitric Acid	50%
Sulphuric Acid	80%

All samples in this experiment are referred to as the chemical name-concentration (%). The percentages refer to how much of the sample was made up of the pure chemical and the remaining percentage was distilled water. 25mL samples of Sulphuric Acid-80%, Nitric Acid-50%, Hydrochloric Acid-50%, and Sulphuric Acid-40% were prepared and provided by laboratory staff and kept in the fume cupboard. A bottle of *Domestos Original Bleach* was bought from a local supermarket and stored in a cupboard in the laboratory. The laboratory conditions were steady at 19.3°C and an 84% Relative Humidity, during the experimental period.

2.1.2 Material Preparation

Materials were selected on a basis of popularity of garments in the UK decided through research on garments found in the most recent chemical attack cases explained in Section 1.1, increasing the likeness of the material composition replicating the material worn during an attack. Sample materials were provided by project supervisor and lab staff. The garments were made up of various material composition and colours, see Table 2. Whole garments were cut into 5cm x 5cm squares to fit into plastic petri dishes to prevent any cross contamination between the various fibres.

Table 2: Whole garments material composition and description

Garment	*Abbreviation*	*Material*	*Brand*
White T-shirt	WC	100% Cotton	Primark
Grey T-shirt	GC	90% Cotton 10% Polyester Pre-shrunk	Gildan
Pink Onesie with White polka dots	PP	100% Polyester	Secret Possessions
Blue Jeans	BD	86% Cotton 12% Polyester 2% Elastane	Primark
Cream Jumper	CA	80% Acrylic 10% Wool 10% Mohair	H&M

2.2 Pilot Studies

An Ethics form and PRA were conducted and approved before experimentation (See Appendix A and B). Two pilot studies, a test on the effect of angle of impact and an observational test, were carried out. Whilst performing the angle of impact test, a reaction occurred between Sulphuric Acid-80% and a white cotton T-shirt. The reaction observed was dissolution.

The second test, observational testing, focused on determining the correct timings and volumes to use in the main experiment. Bleach and Sulphuric Acid-80% were dropped from a 90° angle onto five different garment materials.

2.2.1 Angle of Impact Pilot Test

An initial laboratory session was conducted to determine the ideal volumes, heights, angles and method to implement in the main experiment. The pilot test focused on the investigation into the effect of the angle of impact, as well as any colour change and diameter change observations. A white 100% cotton shirt was clipped to a blood spatter analysis clipboard and set up to investigate the effect at 0°, 10°, 20°, 30°, 40°, 50°, 60°, 70° and 80°. 500µL of bleach was dropped, using a 1000µL pipette, at each angle. The initial diameter was measured of each drop and then the garment was replaced for the next chemical. The method was repeated with Sulphuric Acid-80%, and after the first drops, dissolution was observed on the fabric. The fabric and apparatus were washed with cold water and disposed of safely. To continue with this experiment tiles should be placed between the fabric and the clipboard as the Sulphuric Acid-80% also reacted to the plastic leaving a mark.

2.2.2 Observations Pilot Test

The second test focused on determining the correct timings and volumes to use in the main experiment. Petri dishes were labelled with the chemical, concentration, material, date and time. The corresponding fabric samples (Table 2) were placed in the individual labelled petri dishes. 500µL of bleach was dropped, using a 1000µL pipette, at a 90° angle in the centre of the fabric sample. Changes in the fabric square were recorded, at initial observation, one minute, five minutes, ten minutes, thirty minutes and one hour. Colour change, bleaching, dissolution and charring was observed.

2.3 Main Observational Experiment

2.3.1 Equipment

Equipment necessary for the experiment was determined by trials in the pilot lab and finalised to the quantities listed in Table 3.

Table 3: List of equipment and quantity used in the main experiment

Equipment	***Quantity***
Camera (Nikon AF-S Micro NIKKOR 40mm 1:28G lens)	1
Camera Stand	1
Plastic Petri Dish	125
Timer	5
Sartorius Proline Plus 1000µl Pipette	1
25ml x Sulphuric Acid – 80%	1
25ml x Hydrochloric Acid - 50%	1
25ml x Nitric Acid – 50%	1
25ml x Domestos Original Bleach	1
25ml x Sulphuric Acid – 40%	1

2.3.2 Procedure

Petri dishes were labelled with the chemical, concentration, material, date and time of the initial chemical drop. The corresponding material, 5cm by 5cm sample square, was placed into the corresponding petri dish. A camera was setup on a tripod and stationed at a work bench, set up to ensure a single petri dish was in frame and focused.

In the first test, 500µL of *Domestos Original Bleach* was dropped onto the sample square, using a 1000µL pipette at a 90° angle and a timer was started. Observations were photographed and recorded using visual analysis at the following time intervals: 0 minutes, 5 minutes, 10 minutes, 30 minutes, 1 hour and 24 hours. The observations recorded included: colour change, bleaching, area of colour change, dissolution and charring. The grade assigned to each observation was determined by following a key (Table 4) and the area of colour change was determined using a separate descriptive key (Table 5), and noted in a Microsoft Excel sheet.

This method was followed for all the four other chemicals; however the initial deposition of the chemicals was performed in the fume cupboard following the safety procedures, and the petri dishes were taken out to photograph back on the work bench. The petri dishes were kept on the work bench to analyse the observations at the remaining time intervals. Between the 1 hour and 24 hours mark petri dishes were stored in a cupboard and not on the work bench. The laboratory conditions remained at a steady at 19.3°C and 84% Relative Humidity, during the experimental and waiting period.

Table 4: Key to the grading system of the area of colour change characteristic

Grade	Colour change	Bleaching	Dissolution	Charring
1	No Colour change observed	No Bleaching observed	No Dissolution observed	No Charring observed
2	Original colour appears lighter/darker	Slight bleaching in colour, but original fabric colour is more visible	Fabric has a different texture appearance	Slight charring visible
3	Undertones of original colour are visible, but a different colour is forming	Fabric is half bleached, half original colour	Fabric appears melted but is all attached in one piece	Fabric has charring in the area that the chemical was deposited
4	Different colour is visible, original colour is distinguishable	Fabric is bleached, but original colour is still visible	Fabric is pulling apart but still attached	Fabric has deep brown marks further than the original area of the chemical drop
5	Colour is completely different	Deposition spot turns pure white/ Fully bleached	Chemical has caused fabric to separate from unaffected area	Fabric appears burnt almost

Table 5: Key to the grading system of the area of colour change characteristic

Area of colour change	***Description***
Central	Colour change was observed in the middle of the garment, occupied less than 50% of space.
Peripheral	The colour change was observed on the outer central layer of the garment, occupying less than 50% of space.
Substantial	The colour change can be observed when over 50% of the garment has a different colour than the original garment.
Whole	100% colour change was observed; the original garment colour was no longer visible or distinguishable.

2.4 Data Collection and Recording

Each corresponding grade and characteristic was determined immediately after a photograph for the specific time interval was captured. Photographs were taken on a Nikon AF-S Micro NIKKOR 40mm 1:28G lens camera at 90-degree angle at 40cm distance from the sample.

All grades were recorded into a Microsoft Excel spreadsheet.

Appendix C refers to a photographic log table created for each chemical reaction with every garment. This log should be used as a cross-referencing tool to ensure that the determined grades in the lab are accurate.

The mean and standard deviation were calculated using the AutoSum function on Microsoft Excel, the 2024 version.

3. Results and Discussion

Five chemicals were chosen as the subject for this study, based on initial research and their availability to an undergraduate project student. According to Grierson (2024), corrosive substances are the primary agents used in acid attacks; both acid and alkaline based substances, including household cleaning products that can be highly corrosive, are widely available in store and online. In 2021, *Domestos* was the leading brand in the UK bleach market, with an estimated 11.3 million purchases (Statista, 2022). According to Petruzzi (2025), 10.2 million people in the UK used the brand *Domestos Original* as their main household bleach in 2024. This product was therefore selected as the alkaline substance for this study, to reflect the high likelihood of encountering this brand at a potential crime scene.

Sulphuric, Nitric and Hydrochloric Acid are not as easily accessible to UK residents due to the changes in the government's Serious Violence Strategy, yet they remain as the most reported chemicals in corrosive substance attacks (Home Office, 2018). The concentrations of these acids were chosen specifically to ensure they were corrosive in nature, while remaining safe to use in the project lab. For this reason, Ammonia, another chemical substance found in chemical attacks, was not chosen for the safety of other students and staff members in the project lab. Chemical components, as opposed to branded household products, were selected to expand the applicability of results to other regions, where brands can vary, but the chemical components remain the same.

A grading system (1 – 5) was adopted to allow consistent and direct comparison between the reactions of the different chemical substances on the garments. Grading provided a time-efficient method for recording the changes observed after sample deposition, therefore ensuring an accurate record for each time interval. Generally, a larger grade scale is preferable, as it offers more flexibility during statistical analysis. However, given that the time provided to appoint each sample a specific grade was approximately one minute, the grading scale was limited to 5 different values to simplify the process. Studies show that the use of the smaller grade scales limits the data volume and has a higher chance of being misassigned (Collins and Lundstedt, 2024). Additionally, since the system was created based on subjective observations made during the pilot lab, the continuity of future experiments might be affected, if recreated (Link and Mitic, 2025). Table 4 and 5 show the description for the grading system.

3.1 Sulphuric Acid — 80% Concentration

3.1.1 Colour change grades

As observed in Figure 1, the mean grade in colour change was higher after 24 hours for every garment tested in comparison to the initial mean grade. Colour change is a form of textile damage, and the reaction between any of the five garments and Sulphuric Acid-80% cannot be easily reversed (Gowda and Babu, 2008). Due to its highly corrosive nature, the reaction between Sulphuric Acid and a cotton clothing garment involves the breakdown of cellulose fibres (Wu, 2023). The materials that were made up of cotton, as expected, experienced the highest colour change, and exhibited a steady increase throughout the 24-hour period.

Sulphuric Acid can enhance dye performance by modifying the fibre surface, increasing the colour depth (Navneet Singh Shekhawat *et al.*, 2024). This explains that the changes observed on white cotton, grey cotton, blue denim and cream acrylic was due to discolouration, rather than bleaching (Xia and Wang, 2013). The white cotton garment shows a very clear example of colour change, going from a pure white colour to a darkish brown. The sample was graded a 4 at the 24-hour mark (Table 6), as the colour change did not extend over the whole garment (Appendix D). However, the grade should be altered to a 5 as the garment did experience a full colour change.

For future grading scales for interpreting chemical damage, the grade assigned to colour change should focus primarily on the change of the colour of the garment, rather than how much the chemical expanded throughout the clothing item. The latter should be assigned a separate grading scheme, as shown in Table 5.

Table 6: Colour Change Mean Grades and Standard Deviation for Sulphuric Acid -80%

Garment	Colour Change Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	3.00	0.00	4.00	0.00	4.00	0.00	4.00	0	4.00	0.00	4.00	0.00
Grey Cotton	3.00	0.00	3.00	0.00	3.40	0.55	3.60	0.55	4.00	0.00	4.80	0.45
Pink Polyester	2.00	0.00	2.00	0.00	1.00	0.00	1.20	0.45	1.40	0.55	3.00	0.00
Blue Denim	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	4.00	0.00
Cream Acrylic	2.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00

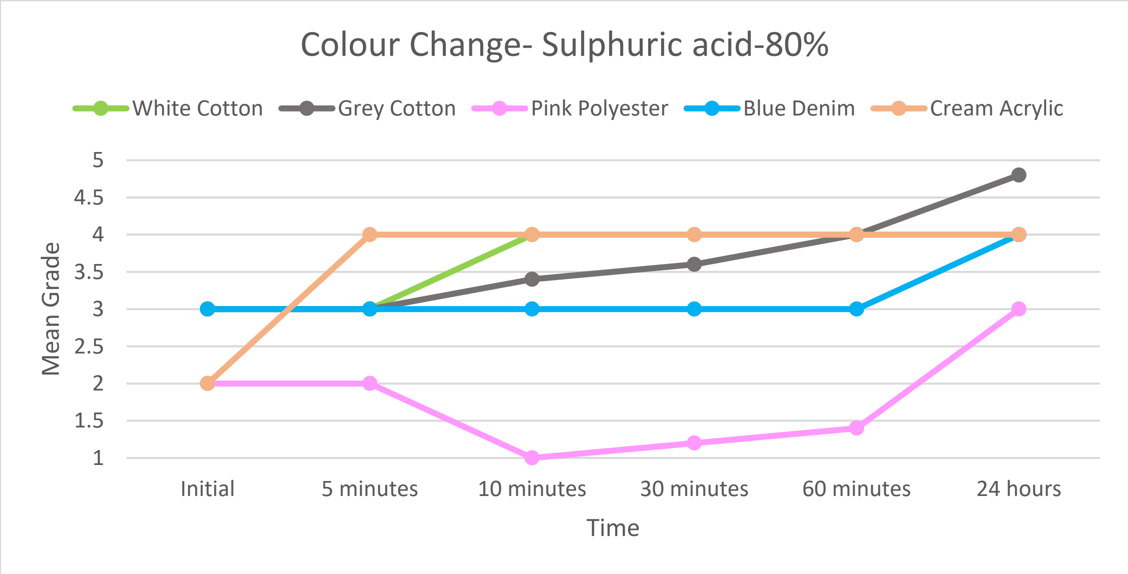

Figure 1: Trend of Mean Colour Change grade in Sulphuric Acid-80% overtime

3.1.2 Bleaching grades

Sulphuric Acid is typically not able to produce a pure white stain on clothing alone, which can be supported by the highest mean bleaching grade of 3 to be achieved (Table 7). However, if mixed with bleach, Hypochlorous Acid and Sodium Sulphate are produced, which would produce a bleaching effect on clothing (Uzzal, 2017).

Grades were determined without regard for the previously assigned grades at an earlier time interval. As a result, at 30 minutes the white cotton garment exhibited a sudden colour change, rising then dropping (Figure 2). The grading system's small range of 5 measures resulted in some anomalies; therefore, a more descriptive model may be preferable, especially since chemicals can bleach, but not always in the standard oxidising way found prevalent in store-bought bleaches (Noyan, Onal and Sarikaya, 2007).

The pink polyester garment, which can be visually seen in Figure 24 (Appendix C), shows a clear yellow stain at the 24-hour mark. This was graded a 3, referring to 'Fabric is half bleached, half original colour' (Table 4), once again being confused with the area of bleaching, as opposed to the process of bleaching. The key to colour change grades, as well as bleaching grades, should focus on just the discolouration observed, and what colour formed.

Table 7: Bleaching Mean Grades and Standard Deviation for Sulphuric Acid -80%

Garment	Bleaching Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	2.00	0.00	2.00	0.00	3.00	0.00	2.00	0.00	2.00	0.00
Grey Cotton	2.00	0.00	2.00	0.00	2.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	2.00	0.00	2.00	0.00	2.00	0.00	1.00	0.00	1.40	0.55	3.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.00	0.00	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00

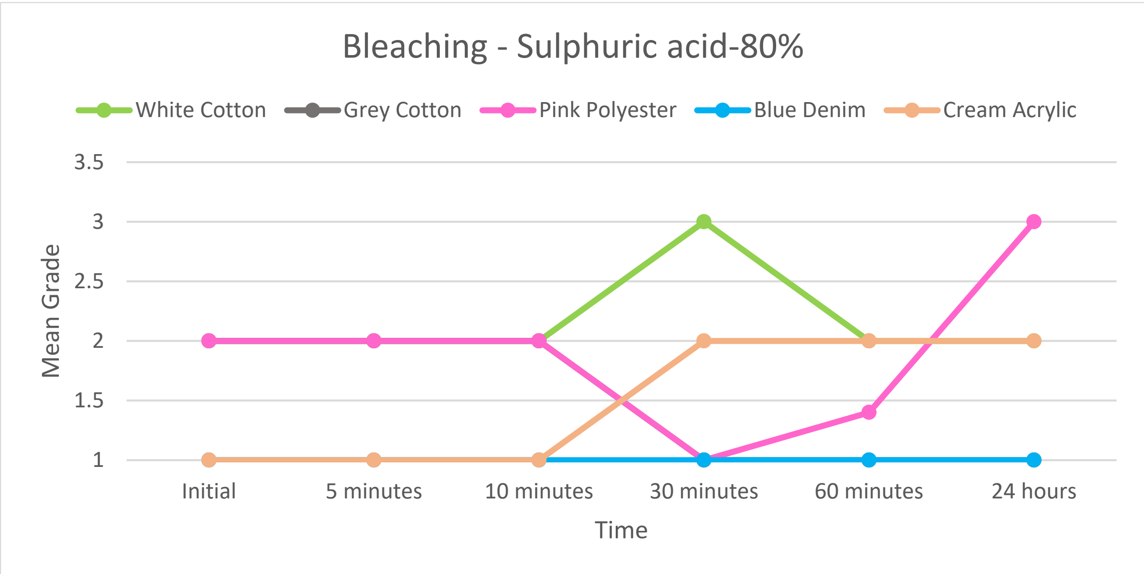

Figure 2: Trend of Mean Bleaching grade in Sulphuric Acid-80% overtime

3.1.3 Dissolution grades

White cotton exhibited the highest mean dissolution grade (see Figure 3) across all five garments tested. The reaction between Sulphuric Acid and cotton primarily involves the hydrolysis of cellulose, the main component of cotton fibres (Sun *et al.,* 2016). During hydrolysis, the cellulose chains begin to break down after approximately 45 to 55 minutes, leading to degradation of the cotton fibres (Sun *et al.,* 2016). When cotton is treated with pure Sulphuric Acid, a dissolution reaction can be observed, distinguishing it from other materials such as polyester (Ruuth *et al.*, 2022). The Sulphuric Acid-80% exposed the stitching in the white cotton garment, which was not visible before reacting with the acid.

For the preservation of the garment, Hunter (2024) suggests washing the clothing under warm running water until all Sulphuric Acid is removed to neutralise the reaction. However, after 24 hours, when disposing of the garment, warm water was run on the garment and further dissolution was observed. The petri dish appeared almost empty, a result which was not seen when washing away the white cotton sample treated with Sulphuric acid-40%. This suggests that the concentration of the chemical has an effect on the level of dissolution, when reacting with cotton garments. A clear contrast in dissolution can be observed between the white cotton garment reacting with Sulphuric Acid-80% and Sulphuric Acid-40%.

Pink polyester was the only garment that did not show a consistent rise in the mean dissolution grade. Between 30 minutes and 60 minutes, the mean decreased from 2 to 1.6, and returned to 1 at the 24-hour mark, as if largely unaffected (Table 8). Polyester possesses moisture-retaining properties and high tensile strength, making it a more durable fabric in comparison to the others (Mahalakshmi *et al.*, 2022). Polyester garments are commonly selected for athletic clothing; therefore, when working with these materials on site, officers should pay greater attention to other characteristics such as bleaching or colour change.

Table 8: Dissolution Mean Grades and Standard Deviation for Sulphuric Acid -80%

Garment	Dissolution Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	3.00	0.00	3.00	0.00	3.80	0.45	4.00	0.00	5.00	0.00
Grey Cotton	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.80	0.45
Pink Polyester	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	1.60	0.55	1.00	0.00
Blue Denim	1.00	0.00	1.60	0.55	1.60	0.55	1.80	0.84	1.60	0.55	3.00	0.00
Cream Acrylic	3.00	0.00	3.00	0.00	3.00	0.00	2.80	0.45	3.00	0.00	3.00	0.00

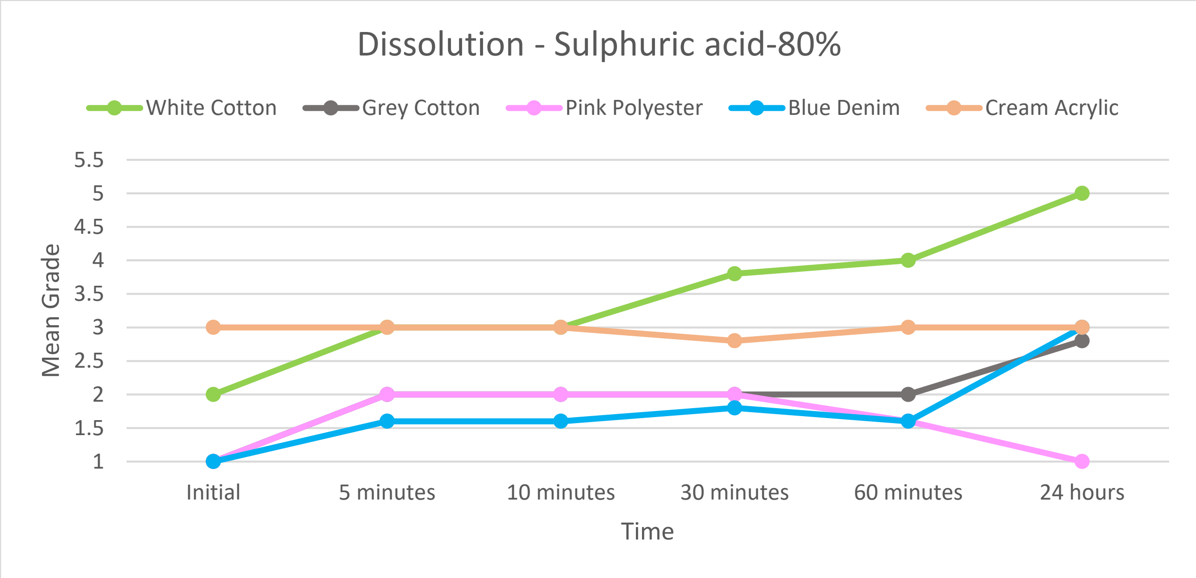

Figure 3: Trend of Mean Dissolution grade in Sulphuric Acid-80% overtime

3.1.4 Charring grades

Concentrated Sulphuric Acid is a powerful dehydrating agent that can react violently with water and organic materials (Riddick and Solutions, 2014). As Sulphuric Acid reacts with materials, it removes water, resulting in the formation of carbon and heat, causing subsequent burns and the development of a charred appearance (UK Health and Security Agency, 2024d).

Among all five chemicals tested, Sulphuric Acid-80% produced the highest mean charring grades across the selected garments. In Figure 4, grey cotton displays an irregular trend: a gradual rise followed by a sharp increase at 30 minutes, then dropping back at 60 minutes. Charring is an irreversible reaction, as it involves the incomplete combustion of materials. Therefore, this sudden peak is unexpected, as a steady increase would typically be observed (Yee and Sohal, 2013). As presented in Table 9 , the standard deviation of 0.00 indicates that all five repats received a grade of 4 at the 30-minute mark. A grade 4, in reference to charring, corresponds to the fabric exhibiting deep brown marks extending further than the original area of the chemical drop.

Although charring was recorded at the 30-minute mark, it was later registered that this analysis resulted from human error, as at 60 minutes charring was no longer visible. The 30-minute grades for grey cotton were not corrected to preserve an accurate representation of the process of immediate grading. Appendix C provides visual evidence of the misclassification.

Table 9: Charring Mean Grades and Standard Deviation for Sulphuric Acid -80%

Garment	Charring Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	3.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	4.00	0.00	1.00	0.00	2.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	3.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	2.00	0.00	2.00	0.00	2.40	0.55	2.60	0.55	3.00	0.00

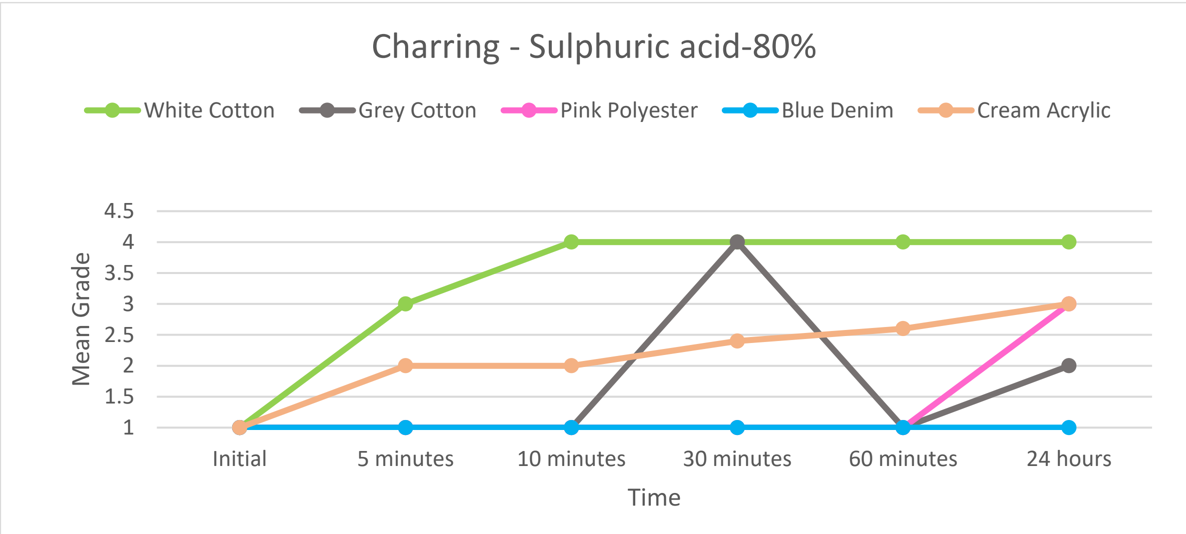

Figure 4: Trend of Mean Charring grade in Sulphuric Acid-80% overtime

3.2 Hydrochloric Acid — 50% Concentration

3.2.1 Colour change grades

At the 24-hour mark, Hydrochloric Acid caused four of the five garments to exhibit substantial or whole colour change (Appendix D). Cream acrylic exhibited no colour change after 24 hours (Table 10), which could potentially be attributed to the fabric being made up of more loosely arranged fibres, resulting in less than 500µL being deposited on the sample. This can also explain the drop observed in Figure 5, which occurred between 10 and 30 minutes, indicating that the Hydrochloric Acid had dried and only began to react after 30 minutes.

After analysing the images (Appendix C), the colour change caused by the Hydrochloric Acid can be more accurately described as the garment becoming lighter or darker, rather than undergoing a full shift to a different colour. Pink Polyester and blue denim experienced the greatest change, increasing by two colour-change grades between the initial application and the 24-hour mark. Blue denim contains 12% polyester, while pink polyester is 100% polyester (Table 2). Although no research has been conducted specifically examining polyester fabric against Hydrochloric Acid, polyester is known to be susceptible to colour change (Allen, Edge and Hussain, 2022). The colour of polyester can change overtime in outdoor conditions due to the variations in UV radiation (Čubrić, Petrov and Čubrić, 2025). Prolonged exposure breaks down the dye molecules in the fibre, resulting in a loss of vibrancy, similar to what was found in this test (Čubrić, Petrov and Čubrić, 2025).

