An Examination of the Working Properties of Agarose Gels for Textile Conservation

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Abstract

Recent developments in poultice treatments have led to the introduction of new materials into textile conservation. Agar and agarose, represent two such products. First used on paintings, these materials have rapidly transitioned into more porous media, despite limited research underpinning how these gels respond on different materials.

This research aims to determine ideal working conditions for agarose on three different fibres. A literature review examines available research and case studies, identifying trends and limits in current practice. Discussion of poultices and gel cleaning systems, in depth examination of the physical properties of agar and agarose, and purchasing criteria inform the experimental phase of the project.

The experimental phase examines agarose at three concentrations and two depths to determine how these gels should be utilised on textile substrates.
Results show that success is dependent on type of fibre, wettability, and gel concentration. The current suggested range should be altered to improve the ability of the gel to draw out and prevent the movement of soiling.

The research develops the use of agarose in textile conservation, providing a visual and empirical source for understanding how these gels work and what factors to take into account for purchasing products and implementing treatment.

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Part I: Introduction and Background

Chapter 1: Introduction

1.0 Introduction

The removal of harmful deterioration products or disfiguring soiling that can cause long term damage is one of the concerns of the conservator as they seek to extend the life of an object, enhancing preservation and often improving the visual appearance[1]. Cleaning processes have developed over time and have been adapted to fit specific specialties, as each medium requires different treatments. In rare cases when a technique can be used across disciplines, it offers a chance to compare treatment methods and processes. The poultice is one such technique. Utilizing the processes of diffusion, poultices control the introduction of moisture into a substrate for humidification or cleaning[2]. Capillary action then draws the moisture or cleaning agent, and by extension soiling, back into the poultice. Developments in this technique, both in terms of process and the material which forms the physical poultice, have resulted in new materials entering the conservation field and their cross disciplinary use.

Most recently conservators have looked for innovative ways to apply cleaning solutions by thickening or gelling the liquid. Natural gelling agents from food science as well as synthetic gels used in other industries, make up what are generally referred to as gel cleaning systems[3].

A gel cleaning system is a cleaning solution that has been thickened by a gelling agent, natural or synthetic, forming a poultice that can be applied to an object. They can contain a range of aqueous cleaning methods including, enzymes, resin soaps, or solvents[4].

Two types of gels are used in these systems: viscous gels and rigid gels. Viscous gels are softer and more malleable, able to be spread across a surface and wiped away. This type of gel is most prevalent in less porous media or in specialties

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[1] AIC, "Guidelines for Practice", http://www.conservation-us.org/about-us/core-documents/guidelines-for-practice#.U-8Z94BdUdI (Accessed August 16, 2014)
[2] *CAMEO,* "Poultice," accessed May 30, 2014, http://cameo.mfa.org/wiki/Poultice.
[3] Stulik et al, *Solvent Gels for the Cleaning of Works of Art: The Residue Question,* (Los Angeles: Getty Publication, 2004), 5-7
[4] Stulik et al, 5-7

where a surface allows for the gel to be wiped away, such as paintings and furniture. These gels include Laponite® RD gel[5], methyl cellulose and xanthan gum. When these gels are employed on a porous substrate a barrier layer is often employed to limit the residues left behind. This layer can limit the contact between the gel and the substrate, reducing the overall effectiveness of the poultice. Rigid gels are stiffer gels that can be picked up and placed on a surface and do not require rinsing to remove gel residues. These types of gels are used in areas of more porous media including paper, ceramics, textiles, and on surfaces that cannot be flushed with water. They include gellan gum[6], agar and agarose gels. Both these types of gels allow for the addition of certain solvents or cleaning agents.

Agarose and agar are clear, rigid gels that offer control over the movement of moisture into a material and are two of the most versatile gels for the introduction of additives[7]. Their ability to control the flow of moisture into an object, as well as ease of use and the lack of residues makes them a valuable multi-disciplinary tool for the conservator. Agar is a product derived from seaweed and is less pure than its component part, agarose. Agarose is extracted from agar and is effectively the gelling component of agar. Comparative research on these gelling agents is limited, however, their versatility and value within the field of conservation is apparent.

Both viscous and rigid gels offer precise control of the application of solvents. Gel cleaning system treatments were first developed in relation to layered surfaces such as paintings and can be formulated to remove a single layer of varnish making them invaluable when working on complex painted or varnished surfaces[8].
Due to the control offered by these systems the use of gels in paintings conservation has become increasingly popular in recent years. With some adaption, the versatility of these cleaning methods can make them a valuable tool across conservation disciplines.

[5] Laponite ® is a synthetic silicate clay that can form a gel when mixed with water
[6] Gellan gum is a polysaccharide produced by a bacteria, Sphingomonas elodea.
[7] Shaeffer, Elizabeth, Joy Gardiner, "New and Current Approaches for Localized Cleaning in Textile Conservation," (Working Draft, *AIC Textile Specialty Group Postprints,* AIC, 2013)
[8] Stulik et al, 7

1.1 The Need For Research

Gel cleaning systems were first used in paintings conservation and have since evolved to fit other specialties. Paintings, at the most basic level, offer a relatively nonporous surface for these materials to work compared to other materials and specialties[9]. Often the goal in using these gels is to remove layers, i.e. varnishes, from the surface of the painting without affecting the paint layers below. The system requires knowledge of the layers that are being removed[10]. Outside of paintings conservation the application of these gels is forced to change as layers are less likely to be removed and soiling has often migrated into the substrate. The use of the poultice to draw out soiling is a common practice in paper, textile, stone and ceramic conservation[11]. The versatility of these gels has allowed them to transition from working from on top of a painted surface to working within the object itself. However, as the material has transitioned into more porous media, questions must be raised in terms of how these gels respond to working within a surface, whether ceramic, textile, or paper. For the textile conservator, the movement of moisture in an object can have a huge effect on cleaning, resulting in tidelines, dye bleed or damage to finished fabrics. The wettability and wicking action of a fibre and the range of different weave structures means that moisture can travel farther than it might in other media, making control of the introduction of moisture paramount for the use of gel and other poultice systems in textile conservation. Laying a foundation of knowledge as to how these gels respond to a textile media is imperative in order to facilitate the use of this treatment. While successful uses of these gels are documented, three main factors prevent effective implementation of this treatment in conservation.

- The lack of information about basic techniques and processes:

The variation in application that can be seen in published case studies indicate that a true working knowledge of how these gels function on a specific media has not been established. Without basic information about the process and techniques

[9] Personal Communication, Dr. Erma Hermens
[10] Stulik et al, 7
[11] Shawna Lemiski, An Investigation of Poulticing Materials for Textile Conservation, The Textile Conservation Newsletter, Supplement (1998):4

used to produce a successful treatment results can be difficult to reproduce and understanding of the treatment undertaken will be limited.

- The cost of materials and the time required for testing and treatment:

The result of the lack of information on basic techniques is an extended period of testing and treatment time. This factor alone can prevent the use of this material, as schedules do not always allow for the time necessary to develop new treatments and make them successful. Furthermore agarose is expensive. This price may limit the treatment to larger institutions, institutions that by their very nature lack the time needed to work with a new material, thus resulting in a stalemate in the development of treatments and methods for application.

- The lack of clear information about the cleaning process and how the gel can be used to control the cleaning process.

The idea behind these gels is well documented, as are positive responses to their use on objects. However their rapid movement through conservation specialties has prevented basic information from being obtained. Each material offers a unique surface and poses distinct issues in terms of how the gel will perform and how the substrate will take up the liquid being introduced. As a result, identifying how to start using these materials remains difficult for the practising conservator.

1.2 Aims

The aims of this project are to investigate the physical and chemical properties of agarose and to undertake preliminary testing in order to identify ideal working standards on common textile fibres through the manipulation of the basic working properties.

1.3 Objectives

This project will assess current trends in the use of agarose gel and identify the limits and contradictions in current practice in order to outline the ideal working methods for the implementation of a gel treatment.

The study will evaluate the existing conservation literature to compare the available research on agar and agarose. Overviews of poultices and gel cleaning systems will provide a foundation in how this method works and its importance in the field of conservation. A discussion of agar and its structure will provide a better understanding of the differences between agar and agarose; a discussion of agarose will outline what properties affect the gel and how it works. This discussion will also clarify what to look for in purchasing agarose to ensure continuity throughout the field.
The information gathered will inform testing, which will identify the ideal methods for using agarose gels on different fabrics.

The results will be discussed to gain an understanding of how these gels work, what the best conditions are, and outline the ideal practice for implementing treatment. The results of this paper will fill the gaps in the existing literature and clarify the processes currently in practice, building a foundation in basic information about these gels and their application on textiles.

Current trends for this treatment require numerous testing phases to determine what concentration of gel to use and how it will respond on a material. This research will show how these gels work on different fabrics by manipulating the gels concentration and depth. This will show how the gels release moisture and how that moisture moves through a textile as well as how effective the gel is at drawing a stain out of a fabric. The research will provide a starting point for developing future treatments.

By outlining information about the product's properties, preparation, purchasing information, as well as clarifying ideal working properties, this paper will reduce the time need for testing. It is hoped that more conservators will be able to use and experiment with this cleaning system, furthering knowledge and answering more of the questions that cannot be covered by this paper.

Chapter 2: Review Of Conservation Literature

2.0 Introduction

The review of literature will seek to outline the use of agar and agarose gels in conservation and bring together case studies from across specialties. The review will highlight current trends in treatments, the range in products used, conflicting information, and the limitations of available research. The aim of the review is to highlight what research is needed to make this treatment practical within the field of textile conservation and thereby inform the experimental phase of this research.

2.1 Analysis of Agar and Agarose In Conservation

The first technical analysis of agarose and agar gels was written by Campani et al in 2007[12]. Simultaneously published in 2007 was Warda et al, which provides an analysis of the gel, discussing possible issues with aging properties and residues[13]. Campani and Warda represent the two available technical papers that explore the effect of agarose in terms of aging and residues.

Use of Agarose and Agar for Preparing "Rigid Gels" by Campani et al provides one of the first published analyses of these gels, looking at how they work and if the gel leaves residues behind[14]. The differences between agar and agarose are investigated as both gels are tested alongside one another. Use of Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography-Mass Spectroscopy (GC-MS) showed that agar left no gel residues behind on porous test plates while minute residues are seen with the application of agarose[15]. The testing suggests that agar could be the better product due to its ability to retain water and the lack of residues. This study did not age the samples being tested, a test which was run by Warda et al on dry agarose and on paper treated with agarose gels[16]. Aged dry samples showed a distinct colour change, indicating a breakdown of the

[12] Elisa Campani et al, "*Use of Agarose and Agar for Preparing Rigid Gels", The Book and Paper Annual 23 (*2004): 93-107.
[13] Jeffery Warda, et al, "Analysis of Agarose, Carbopol, and Laponite Gel Poultices in Paper Conservation," *Journal of the American institute for Conservation* 46 no. 3 (2007): 263-279.
[14] Campani et al, 42.
[15] Campani et al, 42-43.
[16] Warda, et al, 267.

material while the aged paper samples showed no visible change[17].

Campani et al and Warda are the first general studies and remain the only studies that examine these gels in terms of ageing and residues. Each fits within a different specialty but the information they provide has formed the groundwork for the use of gels today. Campani, published originally in Italian and translated into English, is less present in case study bibliographies, possibly indicating difficulty in acquiring the translated work. Warda et al is referenced in numerous papers concerning agarose gels, possibly the result of greater accessibility.

Campani et al begins the trend of the research and use of agar gels in Italy. It was followed by Anzani's examination into using agar to clean plaster in 2008[18]. In 2009 and 2010 was Iannuccelli and Sotgio's work on rigid gels in paper conservation was published. The case study on cleaning the Duomo in Milan was published in 2014[19].
These papers indicate that research into the use of agar is being done in Italy and the results are positive based on the increase in publications and continued use of the material. It also highlights an issue in terms of dissemination of information. While some of these papers have been translated, others remain inaccessible for conservators outside of Europe or without an understanding of Italian.

2.2 Wolbers' Workshops

Richard Wolbers, as the developer of the specialized gel cleaning system for paintings conservation, remains the ideal reference. His work has expanded to bring the idea of gel poultices to various specialties in conservation and revolutionise previous aqueous cleaning methods through the introduction of conductivity. His published work on these gels remains limited. Wolbers presents

[17] Warda, et al, 268.
[18] Marilena Anzani et al, "Use Of Rigid Agar Gels For Cleaning Plaster Objects", trans. D. Kunzelman, *Quaderni del Cesmar 7, no 6.* (2008): 35-55.
[19] These focused on other gels besides agarose. Simonetta Iannuccelli and Silvia Sotgio "Wet Treatments of Works of Art on Paper with Rigid Gellan Gels" *The Book and Paper Annual 29* (2010):25-39; Simonetta Iannuccelli, Silvia Sotgiu, "La Pulitura Superficiale Di Opere Grafiche a Stampa Con Gel Rigidi" *Progetto Restauro*, 49 (2009):15–24.; Davide Gulotta et al, "Setup Of A Sustainable Indoor Cleaning Methodology For The Sculpted Stone Surfaces Of The Duomo Of Milan" *Heritage Science Journal,* Vol 2, no. 6 (2014), accessed May 25, 2014 http://www.heritagesciencejournal.com/content/2/1/6.

his processes and ideas through workshops staged in various countries around the world. They remain the primary source of information regarding the use of gels in conservation[20]. The content of the course vary slightly in that Wolbers formats what he presents to the speciality he is addressing. Reviews of these workshops are available, each one looking at a different specialty, paper, paintings or textiles[21]. The paper and painting workshop reviews are written by paper conservators, affecting how the information is disseminated. The textile review is written by a textile conservator and is the review that exhibits hesitation in implementing the information and practices presented[22].

The ideas presented by Wolbers are useful and seemingly easy to apply, however, outside the workshop there are issues in terms of clarity. Presenting a vast amount of information within a short period of time will inevitably lead to some miss communication or misinterpretation. Though the topics covered involve properties or materials that are dealt with regularly by conservators, are not simple concepts. The practicing conservator can be easily overwhelmed or get swept up in the ideas and fail to ask the questions that will come up in actual practice.

The information presented in these workshops is available outside of the course. Wolbers is open to giving out his slides and quite free with the information about the implementation of these types of treatments. Sections of a presentation made to the Paper Group of the Institute of Conservation (ICON) are even available online via YouTube[23].

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[20] Campani et al, 31

[21] Yadin Larochette, "Wolber's World: A Review of a Textile Wet Cleaning Workshop Held in Oaxaca Mexico," *WAAC Newsletter* 34, no. 1 (2012): 24-26; Alan Derbyshire, V&A Conservation Journal, "Wolbers' Course - A Review", accessed June 14, 2014 http://www.vam.ac.uk/content/journals/conservation-journal/issue-35/wolbers-course-a-review/; Rebecca, Pavitt International Institute For Conservation Of Historic And Artistic Works. "Cleaning of Painted Surfaces - Wolbers Strikes Again!" accessed February 24, 2014, https://www.iiconservation.org/node/3216

[22] Larochette, 26

[23] YouTube "ICON Book and Paper Group, 'The Use of Gels in Aqueous Conservation of Paper" Video, Part 5, accessed November 13, 2013, https://www.youtube.com/watch?v=_Yo6lowgpPA&list=SPNks1HQNOQxS8-7_qZPuRQg6NXnymx71M&index=5. It should be noted that the section discussing agarose gels is partially missing, limiting a full understanding of how these gels are utilised.

The issue with information only being presented by workshop is the restriction of a primary source. Attendees leave the course with a vast amount of knowledge that is then disseminated in a variety of different ways. Second hand information from this type of source has the potential to be very good, depending on the notes and the level of understanding. However, subtle changes to information are inevitable and can result in more confusion. As a result, the papers that have analysed these gels and the case studies covering their use are invaluable in designing a treatment, as they are sometimes closer to a primary source than what is available via word of mouth.

2.3 Paintings

Gel cleaning systems were initially fabricated for paintings conservation, specifically for the removal of varnish layers and cleaning painted surfaces[24]. The theory and process are outlined in Wolbers' *Cleaning Painted Surfaces: Aqueous* Methods, published in 2000. The book examines a range of aqueous cleaning methods and their chemistry. Methods include, but are not limited to, enzymes, chelating agents, emulsions, and surfactants. Each of the methods discussed is followed by a case study that helps to clarify how the treatment is implemented. Each case uses a gel to thicken and apply the cleaning agent. The gels tend to be viscose gels and, as a result, agarose is not covered by this publication. The trend toward viscous gels is also seen in *Solvent Gels for the Cleaning of Works of Art: The Residue Question* by Stulik et al. This work examines the possible residues that can be left behind by these gels on painted or varnished surfaces.

The information provided by Stulik and Wolbers provides an understanding of the initial goals for gel cleaning systems. The recipes and ideas behind cleaning processes, both aqueous and gel based, have elements that can be helpful in understanding how and why these systems are employed and used. However, the differences between media limit their usefulness in outlining a gel treatment for textiles and other porous surfaces.

[24] Richard, Wolbers, *Cleaning Painted Surfaces: Aqueous Methods,* (London: Archetype Publications, 2000) viii; Stulik et al*,* 1.

2.4 Furniture and Wood

One of the earliest trials of gel cleaning systems outside of the paintings specialty was in furniture. The gels are used for the same purpose, to remove varnish layers or clean surfaces. Published case studies focus on the use of viscous gels over rigid gels and are found in Wolbers' *Cleaning Painted Surfaces: Aqueous Methods*[25]. Here the gel cleaning systems use solvents, enzymes and detergents to remove layers[26]. Both these case studies show how the gel system can be formatted to treat very specific problems and remove singular layers from a surface. Outside of this publication few sources are available that cover the use of gel systems on wood and furniture objects. Similar to painting systems, these studies offer another outlook on how this treatment can be implemented and adapted to different surfaces. As with case studies of paintings, these papers provide insight into how the process has developed, and are less helpful in determining how to implement a gel cleaning process for a textile-based object.

2.5 Stone

Case studies in stone conservation prefer the use of agar to agarose, and utilise a different method of application. At the Museum of Fine Art, Boston, agar was used for the treatment of an Etruscan sarcophagus in June 2013. This treatment is presented to the general public through their "Conservation in Action" website[27]. As a result, the description of the treatment is simplified and limited technical information is provided. For the treatment a solvent agar gel was applied in paste form to the stone and allowed to dry overnight, drawing soiling into the gel and out of the stone[28]. The gel dried clear and was easily peeled from the surface of the object the next day. No mention of a rinse is made in the description of the treatment.

[25] Wolbers 74, 81,
[26] Wolbers 74, 81
[27] The Museum of Fine Arts Boston, "Conservation in Action: Etruscan Sarcophagi, June 2013", accessed May 26, 2014, http://www.mfa.org/collections/conservation/conservationinaction_etruscansarcophagi/june2013.
[28] The Museum of Fine Arts Boston, "Conservation in Action: Etruscan Sarcophagi, June 2013".

Agar was also used for cleaning stone sculpture on the interior of the Duomo of Milan[1]. The treatment was heavily tested before application and the surfaces treated were studied using FTIR, Scanning Electron Microscopy (SEM) and Colourimetry to analyse and assess the effectiveness of the treatments[2]. The use of this poultice system was more effective than cleaning done with a cotton swab, and the results are not only visual but also verified by FTIR readings indicating a reduction in the pollutants that had coated the stone. Tween 20, a non-ionic detergent used in biochemical applications, was added to a 3% agar gel to facilitate the cleaning and removal[3].

The possibility of residues from either the gel itself or from additives to the gel are not covered by this paper nor does the treatment appear to have used any type of rinse, gel or water, to reduce any residues of the cleaning agents.

2.6 Ceramics

The use of agarose gels in ceramics conservation has developed out of Campani et al and the work on plaster published by Anzani in 2008[4]. Campani et al, as discussed before, provides the basic research for the use of agar and agarose, supporting their use in conservation. Anzani follows with a case study and thorough examination of the application of these gels on plaster. In 2012 UCLA Getty graduate Cindy Lee Scott applied similar processes to terracotta[5]. More recently, Pouliot, Fair and Wolbers explored methods for reducing staining on ceramics through the use of a series of poultice systems[6]. Four systems are explored through this paper: Laponite® RD Gel, agarose gel, paper pulp, and wet

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[1] Gulotta et al.
[2] Gulotta et al.
[3] Gulotta et al.
Sigma Aldrich, "Tween 20" accessed May 30, 2014 http://www.sigmaaldrich.com/catalog/product/sigma /p9416?lang =en&region=GB.
[4] Anzani, et al, 35-55.
[5] Ravenel, Nancie. Conservators Converse: The Blog of the American Institute for Conservation. "40th Annual Meeting Objects Specialty Group Research And Technical Studies Joint Session, May 9 The Use Of Agar As A Solvent Gel In Objects Conservation By Cindy Lee Scott" accessed May 25, 2014, " http://www.conservators-converse.org/2012/05/40th-annual-meeting-osgrats-joint-session-may-9-the-use-of-agar-as-a-solvent-gel-in-objects-conservation-by-cindy-lee-scott/.
[6] Bruno Pouliot et al, "Rethinking the Approach: Techniques Explored at Winterthur for the Stain Reduction of Ceramics," In *Recent Advances in Glass, Stained Glass, and Ceramics Conservation 2013: ICOM-CC Glass and Ceramics Working Group Interim Meeting and Forum of the International Scientific Committee for the Conservation of Stained Glass.* (Amsterdam: ICOM, 2013).

strength tissue. The paper looks at the application of these poultice materials on a porous material, and examines the change in concentration, rinsing, and timing for these treatments.

While completely focusing in ceramics, the information that is uncovered through this paper is incredibly helpful in understanding some of the issues that may affect the implementation of this type treatment on a textile surface. The application of the poultices on the ceramics shows that redeposition of soiling is a possibility if the gel is allowed to dry too much[7]. Pouliot et al also discusses the issues of rinsing and removing the cleaning agent introduced into the surface of the material; acknowledging the inability to measure the effectiveness of the rinsing method employed[8].

2.7 Paper

The majority of papers on agarose gels within the paper specialty focus on the use of enzymes and the methods of delivery to reduce adhesive or oil based stains. Warda, whose work also examines of the aging properties of agarose, looks at the use of the gel on paper alongside Carbopol® and Laponite® RD gel. Warda et al used a 1% concentration, laid the gel on blotter to remove excess water and applied pressure to encourage moisture exchange[9]. Warda et al was unenthusiastic about the outcomes of the application of agarose; however, adaptions facilitate its effective use[10].

Rigid gels offer a controlled method of application of enzymes for the removal of adhesives. Yana van Dyke provides a practical overview of the process and issues in her discussion of removing glues from an Indian painting[11]. Van Dyke outlines the process of making enzyme gels, including the reasoning behind the choices made, focusing on gel concentration and the effect of the gel on the enzyme. The paper focuses heavily on enzymes, their traits, and how and why they are

[7] Pouliot et al, 220.
[8] Pouliot et al, 215.
[9] Warda, et al, 271.
[10] Warda et al, 272.
[11] Yana van Dyke, Practical Application of Protease Enzymes in Paper Conservation," *The Book and Paper Annual 23 (*2004):100.

employed in paper conservation. However descriptions of the formation of the gels and the comprehensive reasoning behind the choices makes this paper valuable in terms of understanding how and why the choices were made, as well as how agarose works within this context[12]. Van Dyke's work is one of the best available resources as it is comprehensive and thorough. The paper has also been published in two different locations in slightly different forms making the information readily available[13]. Portions of this work was done at Winterthur/University of Delaware Program in Art Conservation (WUDPAC) and relied on the direct input of Richard Wolbers.

Stockman looks at enzyme gels for oil-based stains[14]. The paper looks at a range of treatments, agarose being one of many tested; as a result, few conclusions can be drawn about the overall implementation of this treatment as the paper covers a vast amount of information. The work does briefly discuss the lack of control of the spread of moisture, an issue also mentioned by Warda et al[15].
These papers build upon one another and the work done by Wolbers. Van Dyke and Warda are cited by Stockman and van Dyke is discussed by Wolbers in his presentation to the ICON Paper Group[16]. These works exhibit continuing research and development of a comprehensive process for using these gels on paper.

2.8 Textiles

Papers in textile conservation have been innovative in their application of agarose gels. The use of these gels is documented in a few published case studies though work has mainly focused on samplers.
The majority of published papers and case studies come out of institutions hosting a Mellon Fellow as in the case of the Philadelphia Museum of Art (PMA)[17], or are the work of graduate students, as in the case of the work done by Elizabeth

[12] van Dyke, 102
[13] van Dyke, 105
[14] Denise Stockman, "Treatment Options for Oil Stains on Paper," *Book and Paper Group Annual 26* (2007): 115-126
[15] Warda, et al, 272
[16] YouTube "ICON Book and Paper Group, Video, Part 5
[17]Katherine, Sahmel et al, "Removing Dye Bleed from a Sampler: New Methods for and Old Problem", Unpublished Draft, 2011.

Shaeffer at both the PMA and WUDPAC[18]. These papers are an indication of other issues surrounding this treatment method. The process can be time consuming, almost to the point where it is prohibitive except for the cause of education, so while it works, and works well in the cases published, its limitations are visible and are in need of consideration before this process can be used effectively.

The earliest paper focusing on agarose is by Sahmel et al and focuses on the reduction of dye bleed on a sampler. The treatment uses cyclododecane to prevent further bleeding of the dyes as well as the agarose gels to remove the dye bleed from the ground fabric. The cyclododecane forms a retaining wall around the gel preventing outward movement of the cleaning solution. The research into the object and dyes as well as the process used for this treatment is explicit; however, little is presented in terms of the tests done using the agarose. Shifts between tests and treatment also raise interesting questions. In the case study presented by Sahmel et al the gel was cast and used at an approximate .5 cm thickness for the treatment following the trend that is seen in paper conservation and the concentration ranges shift from 4% for testing to 1% for treatment. The authors note the change was made to "speed the diffusion process", which it would, though it would also result in an introduction of more water into the object. Here it is suggested the gel be pressed into place with the back of a pair of tweezers and the structure broken up to ensure greater contact, a practice not supported by Wolbers[19]. Despite these variances in application procedure, the treatment is effective and the results encourage continued use of these materials.
Despite the positive response to these gels in literature, they are not always the chosen method by which to treat an object. Often agarose is one of many options tested then eliminated due to time and cost restrictions as in the case documented by the Royal Ontario Museum in 2009[20]. Ellis found that the treatment would have been successful during here treatment of an Indian Palampore but had to abandon

[18] Shaeffer, Gardener (Unpublished Draft); University of Delaware College of Arts and Sciences. "Exploring Innovative Cleaning Techniques For Textiles." accessed February 24, 2014, http://www.artcons.udel.edu/news/2012/09/10/innovative-cleaning-techniques-for-textiles.
[19] Katherine, Sahmel et al, Unpublished Draft; YouTube "ICON Book and Paper Group, Video, Part 5
[20] Shirley Ellis, "A Passage in the Life of a Palampore:Conservation." *Journal of the Canadian Association for Conservation* 34 (2009): 22

the method because of the size of the object[21]. It would have required greater treatment time and a large amount of agarose at high cost, two factors that could not be ignored. This decision highlights some of the main issues with this treatment: cost and amount of testing required.

The current published case studies have been worked on a small scale in an effort to control the gels. The treatment is much more difficult to work with on a large scale, as was seen in the treatment by Sophie Younger, head of Sophie Younger Conservation in Perth Scotland and Phillipa Duffus. Younger and Duffus under took the treatment of a series of textile panels, testing numerous methods of cleaning, and in contrast to Ellis, implemented treatments using agar and agarose. This treatment had issues and the use of larger gels proved difficult, as did making up the gel in large batches[22]. Gaining an idea of how to control the gel off an object and using that information to implement a treatment may allow for larger scale projects to proceed with fewer issues, as the action of the gel will be more predictable.

Ellis' issue with cost was also countered by the treatment at Younger Conservation. Younger and Duffus' treatment involved the use of chemical grade agarose as well as food grade agar. Using agar limited the quality of the product but cut the cost of the material drastically, making a large-scale treatment possible[23]. This treatment also highlighted the lack of direct correlation between agar and agarose in terms of gelling capacity and the flow of moisture into the textile. They found that an increase of approximately 1.25% was needed to obtain an agar gel similar in structure to those of agarose, indicating that while agar gels will retain more water, the lower gelling capacity can have an effect on how these materials handle during treatment (Table 3)[24].

While the treatment is becoming more common, confusion about the application of this treatment on textiles is seen outside the lab, in public forums, presentations and even in the workshops presented by Wolbers. Younger and Duffus presented

[21] Ellis, 22
[22] S. Younger, P Duffus, unpublished treatment report
[23] S. Younger, P Duffus, unpublished treatment report
[24] Phillipa Duffus, Sophie Younger " Trials and Tribulations: Experiments with Agar" (Paper ICON Textile Forum, March 31, 2014).

their treatment at the 2014 ICON Textile Group Spring Forum: *Joined Up Thinking: Textiles and the Historic Interior*. Observing the group and listening to questions after the presentations underlined the confusion surrounding this type of treatment. It indicated that, for those who have not had the opportunity to attend a workshop run by Richard Wolbers, the processes, ideas, and use of this material remain unclear. Questions ranged from how the application was done to why certain choices were made.

Discontent can also be seen in those who have attended the workshops as is evident in Larochette's 2012 review of the workshop run in Oaxaca Mexico[25]. She underlines questions she has with the processes but also hints that others were left with questions as well possibly indicating a wider confusion, if not dissatisfaction, similar to that was witnessed at the ICON Forum.

The events at forums that attempt to disseminate this information underline how the answers to basic questions about these gels are not readily available and highlight the confusion that permeates the field.

2.9 Conclusion

The review of conservation literature shows the range of treatments using agar and agarose gels. Trends appear regional, with agar having much more prevalence in Italy while American institutions and conservators follow the suggestions of Richard Wolbers, focusing on the use of agarose.

The range of concentrations as well as the lack of information on time of application and depth of gel shows the limitations of the published treatment case studies (Table 3). The lack of clarity and degree of variability within the material's use shows that more research is needed to understand how these gels work on specific media and what the ideal criteria are for these types of treatments. It must be acknowledged that decisions will be object specific. This does not mean that trends cannot be recognized and used to help formulate and define how best these gels can be utilized. Further research is needed to look at the basic application of these materials, highlight the difference between agar and agarose and develop and understanding as to what affect the choice of gels has on the treatment.

[25] Larochette 26.

The papers and presentations within textile conservation clearly show that there is a gap in available information concerning the implementation of this process within the specialty. The literature is limited to case studies, producing a range of methods for implementing the process. Research is needed at a basic level, covering how these gels respond on a textile media, what the range of concentrations really mean in terms of diffusion into a substrate and what factors can affect how they work.

Chapter 3: Poultices and Gel Cleaning Systems

3.0 Introduction

Chapter 3 will examine the concept of poultices and gel cleaning systems in more detail to outline how they are utilized within conservation. The information presented will provide a foundation in poultice and gel cleaning systems, especially when utilised with agarose gels. Additives to gel cleaning systems will be discussed as gel poultices are made more effective through the addition of cleaning agents. An understanding of how and why these agents are introduced to a system is key in establishing treatments and understanding current practice.

3.1 Poultices

Poultices have been used throughout conservation specialties as a means of cleaning or humidification. Traditionally, they take the form of an absorbent, moist material that can be used to deliver water, a cleaning solution or solvent to dissolve and help remove soiling or staining[54]. A poultice works using the properties of diffusion and capillary action. Diffusion is the movement from high concentration to a lower concentration in order to reach equilibrium[55]. For a poultice, this means that when the dampened poultice material is laid on a dry surface, moisture will move into that object in an effort to balance the system. As the surface of the poultice begins to dry, the capillary action results in drawing moisture up out of the object and back into the poultice in an effort to retain equilibrium in the system[56]. The effectiveness of a poultice can be affected by a number of factors. Because these systems rely on a combination of evaporation and diffusion, environment can limit the success of a poultice treatment. An open system can result in too much evaporation, preventing the cleaning agent from effectively solubilizing soiling and pulling it into the poultice[57]. Covering the treatment limits evaporation, allowing the poultice to dissolve soiling and then draw it out of the substrate. Poultices covered for a shorter amount of time can be

[54] *CAMEO,* "Poultice; Stulik et al, 5.
[55] Karen Thompson "Use Of Poultices For Removing Adhesive Residues From Textiles" (Masters Dissertation, Textile Conservation Centre, The Courtauld Institute of Art, 1993), 6
[56] Lemiski, 5
[57] Karen Thompson "Sepiolite Poulticing- An Alternative for the Cleaning of Textiles" *Conservation News*. Number 53 (1994):50

more effective than those covered for a longer period as the uncovering allows for evaporation, which allows soiling to be drawn into the poultice material[58]. Poultices also are affected by the degree of contact they can achieve with the ground to which they are applied. If contact is limited, capillary action and diffusion are also limited thus preventing the overall effectiveness of the poultice[59].

The most common use within textile conservation is for humidification. A cold poultice or a layered system of damp and dry cloths that facilitates the movement of moisture into an object without direct wetting of the surface is the fundamental system used in contact humidification. While the dry cloth may now be a moisture permeable membrane, such as Gore-Tex® or Sympatex®, the idea remains the same.

If the dampened or wet material is used in direct contact with the object, the poultice can be used to remove or soften materials to facilitate their removal or for the application of enzymes. The benefits of using a poultice system is that it keeps a solution in contact with a surface for a longer period of time, slowing evaporation and drawing soiling out and away from a surface and trapping it within the poultice material[60]. Poultices can be formed using a number of materials including paper pulp, clay, fabric, sponges and gels. Paper pulp, sponges and fabrics hold water within a material that retains its form after the water has been removed, the material may swell, but the overall shape of the poultice material remains unchanged. When mixed with water, clay forms a malleable material that can be used as a poultice. Gels are formed by thickening water based cleaning solutions through the addition of certain types of polymers or high molecular weight material[61].

3.2 Gel Cleaning Systems

Gel cleaning systems are a form of poultice. What differentiates a gel based system from a typical poultice is the use of a gelling agent to thicken a solution whereas a

[58] Thompson, 47
[59] Thompson, 50
[60] Thompson, 10-11
[61] Stulik et al, 5

poultice may relay on the use of a solid material like a sponge or paper pulp to hold onto the solution. Richard Wolbers developed his specialised gel cleaning system to rely on the poultice action of gels while also implementing the processes in a prescribed manner to remove specific layers and protect others. Wolbers' gel cleaning systems first came into use in conservation in the 1980's. The prescribed system was developed for use on paintings as a method to clean surfaces and remove varnish layers [62]. The technique thickens a cleaning agent in combination with a surfactant and pH buffer providing a very controlled introduction of the cleaning solution onto the substrate[63]. It has since been utilised in furniture conservation, however the system is meant for use on layered surfaces, limiting its implementation outside of these two specialties.

Wolbers' cleaning system allows for the use of different cleaning materials, including enzymes, solvents, chelators and detergents. The systems rely on the structure of the gels to control the delivery of cleaning agent and the degree of control allows the cleaning method to be formulated to clean or remove specific elements of the object thus providing the conservator with a tool that can be adapted to numerous situations and materials[64]. Aspects of Wolbers' system have been combined with the more general poultice system forming a gel based poultice that can be used with numerous different products in different ways. Wolbers continuing research into gelling agents has drawn new materials into the field and has helped continue the evolution of these systems within conservation.

3.3 The Introduction of Additives

Agarose gels are the most receptive gelling agent for use with additives in conservation. This is the result of their structure, a lattice shape that will hold water-soluble materials, their neutral charge, and pH. These gels have been used with solvents, enzymes, chelators, and have been suggested for use with bleaches[65].

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[62] Stulik et al, 7
[63] Stulik et al, 7
[64] Stulik et al, 7
[65] van Dyke; Sahmel et al; Shaeffer and Gardner; Helen D. Burgess, "Practical Considerations for Conservation Bleaching," *Journal of the International Institute for Conservation, Canadian Group,* vol 13 (1988):16.

Additives can affect gelling agents and prevent a gelled structure from forming as in the case of chelators. Chelators, which seek to bind with metals, cannot be placed into gels with metal ions[66]. This will not happen in agarose as the gel structure does not contain metal ions and is thus stable under such conditions. Water miscible solvents can be introduced in agarose by soaking gels in a solvent and water mixture after they have been formed. Through diffusion, the gels absorb the solvent. Similar things can be done to introduce chelating agents and other materials that are miscible in water.

Enzymes are more difficult to introduce to these gels. As they are large molecules, the concentration of the gel cannot be too high or their movement will be impeded. Enzymes require the presence of water to work, and are heat sensitive proteins. This increases the need for a lower percentage gel and the purchase of a more expensive low melt gel and cooling before addition to prevent denaturing of the proteins.

[66] YouTube "ICON Book and Paper Group, Video, Part 3.

Chapter 4: Agar and Agarose: Structure and Properties

4.0 Introduction

In this chapter, the structure and properties of agar and agarose will be discussed. As both these materials have been used in conservation, an understanding of the differences between these materials must be gained in order to understand how these gels work and how their structure and chemical properties can affect their overall working properties. This discussion will clarify how the product used for this research was chosen. Available literature is limited in its discussion of what products were used and why. This chapter seeks to clarify what factors and properties need to be considered. Trends in products used by conservators will be examined to clarify the choices that have been made.

4.1 Agar and Agarose

The difference between agar and agarose gels must be understood before a discussion of what they do can commence. In some conversations and literature the terms have become interchangeable[67]. This mixing of terms can lead to great confusion when identifying what was used in the course of a treatment. Agarose is the main gelling component of agar and is purified for scientific use. Agar has not been purified to the same extent, thus retains impurities, like sulphite groups, that make up the charged components of the un-purified gel. These differences are not only basic changes in chemical structure but they affect how these gels work and thus can impact the course of treatment and the decisions made.

4.2 Agar: History and Origin

Agar is a hydrocolloid gelling agent extracted from seaweed[68]. A hydrocolloid is a polysaccharide or protein most commonly used as a gelling agent for aqueous solutions[69]. Agar is the oldest known seaweed based gel, coming into use in Japan around 1658. Agar has been used in food preparations and was not known in the

[67] Phillipa Duffus, Personal Communication.
[68] Armisen, "Agar" In *Thickening and Gelling Agents for Food.* ed. Alan Imeson, (London: Chapman and Hall, 1997), 1
[69] Armisen, Fernando Galatas, and S.A Hispanagar. "Agar" In *Handbook of Hydrocolloids.* edited by Phillips, G O, and P A Williams, (Cambridge: Woodhead Publishing, 2009), 1.

West until the mid 19th century[70]. Since that time, it has found use in biology, mainly as a growth medium for plants and bacteria.
Agar producing seaweeds belong to the Class Rhodophyceae, and are termed "agarophyte seaweeds"[71]. Agar refers to the polysaccharides produced by these seaweeds. Other types of seaweed gelling agents, as alginates and carrageenan, differ by the type of seaweed they originate from and variations in the polysaccharides[72].

4.3 Structure and Components

The structure of agar was identified and dissected by Akaki in 1956[73]. He described agar as two polysaccharides, agarose and agaropectin and outlined the structure of agarose[74]. The polysaccharides are mainly composed of galactose, a monosaccharide, while a small percentage of the structure is made of sulphate esters[75]. Agarose is the gelling component of these gels; it has a greater mass and a lower fraction of sulphate esters than agaropectin[76]. Studies into the component parts of the much more complex agaropectin are limited. Armisen and Armisen et al provide a brief discussion of agaropectin, noting it contains the sulphate components of agar, has little gelling power and has a lower molecular mass that the agarose portion of agar[77].

Agarose takes the shape of a linear polymer of agarobiose units. Agarobiose is the term used for the monomer made of β-(1,4)-(3,6)-Anhydro-L-galactose and α-(1-3)–D-galactose rings (figure 1). Variations within these singular units can occur depending on the species of seaweed and the season in which it is harvested[78]. Traditionally, the gels were extracted from seaweed through freezing, allowed to

[70] Armisen, 1.
[71] Armisen, 2.
[72] Armison, 3-4.
[73] Araki "Structure of the Agarose Constituent of Agar-Agar"
[74] Araki, 138; Armison, Galatas, and Hispanagar, 89.
[75] Armison Galatas, and Hispanagar, 83
[76] Armisen, 10
[77] Armisen, 10
[78] Armisen, 10

thaw and dry, thus producing the flake or powdered agar[79]. The process has since been commercialised, though the principles remain the same.

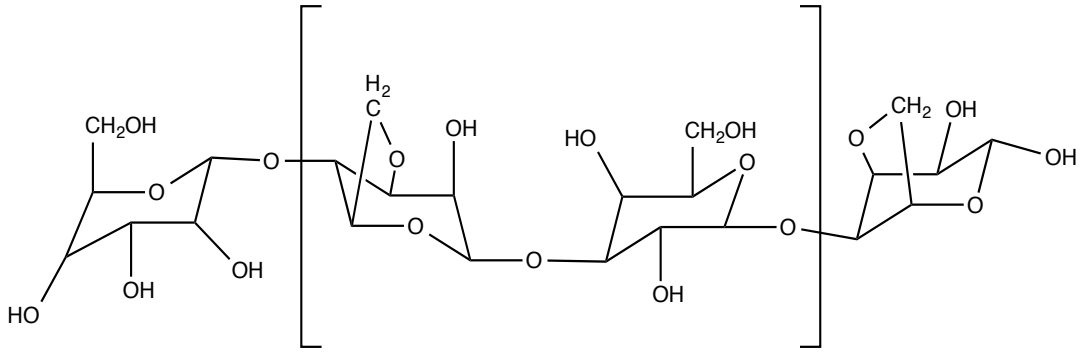

fig. 1: The agarobios monomer, β-(1,4)-(3,6)-Anhydro-L-galactose and α-(1-3)–D-galactose

The rheology, or the movement or flow of the gel decreases as the gel cools (figure 2) [80]. Agarose gels transition from their powdered dry form to a liquid gel in the presence of water and heat. In its liquid state agarose is a random coil, when as it cools the coil forms a double helix through the formation of hydrogen bonds (figure 2)[81]. These double helixes crosslink to form a grid like structure thus forming the rigid gel (figure 2). This structure gives strength to the gels and forms the pores that allow for capillary action and diffusion to take place. This structure is crucial for their use in conservation as it allows the gel to act as a poultice[82].

[79] Armisen, 5-7
[80] Merriam Webster. "Rheology," accessed June 7, 2014, http://www.merriam-webster.com/dictionary/rheology.
[81] K.C., Labropoulos, D.E. Niesz, S.C Danforth, P.G. Kevrekidis, "Dynamic Rheology of Agar Gels:Theory and Experiments. Part I. Development of a Rheological Model," *Carbohydrate Polymers* 50 (2002): 405.
[82] VanDyke, 102

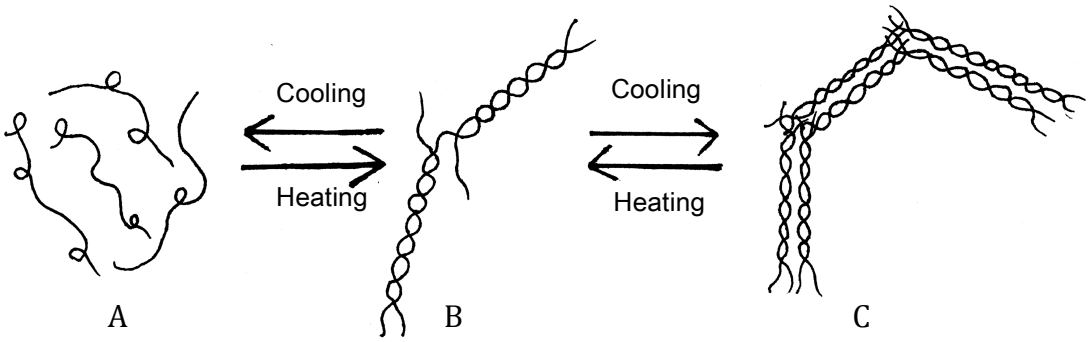

Fig 2: A: Agarose in its liquid phase. B: The double helix forming and crosslinking as the gel cools. C: The crosslinked helixes forming the rigid gel.

4.4 Physical Properties

The physical and chemical properties of agar have been utilized in food and biological sciences. The research done in these fields is invaluable when examining how these gels work and how they can be applied in object treatment. In conservation, agarose gels are unique in their ability to be used with a range of different additives, including chelators, enzymes, water miscible solvents, and bleaches. This ability is caused by the structure of agarose and its neutral charge after the removal of impurities. Other properties will affect how these gels work on a surface and thus play an important role in choosing a gel for use in conservation.

4.5 Gel Hysteresis

One of the most important aspects of agar is gel hysteresis, or the difference between the melting and gelling temperatures[83]. Agar melts at around 80° Celsius and gels at around 35° Celsius[84]. This difference in melting and gelling temperatures produces a gel that is stable over a large temperature range. Agar can also be re-melted and gels reformed without the loss of the physical properties[85].

[83] Armisen, 12
[84] Armisen, 17
[85] Armisen, 11

4.6 Strength and Porosity

Agar's prevalence in food and food science has resulted in research into preparation and its affect on these gels. Strength and porosity are both properties that can be affected by preparation[86]. By understanding how these characteristics relate to one another and how gel preparation affects these properties, gels can be made in a way that will produce the best internal structure and make the treatment more effective.

Gels that are cooled slowly appear to have a larger number pores and this appears to contribute to the overall strength[87]. However, as the concentration of agar increases, the pore size decrease[88]. Furthermore the non-gelling component of agar was shown to interact with water, forming hydrogen bonds that slow down the movement of water through the structure[89]. This movement is variable as slowing down moisture movement is reliant of the water encountering those random portions of the agar gel that will form a hydrogen bond[90]. This results in restricted self-diffusion though the rate by which this occurs cannot be quantified due to the random structure of these gels[91]. Despite the inability to quantify their retention of water, the fact that the gels do retain water can be used in conservation to further control the release of moisture into an object. These factors can be applied to agarose with the caveat that it lacks the charged elements that can restrict water movement.

4.7 Gel Syneresis:

Gel syneresis is the process by which water leaves the gel as it ages[92]. This occurs as the internal structure of the gel contracts, tightening the pores with in the gel[93]. The restriction of the pores results in water being forced from the gel[94]. The

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[86] Ross et al "The effect of Mixing Conditions on the material Properties of an Agar gel-Microstructural and Macrostructural Considerations," *Food Hydrocolloids* 676 (2005): 1.
[87] Ross et al, 8.
[88] Davis et al "Dynamics of Water in Agar Gels Studied using Low and High Resolution 1H NMR Spectroscopy." *International Journal of Food Science and Technology* 45 (2010): 2506.
[89] Davis et al 2506
[90] Davis et al 2506.
[91] Davis et al 2506.
[92] Norman F. Stanley, "Agars," In *Food Polysaccharides and Their Applications, Second Edition.* ed. Alistair M. Stephen, Glyn O. Phillips, Peter A. Williams, (London: Taylor and Francis Group, LLC, 2006), 277
[93] Stanley, 227
[94] Stanley, 227

increase in water released by the gel was observed after 3 days of storage, reaching its height after 6 days [95]. This release can also be forced through the application of weight[96]. The collapse of the gel and subsequent release of water is less pronounced in agar gels that have higher sulphate content[97].

4.8 Properties Listed by Suppliers

Different types of agarose have been used in conservation and the result is a list of products that differ in price, property and source (Table 1). As these factors can affect treatment, having an understanding of how and why they work is essential to ensure that the right product is obtained.

Chemical companies can list upwards to seven properties associated with agarose gels[98]. Four of these properties are considered here, others apply to their scientific application and thus not discussed. Agar gels are not presented to the buyer in the same way and only three properties correspond between the gels: Grade, gelling or transition temperature, and gel strength[99].

4.8.1 Grade:

The trend in literature and workshops indicates a preference for molecular biology grade agarose (Table 1). Agarose is used in biology for a range of different uses including electrophoresis, a technique used to analyse nucleic acids, i.e. DNA[100]. Chemical grade materials are purified and meet a specific standard to ensure they do not interfere with the processes for which they are used[101]. Purification involves the removal of agaropectin and charged components that may restrict gelling capability or movement of material through the gel structure[102]. As a result, agarose gels purchased through a chemical company are purified to a

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[95] Shingo Matsukawa, et al, "Molecular Diffusion in Polysaccharide Gel Systems as Observed by NMR" *Progress in Colloid and Polymer Science* 136 (2009):175; Stanley 227
[96] Stanley 227
[97] Stanley, 227
[98] See Appendix 1
[99] Sigma Aldrich, "Agar," accessed May 31, 3014, http://www.sigmaaldrich.com/catalog/product/fluka/05040?lang=en&region=GB
[100] Stanley, 228.
[101] C.D Viljoen, B.D Wingfield and M.J Wingfield, "Agar, an Alternative to Agarose in Analytical Gel Electrophoresis" *Biotechnology Techniques* vol 7 No. 3 (1993):723-724
[102] Armisen, 10

specified standard. The purity of these gels allow for their use in testing conductivity.

Agar is usually marketed for microbiology as a growth medium for bacteria[103]. It does not require the same degree of purity, thus reducing the supplier properties listed for agar. It is important to note that, due to its impure form, agar cannot be used to measure conductivity.

4.8.2 Gelling and Melting Temperature:

The gelling temperature and melting point are interdependent and should be chosen based on the treatment being considered. General cleaning treatments, the measurement of pH and conductivity can be done with any melting point gel[104]. The heat needed to melt the agarose and the point at which the liquid begins to thicken should not affect these kinds of treatments.

Heat sensitive materials, especially enzymes, would require the use of a low melt gel to prevent denaturing of the enzyme proteins. Low melt gels can be used in the same conditions as a standard grade agarose. Despite the versatility of low melt agarose the price is usually more than double that of the standard agarose (Table 1).

Agar exhibits the same gelling point as a standard agarose gel within a few degrees and low melt agar is not available, forcing later addition of enzymes to agar gels[105].

4.8.3 Electroendosmosis (EEO)

Electroendosmos (EEO) is a measurement of the movement of liquid through a gel. This property is associated with electrophoresis. In electrophoresis, a magnetic field is introduced across the gel. Charged particles within the gel move depending on the degree of charge. In agarose, anions are attached to the gel matrix and thus immobilized. Positively charged cations are not attached and thus are able to move through the gel, inhibiting the flow of moisture through the pores. The greater the movement of cations, the greater the EEO[106]. EEO is measured in units

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[103] Stanley, 228
[104] Richard Wolbers, email message to the Author, April 2, 2014
[105] Campan, 44
[106] Sigma Aldrich. "A9539 SIGMA Agarose," accessed May 31, 2014, http://www.sigmaaldrich.com/catalog/product/sigma/a9539?lang=en&region=GB.

of relative mobility (-mr), which is calculated by dividing the total movement of two standards through the gel during electrophoresis[107]. EEO, as the measurement of mobile cations, is a measurement of the purity of the gel, indicating that agar would have a much higher EEO[108].

In theory, this factor can be used in treatments where the control of the movement of moisture can affect the outcome. However, a comparison of agarose products used in conservation shows that this may have less of an effect. The EEO range for most of the products is .09 and .13-mr. Only the now discontinued FLUKA Agarose used by Campani et al has a noticeably higher EEO at .23-.27-mr. Richard Wolbers suggests the use of a .005-.13 EEO gel for general cleaning and a .12 EEO gel for Enzyme cleaning with changes in concentrations to control the movement of water through the gels[109]. A higher EEO may interfere with some additives, i.e. enzymes, as it restricts the movement of large compounds though the gel. The drop in gel strength indicates that raising the EEO may also interfere with the gelling ability of the agarose.

4.8.4 Gel Strength:

Gel strength is a measurement of the force applied to fracture the gel[110]. Low melt agarose gels exhibit much lower gel strength than agar and standard agarose.

Gel strength appears interdependent upon the melting point and the EEO. EEO would indicate impurities, which may restrict gelling ability (Table 1). The change in melting point may indicate that the chemical process that the agarose goes through to reduce the melting point of the gel is affecting the structure of the gel, reducing the overall strength of the lattice system that forms agarose and agar gels. Discussion with Richard Wolbers indicated that for the conservator, this property little bearing on gel choice and can be overlooked when choosing a product[111].

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[107] Lonza "Appendix B: Agarose Physical Chemistry," accessed July 4, 2014, http://bio.lonza.com/uploads/tx_mwaxmarketingmaterial/Lonza_BenchGuides_SourceBook_Appendix_B_-_Agarose_Physical_Chemistry.pdf 208.

[108] C.D Viljoen, B.D Wingfield and M.J Wingfield, "Agar, an Alternative to Agarose in Analytical Gel Electrophoresis" *Biotechnology Techniques* vol 7 No. 3 (1993):723

[109] Richard Wolbers, email message to the Author, April 2, 2014.

[110] Sigma Aldrich, "Agarose"

[111] Richard Wolbers, email message to the author, April 9, 2014

Properties of Agar and Agarose used in Conservation

Grade	Gelling Temp	Melting Temp	EEO	Gel Strength	Use	Cost	Source
IBI Molecular Biology Grade	36°C	88°C	0.005-0.13	1% gel > 1200g/cm^2	pH Conductivity Cleaning (Suggested by Wolbers)	$111.00/100g	Universal Medical
IBI Molecular Biology Grade, Low Melt Point	24-28°C	65.5°C	0.12	1.5% gel > 500g/cm^2	Enzymes (Suggested by Wolbers)	$295.00/100g	Universal Medical
Agarose LE Molecular Biology Grade	36°C	88°C	0.13	1% gel > 1200g/cm^2	Sampler Treatment, PMA	$104.00/100g	Benchmark Scientific
A9539 Molecular Biology Grade	36°C	N/A	0.09-0.13	1% gel > 1200g/cm^2	This paper	£151.00/ 100g	Sigma Aldrich
Fluka Agarose 05068	34-37°C	N/A	0.23-0.27	1.5% gel ≥ 1500g/cm^2	Campani et al CESMAR 7 Research 2007	Discontinued	Sigma Aldrich
Seakem LE Agarose	34.5-37.5°C	90°C	N/A	1% gel ≥ 1200g/cm^2	Warda et al	N/A	Cambrex Bio Science
Fluka Agar 05040	35°C	70°C	N/A	1% gel > 1200g/cm^2	Campani et al CESMAR 7 Research 2007	£21.70	Sigma Aldrich

Table 1:

Part II: Experimental Phase and Results

Chapter 5: Defining variables

5.0 Introduction

This chapter outlines the goals of this research and highlights the chosen variables, reviewing why each was selected. It draws on the limits of current research outlined in the review of literature and discussion on poultices, agar and agarose.

5.1 Research Questions and Variables

The goal of this research was to clarify the working properties of agarose gels on textiles. The project establishes an understanding as to how current trends in the literature relate to observed working properties. Three main research questions were identified for this project and focus on three variables, fibre type, gel concentration, and gel depth:

- What affect does the textile substrate have on the rates of diffusion and capillary action?

This was measured by how effectively the gels drew out ink from a textile and the degree of contact achieved between the gel and the fabric. The results were gauged by examination of the gels after their removal from the textile.

- How do different gel concentrations work on different fabrics?

This was measured by determining how far ink can travel though a fabric when a gel is applied. Results were collected my measuring to total movement of the ink in the warp and weft directions.

- What role does the depth of gel have on the effectiveness of the treatment?

This question examined whether altering the depth of the gel changes how the gel works in terms of diffusion and capillary action. This was measured though comparison of the gel and fabrics from the two different depths.

5.2 Fibres

For this study, three common natural fibres prevalent in textile collections were chosen for testing: silk, cotton and wool.

These fabrics exhibit different structures and properties and thus react to conditions in a variety of different ways. They should provide a better understanding of how an agarose gel poultice should be adapted when being employed on different materials. They also represent fibres that often undergo cleaning treatments and are thus representative of how objects may respond to treatment.

5.2.1 Structure and Properties

Natural and synthetic fibres react to the introduction of moisture in different ways. The moisture regain of a fibre, or how much moisture a fibre can take up, is dictated by the structure of the fibre as well as the degree of degradation[112]. Water will enter the amorphous regions of the fibre prompting them to swell and working like a plasticizer, prompting greater fibre flexibility[113]. The moisture regain of a highly degraded fibre can pose problems as the wet strength is diminished as their structure breaks down[114].

On the macro level the property of wettability of fibre is key to understanding how a textile responds to the introduction of water or other liquids. Each fibre type exhibits distinctive characteristics that dictate how liquids move through a textile. Wettability can be measured by surface tension, [115]. If the surface tension of the liquid is lower than that of the fibre, the fibre will wet out. If the surface tension of the liquid is higher than the fibre, the ability of the fibre to wet out decreases[116]. The factors that affect surface tension and thus the ability of the fibre to wet out are the structure and finishing process of the fibre. This property means that if the surface tension of the liquid changes, the rate at which a liquid wets out a fabric can also change[117].

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[112] Ágnes Tímár-Balázsy, and Dinah Eastop, *Chemical Principles of Textile Conservation.* (London: Routledge, 1998),15, 34

[113] Tímár-Balázsy, 194

[114] Tímár-Balázsy, 35

[115] Joel Lindberg, "Relationship Between Various Surface Properties of Wool Fibers Part I: Methods for Estimating Wool Fiber Modification" *Textile Research Journal* vol. 23 no. 2, (1953): 585.

[116] Tímár-Balázsy, 199; Lindberg 585.; Kathleen Van de Velde and Paul Kiekens, "The Wettability of Natural Fibres as a Reinforcement for Composites," *Die Angewandte Makromolekulare Chemie* 272, (1999): 87

[117] Lindberg 585

Textile conservators have utilized these properties during wet cleaning treatments to either remove degradation products or to relax creasing that had deformed an object[118]. These traits play a role in poultice systems, forcing the adaption of treatments to fibre type as each fibre will react to the introduction of moisture differently.

5.2.2 Silk

Silk is a natural filament fibre reaching up to 600 metres in length and produced by a silk worm as it spins its cocoon[119]. Roughly 60% of the fibre is crystalline in structure[120]. Silk is hydrophilic, hygroscopic, and can absorb water up to 1/3 its weight. While the crystallinity of the fibre limits absorbency it is more receptive to absorbing water than wool. Hydrophilic fibres like silk allow for a greater rate of wetting as the adhesion properties between the water and fibre are greater prompting the fibre to wet out quickly[121].

5.2.3 Cotton

Cotton is a plant based fibre, the seed hair from the cotton plant. Staple fibres range in length from 0.32 cm to 6.35 cm[122]. The plant exhibits both crystalline and amorphous regions but 70% of the fibre is crystalline[123]. The amorphous regions allow for the formations of holes and capillaries in the cell wall, which helps enhance the fibres ability to absorb water. The hydrophilic nature of this fibre allows cotton to wet out readily.

5.2.4 Wool

Wool refers to fibres that are obtained from a sheep, goat or camelid[124]. Wool fibres can hold large quantities of water due to only 30% of the fibre being crystalline in structure[125]. Despite this, wool fabrics exhibit poor wetting properties due to their structure and the presence of the epicuticle, the outer,

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[118] Tímár-Balázsy, 194
[119] Kathryn L. Hatch, *Textile Science*, (New York: West Publishing Company, 1993),155
[120] Tímár-Balázsy, 11
[121] Tímár-Balázsy, 199
[122] Hatch, 163
[123] Tímár-Balázsy, 11
[124] Hatch, 141
[125] Tímár-Balázsy, 11

water resistant layer of the cuticle on a single fibre that makes the fibre hydrophobic [126].

5.2.5 Choice of Fabrics

To reduce the variables weave and thread count were taken into consideration when identifying which fabrics were to be used. Ideally, fabrics of equal density, thread count, and similar structure would be used. The natural variation and structural differences in these fibres prevents that ideal, however a similar weave was found though the densities of these fibres differ. Plain weave wool delaine, cotton lawn and heavy weight haboti silk were chosen and an average thread count was taken (Table 2). While the range could be considered significant, due to the variation in threads it is unlikely that a closer thread count could have been obtained. All these fabrics were obtained from Whaley's LTD[127].

Average Thread Count of Test Fabrics

Fibre type	**Average Thread Count**
Heavy Weight Silk Haboti	20 threads/.5 cm
Cotton Lawn	26 threads/.5 cm
Wool Delaine	11 threads/ .5 cm

Table 2

5.3 Trends in Gel Concentrations

Trends in gel concentration are difficult to identify; as there are numerous factors that come into play, including the type of treatment being undertaken (Table 3). Reviewing the literature as a whole, conservators appear to use a 1% gel most often. These treatments are usually enzyme treatments and make up a large percentage of the published literature. In textile conservation treatments for cleaning appear to only use 1% or 4% gels, the two extremes of the range of concentrations suggested by Wolbers in his presentations. The two treatments that utilized this range are similar, both used 4% gels for initial testing before transitioning to 1% gels for the treatment. When agar is used, concentrations

[126] Lindberg, 586-587.
[127] See Appendix 2, samples at back

increase, Campani used a .5% higher concentration of agar and Younger and Duffus employed a 1.25% increase from agarose[128]. This indicates a difference in how these gels form and highlights issues in transitioning from agarose to agar.

The concentrations for this project were chosen to show the affect of agarose on the fabrics at the two extremes of the range suggested by Wolbers and at the middle of the suggested range, 1%, 2.5% and 4%. These concentrations would provide an idea of how these gels respond to the fabrics and allow for a better determination to be made in terms of what gel to choose for a specific material if not eliminate portions of the range for successful use on textiles.

Summary of Trends in Conservation Treatments Utilizing Agarose or Agar

Author	**Media**	**Gel Concentration**	**Gel Depth**	**Time Applied**	**Treatment**
Vandyke,	Paper	1.2% Agarose	.5-.8 cm	N/A	Enzymes
Stockman	Paper	1.2% Agarose	N/A	N/A	Enzymes
Warda	Paper	1% Agarose	N/A	1-4 min	Adhesive removal (No Enzymes)
Pouliot et al	Ceramics	2-4.5% Agarose	N/A	N/A	Cleaning
Campani	Ceramics	1.5% Agarose 2% Agar	1 cm	1.5 hr – 2 hr 40 min	Residue investigation
Sahmel/ Mina	Textiles (Wool)	1% Agarose (4% for Tests)	~.5cm	1 hr -15 min	Cleaning
Shaeffer	Textiles (Linen)	1%[129] Agarose (4% for Tests)	N/A	1 hr	Cleaning
Ellis	Textiles (Cotton)	1% Agarose	N/A	N/A	Enzymes
Younger/ Duffus	Textiles (Cotton)	2.25% with Agarose 3.5% with Agar	N/A	2 hr	Cleaning
Gulotta et al	Stone	3% Agar	Painted onto surface	30 min	Cleaning

Table 3

[128] Campani et al 41; S. Younger, P Duffus, unpublished treatment report.
[129] Elizabeth Shaeffer, email message to the author, August 3, 2014. Wolbers discusses the treatment in the ICON videos but states "4%, in that range". This should be disregarded.

5.4 Trends in Gel Depths

Trends in gel depth are difficult to identify as it is often given as a range, approximation, or not recorded. Sahmel et al notes that gel depth "is related to its flexibility and drying time"[130]. Despite the assumed importance of this factor, very few trends can be identified. In the two papers where gel depth is noted it is between .5-.8 cm or measured as an approximation. When a 1% gel is poured onto a flat surface to form disks an average of about .3 cm can be observed, higher concentrations may form thicker gels and trays may be used to raise the depth. The reduction of depth would decrease the possible height of the pores, possibly limiting both the amount of water that can enter the system as well as the solution that can be drawn into the gel.

Without a defined trend for this variable it is difficult to hypothesise about the effect depth of a gel on a treatment. The flexibility gained through a thinner gel may result in better contact as it can laid across an object where a thicker gel, being less flexible, is more likely to sit on the surface.

For this project, .3 cm and .5 cm gels were chosen due to .5 cm use in previous treatments (Table 3). .3 cm gels are in range of the natural depth of these gels when cast on a flat surface. The use of depths that have been used for past treatments or that occurs naturally continues in the vein of trying to make the results of this project both useable and relatable to available literature. Following what the gel tends to do naturally also helps make the results produced here more reproducible.

5.5 Choice of Agarose:

The agarose for this study was chosen after looking at the range of materials used in different case studies, workshops and experiments. The goal was to identify a gel that could be obtained in both Europe and The United States and that would have the properties needed for a basic cleaning treatment.

The trends in EEO, gel strength, and melting point were taken into account (Table 1). This ensured consistency with available research without introducing variables that would prevent the results from being compared.

[130] Sahmel et al, 5

The agarose chosen, A9539 from Sigma Aldrich, is a low EEO gel for molecular biology. The agarose did not have a recorded melting point, however, based on the pattern of the cooling and melting points of agarose products provided by Sigma Aldrich a gelling temperature of 36 °C and a melting point around 88 °C was expected[131]. A9539 is moderately more expensive than the agarose used in current published papers but could be obtained in both Europe and the United States and was still cheaper than other types on the market. Chemical companies sourcing many of the cheaper products used in the US will not ship internationally and thus were not considered for this research.

[131] See Appendix 1

Chapter 6: Preparation of Materials and Testing Procedure

6.0: Introduction

This chapter discusses the preparation for testing. The preparation of the materials for testing took place throughout the experimental phase. Preparation took approximately two weeks and testing occurred over four weeks[132].

6.1 Preparation of Fabrics

Parker Quink®, a washable ink, was used to stain the test samples[133]. Quink was chosen for its ability to move through the textile without separating into different pigments and for the vivid colour that was easily visible in preliminary tests. The circles were painted ~2 mm smaller than the stencil used for application to try and account for the wicking tendency of the fibre[134].

All stains were between two days and four weeks old during the course of testing. This range in age should have no bearing on the mobility of the stains.

6.2 Preparation of Gels:

A macaroon baking mould was used to form the gel disks. To increase the depth, Melinex® strips were cut and made into rings that would sit inside the mould (Figure 3)[135]. These were marked at .5 cm to increase the depth and allow for the formation of thicker gels. .3 cm gels were made using the Melinex® rings placed on a sheet of Melinex® to achieve the thinner gel (Figure 4).

[132] See Appendix 3:
[133] See Appendix 2
[134] See Appendix 2
[135] See Appendix 2

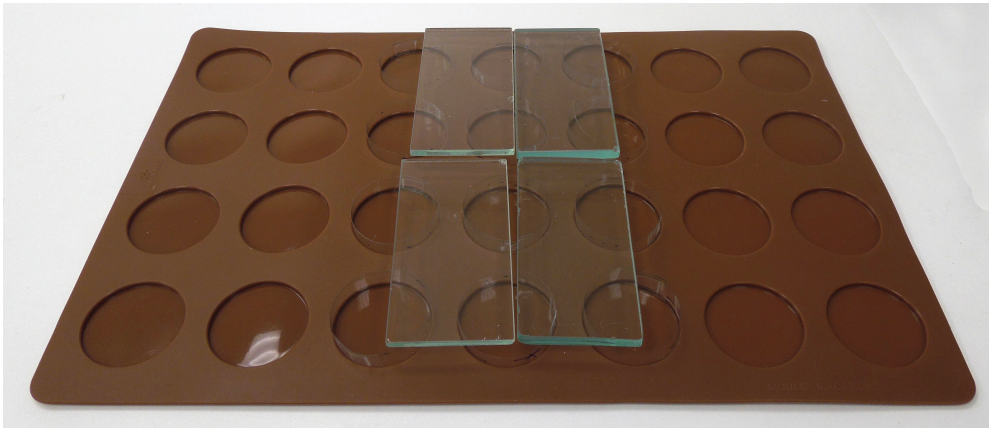

Figure 3: Set up using the silicone macaroon mould for the .5 cm gels

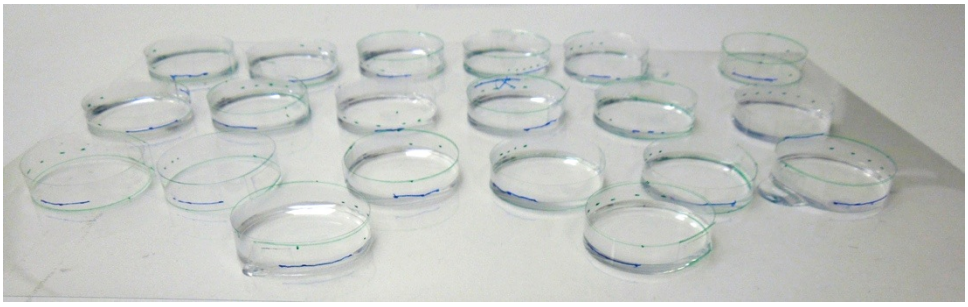

Figure 4: Melinex® rings on Melinex® sheet as used to prepare .3 cm gels.

6.3 Testing process

Fabric samples were chosen at random, one of each of the three fibres. These were laid out on a Melinex® sheet and the circular stains measured from the widest points in the warp and weft directions[136].

Gels were chosen at random from the bag that they were stored in and measured at numerous points around the circumference obtain a depth measurement.

Weights were incorporated into testing to help ensure contact between the fabric and the gel. After initial testing of different weights, three were chosen that were 48.12 g, 47.99 g and 48.13 g, the differences are considered negligible, as variation was deemed unavoidable. The weights were used for both gel depths on all the tests except for the first test at 4% and the last three tests at 1%. This reflects the

[136] Further observations from testing see Appendix 4

initial implementation of the weights within the testing and their removal on the tests that indicated that their use was excessive[137].

Both gel and fabrics were photographed before the gels were put in place.
Gels were placed on the textile and weights placed on top of the gel (figure 5). This system was left in place for an hour. The gels were then examined, and photographed and the following information recorded:

- The degree of contact as visible on the gel
- How the stain was absorbed into the gel matrix.
- The measurement of the ink stains at their new widest points in the warp and weft directions.

Each test was repeated four times to increase the sample size and increase statistical viability.

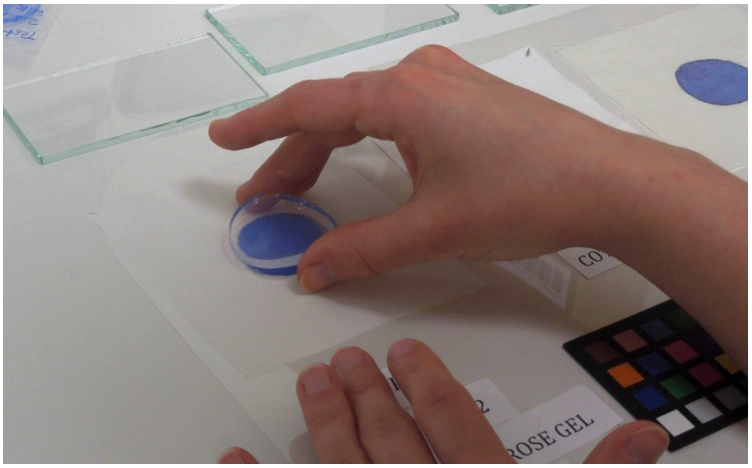

Figure 5: Gel being placed over the stain on the fabric samples.

[137] See Appendix 4

Chapter 7: Results

7.0 Introduction:

This chapter summarises observations on the working properties of the gels at different concentrations and depths. The information gathered through testing will be presented in charts and tables. The results are divided and discussed by fibre type, gel depth, and concentration. The last sections discuss the gels, including the degree of contact they achieved with the different fabrics and the gel's ability to draw the ink out of the fabrics.

The original and the final size of the stain as well as the overall movement are recorded. Images of the final fabric samples provide visuals of the movement through the textile (Figures 6, 9,12,15). The graphs compare the results of these tests, showing the overall movement of the stain for each of the tests in all three concentrations (Figures 7,8,10,11,13,14). These graphs show how a change in the concentration of the gel can effect how water enters, and moves through, a fabric and how it is drawn out of the textile[138].

7.1 Silk

In all the tests where gels were applied to silk, water movement carried the ink outside the original dimensions of the stain. In most cases, this movement resulted in ringing and sometimes a faint tideline[139]. In others, no tideline was evident, indicating even movement through the textile.

The tests using 1% gels at a .5 cm depth showed the largest degree of movement through the textile but the most predictable with an average of 6.3 cm in both directions. The even movement can be accounted for in the size of the sample textiles as, in all cases, the water from the gel reached the edge of the sample (Table 4, Figure 6 and 9).

The tests using 2.5% gels showed an average movement of 2.1 cm in the warp direction and 2.6 cm in the weft direction, three times less than the movement seen in 1% gels. In the last two tests within this concentration the gels were lightly

[138] See Appendix 5
[139] See Appendix 6

pressed down onto the fabric before application of the weights to keep the procedure consistent across the tests. There appeared to be no discernable affect from this change in application. The variation in the warp and weft exhibited in these tests show how unpredictable the movement of moisture can be through the textile media; but also shows how a change in concentration can have an immediate affect on the movement of moisture through the textile. (Table 4, figures 6 and 7)

Tests using 4% gels showed the least movement of moisture through the test samples averaging .5 cm growth in the warp direction and .4 cm in the weft direction. This distance is more than four times less than the movement seen with 2.5% gels. These changes show how small concentration changes can effect how much water the gel releases and how much a textile will wet-out (Table 4 figures 6 and 7).

The tests run using .3 cm gels produced results that were very similar to those produced with .5 cm gels. .3 cm gels exhibited a slight decrease in the movement of the stains in 2.5 % and 4% gels, possibly the result of a reduction of the water content of the gel due to the decrease in depth (Table 5 Figures 6, 8).

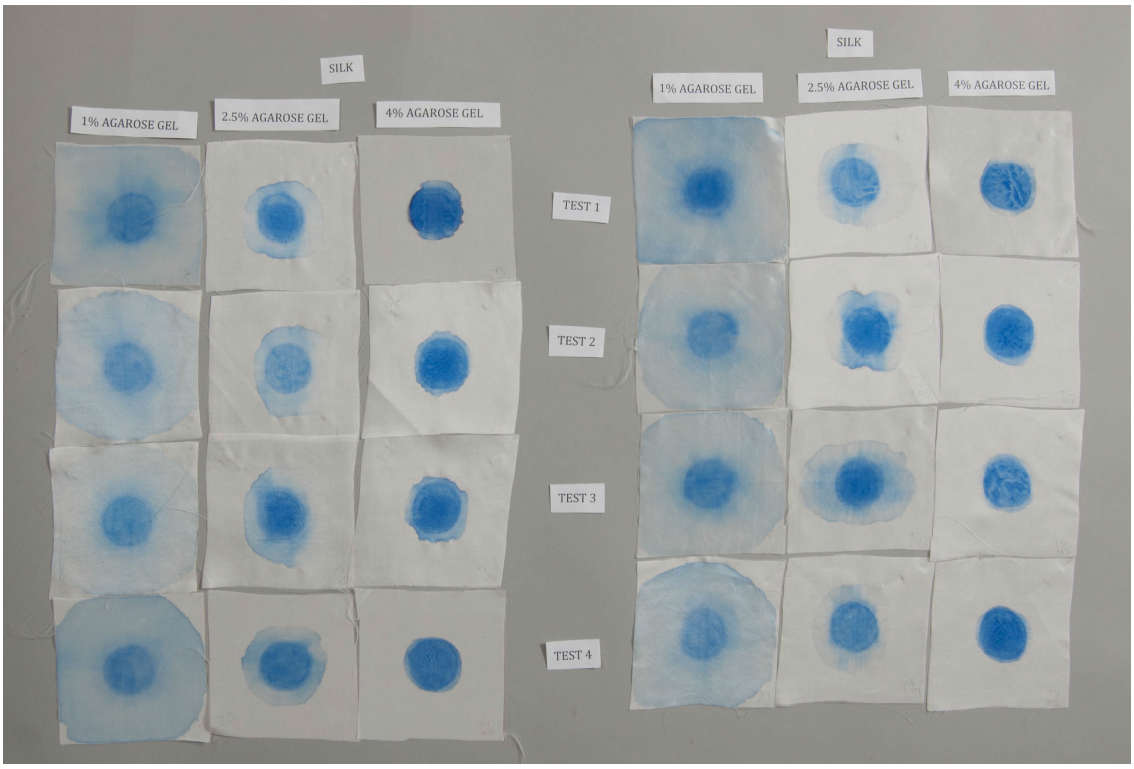

Figure 6: Movement of ink through silk samples. .5 cm gel samples are on the left and .3 cm gel samples on the right. Each column is a concentration and each row the test in that concentration.

The Growth and Total Movement of Ink Stains through Silk After the Application of .5 cm Gels

Concentration of Gel	Stain measurement before Warp x Weft (cm)	Stain Measurements After Gel Application, Warp x Weft (cm)	Total Movement of Stain, Warp x Weft (cm)
1%	3.75 x 3.65	10 x 10	6.25 x 6.35
1%	3.7 x 3.5	10 x 10	6.3 x 6.5
1%	3.7 x 3.6	10 x 10	6.3 x 6.4
1%	3.7 x 3.8	10 x 10	6.3 x 6.2
2.50%	3.9 x 3.4	5.6 x 5.7	1.7 x 2.3
2.50%	3.75 x 3.3	6.35 x 6	2.55 x 2.7
2.50%	3.5 x 3.75	5.9 x 7.2	2.4 x 3.45
2.50%	3.95 x 3.5	5.85 x 5.35	1.9 x 1.85
4%	3.9 x 3.7	4.05 x 3.9	0.15 x 0.2
4%	3.85 x 3.5	4.65 X 4	0.8 x 0.5
4%	3.8 x 3.5	4.7 x 4.35	0.9 x 0.85
4%	3.7 x 3.9	3.7 x 4.1	0 x 0.2

Table 4: Movement of ink through silk using a .5 cm gels

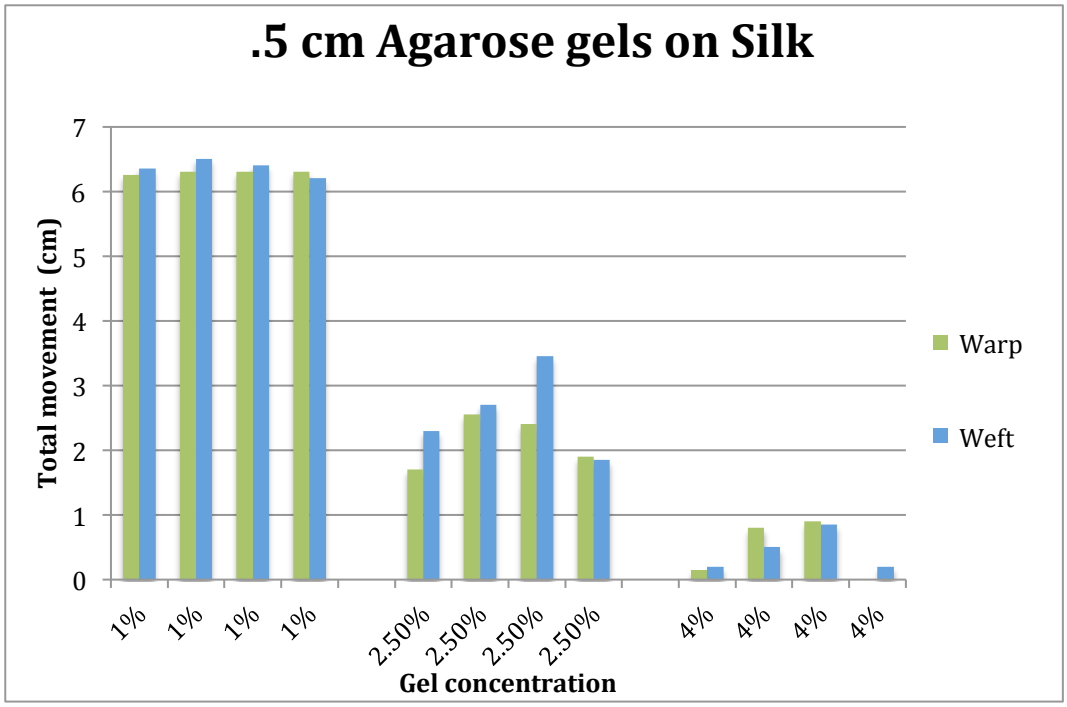

Figure 7: Total movement of the ink stains on silk stains with .5 cm gels.

The Growth and Total Movement of Ink Stains through Silk After the Application of .3 cm Gels

Concentration of Gel	Stain measurement before Warp x Weft (cm)	Stain Measurements After Gel Application, Warp x Weft (cm)	Total Movement of Stain, Warp x Weft (cm)
1%	3.7 x 3.8	10 x 10	6.3 x 6.2
1%	3.8 x 3.4	10 x 10	6.2 x 6.6
1%	3.4 x 3.7	10 x 10	6.6 x 6.3
1%	4 x 3.4	9.7 x 9.85	5.7 x 6.45
2.50%	3.85 x 3. 45	5.8 x 6.6	1.95 x 3.15
2.50%	3.9 x 3.5	5.6 x 5.5	1.7 x 2
2.50%	3.5 x 3.85	5.85 x 8	2.35 x 4.15
2.50%	3.4 x 3.8	5.2 x 6.1	1.8 x 2.3
4%	3.85 x 3.85	4.15 x 4.3	0.3 x 0.45
4%	3.85 x 3.6	4.5 x 3.95	0.65 x 0.35
4%	3.7 x 3.5	4.15 x 4.25	0.45 x 0.75
4%	3.9 x 3.6	4 x 4.2	0.1 x 0.6

Table 5: Movement of ink through silk using a .3 cm gels

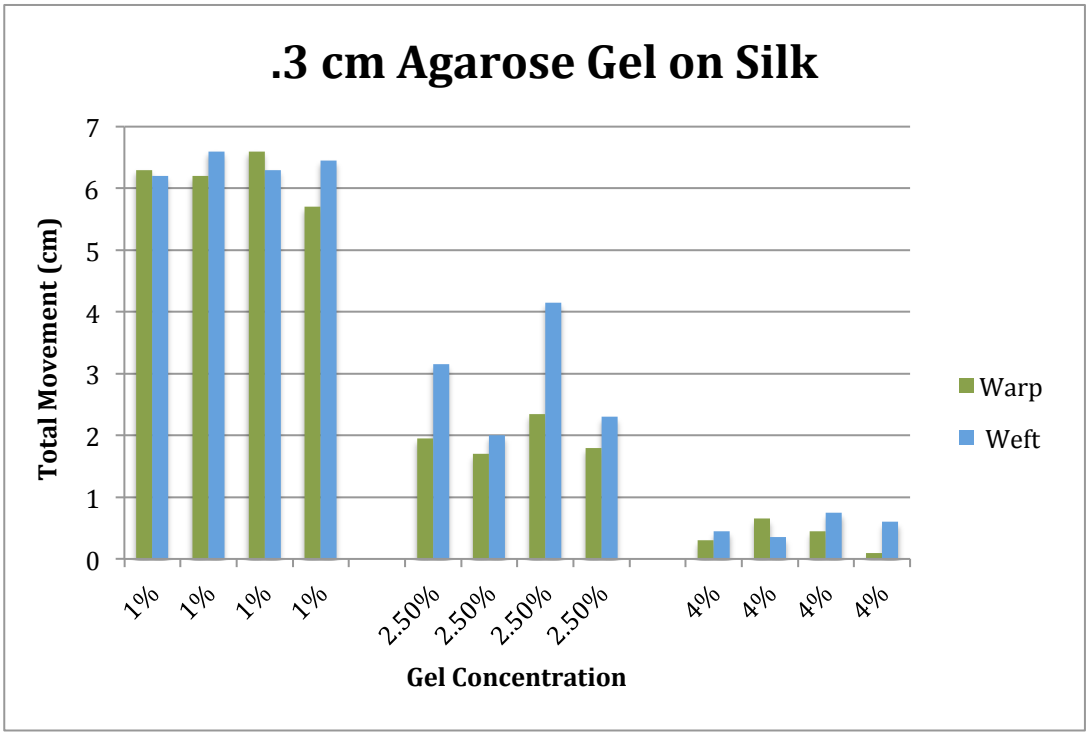

Figure 8: Total movement of the ink stains on silk stains with .3 cm gels.

7.2 Cotton:

Tests using cotton samples were less predictable. The stains did not move evenly through the materials as they did in silk and tidelines were more prevalent in all the tests.

In the tests with .5 cm gels at a 1% concentration, the stains would wick outward resulting in ringing and tidelines where the water spread through the sample. The average movement of the stains was 5.8 cm in both the warp and weft directions. (Table 6 Figures 9, 10)

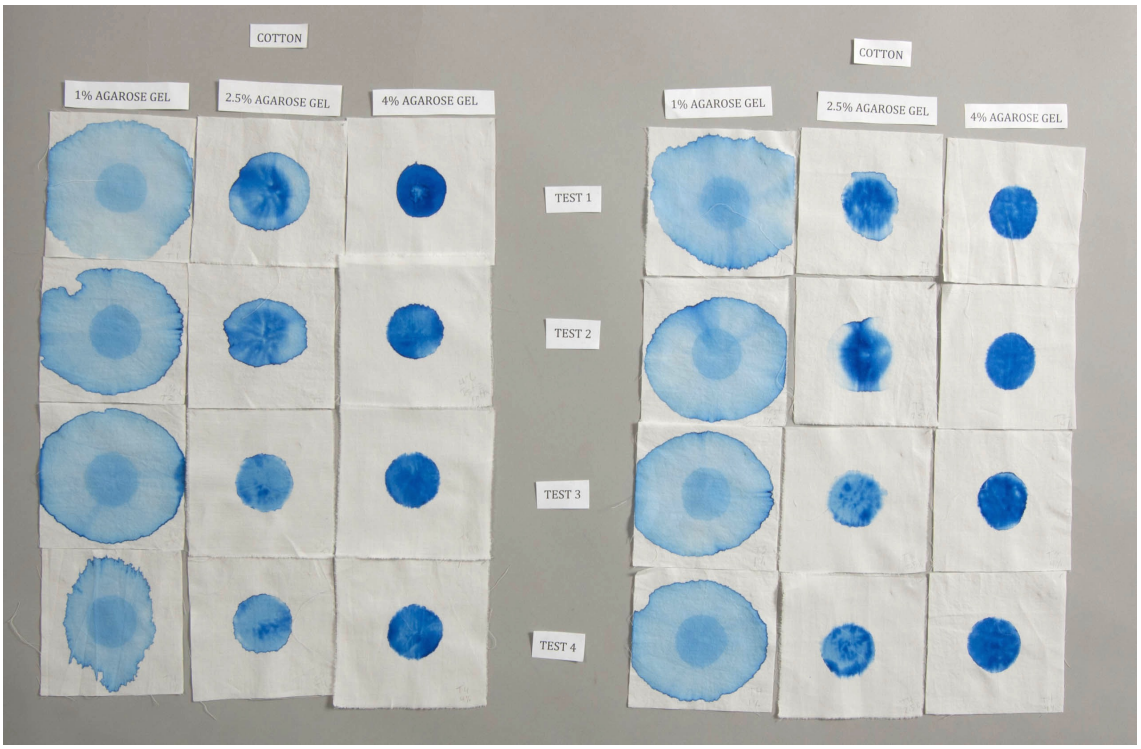

Figure 9: Movement of ink through cotton samples. .5 cm gel samples are on the left and .3 cm gel samples on the right. Each column is a concentration and each row the test in that concentration.

The Growth and Total Movement of Ink Stains through Cotton After the Application of .5 cm Gels

Concentration of Gel	Stain measurement before gel application, from widest points Warp x Weft (cm)	Stain Measurements After Gel Application, Warp x Weft (cm)	Total movement of stain Warp x Weft (cm)
1%	3.75 x 3.45	10 x 9.7	6.25 x 6.25
1%	3.9 x 3.65	9.6 x 9.7	5.7 x 6.05
1%	3.9 x 3.9	9.4 x 10	5.5 x 6.1
1%	3.7 x 3.55	9.5 x 6.5	5.8 x 4.95
2.50%	3.65 x 3.75	5.5 x 5.65	1.85 x 1.95
2.50%	3.65 x 3.8	4.8 x 5.75	1.15 x 1.95
2.50%	3.6 x 3.65	4.1 x 4.1	0.5 x 0.55
2.50%	4.0 x 3.85	4.2 x 4.15	0.2 x 0.3
4%	3.55 x 3.55	3.6 x 3.55	0.05 x 0
4%	3.5 x 3.5	3.6 X 3.55	0.1 x 0.05
4%	3.6 x 3.6	4 x 3.75	0.4 x 0.15
4%	3.5 x 3.8	4.0 x 3.9	0.5 x 0.1

Table 6: Movement of ink through cotton using a .5 cm gels

2.5% gels showed less movement than 1% gels. The size of the staining increased by almost 2 cm. Once finger pressure was applied to the tests using 2.5% gel contact drastically improved and the tidelines and ringing diminished, the staining moving less than 1 cm. (Table 6 Figures 9, 10)
The test using 4% gels showed the least movement, less than a centimetre for each test. The stiffer gel was able to make less contact with the textile substrate, reducing the amount of ink drawn out of the fabric, as well as the tidelines and ringing that was seen in the tests utilising lower percentage gels. (Table 6 Figures 9, 10)

The gels at .3 cm depth followed the trends exhibited in .5 cm gels. While there appeared to be some reduction in the movement of the stain, the average of the tests were remarkably similar indicating the limited effect a change in depth could have. (Table 7 Figures 9,11)

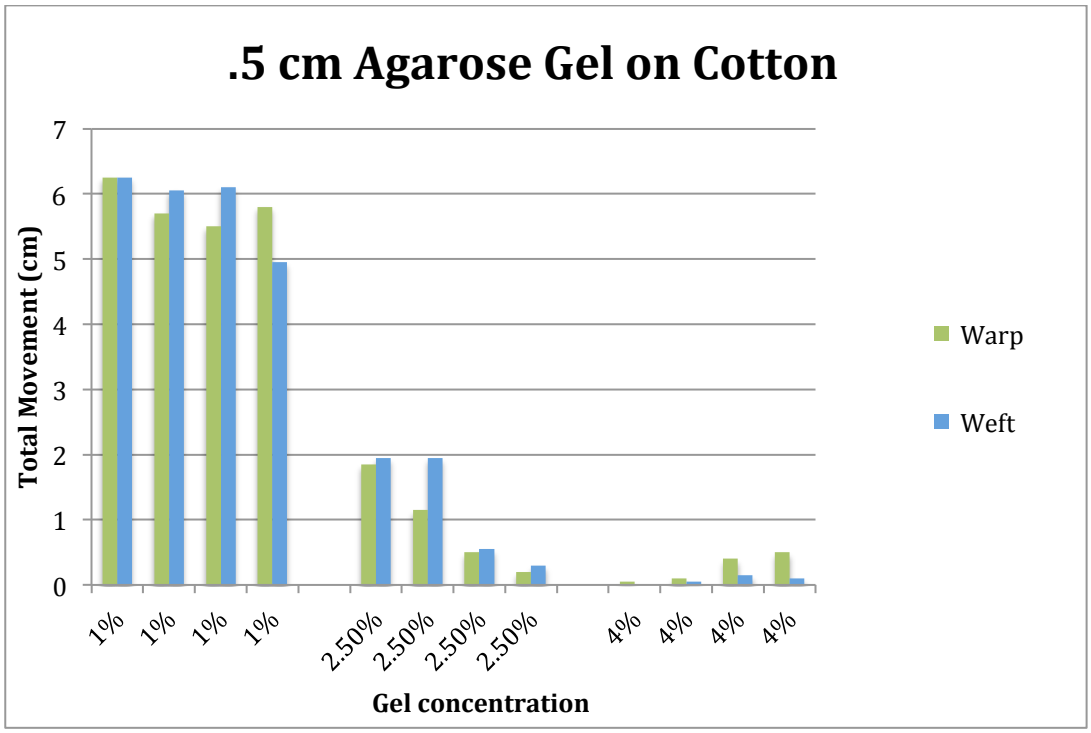

Figure 10: Total movement of the ink stains on cotton samples with .5 cm gels.

The Growth and Total Movement of Ink Stains through Cotton After the Application of .3 cm Gels

Concentration of Gel	Stain measurement before gel application, from widest points Warp x Weft (cm)	Stain Measurements After Gel Application, Warp x Weft (cm)	Total movement of stain Warp x Weft (cm)
1%	3.7 x 3.5	9.35 x 10	5.65 x 6.5
1%	3.5 x 3.5	9.8 x 8.8	6.3 x 5.3
1%	3.8 x 3.5	8.7 x 9.6	4.9 x 5.9
1%	3.9 x 3.7	8.6 x 9.4	4.7 x 5.7
2.50%	3.9 x 3.5	4.8 x 4.1	0.9 x 0.6
2.50%	3.6 x 3.7	5.3 x 5.5	1.7 x 1.8
2.50%	3.6 x 3.6	4 x 4.5	0.4 x 0.9
2.50%	3.5 x 3.6	4.1 x 4	0.6 x 0.4
4%	3.9 x 4.2	4.2 x 4.1	0.3 x 0.1
4%	3.9 x 3.5	4 x 3.7	0.1 x 0.2
4%	4.1 x 3.5	4.1 x 3.8	0 x 0.3
4%	3.6 x 3.8	4 x 3.9	0.4 x 0.1

Table 7: Movement of ink through cotton using a .3 cm gels

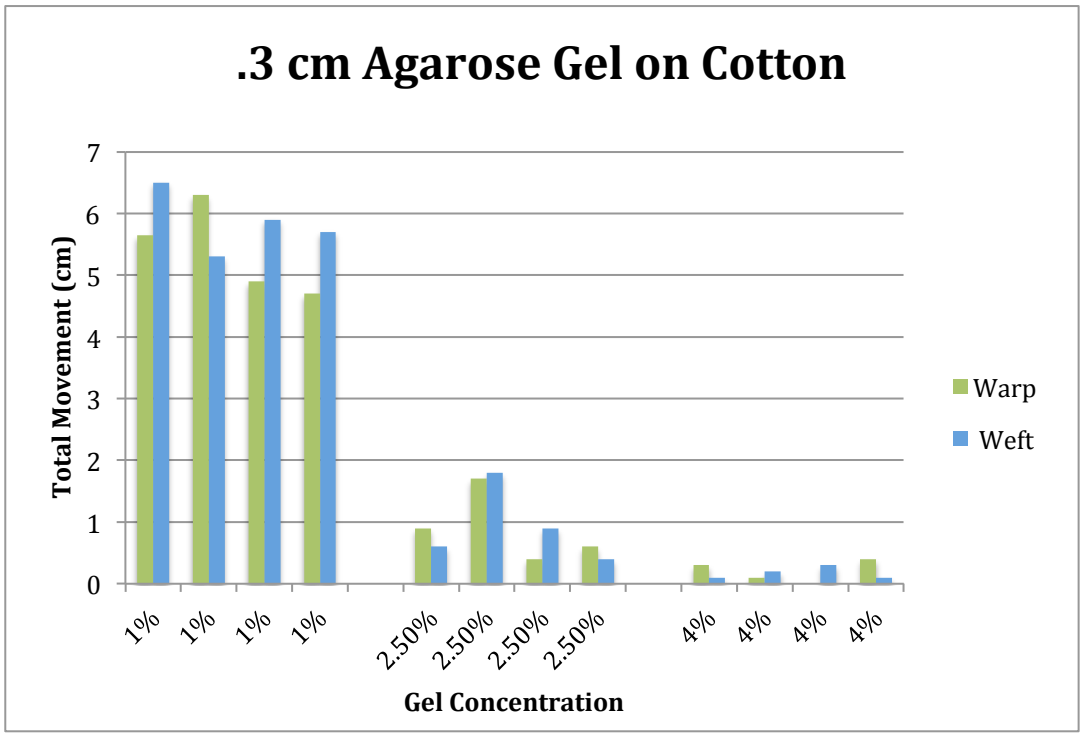

Figure 11: Total movement of the ink stains on cotton samples with .3 cm gels.