Table 10: Colour Change Mean Grades and Standard Deviation for Hydrochloric Acid -50%

Garment	Colour Change Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	4.60	0.55
Grey Cotton	2.00	0.00	4.20	0.45	3.00	0.00	3.00	0.00	4.40	0.55	3.00	0.00
Pink Polyester	1.00	0.00	1.40	0.55	1.80	0.45	1.80	0.45	1.80	0.45	3.00	0.00
Blue Denim	3.00	0.00	4.00	0.00	4.20	0.45	4.20	0.45	4.20	0.45	5.00	0.00
Cream Acrylic	1.40	0.55	3.00	0.00	3.00	0.00	1.40	0.55	2.00	0.00	2.00	0.00

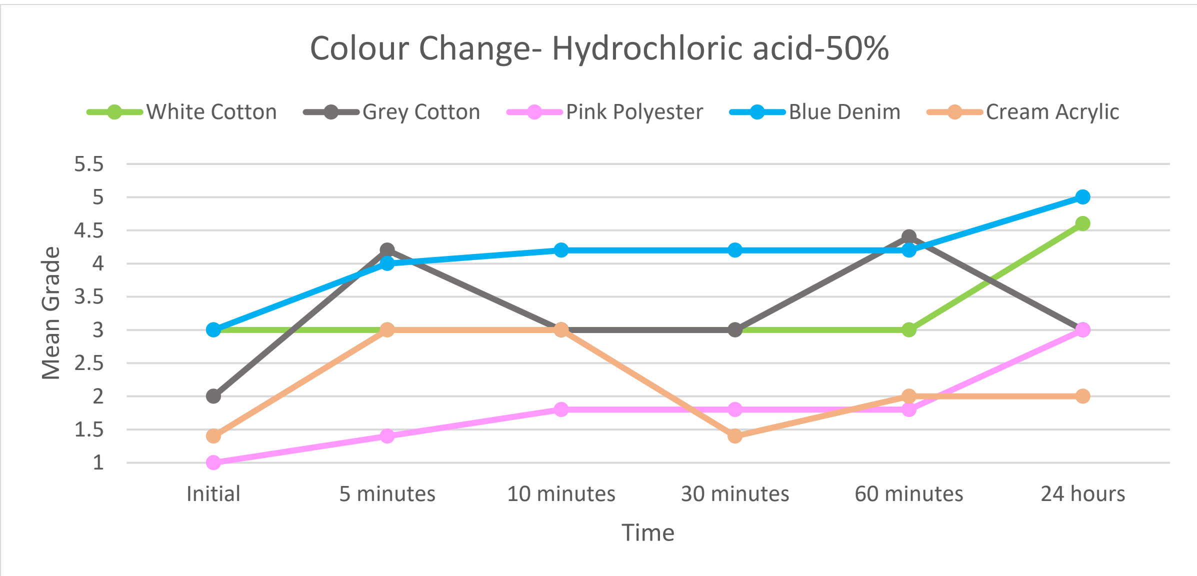

Figure 5:Trend of Mean Colour Change grade in Hydrochloric Acid-50% overtime

3.2.2 Bleaching grades

Hydrochloric Acid does not bleach in typical forms of oxidisation. Instead, it breaks down dyed fibres and molecules causing the colour to fade (Lin, Chang and Hsu, 2009). Hydrochloric Acid breaks the cellulose chains in cotton garments, resulting in fading and light patches (Lin, Chang and Hsu, 2009). Wool is made up of protein fibres, and, when reacting with a strong acid, such as Hydrochloric Acid, those peptide bonds break, leading to dye loss or yellowing (Negi, 2025).

White cotton, cream acrylic and pink polyester showed the greatest increase in bleaching by the end of the 24-hour period (Table 11). The maximum mean grade attainted was 3, indicating that fabric sample was half bleached and half unaffected. Even though the pink polyester garment changed its shade of pink, looking at the key for the grading system, this would fall under colour change, not bleaching, as the original deposition spot was still identifiable after the 24hour mark. Appendix C confirms that the grades for white cotton and cream acrylic were determined by bleaching, whereas colour change was used for pink polyester.

The mean charring grades in pink polyester remained stable until the 10 minute mark, then dropped before rising again after 30 minutes (Figure 6). Since bleaching is an irreversible reaction, grades should not be dropping overtime (Clifton, 2025). After reviewing Appendix C, the observations can be misinterpreted as either the material lightning or colour change, resulting in grades that do not follow a consistent pattern. To avoid incorrect classification, the grading system should have a higher-grade boundary or more specific conditions assigned to each grade category to prevent misclassification.

Table 11: Bleaching Mean Grades and Standard Deviation for Hydrochloric Acid -50%

Garment	Bleaching Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00

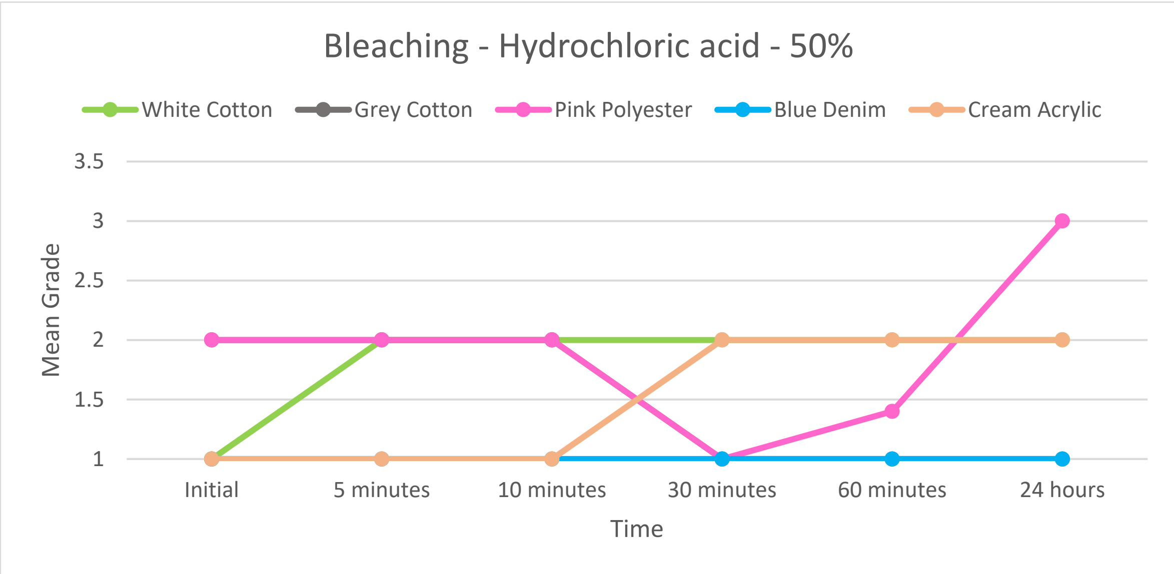

Figure 6: Trend of Mean Bleaching grade in Hydrochloric Acid-50% overtime

3.2.3 Dissolution grades

It is important to note that in Figure 7, white cotton and pink polyester are displayed and follow the same pattern as blue denim, having a mean dissolution grade of 1 throughout the 24-hour period. See Table 12 for mean dissolution grades at each time interval.

Cotton fibres are typically resistant to Hydrochloric Acid; therefore, they cannot be dissolved. However, there are certain conditions under which it is probable (A.A. El-Meligi, S.H. Sanad and Ismail, 2004). The extent of dissolution would be determined by the Hydrochloric Acid concentration, the surrounding environment's temperature, humidity, and exposure period (A.A. El-Meligi, S.H. Sanad and Ismail, 2004). The 50% concentration of Hydrochloric Acid, at 19.3°C and 84% relative humidity, did not cause a dissolution effect; further testing should utilise a greater concentration and/or warmer temperatures. According to Pacheco (2007) research, a higher temperature and concentration of Hydrochloric Acid will often cause fabric deterioration. However, the study mentions that even dilute concentrations will attack and weaken textiles fibres. Further investigation on the effect of Hydrochloric Acid, as well as that of other chemicals, can be observed microscopely. Garments should be examined under a polarising light microscope to ensure a more precise observation. Polarising light microscopes are utilised to visualise fine detail while examining fibres or textiles (Valentino *et al.*, 2024).

The mean dissolving level in the cream acrylic garment samples decreased during the 24-hour period. The cream acrylic garment, shown in Appendix C, resembles a woollen jumper, with distinctive fibres pulled more apart than the other examined garments. The cream acrylic garment's standard deviation was higher than 0 (Table 12), possibly due to not all 500µL of Hydrochloric Acid touching the garment and seeping directly into the petri dish, resulting in the range of dissolving levels. In some cases, the acid damage on wool and other materials produced by Hydrochloric acid is only evident after the garment has been washed or laundered, as the heat from the drying and the pressure can cause disintegration (Pacheco, 2007). Therefore, investigators should be strongly recommended to make a note of the temperature, as heat influences material composition.

Table 12: Dissolution Mean Grades and Standard Deviation for Hydrochloric Acid -50%

Garment	Dissolution Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Grey Cotton	2.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	2.40	0.55	2.60	0.55	2.40	0.55	2.00	0.00	1.20	0.45	1.00	0.00

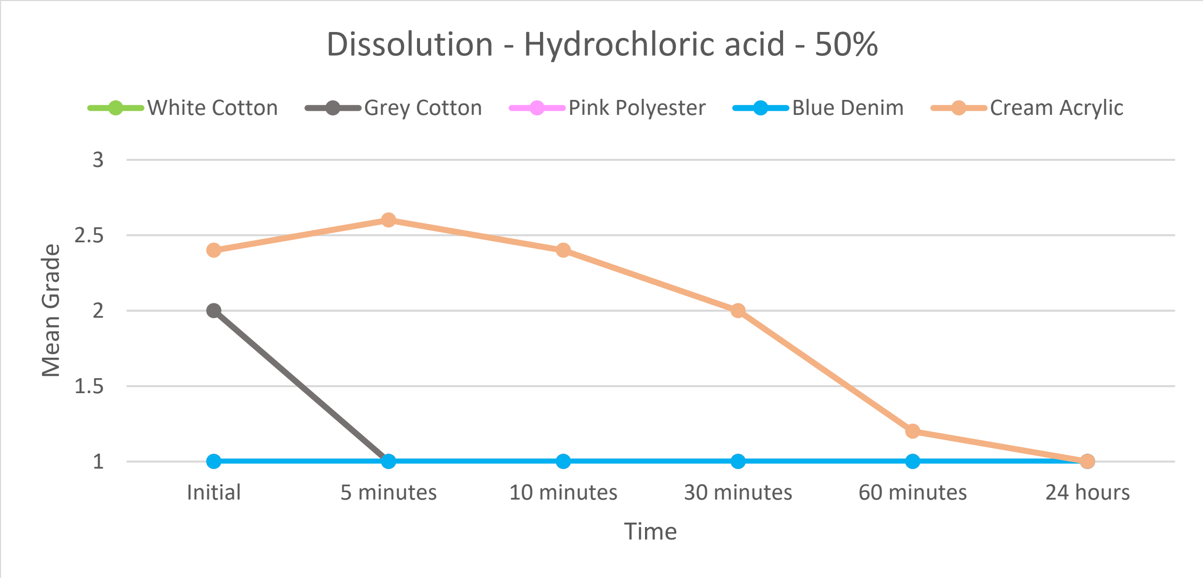

Figure 7: Trend of Mean Dissolution grade in Hydrochloric Acid-50% overtime

3.2.4 Charring grades

As shown in Figure 8, the mean charring grade for each garment stayed at 1. It should be noted that all lines are present and are stacked because they all follow the same trend. It can be confidently stated that no charring was visible, as confirmed by the standard deviation for each sample's charring grade, which remained at a constant 0, as shown in Table 13.

Hydrochloric Acid is not a dehydrating agent, and so it does not remove water from organic compounds (UK Health Security Agency, 2024a). Charring requires a powerful dehydrating agent, whereas Hydrochloric Acid induces hydrolysis, fibre destruction and corrosion (Saeid and Chojnacka, 2014). As a result, the lowest charring mean grade of 1 was expected. In this study, the only other chemical that exhibited low charring grades all under 1.5 was Sodium Hypochlorite-5%, which can be a good initial sign to either rule out or determine whether these chemicals were possibly used in an attack.

Table 13: Charring Mean Grades and Standard Deviation for Hydrochloric Acid -50%

Garment	Charring Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.00	0.00	1.00	0.00.	1.00	0.00	1.00	0.00	1.00	0.00

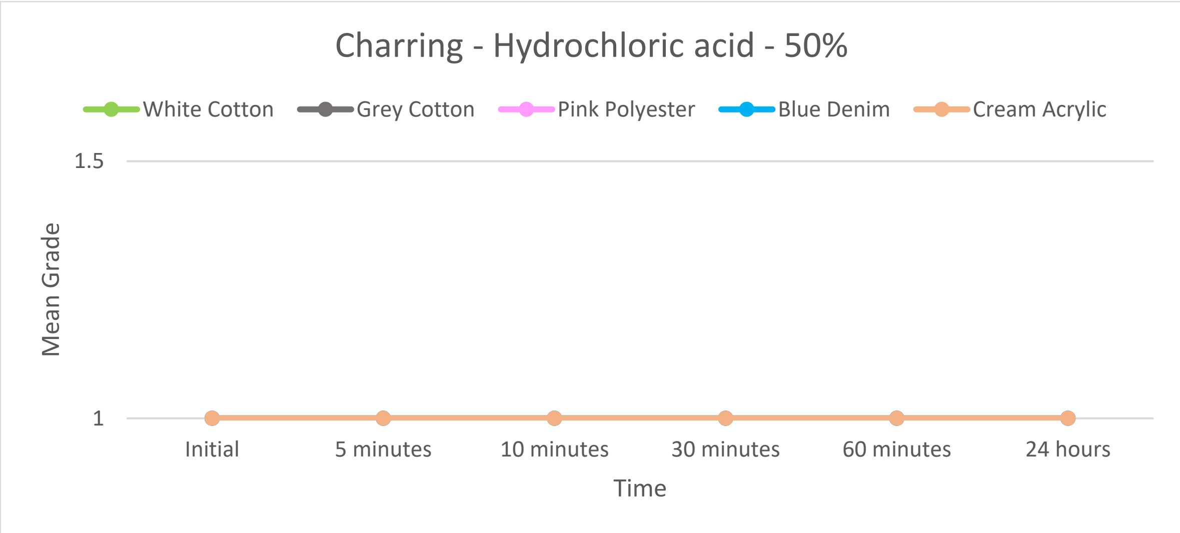

Figure 8: Trend of Mean Charring grade in Hydrochloric Acid-50% overtime

3.3 Nitric Acid — 50% Concentration

3.3.1 Colour change grades

After being exposed to Nitric Acid- 50% for 24 hours, each garment showed a distinctive colour change (Figure 9, Table 14). As seen in Appendix C, the blue denim and cream acrylic garment underwent a yellowing colour change. Nitric Acid generally undergoes a xanthoproteic reaction, resulting in a stable yellow colouration in protein-based fibres, such as silk and wool. (Bol and Montanari, 2024a).

Because of the sharp contrast between the original colour and the subsequent yellow discolouration, which made the Nitric Acid appear nearly fluorescent, the blue denim exhibited the most noticeable change (see Appendix C). By attacking aromatic rings found in organic materials, and adding a nitro group (-NO_2), Nitric Acid can colour fabrics yellow or orange by creating yellow nitro-compounds (Bol and Montanari, 2024a). Nitration can change the aromatic chromophores found in many textile colours. Due to this alteration, the compounds' ability to absorb light is altered, making them appear yellow after absorbing violet or blue wavelengths (Aspland, 1997). The observed discolouration is distinguished from bleaching responses by the nitration reaction.

Table 14: Colour Change Mean Grades and Standard Deviation for Nitric Acid -50%

Garment	Colour Change Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.20	0.55
Grey Cotton	3.00	0.00	3.00	1.10	3.00	0.00	3.60	0.55	4.00	1.00	3.60	0.55
Pink Polyester	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	4.00	0.00	5.00	0.00
Blue Denim	2.00	0.00	4.20	0.45	4.20	0.45	4.40	0.55	4.40	0.55	4.20	0.45
Cream Acrylic	2.00	0.00	1.80	0.45	1.60	0.55	4.00	0.00	4.00	0.00	5.00	0.00

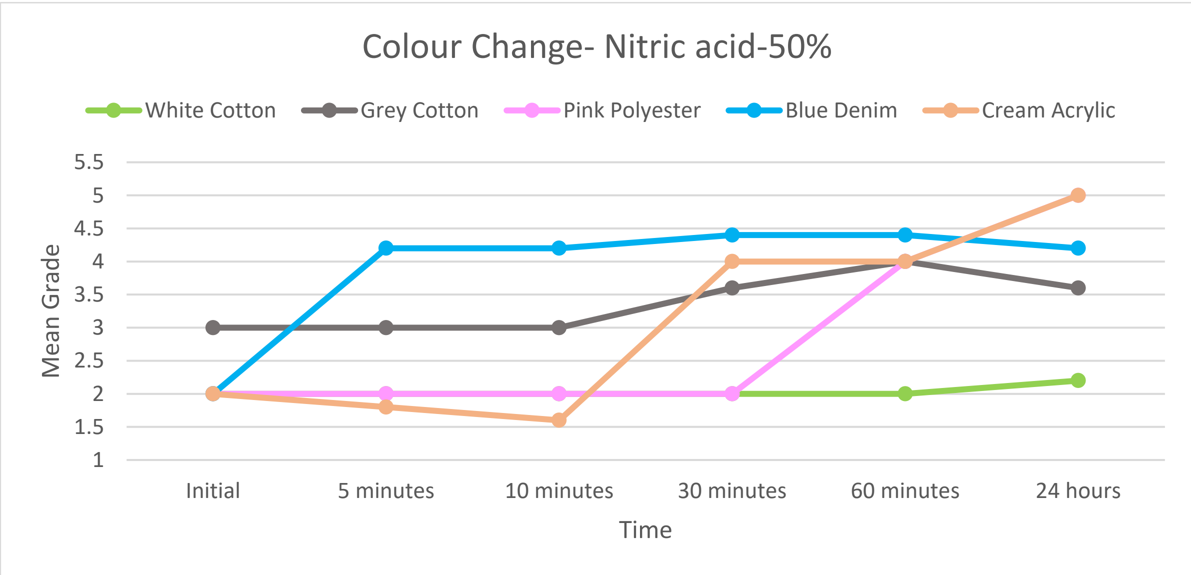

Figure 9: Trend of Mean Colour Change grade in Nitric Acid-50% overtime

3.3.2 Bleaching grades

The mean bleaching levels observed in the garments were lower than the mean discolouration grades (Table 14 and Table 15).The highest mean dissolution grade was 2.2 for the white cotton material (Figure 10), which is most likely because Nitric Acid does not undergo the traditional chemical bleaching reactions found in store-bought bleaches. Nitric Acid performs nitration reactions, as mentioned in Section 3.3.1. Although Nitric Acid can oxidise, it causes fibre degradation rather than direct dye loss (Venkataraman, 1978). At sufficiently high concentrations, Nitric Acid has the potential to destroy enough dye molecules to transform the garments appearance to a pale or faded colour (Zollinger, 2003).

Therefore, separating bleaching and discolouration into two separate measures may not be the most accurate way to evaluate how Nitric Acid affects fabric. Both results show a type of colour change, but they vary primarily in the chemical processes that underlie them: oxidation and nitration. This differentiation may not be the most effective approach for quick, on-scene analysis, according to the overlap in the observed findings. Using a single colour change grading system and conducting additional investigation to ascertain if the change was caused by bleaching or discolouration would be a more logical approach. This system would help determine whether the pink polyester turned lighter from bleaching or colouring properties, as the 24-hour mark could fall under the two categories.

Table 15: Bleaching Mean Grades and Standard Deviation for Nitric Acid -50%

Garment	Bleaching Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.20	0.45
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	2.00	0.00	2.00	0.00
Blue Denim	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00
Cream Acrylic	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00

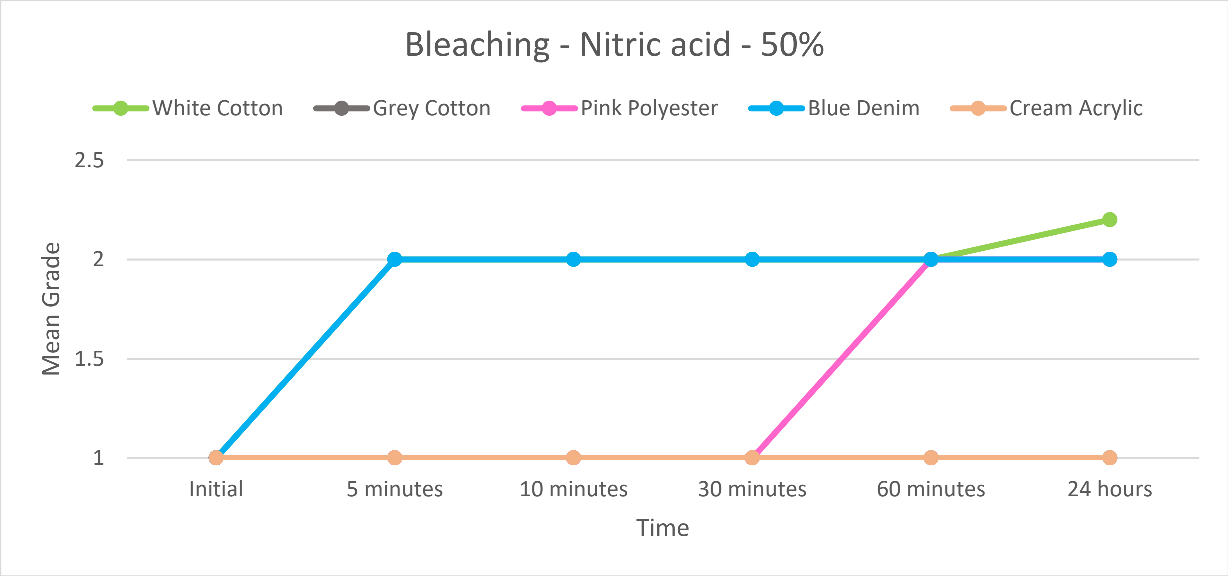

Figure 10: Trend of Mean Bleaching grade in Nitric Acid-50% overtime

3.3.3 Dissolution grades

Of the five chemicals, cream acrylic dissolved the most. Polyacrylonitrile (PAN) polymers which are found in acrylic garments, can dissolve in aqueous Nitric Acid, causing significant structural disruption, as illustrated in Figure 11 (Stoy *et al.*, 1974).

Nitric Acid causes fibre degradation rather than direct dye loss through oxidation (Venkataraman, 1978). Under the conditions used in this experiment, neither cotton nor polyester developed a visible degradation pattern (Table 16). Nitric Acid is a strong oxidizing agent but not an effective solvent for cellulose or polyester, which is consistent with its behaviour (Zhu *et al.*, 2025). The low dissolution grades can be used to identify Nitric Acid-50%, in comparison to Sulphuric Acid-80%, which had high dissolution grades.

Table 16: Dissolution Mean Grades and Standard Deviation for Nitric Acid -50%

Garment	Dissolution Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.60	0.55	2.40	0.55	2.00	0.00	2.00	0.00	2.00	0.00

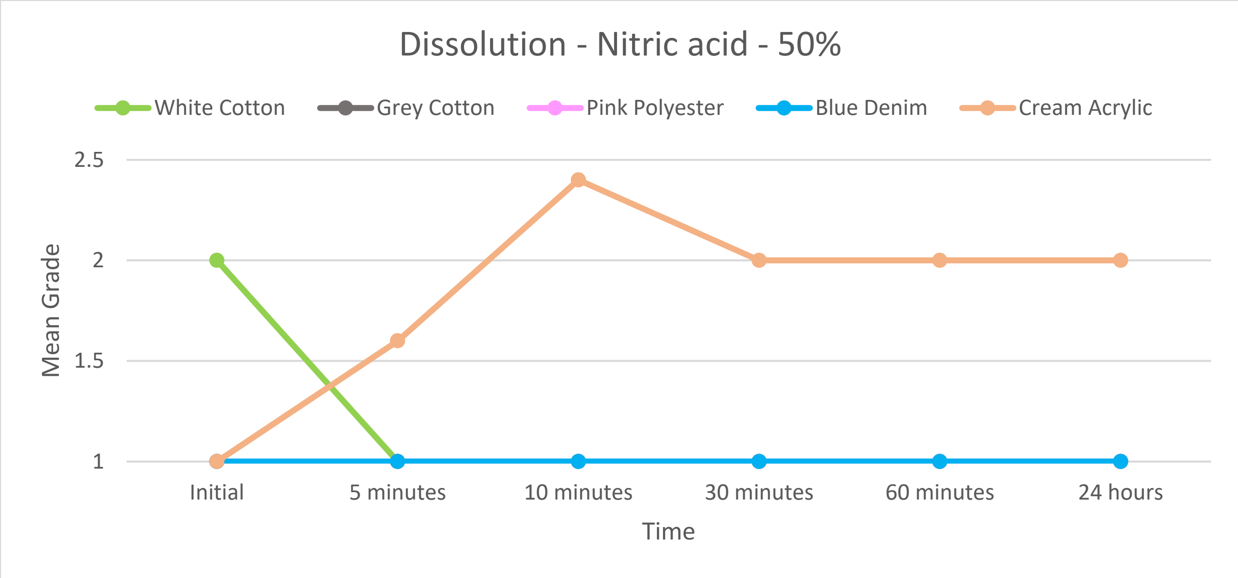

Figure 11: Trend of Mean Dissolution grade in Nitric Acid-50% overtime

3.3.4 Charring grades

Nitric Acid reacts strongly with organic substances: oxidising organic materials with Nitric Acid results in charring due to the excessive heat produced by highly exothermic reactions (Bench Chem, 2025). Therefore, charring was expected. Cream acrylic and blue denim had the greatest mean charring grade, but they were also the only materials with a standard deviation greater than 0 (Table 17, Figure 12). This variability is expected in textile damage experiments, as fibres do not degrade uniformly, resulting in slight differences between individual samples.

According to Stoy *et al.* (1974), acrylic fibres are susceptible to Nitric Acid. Their method of hydrolysing polyacrylonitrile polymers demonstrated that fibres are hydrolysed using 40%–80% Nitric Acid at 25–60°C. The cream acrylic fibre was tested with Nitric Acid-50% and gradually charred over the course of 24 hours. There is little research on the charring proprieties of Nitric Acid on different polymers, which urges for more research conducted surrounding the degradation process.