7.3 Wool

Wool's limited wettability reduced the degree of tidelines compared to tests on cotton and silk. The resistance to water limited the degree of wicking and prevented the ink from moving through the fibre at the rate seen in other fabrics.

In tests using 1% gels on wool the ink stains were mobilized, though not to the same extent seen in cotton and silk. The wool fabrics exhibited harder tidelines than silk. The movement in the warp direction averaged 4.59 cm and the movement in the weft direction averaged 4.45. (Table 8, Figure 12, 13) Tests run at 2.5 % showed much less movement, the stains in the warp direction moving only and average of .56 cm and .38 cm in the warp direction (Table 18, Figure 12, 13). Tests using 4% gels exhibited little to no movement of the ink, resulting in an average growth of .3 cm.

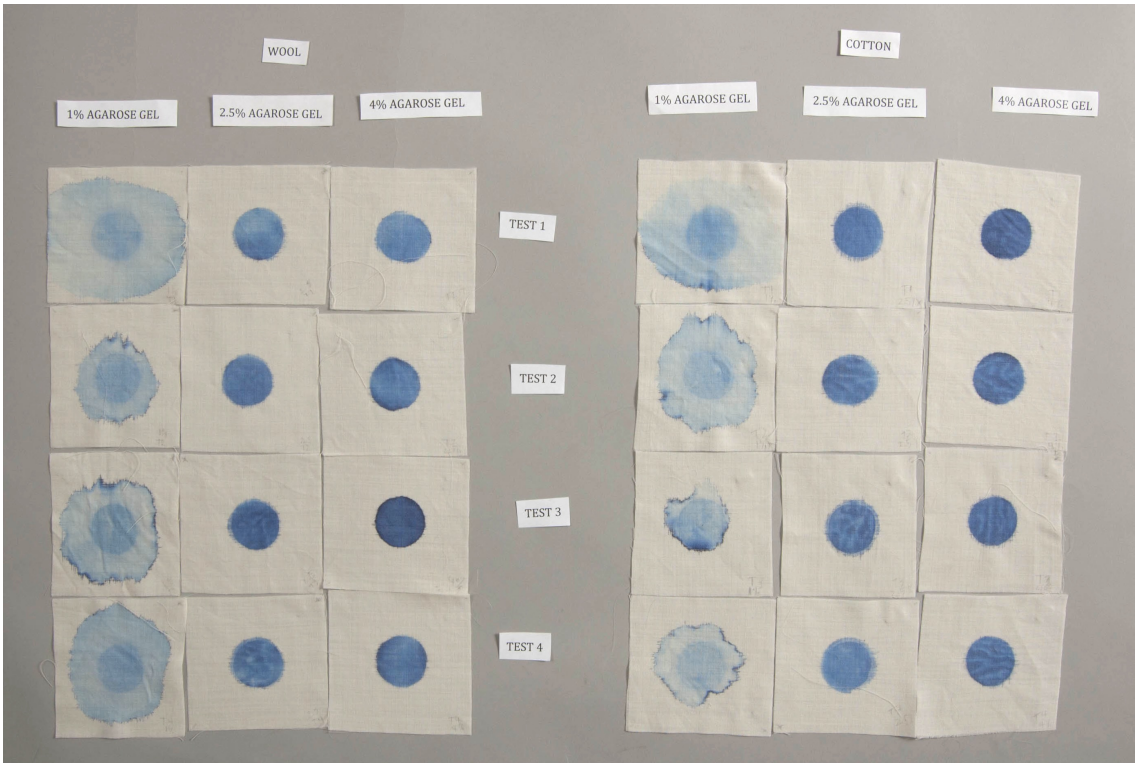

Figure 12: Movement of ink through wool samples. .5 cm gel samples are on the left and .3 cm gel samples on the right. Each column is a concentration and each row the test in that concentration.

The results from the tests run using a .3 cm gel followed the trend seen in the other two fabrics with the average of the two depths being very similar through all the concentrations tested (Table 9 Figure 12, 14).

The Growth and Total Movement of Ink Stains through Wool After the Application of .5 cm Gels

Concentration	Stain measurement before gel application, Warp x Weft (cm)	Stain Measurements After gel application, Warp x Weft (cm)	Total movement of stain Warp x Weft (cm)
1%	3.7 x 3.45	8.4 x 10	4.7 x 6.55
1%	3.7 x 3.4	7.35 x 8.5	3.65 x 5.1
1%	3.9 x 3.5	5.1 x 5	1.2 x 1.5
1%	3.7 x 3.7	6.4 x 6.2	2.7 x 2.5
2.50%	4 x 3.55	4.2 x 3.8	0.2 x 0.25
2.50%	3.3 x 3.8	3.8 x 4.2	0.5 x 0.4
2.50%	4.05 x 3.35	4.5 x 4.1	0.45 x 0.75
2.50%	3.5 x 3.6	4.1 x 4.2	0.6 x 0.6
4%	3.6 x 3.7	4 x 3.8	0.4 x 0.1
4%	3.7 x 3.8	3.8 x 4	0.1 x 0.2
4%	3.7 x 3.6	3.8 x 3.7	0.1 x 0.1
4%	3.5 x 3.75	3.95 x 4.05	0.45 x 0.3

Table 8: Movement of ink through wool using a .5 cm gel.

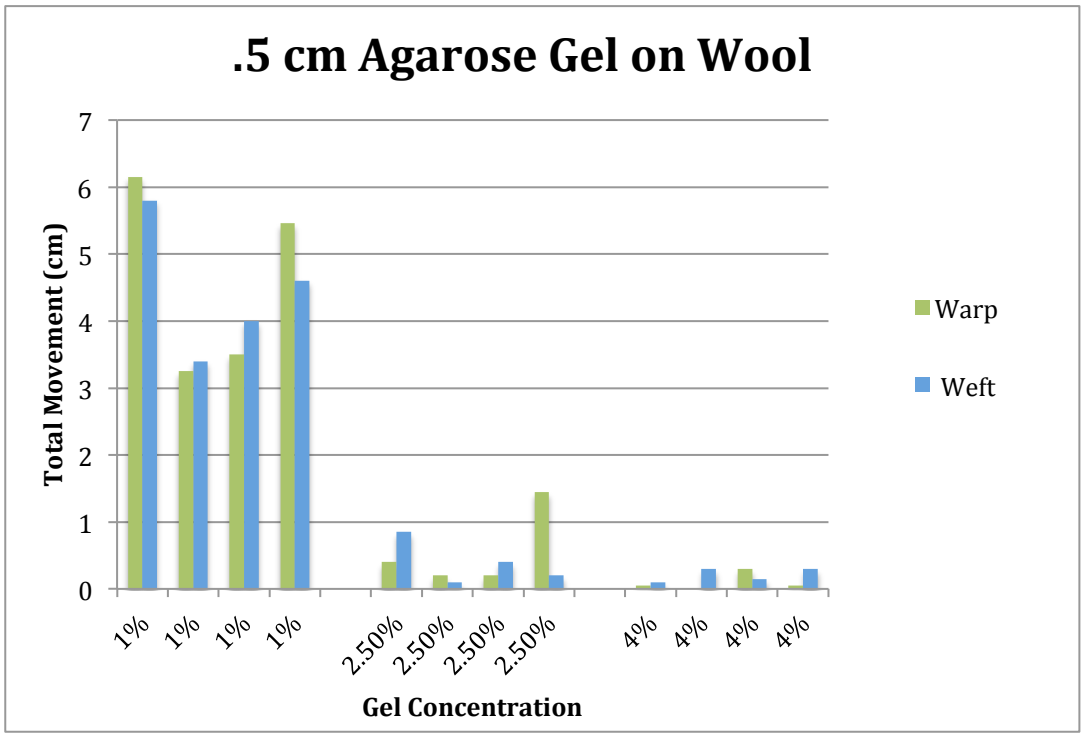

Figure 13: Total movement of the ink stains on wool samples with .5 cm gels.

The Growth and Total Movement of Ink Stains through Wool After the Application of .3 cm Gels

Concentration	Stain measurement before gel application, from widest points Warp x Weft (cm)	Stain Measurements After gel application, fro widest points- Weft (cm)	Total movement of stain Warp x Weft (cm)
1%	3.25 x 4.2	9.4 x 10	6.15 x 5.8
1%	3.65 x 3.4	6.9 x 6.8	3.25 x 3.4
1%	4.5 x 3.5	8 x 7.5	3.5 x 4
1%	3.8 x 3.5	8.8 x 8.1	5.46 x 4.6
2.50%	3.6 x 3.65	4 x 4.5	0.4 x 0.85
2.50%	3.7 x 3.8	3.9 x 3.9	0.2 x 0.1
2.50%	3.8 x 3.6	4 x 4	0.2 x 0.4
2.50%	3.4 x 4.2	4.85 x 4.4	1.45 x 0.2
4%	3.55 x 3.9	3.6 x 4	0.05 x 0.1
4%	3.85 x 3.5	3.85 x 3.8	0 x 0.3
4%	3.4 x 3.85	3.7 x 4.0	0.3 x 0.15
4%	3.8 x 3.7	3.85 x 4.0	0.05 x 0.3

Table 9: Movement of ink through wool using a .3 cm gel.

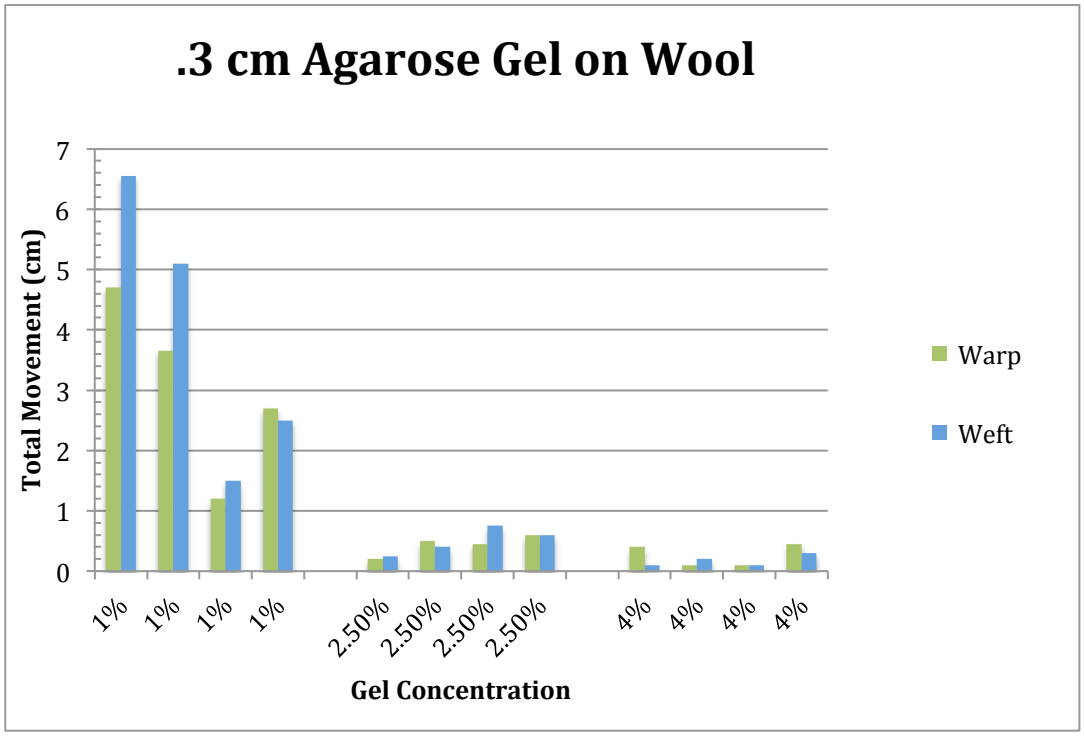

Figure 14: Total movement of the ink stains on wool samples with .3 cm gels.

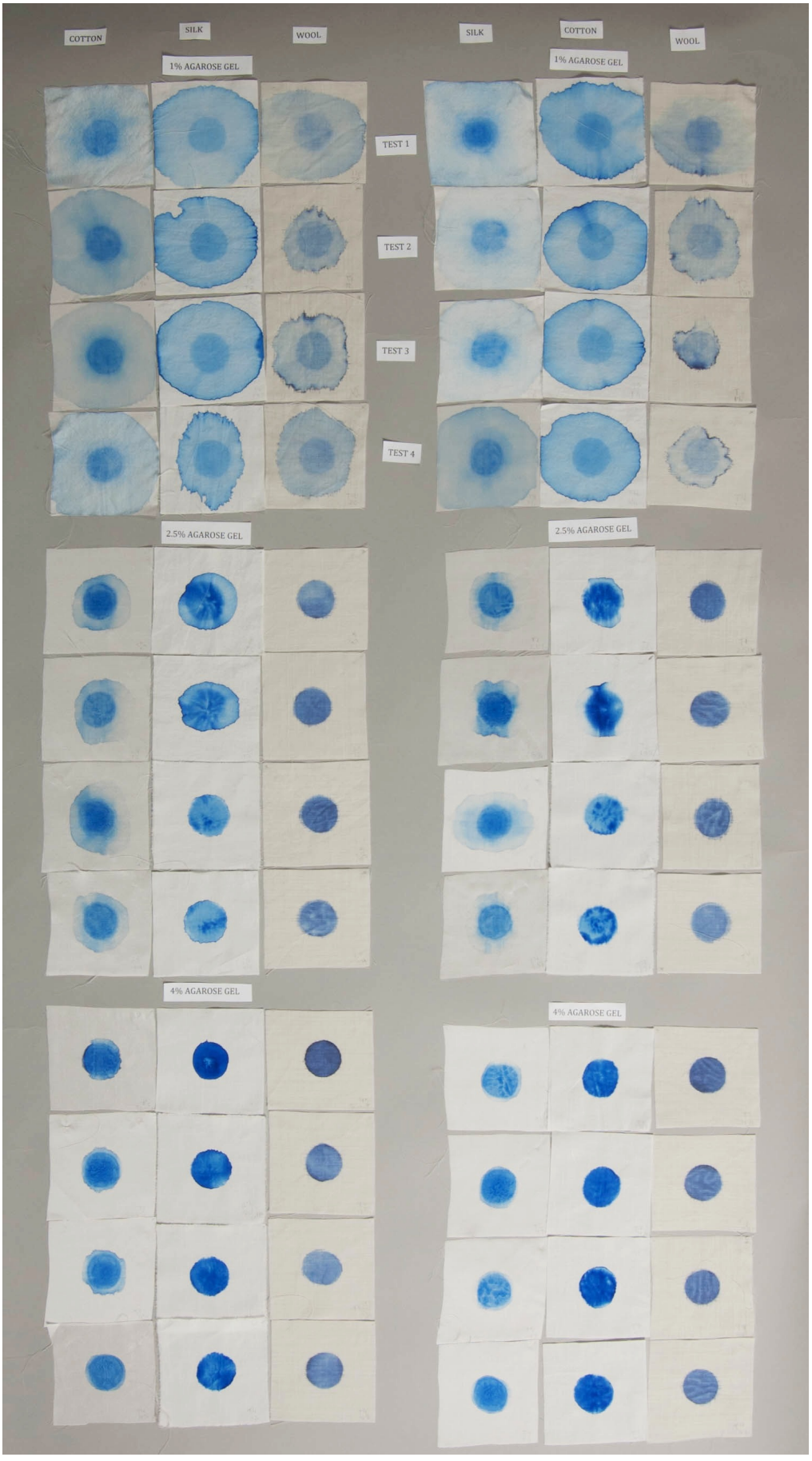

Figure 15: Movement of ink through fabric samples. .5 cm gel samples are on the left and .3 cm gel samples on the right. Each column is a concentration and each row the test in that concentration.

7.4 Gel Properties:

Concentrations differed in their liquid state, affecting how individual gels formed. 4% gels were thicker in their melted state where as 1% gels had a similar viscosity to water. 2.5% gels were more viscous than 1% gels but still easy to pour. The moulds used for this project meant that the 4% gels were almost impossible to form as the water resistance form the silicone mound and the surface tension of the gel led to gel thicker blocks. Those gels with a lower viscosity would form thinner blocks. Thinner gel blocks were more flexible and lower concentration gels had a softer the structure. Decrease in gel concentration increased flexibility. 1% gels were the softest, easily moulding to the contours of the textile and allowing the grain to imprint across the surface. 1% gels clearly exhibited "weeping", a spontaneous release of water as a result of syneresis, outlined by Arnott[140]. These gels were much more difficult to work with, they had to be handled with care as to not crush or deform the gel. The rapid loss of water also resulted in a decrease in depth. 2.5% gels were slightly firmer, they would bend, and impression of the weave structure could be found through the surface of the gel. These gels were easier to handle, they could be picked up and moved, though the surface of the gel was still easily scarred. 4% gels were much firmer, very few impressions could be found on the gel surface without the application of weight. These gels were the easiest to handle but also inflexible and bending them caused them to crack.

7.4.1 Gel Depth

The depth of gel was limited in how it could be controlled. Gels were poured individually and some variation in the depth was inevitable. The gels used under the .5 cm depth tests ranged from 0.45 -0.7 cm in height. The gels used in the .3 cm tests ranged from 0.3- 0.45 cm in depth. (Tables 10-12)

The height was taken on the outer circumference and included the ridge formed by the meniscus. The interior depth would be slightly less then the exterior depth. The interior depth could not be measured without a cross section and the gels

[140] Struther Arnott, A. Fulmer, W. E Scott, "The Agarose Double Helix and its Function in Agarose Gel Structure," *Journal of Molecular Biology* 90 (1974): 269.

changed in depth after application on the textile making measurements on the gels after application inaccurate.

7.4.2 Gel Contact

The contact achieved by the gel on the different fabrics could be observed after the removal of the gels from the fabric. The textile left a grain imprint on the gels were it was in contact with the textile and distinctive patterning could be seen (Images 16-19). The degree of contact quantified using a numbered scale.

0- No visible contact

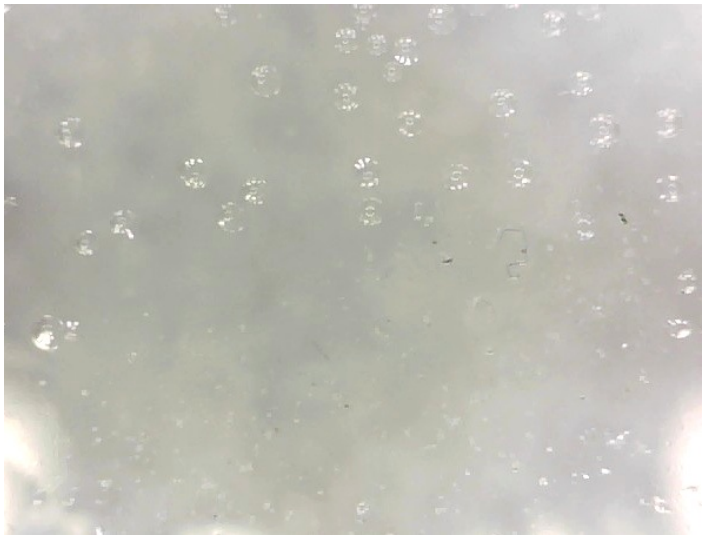

Figure 16: Agarose gel 200x magnification

1- Limited visible contact at the edge or centre of the gel

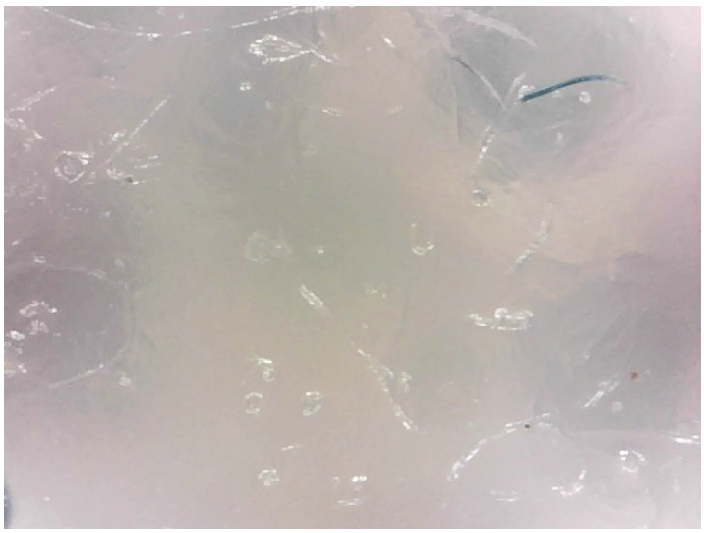

Figure 17: Agarose gel 200x magnification

2- Good contact around the edges and some through the centre

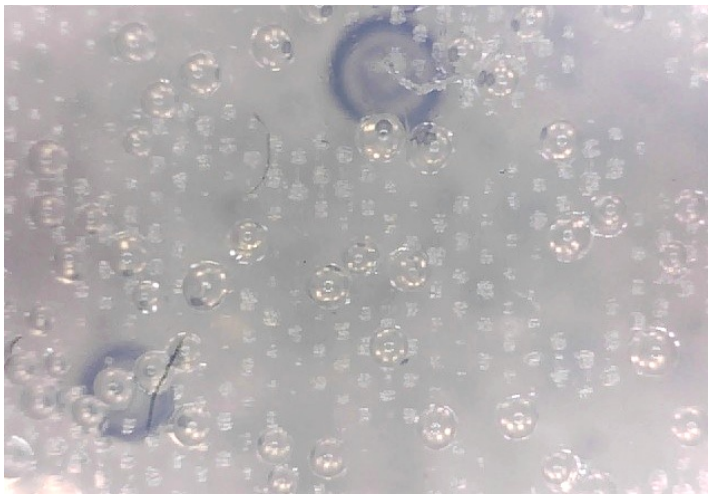

Figure 18: Agarose gel 200x

3- Excellent contact through the whole gel

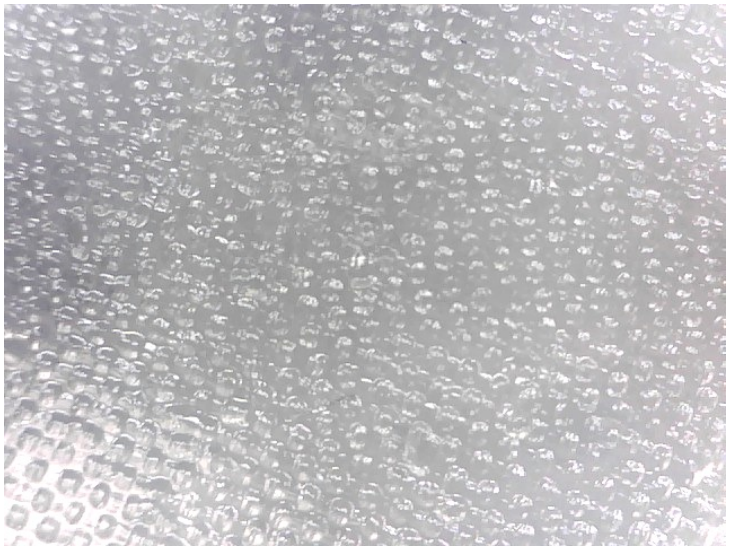

Figure 19: Agarose gel 200x

The uptake measures the effectiveness of the gel, or how much of the ink it was able to draw out of the textile. This was observed both directly after the removal of the gels as well as days after the testing. The pattern of ink through the gel provided some indication of how much ink was being drawn from the substrate. This patterning was used to initially quantify the uptake using the numbered scale below. After the ink diffused through the gel the overall colour could be used to determine how much ink had been taken up (figures 20-23, 27). This overall colour was factored into the initial score as patterning, though important did not accurately represent how much ink a gel was able to pull from the fabric as the

overall coloration of a gel later showed less uptake of the ink compared to tests exhibiting the spotted or halo patterning[141].

0- No Colour Visible

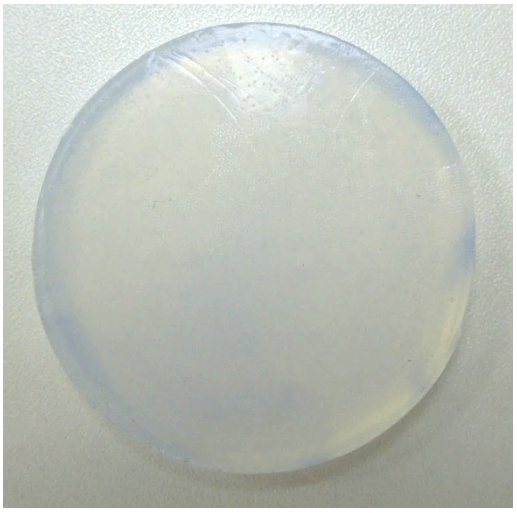

Figure 20

1- Faint Blue and /or Blue Spots

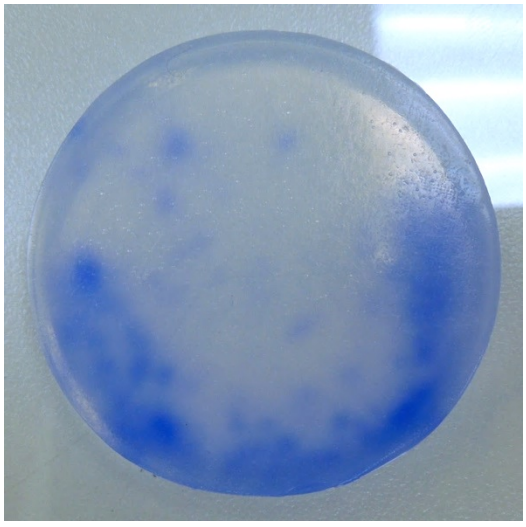

Figure 21

[141] See Appendix 7

2- Medium Blue and/or a halo pattern

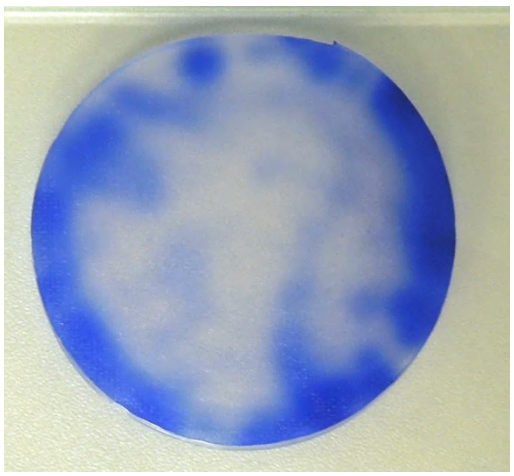

Figure 22

3- Deep Blue and/or coloured throughout

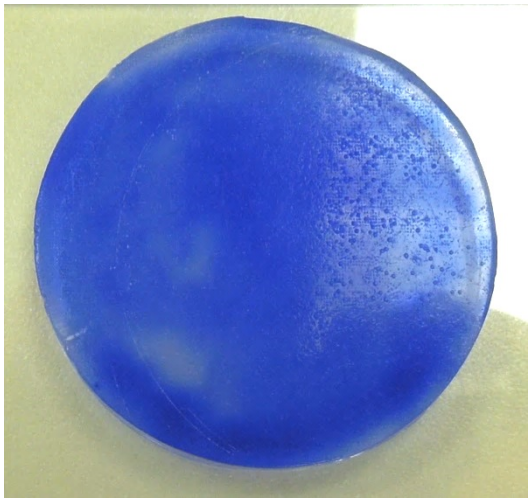

Figure 23

7.5 Gels After Testing:

The results from the examination of the gels after application on the textile samples should not be considered without first understanding the results on the textiles themselves. In some cases the visual of the gel indicates a successful application and reduction of the ink in the textile when in actuality the tests have resulted in extensive ringing or tidelines making the use of that gel on a particular textile inadvisable. However, these gels do present a better understanding of how

each of the concentrations affectively or ineffectively drew ink from the textile and how depth may affect that ability.

In all cases 1% gels showed a visible decrease in height after application to the textile most likely due to the movement of water out of the gel and into the textile. Similar decreases were seen in some 2.5% gels though this was less visible in the .5 cm gels. No such decrease was observed with 4% gels.

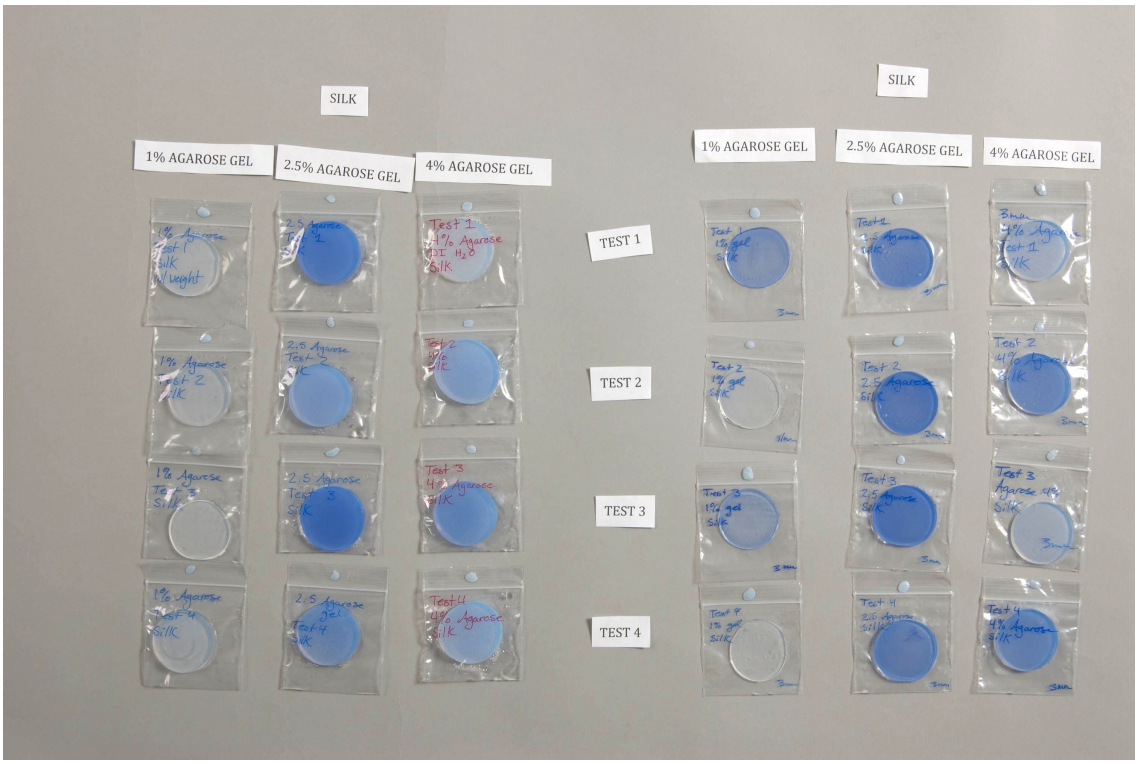

Figure 24: Gels applied to silk after ink diffused through the gel. On the left .5 cm gel, on the right .3 cm gels

7.5.1 Gels on Silk:

The gels applied to silk showed that 2.5% gels were able to draw a larger amount of ink out of the textile (Figure 24, Table 10). 4% gels were less successful and 1% gels were the least successful at drawing out the ink. A range within each of these concentrations was also visible indicating natural variation whether due to contact with the textile or structure of the gel. There was some discernable difference in the two different depths of gel. 2.5 % gels at .3 cm showed a slight increase in the amount of ink drawn out of the gel in two tests; better absorption was also seen in the 1% gels at .3 cm, where as the 4% gels were more consistent in the .5 cm gels.

Degree of Contact and Ink Uptake of Agarose on Silk

Test	Gel Depth	Gel Concentration	Contact	Uptake Of Ink Into Gel
Test 1	0.5-0.55	1%	3	1
Test 2	0.5-0.55	1%	3	1
Test 3	0.45-0.5	1%	3	1
Test 4	0.55	1%	3	1
Test 1	0.3-0.35	1%	3	3
Test 2	0.35	1%	3	1
Test 3	0.35- 0.4	1%	3	1
Test 4	0.35-0.4	1%	3	1
Test 1	0.55-0.6	2.50%	3	2
Test 2	0.6-0.65	2.50%	3	1
Test 3	0.5	2.50%	3	2
Test 4	0.5-0.55	2.50%	3	1
Test 1	0.35	2.50%	2-3	2
Test 2	0.35	2.50%	3	2-3
Test 3	0.35-0.4	2.50%	3	3
Test 4	0.35-0.4	2.50%	3	3
Test 1	0.5	4%	3	1
Test 2	0.55	4%	3	1
Test 3	0.5-0.55	4%	3	1
Test 4	0.6-0.7	4%	3	1
Test 1	0.35-0.4	4%	2	1
Test 2	0.3-0.45	4%	2	1
Test 3	0.3-0.35	4%	2	1
Test 4	0.4	4%	2	1-2

Table 10:

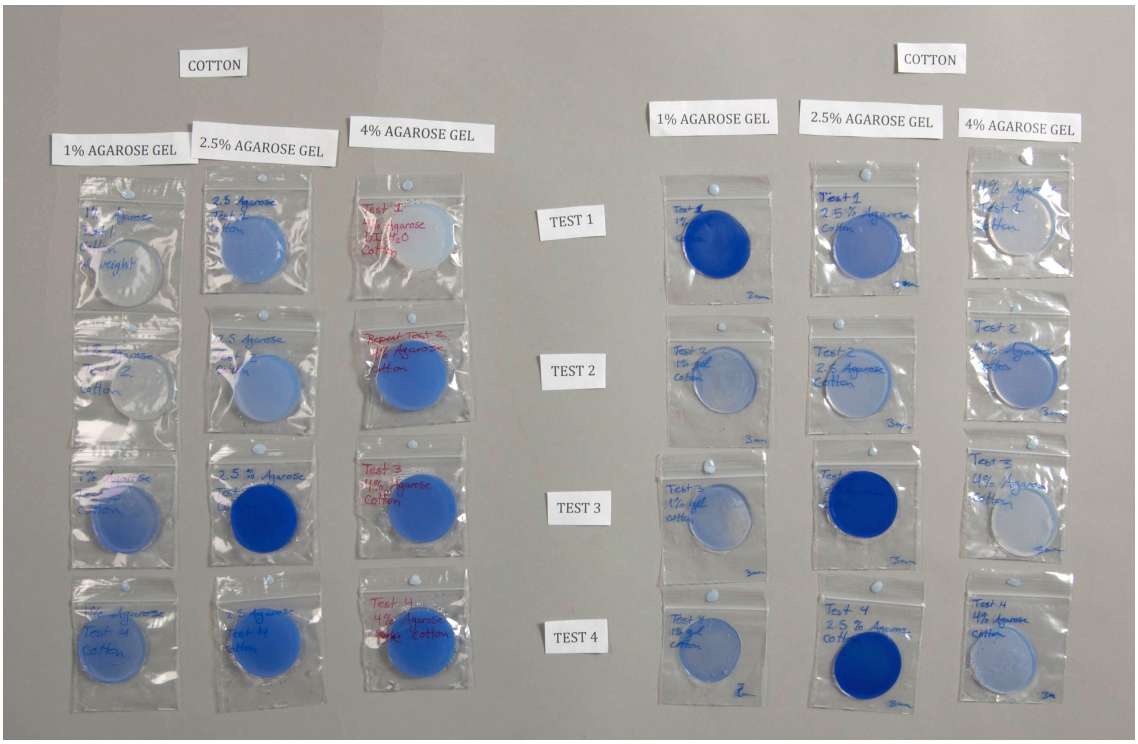

Figure 25: Gels applied to cotton after ink diffused through the gel. On the left .5 cm gel, on the right .3 cm gels

7.5.2 Gels on Cotton:

Gels on cotton showed an increase in the amount of ink that was pulled from the textile in comparison to those used on silk (Figure 25, Table 11). Overall the 2.5% gels exhibited the largest uptake of ink, especially in the last two tests where finger pressure was applied to the gels. Here the depth of gel appeared to have less of an affect on the ability of the gels to draw the ink from the fabrics. In the case of 1% gels the weighted 1% .3 cm gel showed a massive uptake of ink in comparison to the un-weighted samples.

Degree of Contact and Ink Uptake of Agarose on Cotton

Test	Gel Depth (cm)	Gel Concentration	Contact	Uptake of Ink into Gel
Test 1	0.55-0.6	1%	3	3
Test 2	0.5-0.55	1%	3	1
Test 3	0.6	1%	3	2
Test 4	0.55	1%	3	3
Test 1	0.3-0.35	1%	3	3
Test 2	0.35-0.4	1%	2	1
Test 3	0.3-0.35	1%	3	1
Test 4	0.3-0.35	1%	3	1
Test 1	0.5-0.55	2.50%	1	2
Test 2	0.55	2.50%	1	1
Test 3	0.45-0.55	2.50%	3	3
Test 4	0.6	2.50%	3	3
Test 1	0.35	2.50%	1	2
Test 2	0.3-0.35	2.50%	1	1
Test 3	0.3-0.35	2.50%	3	3
Test 4	0.25-0.3	2.50%	3	3
Test 1	0.5-0.6	4%	0	0
Test 2	0.45-0.5	4%	1	2
Test 3	0.4-0.5	4%	2	2
Test 4	0.65	4%	2	2
Test 1	0.4	4%	1	1
Test 2	0.35	4%	1	1
Test 3	0.3-0.45	4%	1	1
Test 4	0.3-0.35	4%	1	1

Table 11:

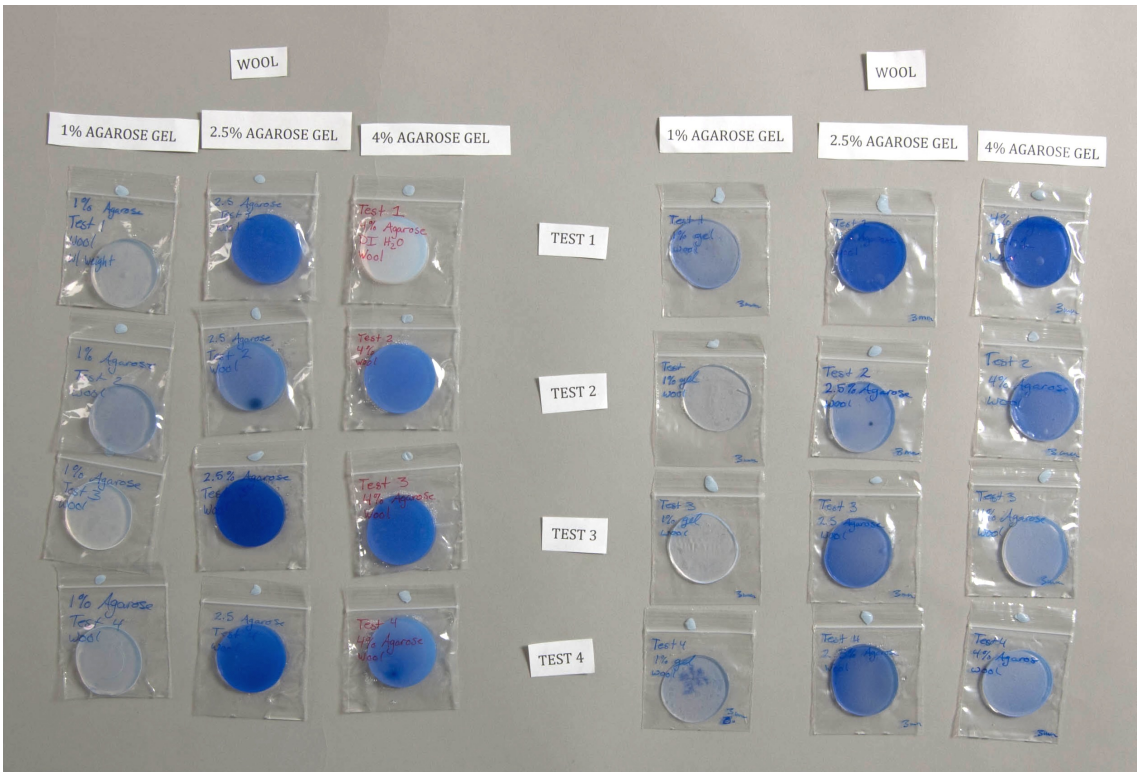

Figure 26: Gels applied to wool after ink diffused through the gel. On the left .5 cm gel, on the right .3 cm gels

7.5.3 Gels on Wool

The three concentrations of gel on wool followed a similar pattern to those seen on silk and cotton (figure 26). 1% gels exhibited a slight decrease in ink uptake while contact remained the same. 2.5% gels indicated a better overall removal of ink from the textile substrate. 4% gels showed less overall removal of the ink, than tests using 2.5% gels. Decreasing the depth on wool showed a decline in the ability of the gel to draw the ink from the textile. This is possibly the result of the decrease in the strength of capillary action from the reduction of the height of the gel.

Degree of Contact and Ink Uptake of Agarose on Wool

Test	Gel Depth (cm)	Gel Concentration	Contact	Uptake of Ink into Gel
Test 1	0.55-0.6	1%	3	1
Test 2	0.5-0.55	1%	3	1
Test 3	0.6	1%	3	1
Test 4	0.55	1%	3	3
Test 1	0.3-0.35	1%	3	1?
Test 2	0.3-0.35	1%	3	2
Test 3	0.3-0.35	1%	0	0
Test 4	0.35	1%	2	2
Test 1	0.5-0.55	2.50%	2	3
Test 2	0.55	2.50%	1	2
Test 3	0.45-0.55	2.50%	2	2
Test 4	0.6	2.50%	2	2
Test 1	0.3-0.35	2.50%	2	2
Test 2	0.35	2.50%	1	2
Test 3	0.3	2.50%	2	2
Test 4	0.35	2.50%	2-3	2
Test 1	0.5-0.6	4%	0	1
Test 2	0.45-0.5	4%	1	2
Test 3	0.4-0.5	4%	1	2
Test 4	0.65	4%	1	2
Test 1	0.4	4%	1	1
Test 2	0.3-0.4	4%	1	1
Test 3	0.35-0.4	4%	1	1
Test 4	0.35	4%	1	1

Table 12:

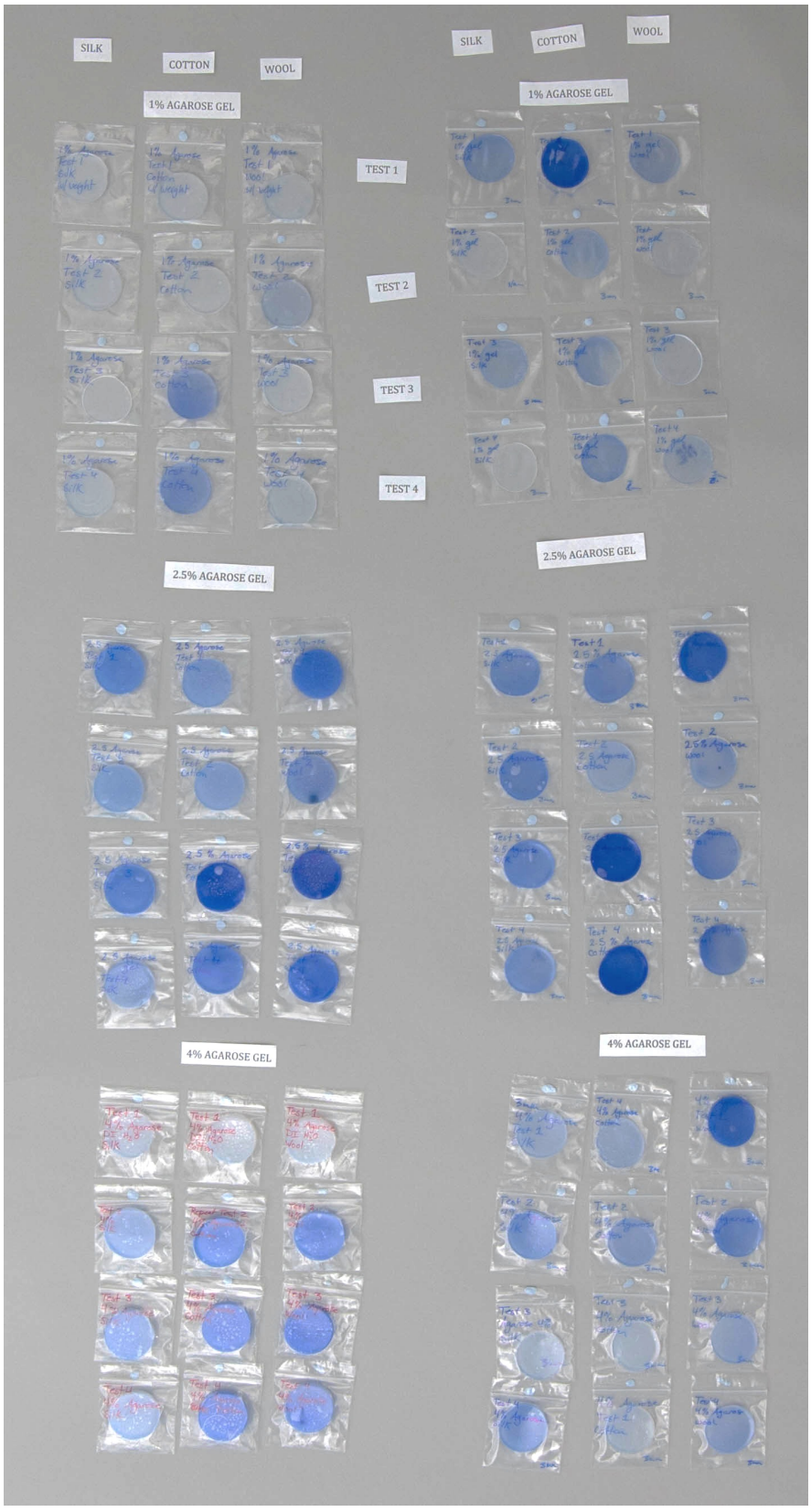

Figure 27: Gels after diffusion of the ink. Left: .5 cm gels divided by concentration. Right: .3 cm gels divided by concentration

Chapter 8: Analysis and Discussion

8.0 Introduction

The aim of this research was to investigate the physical and chemical properties of agarose and to undertake testing to identify ideal standard conditions on common textile fibres through the manipulation of the basic working properties. To achieve this aim three main research questions were outlined:

- What affect does the fabric media have on the effectiveness of these gels, i.e. how well do they draw staining out of the textile?
- How do different gel concentrations work on different fabrics?
- What role does the depth of gel have on the effectiveness of the treatment?

This chapter will show how the results gathered through testing provided answers to these questions and clarify how the gels should be used within the field of textile conservation. The factors that may have affected these tests will be discussed to clarify portions of the experimental phase and validate the conclusions that have been drawn from the test results. The three variables that were manipulated, depth, concentration, and fibre type, will be discussed to explain how they affect the working properties of the gel. These factors will then be used to establish a starting point for future treatments and research.

8.1 Statistical Analysis:

The variation within the standard deviations of the tests conducted precluded the use of statistical analysis for this project[142]. Ideally for statistical testing to be done on a data series standard deviation would not exhibit a difference greater than three times the smallest deviation. As this was not the case for the data set collected, conclusions are drawn not through statistical analysis but by observation and examination of both the visual results from the tests and the graphed numerical results.

8.2 Discussion

The following discussion examines the results presented and looks to explain what they mean for the long-term implementation of this type of treatment.

[142] See Appendix 5

8.2.1 Depth

The decrease in the depth seen in 1% and 2.5 % gels may indicate a collapse of the gel structure as water left the system and the height of the gel decreased. The extent to which this occurs in 1% gels may further explain the lack of movement up into the gel, as the larger pores may not be able to support themselves after the loss of water, causing them to shrink, if not collapse.

Overall, depth had little effect in how far a stain travelled through the textile. The difference between the .5 cm gels and .3 cm gels was in how the soiling left the fabric sample. In the 4% gels and .3 cm depth, removal was less than that seen in the .5 cm gel tests.

With the decrease in depth, the amount of water, contact between textile and gel, or the amount of capillary pressure decreases, limiting how the stain can move. This reduces capillary forces, resulting in less ink entering the gel. This suggests that a deeper gel would increasing the water content enough to move soiling or achieve better contact, drawing soiling up into the gel

8.2.2 Fibre Type

The wetting capability of each fibre, as discussed in Chapter 5, has an effect on how moisture moves through the fabric and how the ink moves through the fibre and into the gel (Figure 28). The fibre's affinity for water as well as the contact achieved by the gel and fabric played a large role in the results of these tests.

8.2.2.1 Silk

Silk's hydrophilic nature, wettability, and ability to absorb water up 1/3 its weight, means that water is quickly pulled from the gel into the fibres. The crystalline structure of the fibre limits how much water the fibre can absorb, but encouraged the movement of the water through the fabric samples. The thin nature of the fabric may have also had an effect on the results of these tests, a thicker silk with a more dense weave may respond differently, though it remains likely that the fibre will wet out rapidly.

Moisture floods the substrate with 1% and 2.5% gels. 1% gels wash the ink deeper into the fabric and fail to draw it into the gel. While 2.5% gels still exhibit ringing, the gels visibly draw more ink from the textiles. 4% reduce ringing, though movement is still visible. It appears that 2.5% gels strike some form of balance between contact and moisture that results in the best ink uptake of all the tests on silk. The lighter tones of the 1% gels applied to silk were likely the result of the rapid movement of the ink away from the gel as water moved into the textile. The light tone of 4% gels possibly the result of the limited water movement into the substrate.

8.2.2.2 Cotton

The hydrophilic nature of cotton increases the material's wetting ability and results in the rapid movement of moisture through the textile. This fabric had a similar thread count to the silk, which may have an overall effect on how quickly the moisture moves through the textile.

Water acts as a plasticiser due to cotton's structure and reaction to moisture. As these tests were done on a Melinex® sheet placed on a table it is possible that the lack of contact is the result of fabric adhering down to the table. The gel, being rigid, cannot follow the contour of the textile as it adheres to the Melinex® sheet. The application of finger pressure in the tests using 2.5% gels rectifies this issue. The application of finger pressure may result in direct movement of water into the textile substrate but also ensures adhesion between the gel and the fabric. The slightly more flexible nature of the 2.5 % gel helps to retain contact throughout the test, as does the application of the weight. It is doubtful whether this will be seen in tests using 4% gels as the lack of flexibility of these gels may prevent the movement with the textile. The success of the 2.5 % treatment is not mirrored in the 1% tests because of the increase in moisture entering the system. The water is forced to spread further through the textiles as the system tries to reach equilibrium, resulting in a greater dispersion of ink.

The gels from the 2.5% tests show a visible increase in the amount of ink that is drawn out of the textile indicating that a balance been achieved that introduces enough moisture to solubilise the ink but not enough to cause ringing and tidelines. The amount of ink drawn from the textile diminished in 4% gels,

possibly indicating that the water entering the system was not enough to mobilize the ink within the cotton fibres.

8.2.2.3 Wool

The test samples using wool were the easiest to control because of the limited wettability of the fabric. The natural water resistance exhibited by wool prevents movement through the textile and thus manages to contain the staining in a way that is not possible with the more hydrophilic silk and cotton. When the ink does move through the textile it happens at a much slower rate, making time a controlling factor for treatments on wool (Figure 28). 1% gels can be used for this very reason. However, the degree to which ink is removed diminishes as a result of increased movement of water into the textile. If the time of application is reduced, a 1% gel on wool might be acceptable, though the spread of moisture and wicking would need to be monitored.

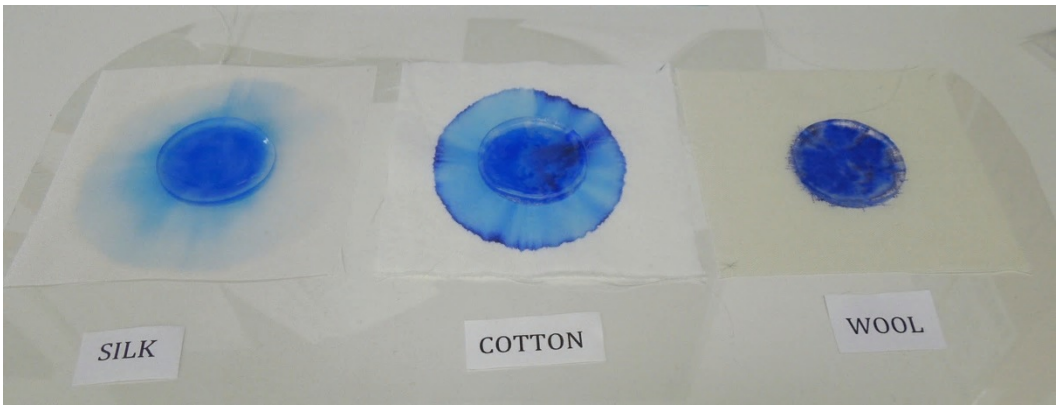

Figure 28: 1% Agarose gels at 3 mm depth after 30 minutes

2.5% gels offer better control and a stronger system of capillary action that results in greater removal of the ink from the textile and thus is a better starting point for treatments on wool. 4% gels will form a system of capillary action with the textile and can be used when the moisture content needs to limited and thus remain a viable concentration depending on the treatment.

The differences seen in the change in depth on wool is likely the result of a decrease in water entering the system thus limiting the movement of the ink. The

fabric samples suggest greater movement within the textile indicating that the gels lacked the ability to draw the ink from the textile substrate. The differences in colour of the gels in the .5 and .3 cm depths supports this, indicating that capillary strength may diminish as gels decrease in depth.

8.3 Ideal Working Properties

The results of these tests suggest a shift in the suggested concentration range of agarose gels used on textiles from 1% to 4% to 2.5% to 4% gels with a possible increase to 4.5% gels. The ideal starting point for many natural fibres with moderate to limited wetting capability is 2.5%. The flexibility offered at this concentration helps ensure good contact between the gel and the fabric and the amount of moisture that is able to enter the system is able to solubilise staining while also achieving a system of capillary action between the gel and fabric, the key factors for an effective poultice. The gel also retains its shape, not loosing depth to the same degree seen in 1% gels. This may indicate the gel is retaining its internal structure, leaving pores intact which is imperative to ensure the gel is able to draw the moisture back out of the textile. Variations from this concentration would have their merits. A 2% gel can and has been used for enzyme treatments[143]. Use of a 2.5% gel may be possible with this type of treatment though it would be reliant on the wettability of the fibre and the size of the enzyme. When a dryer gel is needed a 3% gel should retain some of the flexibility that is imperative to establishing and maintaining contact with the textile while reducing the amount of water that can move into the fibre.

On textiles that wet out quickly, such as silk, higher concentrations of at least 4% if not 5% should be utilized. An increase to a 4.5% concentration may prevent ringing and tidelines. Increasing the concentration would limit how silk could be cleaned, as a gel of such a high concentration cannot be used with many additives, as the pore size would be too restrictive. It is possible that the application of finger pressure as used with the 2.5% gels on cotton applied to a 4% gel on silk may establish better adhesion between the gel and fabric reducing the spread of water and increasing capillary exchange between textile and gel.

[143] See Appendix 9

Contact is key to establishing a system of capillary action that will result in the removal of soiling from a textile substrate. Tests show that the best contact does not ensure the best results. Results depend on the concentration of the gel in combination with the textile substrate. Furthermore, the property of wettability must be considered when forming gels with any additive or cleaning solution. If an additive to the gel will change the surface tension of the water, the textile to which it is applied will wet out differently. Considering this is imperative when planning a treatment, as it will impact the gel used.

Conclusion

This project sought to outline how agarose gels work on different textiles at different depths and concentrations to better understand how to implement their use on a textile substrate. Through testing and analysis the project has achieve this aim. The results provide information for the practising conservator to help develop a treatment using agarose gels. This research allows for a number of conclusions, the most important of which is a shift in the working concentration range suggested by Richard Wolbers from 1%-4% to 2.5% -4% with a possible increase to 4.5%. The results of these tests also reiterate the fact that, on a textile media, ensuring contact between poultice and textile is imperative for the success of the treatment.

The concentration range suggested 2.5%-4% is still problematic. 2.5% gels offer the best contact with a textile, their flexibility allows them to bend, and adhere to the weave structure encouraging the formation of a system of diffusion and capillary action imperative to poultice treatments. This concentration however does not retain water to the same degree seen in 4% gels, thus making its application risky on some objects. 4% gels, while offering finite control of the introduction of moisture, cannot achieve contact with the textile to the same degree limiting the overall effectiveness of diffusion and capillary action. Use of these gels on silk remains inadvisable do to the lack of control over the movement of water into the textile.

The wettability of these fibres is paramount to the success or failure of these treatments. The tests for this project were run using water, a standard that will aid in the overall understanding of how moisture will enter a textile when introduced by these gels. Any cleaning solution or additive mixed into the gel may change the surface tension of the liquid entering the textile and thus the degree and speed to which a fibre wets out. With the introduction of additives, timing, testing, and observation will be essential for the overall success of these treatments.

The research presented here develops the use of agarose in textile conservation, providing a visual and empirical source for understanding how these gels work and what factors to take into account for purchasing products and implementing treatment. It is hoped that the information gathered through this study will encourage broader use and research that will continue to facilitate the use of these gels in conservation.

Further Research

The success of this project has uncovered numerous avenues of research to explore. Further work into the properties of agarose gels is needed. While it is clearer what percentages and depths should be considered for use on a range of textile substrates, a number of issues with the implementation of this treatment remain. Another study examining different concentrations and the gels affect on historic textiles may improve upon the data gathered through this study offering more information on ideal concentrations and how the gel works on aged or degraded fibres.

The ability to rinse cleaning agents from textile substrates should be examined before some cleaning procedures can be utilized safely.

The use of agar in conservation needs to be clarified. Its prevalence in Italy and appearance in The United States and successful application by Younger and Duffus in the United Kingdom would suggest the use of this cheaper product is valid and would make this treatment much more cost effective[144]. Defining its working properties would present a clearer understanding of what adaptions are necessary and what issues might be encountered in the transition between agarose and agar.

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Appendixes

Appendix 1: Agarose Product Information

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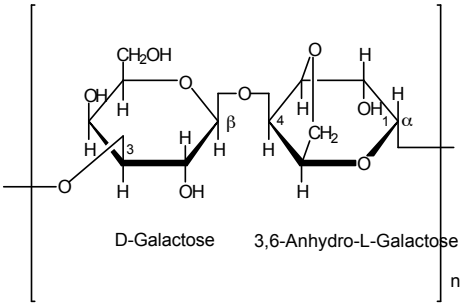
ProductInformation

AGAROSE

CAS NUMBER: 9012-36-6
CAS NUMBER: 39346-81-1 (products A9414, A4018, A6560, A9045, A0701)
SYNONYMS: 3,6-Anhydro-α-L-galacto-β-D-galactan; FastLane agarose; Indubiose A4; NuSieve GTG; Odigose; Seakem; Sepharose



PRODUCT DESCRIPTION - APPLICATIONS:

Agarose is a purified linear galactan hydrocolloid isolated from agar or agar-bearing marine algae. Structurally, it is a linear polymer consisting of alternating D-galactose and 3,6-anhydro-L-galactose units. As a gelling agent, agarose is used: **1.)** to separate nucleic acids electrophoretically because its gels have larger pore sizes than polyacrylamide gels at low concentrations. Unlike polyacrylamide, the consistency of the gels is more solid (but also less elastic); **2.)** To demonstrate cross reaction in IEP (Immuno electrophoresis) and Ouchterlony (double diffusion) plates in which antibody-antigen precipitin lines are studied; **3.)** to make gel plates or overlays for cells in tissue culture. **4.)** To form a gel matrix (either beaded and/or crosslinked) which can be used in chromatographic separations.[1]

PROPERTIES OF AGAROSES OFFERED BY SIGMA:

Please refer to the table on pages 4-8.

Sulfate content may be used as an indicator of purity, since sulfate is the major ionic group present.

Gel strength is the force that must be applied to a gel to cause it to fracture.

The **gel point** is the temperature at which an aqueous agarose solution forms a gel as it cools. Agarose solutions exhibit hysteresis in the liquid-to-gel transition - that is, their gel point is not the same as their melting temperature.

PROPERTIES OF AGAROSES OFFERED BY SIGMA: (continued)

Anionic groups in an agarose gel are affixed to the matrix and cannot move, but dissociable cations can migrate toward the cathode in the electrophoresis unit, giving rise to **electroendosmosis (EEO)** - a movement of liquid through the gel. Since electrophoretic movement of biopolymers is usually toward the anode, EEO can disrupt separations because of internal convection.

USAGE INSTRUCTIONS FOR MAKING GELS:

Boiling water bath method:

a. Add any buffer of choice (usually with an ionic strength, μ,[2] of 0.03-0.10) and a stir bar to a beaker which can hold 2-4 times the volume of the desired solution.[3]
b. Slowly sprinkle the agarose powder into the liquid while stirring to prevent clumping.
c. Weigh the beaker and solution before heating.
d. Cover the beaker with plastic wrap and pierce a hole in the wrap for ventilation.
e. Bring the solution to a boil and allow it to boil for 5-10 minutes stirring continuously, until agarose dissolves completely. To avoid charring, use a boiling water bath rather than directly applied heat.[3]
f. Add enough hot distilled water to return the contents to the original weight; mix continuously.
g. Allow the mixture to cool to 50-55°C, at which temperature it is ready to be cast into cassettes which have been pre-warmed to 50-55°C.[3]

Microwave method 1 (for gels ≤2% w/v):

a. Add any buffer of choice (usually with an ionic strength, μ,[2] of 0.03-0.10) and a stir bar to a beaker which can hold 2-4 times the volume of the desired solution.[3]
b. Slowly sprinkle the agarose powder into the liquid while stirring to prevent clumping.
c. Remove the stir bar.
d. Weigh the beaker and solution before heating.
e. Cover the beaker with plastic wrap and pierce a hole in the wrap for ventilation.
f. Place the solution in a microwave oven and heat on HIGH power for 2 minutes.
g. Remove the solution from the oven very carefully; any microwaved solution may be superheated and could foam over the container's rim if agitated. Swirl gently to re-suspend any remaining agarose particles.
h. Reheat on HIGH power for 1-2 minutes or until the solution comes to a boil. Boil for 1 more minute or until the solution is clear and the agarose is completely dissolved.
i. Remove the solution from the oven very carefully and swirl it gently.
j. Add enough hot distilled water to return the contents to the original weight; mix continuously.
k. Allow the mixture to cool to 50-55°C, at which temperature it is ready to be cast into cassettes which have been prewarmed to 50-55°C.[3]

Microwave method 2 (for gels >2% w/v):

Follow the same protocol as for ≤2% gels (above), but use a MEDIUM instead of HIGH power setting in step f.

OTHER GELLING AGENTS:

1. Agar: Separate data sheet is available.

2. Gelatin: Separate data sheet is available.

3. Phytagel (Sigma product number P8169): Phytagel is an agar substitute produced from a bacterial carbohydrate composed of glucuronic acid, rhamnose and glucose. It produces a clear, colorless, high strength gel which aids in detection of microbial contamination. Phytagel provides an economical alternative to agar as a gelling agent (agar contain about 70% agarose). Originally developed for microbial applications, Phytagel is a good choice in any application (such as plant cell culture) where some agar products tend to inhibit growth due to unidentified impurities. To prevent clumping, Phytagel should be added to culture medium that is at room temperature, with rapid stirring.

4. Agargel (Sigma product number A3301): Agargel is a blend of agar and Phytagel which was developed to help control vitrification in plant tissue cultures. Agargel provides the positive attributes of agar and Phytagel, is cheaper than agar, and is superior to Phytagel in applications where vitrification is a problem. Agargel produces a semiclear gel which allows for better detection of contamination.

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2. $\mu = 2 S_i C_i \times Z_i^2$ C_i = molar concentration of a given ion
   Z_i = charge of a given ion
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3. A. T. Andrews, *Electrophoresis: Theory, Techniques, and Biochemical and Clinical Applications*, 2nd Ed., p. 149, A. R. Peacock and W. F. Harringdon, Eds., Oxford Science Publications, Clarendon Press, Oxford (1993).

AGAROSE

PRODUCT	NAME - DESCRIPTION	SULFATE	GEL STRENGTH (g/cm^2)	GEL POINT (°C)	MELTING T. (°C)	EEO
A0169	Agarose Type I-A: Low EEO	<0.20%	>1200 at 1.0% >2500 at 1.5%	36±1.5 at 1.5%	87±1.5	0.09-0.13
A0576	Agarose Type I-B: Low EEO Exceptionally high gel strength makes this agarose particularly suitable for separating high molecular weight nucleic acids at low gel concentrations	≤0.12%	≥1800 at 1.0% ≥3200 at 1.5%	36±1.5 at 1.5%	86±2.0	≤0.12
A6013	Agarose Type I: Low EEO	≤0.15%	≥1200 at 1.0%	36±1.5 at 1.5%	N/A	0.09-0.13
A9918	Agarose Type II-A: Medium EEO	<0.25%	>1000 at 1.0%	36±1.5 at 1.5%	87±1.5	0.16-0.19
A6877	Agarose Type II: Medium EEO	≤0.20%	≥1000 at 1.0%	36±1.5 at 1.5%	N/A	0.16-0.19
A9793	Agarose Type III-A: High EEO	<0.25%	>750 at 1.0% >1000 at 1.5%	36±1.5 at 1.5%	87±1.5	0.23-0.26
A6138	Agarose Type III: High EEO	≤0.20%	≥650 at 1.0%	36±1.5 at 1.5%	N/A	0.23-0.26
A9668	Agarose Type IV-A: Special High EEO	<0.30%	>700 at 1.0% >1000 at 1.5%	35±1.5 at 1.5%	87±1.5	≥0.30
A3643	Agarose Type IV: Special High EEO Characterized by lower sulfate content and lower non-specific protein binding capacity than Type III. It is useful for electrophoretic techniques requiring a high degree of cathodal movement. Trailing and smearing of protein due to non-specific binding is minimized.	≤0.25%	≥650 at 1.0%	36±1.5 at 1.5%	N/A	≥0.30
A3768	Agarose Type V: High Gelling Temperature Higher gelling Temperature and lower EEO the Type I	≤0.30%	≥800 at 1.0%	42±1.5 at 1.5%	N/A	≤0.10
A7174	Agarose Type VI-A: High Gelling Temperature	<0.20%	>900 at 1.0% >1200 at 1.5%	41±1.5 at 1.5%	95±1.5	≤0.14
A3893	Agarose Type VI: High Gelling Temperature Higher gel strength than type V	≤0.20%	≥1000 at 1.5%	42±1.5 at 1.5%	N/A	<0.10

AGAROSE

PRODUCT	NAME - DESCRIPTION	SULFATE	GEL STRENGTH (g/cm^2)	GEL POINT (°C)	MELTING T. (°C)	EEO
A0701	Agarose Type VII-A: Low Gelling Temperature Excellent for in-gel enzymatic reactions and cloning assay and for recovery of heat-labile samples after electrophoresis.	≤0.10%	≥250 at 1.0% 500 at 1.5%	26±2.0 at 1.5%	≤65.5	≤0.12
A4018	Agarose Type VII: Glow Gelling Temperature A low gelling temperature derivative with unique gelling properties. Gels form at <30EC and remelt at temperatures >65EC. Gels exhibit excellent clarity and are particularly useful for preparation of media containing heat-labile materials.	≤0.10%	≥200 at 1.0%	26-30 at 1.5%	≤65	≤0.10
A4905	Agarose Type VIII For isoelectric focusing. High gel strength. EEO not detectable.	≤0.20%	≥500 at 1.0%	N/D	N/A	N/D
A2576	Agarose Type IX-A: Ultra-low Gelling Temperature Yields unusually strong gels for an ultra-low gelling agarose. Ideal for electrophoresis of heat-labile samples and for growth of hybridomas and other cell lines.	≤0.14%	≥100 at 1.0% ≥400 at 1.5%	≤17 at 1.5%	≤60	≤0.11
A5030	Agarose Type IX: Ultra-low Gelling Temperature Gelling Temperature Gelling occurs at 8-17EC and remelt at <50EC	≤0.10%	≥75 at 2.0%	8-17 at 0.8%	≤50	≤0.05
A3038	Agarose Type XI: Low Gelling Temperature Suitable for separation of small nucleic acid fragments.	≤0.15%	≥500 at 4.0%	≤35 at 4.0%	≤65	≤0.15
A7299	Agarose Type XII: Low Viscosity for Beading Recommended for preparation of agarose beads.	≤0.20%	≥500 at 1.0% ≥900 at 1.5%	41±1.5 at 1.5%	87±1.5	<0.14

AGAROSE

PRODUCT	NAME - DESCRIPTION	SULFATE	GEL STRENGTH (g/cm^2)	GEL POINT (°C)	MELTING T. (°C)	EEO
A4679	Agarose **Electrophoresis Reagent** Suitable for standard immunoelectrophoresis and immunodiffusion	≤0.20%	≥1200 at 1.0%	36±1.5 at 1.5%	88±1.5	0.09-0.13
A9311	Agarose: Medium EEO **Electrophoresis Reagent**	≤0.35%	≥1000 at 1.0%	36±1.5 at 1.5%	N/A	0.16-0.19
A4804	Agarose **Electrophoresis Reagent** Suitable for isoelectric focusing.	≤0.10%	>700 at 1.5%	32±2.0 at 0.8%	N/A	<0.02
A5304	Agarose **Electrophoresis Reagent** Suitable for counterimmunoelectrophoresis and immunoelectrophoretic techniques with significant cathodal migration.	≤0.30%	≥700 at 1.0%	36±1.5 at 1.0%	N/A	≥0.30
A8455	Agarose **Molecular Biology Reagent** DNase and RNase: none detected. Separates small DNA fragments (200-800 base pairs) with a resolution approximately equal to acrylamide.	N/A	N/A	<30	<70	#0.35
A6560	Agarose Type VII: Low Gelling Temperature **Plant Cell Culture Tested** A low gelling temperature derivative with unique gelling properties. Gels form at <30EC and remelt at >65EC. Gels exhibit excellent clarity and are useful for the preparation of media containing heat-labile materials.	≤0.10%	≥200 at 1.0%	26-30 at 1.5%	≤65	≤0.10
A9539	Agarose: For Routine Use **Molecular Biology Reagent** DNAse, RNase and protease: none detected. Used routinely at Sigma for analysis and purification of nucleic acids	≤0.15%	≥1200 at 1.0%	36±1.5 at 1.5%	N/A	0.09-0.13

AGAROSE

PRODUCT	NAME - DESCRIPTION	SULFATE	GEL STRENGTH (g/cm^2)	GEL POINT (°C)	MELTING T. (°C)	EEO
A2929	Agarose: For Pulsed Field Electrophoresis Running Gel **Molecular Biology Reagent** DNase and RNase: none detected. Suitable for the separation of high molecular weight DNA. Gels are easy to handle and give faster separation and better resolution of high molecular weight DNA by field inversion electrophoresis than product A9539.	≤0.20%	N/A	42±1.0	N/A	≤0.08
A3054	Agarose: For Pulsed Field Electrophoresis Sample Preparation **Molecular Biology Reagent** DNase and RNase: none detected. Suitable for making gel plugs when separating high molecular weight DNA without the shearing encountered by conventional isolation techniques. While embedded in plugs made from this agarose, cells can be lysed and the released DNA can be digested with restriction endonucleases.	≤0.15%	N/A	≤30	N/A	≤0.10
A9414	Agarose: Low Melting Point **Molecular Biology Reagent** DNase, RNase and protease: none detected.	<0.10%	N/A	~30	~65	≤0.10
A2790	Agarose: Wide Range **Molecular Biology Reagent** DNase, RNase and protease: none detected. Capable of separating DNA fragments with 50-1,000 base pairs on a single 3% gel.	<0.35%	N/A	≤35	≤65	<0.15
A7431	Agarose: Wide Range/Standard 3:1 Ratio **Molecular Biology Reagent** DNase and RNase: none detected. Composed of 3 pars low gelling temperature agarose and 1 part high gelling temperature agarose, this product is specially formulated to form strong, flexible gels for separation of small (#1 kb) PCR products, DNA and RNA.	≤0.15%	N/A	34±1.5	≤90	N/A

AGAROSE

PRODUCT	NAME - DESCRIPTION	SULFATE	GEL STRENGTH (g/cm^2)	GEL POINT(°C)	MELTING T. (°C)	EEO
A9702	Agarose Gel Mixture: 1% Agarose in TAE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____
A9827	Agarose Gel Mixture: 1.5% Agarose in TAE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____
A9952	Agarose Gel Mixture: 2% Agarose in TAE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____
A0203	Agarose Gel Mixture: 1% Agarose in TBE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____
A0328	Agarose Gel Mixture: 1.5% Agarose in TBE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____
A0453	Agarose Gel Mixture: 2% Agarose in TBE Buffer **Molecular Biology Reagent** DNase, RNase and protease: none detected.	_____	_____	_____	_____	_____

N/A = Not Available
N/D = Not Detectable
___ = Not Applicable

Appendix 2: Suppliers list

Agarose
Sigma-Aldrich Company Ltd.
The Old Brickyard
New Road Gillingham
Dorset, SP8 4XT
Phone: +44 1747 833000
Website: http://www.sigmaaldrich.com/united-kingdom.html

Macaroon mould
Lakeland
18A Buchanan Galleries
Buchanan Street
Glasgow G1 2FF
Phone: +44 0141 331 1112
Website: http://www.lakeland.co.uk/Homepage.action

Parker Quink®
Rymans
211 Byres Road
Glasgow G12 8TN
Phone: +44 0141 439 1500
Website: http://www.ryman.co.uk/

Dehyphon LS45
Conservation by Design
Timecare Works
5 Singer Way Kempston,
Bedford MK42 7AW
Phone: +44(0)1234846300
Website: http://www.conservation-by-design.co.uk/Home.aspx?pagename=home

Wool delaine, cotton lawn, heavy weight silk haboti (See Samples at back)
Whaleys (Bradford) LTD
Harris Court
Great Horton, Bradford
West Yorkshire
BD7 4EQ
Telephone: +44 (0) 1274 576718
Website: http://www.whaleys-bradford.ltd.uk/

Melinex:
Preservation Equipment Ltd.
Vinces Road
Diss Norfolk
IP22 4HQ
Telephone: +44 (0)1379 647400
Website: http://www.preservationequipment.com/Home

Appendix 3: Preparation and Recipe

A2.0 Introduction:

Appendix 2 discusses the pretesting that helped to define this project. Further space is dedicated to a more in depth discussion of the preparation of fabrics and materials as well as the recipe used to make up the agarose gels.

A2.1 Pre-Tests

For this project a stain needed to be identified that would move with water, indicating how these gels and absorb staining and how much moisture they can introduce to a substrate.

Six stains were tested: Coffee, tea, red wine, orange juice, Parker Quink® washable ink and Talens Ecoline® liquid watercolour, colour 666, Pastel Green. Five drops from a pipette were applied to samples of silk, cotton, and wool and allowed to dry. After the stains dried, double the amount of water was dropped on to the stains and movement was observed. Coffee, tea and orange juice exhibited no movement, red wine showed limited movement, and the two washable inks moved easily through the textile samples. The washable watercolour ink separated out into two distinct colour components making it less desirable for the planned tests. As a result, Parker Quink® was chosen to stain the fabrics.

During these tests the way each of the fabrics took up the stains was observed and resulted in an adaption of the application method to ensure even staining for the actual tests samples.

A2.2 Preparation of Fabrics

Fabric samples were prepared to ensure continuity across all of the samples and to reduce outside variables as much as possible. Cotton and silk were cut in ten centimetre squares and wool fabric was soured at 40 degrees for 10 -20 minutes in a .1% Dehyphon LS45® solution to remove any finish or oils and rinsed. Scouring also helped improve the absorption of ink into the wool fibres. The wool was blocked out, left to try and then cut into 10 cm squares.

A stencil was made from polythene to the same diameter of the gels being formed. The fabric was laid on blotter, the stencil was laid across the fabric samples, held in place with weights, and Parker Quink®, was then painted on using a brush (Figure A1)[145]. The blotter helped control the spread of the ink, drawing it down into the blotter and out of the fabric, helping ensure controlled application allowing for the formation of regular circles on fabrics with a range of different wetting characteristics (Figure A1). Wool, even after scouring, resisted the introduction of the ink and thus was the easiest to apply as very little wicking occurred. Cotton readily absorbed the ink, pulling it out of the brush and limiting control over the application. While the ink did not tend to wick along individual fibres it would pool wherever the brush was placed leading to uneven application and forcing the use of a dryer brush for initial application, following the perimeter of the stencil and then filling in the interior. Silk also readily absorbed the ink, with stains more likely to wick out along individual fibres resulting in less control in their application. In all cases there were some stains that exceeded the stencil boundary due to wicking

Figure A1: Application of Ink to fabric samples

A2.3 Preparation of Agarose

Agarose was weighed out according to the percentage being made. For the preparation of .5 cm gels 100 millilitres of deionized water was used to ensure the

[145] Samples at back

production of enough gels for the tests. For .3 cm gels the amount was decreased to 50 ml. Water was then added and the solution was placed on a hot plate with a stir bar and covered. The gel, water mixture was heated to at least 85° Celsius or until the solution was clear and no powder was visible in the beaker. The liquid gel was then poured into the macaroon moulds to for the individual gel disks. The mould had a slight curve and thus was weighted to try and keep the disks as even as possible. After about a half hour the gels had set and cooled and could be removed from the mould, bagged and stored in the refrigerator until use.

A2.4 Recipe For 2.5 % Agarose Gel at .5 cm Depth:

Equipment:
Hot plate/stir[146]
Beaker(s) or Bain-marie
Magnetic stir bar

Ingredients:
2.5 g agarose
100 ml of deionised water[147]

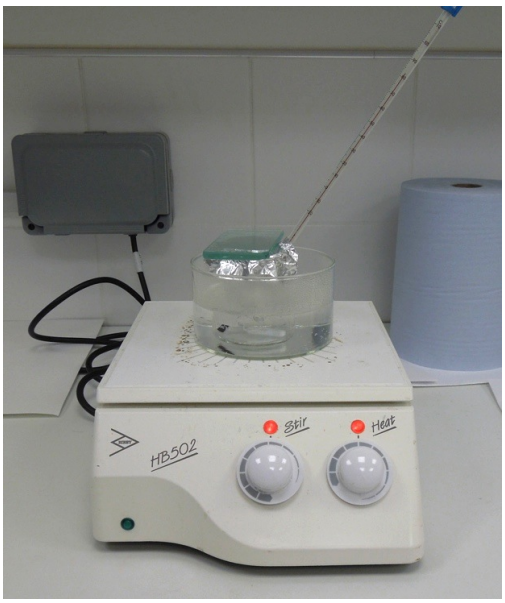

Figure A2: The agarose being heated using the ban-Marie system, the beaker is kept covered to reduce evaporation.

- Combine agarose and water in a beaker
- Add magnetic stir bar and cover.
- Heat using a bain-Marie on a hot plate until the solution reaches 85-88 degrees Celsius. At this point the solution should be clear and no agarose powder visible (Figure A2).
- Remove beaker from bain-Marie and pour liquid into mould if using. Allowing the liquid gel to cool slightly before pouring should allow for the formation of thicker gels if the agarose is being poured out on a sheet[148].

[146] The solution can be stirred intermittently throughout cooking if a hotplate with stir capabilities is not at hand. The beaker should be kept covered through most of the cooking process to prevent loss of moisture and thus a change in the concentration of the gel.
[147] Amounts as low as 25 ml of a 1% gel have been prepared using this system, less may be difficult to handle depending on the concentration being made as, even in their melted state, 4% gels are thick and set quickly.
[148] For this project the gels were poured directly into moulds with no cooling time added as the depth of the gel was one of the variables being controlled. If enzymes are being used the cooling process is necessary to ensure the heat does not denature the enzyme.

Appendix: 4 Further Observations from Testing

A4.0 Introduction

Appendix 4 summarises further observations from testing and preparation. Many of these pertain to the practical use of these gels and have less impact on the overall project results. The first section is dedicated to aspects of the project that may have affected the results of the testing and discusses in depth the decision behind using weights.

A4.1 Factors Affecting Testing:

Natural variation in testing was inevitable as each test was preformed four times to ensure statistical viability, a total of 72 tests. The following section outlines portions of the testing and elements that may have affected the overall results of this project and that should be taken into account when implementing this type of treatment.

A4.1.1 Ink Application

Each textile absorbed ink differently thus the samples had different amounts of ink in the fibres. This may have affected how much ink the gels drew out of the textile and how much ink was visible in the gel. By applying the gels for a set time, 1 hour, and by making comparisons both within the range of a single textile as well as across the three different fibre types it is hoped that this variable is negligible.

A4.1.2 Order of Testing:

The testing done for this project started with the firmer 4% gels. This initial work with the stiffer material led to the implementation of the weights. Had research began with the lower concentrations first it is likely that the weights would not have been implemented or would have only been put to use on the higher percentage gel. This would have had an overall effect on the results, including a possible reduction of the movement of ink through the textile and a better understanding of what gels are able to achieve contact with a surface and to what extent.

A4.1.3 Gel Formation and Use of Weights

In both processes used to form the gel blocks, the surface tension allowed a meniscus to form when the gel was poured and resulted in a raised ridge around the gel. This was not trimmed off, as it was difficult to ensure an even surface. The weights were applied to the gels to increase the degree of contact across the surface of the material. While the flat side of the gel was placed on the textile sample the weight would have had the most contact with the outer portion of the gel thus the pattern of a contact "halo" around the exterior of the gel. This became less of an issue the 2.5% and 1% concentrations and with the implementation of finger pressure on the gel before applying the weight. Wolbers does not support the use of either of these methods as he believes capillary action alone has the power to clean the surface. This may be because paintings and furniture offer a harder surface on which to apply the gels. However, as the process of capillary action cannot begin without contact between the two surfaces, these methods offered one way to ensure contact between gel and the more mobile textile. Ensuring contact between the two materials had an effect on the test results and the methods used to force that contact had an effect on the growth of the stain[149].

These experiments showed that it is difficult to achieve contact between fabrics with higher concentration gels. In the case of these tests, finger pressure should have been applied first to attempt to achieve the desired result without the addition of weight. It is likely that the weight is useful for the more rigid 4% gel and lighter weights or finger pressure applied with gels 2.5% and lower. The removal of the weights during the 1% tests does not have statistical effect on the results due to the variation in standard deviation already present through the sample group.

A4.2 Other Observations From Testing

The following sections overview the observations from handling and storing gels and their use on textile materials.

[149] Appendix 8

A4.2.1 Remelting:

Campani et al and others note that the gel scraps can be re-melted and recast[150]. During this experiment 4% gels were re-melted in an effort to reduce the depth of the gel they had formed. As agarose is a highly stable material the gels were difficult to return to their liquid state, even after surpassing the original melting temperature of the gel pieces of unmelted gel were visible. When recast, the gels exhibited a change in texture, appearing grainy in comparison to a freshly made material, possibly the result of not achieving a complete melt of the precast gels. It is likely that the loss of water between the original casting of the gel and during the remelting process increased gel concentration. This would have resulted in greater viscosity when the gel melted. Gels of a lower percentage may have melted easier as the water content would have been higher and the liquid less viscous, allowing for a smoother recast gel to be formed. How these gels worked in comparison to the original 4 % gels was not tested as fresh gels were made for each stage of this research to reduce variables.

A4.2.2 Storage:

The gels used for this project never aged more than 4 days. Gels below 4% were easily marked on the surface. Stacking the gels in storage resulted in impressions being pressed into the surface of the gel. To avoid this, the gels should be stored separately or stacked wrong sides together and placed on a flat surface. This will ensure the surface of the gel placed on the object is smooth and flat, helping to encourage overall contact with the material.

Gels should be brought up to room temperature before use. A cold gel was wetter than a gel at room temperature as decreasing the temperature leads to the molecules moving closer together forcing water out of the pores where as a gel at room temperature is able to retain water as the pores of the gel are not constricted.

1% gels appear to mould much faster than 2.5% and 4% gels due to their higher water content. The unused gels were stored in a refrigerator and upon the conclusion of this project only 1% gels were showing signs of mould after 4 weeks.

[150] Campani et al

A4.2.3 Placement and Handling:

Gel concentration affects the ease of placement as well as how these gels can be handled. Contact with bare hands should be avoided. On lower concentration gels gloves prevent impressions on the surface of the gel, this is less of an issue with gels at a higher concentration. If the gels are to be used for conductivity or pH testing the salts and oils on the hands may affect the reading, further supporting the use of gloves[151].

1% gels are incredibly soft and wet. Movement with tweezers cuts into the gel leaving a permanent mark on the surface thus reducing contact within that area. The gels are overall difficult to handle as the surface is easily marked. These gels however offer the flexibility and movement that is needed to drape over a surface. This flexibility along with the soft nature of such a low concentration gel is most likely the cause for the high degree of contact achieved by these gels.

2.5 % gels are slightly more rigid and, as a result, easier to handle. These gels can be picked up and moved and, though they are less flexible than 1% gels. They do retain the ability to bend to some degree, especially at a lower depths.

4% gels are very rigid, they do not exhibit the flexibility seen in 1% and 2.5% gels and thus can crack if bent. This limits their ability to contour to a surface. The 4% gels are the easiest to handle, they are a much dryer gel and the surface is not as easily damaged.

A4.2.4 Gel size:

The size of the poultice should be considered when applying gels to a textile. Gels larger than the stain or area being treated can result in greater movement of the stain as a water mobile stain will follow the path of moisture. As a result the practice of cutting the gels to fit a stain is reinforced and encouraged when implementing this system.

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[151] , YouTube, *The Getty Conservation Institute* "Making Agarose gel and Preparing Agarose plug" Video, accessed July 30, 2014, https://www.youtube.com/watch?v=SX4n2DO6Lao.

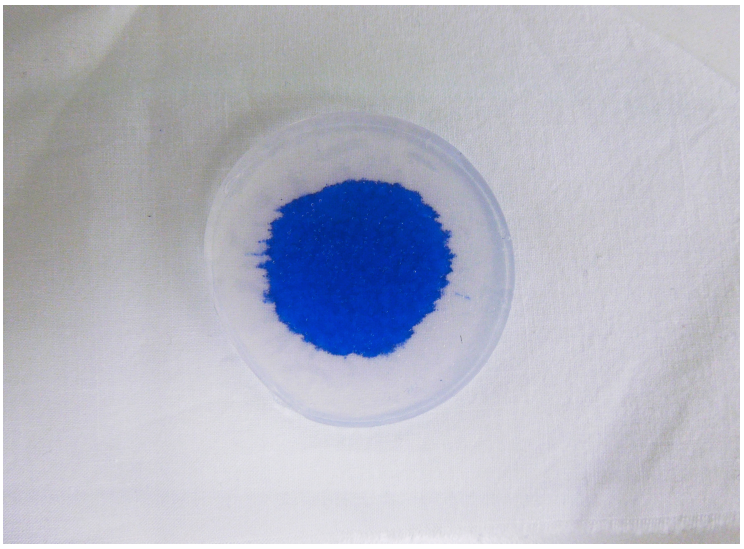


Figure A3: Ink stain on cotton just after gel was applied

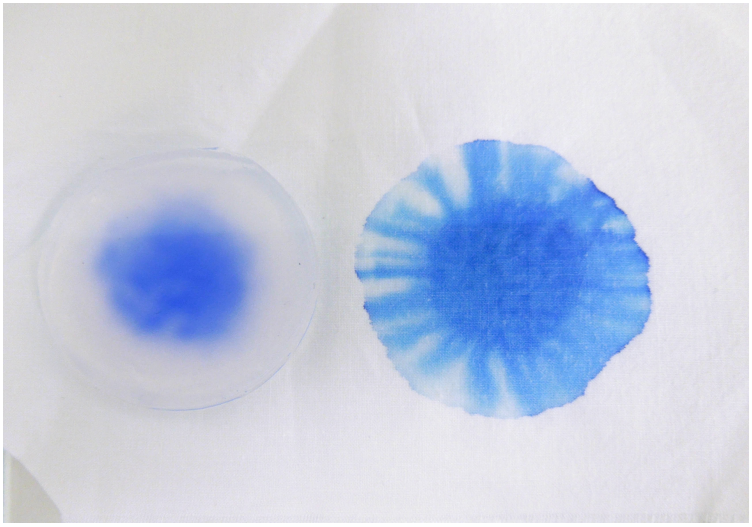


Figure A4: The ink stain after gel application for 1 hour.

A4.2.5 Diffusion Through Gel

The process of diffusion continues after the gel is removed from the substrate. The later images of the test gels (Figure 27) show how diffusion results in an even coloured gel despite initial uneven up take of the staining[152]. Such movement makes initial observations of the gel essential to understand how they work on a surface. The patterning shows what areas have had better contact between gel and substrate and aids in understanding the movement of the stain in the textile.

[152] See Appendix 7

Appendix 5: Further Discussion of Results

A5.0 Introduction

The following section provides further information on the tests done for this project. Graphs summarise the overall results for the tests done in each concentration and fabric to show the variation within test groups. The tables summarising the standard deviation show the range in results that prevented statistical analysis.

A5.1 Overall Results:

The results from this testing indicated that the fibre type and concentration of the gels have the greatest affect on the movement of the ink through the textile and how the gel was able to draw ink from the substrate.

The parallel dot graphs clearly depict the similarities in the results both within a fibre group as well as between the different gel depths (Figure 6). This also shows that 1% gels resulted in the greatest movement of the ink. The charts clearly depict the differences between the fibre types. Both silk and cotton were fairly consistent in their movement where as wool exhibited greater variety.

The interaction graphs reiterate the limited effect of the depth of the gel but use the average of the results from the four tests (Figure 7). Again this graph highlights the greater variations in the tests done on wool. These graphs also show the decline in the overall movement of the ink between fabric types. The graphs highlight the drastic decrease in movement as a result of the change in gel concentration.

These figures summarise the data set overall and show clearly that the variables that had the greatest affect on how the ink was able to move through the textile are the gel concentration and the type of fibre to which it was applied.

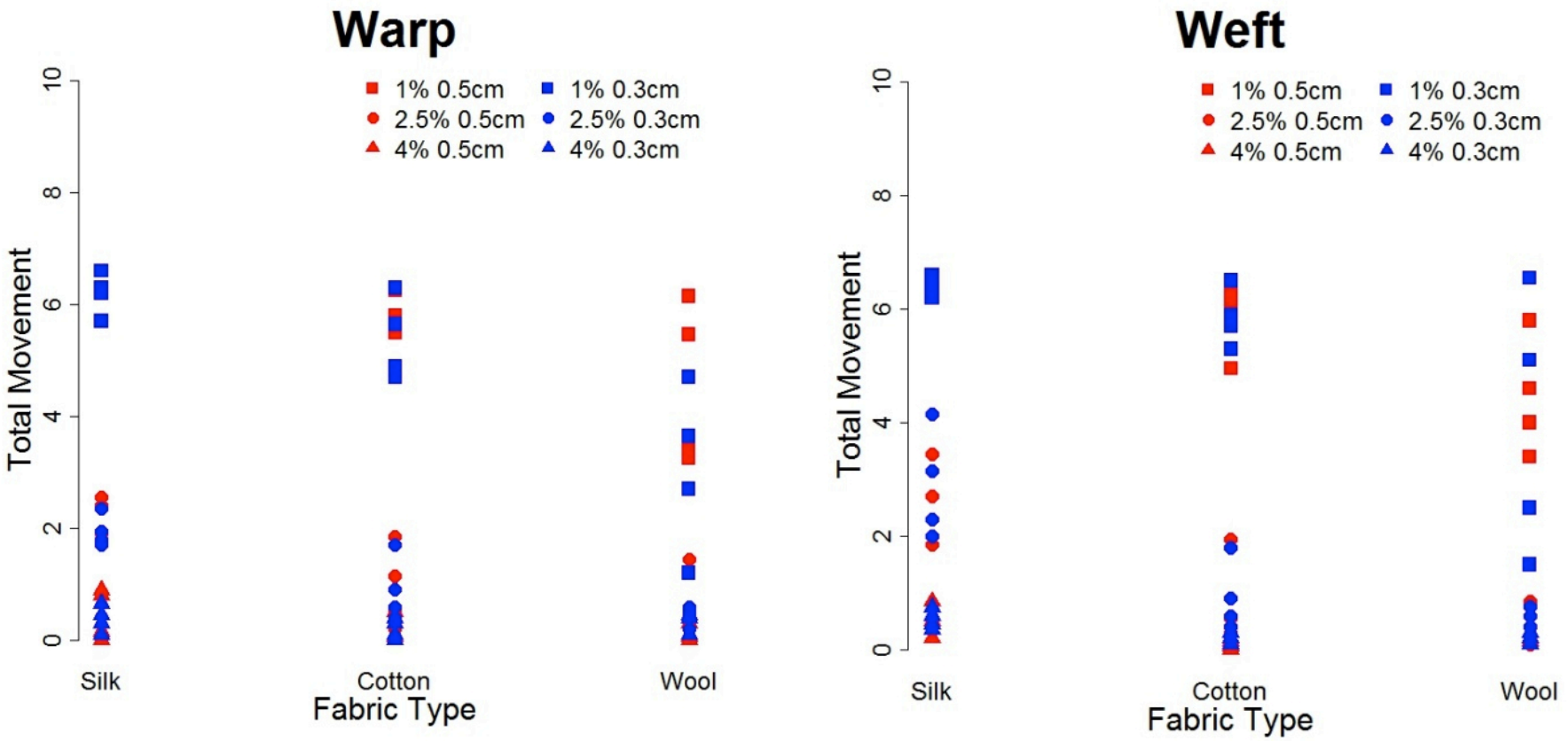


Figure A5: Parallel Dot Graph depicting the results from all tests and allowing for cross test comparisons to be made.