Nitric Acid-50% and Hydrochloric Acid-50% coloured and bleached the cream acrylic, pink polyester, white cotton and grey cotton garments in comparable amounts. However, the charring quality is what can distinguish the two chemicals.

Table 17: Charring Mean Grades and Standard Deviation for Nitric Acid -50%

Garment	Charring Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.40	0.55	1.60	0.55	2.40	0.55	3.00	0.71	3.80	0.45
Cream Acrylic	1.00	0.00	2.60	0.55	3.00	0.00	3.20	0.45	3.20	0.45	3.40	0.55

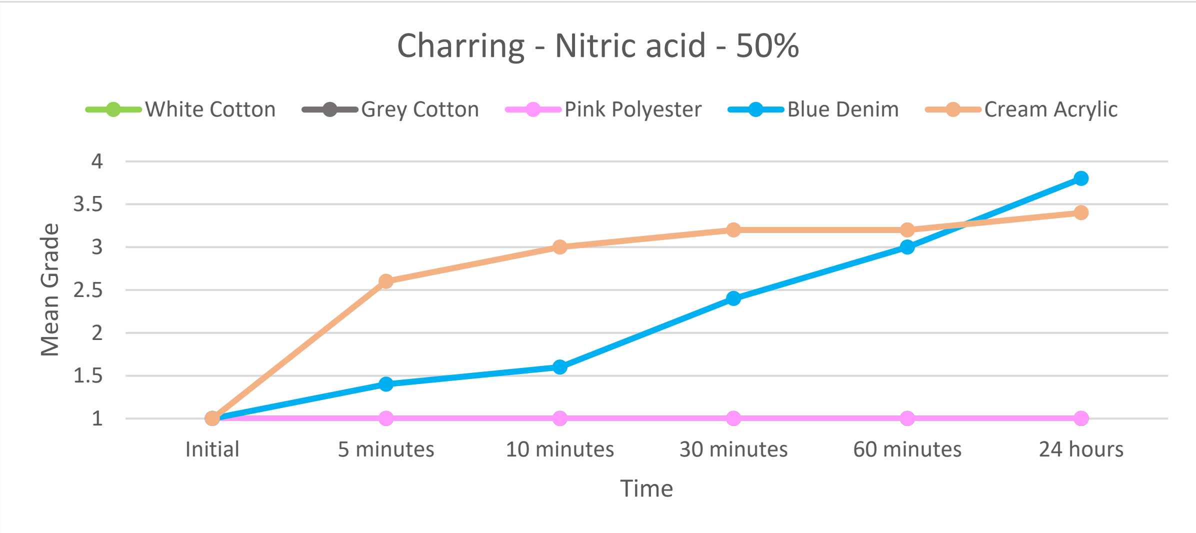

Figure 12: Trend of Mean Charring grade in Nitric Acid-50% overtime

3.4 Sodium Hypochlorite — 5% Concentration

3.4.1 Colour change grades

Sodium Hypochlorite is an oxidising agent that makes dyes lighter. Unless the concentration of Sodium Hypochlorite is very high, it does not always result in a completely new colour. According to research (Adeboye *et al.*, 2024), bleaches containing 1% Sodium Hypochlorite can effectively remove colour from fabrics that have been dyed, whereas higher concentrations can do it considerably more quickly. The *Domestos Original Bleach* used in this experiment is made up of 5% Sodium Hypochlorite, which is not strong enough to completely change the colour of garments.

Although pink polyester reached a mean colour change grade of 5 (Table 18), it is possible that the fabric sample turned to a lighter, more vibrant pink, which could be categorised closer to a bleaching effect. Grey cotton was the only garment that experienced a decrease in the mean colour changing grade. Chemical treatments are frequently ineffective when trying to fully remove dyes from cotton fabrics compared to polyester, which had a full colour change (Figure 13) (Chatha *et al.*, 2012). If a higher concentrated bleach was used, all of the garments would be expected to have higher mean colour change grades.

Table 18: Colour Change Mean Grades and Standard Deviation for Domestos Original Bleach

Garment	Colour Change Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00
Grey Cotton	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	5.00	1.40
Blue Denim	2.00	0.00	2.00	0.00	3.00	0.00	3.00	0.00	4.00	0.00	4.00	0.00
Cream Acrylic	1.80	0.45	2.00	0.00	1.20	0.45	1.20	0.45	1.00	0.00	1.00	0.00

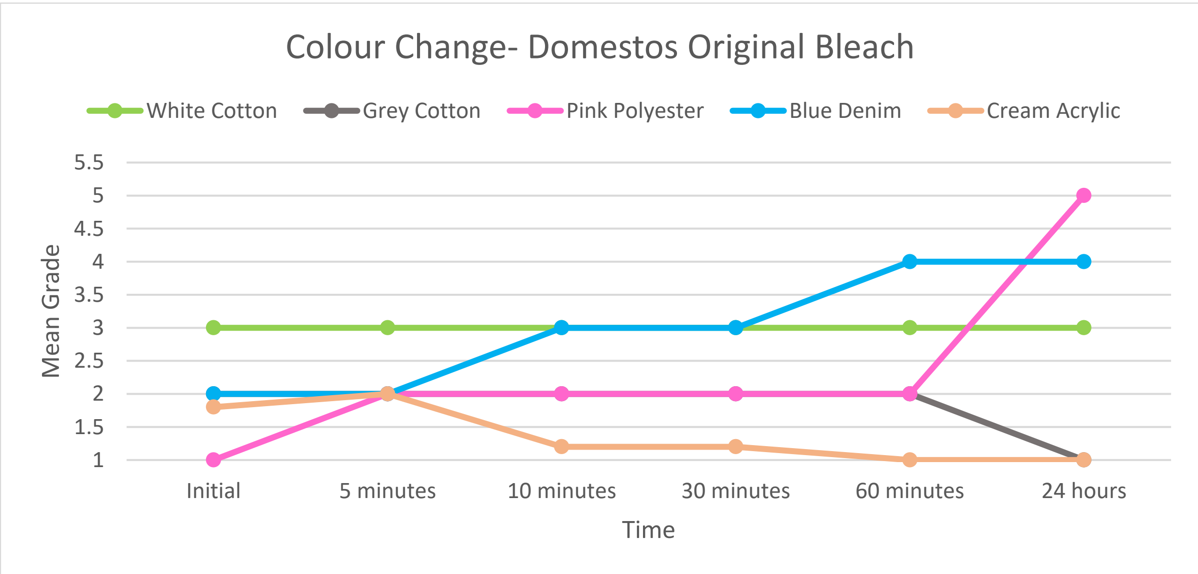

Figure 13: Trend of Mean Colour Change grade in Domestos Original Bleach overtime

3.4.2 Bleaching grades

Sodium Hypochlorite is a strong oxidising agent which breaks bonds in dye molecules, causing the materials to turn white or colourless (UK Health Security Agency, 2024b). Sodium Hypochlorite attacks chromophores, parts of the dye molecules responsible for absorbing visible or UV light, which breaks the systems, causing the molecule to no longer be able to absorb visible light wavelengths (Okeola *et al.*, 2022).

As expected, most garments experienced a high mean bleaching grade by the end of the 24-hour period. However, cream acrylic and grey cotton had a mean bleaching grade of 1 (see Table 19). As explained in 3.2.1, the cream acrylic garment has looser fibres, which could result in not absorbing all the *Domestos Original Bleach*. However, the behaviour of white cotton, compared to grey cotton, was unexpected. Figure 14 shows that bleaching levels in white cotton increased steadily, whereas grey cotton garments did not alter since the original deposition. According to research (Shao *et al.*, 2025), bleaching often removes the visible colour, not the dye molecules: therefore, the degraded dye compounds remained in the fabric, giving off a light grey tint. Grey dye is made up of more colour dyes than white dye, but the latter releases colour faster since it is often made up a single pure pigment (Cotton Incorporated, 2003).

Table 19: Bleaching Mean Grades and Standard Deviation for Domestos Original Bleach

Garment	Bleaching Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	2.00	0.00	3.00	0.00	4.00	0.00	4.00	0.00	4.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	2.00	0.00	4.00	0.00
Blue Denim	1.00	0.00	2.00	0.00	3.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00
Cream Acrylic	1.00	0.00	1.60	0.55	1.20	0.45	1.20	0.45	1.00	0.00	1.00	0.00

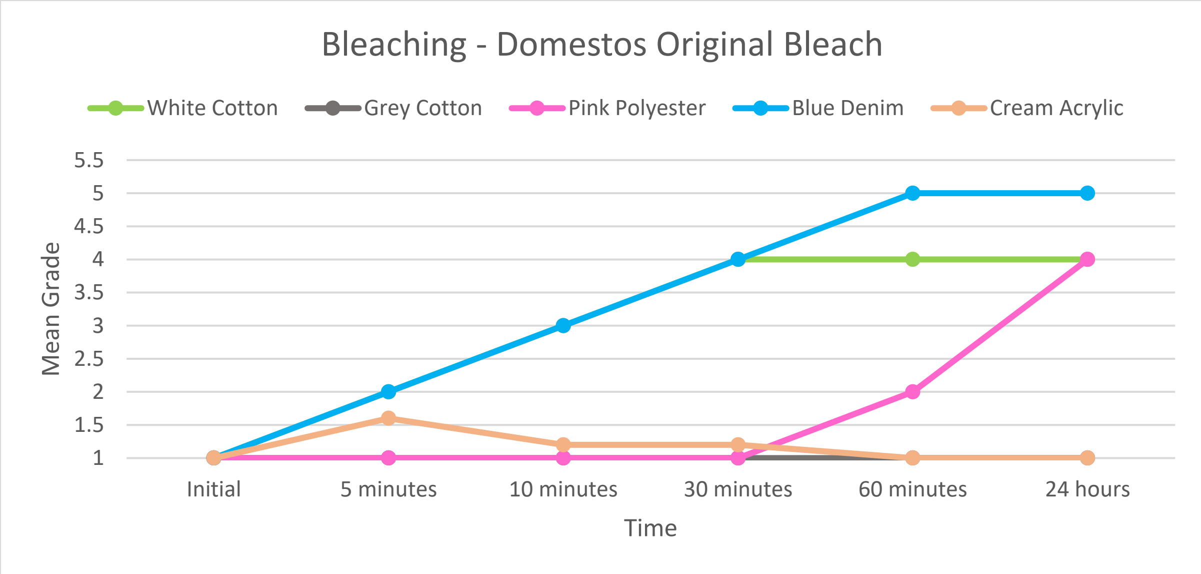

Figure 14: Trend of Mean Bleaching grade in Domestos Original Bleach overtime

3.4.3 Dissolution grade

According to research (Adeboye *et al.*, 2024), Sodium Hypochlorite -5.25% has minimal surface effects on an acrylic material, with the researcher describing the material sample as remaining structurally intact. The garments tested in this study did not have any dissolution grades over 2.5 after being exposed to Sodium Hypochlorite-5%. The S.D was greater than 0 for the cream acrylic because the garment had a looser fibre structure. The observed dissolution had a varying covered area in each of the five samples, while a fabric with tighter fibres would have been assigned a higher grade (Table 20). Unless the bleach is used in excessive amounts, the fibre structure should not weaken; as only 500µL was deposited, the fibre structure kept intact for the garments tested (Li, Wang and Wang, 2016).

Based on the research and the low mean dissolution grades (Figure 15), we can assume garments attacked with traditional bleaches should not experience dissolution characteristics that would be observed at eye-level, differentiating bleach from the other acids in this work.

Table 20: Dissolution Mean Grades and Standard Deviation for Domestos Original Bleach

Garment	Dissolution Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.80	0.45	1.20	0.45	1.20	0.45	1.20	0.45	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	2.00	0.00	2.20	0.45	2.20	0.45	1.60	0.55	1.00	0.00

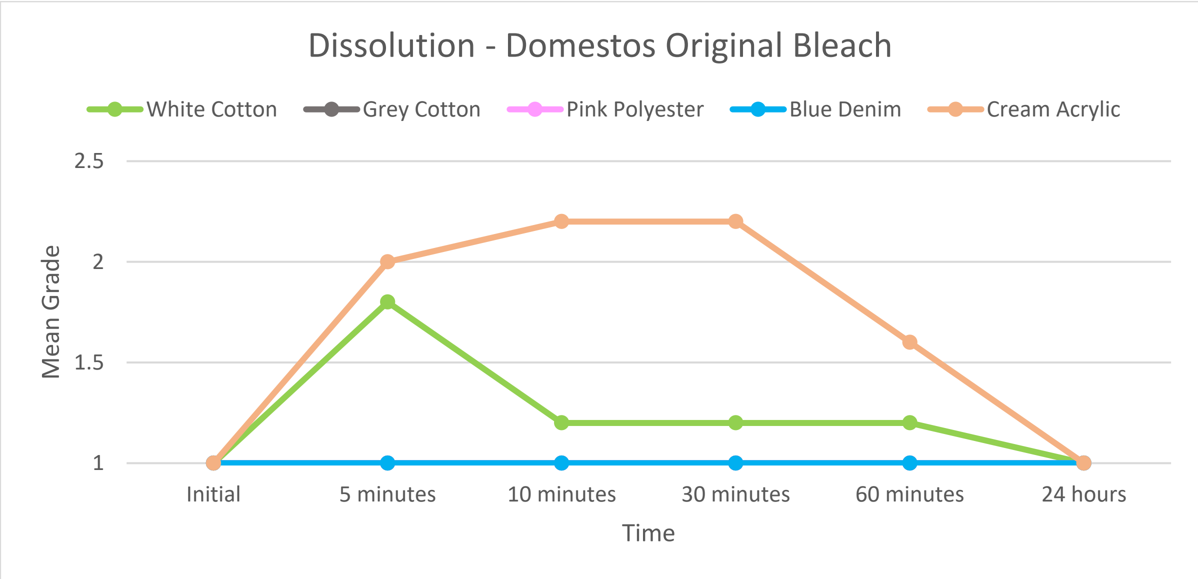

Figure 15: Trend of Mean Dissolution grade in Domestos Original Bleach overtime

3.4.4 Charring grade

Bleach does not char synthetic fibres such as acrylic or polyester. Instead, Sodium Hypochlorite chemically degrades polymer chains, resulting in surface damage, as opposed to the carbonisation of a material (Hughes, Fujita and Suye, 2015).

Cream acrylic was the only garment tested that showed slight charring properties (Figure 16). As no garment had a mean charring grade of more than 2, it can be concluded that Sodium Hypochlorite does not char the specific garments tested, distinguishing it from the other acids studied (Table 21). Hydrochloric Acid-50% also did not cause charring on the garments after being tested; however, the bleaching grades can distinguish the two chemicals apart.

Table 21: Charring Mean Grades and Standard Deviation for Domestos Original Bleach

Garment	Charring Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.20	0.45	1.40	0.90	1.40	0.00	1.00	0.00	1.00	0.00

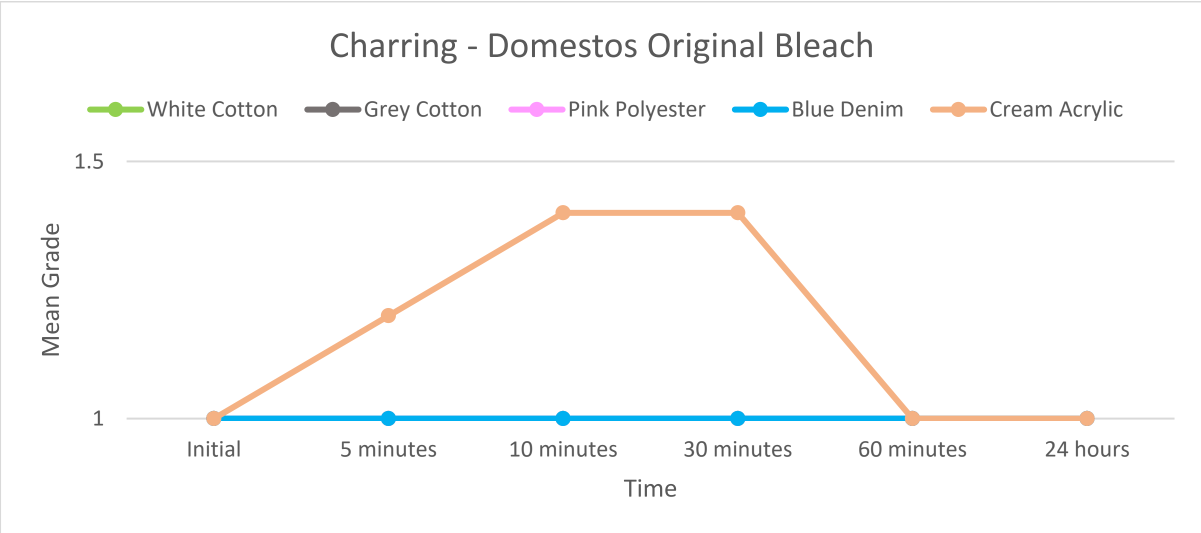

Figure 16: Trend of Mean Charring grade in Domestos Original Bleach overtime

3.5 Sulphuric Acid — 40% Concentration

Sulphuric Acid with concentrations between 37% and 40% can be exposed to the general public in the form of lead-acid batteries or cleaning products, such as acid drain blockers (UK Health and Security Agency, 2024b). Sulphuric Acid is not persistent, and, when in contact with water or soil, it is expected to dissociate into sulphate, therefore reducing the number of hazards with this chemical (UK Health and Security Agency, 2024b).

3.5.1 Colour change grades

The garments that showed the highest mean colour change grades were the three garments that were made up of cotton, with the blue denim being made up of 86% (Figure 17).

According to Gao (2025), at lower concentrations, Sulphuric Acid significantly degrades cotton fibres. This explains why these garments produced similar grades to those tested in Sulphuric Acid-80%. However, the standard deviation (Table 22) was higher in comparison to the results in Table 6 for Sulphuric Acid-80%. A standard deviation of around 0.5 indicates that data is more concentrated around the mean in comparison to 0. If an investigator is uncertain between the two concentrations, making a note of the chemical is important, and the exact concentration can be then determined later in the lab or inferred or using the remaining factors tested in this experiment.

Research by Anon (1958) found that moistened wool with weak Sulphuric Acid can minimise colour determination, despite the highest mean grade of cream acrylic being 2. A test should be conducted on garments of the same colour and material composition, but with varying fibre strength.

Table 22: Colour Change Mean Grades and Standard Deviation for Sulphuric Acid -40%

Garment	Colour Change Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	3.60	0.55	3.60	0.55	3.80	0.45	4.40	0.90	4.80	0.45
Grey Cotton	2.00	0.00	3.40	0.55	3.60	0.55	4.60	0.55	4.60	0.55	4.80	0.45
Pink Polyester	1.00	0.00	1.80	0.45	2.00	0.00	2.00	0.00	3.00	0.00	1.00	0.00
Blue Denim	2.20	0.45	4.00	0.00	4.20	0.45	4.20	0.45	4.40	0.55	4.60	0.55
Cream Acrylic	1.00	0.00	2.00	0.00	2.00	0.00	2.00	0.00	1.60	0.55	1.00	0.00

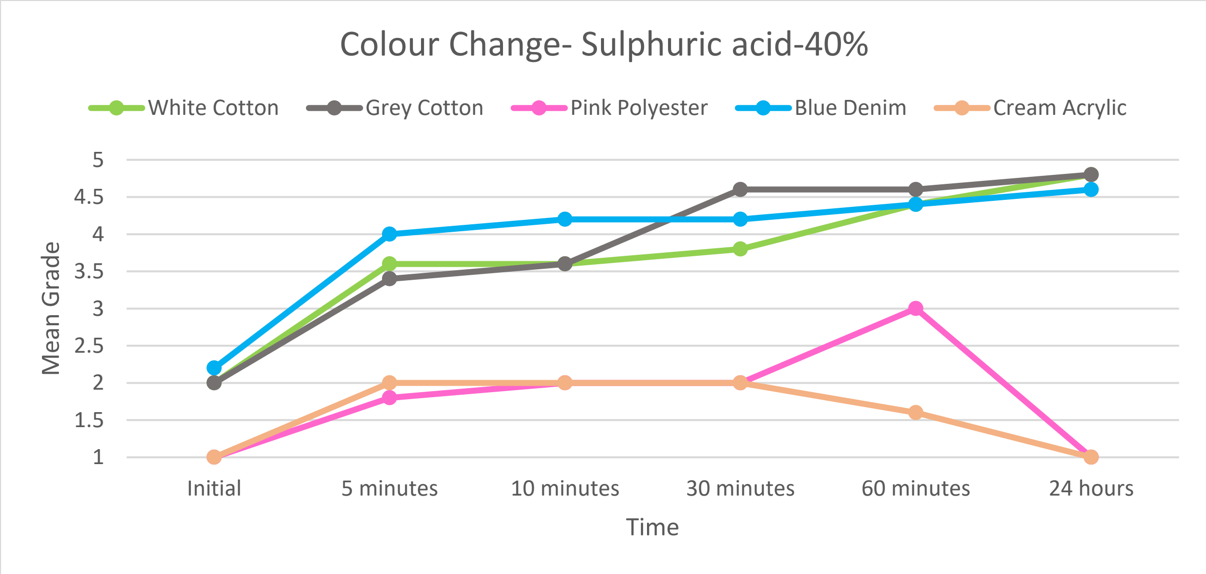

Figure 17: Trend of Mean Colour Change grade in Sulphuric Acid-40% overtime

3.5.2 Bleaching grades

Sulphuric Acid bleaches garments in the form of oxidisation, and its concentration can significantly affect the process (UK Health and Security Agency, 2024c). A higher concentration of Sulphuric Acid is more effective in oxidising substance, as it can more readily oxidise and provide more power than a lower concentration (Golodov and Kashnikova, 1988). This pattern is consistent, when comparing Table 7 to Table 23, as the bleaching mean grade is lower for each garment.

In Figure 18, there is a pattern of the mean bleaching level decreasing after 30 minutes. Higher concentrations of Sulphuric Acid can evaporate slowly over time but penetrate deeper into materials that are susceptible to degradation (UK Health Security Agency, 2024c). The low concentration of 40% may have evaporated before it was able to seep into the fibre structure and caused bleaching.

Table 23: Bleaching Mean Grades and Standard Deviation for Sulphuric Acid -40%

Garment	Bleaching Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	2.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	2.00	0.00	1.00	0.00
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.60	0.55	2.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	2.00	0.00	2.20	0.45	2.20	0.45	1.60	0.55	1.00	0.00

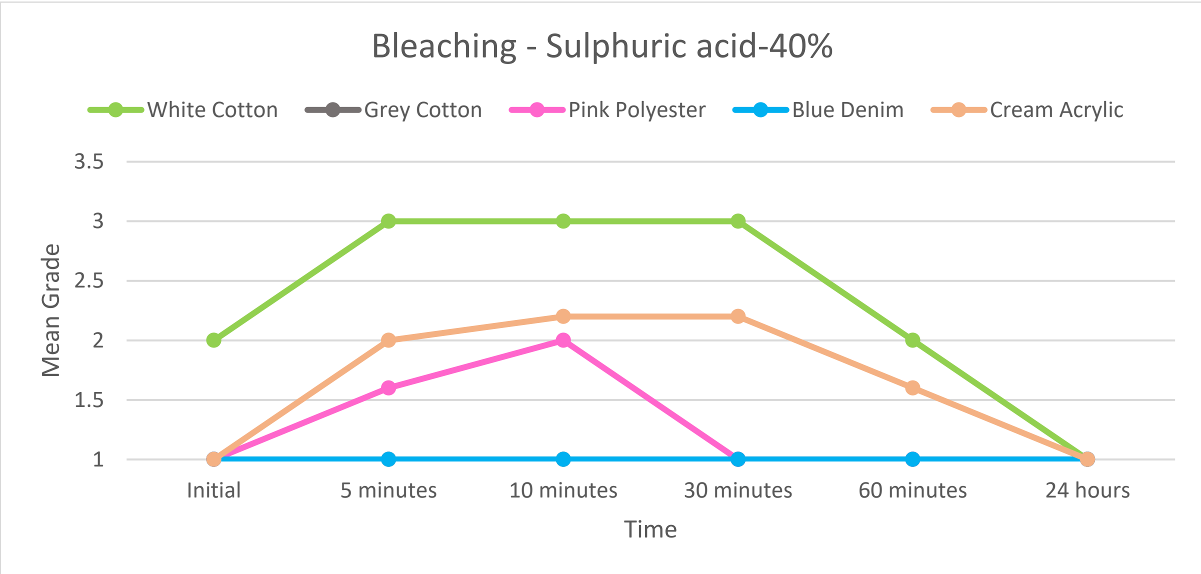

Figure 18: Trend of Mean Bleaching grade in Sulphuric Acid-40% overtime

3.5.3 Dissolution grade

As seen in Table 24, the garments exposed to Sulphuric Acid-40% had consistent mean grades of 1 or 2, remaining quite low on the dissolution scale, whereas Sulphuric Acid- 80% showed higher dissolution mean grades (Table 8). The most noticeable difference was with the white cotton garment, which, after the 24-hour mark, had an assigned grade 1, while, with Sulphuric Acid-40%, the grade rose to a 5 at the 24-hour mark (Figure 19).

According to Carlysle-Davies, Mudiyanselage and Chanaka Bandara (2022), Sulphuric Acid does dissolve garments from concentrations over 50%, as the result from their test on a cotton garment, which resulted in bubbling. The bubbling left a mark through both sides of the garments, a characteristic observed in this test but not compared.

Table 24: Dissolution Mean Grades and Standard Deviation for Sulphuric Acid -40%

Garment	Dissolution Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
.Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	2.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	2.00	0.00	2.20	0.45	2.20	0.45	2.00	0.71	2.00	0.00

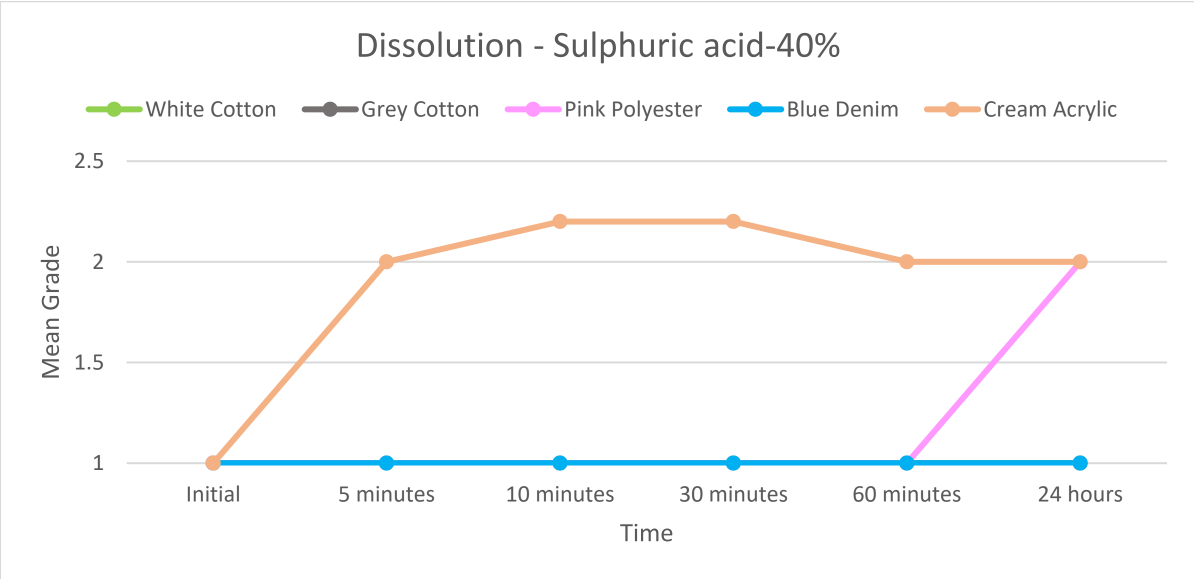

Figure 19: Trend of Mean Dissolution grade in Sulphuric Acid-40% overtime

3.5.4 Charring grade

According to BenchChem (2025b), excessively high concentrations of Sulphuric Acid can generate aggressive side reactions, such as oxidisation, which results in charring. To reduce this reaction, it is recommended to lower the concentration. The Sulphuric Acid - 40% caused a minor charring reaction, of 3.5, in white cotton at the end of the 24-hour period (Table 25,Figure 20). However, all garments remained in their original state. The concentration of Sulphuric Acid is exactly proportional to the intensity of the reaction of the charred product (Taki, 2025). Therefore, if charring is visible, and all the other indicators of Sulphuric Acid are present, an investigator may conclude that the chemical has a concentration of more than 40%.

Table 25: Charring Mean Grades and Standard Deviation for Sulphuric Acid -40%

Garment	Charring Grade											
	Initial		5 minutes		10 minutes		30 minutes		60 minutes		24 hours	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
White Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	3.20	1.10
Grey Cotton	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Pink Polyester	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Blue Denim	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00
Cream Acrylic	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00

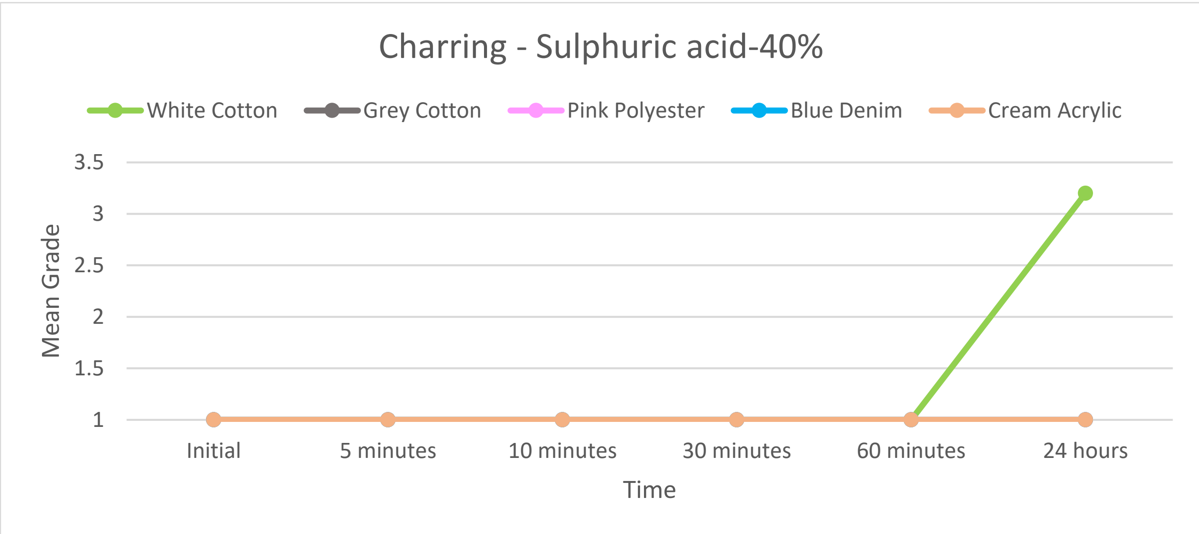

Figure 20: Trend of Mean Charring grade in Sulphuric Acid-40% overtime

4. Conclusion

The aim of the study was to investigate the macroscopic effects of varying chemicals on different fabrics and create a grading system for chemical attacks. Different materials exhibit, time dependent degradation and discolouration patterns when exposed to corrosive chemicals.

Sulphuric Acid-80% exhibited one of the highest dissolution reactions out of every chemical tested. The white cotton t-shirt showed a clear observation by the t-shirt turning brown and then clear, with the inside stitching becoming visible after 24 hours. The acid can be distinguished by its ability to change a garments original colour through oxidation and high dissolving properties. At high concentrations charring can be observed after 1 hour, however this effect was dependent on the material of the garment.

Sulphuric Acid-40% had similar mean colour grades for all fabric types to Sulphuric Acid-80% however, the acid did not show any signs of charring, distinguishing the two concentrations from one another. Both had dissolving properties however Sulphuric Acid-40% had lower overall grades. To see when the two concentrations exhibit the same lengths of the effect, a test with a greater time interval would be recommended.

Hydrochloric Acid-50% caused the garment squares to turn lighter, as opposed to fully changing colour. The only acid tested that had that effect that could be described as closer to bleaching. Dissolution and charring were not observed on any garment tested, dissolutions highest grade was 2.6, but decreased 5 minutes after the garment had dried. No charring being present can distinguish this acid from the other chemicals tested.

Nitric Acid – 50% caused the blue denim garment to turn into a yellow colour as Nitric Acid undergoes a xanthoproteic reaction, resulting in a stable yellow colouration in protein-based fibres. The acid goes through oxidation, not bleaching. Nitric Acid is a strong oxidizing agent but not an effective solvent for cellulose or polyester, therefore it did not result in high dissolution grades. However, Nitric Acid-50% had visible charring which distinguishes it from the other acids, even though Sulphuric Acid-80% caused materials to char the other properties did vary.

Sodium Hypochlorite – 5%, was the alkali in the *Domestos Original Bleach* that was analysed. The discolouration observed in the garments was as a result of bleaching as Sodium Hypochlorite is a powerful bleaching agent, which stage is nicely presented in the blue denim garment. Sodium hypochlorite chemically degrades polymer chains, resulting in surface damage as opposed to the carbonisation of a material, which is why the garments tested in this study exhibited low scores however, Sodium Hypochlorite can cause charring so it should not be disregarded as one of its properties. Dissolution however should not occur when using traditional bleaches, which can differentiate it from other alkalis.

The chemical distinctive results can aid in the creation of specific and descriptive grading system, to help distinguish any chemical damage on scene by investigators. If a cumulative grading system was published and shared nationality with visual aids, investigators could also have an easier time determining the exact time of the attack. The merging of the colour change and bleaching category is suggested, as well as creating a higher-grade scale to decrease the level of subjectivity.

5. Further Work

The results of this test are promising however further work is needed to improve its value to crime scene investigators and police staff. Additional variables, such as fibre strength and fibre structure, can be evaluated to see if they have an effect after being treated with a chemical. Different garments with a fibre structure more like that of the cream acrylic garment should be tested. Fibres pulled further apart would take longer to absorb the chemical, and as observed with the cream acrylic garment, this might have various impacts, such as a smaller colour change mean grade compared to garments with a compact fibre composition (Pang *et al.*, 2013).

A consideration should be given to combining the colour change and bleaching grade into a singular grade: Discolouration. As a chemical undergoes oxidation or nitration, as in this test, we can expect to see only one of the two effects. The labels for the discolouration grades should refer to both bleaching and colour change effects, and an investigator could include a note describing which effect they believe is more visible.

Because of the safety precautions for the test environment, certain chemicals were not tested. Ammonia, as previously stated, was not tested, however given its increased appearance in chemical attacks, it would be valuable to collect data against other garment types and colours using the same method as in this test (Vadysinghe *et al.*, 2021). Other chemical weapons used in acid assaults include chlorine and cyanide, both of which can be tested using the same method (DeLuca *et al.*, 2020). Chlorine is easily accessible and so is cyanide, however its possession is illegal in the UK under The *Poisons Act 1972* (2015), so it is best to detect the signs sooner. These chemicals, along with the five tested, could be also evaluated in outdoor conditions to recreate crime scenes that do not occur indoors but do occur outside the home (Song, Armstrong and Murray, 2020). If an outdoor test is attempted, the chemicals must be stored accordingly, as prolonged exposure is not safe (Fouzi, Aziz and Yaakub, 2024).

If any of these suggestions are implemented, or the original method is used, more time intervals and a greater number of repeats is recommended. Attacks can go unreported for longer than 24 hours and for that reason the time since deposition should be extended to at least a week to increase the value. Due to the lower number of repeats, statistical analysis was not performed on this dataset. Low repeat numbers do not convey data effectively; column heights could be not drastically different, making error bars hard to interpret (Vaux, Fidler and Cumming, 2012). The Kruskal-Wallis Test requires a larger sample size; the small sample size increases the risk of data being disproportionate as a minor grade can cause more variability in the test.

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7. Appendices

Appendix A – Ethics Disclaimer Form

Appendix B – PRA Form

Appendix C – Photograph Log Tables of Garments after Chemical Deposition

Appendix D –Grades assigned to the Area of Colour Change

Appendix A – Ethics Disclaimer Form

RESEARCH ETHICS

Disclaimer Form

University of Staffordshire

The following declaration should be made in cases where the researcher and the supervisor (where applicable) conclude that it is not necessary to apply for ethical approval for a specific research project.

PART A: TO BE COMPLETED BY THE RESEARCHER

Name of Researcher:	**Emma Szarlej**
School:	**Health, Education, Policing and Sciences**

Student/Course Details (If Applicable)		
Student ID Number:		**23011246**
Name of Supervisor(s)/Module Tutor:		**Claire Gwinnett**
PhD/MPhil project: ☐		
Taught Postgraduate ☐ Project/Assignment:	Award Title:	
Undergraduate ☒ Project/Assignment	Module Title:	**Forensic Research Project**

Project Title:	**Investigation into Chemical Attacks By using Textile Damage Analysis of Whole Garments**
Project Outline:	Reconstructing the visual aspect of a chemical attack through testing various chemicals on different material samples and analysing the textile damage through fibre analysis as well as determining the damage over certain time frames. The aim of this project is to aid investigators in the rapid identification of chemical attack scenes to determine the time elapsed since the incident and the specific chemical used. This will help in the search for the weapon or chemical agent, and reduce the time required for the investigation of chemicals, which is currently an under looked area in forensics. At the end of this research project, I will create a reference chart that can indicate which chemical was used under a range of condition, which include: - Textile material - Time since deposition - Angle of deposition - Environmental conditions (temperature / humidity).
Give a brief description of research procedure (methods, tests etc.)	The general method for this project will involve depositing different chemicals onto various sample materials and observing the different characteristics such as stain colour, textile damage, size of the stain. The independent variables will include:

	- The angle the chemical is deposited from, - Volume of the chemical, - Time since deposition, - Colour of fabric stain, - Material of the fabric sample. I will be using micropipettes to deposit the chemical onto the sample materials; the sample materials will be chosen based off the available fabrics in the project lab. Test 1: The height of the chemical drop will remain constant, as the volume deposited will vary. Test 2: The angle of the chemical deposited will be changed; the volume will remain constant. Test 3 : The chemical volume is kept constant; the sample material will change. Throughout all three tests, each sample will be also observed over time to note any change that occur. The size of the stain will be measured using a ruler, the fibre damage will be analysed under a stereomicrospe and where appropriate a polarising light microscope may be be used for more detailed fibre damage analysis.The colour of the stain will be visually observed , maybe finding a universal colour comparator, for more accuracy.		
Expected Start Date:	**06/10/25**	Expected Date:	**06/10/26**

Declaration

I/We confirm that the University's Ethical Review Policy has been consulted and that all ethical issues and implications in relation to the above project have been considered. I/We confirm that ethical approval need not be sought. I/We confirm that:

The research does not involve human or animal participants	☒
The research does not present an indirect risk to non-participants (human or animal).	☒
The research does not raise ethical issues due to the potential social or environmental implications of the study	☒
The research does not re-use previously collected personal data which is sensitive in nature, or enables the identification of individuals.	☒
Has a risk assessment been completed for this project?	☐Yes ☒N/A

Signature of Researcher:		Date:	06/11//25
Signature(s) of Project Supervisor(s) (if student) OR Signature of Head of Department/ Senior Researcher (if staff)	Claire Gwinnett	Date:	20/11/25

NB: If the research departs from the protocol which provides the basis for this disclaimer then ethical review may be required and the applicant and supervisor (where applicable) should consider whether or not the disclaimer declaration remains appropriate. If it is no longer appropriate an application for ethical review **MUST** be submitted.

Appendix B – PRA Form

Procedure:

- Academics or session lead to complete Risk Assessment for all practical classes/activities, Technical team for all support aspects this is then reviewed as required
- Researchers/Experimenters are to complete a Risk Assessment in consultation with their project advisor and technical staff as appropriate.
- No laboratory work is to commence without a suitable and comprehensive risk assessment being signed off by a competent person detailed in the laboratory handbook.
- Researchers/Experimenters to keep copies of Risk Assessments when working in the laboratories.

Notes:

- The risk assessment must be reviewed when any changes are made to the equipment, materials, procedure, personnel or if there is a near miss or accident
- Any staff member can stop experimental work if no risk assessment is in place, or if, in their opinion, there is a risk to safety. If anybody else has concerns, they must raise it immediately to a member of staff.
- Add rows as necessary
- If substances are used, then you must fill out the COSHH section 3-6. The COSHH regulations link is available here: - Control of substances hazardous to health (COSHH). The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance L5 (hse.gov.uk)

Review Date	Reviewed by	Amended – Yes/No	Approval

Risk assessment Reference **(Technical Services Only)**	

Name	Emma Szarlej	Supervisor name	Claire Gwinnett
Email address	s011246n@student.staffs.ac.uk	Supervisor email	C.Gwinnett@staffs.ac.uk
Level of study	Level 6	Course title	Forensic Investigation
Module number	FORE60369	Module title	Forensic Research Project
Session/project title	Investigation into Chemical Attacks By using textile damage analysis of whole garments		
Ethics approved (use BABAO for skeletal remains)	Yes ☐ No ☒ Not applicable ☐		

Description of experimental procedure/practical session (500 words max)

This project will involve the deposition of chemicals onto cut garment samples to recreate the action of a chemical attack, using textile damage analysis for the interpretation of results
At the end of this research project, I will create a reference chart that can indicate which chemical was used under a range of conditions, which include:

- Up to ten textile materials, including a range of common garment types such as cotton, polyester
- Exposure over time, up to one week since deposition
- Angle of deposition

The general method for this project will involve depositing different chemicals onto various sample materials and observing the different characteristics such as stain colour, textile damage, size of the stain. The independent variables will include:

- The angle the chemical is deposited from,
- Volume of the chemical,
- Time since deposition,
- Colour of fabric stain,
- Material of the fabric sample.

I will be using micropipettes to deposit the chemical onto the sample materials; the sample materials will be chosen based off the available fabrics in the project lab.
Test 1: The height of the chemical drop will remain constant, as the volume deposited will vary.
Test 2: The angle of the chemical deposited will be changed; the volume will remain constant.
Test 3 : The chemical volume is kept constant; the sample material will change.

Throughout all three tests, each sample will be also observed over time to note any change that occur.
The size of the stain will be measured using a ruler, the fibre damage will be analysed under a stereomicroscope and where appropriate a polarising light microscope may be be used for more detailed fibre damage analysis. The colour of the stain will be visually observed , maybe finding a universal colour comparator, for more accuracy.

Risk Assessment

Risk assessment score

		Consequence				
		Negligible (minimal first aid only) 1	Minor (minor injuries) 2	Moderate (major injury) 3	Major (life changing injury) 4	Catastrophic (Danger of death) 5
Likelihood	Almost certain 5	5	10	15	20	25
	Likely 4	4	8	12	16	20
	Possible 3	3	6	9	12	15
	Unlikely 2	2	4	6	8	10
	Rare 1	1	2	3	4	5

Hazard list

Hazards inherent in the work, record details and possible injury: (e.g., Equipment, procedures, general chemical hazards, invertebrate work, body fluid sampling etc.)	Risk score	Record precautions which will be taken: (*e.g.,* Include any standard operating procedures, codes of practice, faculty policies you will be following) **Use Hierarchy of Control Measures to reduce risks.**	New risk score
Sharps	4	Handle sharp equipment carefully Leave enough space from your hand to not cut skin Make people around you aware that you are using sharp material	2
Chemical fumes	4	Use fume cupboard Wear appropriate PPE (lab coat/safety goggles), and any PPE requirement for safe chemical use Don't be directly above chemical	2
Solvent and Sample spills	9	Always wear appropriate level of PPE (lab coat/ safety goggles) Use the spill kit in the lab, as demonstrated during the Lab induction Don't pour any solvent down the drain	1
Micropettes	4	Change pipette tip when using different chemicals Do not overfill pipette If mixed alert the attention of Lab Staff immediately	1
Glassware	2	Handle with care Ensure there are no cracks in glassware before using	1
Microscopes	3	Handel with care and ensure that cables are intact and microscope has passed PAT testing before use	2

Who may be at risk?

Staff – Day shift	Staff – Out of hours	Postgraduate students	Undergraduate students	New or expectant mothers	Contractors	Public	Other, please state below
☒	☐	☐	☒	☐	☐	☐	

What level of risk do you assign to this work?

Low	Medium Low	Medium	High
☐	☒	☐	☐

If the risk assessment is classified as high, then **no work** is to be undertaken. First, follow hierarchy of controls to reduce risks.

If no COSHH assessment is required, then please click here.

Control of Substances Hazardous to Health (COSHH)

COSHH assessment

Control of substances hazardous to health (COSHH). The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance L5 (hse.gov.uk)

Links and table below to aid completing the COSHH assessment.

Minimum PPE are lab coat/safety glasses

Addition PPE:		
Fume cupboard (FC)	Laminar flow cabinets (LF)	Microbiological Safety cabinet (Cab)
Nitrile gloves (NG)	Vinyl gloves (VG)	Cryogenic gloves (CG)
Face shield (FS)	Face Mask FFP1	Face Mask FFP2
Face Mask FFP3	Respirator (R)	Other (provide details)
All INFORMATION CAN BE FOUND WITHIN MSDS (MATERIAL SAFETY DATA SHEETS) ON THE INTERNET, SCIENCES CHEMICAL DATABASE ON-LINE OR WITHIN EACH OF THE LABORATORIES		

Use safety data sheets where possible.

Hazard and Precaution statements list, should also be stated on the MSDS - GHS Classification (nih.gov)

Work Exposure Limits (WEL) if not stated on (M)SDS - EH40/2005 Workplace exposure limits (hse.gov.uk)

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
Battery Acid (Diluted Sulphuric acid)	ReAgent https://www.chemicals.co.uk/uploads/documents/44%20-%201291%20-%20SDS10295.pdf?srsltid=AfmBOoqbt-ZUZFiObXX0eN6hre19MYEkwDwB6H3J6HWmr9mv5c_K33kl	C	Full length gloves R (when there is inadequate ventilation)	L	Up to 10ml 50 % solution 30 % solution	H314 Causes severe skin burns and eye damage.	**P260** Do not breathe vapour/ spray **P280** Wear protective gloves/ protective clothing/ eye protection/ face protection. **P305 + P351 + P338** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do so. Continue rinsing. **P310** Immediately call a POISON CENTER/ doctor. **P501** Dispose of contents / container	0.1 mg/m^3

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
							in accordance with local regulations.	
Bleach Domestos Bleach https://www.tesco.com/groceries/en-GB/products/257259605 (Sodium hypochlorite- active ingredient)	Sigma-Aldrich https://www.sigmaaldrich.com/GB/en/sds/sigald/425044?userType=undefined	C, W	NG FC	L	Up to 10ml 4.5g per 100g <5%	H290 May be corrosive to metals H314 Causes severe skin burns and eye damage H410 Very toxic to aquatic life with long lasting effects	**P234** Keep only in original packaging **P273** Avoid release to the environment. **P280** Wear protective gloves/protective clothing/eye protection / face protection. **P303+ P361 + P353** IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water **P304 + P340 + P310** IF INHALED: Remove person to fresh air and keep	

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
							comfortable for breathing. Immediately call a POSION CENTER/ doctor. **P305 + P351 + P338** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do so. Continue rinsing.	
Hydrochloric Acid (HCl)	Sigma-Aldrich https://www.sigmaaldrich.com/GB/en/sds/SIGMA/H1758?userType=undefined	C, I	NG FC	L	Up to 10ml 50 % solution 30 % solution	H290 May be corrosive to metals H314 Causes severe skin burns and eye damage.	**P234** Keep only in original packaging **P261** Avoid breathing mist or vapours **P271** Use only outdoor or in a well-ventilated area	5/8 ppm 8 mg/m3

University of Staffordshire

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
						H335 May cause respiratory irritation	**P280** Wear protective gloves/protective clothing/eye protection / face protection. **P303+ P361 + P353** IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water **P305 + P351 + P338** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do so. Continue rinsing.	

University of Staffordshire

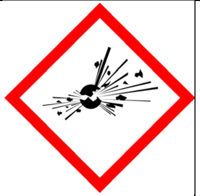
Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
Nitric Acid (HNO3)	Sigma Aldrich https://www.sigmaaldrich.com/GB/en/sds/sial/695041?userType=undefined	O , T+ , C	FC	L	Up to 10ml 50% solution	H272 May intensity fire; oxidiser H290 May be corrosive to metals H314 Causes severe skin burns an eye damage H331 Toxic if inhaled	**P210** Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking. **P220** Keep away from clothing and other combustible materials. **P280** Wear protective gloves/protective clothing/eye protection / face protection. **P303+ P361 + P353** IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water	STEL 1 ppm 2.6 mg/m3

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
							P304 + P340 + P310 IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POSION CENTER/ doctor. **P305 + P351 + P338** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do so. Continue rinsing.	
Sulphuric Acid (H_2SO4)	Sigma Aldrich https://www.sigmaaldrich.com/GB/en/sds/	C	Face Mask FFP2 FC	L	Up to 10ml 80% solution	H290 May be corrosive to metals.	**P234** Keep only in original packaging **P280** Wear protective gloves/	0.05 mg/m3 Mist

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
	aldrich/339741?userType=undefinedhttps://www.sigmaaldrich.com/GB/en/sds/aldrich/339741?userType=undefined					H314 Causes severe skin burns and eye damage	protective clothing / eye protection / face protection **P303+ P361 + P353** IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water **P304 + P340 + P310** IF INHALED: Remove person to fresh air and keep comfortable for breathing. Immediately call a POSION CENTER/ doctor. **P305 + P351 + P338** IF IN EYES: Rinse cautiously with water for several	

Substance involved (e.g., chemicals including reagents, intermediates, products, and by-products):	SDS source (e.g. Fisher Scientific/Sigma Aldrich)	Hazard Class (see below abbreviation letter e.g., C, F):	Handling precautions as above (abbreviation letter e.g., FC):	Physical State (solid (S), liquid (L), gas (G), mist (M), fume (F), dust (D)	Quantity and concentration to be used: ml/g, % solution/M	Hazard statement Code (H code)	Precautionary Statements (P-Code) Prevention	Workplace exposure limit (STEL/WEL)
							minutes. Remove contact lenses, if present and easy to do so. Continue rinsing. **P363** Wash contaminated clothing before reuse.	

Hazard pictograms

Select all hazard pictograms that apply to **all** the work activity								
 Corrosive (C)	 Caution (H, I)	 Flammable (F)	 Longer Term Health Hazards (M)	 Acute Toxicity (T+)	 Oxidising (O)	 Dangerous to the environment (W)	 Explosive (E)	 Gases Under Pressure (G)
☒	☒	☐	☐	☒	☒	☒	☐	☐

Special hazards

Are there any special hazards associated with work / procedure?	Yes ☐	No ☒
If yes, then state:		
1. Is the activity/substances risk of thermal runaway or explosion?	Yes ☐	No ☒
2. Does the activity involve handling or storing pyrophoric or unstable substances such as peroxides?	Yes ☐	No ☒
3. Are any substances capable of forming an explosive atmosphere?	Yes ☐	No ☒
If the answer is yes to Q1, a Dangerous substance, and Explosives Atmosphere (DSEAR) assessment must be completed. If it is yes to Q2 and Q3 then a DSEAR procedure should be followed (i.e. check LELs using calculator and have ignition sources been considered along with emergency plans.		
Has the above statements and procedures been followed? Yes ☐	No ☐	

Biological hazards

In addition to COSHH, Biosafety must also be considered. Please ensure that the following biological hazards are filled out appropriately, refer to Health and Safety Executive England, Advisory Committee on Dangerous Pathogens [Approved List of biological agents (hse.gov.uk)](hse.gov.uk) for info.