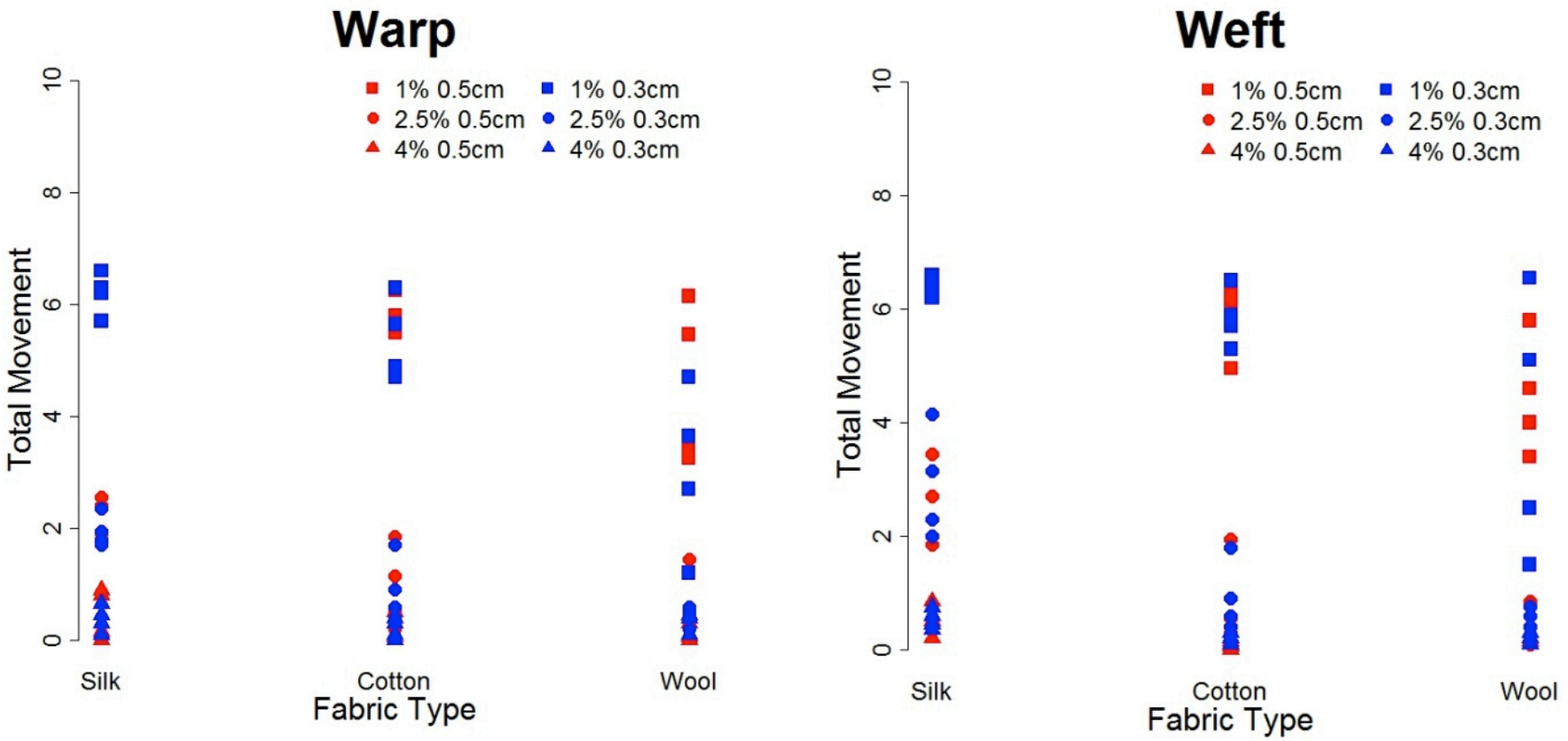


Figure A5: Parallel Dot Graph depicting the results from all tests and allowing for cross test comparisons to be made.

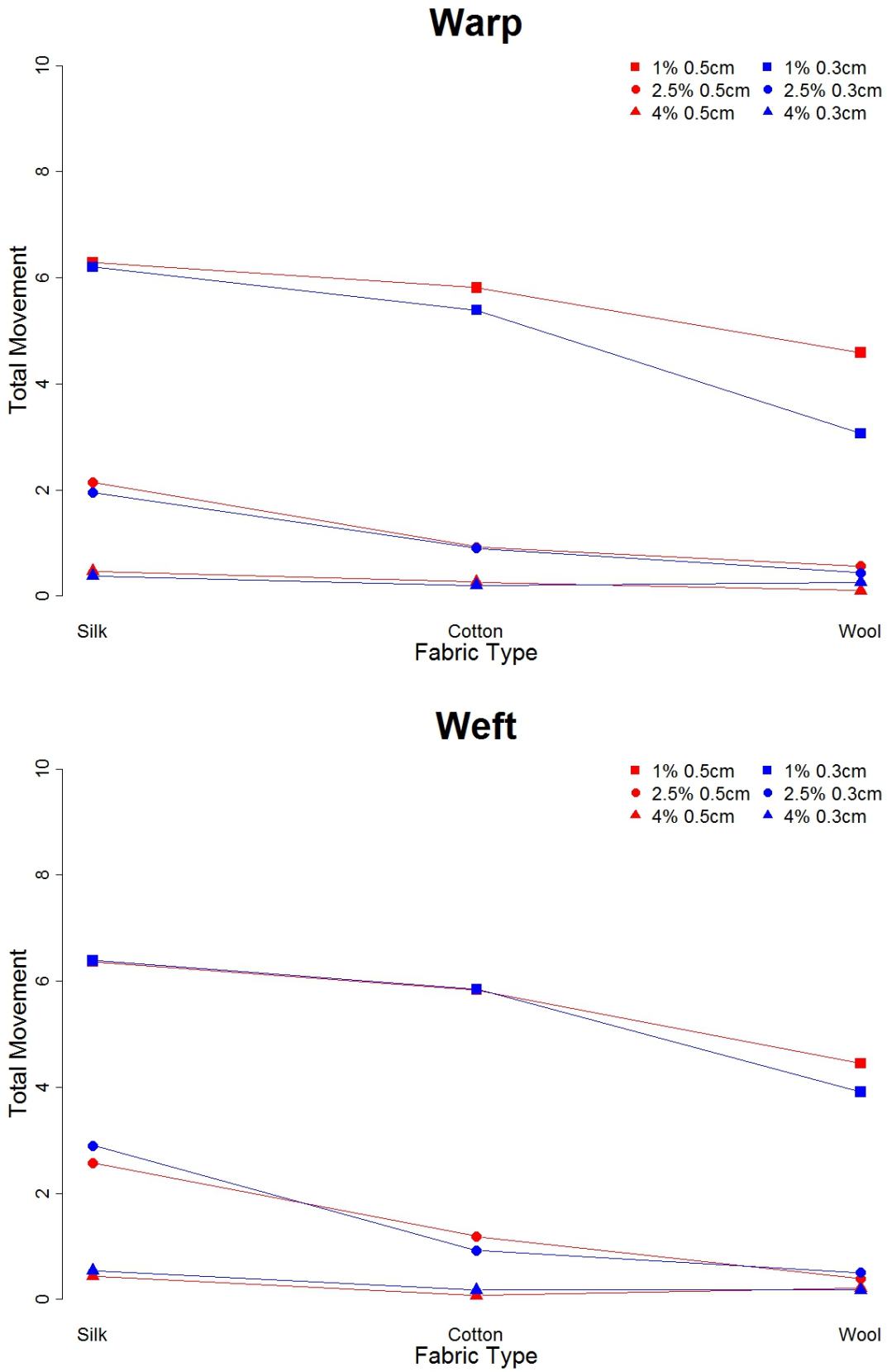


Figure A6: Interaction Graphs depicting the average of the each of the four tests clarifying the data presented in the Parallel line graph and allowing for comparison across concentrations and fabrics.

A5.2 Individual Tests

The bar graphs chart differences in the total movement of the ink through the textile samples for the four tests done. This comparison is done to show the variation between the tests both in terms of movement in the warp and weft direction as well as in how far the ink and water from the gel were able to travel through the textile. These variations are important to note as they show how the extent to which water will travel through a fabric will vary. For these experiments variables such as contact, gel depth and the temperature had an effect on the results. These graphs very in scale so the differences that are shown may not be as drastic as they appear.

A5.3 Silk:

There was some minimal variation within the different concentrations applied to silk. Those in the tests using 1% gels the original ink stain almost always reached the outer limits of the textile sample resulting in fairly even results. There were outliers in the results from other concentration indicating the variation possible within testing and the unpredictability of the movement of moisture through this fabric. There was very little difference in the movement of the ink between the two depths of gel.

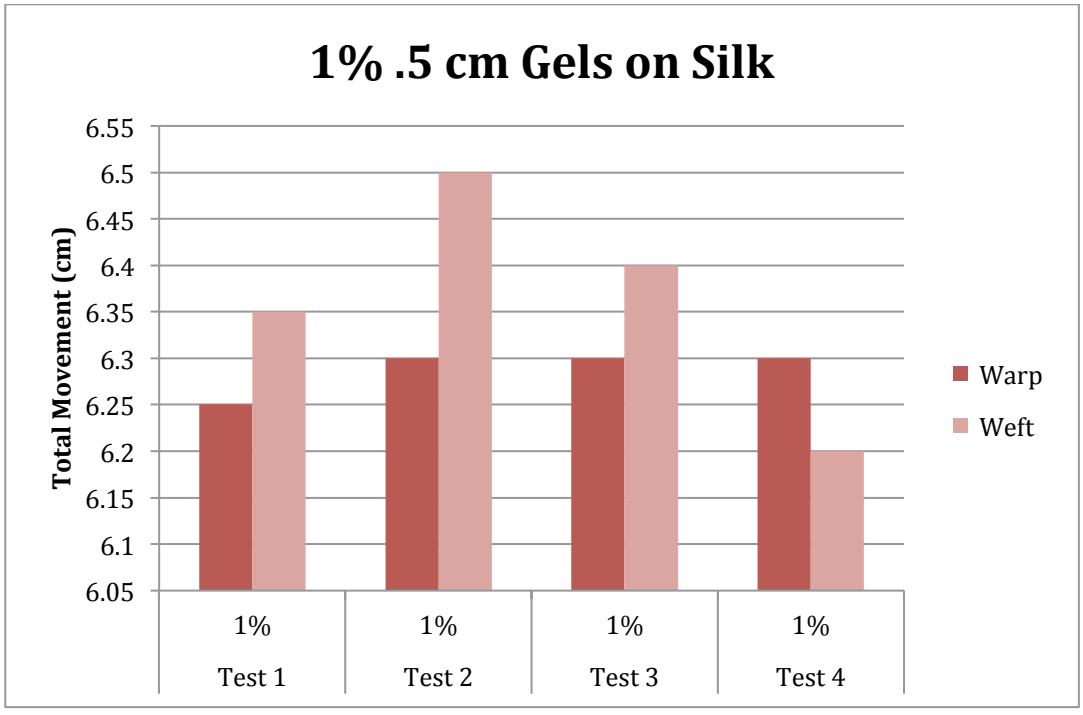


Figure A7: The results of the four tests using 1% .5 cm gels on silk

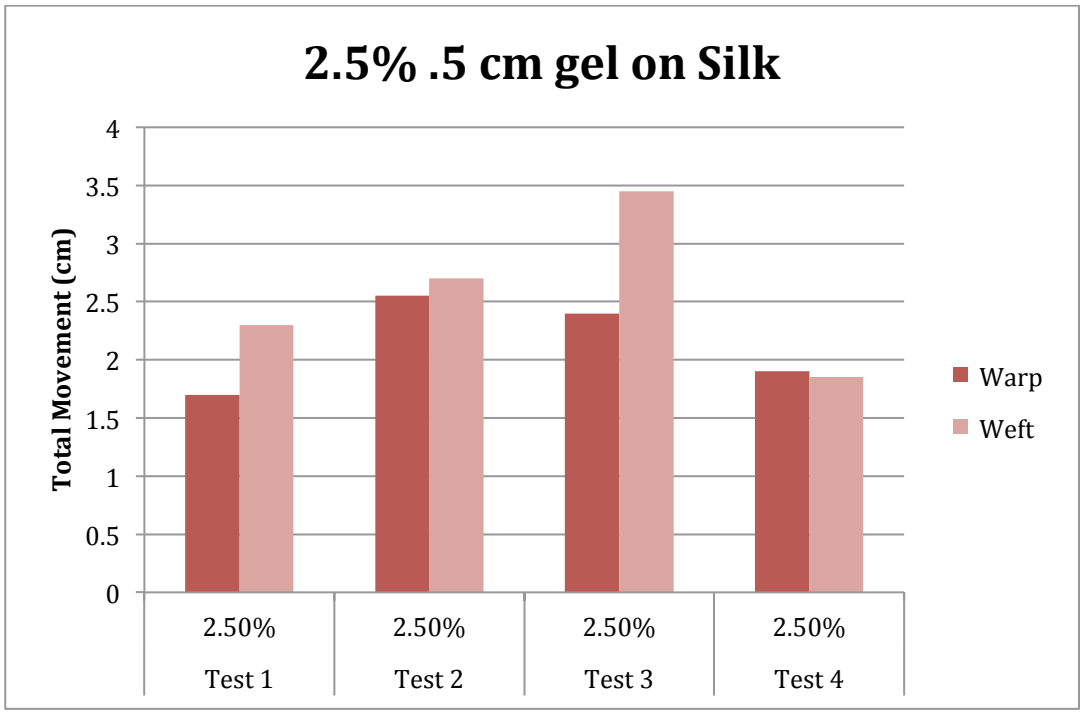


Figure A8: The results of the four tests using 2.5% .5 cm gels on silk

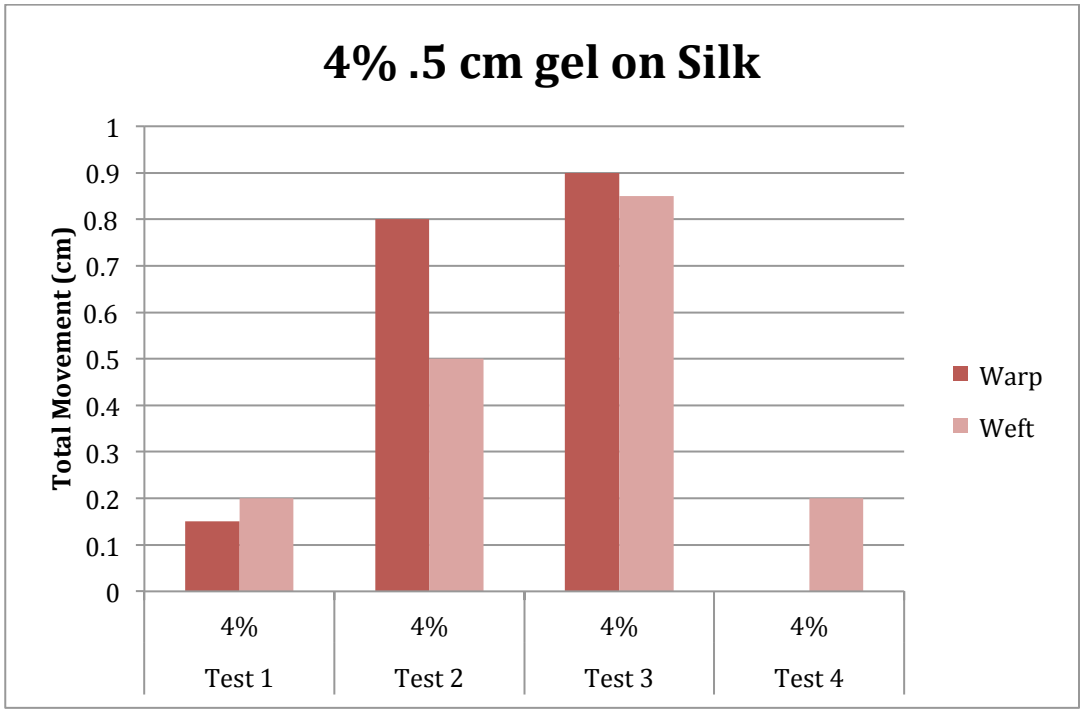


Figure A9: The results of the four tests using 4% .5 cm gels on silk

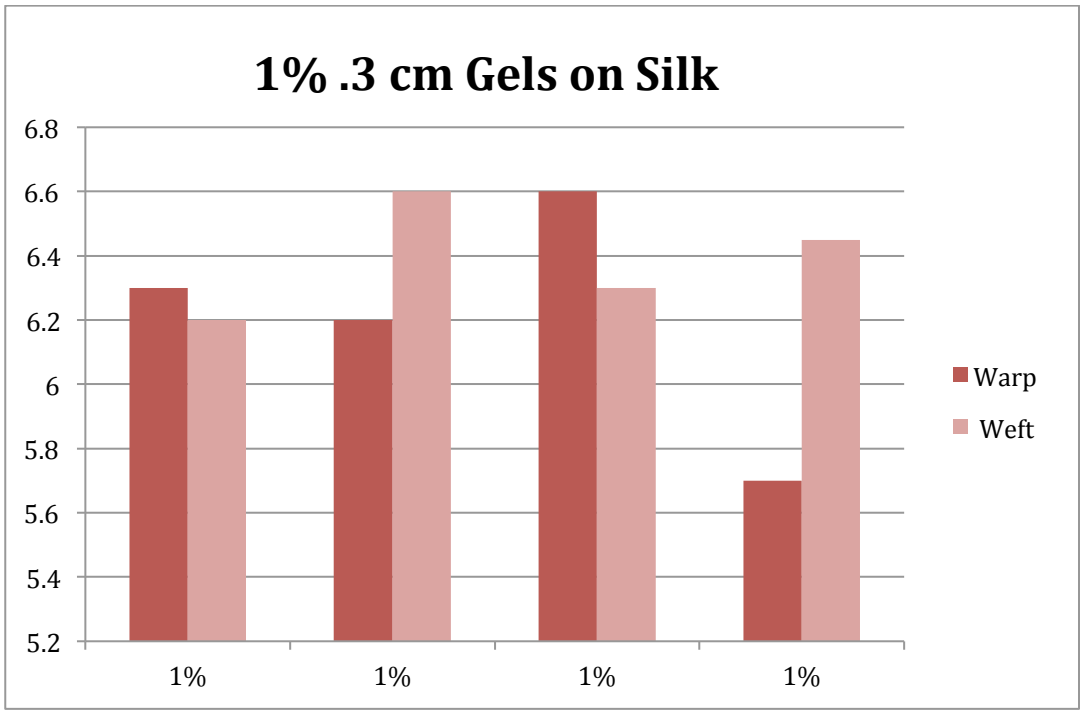


Figure A10: The results of the four tests using 1% .3 cm gels on silk

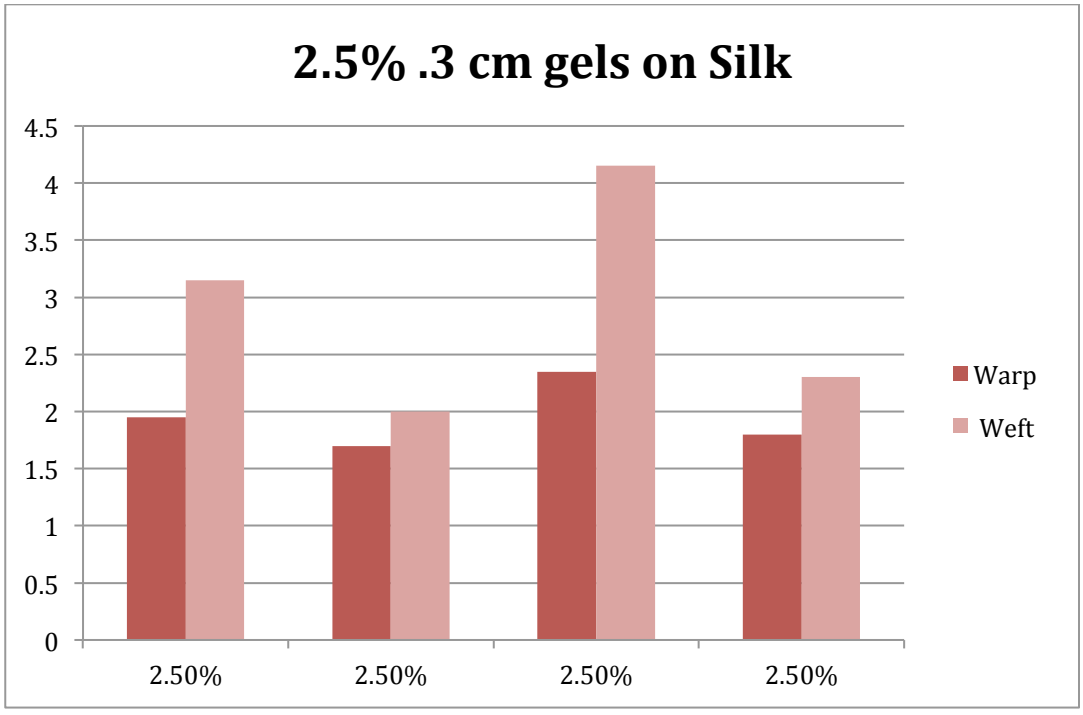


Figure A11: The results of the four tests using 2.5% .3 cm gels on silk

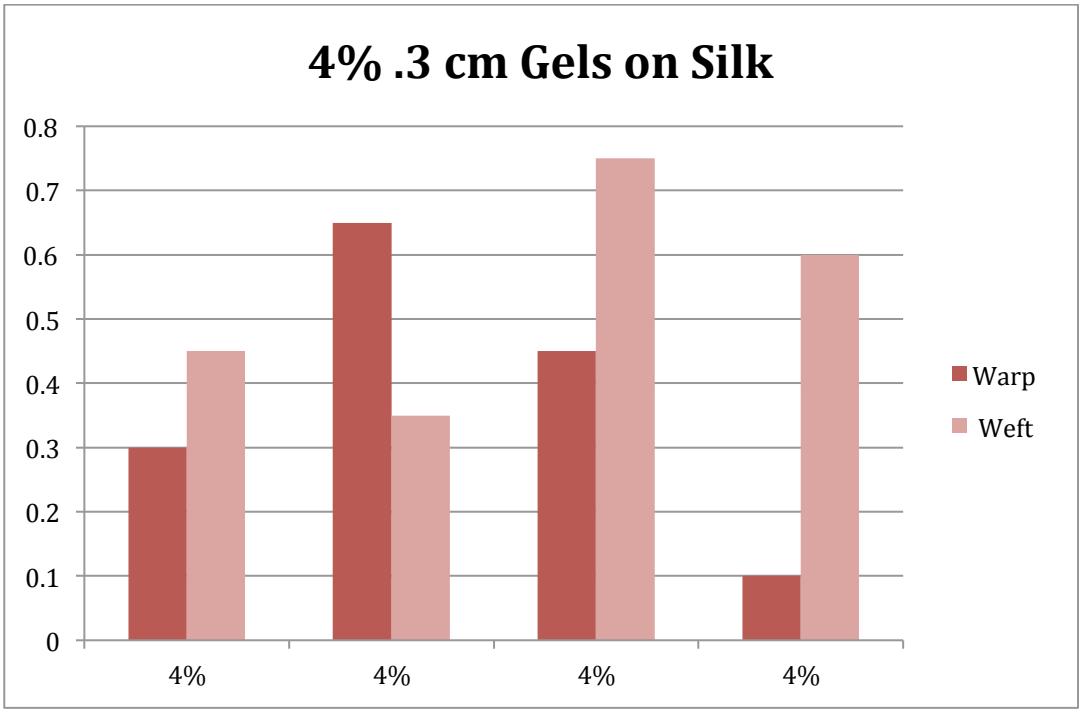


Figure A12: The results of the four tests using 4% .3 cm gels on silk

A5.4 Cotton:

Cotton fabrics exhibited a similar trend to those seen on silk, though overall movement of the ink was slightly less. The range seen in 1% gels increased and there was greater differnetiation in 1% gels, as the stains did not always reach the outer limits of the sample fabric. The drastic decrease in the movement of the ink in the 2.5% gels indicate the application of finger pressure. The movement of the ink in the 4% tests also increased with the application of the weights after Test 1, though the increase was measured in millimeters and thus was not as drastic as it first seems.

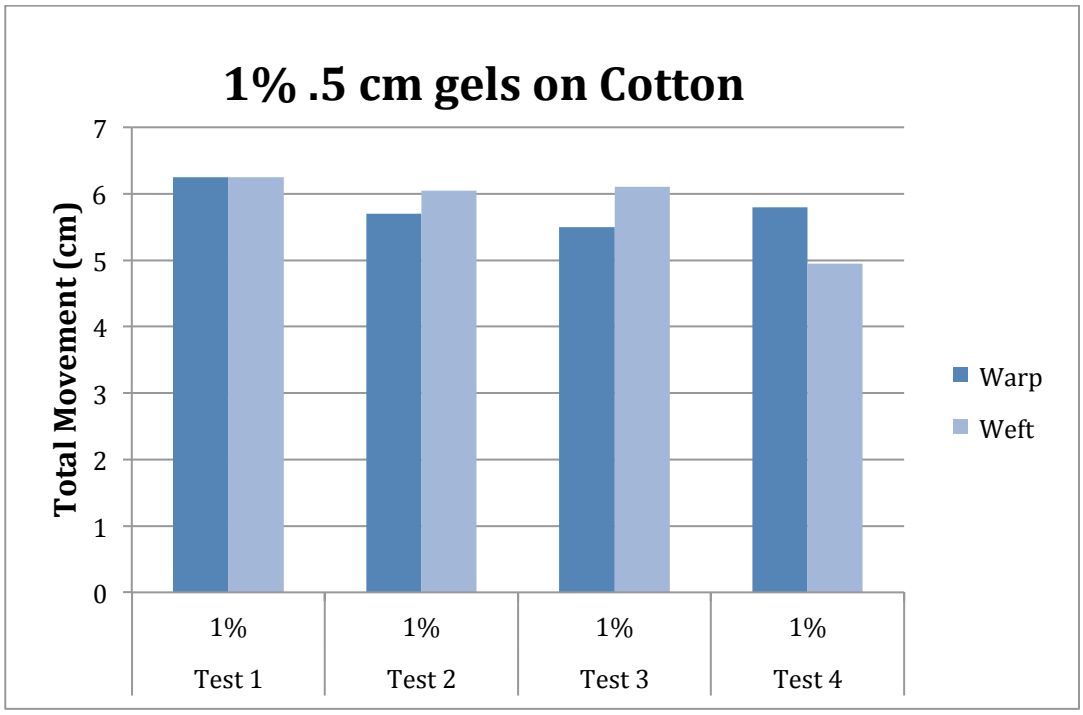


Figure A13: The results of the four tests using 1% .5 cm gels on cotton

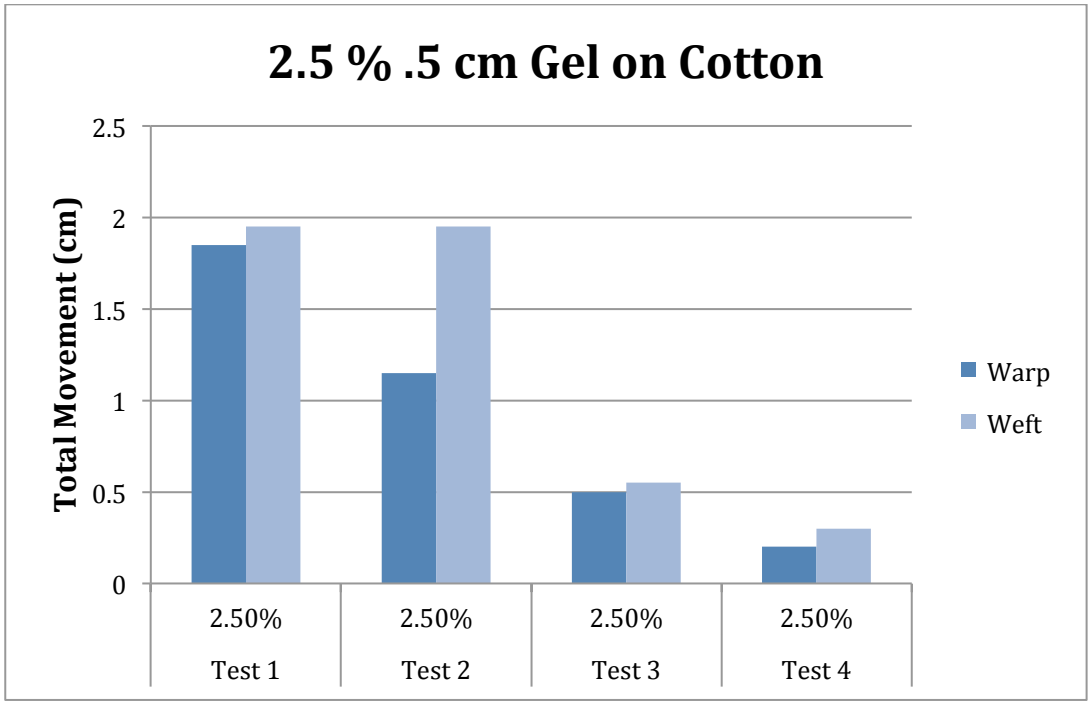


Figure A14: The results of the four tests using 2.5% .5 cm gels on cotton

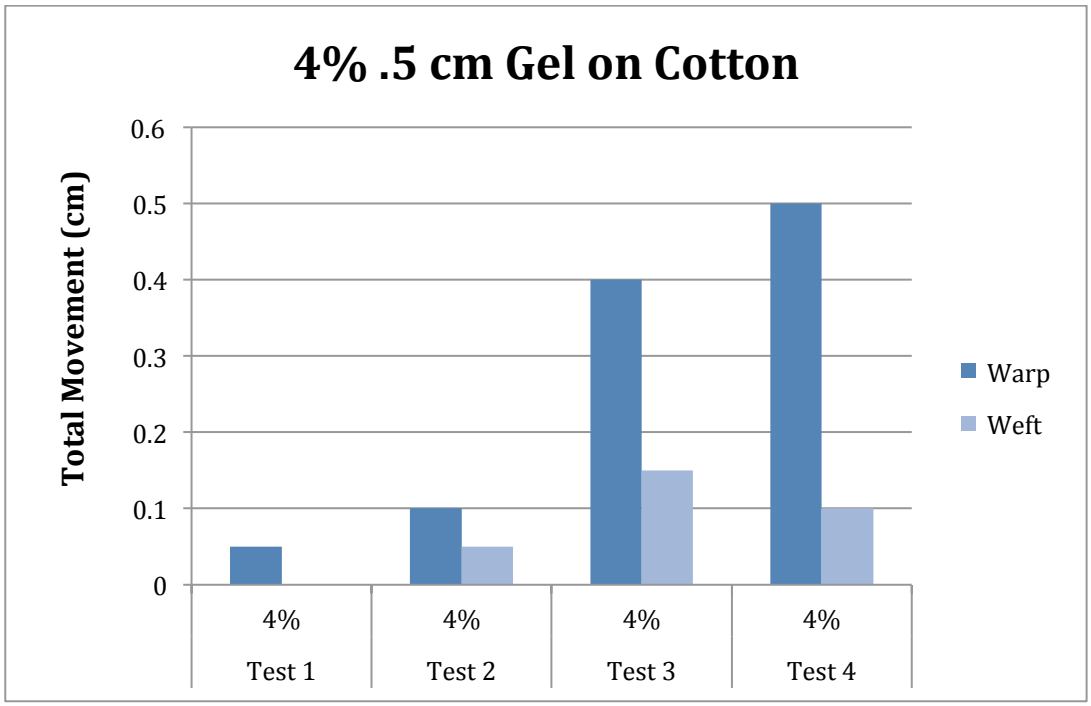


Figure A15: The results of the four tests using 4% .5 cm gels on cotton

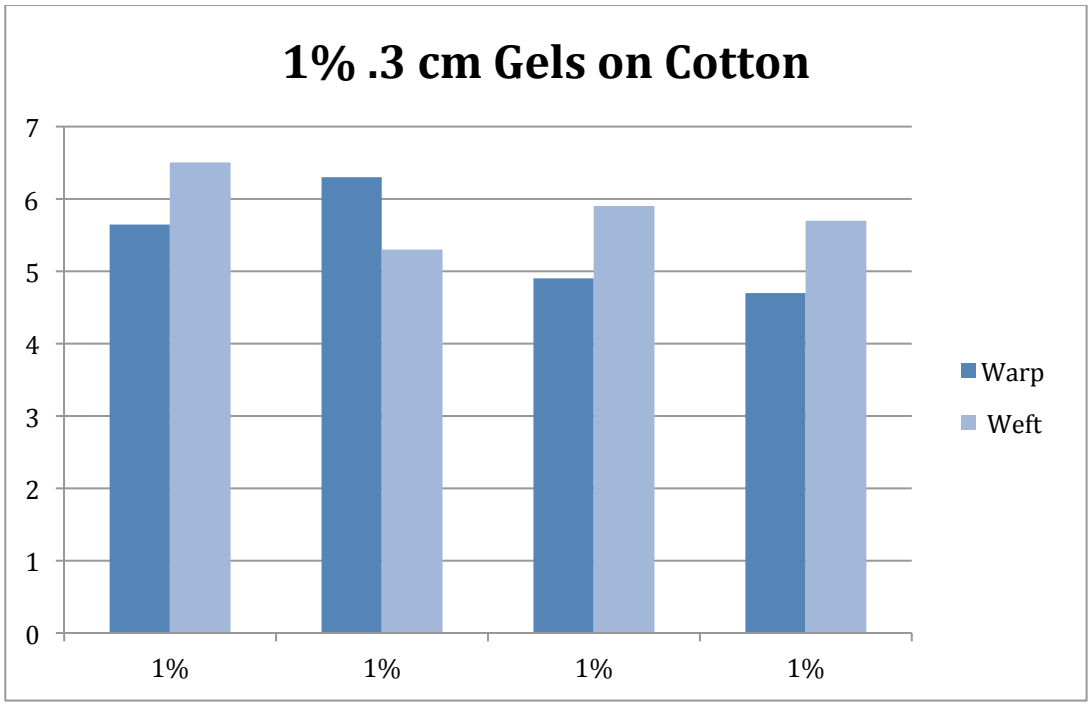


Figure A16: The results of the four tests using 1% .3 cm gels on cotton

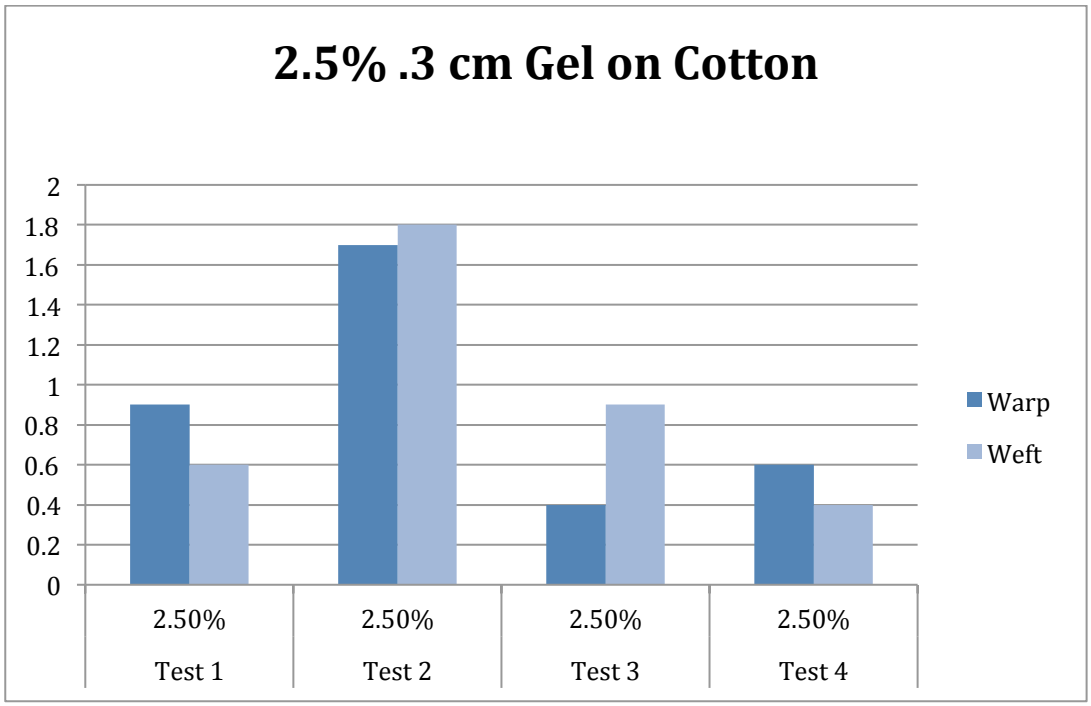


Figure A17: The results of the four tests using 2.5% .3 cm gels on cotton

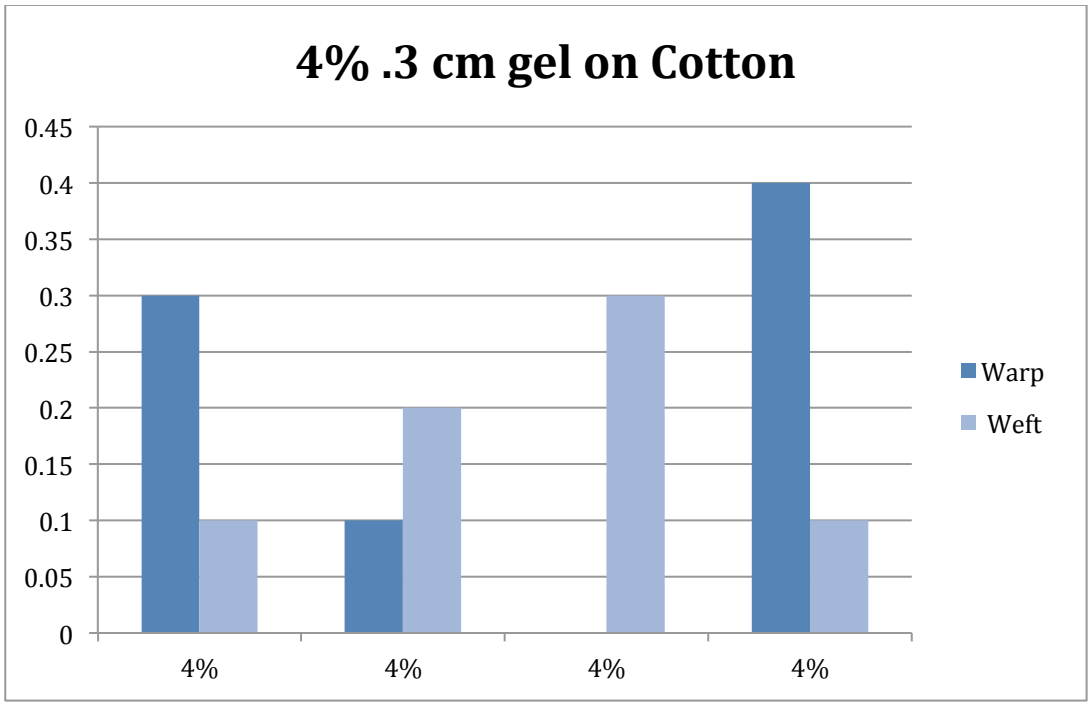


Figure A18: The results of the four tests using 4% .3 cm gels on cotton

A5.5 Wool:

Wool test samples showed much more variation within each concentration. This was especially visible in those tests using 1% gels. 4% gels also presented some

variation in results, though once again, the movement was measured in millimetres and thus the variation in the tests was less than it first appears.