Microbiology

Microorganism	Strain designation number (If known)	Source (supplier, depositor, sample location)	Classification (Hazard group, Classification group)	Growth media	Hazard group definition (Also include any known hazards such as specific infections and/or diseases)	Precautions to be implemented in work to mitigate infection risk (includes additional PPE requirements or method of working, refer to additional PPE in COSHH section above)

Tissue Culture

Cell Line	Source	Classification	Growth media	Hazard	Precaution

Genetic modification (GM)

Are genetic modification procedures required?	Yes ☐	No☒
If yes, then follow GM protocols		
Have you submitted a GM risk assessment?	Yes ☐	No☒
Has the GM risk assessment been approved?	Yes ☐	No☒

Human Tissue Act and other Policies

Are there any specific conditions to be adhered to e.g., Human Tissue Act, body fluid policy? (If yes give details below)	Yes ☐	No☒
Enter details here		
If working with body fluids, have you completed the body fluids declaration?	Yes ☐	No☒

Other biological material

Material (e.g. fluids, bone, meat etc.)	Hazard	Precaution	Quantity to be used

Storage and Disposal

Storage requirements – How are the materials to be stored?	
Stored in sealed containers	
Disposal information – How will the waste be disposed?	professional chemical waste through technicians
Are there any special disposal requirements? **If yes, please state requirements: -**	Yes ☒ No☐ **Professional chemical waste**

Emergency Plans

Do procedures require further emergency plans other than stated in codes of practice or standard procedure risk assessments? If yes, then state below	Yes ☐ No ☒
Spills	
Fire	
First Aid	
Other	

Approval

Risk assessment completed by	Emma Szarlej
Date submitted	07/11/25
Supervisor (or session lead) approval signed	Claire Gwinnett
Date of supervisor approval	20/11/25
H&S approval signed	A.Osborne
Date of H&S approval	25/11/2025
Review date	
Any other comments	

Appendix C – Photograph Log Tables of Garments after Chemical Deposition

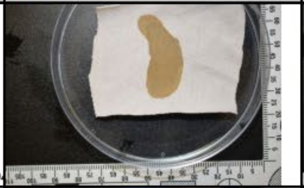
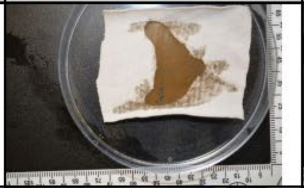
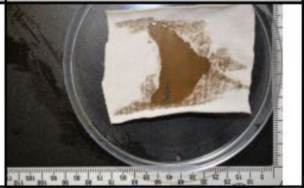
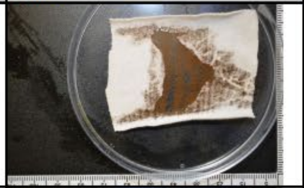
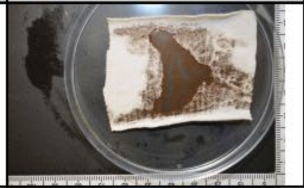
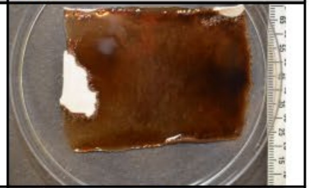
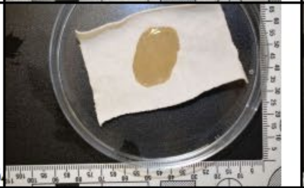
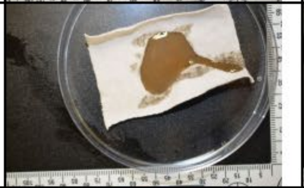
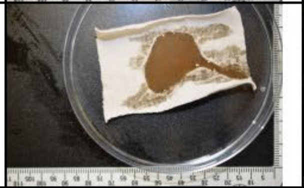
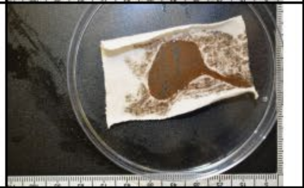
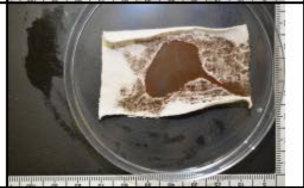
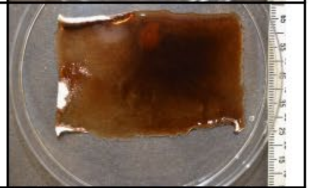
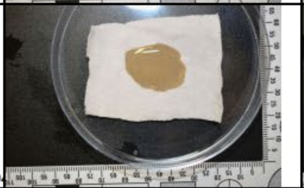
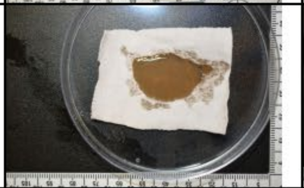
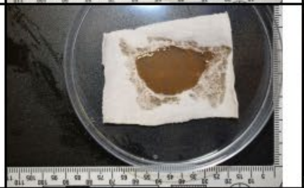
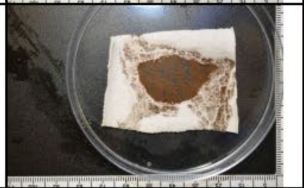
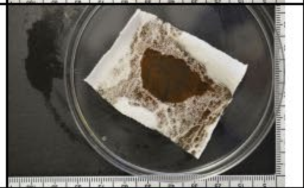
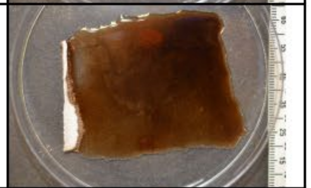
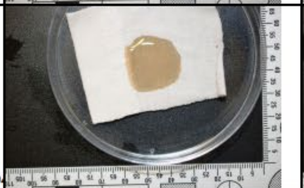
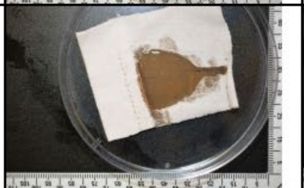
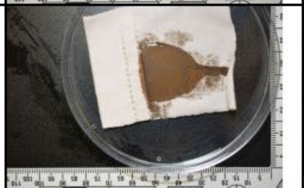
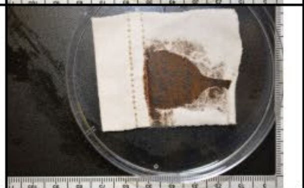
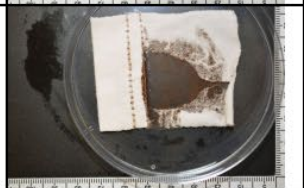
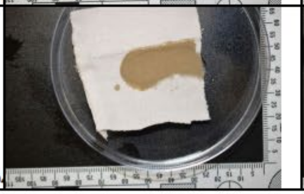
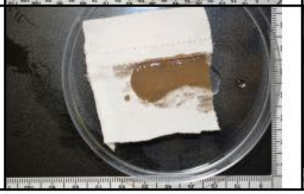
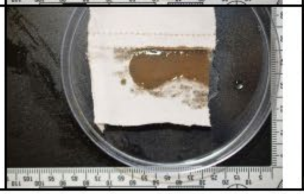
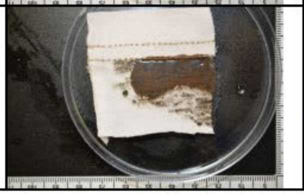
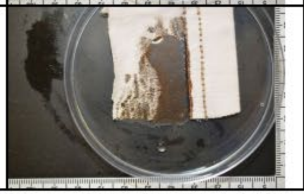
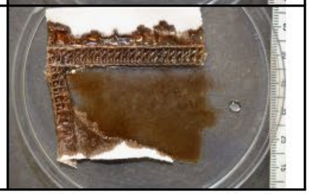
	0 MIN	5 MIN	10 MIN	30 MIN	1 HOUR	24HRS
WCH2SO						
WCH2SO						
WCH2SO						
WCH2SO						
WCH2SO						

Figure 21: Sulphuric Acid - 80% on White Cotton

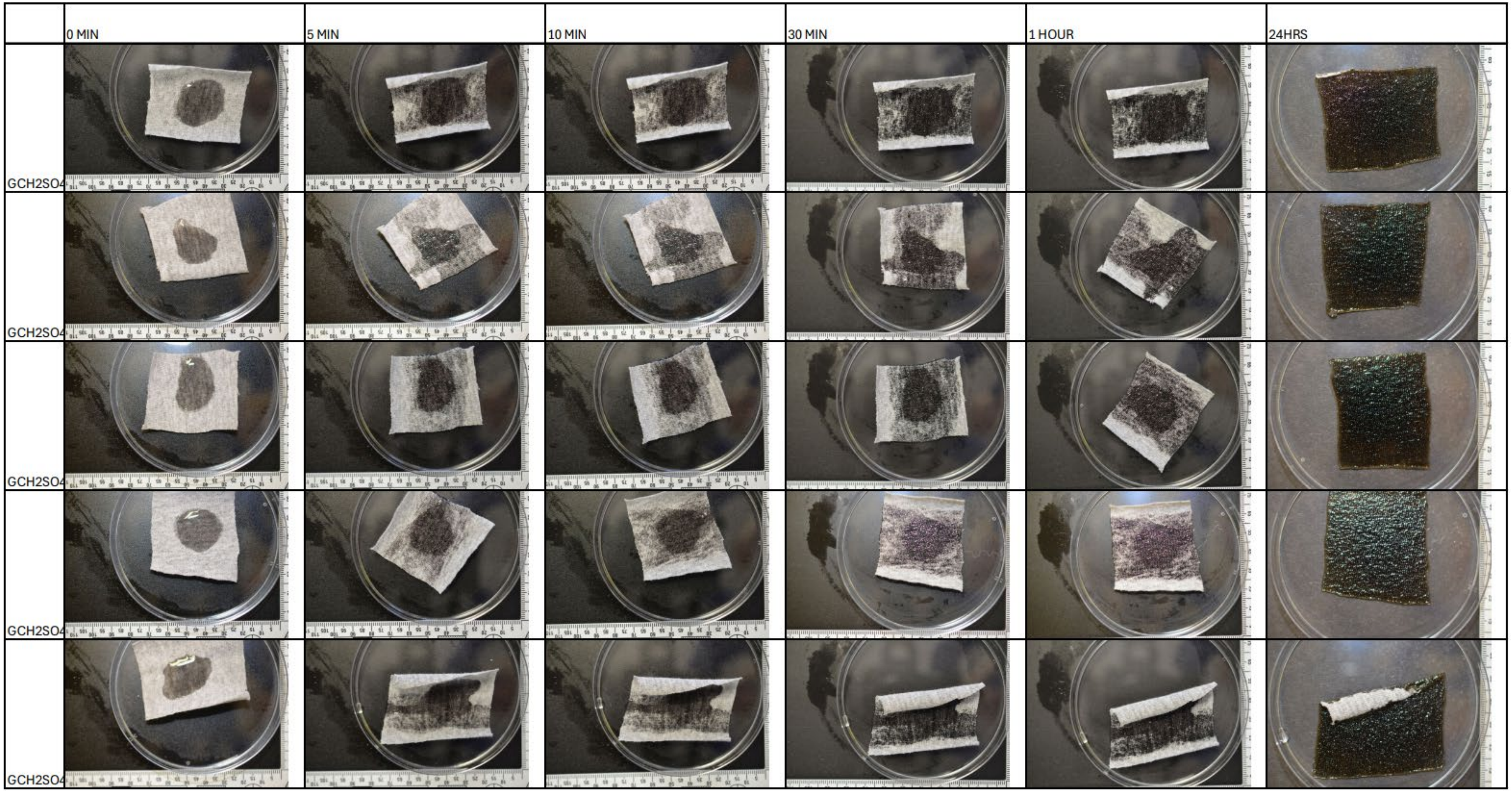


Figure 22: Sulphuric Acid - 80% on Grey Cotton

Figure 23: Sulphuric Acid - 80% on Pink Polyester

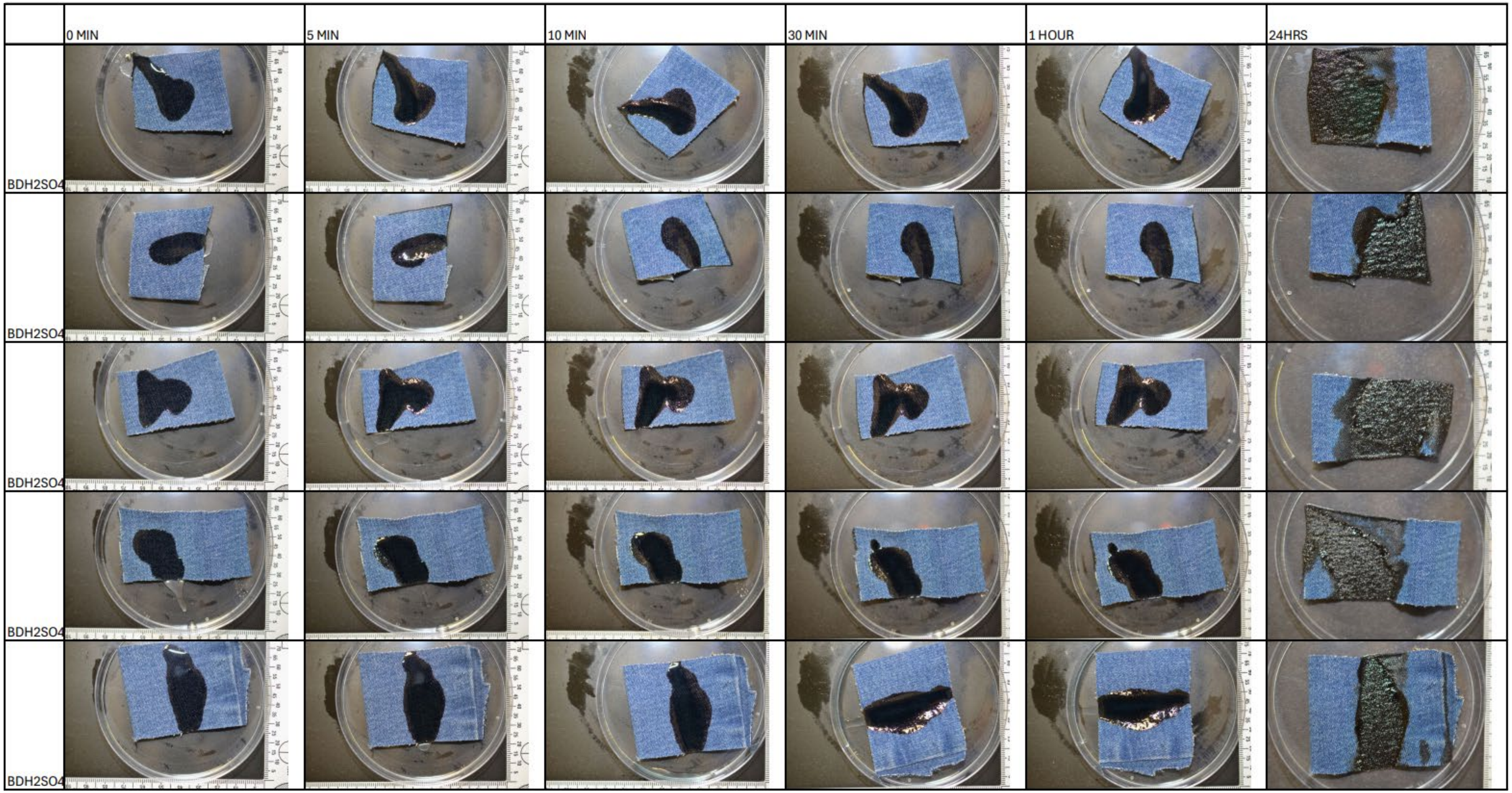


Figure 24: Sulphuric Acid - 80% on Blue Denim

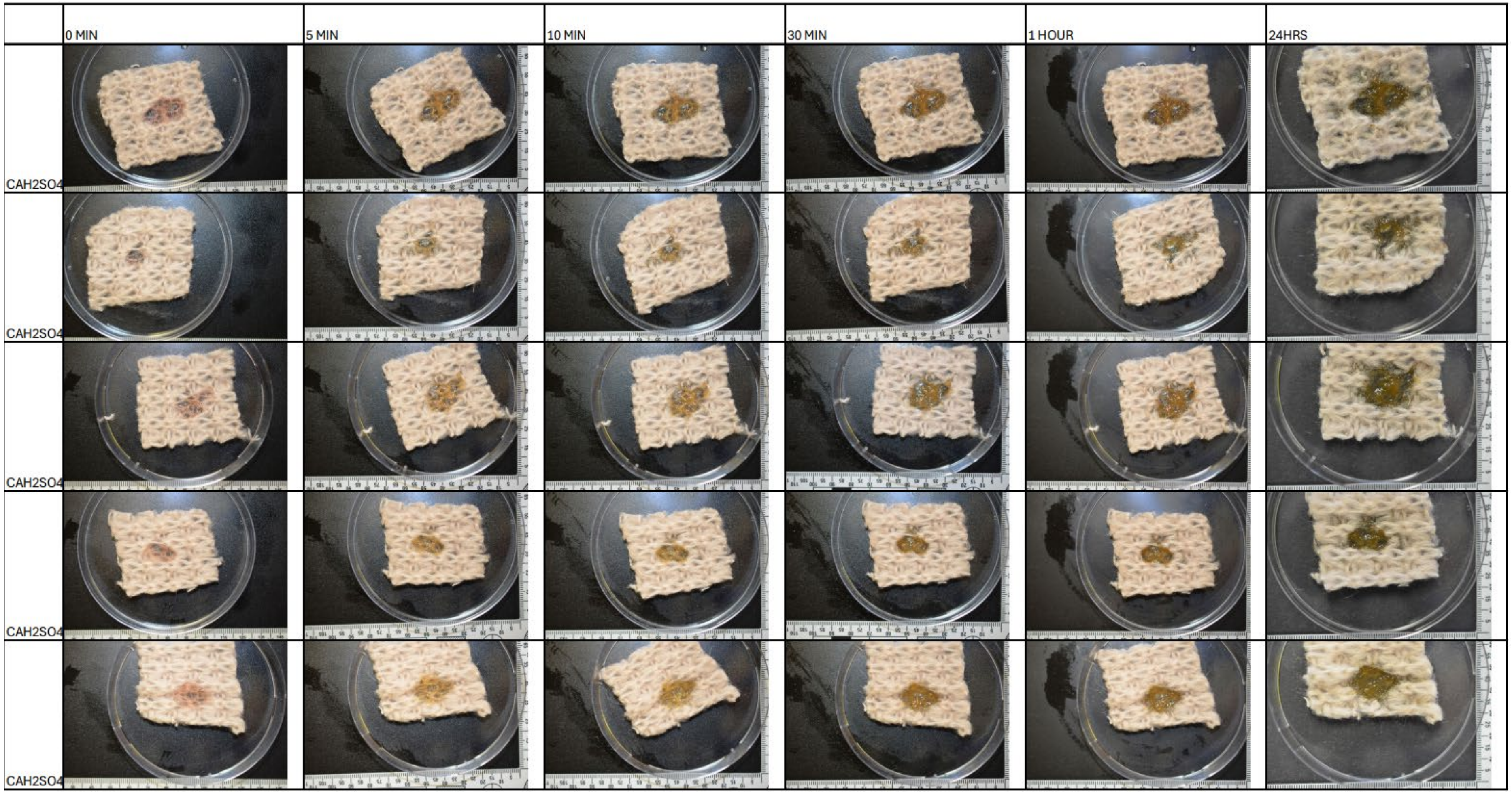


Figure 25: Sulphuric Acid - 80% on Cream Acrylic

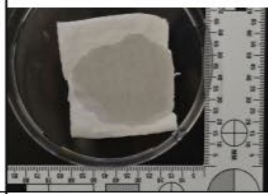
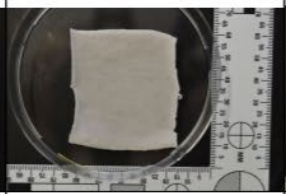
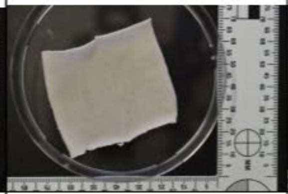
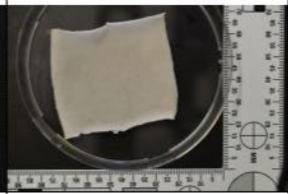
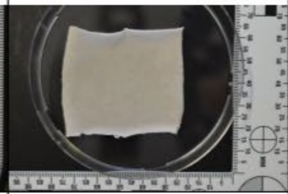
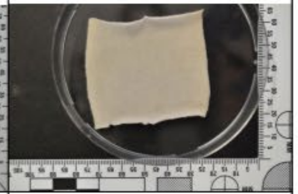
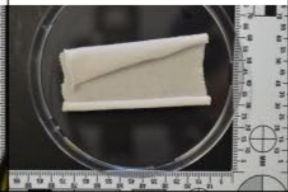
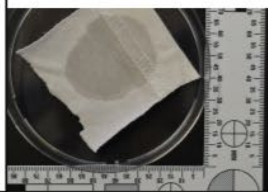
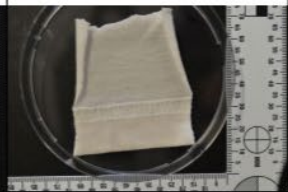
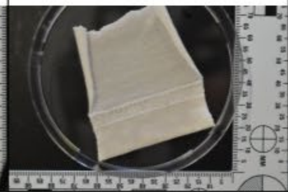
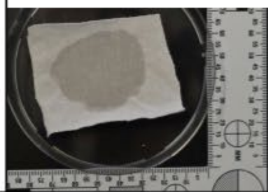
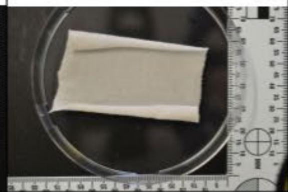
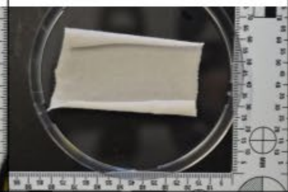
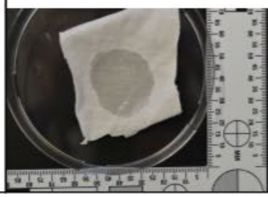
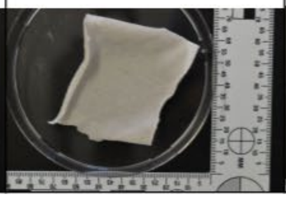
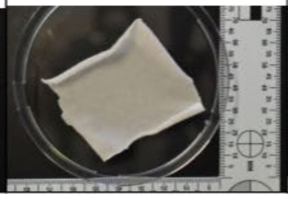
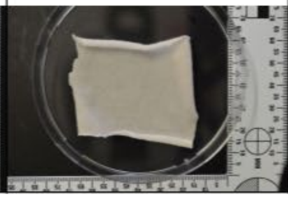
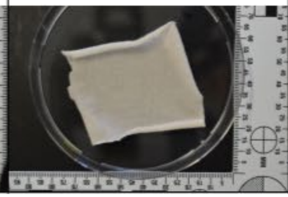
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
WCHCL1						
WCHCL2						
WCHCL3						
WCHCL4						
WCHCL5						

Figure 26: Hydrochloric Acid - 50% on White Cotton

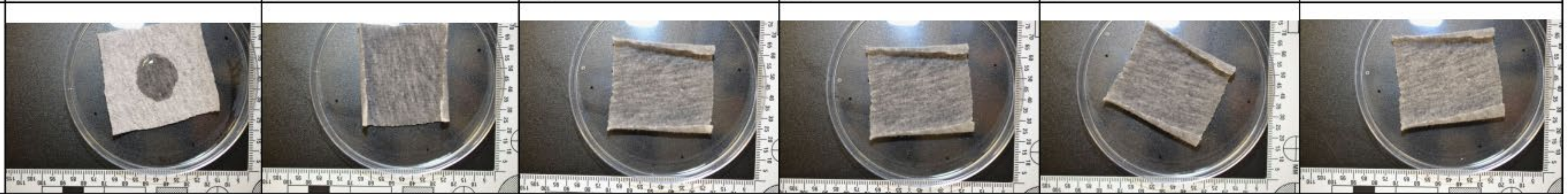
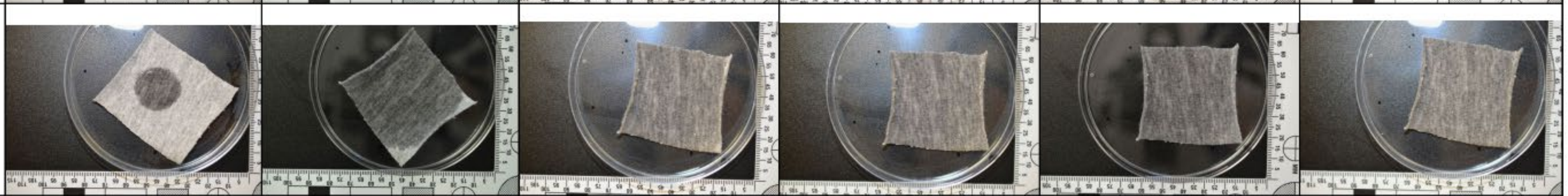
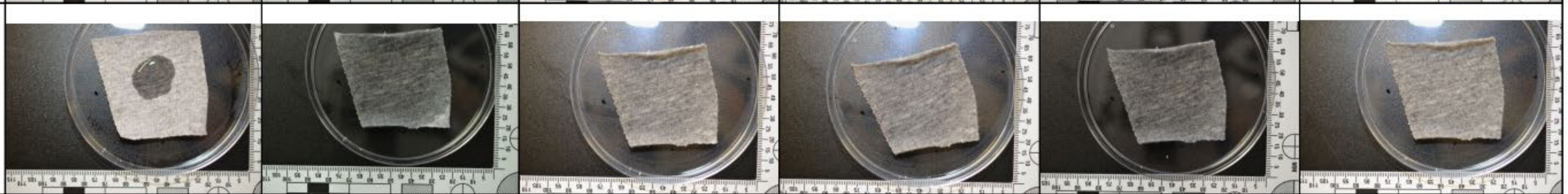
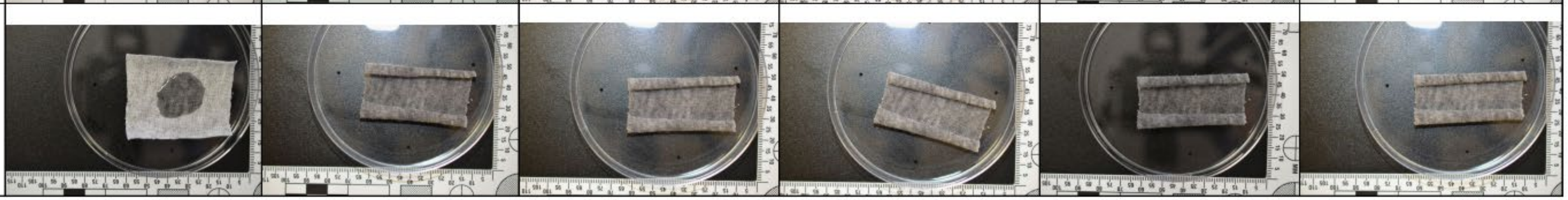
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
GCHCL1						
GCHCL2						
GCHCL3						
GCHCL4						
GCHCL5						