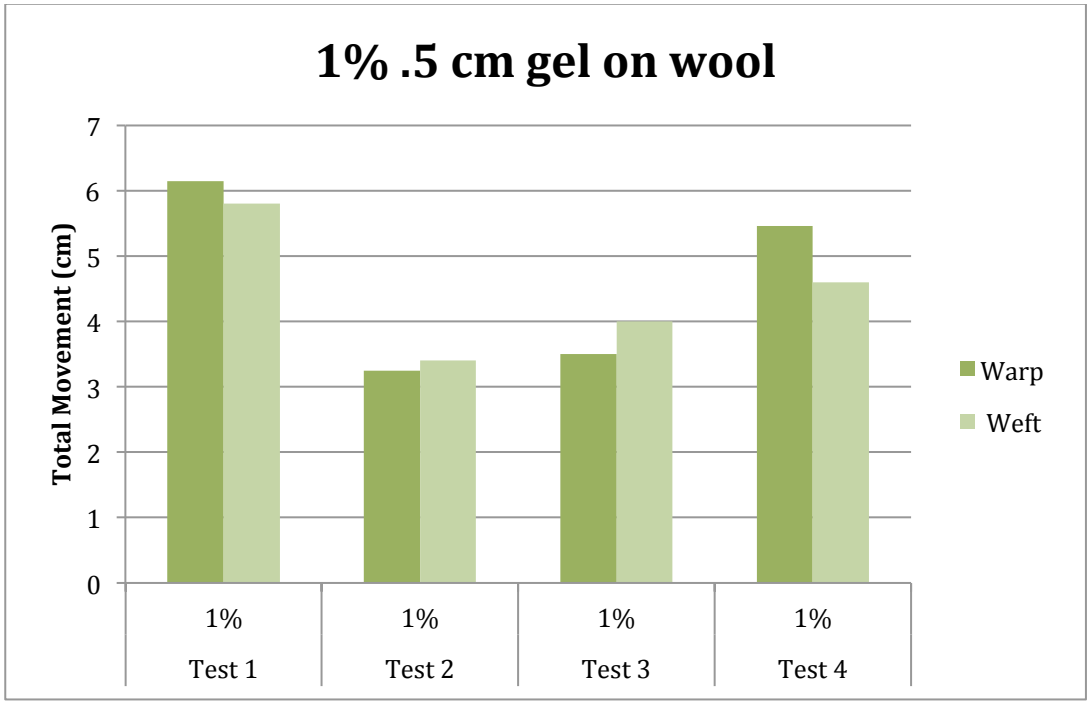


Figure A19: The results of the four tests using 1% .5 cm gels on wool

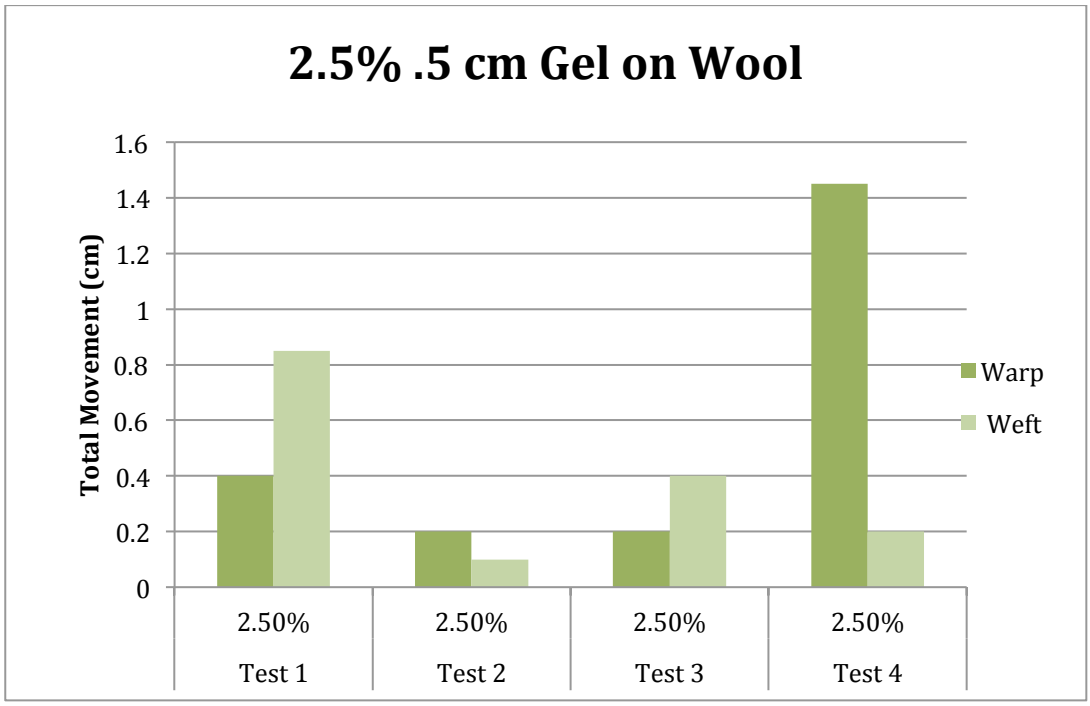


Figure A20: The results of the four tests using 2.5% .5 cm gels on wool

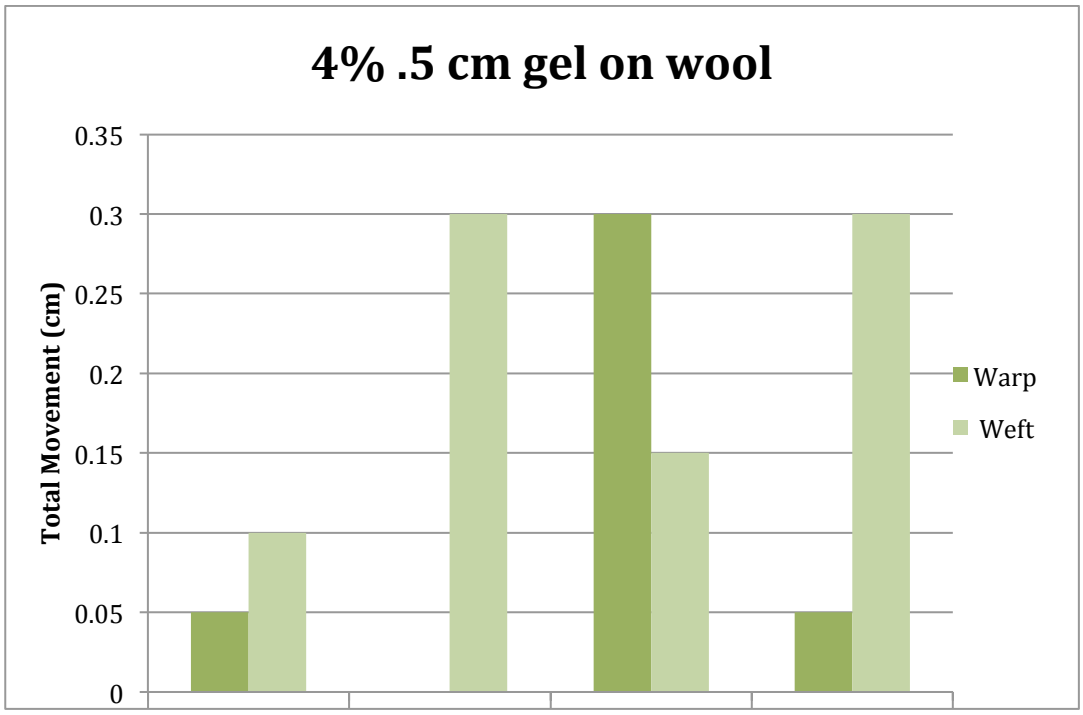


Figure A21: The results of the four tests using 4% .5 cm gels on wool

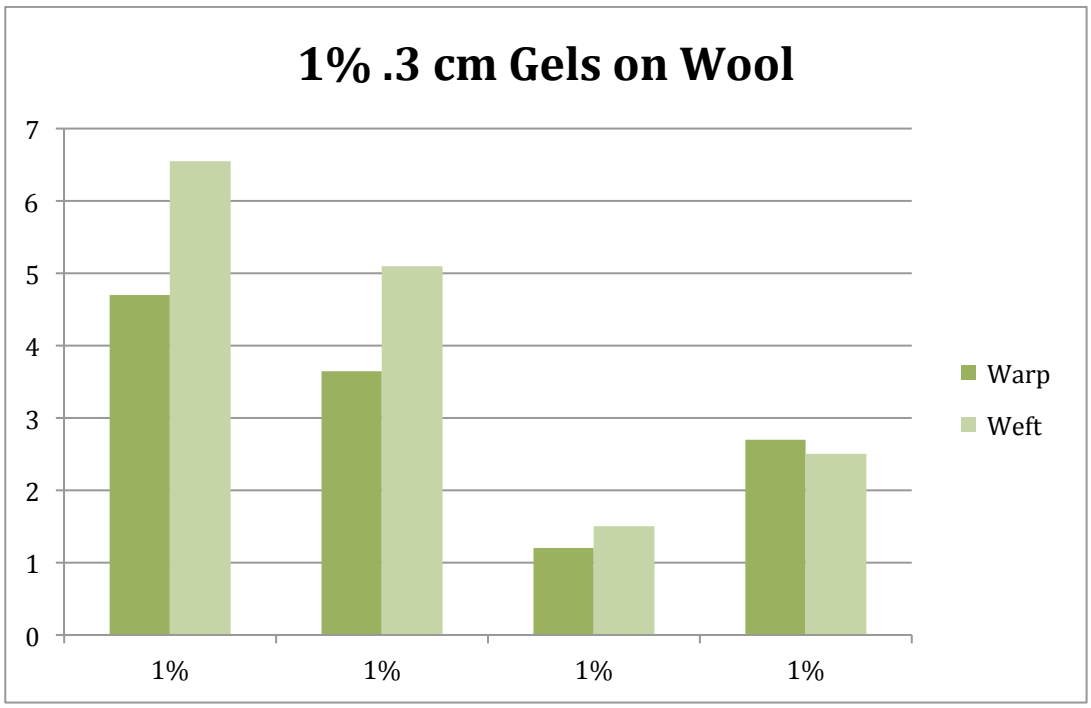


Figure A22: The results of the four tests using 1% .3 cm gels on wool

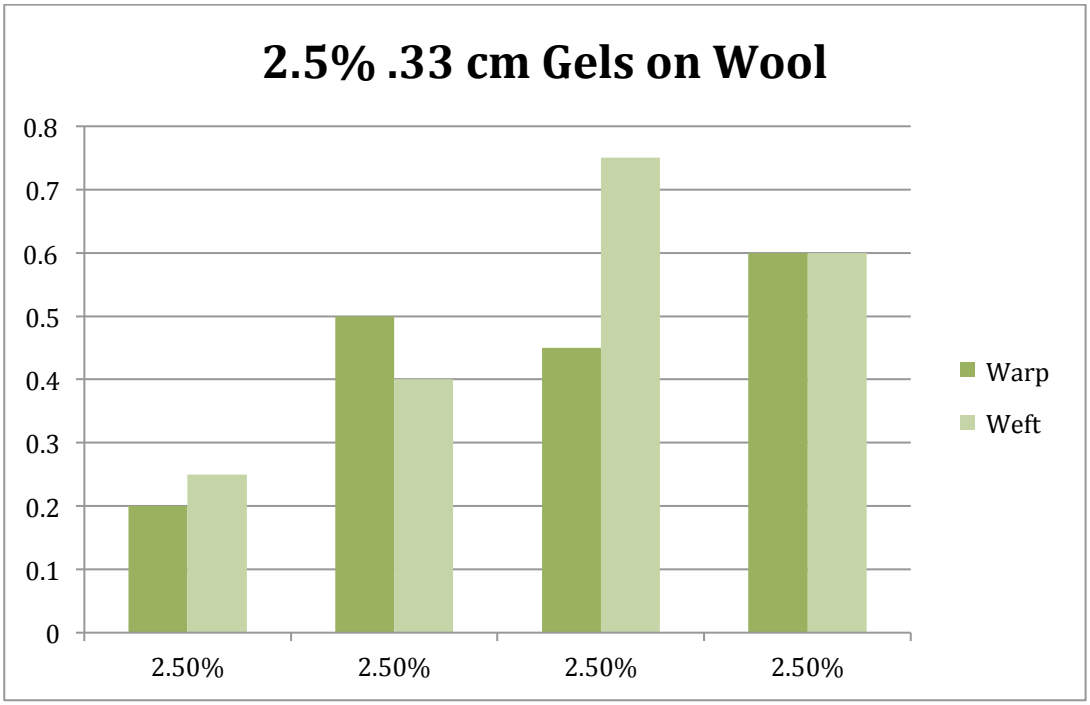


Figure A23: The results of the four tests using 2.5% .3 cm gels on wool

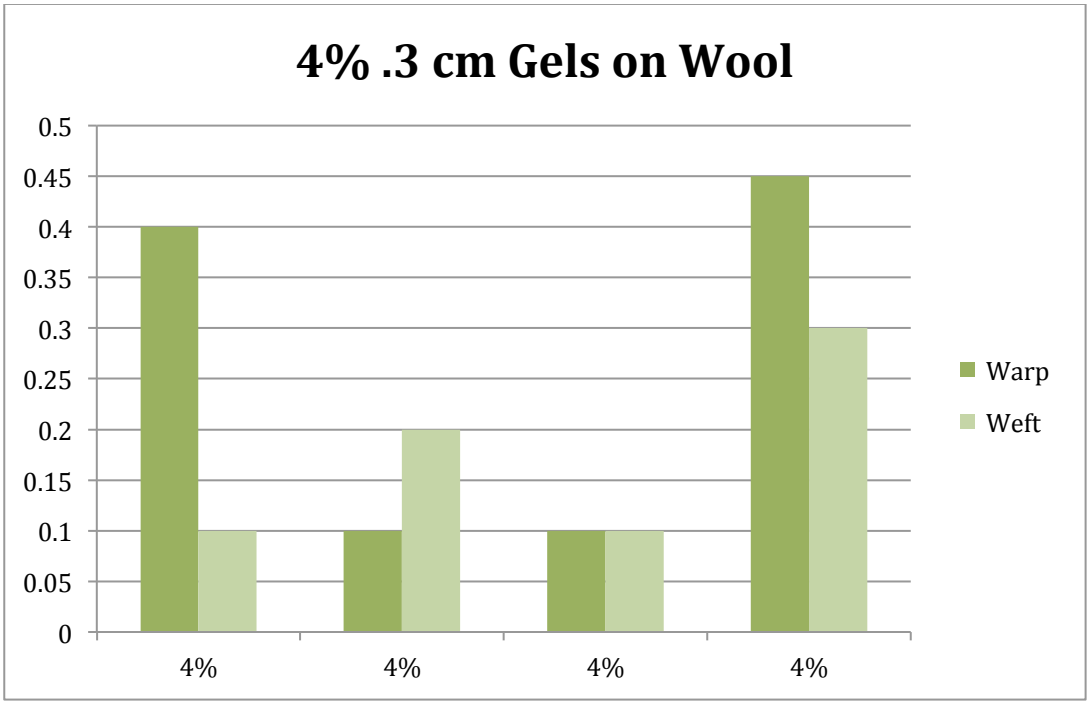


Figure A24: The results of the four tests using 4% .3 cm gels on wool

A5.6 Standard Deviation

The standard deviation of each fabric type and gel depth were calculated to determine range of the data from the results. Tables 4 and 5 show the standard deviations for all the concentration of .5 cm and .3 cm gels that were tested for

both the warp and weft measurements. The range of results gathered for this study resulted in very different standard deviations. The highest standard deviation was 2.322, 37 times the lowest standard deviation of .065.
Due to the high degree of variation, statistical analysis was precluded as the data range meant that analysis would not produce accurate results.

While the high standard deviation is the result of an anomaly in the testing, the variance within wool is the result in a remarkable difference. This variation is a natural result of the fabrics used and not caused by the experimental process. Due to the this variation the results have focused on visual examinations and the graphed data presented in the body of the work as well as in this appendix.

Standard Deviation of Movement of Ink in the Warp Direction

Concentration	Depth	Silk	Cotton	Wool
1%	0.5 cm	0.025	0.317	1.435
2.5%	0.5 cm	0.403	0.733	0.599
4%	0.5 cm	0.453	0.221	0.135
1%	0.3 cm	0.374	0.733	1.486
2.5%	0.3 cm	0.286	0.572	0.170
4%	0.3 cm	0.233	0.183	0.189

Table A1: Warp Standard Deviations

Standard Deviation of Movement of Ink in the Warp Direction

Concentration	Depth	Silk	Cotton	Wool
1%	0.5 cm	0.125	0.598	1.025
2.5%	0.5 cm	0.679	0.886	0.333
4%	0.5 cm	0.309	0.065	0.103
1%	0.3 cm	0.175	0.500	2.322
2.5%	0.3 cm	0.965	0.618	0.220
4%	0.3 cm	0.175	0.096	0.096

Table A2: Weft Standard Deviations

Appendix 6: Descriptions of Ink Movement Through Textile Samples

Tideline- a hard more concentrated line of staining along the outer edge of a ring mark or liquid based stain**.**

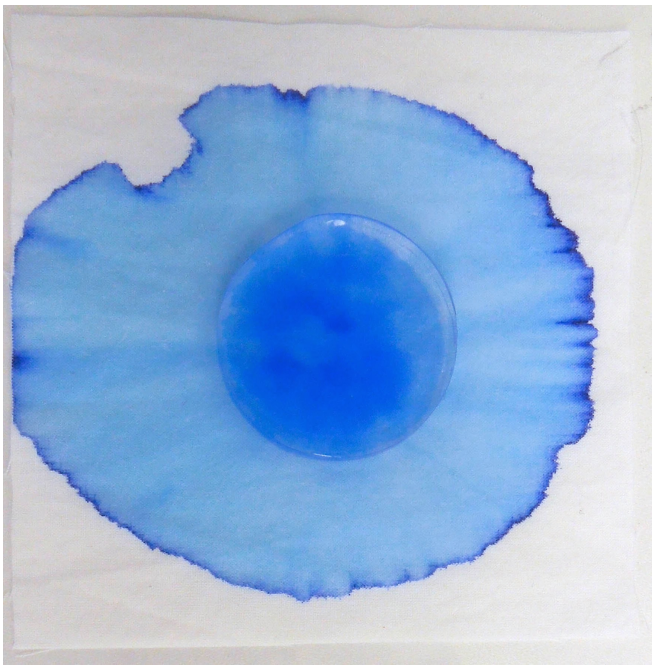


Figure A25: 1% gel on Cotton

Ringing- outward even movement that results in a stain but does not include tidelines

Figure A26: 1% gel on Silk

Mottled Stains- movement of the stain within the original surface area resulting in internal tidelines.

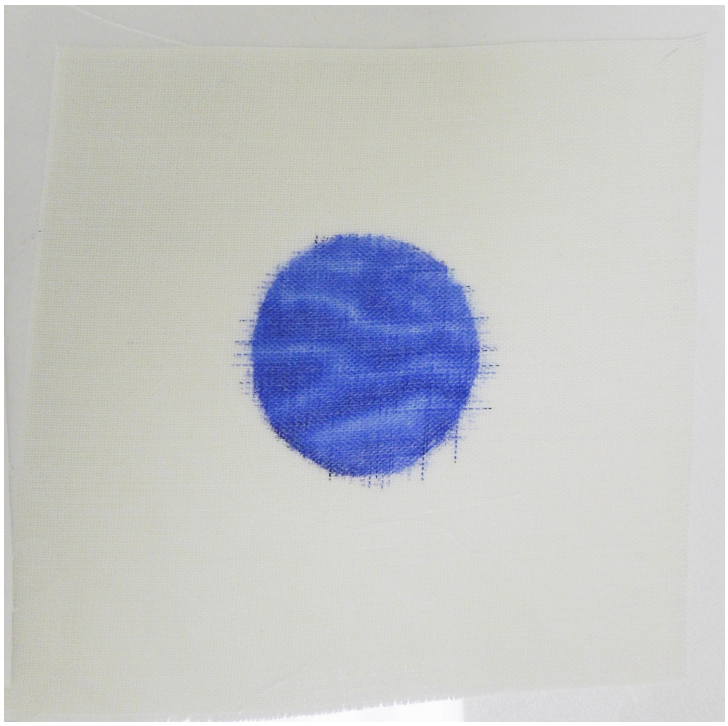


Figure A27: 4% gel on Wool

Appendix 7:

A7.0 Introduction

Appendix 7 presents images from the testing process to provide visual information on how these gels react on different fabrics. The uptake patterns in the gels are important as they show how uptake can be limited to specific areas of the gel. This patterning was sometimes echoed in on the ink stain on the textile where as in other cases uptake appeared to be much more even.

A7.1 Testing Images:

The following images depict the test fabrics before and after gel application. In some tests the gels were photographed before testing while in others before image were not taken, in these cases in progress images have been included to show the movement of the ink stain through the textile. After images were taken of the gels to record the pattern of the ink as it was drawn into the gel for all tests. The images have been presented here in the same order they were discussed within the body of the paper. This is not the order in which the tests were done. Tests began with 4% gels and thus those tests show the early adaptions made during testing. Notes on specific tests and adaptions that were employed will be discussed with the corresponding image when necessary. Due to data storage issues the images for Test 3 of the 4% gels at .3 cm depth are missing. Only the individual after images of each of the gels has been included. In progress images were not included for every test as the images were not always taken at specific times, thus are unable to reflect a specific point during testing. The in progress images that have been included show the speed at which water is able to leave some of these gels and enter the textile.

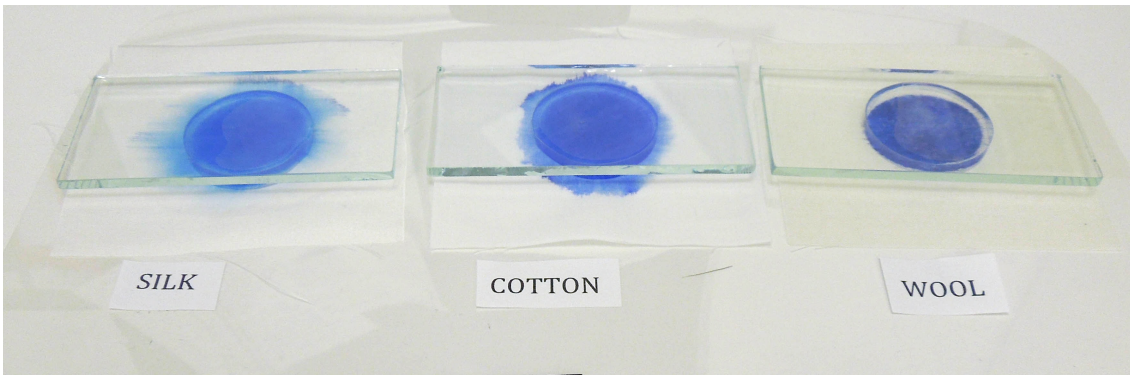


Figure A28: Test 1: 1% .5 cm gel in progress

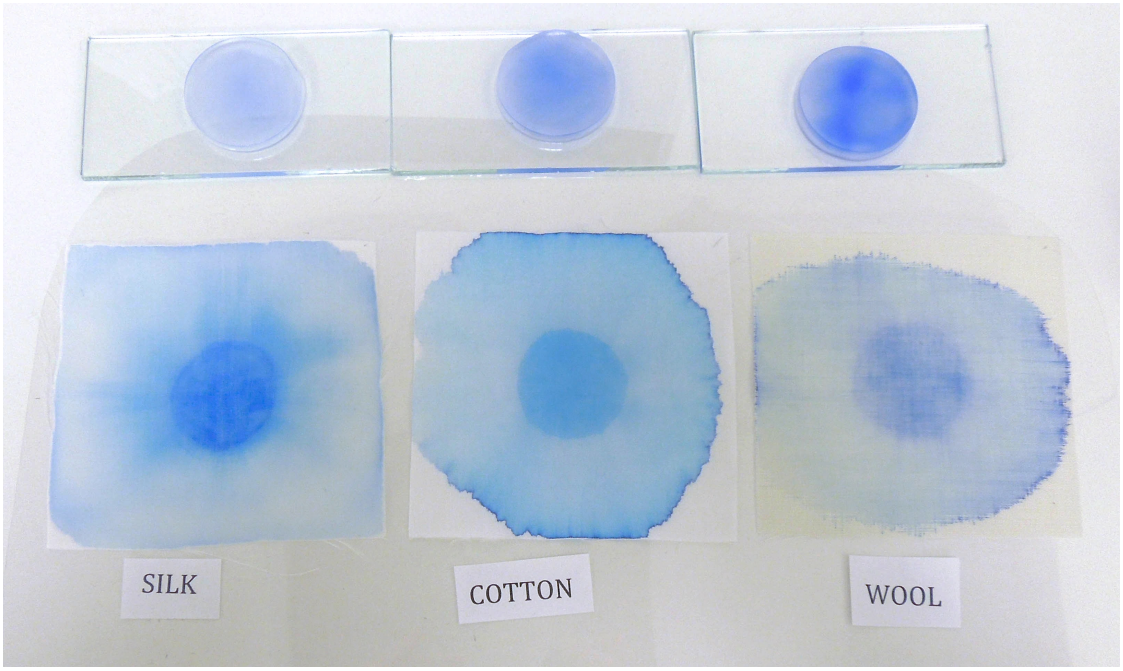


Figure A29: Test 1: 1% .5 cm gel, after

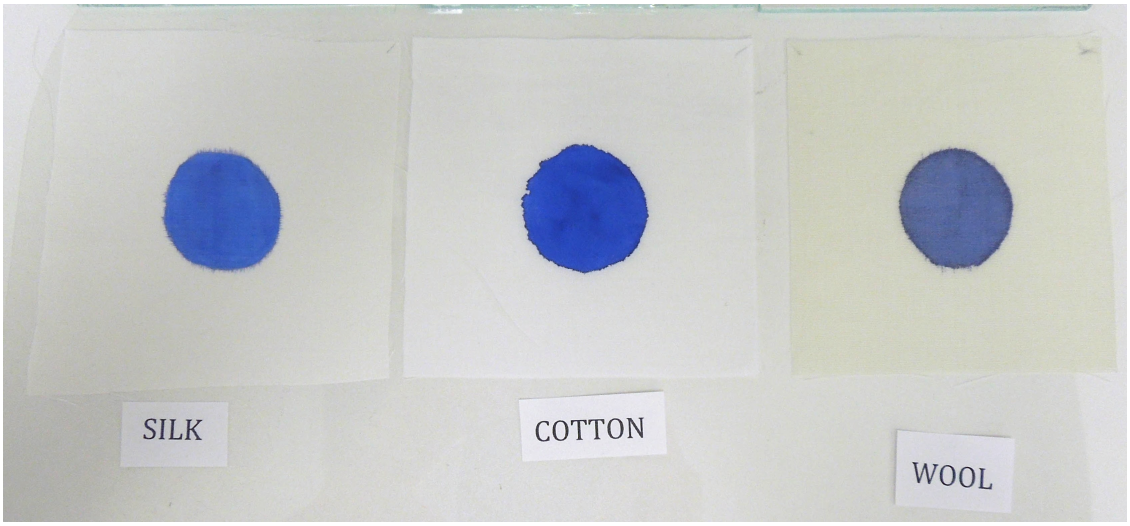


Figure A30: Test 2: 1% .5 cm gel, before

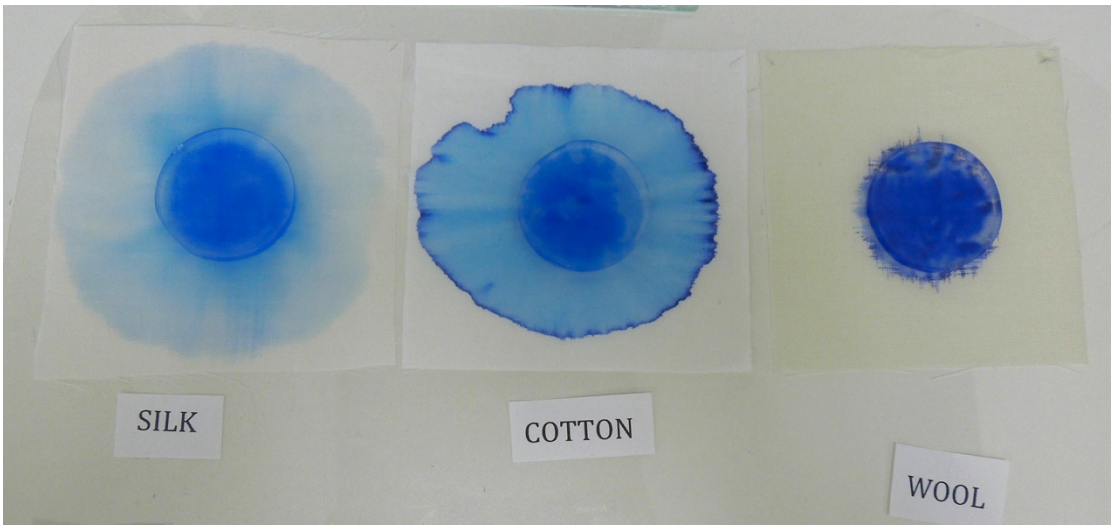


Figure A31: Test 2: 1% .5 cm gel, after

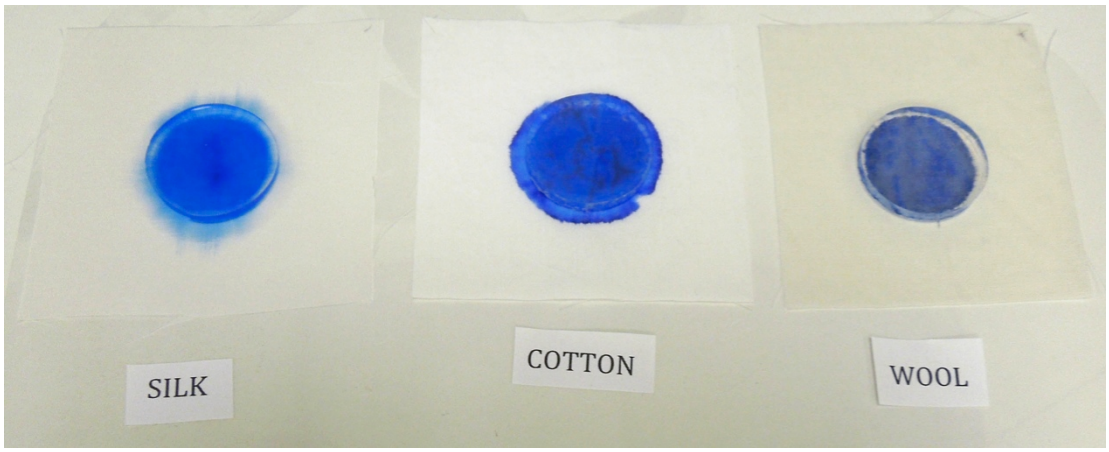


Figure A32: Test 3: 1% .5 cm gel, in progress

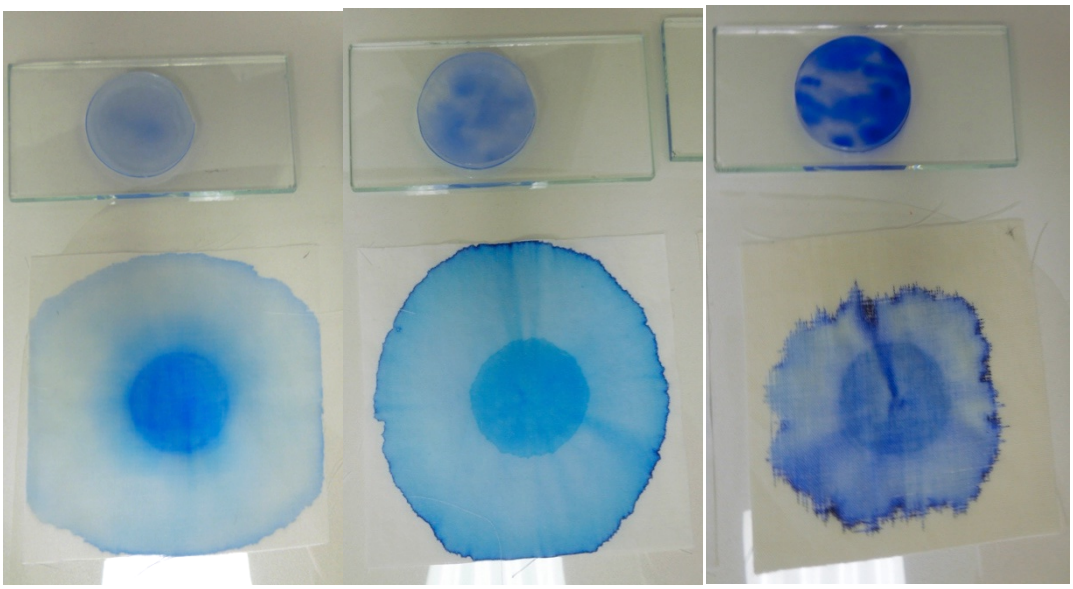


Figure A33: Test 3: 1% .5 cm gel, after

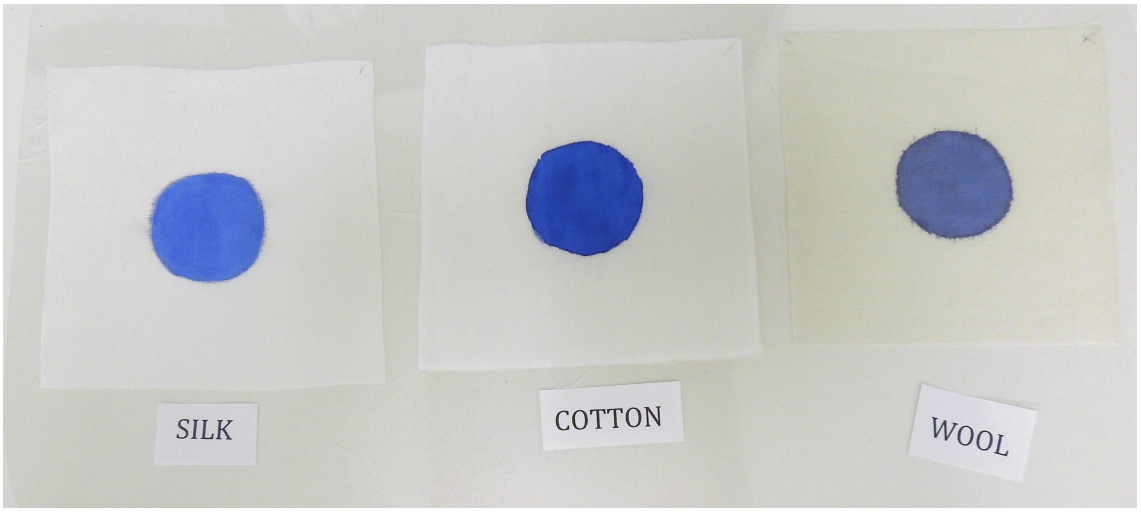


Figure A34: Test 4: 1% .5 cm gel, before

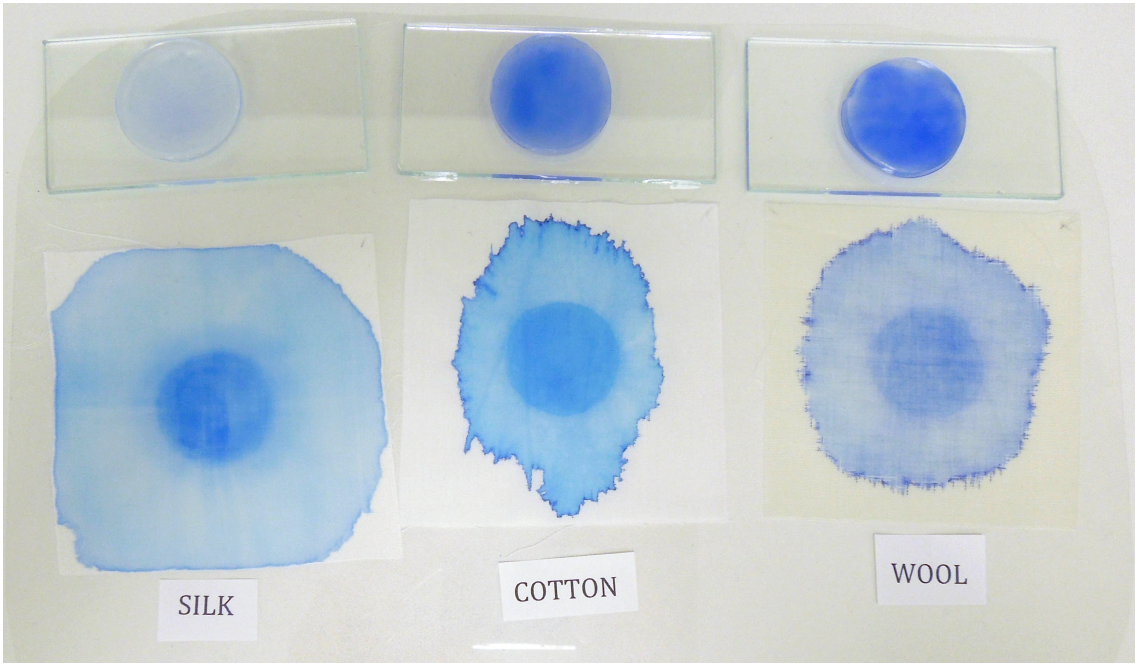


Figure A35: Test 4: 1% .5 cm gel, after

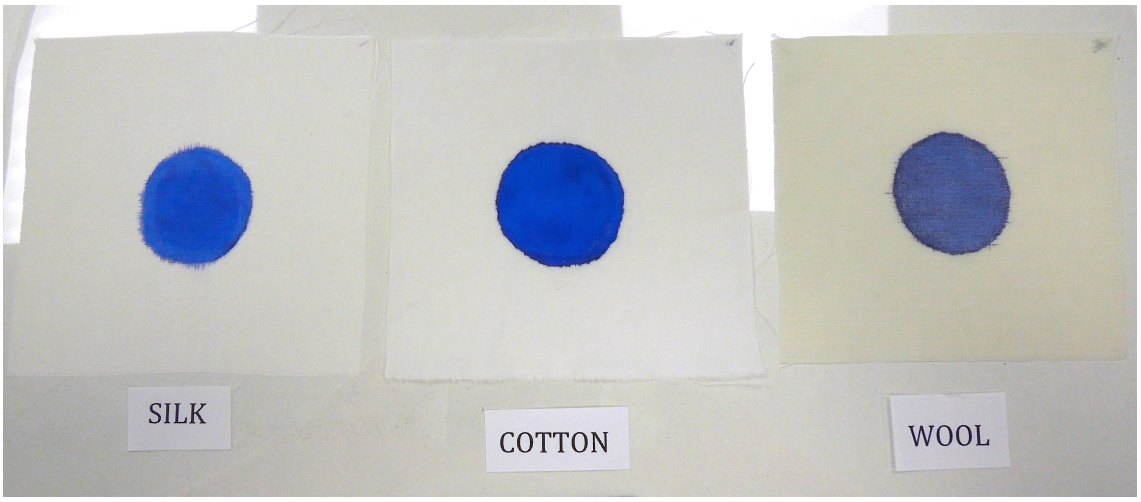


Figure A36: Test 1: 2.5% .5 cm gel, after

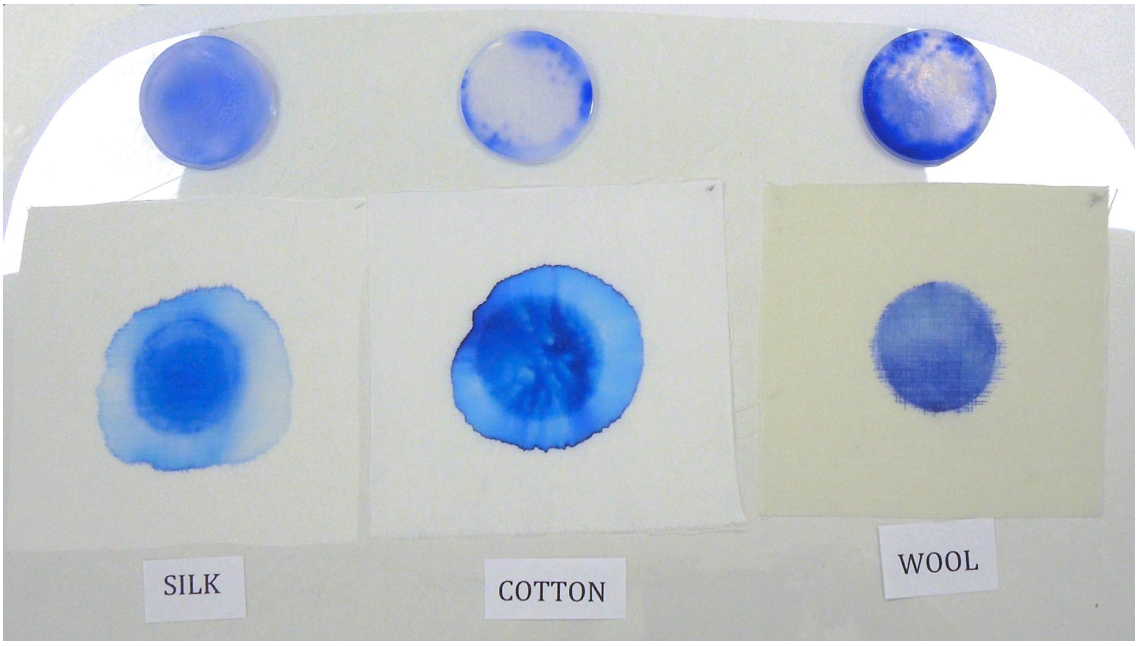


Figure A37: Test 1: 2.5% .5 cm gel, after

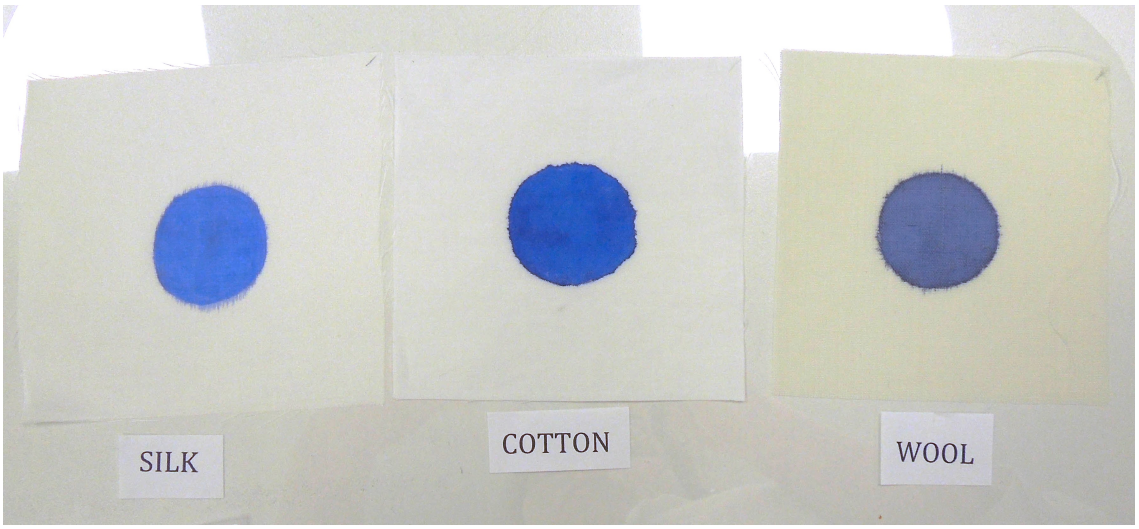


Figure A38: Test 2: 2.5%, .5 cm gel, before

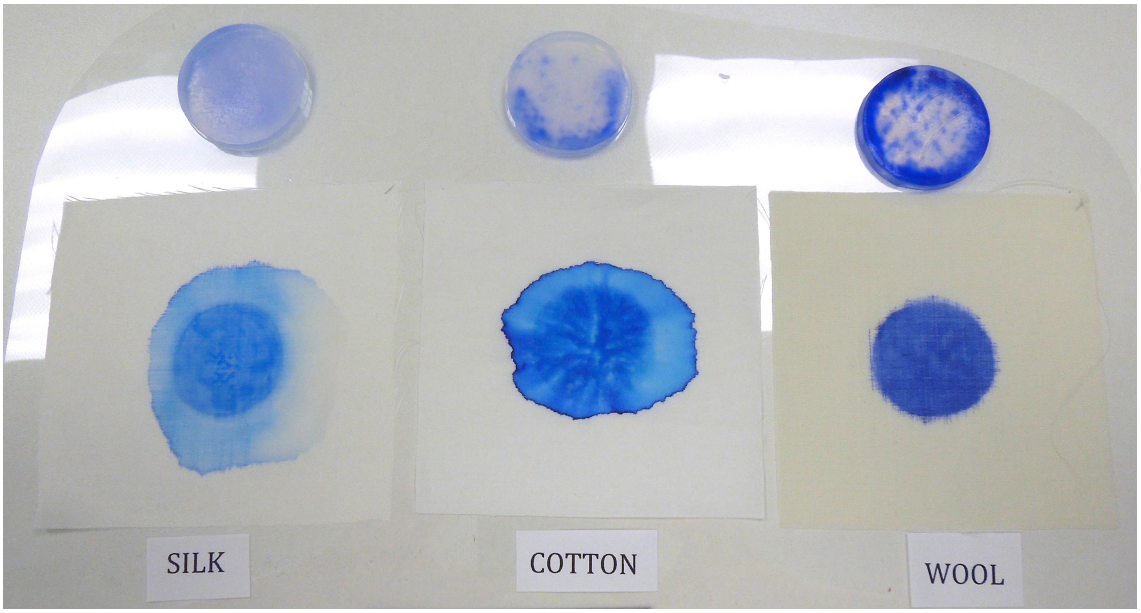


Figure A39: Test 2: 2.5%, .5 cm gel, after

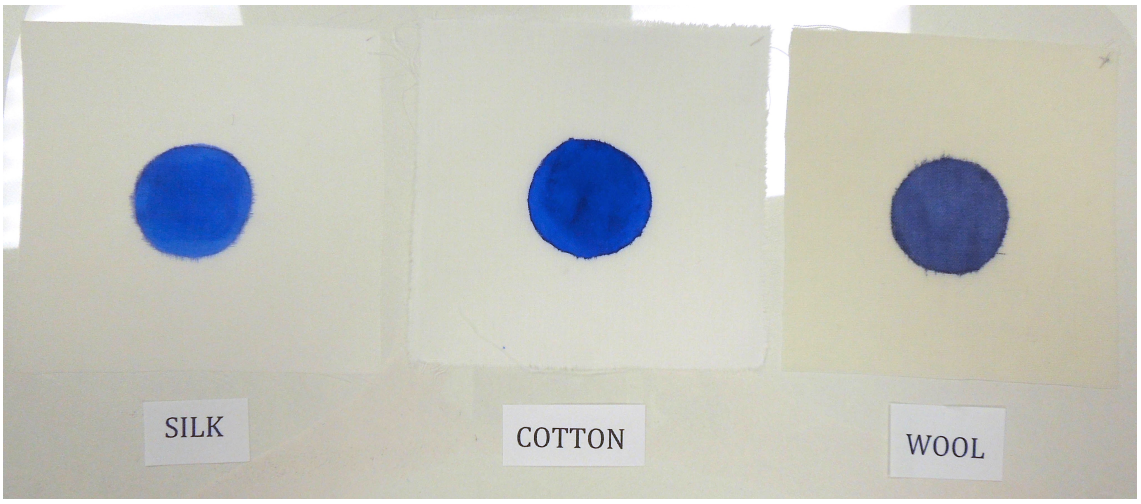


Figure A40: Test 3: 2.5% .5 cm gel, before

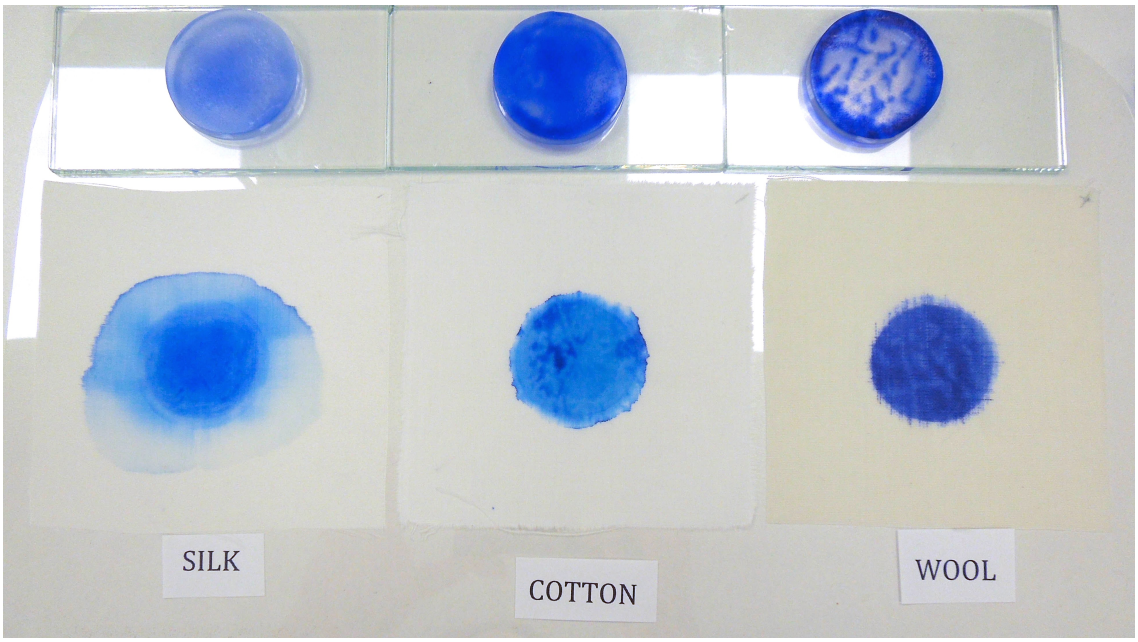


Figure A41: Test 3: 2.5% .5 cm gel, after

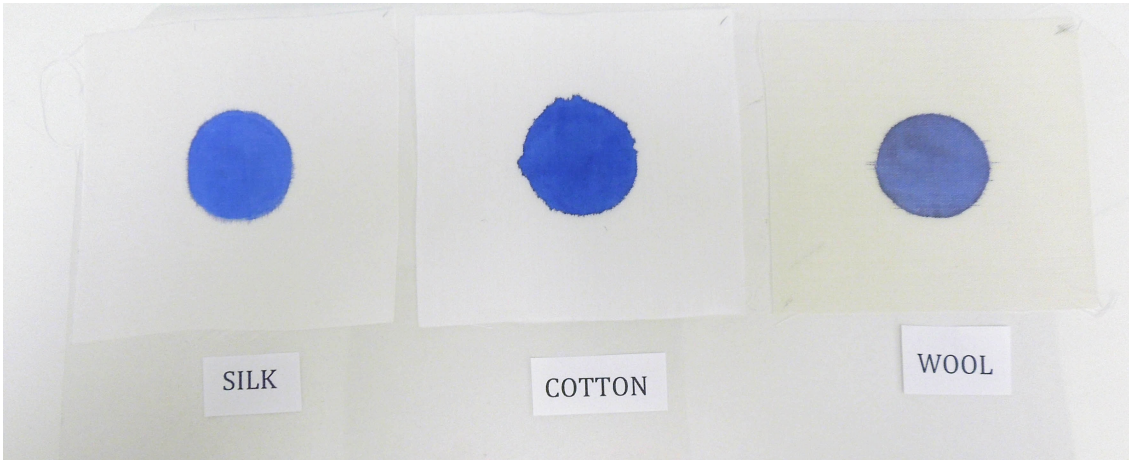


Figure A42: Test 4: 2.5 % .5 cm gel, before

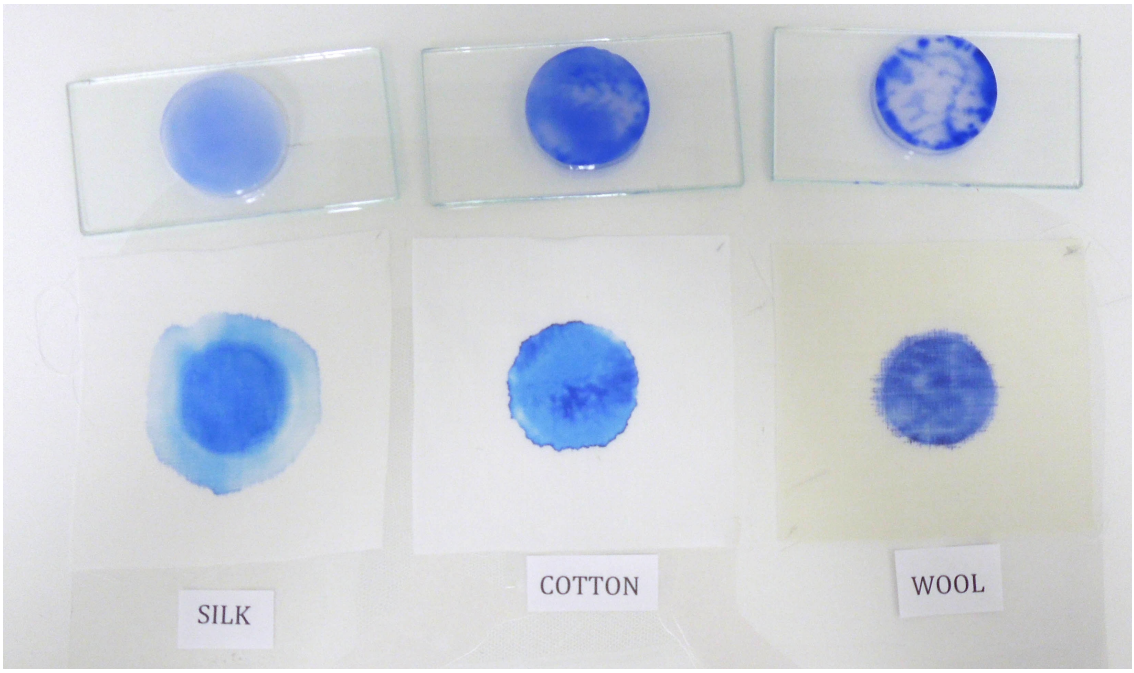


Figure A43: Test 4: 2.5 % .5 cm gel, after

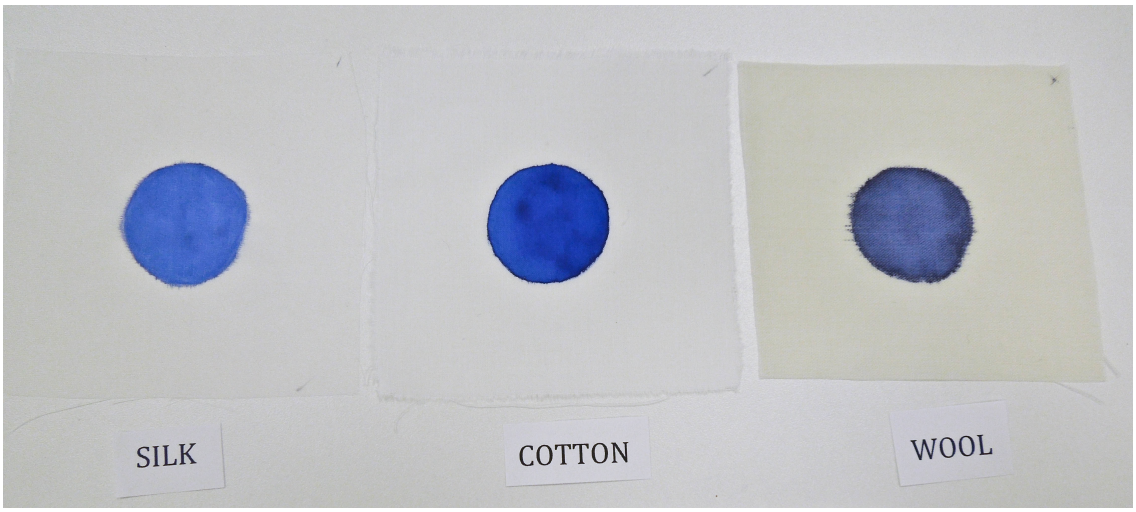


Figure A44: Test 1: 4% .5 cm gel, before

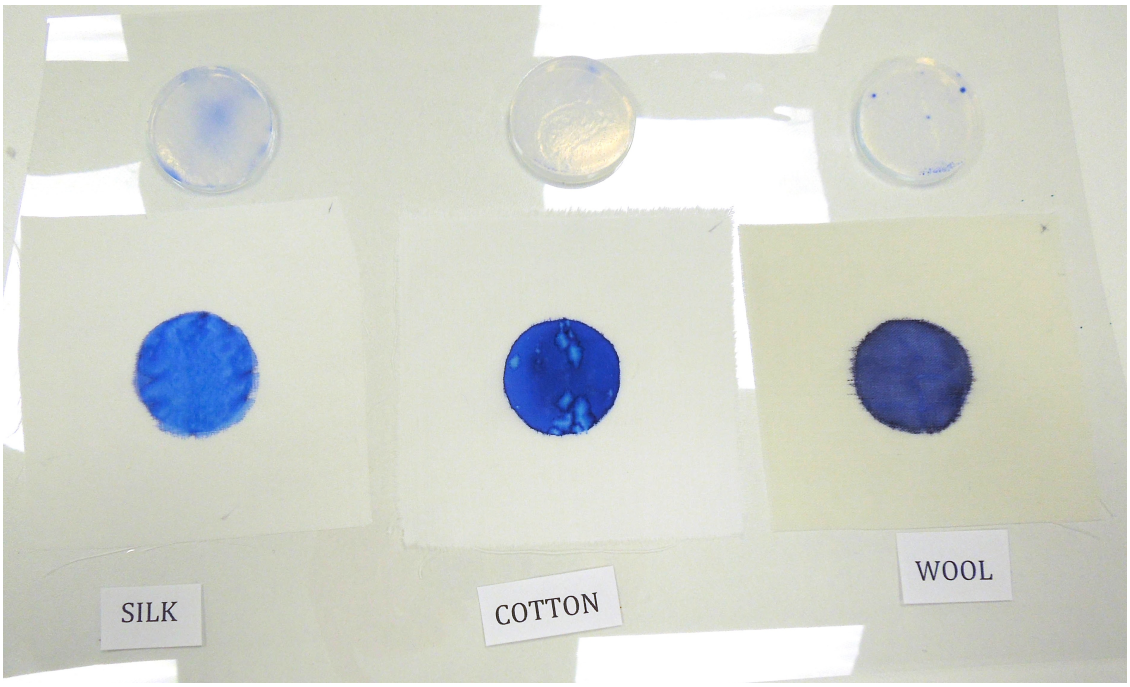


Figure A45: Test 1: 4% .5 cm gel, before

Test 1 with 4% gels was the first test run and thus did not use weights to increase contact between the gel and the textile. The results show how that contact was restricted and the resulting limited movement of the ink into the gel.

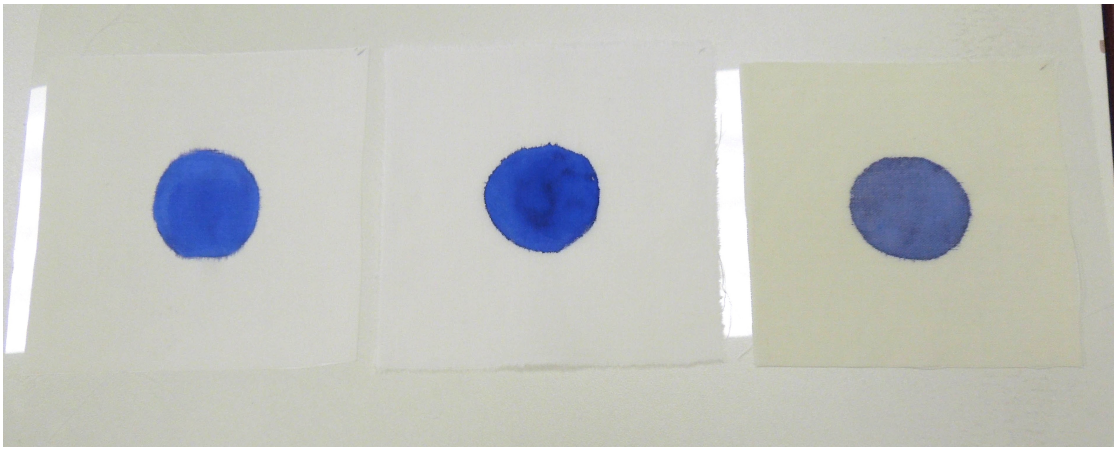


Figure A46: Test 2: 4% .5 cm gel, before

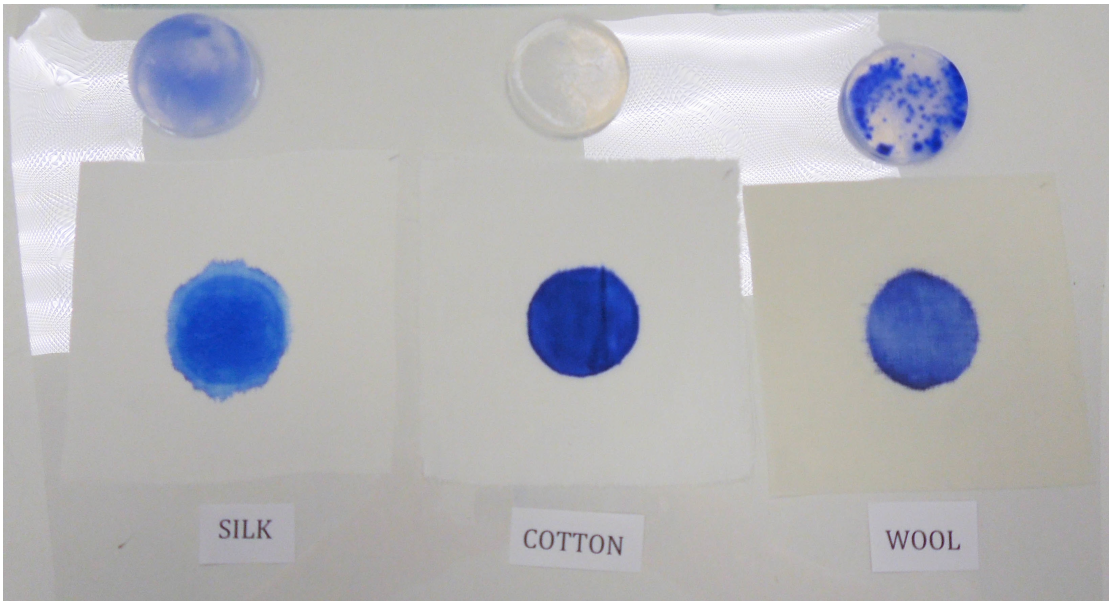


Figure A47: Test 2: 4% .5 cm gel, after

Test two was the first test run with weights. Inspection of the gel used on cotton after testing showed that it had been placed on the textile with the meniscus ridge face down, thus limiting contact between the textile and the gel. In order to ensure the weights were working a single test using 4% gel on cotton was rerun, this single result is what has been included in the data set and the images are below.

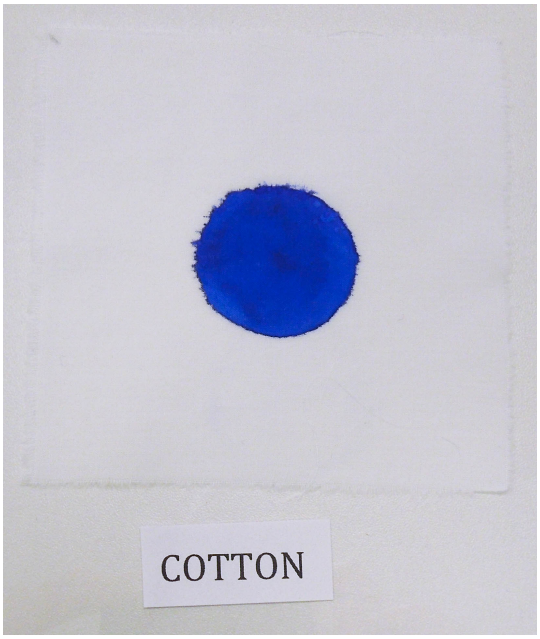


Figure A48: Test 2: 4% .5 cm gel on cotton retest, before

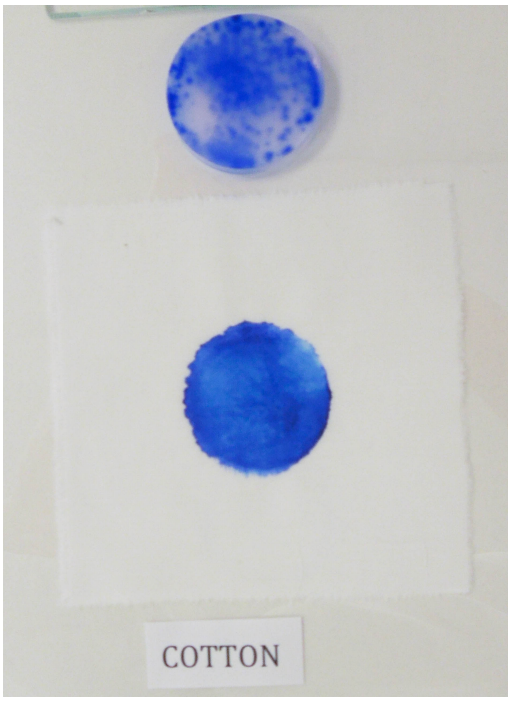


Figure A49: Test 2: 4% .5 cm gel on cotton retest, after

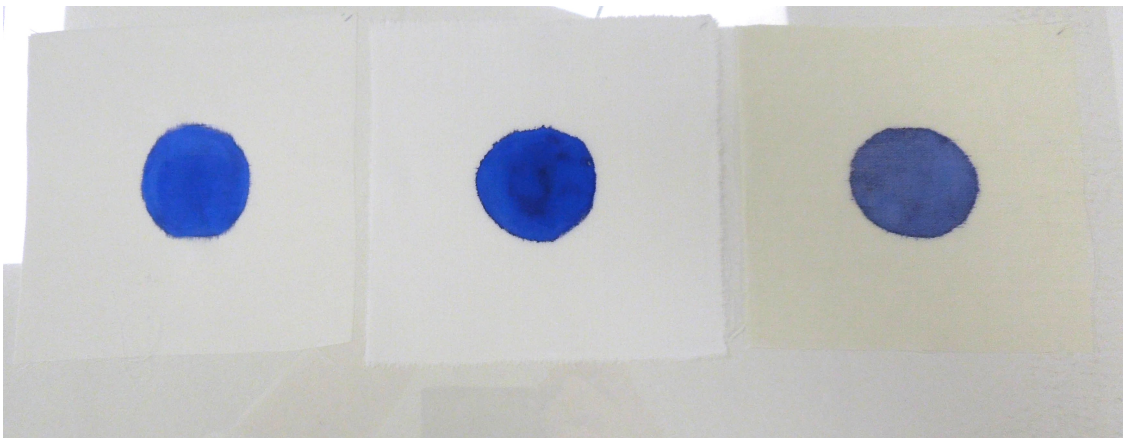


Figure A50: Test 3: 4% .5 cm gel, before

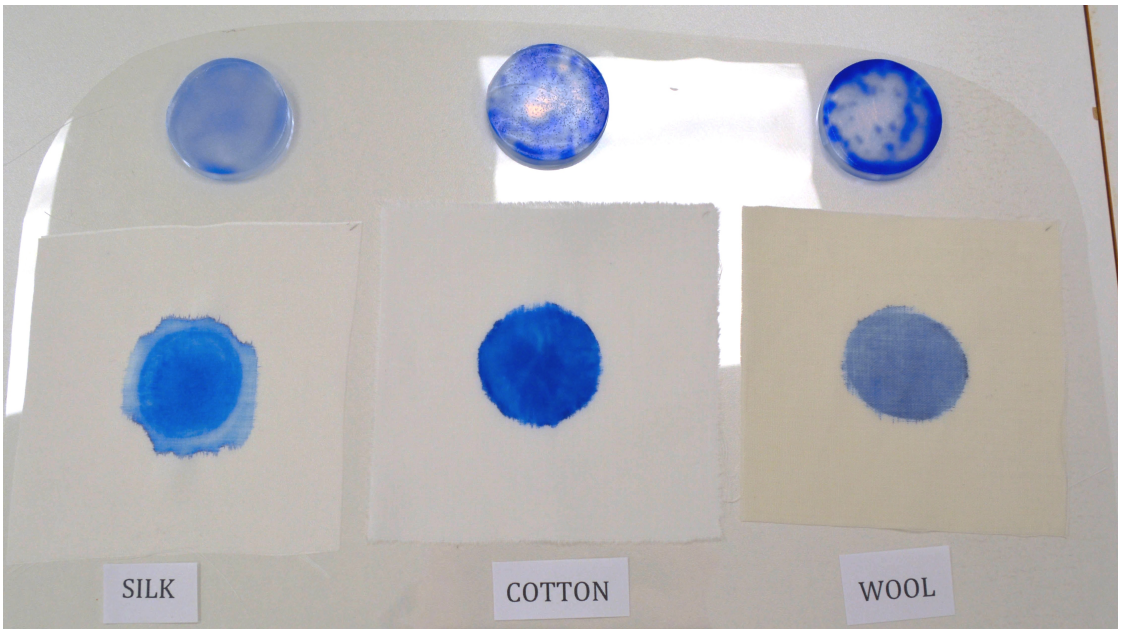


Figure A51: Test 3: 4% .5 cm gel, before

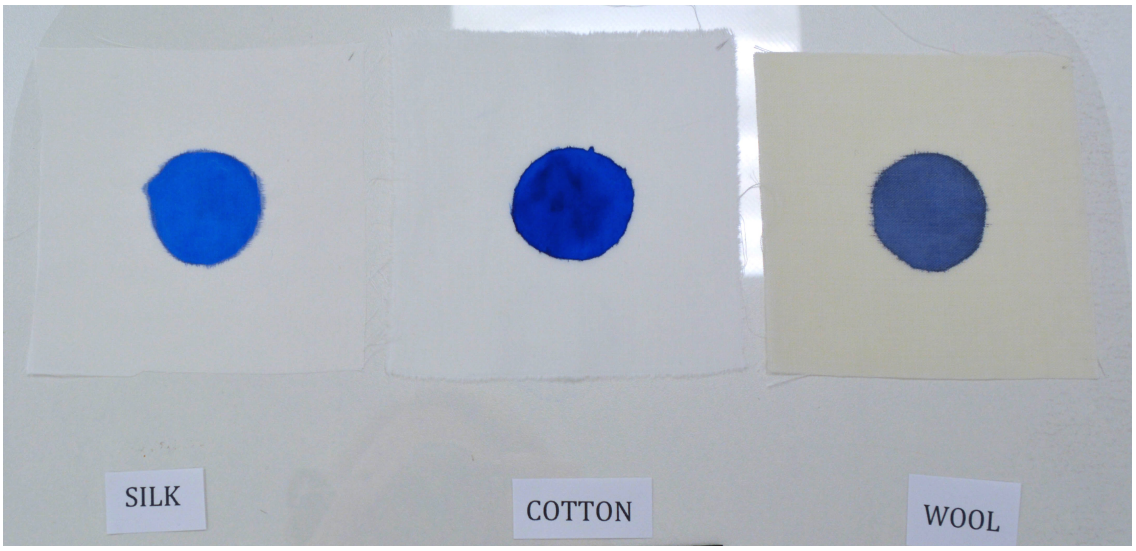


Figure A52: Test 3: 4% .5 cm gel, before

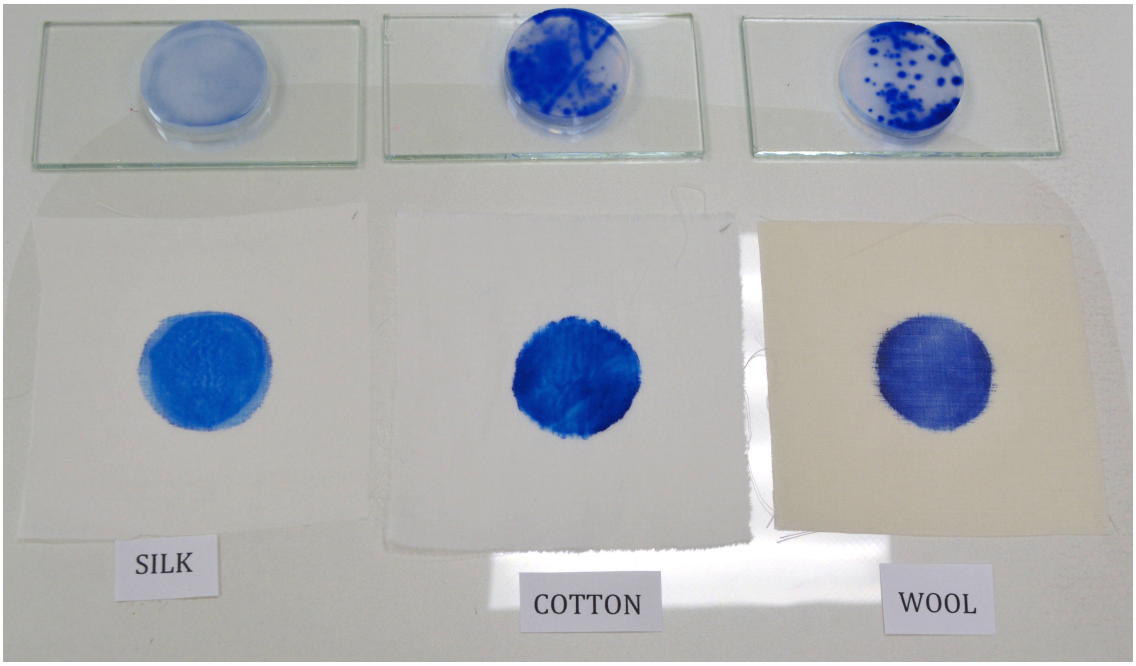


Figure A53: Test 4: 4% .5 cm gels, after

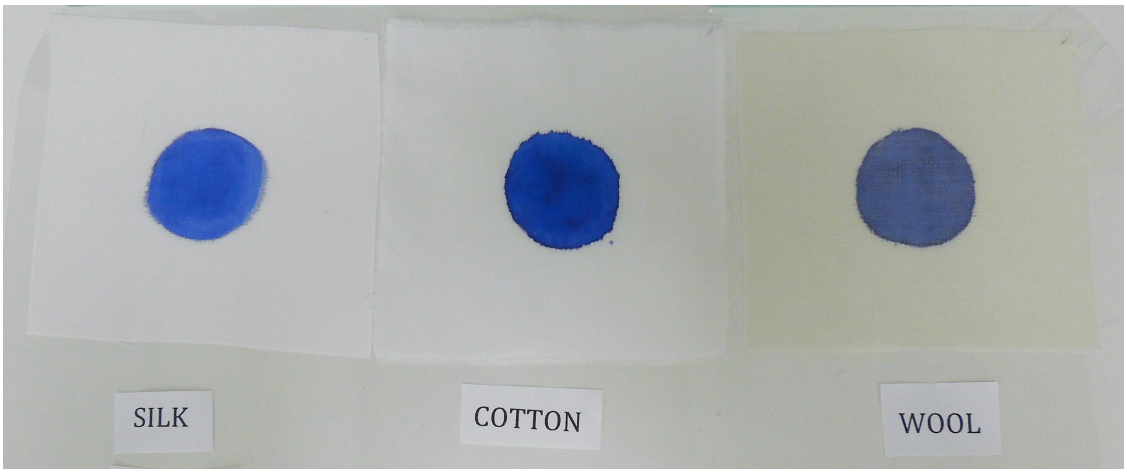


Figure A54: Test 1: 1% .3 cm gel, before

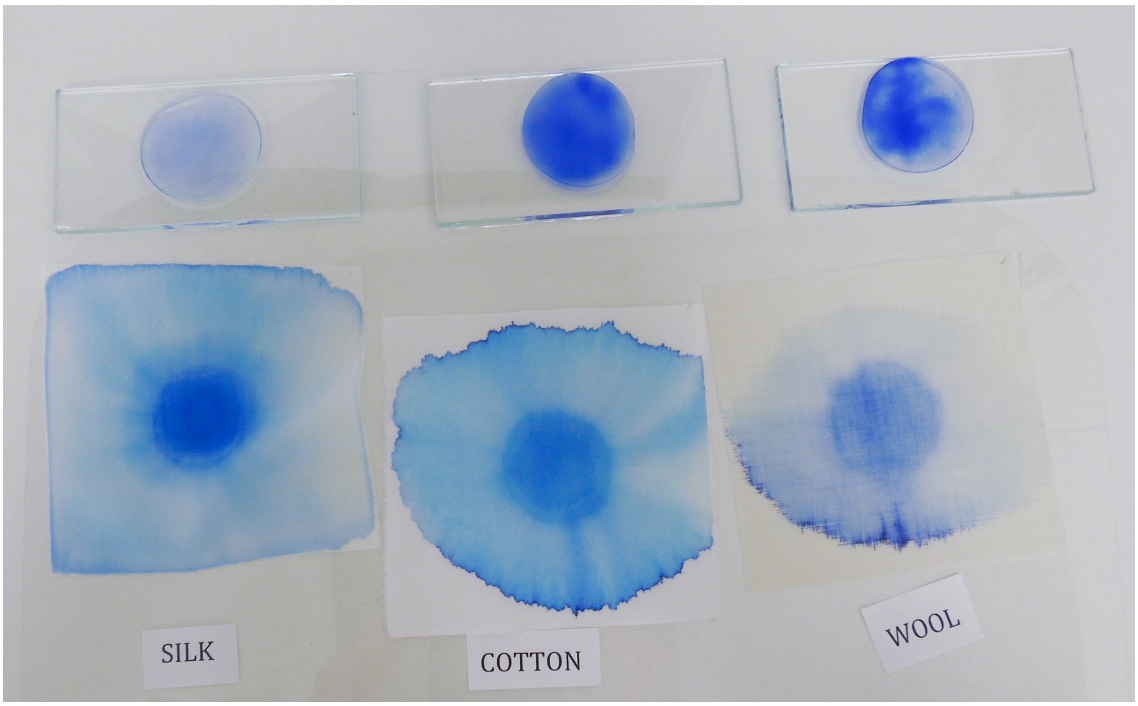


Figure A55: Test 1: 1% .3 cm gel, after

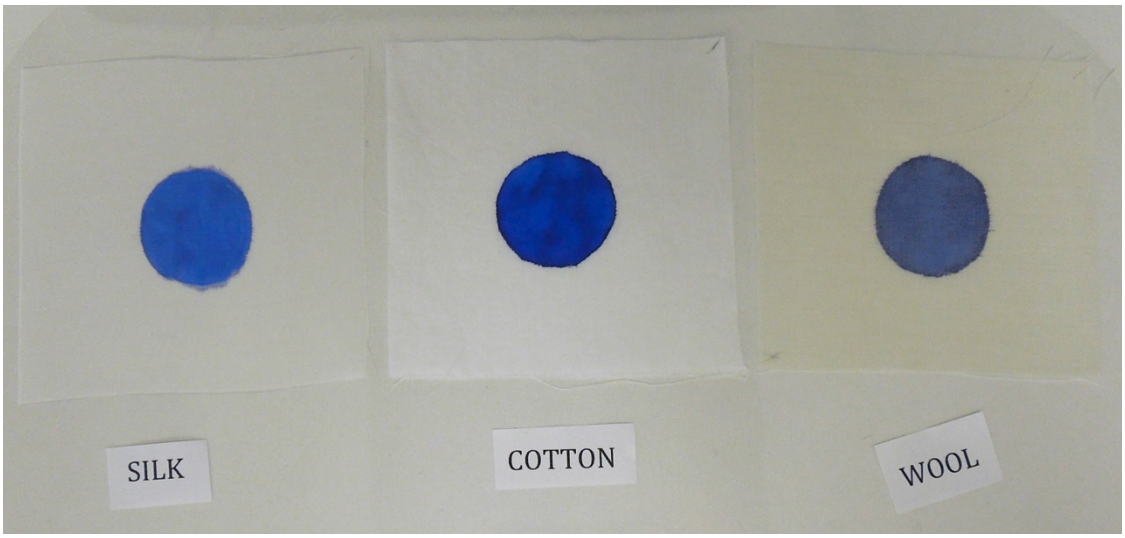


Figure A56: Test 2: 1% .3 cm gel, before

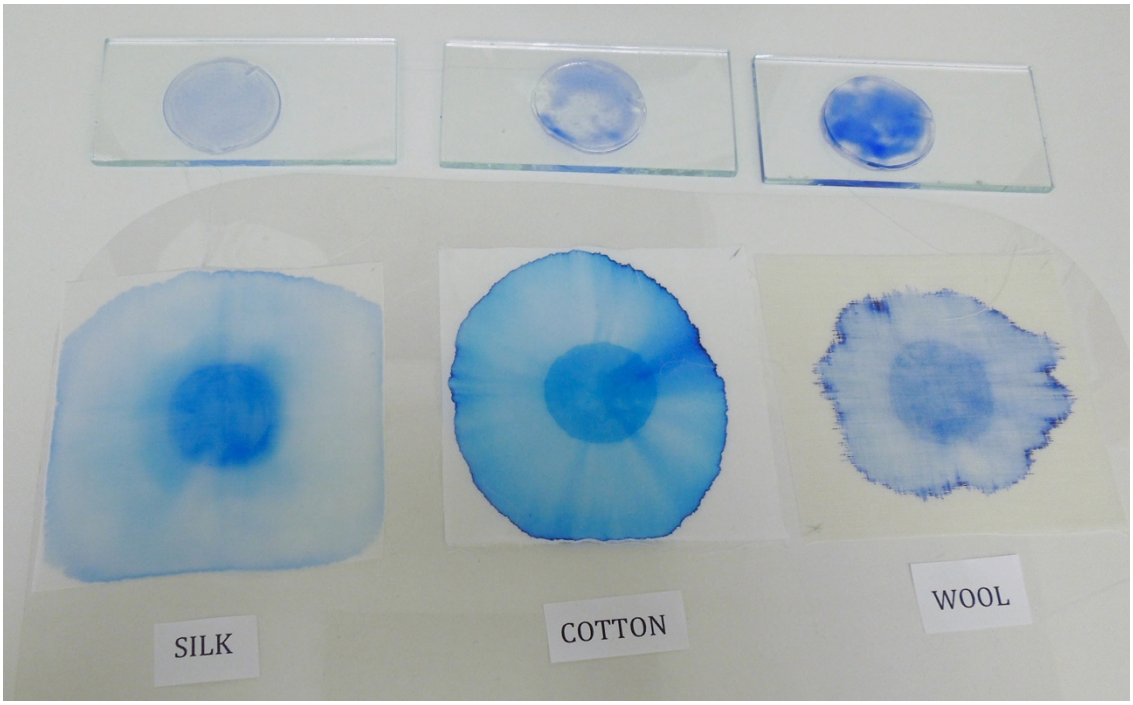


Figure A57: Test 2: 1% .3 cm gel, after

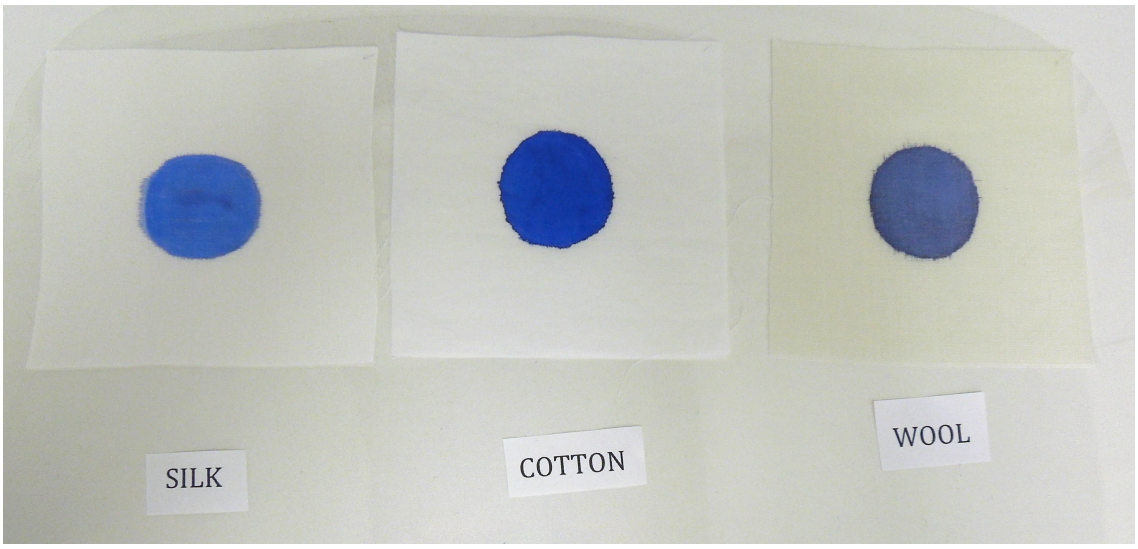


Figure A58: Test 3: 1% .3 cm gels, before

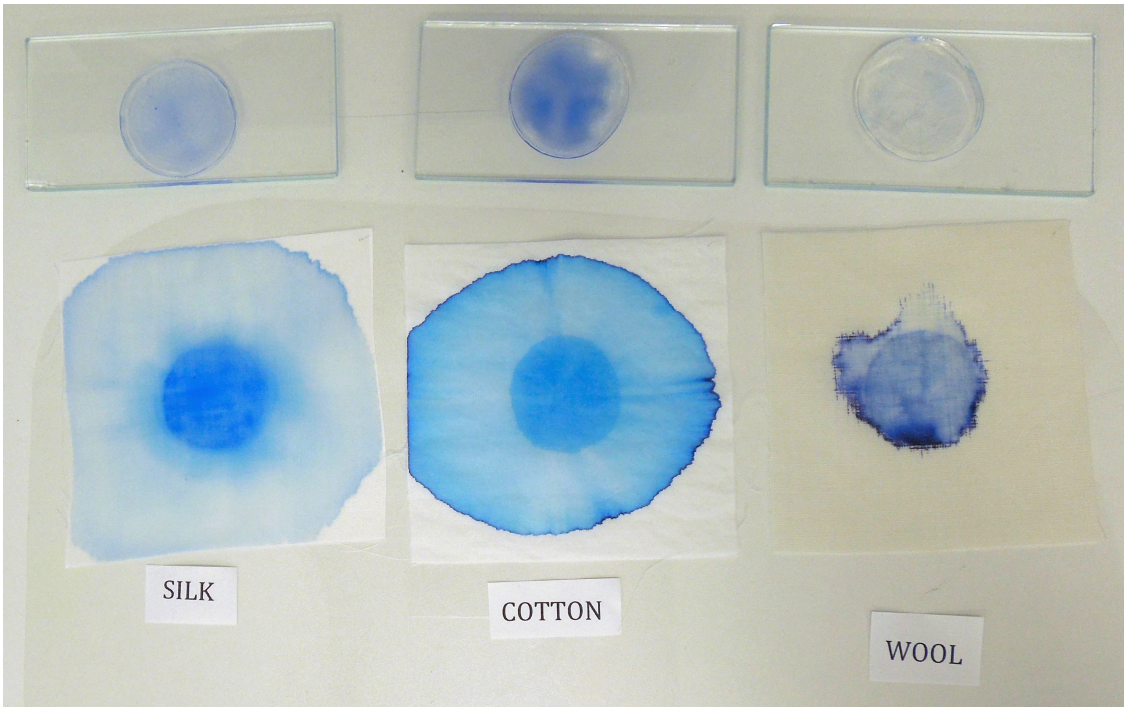


Figure A59: Test 3: 1% .3 cm gels, after

The gel applied to the wool sample in Test 3 at 1% with .3 cm gels may have been placed with the meniscus ridge face down. However, due to the soft nature of 1% gels and the loss of height that was exhibited by this concentration this could not be verified and thus the test was not repeated.