Figure 27: Hydrochloric Acid - 50% on Grey Cotton

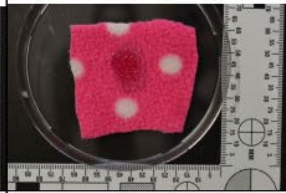
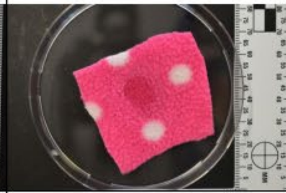
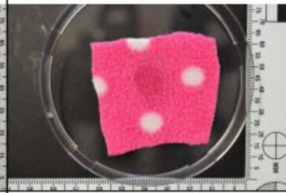
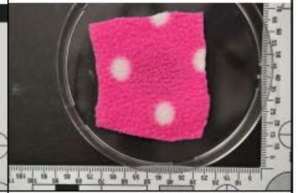
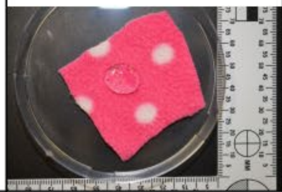
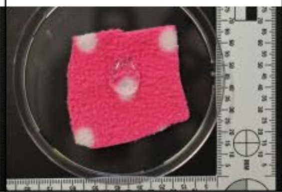
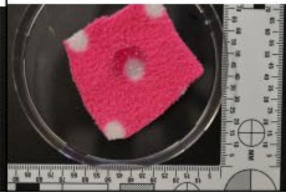
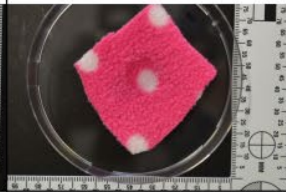
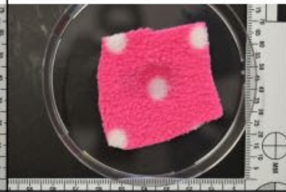
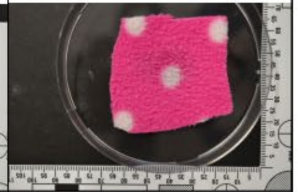
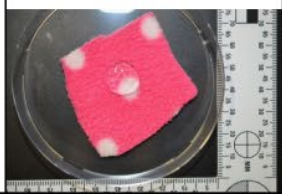
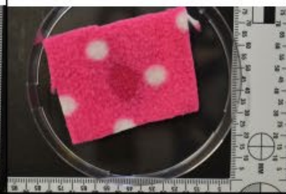
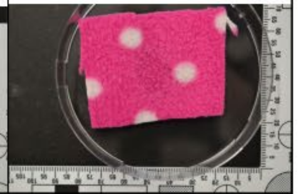
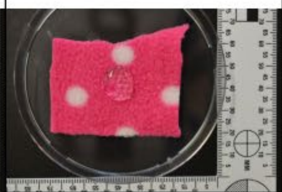
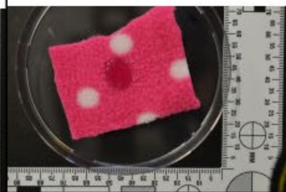
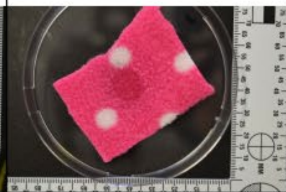
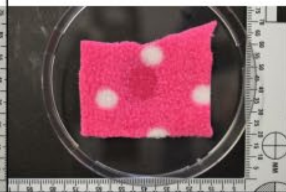
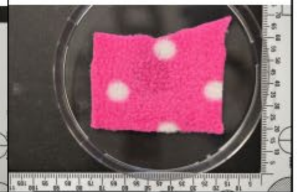
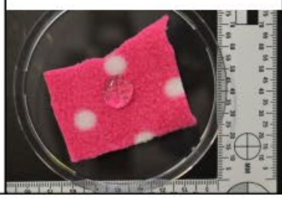
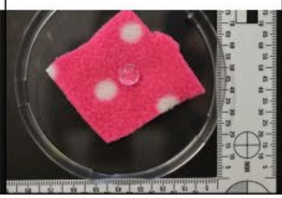
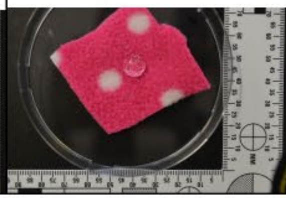
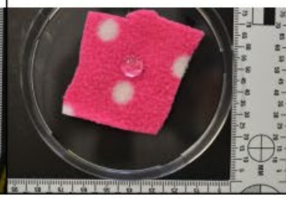
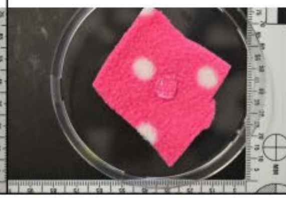
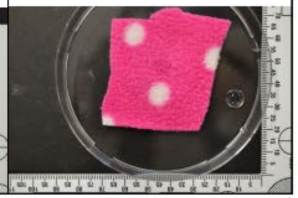
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
PPHCL1						
PPHCL2						
PPHCL3						
PPHCL4						
PPHCL5						

Figure 28: Hydrochloric Acid - 50% on Pink Polyester

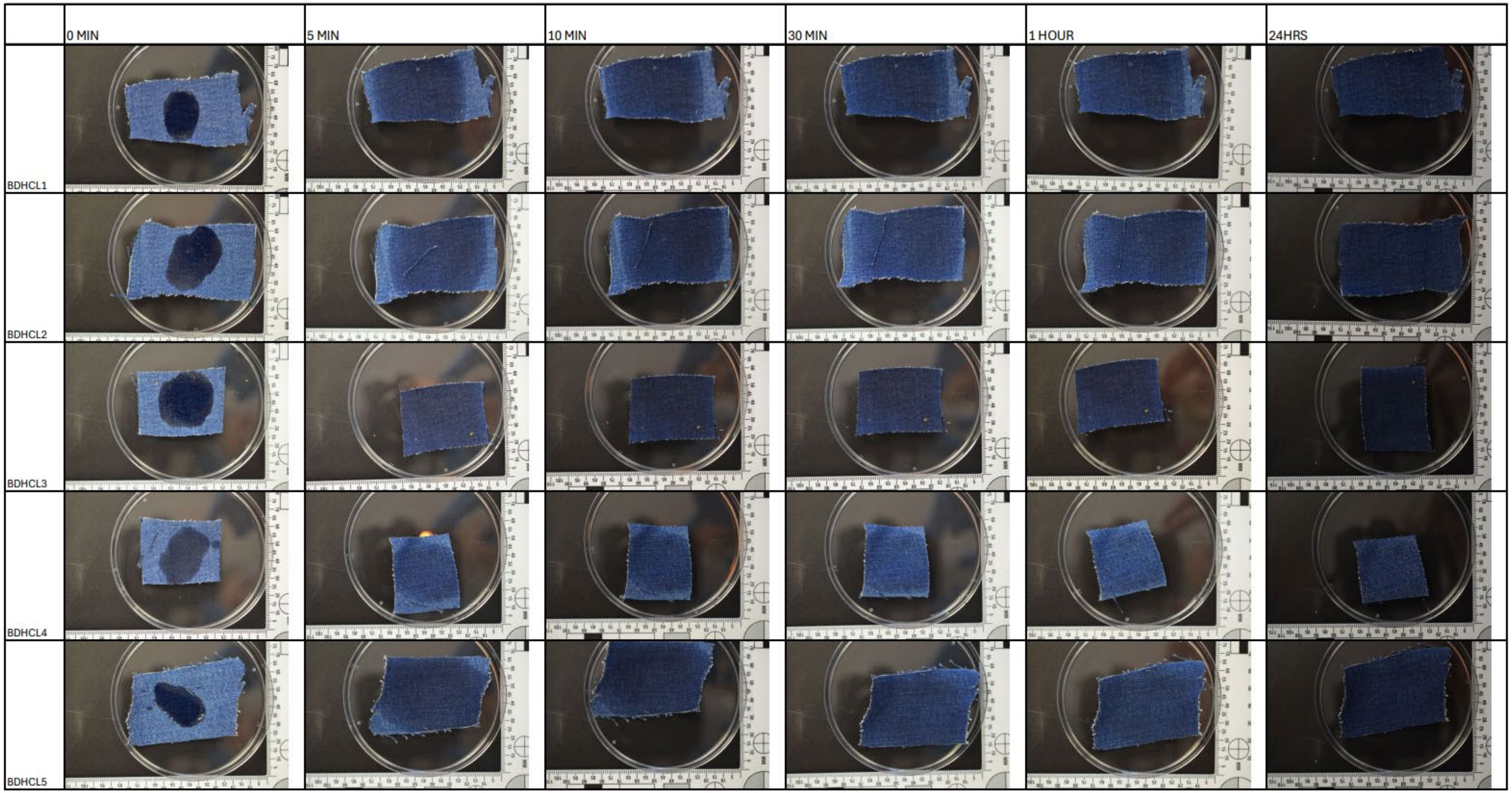


Figure 29: Hydrochloric Acid - 50% on Blue Denim

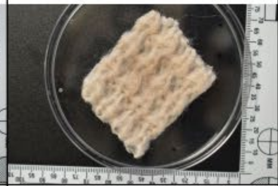
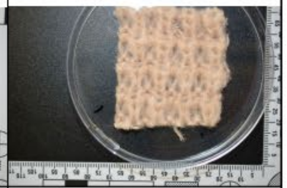
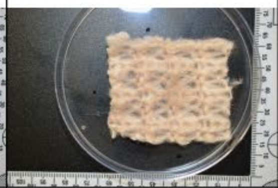
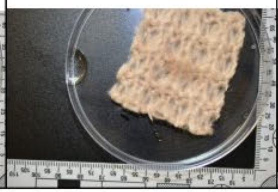
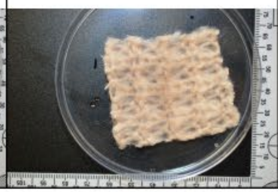
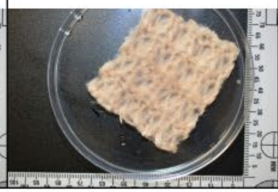
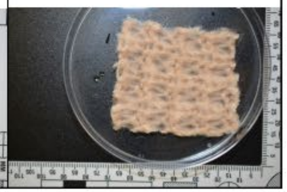
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
CAHCL1						
CAHCL2						
CAHCL3						
CAHCL4						
CAHCL5						

Figure 30: Hydrochloric Acid - 50% on Cream Acrylic

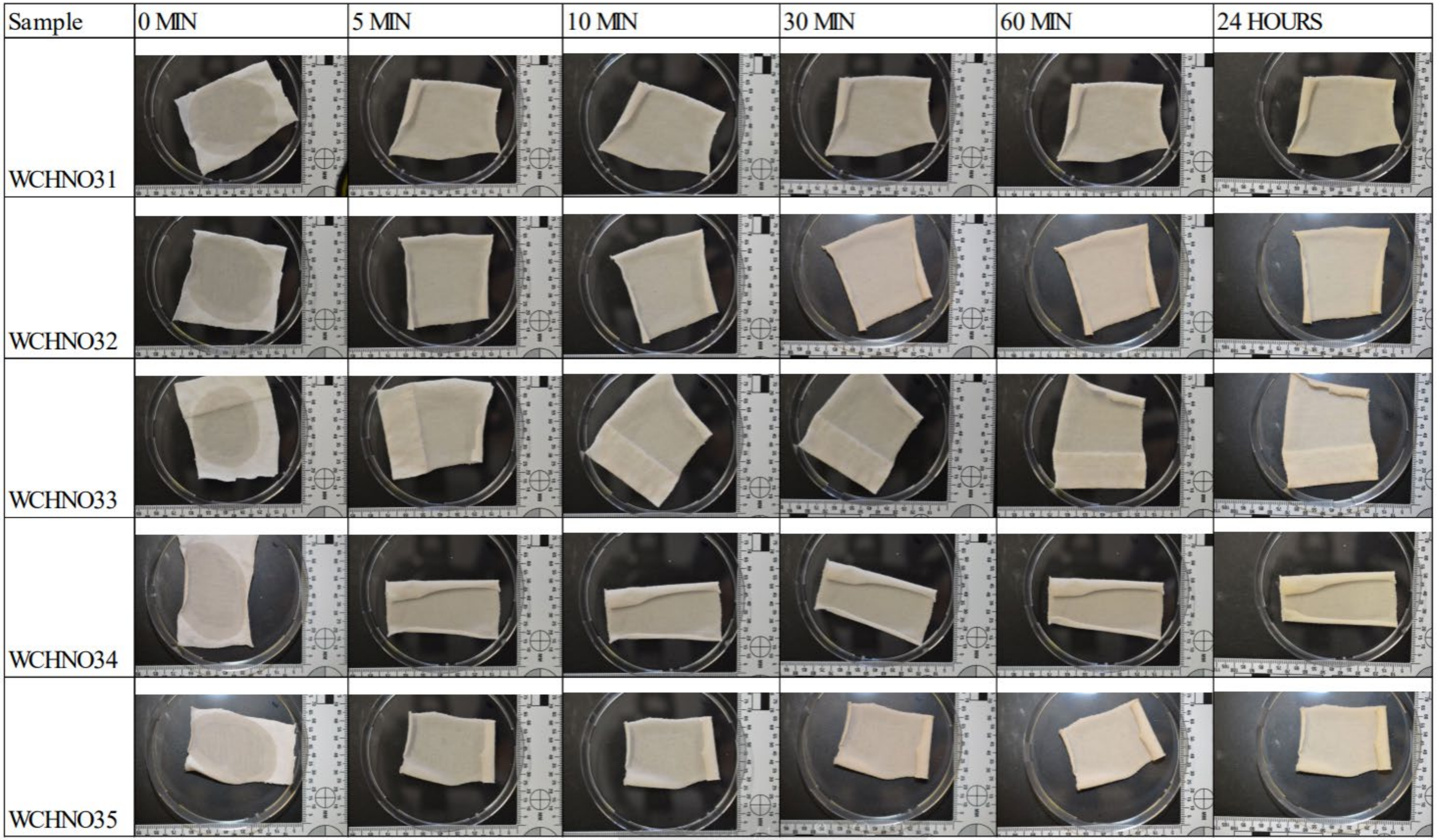


Figure 31: Nitric Acid - 50% on White Cotton

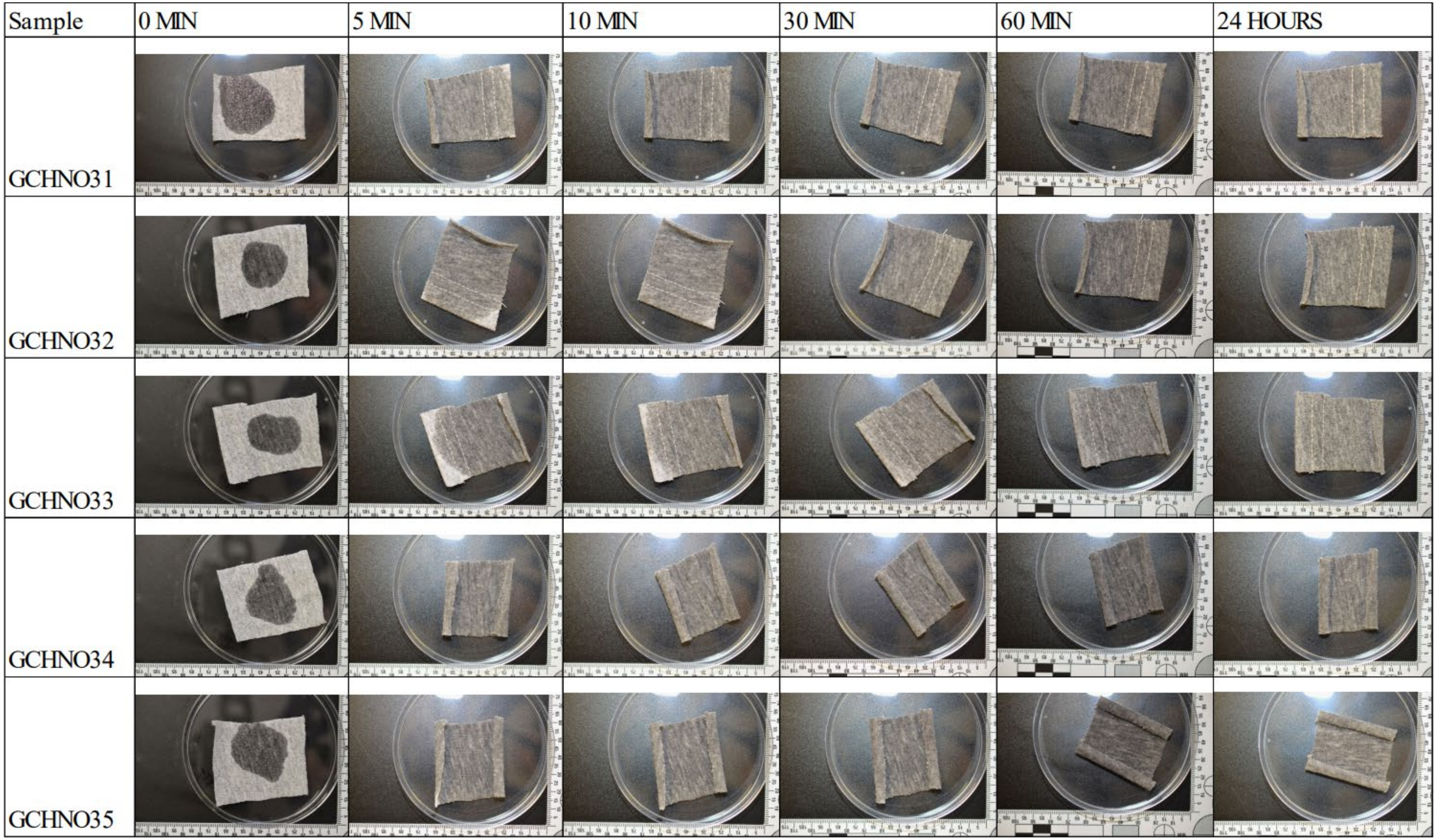


Figure 32: Nitric Acid - 50% on Grey Cotton

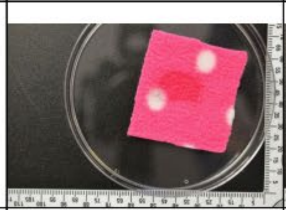
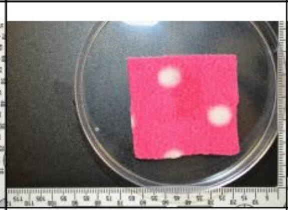
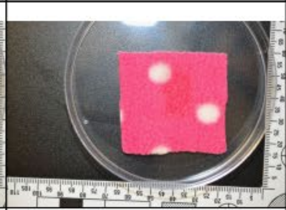
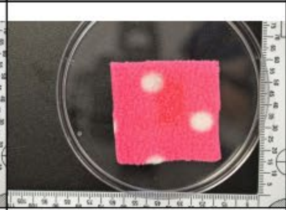
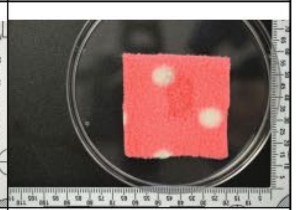
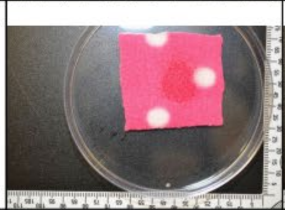
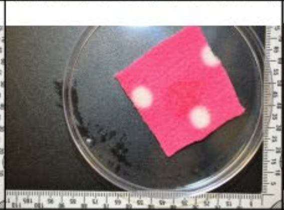
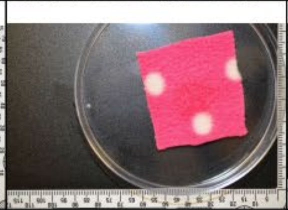
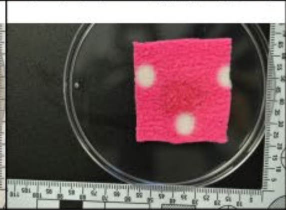
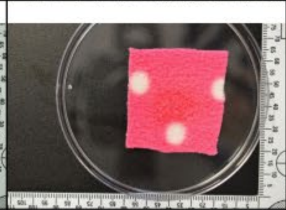
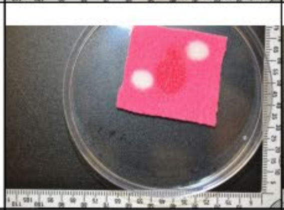
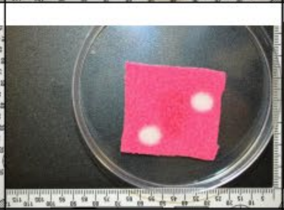
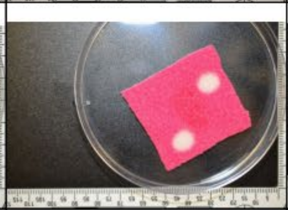
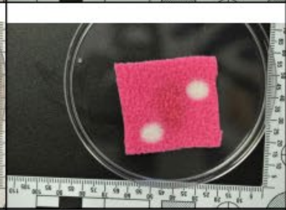
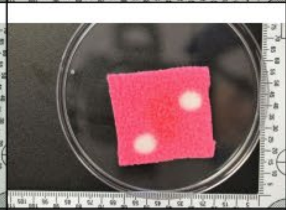
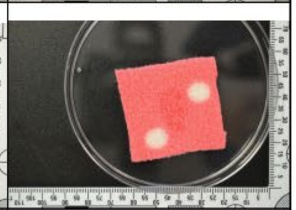
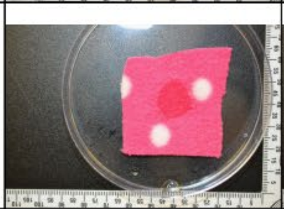
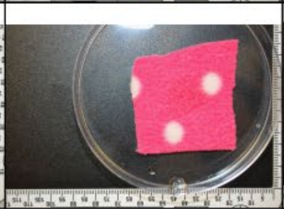
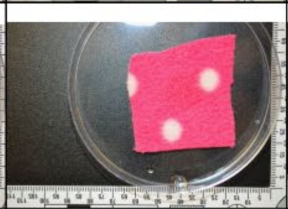
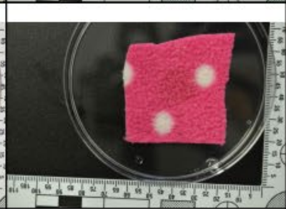
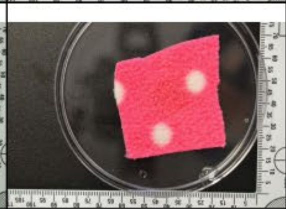
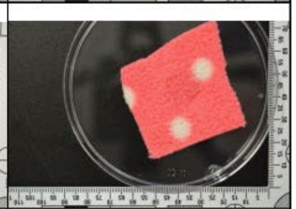
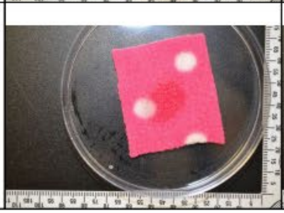
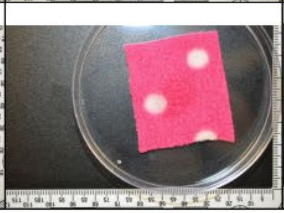
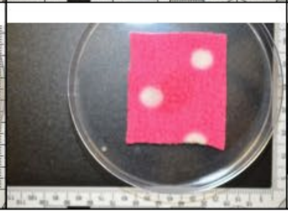
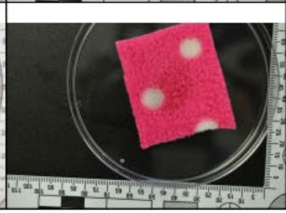
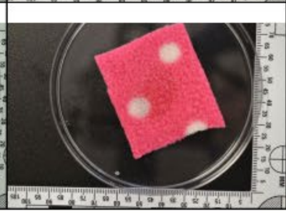
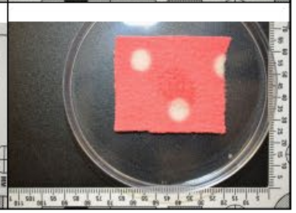
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
PPHNO31						
PPHNO32						
PPHNO33						
PPHNO34						
PPHNO35						

Figure 33: Nitric Acid - 50% on Pink Polyester

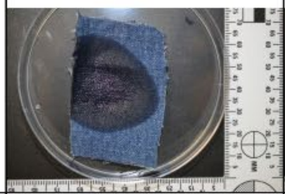
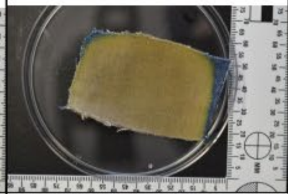
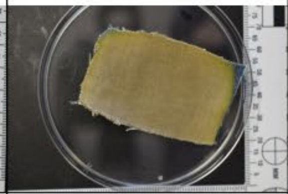
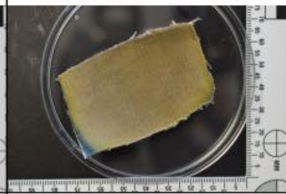
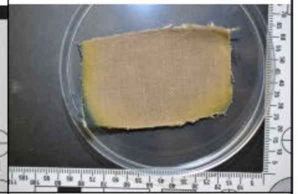
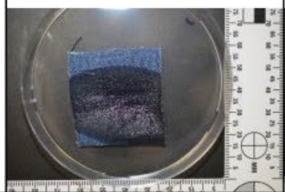
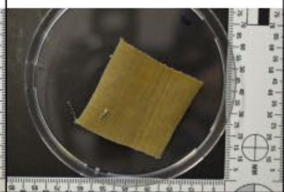
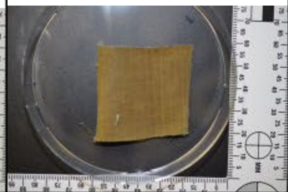
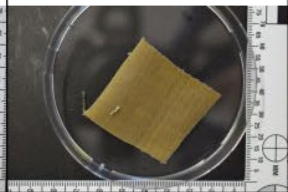
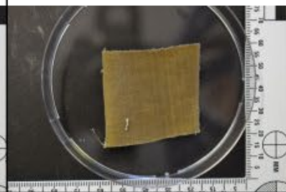
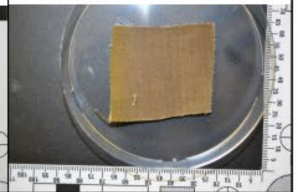
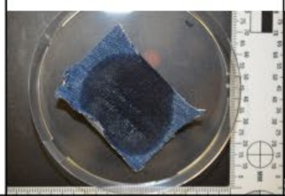
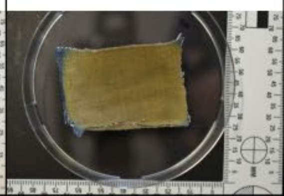
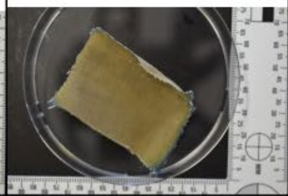
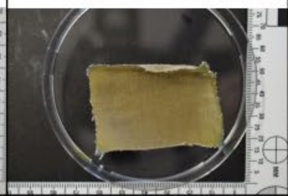
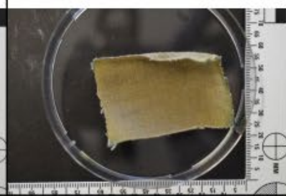
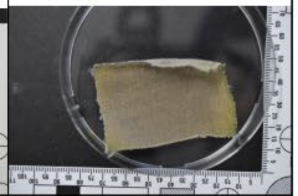
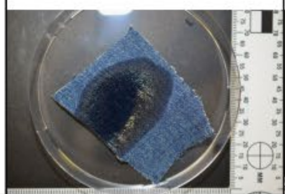
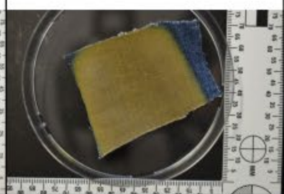
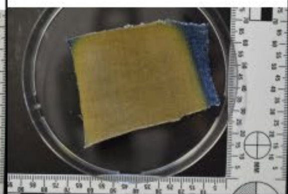
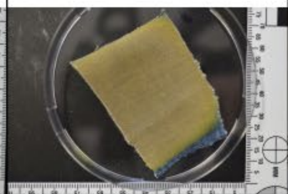
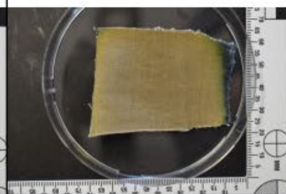
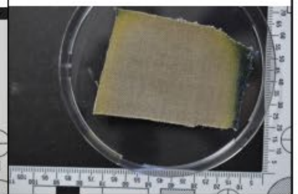
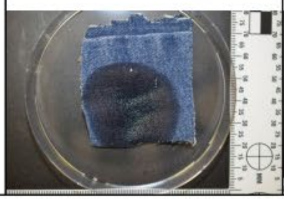
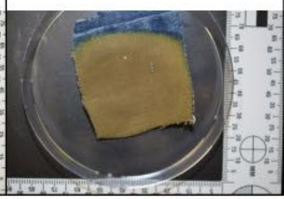
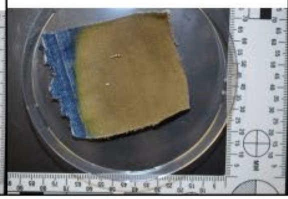
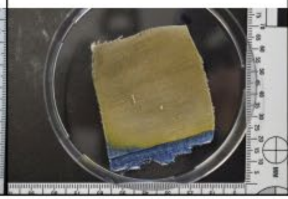
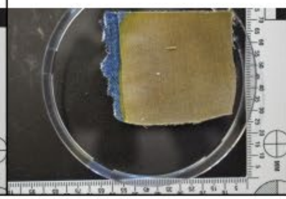
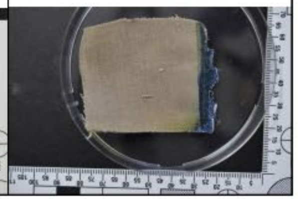
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
BDHNO31						
BDHNO32						
BDHNO33						
BDHNO34						
BDHNO35						

Figure 34: Nitric Acid - 50% on Blue Denim

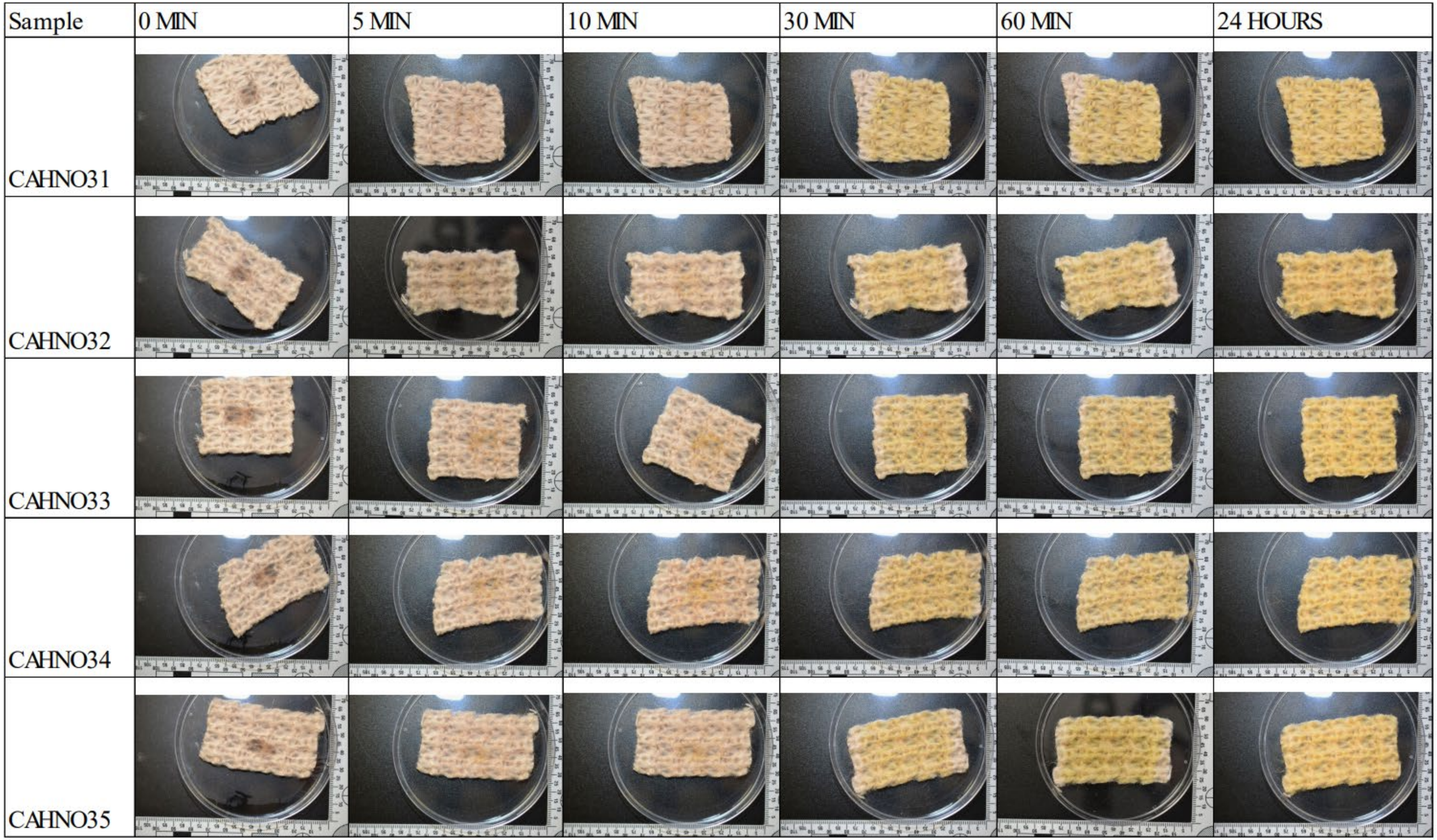


Figure 35: Nitric Acid - 50% on Cream Acrylic

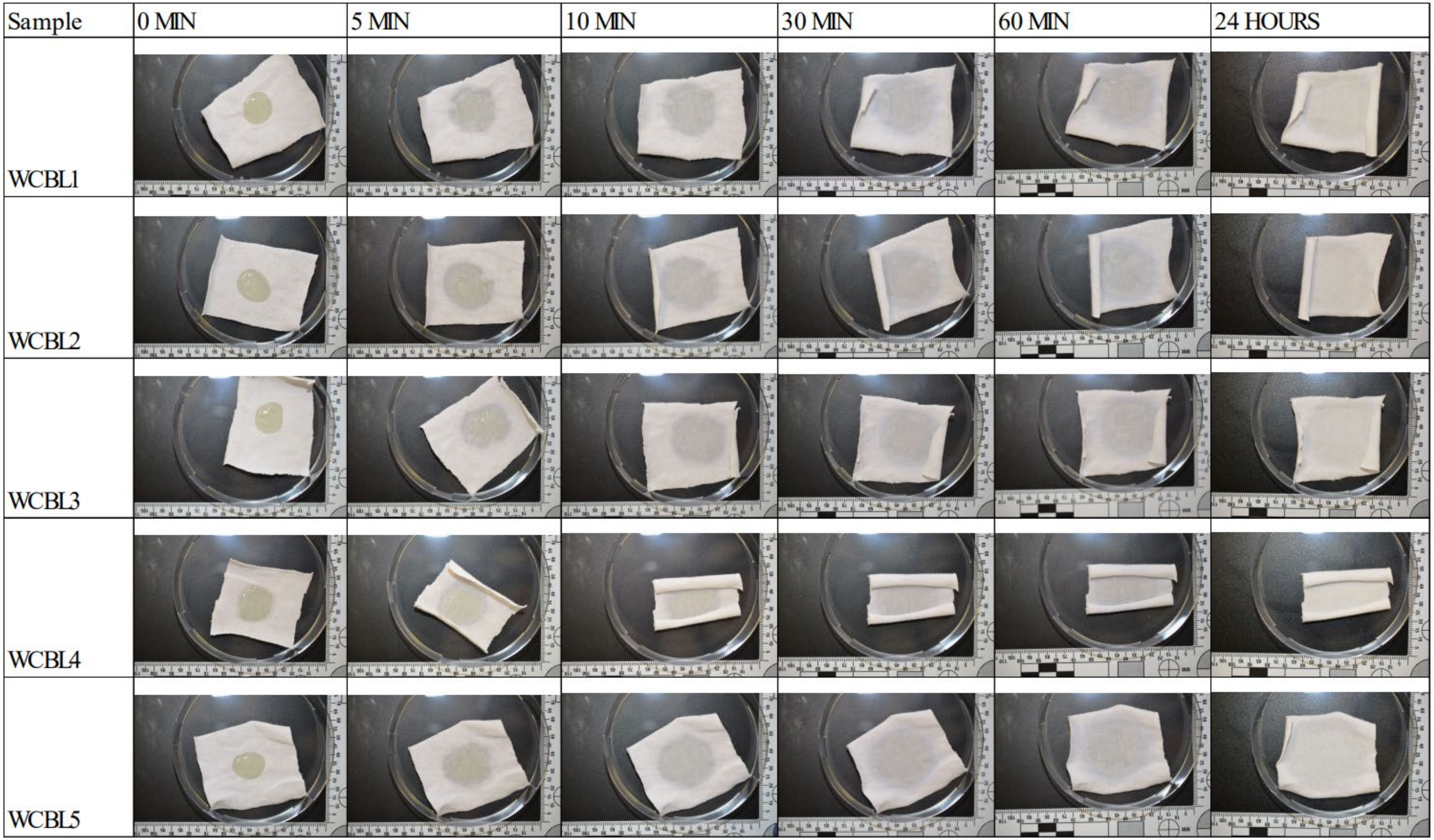


Figure 36: Domestos Original Bleach on White Cotton

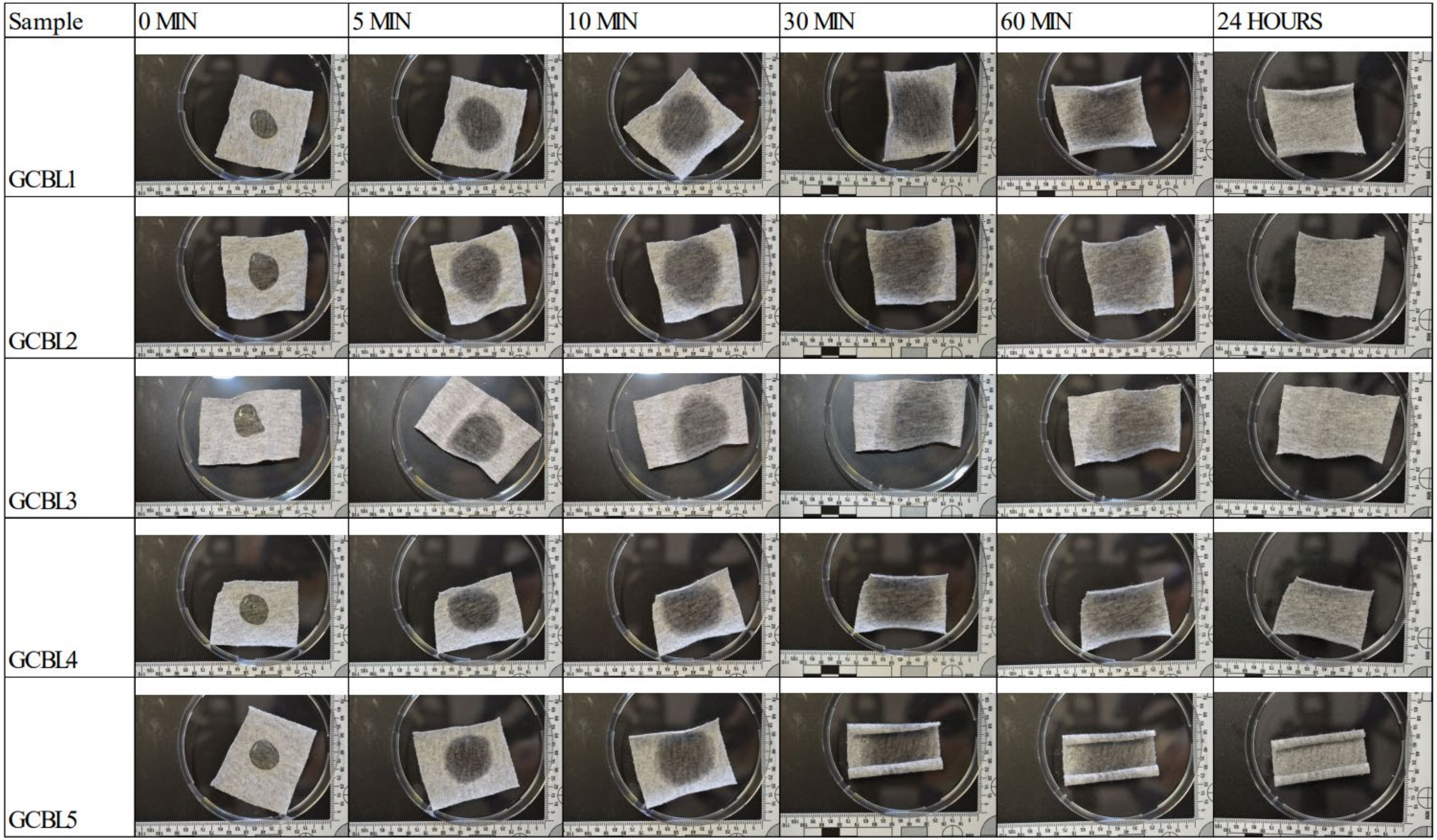


Figure 37: Domestos Original Bleach on Grey Cotton

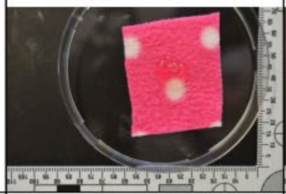
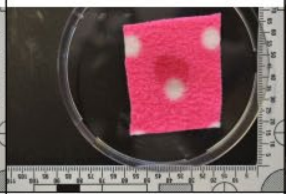
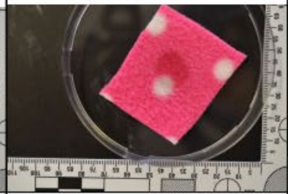
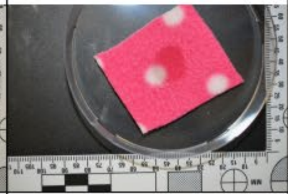
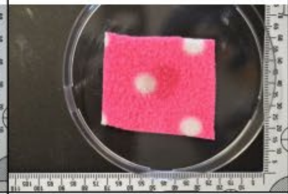
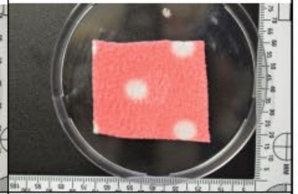
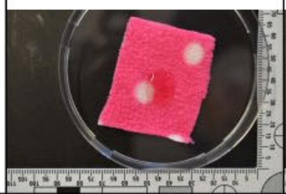
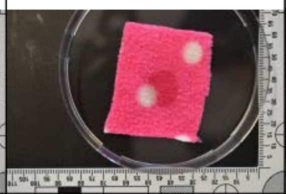
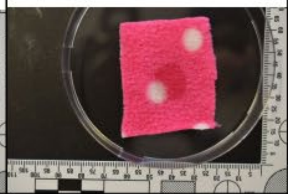
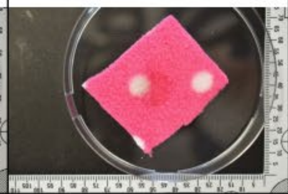
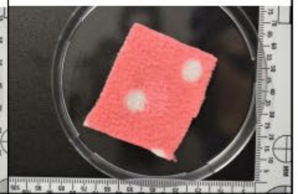
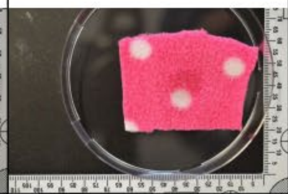
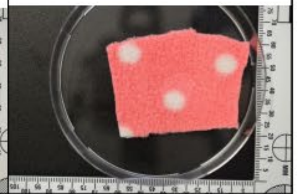
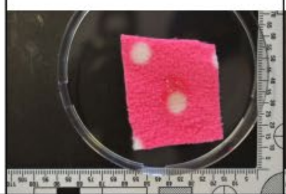
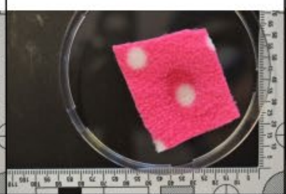
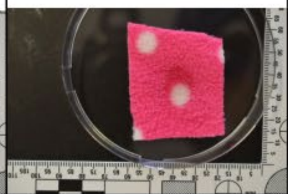
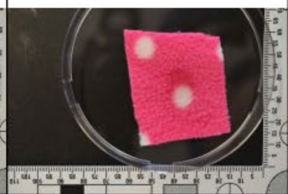
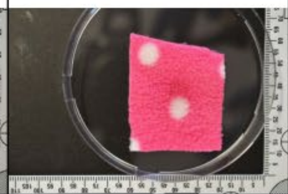
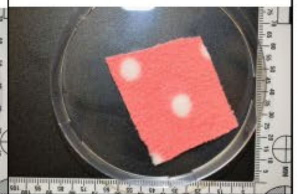
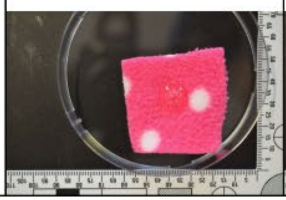
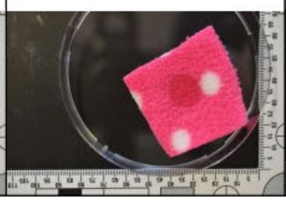
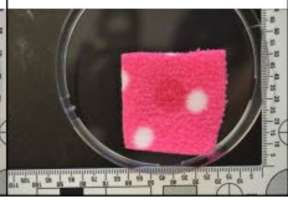
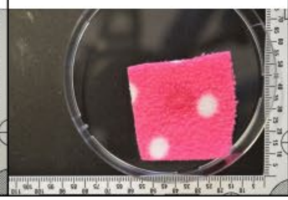
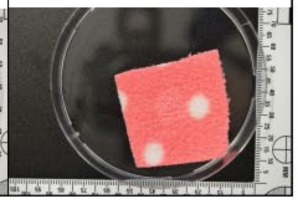
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
PPBL1						
PPBL2						
PPBL3						
PPBL4						
PPBL5						

Figure 38: Domestos Original Bleach on Pink Polyester

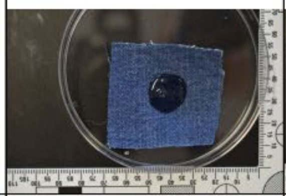
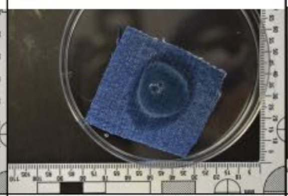
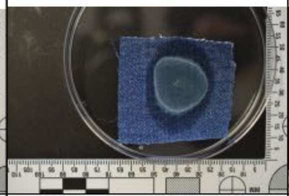
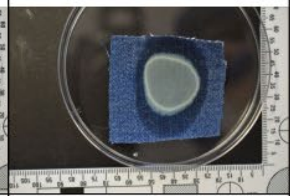
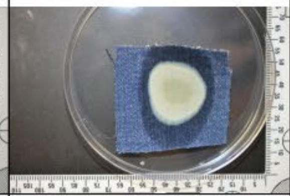
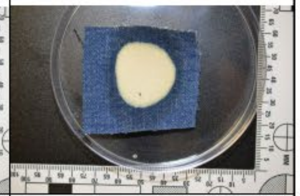
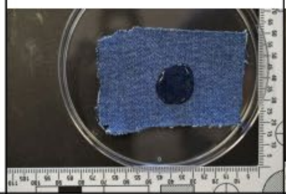
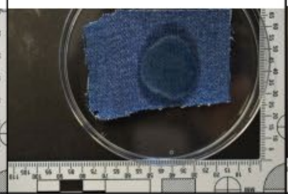
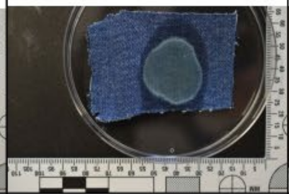
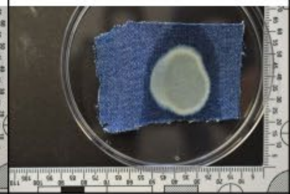
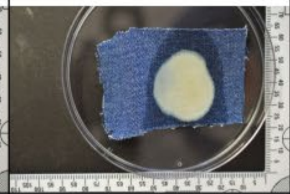
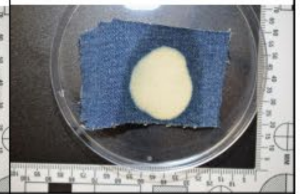
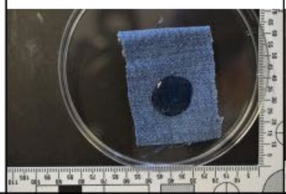
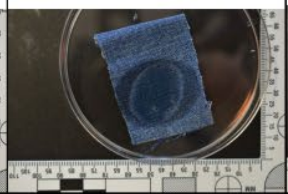
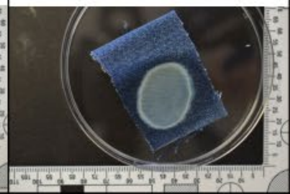
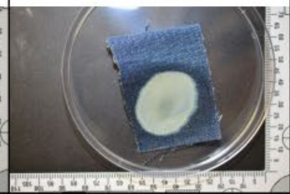
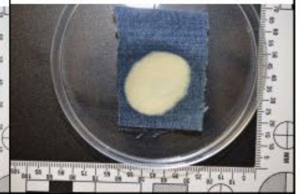
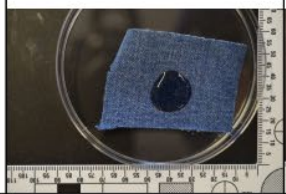
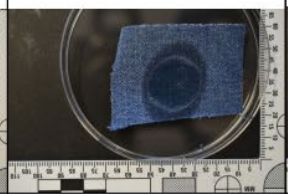
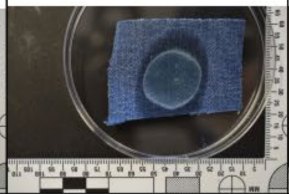
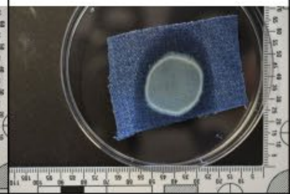
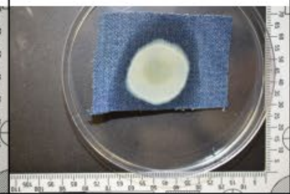
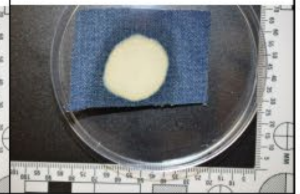
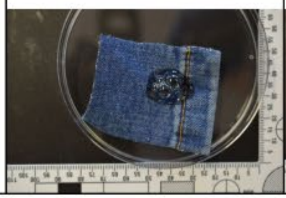
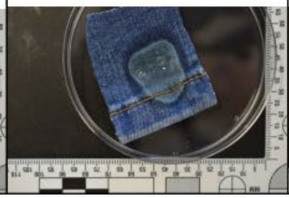
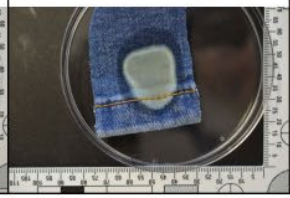
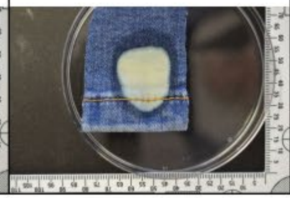
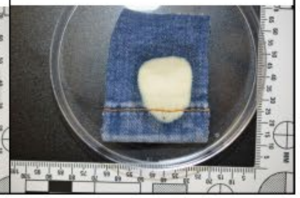
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
BDBL1						
BDBL2						
BDBL3						
BDBL4						
BDBL5						

Figure 39: Domestos Original Bleach on Blue Denim

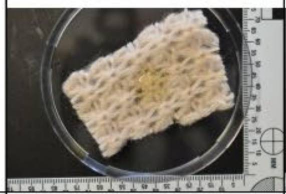
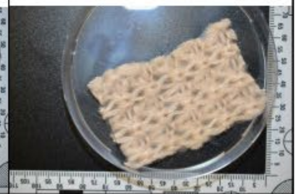
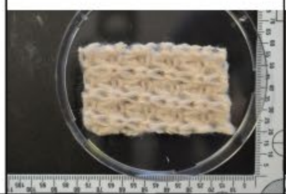
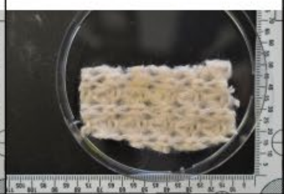
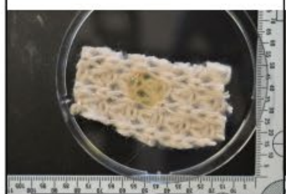
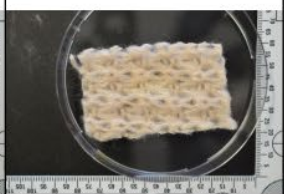
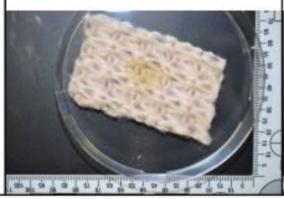
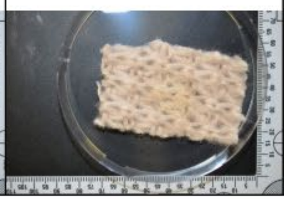
Sample	0 MIN	5 MIN	10 MIN	30 MIN	60 MIN	24 HOURS
CABL1						
CABL2						
CABL3						
CABL4						
CABL5						

Figure 40: Domestos Original Bleach on Cream Acrylic

Figure 41: Sulphuric Acid - 40% on White Cotton

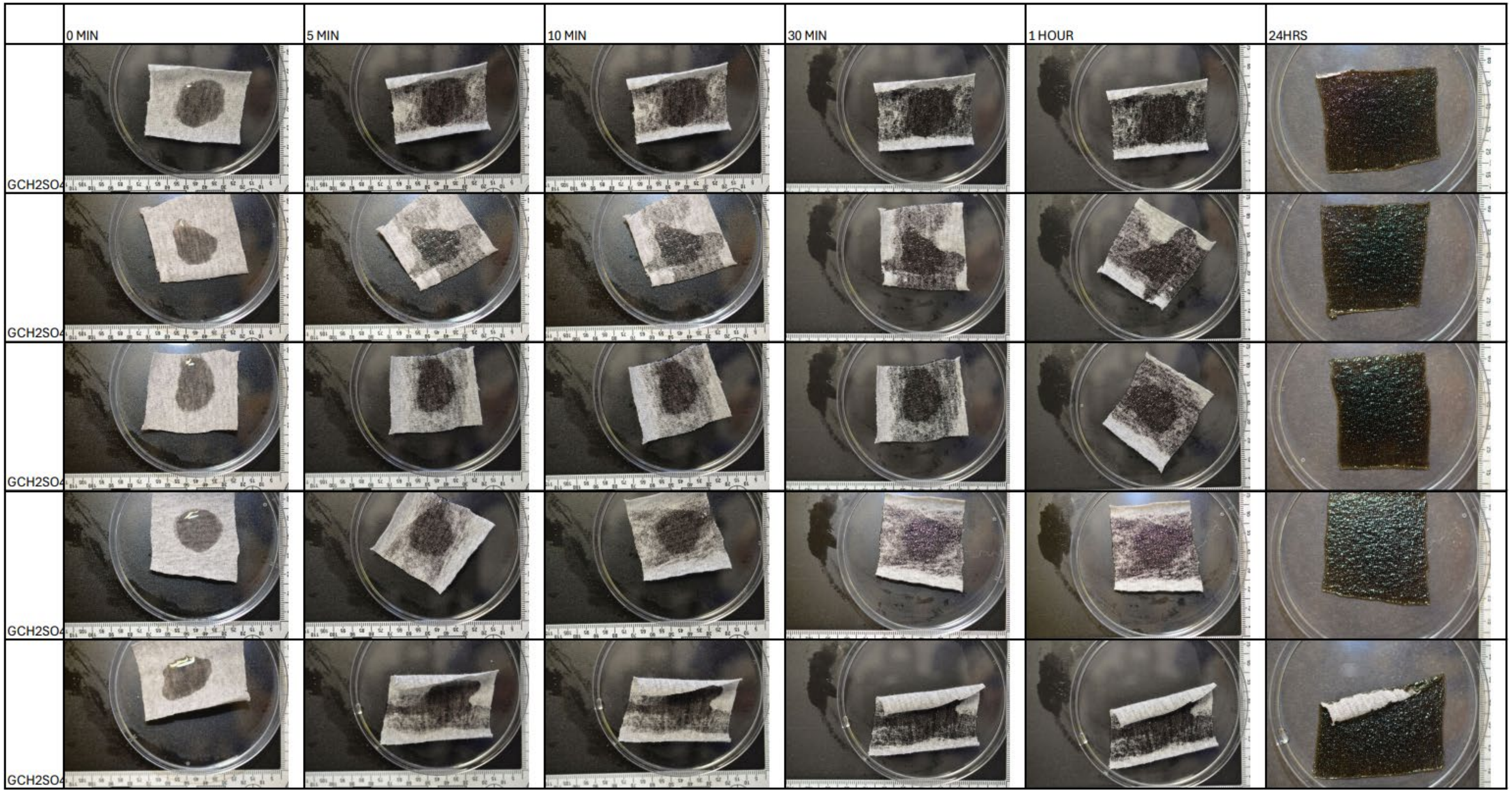


Figure 42: Sulphuric Acid - 40% on Grey Cotton

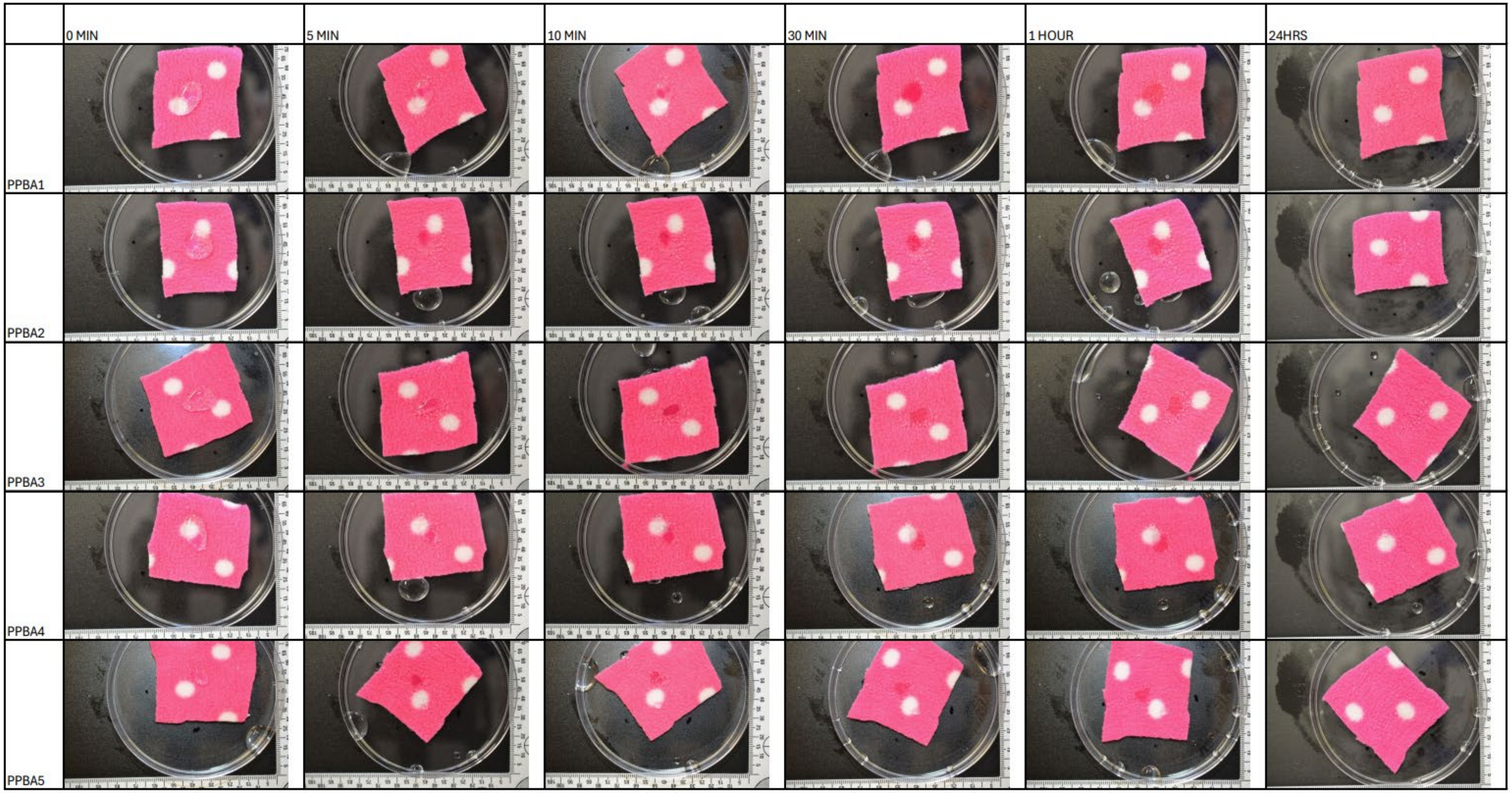


Figure 43: Sulphuric Acid - 40% on Pink Polyester

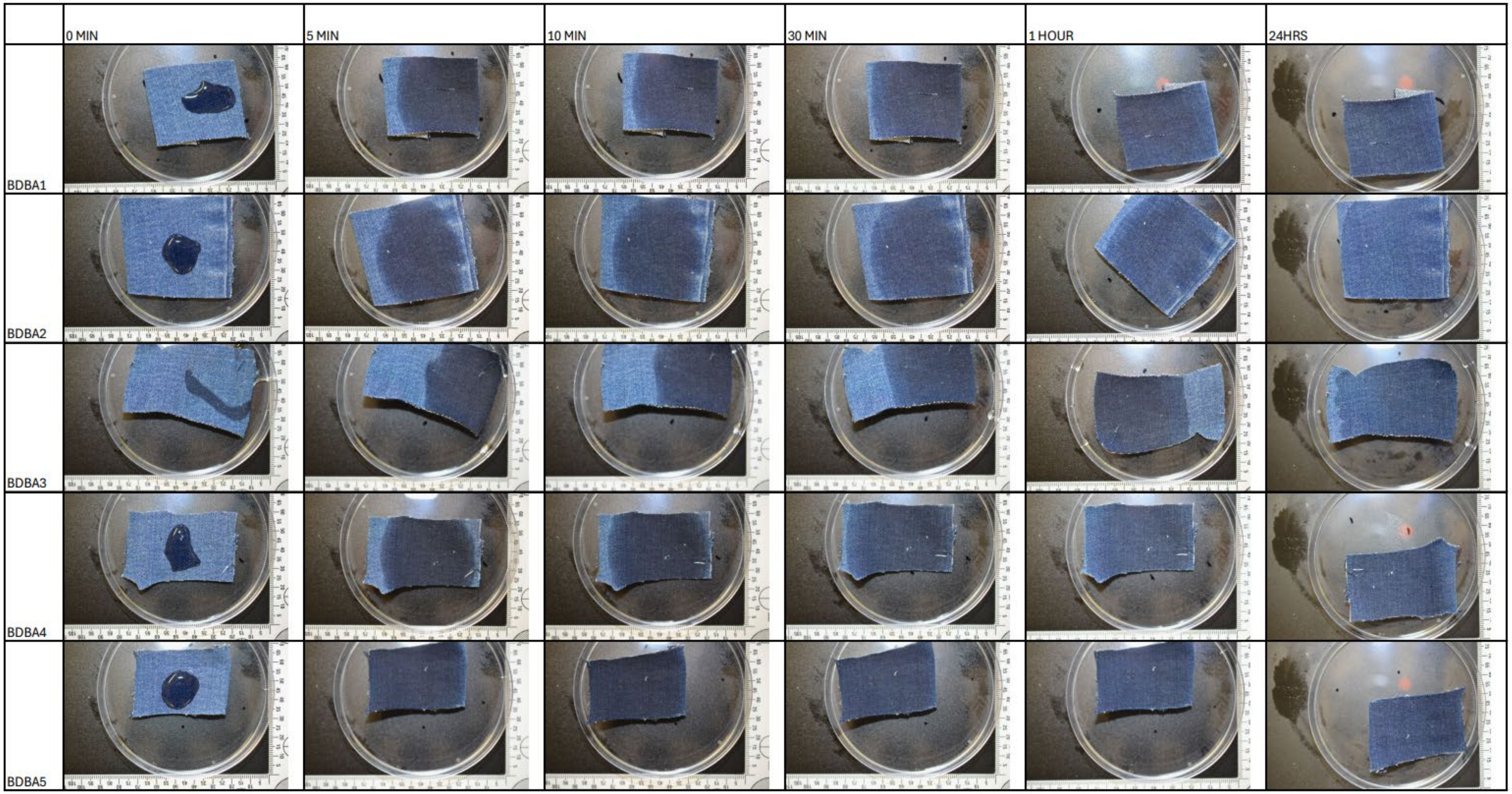


Figure 44: Sulphuric Acid - 40% on Blue Denim

Figure 45: Sulphuric Acid - 40% on Cream Acrylic

Appendix D – Grades assigned to the Area of Colour Change

				0 minutes	5 minutes	10 minutes	30 minutes	60 minutes	24 hours
SAMPLE CODE	Repeat Number	Fabric	Chemical	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change
WCH2SO41	1	White Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Substantial
WCH2SO42	2	White Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Substantial
WCH2SO43	3	White Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Substantial
WCH2SO44	4	White Cotton	H2SO4	Central	Central	Central	Central	Substantial	Substantial
WCH2SO45	5	White Cotton	H2SO4	Central	Central	Central	Central	Substantial	Substantial
GCH2SO41	1	Grey Cotton	H2SO4	Central	Substantial	Substantial	Substantial	Substantial	Whole
GCH2SO42	2	Grey Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Whole
GCH2SO43	3	Grey Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Whole
GCH2SO44	4	Grey Cotton	H2SO4	Central	Central	Central	Substantial	Substantial	Whole
GCH2SO45	5	Grey Cotton	H2SO4	Central	Substantial	Substantial	Substantial	Substantial	Substantial
PPH2SO41	1	Pink Polyester	H2SO4	Central	Central	Central	Central	Central	Central
PPH2SO42	2	Pink Polyester	H2SO4	Central	Central	Central	Central	Central	Central
PPH2SO43	3	Pink Polyester	H2SO4	Central	Central	Central	Central	Central	Central
PPH2SO44	4	Pink Polyester	H2SO4	Central	Central	Central	Central	Central	Central
PPH2SO45	5	Pink Polyester	H2SO4	Central	Central	Central	Central	Central	Central
BDH2SO41	1	Blue Denim	H2SO4	Central	Central	Central	Central	Central	Substantial
BDH2SO42	2	Blue Denim	H2SO4	Central	Central	Central	Central	Central	Substantial
BDH2SO43	3	Blue Denim	H2SO4	Central	Central	Central	Central	Central	Substantial
BDH2SO44	4	Blue Denim	H2SO4	Central	Central	Central	Central	Central	Substantial
BDH2SO45	5	Blue Denim	H2SO4	Central	Central	Central	Central	Central	Central
CAH2SO41	1	Cream Acrylic	H2SO4	Central	Central	Central	Central	Central	Central
CAH2SO42	2	Cream Acrylic	H2SO4	Central	Central	Central	Central	Central	Central
CAH2SO43	3	Cream Acrylic	H2SO4	Central	Central	Central	Central	Central	Central
CAH2SO44	4	Cream Acrylic	H2SO4	Central	Central	Central	Central	Central	Central
CAH2SO45	5	Cream Acrylic	H2SO4	Central	Central	Central	Central	Central	Central

Figure 46: Area of Colour Change grades for Sulphuric Acid - 80%

				0 minutes	5 minutes	10 minutes	30 minutes	60 minutes	24 hours
SAMPLE CODE	Repeat Number	Fabric	Chemical	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change
WCHCL1	1	White Cotton	HCL	Central	Central	Substantial	Substantial	Substantial	Whole
WCHCL2	2	White Cotton	HCL	Central	Substantial	Substantial	Substantial	Substantial	Whole
WCHCL3	3	White Cotton	HCL	Central	Substantial	Substantial	Substantial	Substantial	Whole
WCHCL4	4	White Cotton	HCL	Central	Substantial	Substantial	Substantial	Substantial	Whole
WCHCL5	5	White Cotton	HCL	Central	Central	Substantial	Substantial	Substantial	Whole
GCHCL1	1	Grey Cotton	HCL	Central	Substantial	Substantial	Substantial	Substantial	Substantial
GCHCL2	2	Grey Cotton	HCL	Central	Substantial	Whole	Substantial	Substantial	Substantial
GCHCL3	3	Grey Cotton	HCL	Central	Substantial	Substantial	Whole	Whole	Substantial
GCHCL4	4	Grey Cotton	HCL	Central	Substantial	Substantial	Whole	Whole	Substantial
GCHCL5	5	Grey Cotton	HCL	Central	Whole	Whole	Whole	Whole	Whole
PPHCL1	1	Pink Polyester	HCL	Absent	Central	Central	Central	Central	Substantial
PPHCL2	2	Pink Polyester	HCL	Central	Central	Central	Central	Central	Substantial
PPHCL3	3	Pink Polyester	HCL	Central	Central	Central	Central	Central	Substantial
PPHCL4	4	Pink Polyester	HCL	Central	Central	Central	Central	Central	Substantial
PPHCL5	5	Pink Polyester	HCL	Central	Central	Central	Central	Central	Substantial
BDHCL1	1	Blue Denim	HCL	Central	Substantial	Substantial	Substantial	Substantial	Whole
BDHCL2	2	Blue Denim	HCL	Central	Central	Central	Substantial	Substantial	Whole
BDHCL3	3	Blue Denim	HCL	Central	Substantial	Whole	Whole	Whole	Whole
BDHCL4	4	Blue Denim	HCL	Central	Central	Central	Central	Substantial	Whole
BDHCL5	5	Blue Denim	HCL	Central	Substantial	Substantial	Substantial	Substantial	Whole
CAHCL1	1	Cream Acrylic	HCL	Central	Central	Central	Central	Absent	Absent
CAHCL2	2	Cream Acrylic	HCL	Central	Central	Central	Central	Absent	Absent
CAHCL3	3	Cream Acrylic	HCL	Central	Central	Central	Central	Absent	Absent
CAHCL4	4	Cream Acrylic	HCL	Central	Central	Central	Central	Absent	Absent
CAHCL5	5	Cream Acrylic	HCL	Central	Central	Central	Central	Absent	Absent

Figure 47: Area of Colour Change grades for Hydrochloric Acid

				0 minutes	5 minutes	10 minutes	30 minutes	60 minutes	24 hours
SAMPLE CODE	Repeat Number	Fabric	Chemical	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change
WCHNO31	1	White Cotton	HNO3	Central	Whole	Substantial	Substantial	Substantial	Whole
WCHNO32	2	White Cotton	HNO3	Central	Whole	Whole	Whole	Whole	Whole
WCHNO33	3	White Cotton	HNO3	Central	Whole	Whole	Whole	Whole	Whole
WCHNO34	4	White Cotton	HNO3	Central	Whole	Whole	Substantial	Whole	Whole
WCHNO35	5	White Cotton	HNO3	Central	Whole	Substantial	Substantial	Substantial	Substantial
GCHNO31	1	Grey Cotton	HNO3	Central	Substantial	Whole	Substantial	Substantial	Substantial
GCHNO32	2	Grey Cotton	HNO3	Central	Substantial	Substantial	Whole	Whole	Whole
GCHNO33	3	Grey Cotton	HNO3	Central	Substantial	Substantial	Substantial	Substantial	Substantial
GCHNO34	4	Grey Cotton	HNO3	Central	Whole	Whole	Whole	Whole	Whole
GCHNO35	5	Grey Cotton	HNO3	Central	Substantial	Whole	Whole	Whole	Substantial
PPHNO31	1	Pink Polyester	HNO3	Central	central	Central	Central	Central	Whole
PPHNO32	2	Pink Polyester	HNO3	Central	Central	Central	Central	Central	Whole
PPHNO33	3	Pink Polyester	HNO3	Central	Central	Central	Central	Central	Whole
PPHNO34	4	Pink Polyester	HNO3	Central	Central	Central	Central	Central	Whole
PPHNO35	5	Pink Polyester	HNO3	Central	Central	Central	Central	Central	Whole
BDHNO31	1	Blue Denim	HNO3	Central	Substantial	Substantial	Peripheral	Substantial	Substantial
BDHNO32	2	Blue Denim	HNO3	Central	Whole	Whole	Whole	Whole	Whole
BDHNO33	3	Blue Denim	HNO3	Central	Substantial	Substantial	Whole	Whole	Whole
BDHNO34	4	Blue Denim	HNO3	Central	Substantial	Substantial	Peripheral	Substantial	Substantial
BDHNO35	5	Blue Denim	HNO3	Central	Substantial	Substantial	Peripheral	Substantial	Substantial
CAHNO31	1	Cream Acrylic	HNO3	Central	Central	Central	Substantial	Substantial	Whole
CAHNO32	2	Cream Acrylic	HNO3	Central	Central	Central	Substantial	Substantial	Whole
CAHNO33	3	Cream Acrylic	HNO3	Central	Central	Central	Substantial	Whole	Whole
CAHNO34	4	Cream Acrylic	HNO3	Central	Central	Central	Substantial	Substantial	Whole
CAHNO35	5	Cream Acrylic	HNO3	Central	Central	Central	Substantial	Substantial	Whole

Figure 48: Area of Colour Change grades for Nitric Acid

				0 minutes	5 minutes	10 minutes	30 minutes	60 minutes	24 hours
SAMPLE CODE	Repeat Number	Fabric	Chemical	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change
WCBL1	1	White Cotton	BLEACH	Central	Central	Central	Central	Central	Central
WCBL2	2	White Cotton	BLEACH	Central	Central	Central	Central	Central	Central
WCBL3	3	White Cotton	BLEACH	Central	Central	Central	Central	Central	Central
WCBL4	4	White Cotton	BLEACH	Central	Central	Central	Central	Central	Central
WCBL5	5	White Cotton	BLEACH	Central	Central	Central	Central	Central	Central
GCBL1	1	Grey Cotton	BLEACH	Central	Central	Central	Central	Central	Central
GCBL2	2	Grey Cotton	BLEACH	Central	Central	Central	Central	Central	Central
GCBL3	3	Grey Cotton	BLEACH	Central	Central	Central	Central	Central	Central
GCBL4	4	Grey Cotton	BLEACH	Central	Central	Central	Central	Central	Central
GCBL5	5	Grey Cotton	BLEACH	Central	Central	Central	Central	Central	Central
PPBL1	1	Pink Polyester	BLEACH	Central	Central	Central	Central	Substantial	Whole
PPBL2	2	Pink Polyester	BLEACH	Central	Central	Central	Central	Substantial	Whole
PPBL3	3	Pink Polyester	BLEACH	Central	Central	Central	Central	Substantial	Whole
PPBL4	4	Pink Polyester	BLEACH	Central	Central	Central	Central	Substantial	Whole
PPBL5	5	Pink Polyester	BLEACH	Central	Central	Central	Central	Substantial	Whole
BDBL1	1	Blue Denim	BLEACH	Central	Peripheral	Peripheral	Peripheral	Central	Central
BDBL2	2	Blue Denim	BLEACH	Central	Peripheral	Peripheral	Peripheral	Central	Central
BDBL3	3	Blue Denim	BLEACH	Central	Peripheral	Peripheral	Peripheral	Central	Central
BDBL4	4	Blue Denim	BLEACH	Central	Peripheral	Peripheral	Peripheral	Central	Central
BDBL5	5	Blue Denim	BLEACH	Central	Peripheral	Peripheral	Peripheral	Central	Central
CABL1	1	Cream Acrylic	BLEACH	Central	Central	Central	Central	Central	Central
CABL2	2	Cream Acrylic	BLEACH	Central	Central	Central	Central	Central	Central
CABL3	3	Cream Acrylic	BLEACH	Central	Central	Central	Central	Central	Central
CABL4	4	Cream Acrylic	BLEACH	Central	Central	Central	Central	Central	Central
CABL5	5	Cream Acrylic	BLEACH	Central	Central	Central	Central	Central	Central

Figure 49: Area of Colour Change grades for Domestos Original Bleach

				0 minutes	5 minutes	10 minutes	30 minutes	60 minutes	24 hours
SAMPLE CODE	Repeat Number	Fabric	Chemical	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change	Area of colour change
WCBA1	1	White Cotton	BATTERY	Central	Substantial	Substantial	Substantial	Whole	Whole
WCBA2	2	White Cotton	BATTERY	Central	Substantial	Substantial	Substantial	Whole	Whole
WCBA3	3	White Cotton	BATTERY	Central	Central	Substantial	Substantial	Substantial	Whole
WCBA4	4	White Cotton	BATTERY	Central	Central	Central	Central	Central	Substantial
WCBA5	5	White Cotton	BATTERY	Central	Substantial	Substantial	Substantial	Whole	Whole
GCBA1	1	Grey Cotton	BATTERY	Central	Substantial	Substantial	Substantial	Whole	Whole
GCBA2	2	Grey Cotton	BATTERY	Central	Central	Substantial	Substantial	Whole	Whole
GCBA3	3	Grey Cotton	BATTERY	Central	Substantial	Substantial	Whole	Whole	Whole
GCBA4	4	Grey Cotton	BATTERY	Central	Central	Central	Substantial	Substantial	Substantial
GCBA5	5	Grey Cotton	BATTERY	Central	Central	Central	Substantial	Substantial	Whole
PPBA1	1	Pink Polyester	BATTERY	Central	Central	Central	Central	Central	Central
PPBA2	2	Pink Polyester	BATTERY	Central	Central	Central	Central	Central	Central
PPBA3	3	Pink Polyester	BATTERY	Central	Central	Central	Central	Central	Central
PPBA4	4	Pink Polyester	BATTERY	Central	Central	Central	Central	Central	Central
PPBA5	5	Pink Polyester	BATTERY	Central	Central	Central	Central	Central	Central
BDBA1	1	Blue Denim	BATTERY	Central	Substantial	Substantial	Substantial	Whole	Whole
BDBA2	2	Blue Denim	BATTERY	Central	Substantial	Substantial	Substantial	Substantial	Whole
BDBA3	3	Blue Denim	BATTERY	Central	Substantial	Substantial	Substantial	Substantial	Substantial
BDBA4	4	Blue Denim	BATTERY	Central	Substantial	Substantial	Substantial	Substantial	Substantial
BDBA5	5	Blue Denim	BATTERY	Central	Whole	Whole	Whole	Whole	Whole
CABA1	1	Cream Acrylic	BATTERY	Central	Central	Central	Central	Central	Central
CABA2	2	Cream Acrylic	BATTERY	Central	Central	Central	Central	Central	Central
CABA3	3	Cream Acrylic	BATTERY	Central	Central	Central	Central	Central	Central
CABA4	4	Cream Acrylic	BATTERY	Central	Central	Central	Central	Central	Central
CABA5	5	Cream Acrylic	BATTERY	Central	Central	Central	Central	Central	Central

Figure 50: Area of Colour Change grades for Sulphuric Acid – 40%