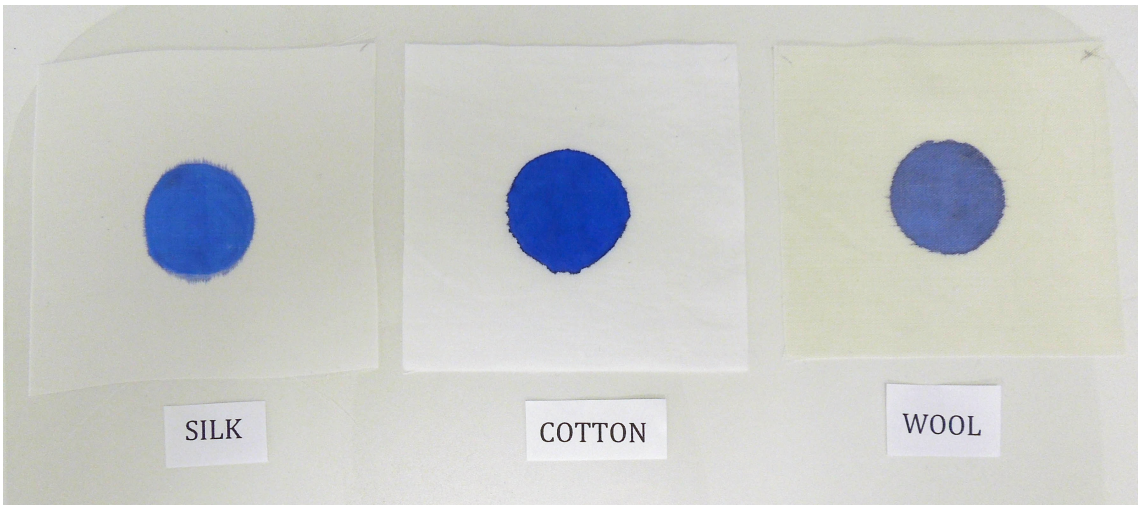


Figure A60: Test 4: 1% .3 cm gel, before

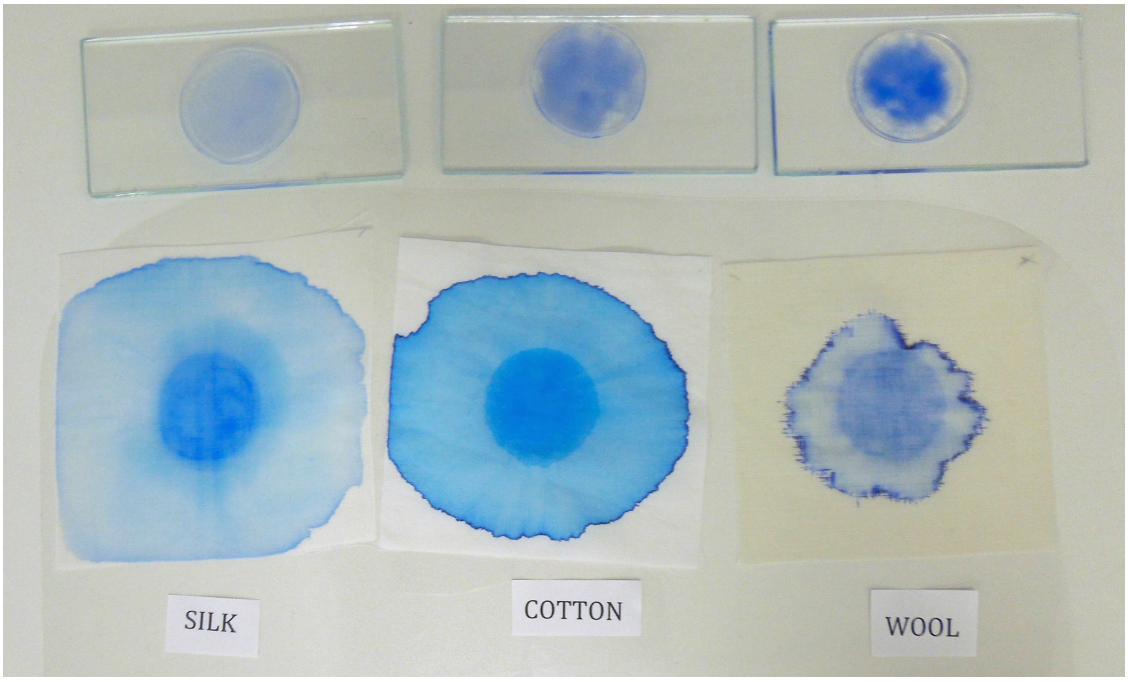


Figure A61: Test 4: 1% .3 cm gel, after

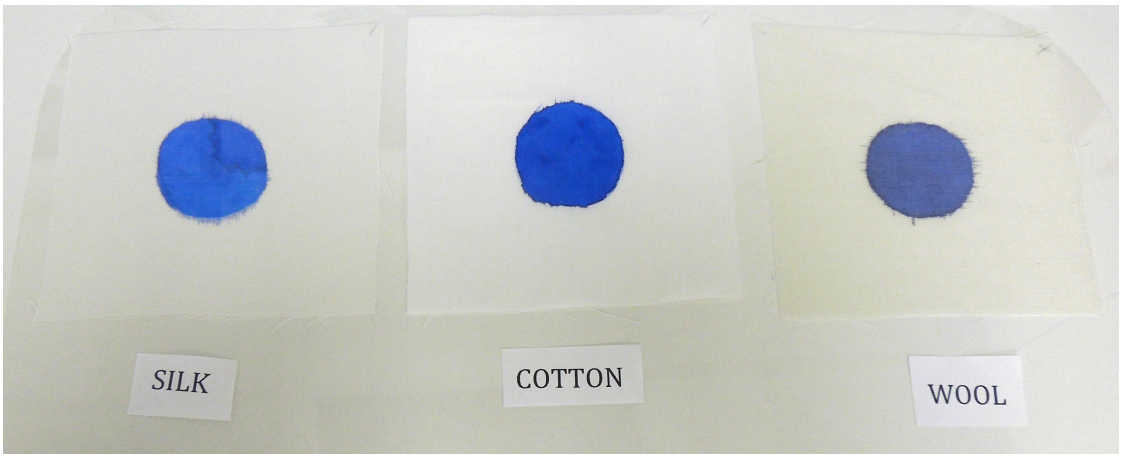


Figure A62: Test 1: 2.5 % .3 cm gel, before

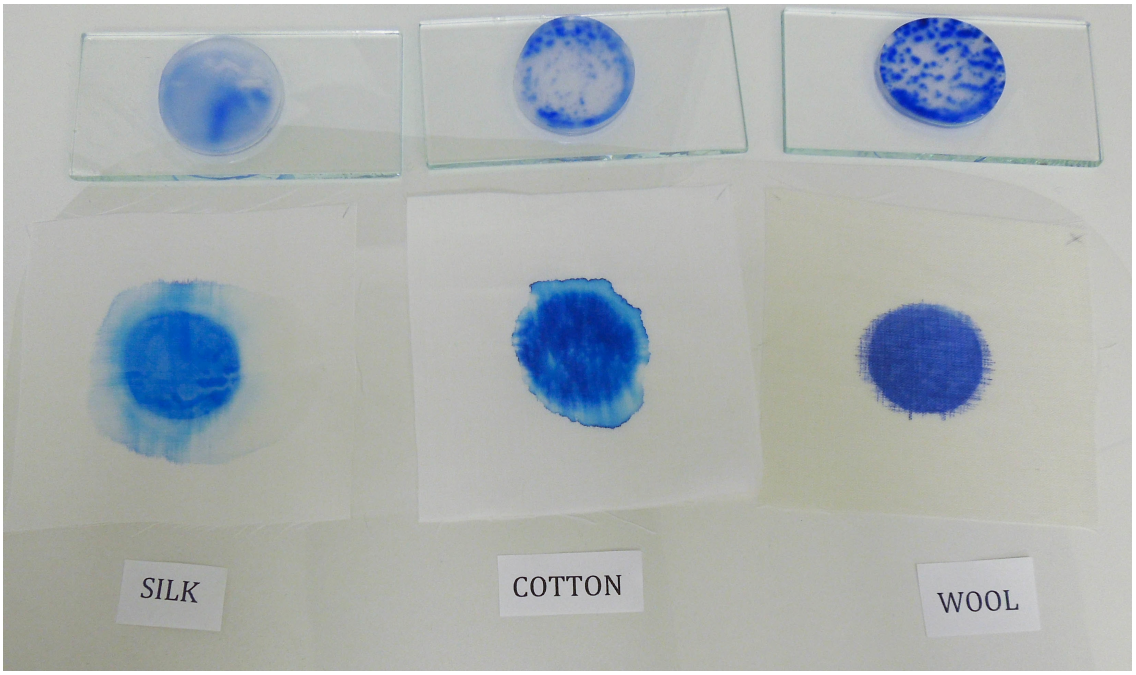


Figure A63: Test 1: 2.5 % .3 cm gel, after

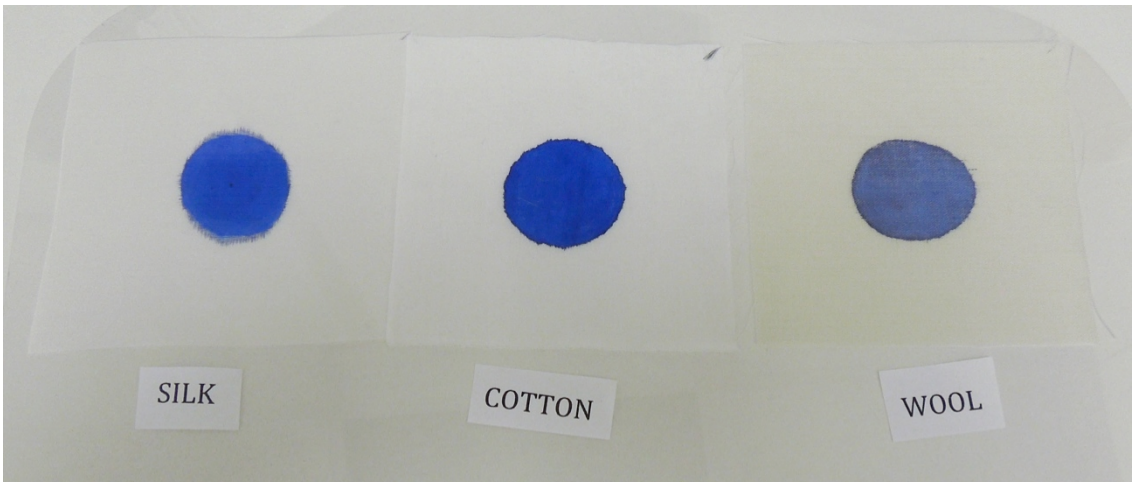


Figure A64: Test 2: 2.5% .3 cm gel, before

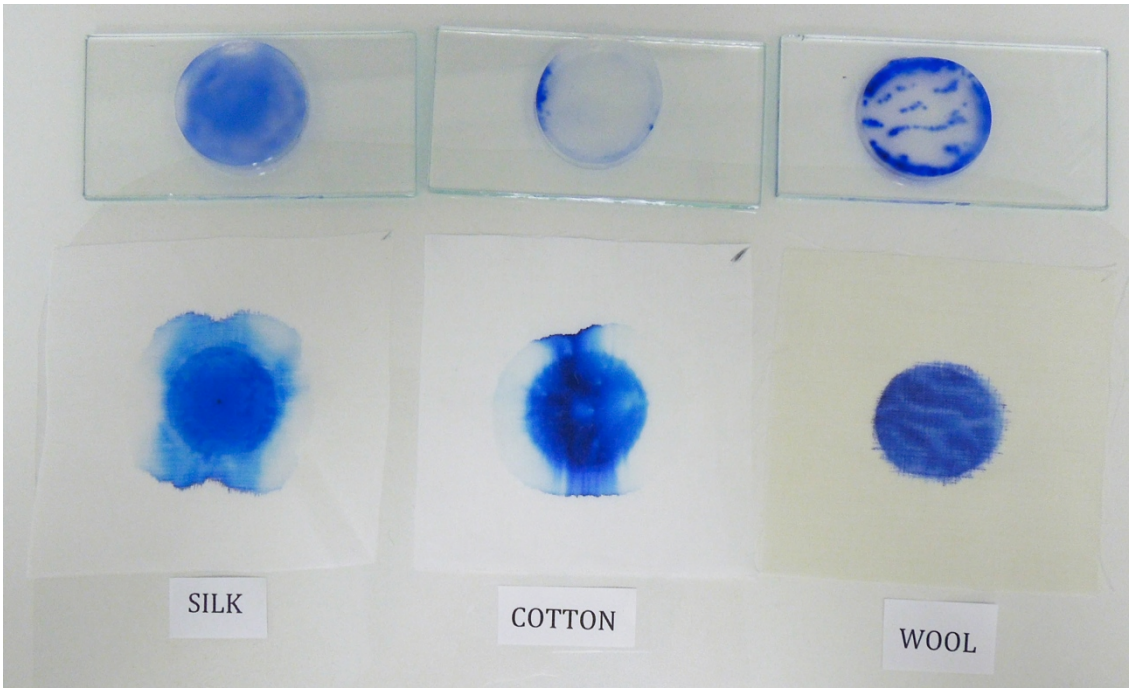


Figure A65: Test 2: 2.5% .3 cm gel, after

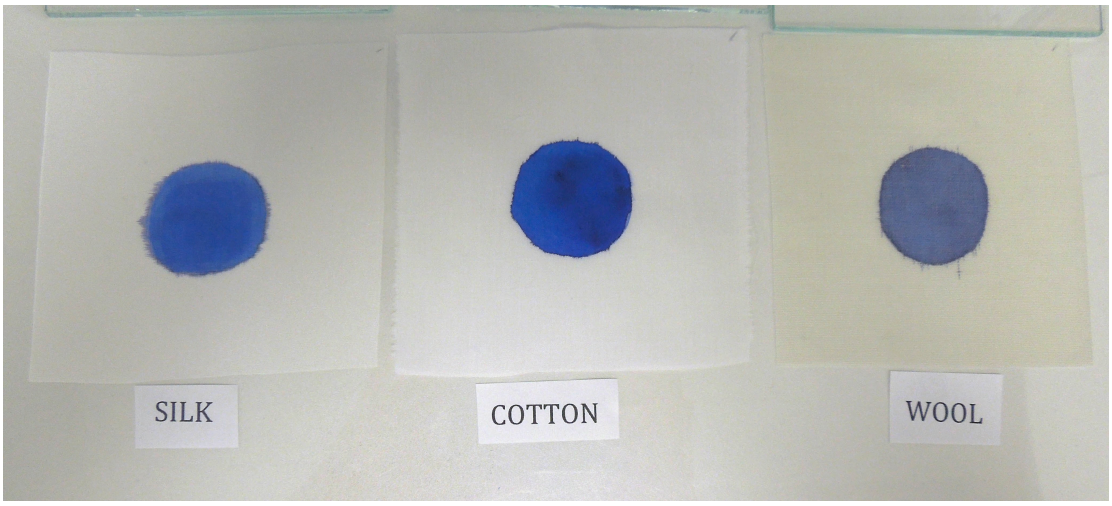


Figure A66: Test 3: 2.5% .3 cm gels, before

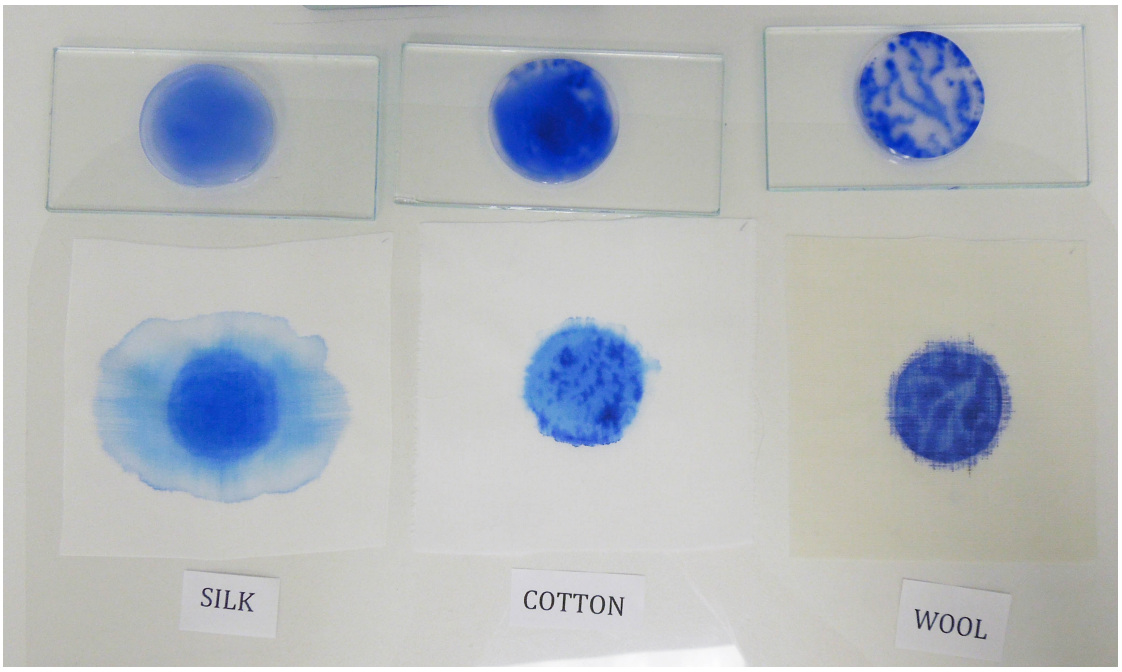


Figure A67: Test 3: 2.5% .3 cm gels, after

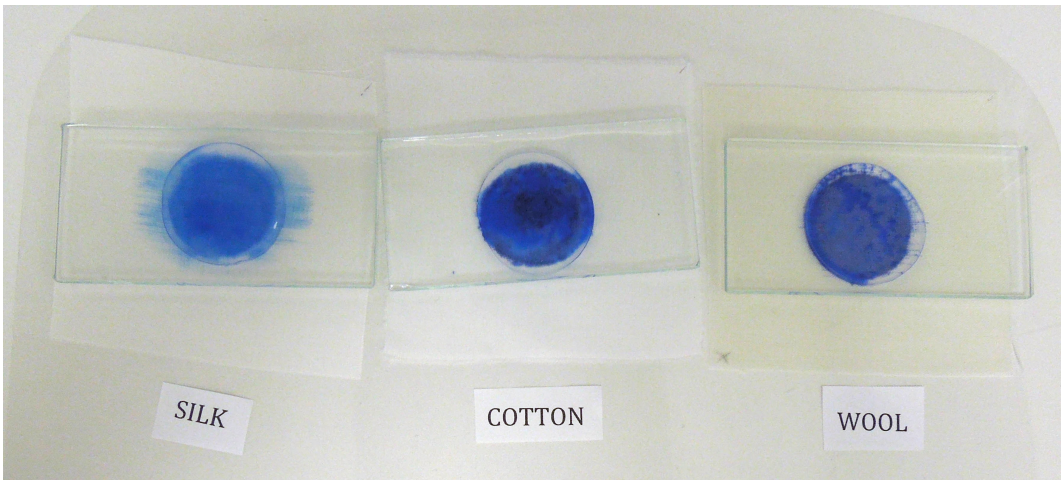


Figure A68: Test 4: 2.5 % .3 cm gel, in progress

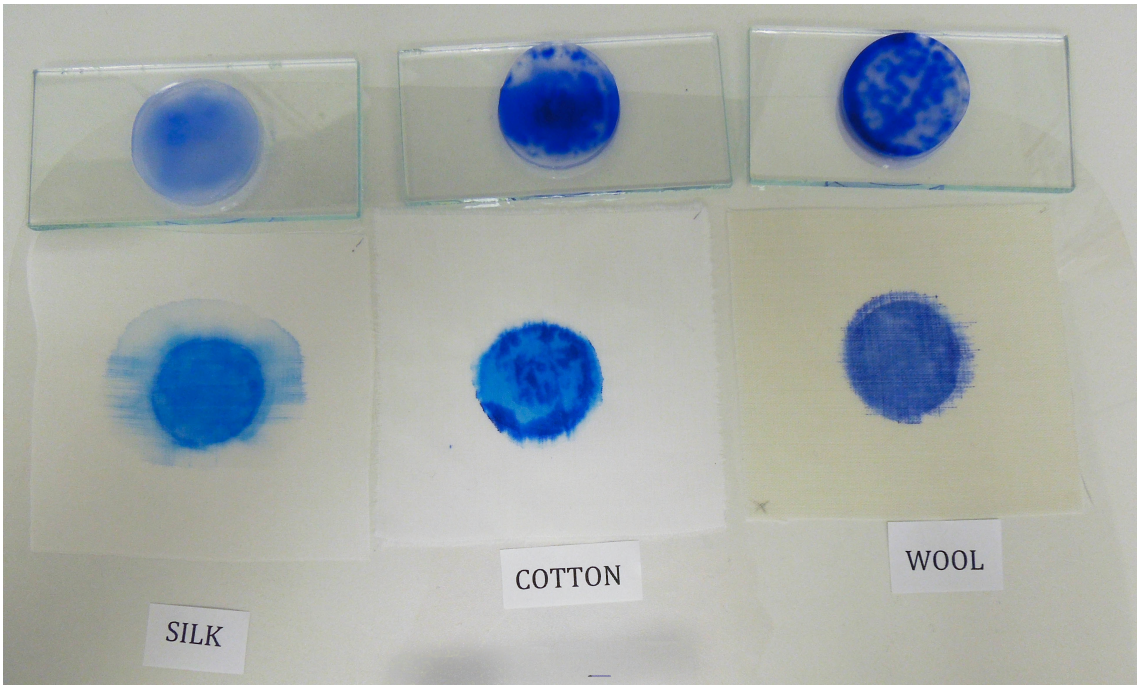


Figure A69: Test 4: 2.5 % .3 cm gel, after

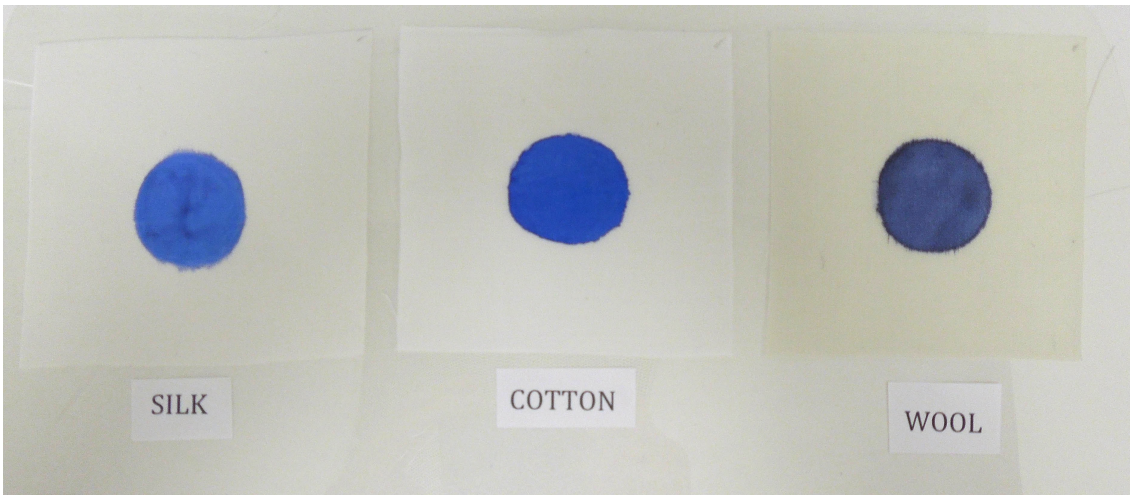


Figure A70: Test 1: 4% .3 cm gel, before

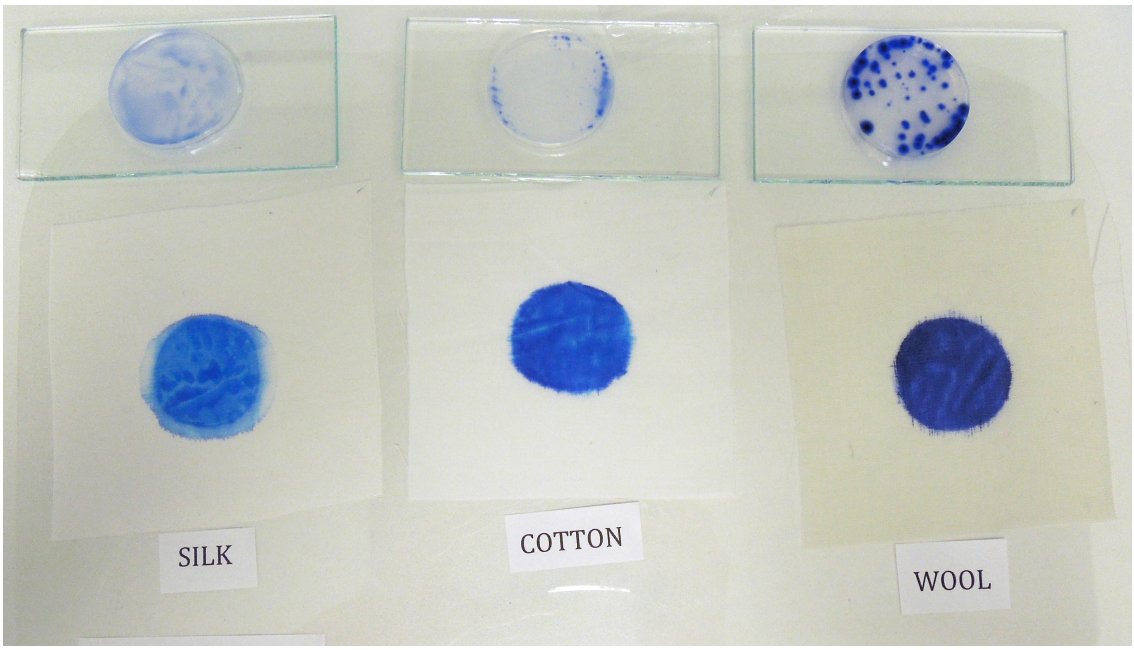


Figure A71: Test 1: 4% .3 cm gel, after

Upon diffusion the 4% gel at .3 cm on wool showed a much higher ink concentration than other gels applied to that fabric. This is an anomaly and appears to be more the result of the amount of ink applied to the textile and not necessarily a greater degree of contact, this is seen below.

Figure A72:
Test 1: 4% .3 cm gel wool sample before testing, the ink is clearly heavily applied and highly concentrated in certain areas.

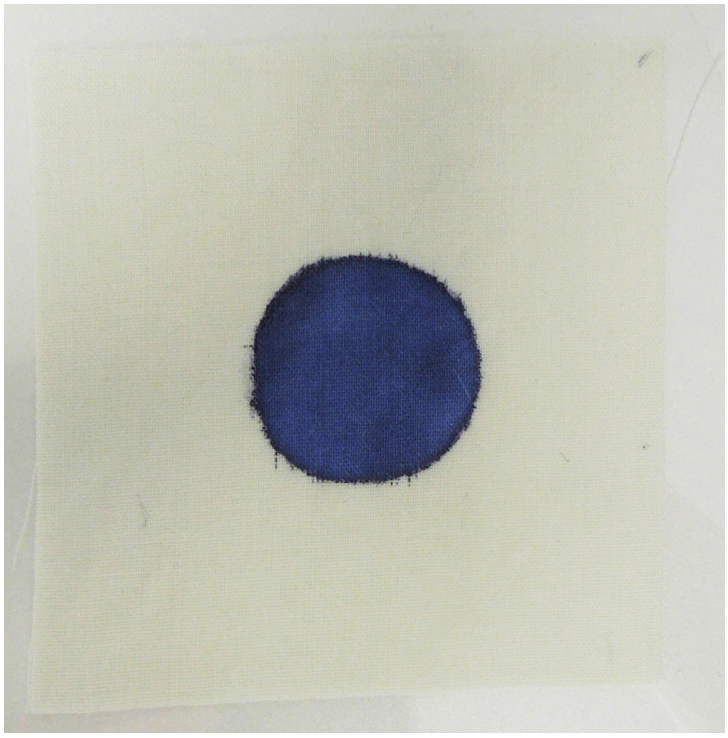
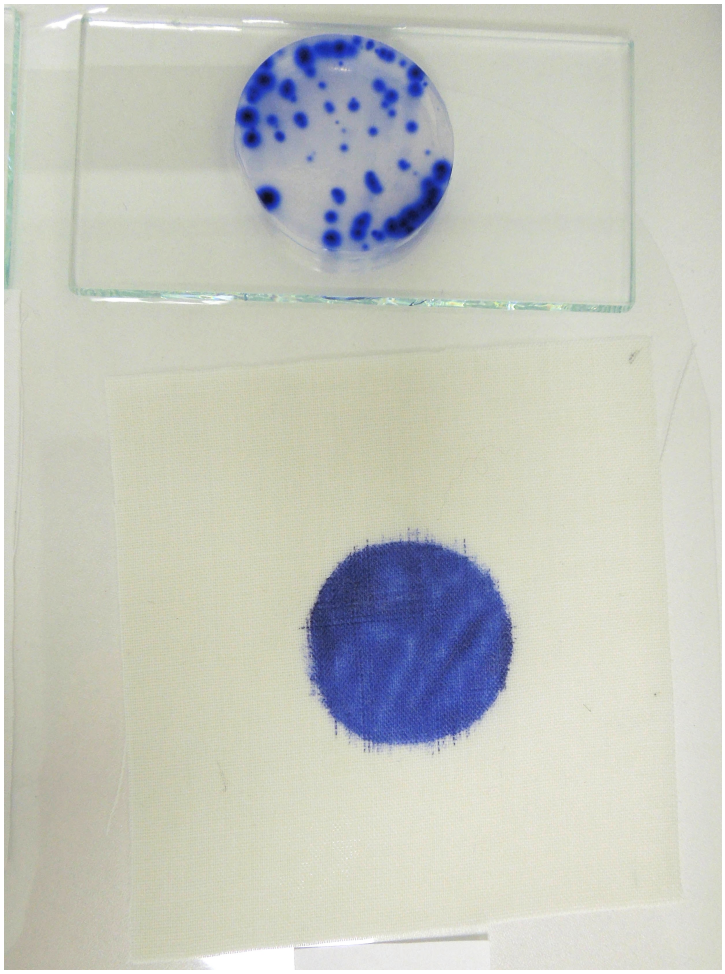


Figure A73:
The fabric and gel from the 4% .3 cm test after removal of the gel. The majority of the uptake of the ink has occurred in areas with higher ink concentrations



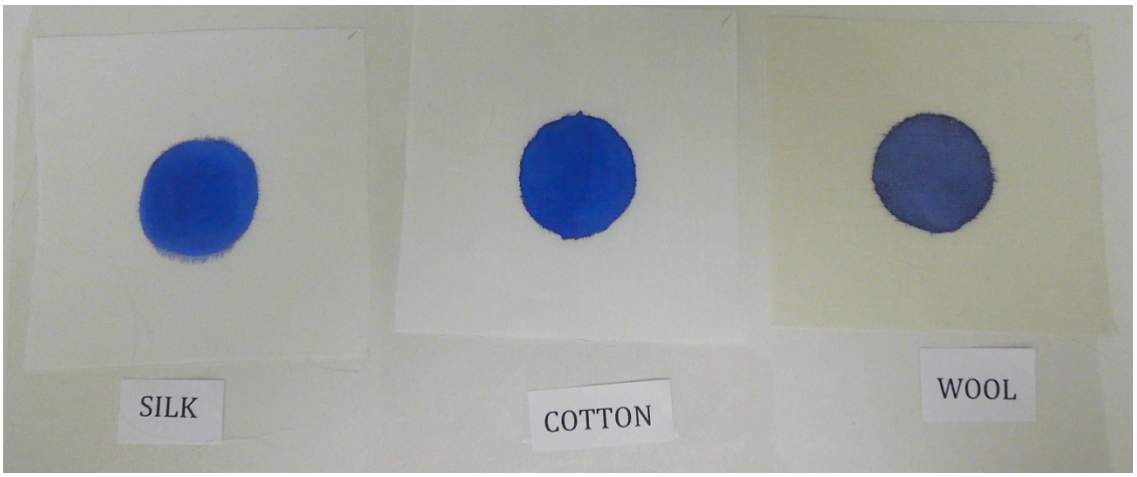


Figure A74: Test 2: 4% .3 cm Gel, before

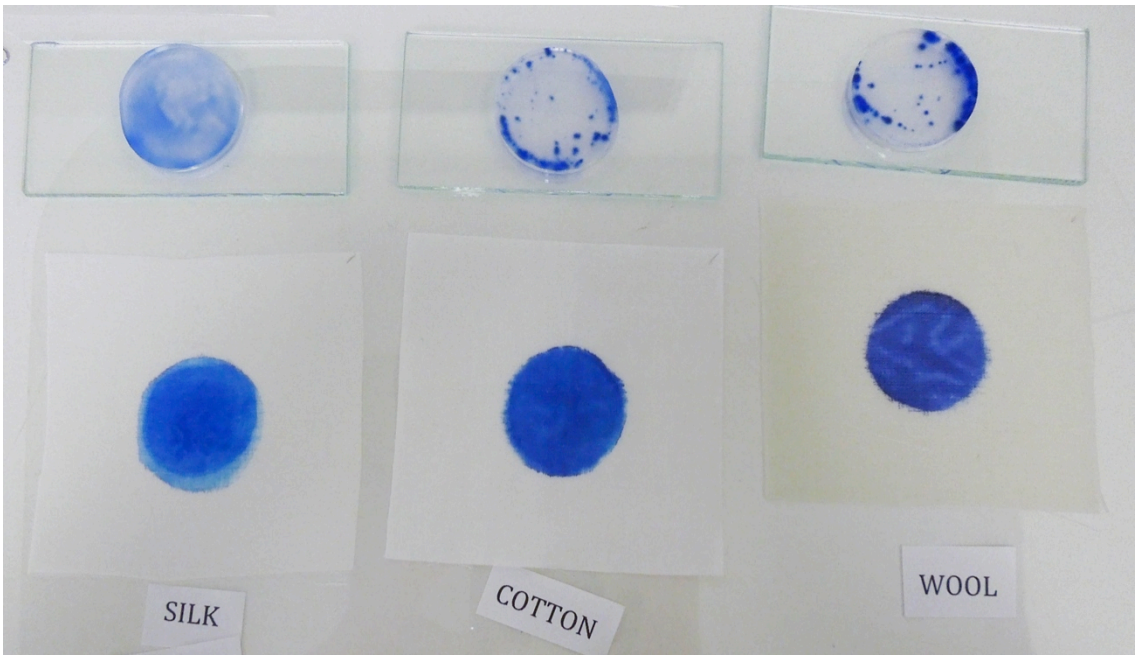


Figure A75: Test 2: 4% .3 cm Gel, after

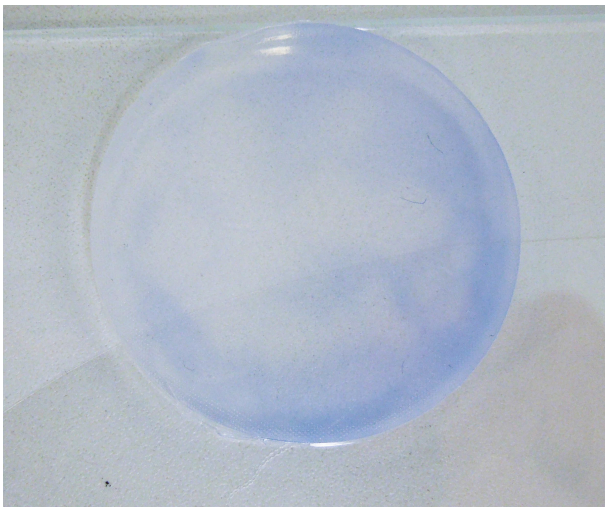


Figure A76: Test 3: 4% .3 cm gel after application on silk

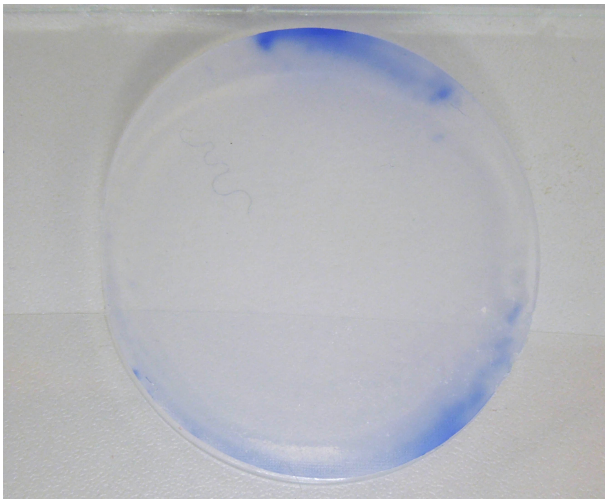


Figure A77: Test 3: 4% .3 cm gel after application on cotton

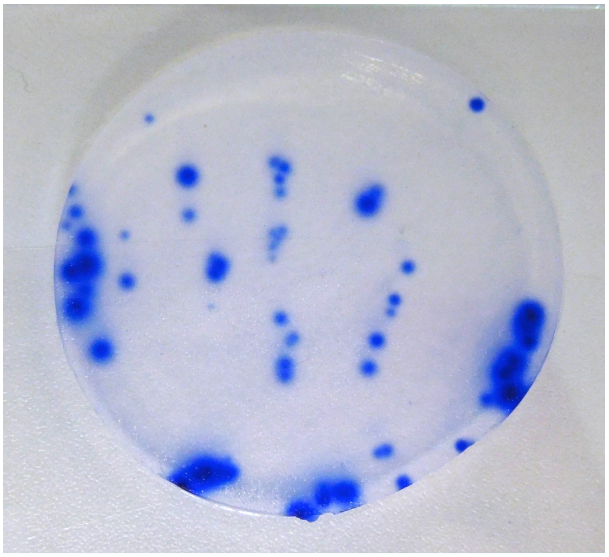


Figure A78: Test 3: 4% .3 cm gel after application on wool

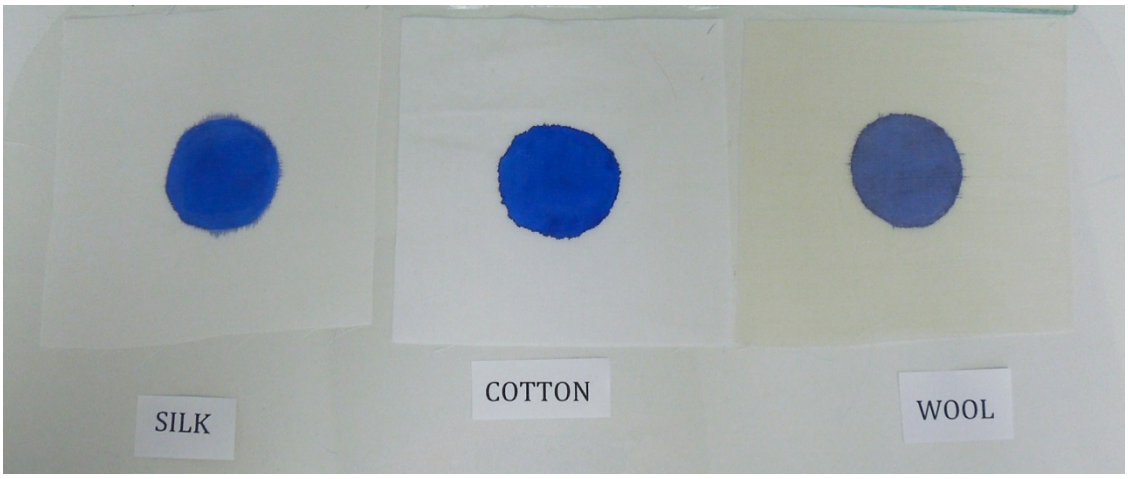


Figure A79: Test 4: 4% .3 cm gels, before

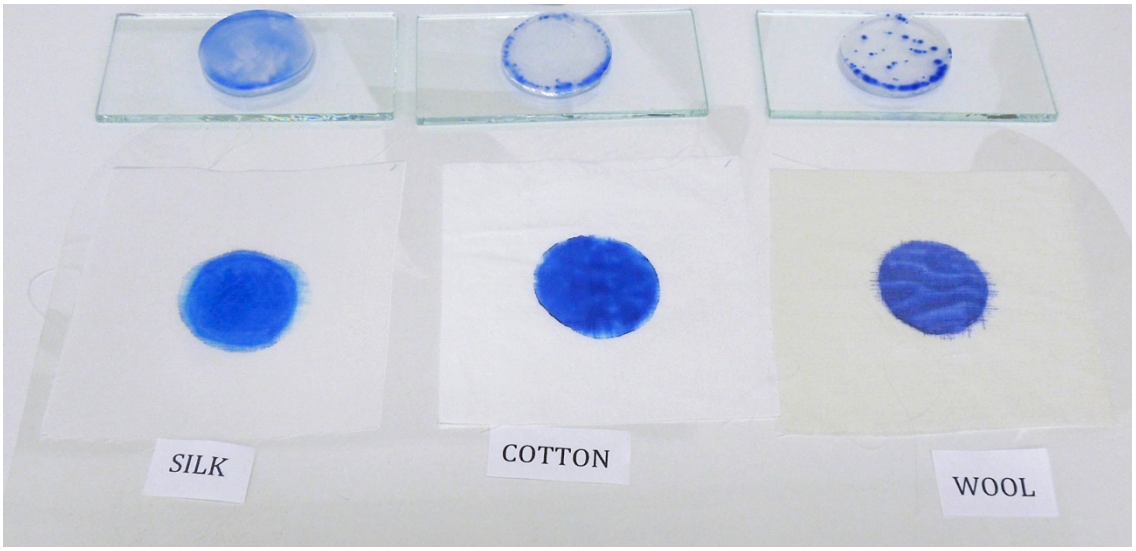


Figure A80: Test 4: 4% .3 cm gels, after

Appendix 8: Tests Without Weights

A8.0 Introduction:

The weights applied to the gels in this study did have an affect on contact and how much moisture left the gels. This section will discuss that affect across the four concentrations.

A8.1 1% Gels:

The weights were removed from 1% gels after the first test and that affect is documented in the body of the paper. The removal of weights had no visible effect as in most cases the water and ink reached the edges of the textile samples in both tests with weight and without. This meant the affect of removing the weights cannot be measured based on the tests done.

A8.2 2.5% Gels:

2.5% gels were only tested with weights. To try and see what the effect of the gel without weights a single test using 2.5% gel on a silk sample was run (Figure: A77-A79)

The results show that the spread of moisture through the silk diminishes with the removal of weights (Table A1). The extent of this is difficult to discern based on the range of movement exhibited in the weighted tests. If the extremes of this range are seen as the maximum and minimum distance the moisture moved through the silk the removal of the weights could reduce that movement between .3 cm and 2.75 cm.

The coloration of the gel and overall good contact with the material indicates that, for this concentration on silk, the weight has very little effect on how much ink is drawn into the gel.

Depth	%	Fabric	Stain Measurement Before gel Application	Stain Measurement After gel Application	Total movement of stain (cm)	Gel Depth (cm)	Contact	Uptake of Gel
0.3	2.5	Silk	3.9 x 3.5	5.3 x 4.9	1.4 x 1.4	3.5	3	3

Table A3: Results from tests with unweighted 2.5% gel on silk

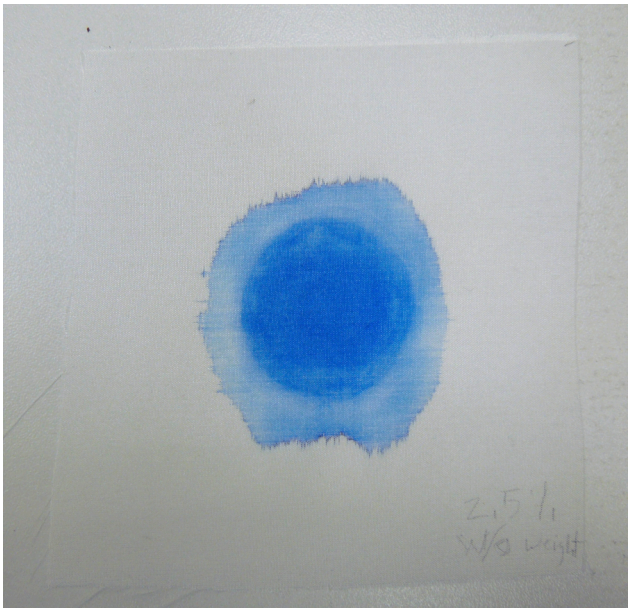


Figure A81: Unweighted silk sample after gel application

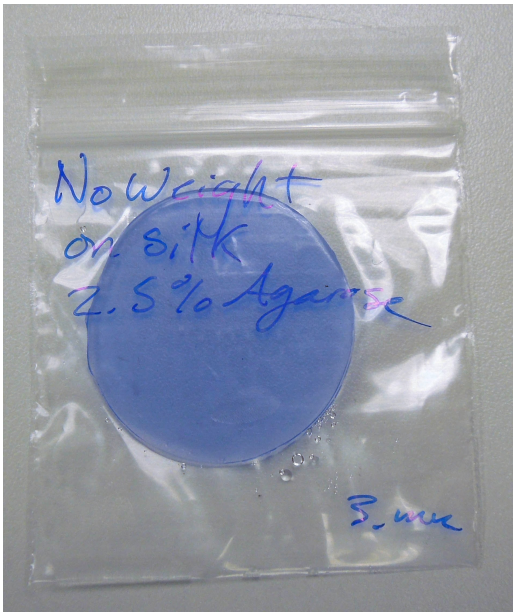


Figure A82: The gel after ink has diffused

Figure A83: Comparison of weighted and unweighted gels.
Left: The 4 tests using .3 cm 2.5% gels applied to silk with weights
Right: The .3 cm 2.5% gel applied to silk with no weight

Appendix 9: Enzyme Treatments with 2% Gel

A9.0 Introduction

Wolbers' textile workshops have supported the use of 2% agarose gels for enzyme treatments where as published literature tends to use a much lower concentration (Table 3). Enzyme practical lessons as well as object treatments at the Centre for Textile Conservation at the University of Glasgow have shown that this higher concentration is effective[153]. The following images document the use of a 2% protease enzyme gel on a linen embroidery to reduce staining from animal glue. The animal glue had caused a stiffening of the fibres and left a yellow stain (Figure A80). It was hoped that the application of enzymes would reduce the staining and increase the flexibility of the fibres.

A9.1 Treatment

A 2% gel was made using the system discussed in Appendix 2. The gel was heated uncovered, as the enzyme would be added in liquid form after the gel had been cooled. It was hoped that the addition of the enzyme would replace the water that evaporated during the heating process. This however is unconfirmed and thus the concentration can only be an approximation. The gel was cast thin, ~.3 cm, as no moulds were used to increase the height. The gel was cut to the shape of the stain and left in place between 10-15 minutes (Figure A81). In most cases two applications were made to help further reduce the staining. The movement of moisture from the gel was made obvious due to the coloration of the enzyme solution (Figure A82); in some cases this formed a hard tideline that could be removed with water. The area was rinsed using softened water on a suction table and blotter was used to help draw out the brown colouring of he enzyme solution from the textile.

The treatment was successful, resulting in reduced staining and a more flexible fabric (Figure A83). This treatment shows that a higher concentration gel is affective for the use of enzymes; it might be possible with some fabrics to further increase the concentration of the gel due to the degree of wicking and the wettability of the fibre. However, the pore size of the gel must be taken into account to ensure movement of the enzyme in and out of the gel.

[153] Emily Austin, unpublished treatment report, CTC.187

Figure A84: The stain before treatment. ©University of Glasgow

Figure A85: The cast enzyme gel being cut into the shape of the stain. © University of Glasgow

Figure A86: The enzyme gel in place on the stain. ©University of Glasgow

A87: The stain after treatment with the enzyme gel. ©University of Glasgow

SIGMA-ALDRICH

sigma-aldrich.com

SAFETY DATA SHEET

according to Regulation (EC) No. 1907/2006
Version 5.3 Revision Date 30.04.2014
Print Date 03.07.2014

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Agarose
Product Number	:	A9539
Brand	:	Sigma
REACH No.	:	A registration number is not available for this substance as the substance or its uses are exempted from registration, the annual tonnage does not require a registration or the registration is envisaged for a later registration deadline.
CAS-No.	:	9012-36-6

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses	:	Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich Company Ltd. The Old Brickyard NEW ROAD, GILLINGHAM Dorset SP8 4XT UNITED KINGDOM
Telephone	:	+44 (0)1747 833000
Fax	:	+44 (0)1747 833313
E-mail address	:	eurtechserv@sial.com

1.4 Emergency telephone number

Emergency Phone #	:	+44 (0)1747 833100

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Not a hazardous substance or mixture according to Regulation (EC) No. 1272/2008.
This substance is not classified as dangerous according to Directive 67/548/EEC.

2.2 Label elements

The product does not need to be labelled in accordance with EC directives or respective national laws.

2.3 Other hazards - none

SECTION 3: Composition/information on ingredients

3.1 Substances

CAS-No.	:	9012-36-6
EC-No.	:	232-731-8

No components need to be disclosed according to the applicable regulations.

SECTION 4: First aid measures

4.1 Description of first aid measures

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration.

In case of skin contact
Wash off with soap and plenty of water.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
no data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Carbon oxides

5.3 Advice for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

5.4 Further information
no data available

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Avoid dust formation. Avoid breathing vapours, mist or gas.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling
Provide appropriate exhaust ventilation at places where dust is formed.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Components with workplace control parameters
Contains no substances with occupational exposure limit values.

8.2 Exposure controls

Appropriate engineering controls
General industrial hygiene practice.

Personal protective equipment

Eye/face protection
Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

The selected protective gloves have to satisfy the specifications of EU Directive 89/686/EEC and the standard EN 374 derived from it.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
Choose body protection in relation to its type, to the concentration and amount of dangerous substances, and to the specific work-place., The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: powder Colour: white

b)	Odour	no data available
c)	Odour Threshold	no data available
d)	pH	no data available
e)	Melting point/freezing point	no data available
f)	Initial boiling point and boiling range	no data available
g)	Flash point	no data available
h)	Evapouration rate	no data available
i)	Flammability (solid, gas)	no data available
j)	Upper/lower flammability or explosive limits	no data available
k)	Vapour pressure	no data available
l)	Vapour density	no data available
m)	Relative density	no data available
n)	Water solubility	10 g/l at 80 °C
o)	Partition coefficient: n-octanol/water	no data available
p)	Auto-ignition temperature	no data available
q)	Decomposition temperature	no data available
r)	Viscosity	no data available
s)	Explosive properties	no data available
t)	Oxidizing properties	no data available

9.2 Other safety information
no data available

SECTION 10: Stability and reactivity

10.1 Reactivity
no data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
no data available

10.4 Conditions to avoid
no data available

10.5 Incompatible materials
Strong oxidizing agents

10.6 Hazardous decomposition products
Other decomposition products - no data available
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitisation
no data available

Germ cell mutagenicity
no data available

Carcinogenicity

IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Reproductive toxicity
no data available

Specific target organ toxicity - single exposure
no data available

Specific target organ toxicity - repeated exposure
no data available

Aspiration hazard
no data available

Additional Information
RTECS: Not available

To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

SECTION 12: Ecological information

12.1 Toxicity
no data available

12.2 Persistence and degradability
no data available

12.3 Bioaccumulative potential
no data available

12.4 Mobility in soil
no data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects

no data available

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company.

Contaminated packaging
Dispose of as unused product.

SECTION 14: Transport information

14.1 UN number

ADR/RID: -	IMDG: -	IATA: -

14.2 UN proper shipping name

ADR/RID: Not dangerous goods
IMDG: Not dangerous goods
IATA: Not dangerous goods

14.3 Transport hazard class(es)

ADR/RID: -	IMDG: -	IATA: -

14.4 Packaging group

ADR/RID: -	IMDG: -	IATA: -

14.5 Environmental hazards

ADR/RID: no	IMDG Marine pollutant: no	IATA: no

14.6 Special precautions for user
no data available

SECTION 15: Regulatory information

This safety datasheet complies with the requirements of Regulation (EC) No. 1907/2006.

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture

no data available

15.2 Chemical Safety Assessment
For this product a chemical safety assessment was not carried out

SECTION 16: Other information

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Newell Rubbermaid Brands That Matter | Office Products Group

MATERIAL SAFETY DATA SHEET **MSDS # 96112**

Section One: Identification

Sanford, L.P.
2707 Butterfield Road
Oak Brook, IL 60523 USA
800-323-0749 or 630-481-2000

EMERGENCY MEDICAL NUMBER:
888-786-0972

Product Name: Parker Quink/Penman Inks

Colors: Quink:Washable Royal Blue, Permanent Blue, Blue Black, Black, Red, Turquoise, Green, Brown Penman: Sapphire Blue, Ebony Black, Emerald Green, Mocha Brown, Ruby Red

Includes: Duofold (Centennial and International), Ellipse, Frontier, Inflection, Parker 45, Parker 100, Reflex, Sonnet Premier, Vector

Section Two: Hazard Identification

This product is considered safe under normal use conditions.

Section Three: Composition

Water, diethylene glycol (111-46-6), dyes, preservatives

Section Four: First Aid Measures

Inhalation: Not an inhalation hazard.

Skin Contact: Wash with soap and water.

Eye Contact: Wash through with clear, tepid water.

Ingestion: The mouth may be cleansed with a soap and water solution. If a large amount is ingested (several pens), consult a physician.

Section Five: Fire Fighting Measures

Flash Point: Not flammable

Flammability Limits (% by volume): Lower: Not applicable Upper: Not applicable

Extinguishing Media: Dry chemical, foam, carbon dioxide, water spray

Special Fire Fighting Measures: In fires involving large quantities, use self-contained breathing apparatus and other protective gear.

Unusual Fire and Explosion Hazards: Hazardous decomposition products may be released in fire situation.

Section Six: Accidental Release Measures

In Case of Spill or Accidental Release: Wipe up with absorbent material

Section Seven: Handling and Storage

Handling: Do not shake pen.

Storage: No unusual storage requirements

Section Eight: Exposure Controls and Personal Protection

Eye Protection: None under normal use conditions.

Clothing: None under normal use conditions.

Respirator: None under normal use conditions.

Ventilation: None under normal use conditions.

Section Nine: Physical and Chemical Properties

For ink unless otherwise specified:

Boiling Point:	Not available
Specific Gravity:	Not available
Vapor Pressure:	Not available
Solubility in Water:	Soluble
Evaporation Rate:	Not available
Appearance/Odor:	Colored liquid; mild odor

Section Ten: Stability and Reactivity

Stability:	Stable
Conditions to Avoid:	None known
Chemical Incompatibility:	None known
Hazardous Decomposition:	May product oxides of carbon, nitrogen, and various hydrocarbons in fire.
Hazardous Polymerization:	Will not occur.

Section Eleven: Toxicological Information

See Section Two: Hazard Identification for any hazards

Section Twelve: Ecological Information

Not available

Section Thirteen: Disposal Considerations

Dispose in accordance with Federal, State, and Local Regulations.

Section Fourteen: Transport Information

DOT:	Not regulated
IATA:	Not regulated
IMO:	Not regulated

Section Fifteen: Regulatory Information

TSCA: The product listed on this Material Safety Data Sheet is not listed on the Toxic Substances Control Act Inventory. All ingredients used to manufacture this product are listed on the TSCA Inventory

Section Sixteen: Other Information

HMIS Code	
Health	N/A
Flammability	N/A
Reactivity	N/A
Personal Protection	N/A

0=Minimal / 4 = Severe

NewellRubbermaid, Inc (Sanford L.P.) has been advised by Counsel that the OSHA Hazard Communication Standard and the Health Canada Workplace Hazardous Materials Information Standard do not apply to the product described in this Material Safety Data Sheet. The reasons for the exemptions are contained in 29 CFR 1910.1200(b)(6)(ix) as amended Sept 14, 2009 per the Code of Federal Regulations and also Canadian Hazardous Products Act part 12 section (f) as amended June 1, 2009. The information contained in this MSDS is forwarded to you for your information, but is not meant to imply that the product is covered by nor is this MSDS meant to comply with all requirements of the hazard communication standards.

Appendix 11: Risk Assessment and COSHH Assessment

University of Glasgow

RISK ASSESSMENT FORM

School: Culture and Creative Arts	**Section:** Centre For Textile Conservation and Technical Art History	**Location:** Room number(s) 309A, 310	**Reference No:** R /13-14____	**Related COSHH Form (if applicable):** /13-14_____

Description of activity:
Dissertation Research: Testing agarose gels using three different fabrics that have been stained using ink. Wool fabrics will need to be scoured, and all materials cut to the sample size and stained. Agarose gels will be made and stored throughout the testing process.

Persons at risk:
Staff and students

Is operator training/supervision required? If yes, please specify: no

Hazards/ Risks	Current controls	Are these adequate?	What action is required if not adequately controlled?
Heating Element/Hot plate	Use signage to indicate when plate is hot and be aware of when element is use	**Yes**	
Electrical equipment	Contain cords to avoid trip hazards, ensure equipment is in good working order and has been PAT tested	**Yes**	
Sharp/Cutting Implements	Use appropriate techniques to ensure safe working practice, handle with care, cover blades when not in use	**Yes**	

	and dispose of used blades in proper disposal container.		
Use of Glassware	Handle with care if breakage occurs dispose in proper container or repair box.		
Scouring of Wool using hotplate and Dehyphon LS45	Use proper PPE and good workroom practice.	**NO**	**See COSHH**
Preparation of Gels with Agar/Agarose powder	Use appropriate PPE during preparation, Gloves, eye protection, lab coat.		

Completed by (print name and position, and sign): Emma Schmitt (student)	**Date:** 21.05.2014
Approved by (print name and position, and sign): Kate Thompson (K. THOMPSON)	**Date:** 22.05.2014

University of Glasgow

COSHH Assessment Form

School: Culture and Creative Arts
Section: Centre for Textile Conservation and Technical Art History
Project Title:

File ref: C_____
Related Assessment Form: R_____
Date:

Room Number(s):309A, 310

Building: The Robertson Building

Persons involved: Students and Tutors

Description of procedure:
Scouring wool in preparation for dissertation research

Substance used	Quantities used	Frequency of use	Hazards identified	Exposure route
Dehyphon LS45 A low Foaming Nonionic Surfactant with Sufficient Stability in in Alkaline media (e.g. carbohydrates, silicates, phospahtes) and acidic media (e.g. phosphoric acid, citric acid)	>1g	Twice	Eye/skin Irritation Ingestion	Skin Contact Eye Contact Ingestion

Could a less hazardous substance (or form of the substance) be used instead? **no**

Justify not using it: Required for research process

What measures have you taken to control risk?

Engineering controls:
Eyewash facilities

Personal Protective Equipment:
Wear Labcoat, Goggles, Gloves

Management measures:
Good workroom practice

Checks on control measures: Tutors

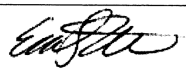
Is health surveillance required? **no**

Training requirements:

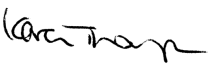
Emergency procedures: Eye Contact: Flush with water
Skin Contact: Flush with water
Seek medical attention if ingested

Waste disposal: Do not Empty into Drains, Very toxic to aquatic organisms.

Name and position of assessor: Emma Schmitt, Student

Signature: 

Name of supervisor (student work only): K. THOMPSON

Signature: 

Name of Head of School or nominee:

Signature: