Hunter, Michelle (2016) *Let there be light? An investigation into the fading characteristics of the early synthetic dye magenta.* [MPhil]

http://endeavour.gla.ac.uk/174/

Let there be light?
An investigation into the fading characteristics of the early synthetic dye magenta

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Submitted in partial fulfillment of the requirements for the
Master of Philosophy Textile Conservation in the
School of Culture and Creative Arts, University of Glasgow,
August 18, 2016.

Abstract

Magenta, was discovered in 1858 and quickly became the first commercially successful synthetic dye. It was first synthesized and classified as a basic dye. Basic dyes have been historically recorded as being highly sensitive to light. Since light is required to view historic textiles, an issue presents when attempting to strike a balance between preserving the textile and providing access through display, examination, study, or conservation treatment. The aim of this research was to investigate if magenta was as light sensitive as it was historically be reported and if it is light sensitive in a museum environment.

This investigation evaluated colour and chemical changes within silk and wool magenta dyed model test fabrics. They were subjected to a range of six different lighting scenarios chosen to mimic likely lighting scenarios textiles may be exposed to during display, examination, and treatment. Colour and chemical changes were evaluated using a spectrophotometer and ultra high performance liquid chromatography coupled with photo diode array detection (UHPLC-PDA). Results generated from the study indicate that both colour and chemical changes occur when magenta is exposed to light.

Acknowledgements

Firstly, I would like express my gratitude to the generous support I have received from the The Textile Conservation Foundation and the University of Glasgow throughout my studies. I would not have been able to complete my studies with this assistance.

I would like to express my thanks to my supervisor Dr. Anita Quye for entrusting me with this research and providing support throughout this process. I would also like to thank Dr. Jing Han who became my secondary supervisor, thank you for patiently teaching me the art of the dye extractions and the Empower™ system.

My sincerest thanks go to the teaching staff at the Centre for Textile Conservation. Thank you for providing the support and encouragement that helped me get through the last two years.

I would also like to thank my family and friends from across the oceans for your encouragement in chasing my dreams. Lastly to Simon, thank you for always believing in me.

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Part I: Background Information

Chapter 1: Introduction and current state of research

1. Introduction

Since the Iron Age textiles have been coloured using a wide range of materials, many of which are organic in nature.[1] For conservators, the potential for these textile colourants to fade or change when exposed to light is of great concern as both are cumulative and irreversible processes. For this reason light is classified as one of ten agents of deterioration to historic objects.[2] Since light is required to view historic textiles, an issue presents when attempting to strike a balance between preserving the textile and providing access through display, examination, study, or conservation treatment.

The results of colour change in an object, whose value is predominantly pictorial, such as a tapestry, can visually disrupt and take away from its interpretation.[3] Faded areas of previous conservation repair can be visibly obtrusive and may cause more damage to occur from attempts to replace it. Colour changes in textiles that occur before entering a museum present issue with the interpretation and expectations of historic colour palettes.[4] Colour changes are not the only concern as light may cause dyes to behave as a sensitizer, aiding in the degradation and weakening of the textile substrate.[5] Light can also break down and potentially destroy the chemical structure of a dye molecule, making identification and

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[1] Neri Pozza, *The Art of Dyeing in the History of Mankind* (Vienza: Officine Grafiche STA, 1973), 3.

[2] "Agents of Deterioration," Government of Canada, http://canada.pch.gc.ca/eng/1444330943476 (accessed July 3, 2016).

[3] Karen Finch, "The History and Development of Tapestry Conservation," in *The Misled Eye. Reconstruction and Camouflage Techniques in Tapestry Conservation Symposium*, ed. J. Barnett, and S. Cok, 45-54 (Amsterdam: Textile Restauratoren Overleg Nederland, 1994).

[4] Sam Vettese Forester and Robert Christie, "The Significance of the Introduction of Synthetic Dyes in the Mid 19th Century on the Democratisation of Western Fashion," *Journal of the International Colours Association*, no. 11 (2013): 8-9.

[5] Ágnes Tímár-Balázsy and Dinah Eastop, *Chemical Principles of Textile Conservation* (Oxford: Butterworth-Heinemann, 1998), 90.

information regarding its chemical composition difficult to obtain.[6] Some textile colourants are more sensitive to light than others and therefore have a higher chance of fading and changing when exposed to light. Information regarding the provenience and history of the textile colourant must be assessed to determine if it has known to be light sensitive.[7]

One of the major developments of the 19th century was the chemical synthesis of textile dyes. Among the first synthesized, was a range of dyes created using a base of aniline, a colourless byproduct of coal tar.[8] The first aniline based dye was a purple dye called Mauveine, discovered in 1856. Mauveine led to the subsequent discovery of a range of synthetic colours known as aniline or coal tar colours.[9] These new aniline colourants gained quick popularity, as they were much simpler to apply to cloth than natural dyes and in some instances were able to create brighter and more striking colours.[10]

As time and experience with this new range of dyes progressed, some were found to be fugitive with quite poor light- and wet-fastness properties. This means that the dyes faded quickly when exposed to light and when in contact with water. At one point in history the term 'aniline colour' was thought to be synonymous with fugitive.[11] Literature has even suggested that a day of exposure to sunlight can

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[6] Anita Quye and Jing Han, "Typically Variable? A Chemical Study of Commercial Aniline Dyes in a 19th century Sample Book" (paper presented at the Dyes in History and Archeology 34th Conference, Greece, October 2015).

[7] Stefan Michalski, "The Lighting Decision," in *Fabric of an Exhibition: An Interdisciplinary Approach Postprints*, 97-104 (Ottawa: Government of Canada, 1997) p.101-102.

[8] L.F. Haber, *The Chemical Industry During the Nineteenth Century* (Oxford: Clarendon Press, 1958), 80-81.

[9] Anthony Travis, *The Rainbow Makers: The Origins of the Synthetic Dyestuffs Industry in Western Europe* (London: Associated University Press, 1993), 67.

[10] Alan Dronsfield and John Edmonds, *The Transition from Natural to Synthetic Dyes 1856-1920* (Bucks: John Edmonds, 2001), 10-11.

[11] Arthur Dufton, "The Fading of Colours," *Journal of the Society of Dyers and Colourists* (1891): 90.

bleach the aniline colour from a textile.[12] Since aniline dyes are said to fade in the mere presence of sunlight, it comes to question if the same may processes occur with controlled indoor lighting, such as a conservation laboratory or exhibition space found within a museum.

Dr. Anita Quye initially questioned the fading of early aniline dyes in museum lighting when looking through historic dye manuals.[13] The significance of these manuals is in the historic knowledge of the practical application of dyes and recipes. Often these manuals include a sample of dyed fabric alongside the recipe. The dyed samples hold key information into the chemical composition and can provide insight into how they are synthesized.[14] Because of the first hand information they contain it is important to question if any damage to the sample is occurring when these pages come into contact with light.[15] The same can be said for other textiles that have been dyed with early aniline dyes, whose significance may lie in their visual appearance.

1.2 Magenta

The focus of this dissertation is to investigate and evaluate the changes in colour and chemical structure caused by exposure to light using one early aniline dye, magenta or fuchsine, as an experimental case study. Magenta, a bright red-blue dye, was discovered in 1858 and its commercial production began shortly after in

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[12] Stanley Forrester, "The History of the Development of the Light Fastness Testing of Dyed Fabrics up to 1902," *Textile History Journal*, no.6, vol. 1 (1975): 69.

[13] Anita Quye, "Dye Manual Research"(Lunch Time Talk, Centre for Textile Conservation, University of Glasgow, March 22, 2016); Anita Quye, "Dye-Versity. Researching 19th c. Dyeing Manuals" (Institute of Conservation Scotland Paper Conservators in Scotland Meeting, University of Edinburgh Archives, April 25, 2016).

[14] Anita Quye. 'The Power of Two: Uniting Chemical and Historical Research of 19th c. Early Synthetic Dyes for Conservation" (Institute of Conservation 2016 Triennial Conference, Aston University, Birmingham, June 16, 2016).

[15] Anita Quye, "Filtered Light on Light-Sensitive Dyes: A Pilot Project," Center for Textile Conservation Academic Blog (Blog), May 17, 2016, http://textileconservation.academicblogs.co.uk/filtered-light-on-light-sensitive-dyes-a-pilot-project/

1859.[16] Magenta was first synthesized and classified as a 'basic' dye because of its positively charged (cationic) chemical structure.[17] Throughout this magenta will be in inference to basic magenta, unless specified. Magenta is credited with being the most commercially successful and widely used early aniline dye.[18] It also served as an important intermediate and was used to create a range of violet and blue aniline dyes.[19] Magenta will be used in this study as it historically known as being one of the early aniline dyes that is sensitive to light.[20]

1.3 Layout of the dissertation

This dissertation focuses on the fading and colour changes of one early aniline dye, magenta, through an experimental case study. This dissertation is laid out in two parts. Part one provides the reader with background information relevant to the dissertation topic, and this is found in chapters 1 through 3. Chapter 1 provides an introduction to the subject of the experiment, including a literature review and discussion of the research objectives and questions at play. Chapter 2 examines the current state of knowledge within the profession regarding the light fastness of magenta and other early aniline dyes. Chapter 3 highlights the history of magenta, its invention, synthesis, and use as a textile dye. The last section of part one is supplied in chapter four, which aims to investigate the mechanisms of light. This includes how we see colour and how it acts as an agent of deterioration.

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[16] Eve-Anne Scholler, "Understanding and Identifying Fuchsine in Dress and Textile Collections: A Methodology" (MLitt dissertation, School of Culture and Creative Arts, University of Glasgow, 2014), 8-9; Travis, 67-70.

[17] C. Cooksey and A. Dronsfield, "Fuchsine or Magenta: The Second Most Famous Aniline Dye. A short memoir on the 150th anniversary of the first commercial production of this well known dye," *Biotechnic & Histochemistry,* vol.84, no.4 (2009), 179.

[18] Ibid.

[19] Pozza, 281; Aftalion, 37.

[20] John Mills and Raymond White, *The Organic Chemistry of Museum Object,* 2nd ed. (Oxon: Routledge, 2011), 153

Part two delivers the experimental case study and includes the final four chapters of the dissertation. The experimental setup and creation of model test fabrics, lighting scenarios, and monitoring will be described within chapter five. Evaluations of colour change and the effects of light on the chemical profile will then be presented in chapters six and seven, respectively. In conclusion, chapter eight will present the overall results and the impact and further research required in relation to the topic.

1.4 Review of the literature

1.4.1 Introduction

The aim of this section is to explore the current status of the literature, including information on both early aniline dyes in general, as well as magenta in particular. Information related to the fading of aniline dyes will be assessed with specific mention of the gaps in the literature to further emphasize the importance of this research. Exploration of historical information regarding light fastness will then be presented from the contexts of conservation science, textile conservation, and dress and textile sources. These sources will be assessed to determine trends and variances in the information available. The results of this literature review will be used to develop the research questions, aims, and objectives for this study.

To date much of the information available to assist in assessing the risk of exposing textile dyes to light and colour change has focused on natural dyes.[21] This only gives partial information when understanding the fading and colour changes of textile colourants. More specifically, it does not provide useful information in cases

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[21] H. C. A. van Beek and P. M. Heertjes, "Fading by Light of Organic Dyes on Textiles and Other Materials," *Studies in Conservation*, vol. 11, no. 3 (1966): 123-132; Tim Padfield and Sheila Landi, "The Light-Fastness of Natural Dyes," *Studies in Conservation,* vol.11, no.4 (1966): 181-196; Patricia Crews, "Fading Rates of Some Natural Dyes," *Studies in Conservation*, vol. 32, no. 2 (1987): 66, 72; Maria Perla Colombini et al., "Colour Fading in Textiles: A Model Study on the Decomposition of Natural Dyes," *Microchemical Journal*, 85 (2007): 174-182.

where natural dyes are not used, such as those using magenta and other synthetic dyes.

1.4.2 Historic expectation of light fastness

In 1870, Slater first made mention the effect of light on magenta.[22] In his work *The Manual of Colours and Dye Wares,* he discussed how magenta is applied to fabrics along with a short sentence stating that magenta is not a fast colour and that "a few hours exposure to full bright sunshine generally suffices to injure very strikingly ribbons, curtains, etc."[23] A similar statement was published by Napier a few years later in 1875, where he described that magenta, "becomes very light when exposed to the sun, often in a few hours."[24]

Kallab conducted one of the first investigations into the light fastness properties of dyes including synthetic dyes in 1872.[25] 55 different dyes were exposed to sunlight during July, August, and September 1872.[26] He evaluated the samples 3 to 8 days, as well as, 3 months after exposure to sunlight. In 1874 Crookes translated and highlighted the results of this investigation.[27] He noted that magenta was of one of Kallab's samples and it was observed to turn "duller and paler" after three to eight days and "blueish, much bleached" after three months exposure to sunlight.[28]

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[22] J.W. Slater, *The Manual of Colours and Dye Wares: The properties, applications, valuation, impurities, and sophistications* (London: Bentley and Co, 1870), 110- 112.

[23] Slater, 112.

[24] James Napier, *A Manual of Dyeing and Dyeing Receipts Composing a System of Elemental Chemistry as Applied to Dyeing* (London: Charles Griffin & Co, 1875), 11.

[25] Forrester, 66; William Crookes, *A Practical Handbook of Dyeing and Calico Printing* (London: Longmans, Green, and Co, 1874), 660, https://archive.org/stream/gri_c00033125000912127#

[26] Forrester, 69; Crookes, 660.

[27] Ibid.

[28] Ibid.

Hummel also conducted a similar study using approximately 100 different dyes on wool, which is discussed in an 1888 publication.[29] He observed the samples after one-, two-, four-, eight-, and twelve-month exposures to an undefined source of light. For each dye he assigned a value of fast, medium, or fugitive.[30] Magenta was noted as being fugitive.[31]

In 1964, Giles suggested that these historic tests were conducted with everyday lightfast requirements in mind.[32] He states that conservation has a different set of different standards in mind as lighting within museums typically attempts to eliminate the harmful effects of light, through filtration.[33] These historic sources use direct sunlight as a way of measuring light fastness, which makes them not very applicable to gathering information regarding colour change and fading of light sensitive dyes in a museum setting.

In his research into the science of dyes and pigments, McLaren explains, "all of the dyes discovered up to 1869 were extremely fugitive, a few hours exposure to bright sunshine will destroy them completely."[34] In 1975 Forrester complied a review of the development of light fastness testing up to 1902.[35] In this review he highlights some of the historic light fastness studies that had been conducted in order to better understand the impact that light has on a wide variety of both natural and synthetic textile dyes.[36]

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[29] J.J. Hummel, *The Dyeing of Textile Fibres* (London: Cassel & Company Ltd., 1888), p.487-488.
[30] Ibid.
[31] Hummel, 487.
[32] C.H Giles, "The Fading of Colouring Matters," *Studies in Conservation*, vol. 9, no. 1 (1964): 11.
[33] Ibid.
[34] K. McLaren, *The Colour Science of Dyes and Pigments* (Bristol: Adam Hilger, Ltd, 1983), 15.
[35]Forrester, 52-88.
[36] Forrester, 65, 80.

1.4.3 Textile conservation, conservation, and general museum manuals

One of the first published works devoted to textile conservation, *Textile Conservation,* edited by J.E. Leene in 1972 contains an entire chapter devoted to natural dyestuffs.[37] Within this chapter the poor light fastness of both natural and synthetic dyestuffs is discussed.[38] It is suggested that, "at the end of the nineteenth century, industrial dyeing was at a low level", and that at this time synthetic and natural dyes were being used with results that were "equally as bad."[39] She goes on to state that this has given synthetic dyes a bad reputation that they are still attempting to overcome in current times. As the writing goes on it is clear that this statement is in respect to synthetic dyes being used as a repair material and not about a conservator's expectations of how dyes will behave when they are exposed to light.[40] The concept of avoiding light fast dyes for conservation purposes is echoed in Landi's textile conservation manual published in 1998.[41] She briefly mentions that early basic synthetic dyes were brilliant in colour, but had poor fastness to light. In her conclusions she states that basic dyes are best to, "avoid for conservation purposes".[42] However, the ramifications of exposing light sensitive dyes to light are not discussed. Finch and Putnam mention the fugitive nature of aniline dyes and discuss their current use in man made fibres, stating that this was their 'true potential'.[43] Flury Lemburg's work in Textile Conservation and research also makes no mention to the fading of synthetic or natural dyes.[44]

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[37] Johanna M. Diehl, "Natural Dyes," in *Textile Conservation*, ed. J.E. Leene, 23-31 (London: Butterworth & Co, 1972), 23-31.

[38] Diehl, 25.

[39] Ibid.

[40] Ibid.

[41] Shelia Landi, *The Textile Conservators Manual* (London: Butterworth-Heinemann, 1998), 17.

[42] Ibid.

[43] Karen Finch and Greta Putnam, *Caring for Textiles* (London: Barrie and Jekins Ltd, 1977), 18.

[44] Mechthild Flury-Lemberg, *Textile Conservation and Research: A Documentation of the Textile Department on the Occasion of the Twentieth Anniversary of the Abegg Foundation* (Switzerland: Abegg-Stiftung Bern, 1998).

In 2007, Barnett published an article compiling the available literature and the conservation issues of synthetic organic dyes used between 1856 and 1901.[45] Barnett goes onto discuss that most of the investigations, research, and published literature has focused on natural dyes and very little has been conducted into synthetic dyes.[46] Barnett is unsure why this is, but suggests it could be due to lack of motivation, opportunity, or that the study of synthetic dyes can be unwieldy at times.[47] Early synthetic dyes can be a cumbersome subject to study, as they can vary greatly in their chemical composition due to a number of factors such as starting synthesis reactions.[48] Projects like DYE-versity are working to evaluate and understand the complex chemical make up of early synthetic dyes and how information such as this can be used in order to better care for historical textiles.[49]

The light sensitive aspects of early aniline dyes are also touched on in several different general conservation and museum environment manuals.[50] Kühn, states some of the earliest of the synthetic and basic dyes were so light sensitive that dress materials were known to bleach severely in the course of one sunny day.[51] Thomson also lists magenta as a highly fugitive colour that will change when exposed to light.[52]

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[45] Jennifer Barnett, "Synthetic Organic Dyes. 1856-1901: an introductory literature review on their use and related issues in textile conservation," *Reviews in Conservation*, 8 (2007): 67.
[46] Ibid.
[47] Ibid.
[48] Quye and Han, "Typically Variable? A Chemical Study of Commercial Aniline Dyes in a 19th century Sample Book."
[49] Quye, "Dye-Versity. Researching 19th c. Dyeing Manuals."
[50] Hermann Kühn, *Conservation and Restoration of Works of Art and Antiquities-Volume 1* (London: Butterworths, 1986); Gary Thomson, *The Museum Environment* (London: Butterworths, 1986).
[51] Kühn,172.
[52] Thomson, 12.

1.4.4 Scientific conservation manuals

Conservation manuals devoted to the scientific understanding of both textiles and museum objects have paid some attention to the fading of early synthetic dyes. Much like the many textile conservation manuals, this information is limited to the fact that these dyes are light sensitive.[53] Tímár- Balázy and Eastop's *Chemical Principles of Textile Conservation* make specific mention to magenta, but only mention the fact that it is a basic dye introduced in the second half of the 19th century as well as examination of its chemical structure.[54] The only mention to specific fading within the lightfastness/colour fastness of dyes section of the text is in relation to ratings against blue wool standards. This discussion states that "light fastness of basic dyes depends on their individual structure" and places high light fastness at 6 to 7 using blue wool standards for acrylic fibres, but makes no mention to any other fibre type.[55] The subject index at the back of the book makes no mention to synthetic dyes within the text.[56]

In 1987, Mills and White published their first edition of *The Organic Chemistry of Museum Objects*, which aims to provide information on the "composition, chemistry, and analysis of objects in museum collections."[57] A section devoted to the understanding of organic colourants specifically mentions magenta, stating, "fuchsine gave a very bright colour to wool, silk, and cotton, but has poor light fastness, fading to a pale mushroom colour when exposed to light".[58] This statement has been carried across to the updated second edition published in 2011. Both of these statements are not referenced to any specific piece of literature or scientific study.

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[53] John Mills and Raymond White, *The Organic Chemistry of Museum Objects* (London: Buttersworth & Co, 1987); Mills and White, *The Organic Chemistry of Museum Objects*, 2nd ed.; Tímár- Balázy and Eastop.
[54] Tímár- Balázy and Eastop, 73.
[55] Tímár- Balázy and Eastop, 93.
[56] Tímár- Balázy and Eastop, 431-443.
[57] Mills and White, i.
[58] Mills and White, 153.

In 1991, a group of textile conservation interns at the Smithsonian Institution complied a document outlining the chemistry, constitution, date, and properties of important early synthetic dyes.[59] This document was created for the purpose of aiding conservators and is freely available through the Smithsonian Institute's website.[60] The properties of basic magenta are listed along with the light fastness properties on silk, wool, and cotton using the American Test Method (AATCC) and ISO standards taken from the Colour Index Volume IV.[61] Low lightfast values between 1 and 2 were reported.

1.4.5 Dress and Textile History

The expectation of fading when using early aniline dyes has made an appearance in dress and textile history. Early aniline dyes were not only available commercially at the time, but were also available for domestic use.[62] A book published in 1972 on how Victorian clothing was cleaned and cared for explains the use to new aniline dyes and their bright and "startling shades as magenta".[63] Although it does not mention the fugitive properties of aniline dyes, it does state that "discolouration from exposure to light and damp, and fading, caused by a combination of light and fugitive dyes, were a frequent source of trouble for the Victorian housewife".[64]

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[59] Mary Ballard, *Important Early Synthetic Dyes: Chemistry, Constitution, Date, and Properties,* Washington: Conservation Analytical Laboratory Smithsonian Institution. Accessed August 1, 2015. https://www.si.edu/mci/downloads/reports/IESD-CCDP1991.pdf

[60] Ibid.

[61] Ballard, 102.

[62] Edward McDermott, *The Popular Guide to the International Exhibition 1862* (Cambridge: Cambridge University Press, 2014), ix.

[63] Christina Walkely and Vanda Foster, *Crinolines and Crimping Irons: Victorian Clothes: how they were cleaned and cared for* (London: Peters Own Limited, 1978), 22.

[64] Walkely and Foster, 163.

Ginsburg makes specific mention to a dress belonging to the Victoria and Albert Museum (T118-B-1979) thought to have been dyed with magenta dye.[65] This dress is attributed to a Parisian dressmaker who made garments for Empress Eugenie, the wife of Napoleon III.[66] The bright and vivid colours of early aniline dyes have been said to have been, "enthusiastically received" by Emperor Napoleon III and his wife, who was revered as a leader of fashion.[67] The dress was constructed from "magenta silk, lavishly trimmed with pinked and pleated bands".[68] A small sentence following the description states, "unfortunately the magenta dye is too fugitive to permit display".[69] A quick search of the Victoria and Albert museum website shows that this gown is currently on display in the fashion gallery.[70] It is not known how long the gown has been on display or the lighting conditions within this gallery.

1.4.6 Problems with available information

The issues with the literature available is the lack of data that specifies, other than direct sunlight, the lighting conditions that can fade and change the colour of magenta and early aniline dyes. The historic literature suggests that magenta dye on a textile can essentially be destroyed when exposed to sunlight in a matter of hours. One historic experiment has shown that when exposed to sunlight magenta can turn duller, paler, and overall becoming a more blue hue.[71] The results from the literature review shows that there is no current published evidence

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[65] Madeline Ginsburg, "Women's dress before 1900" in *Four Hundred years of Fashion,* ed. Natalie Rothstie, 13-48 (London: William Collins and Sons & Co Ltd, 1984), 40.
[66] Ibid.
[67] K.G. Ponting, *A Dictionary of Dyes and Dyeing* (London: Bell & Hayman Limited, 1980), 15.
[68] Ginsburg, 40.
[69] Ginsburg, 40.
[70] "Dress," Victoria and Albert Museum, http://collections.vam.ac.uk/item/O115837/dress-vignon/ (accessed July 5, 2016).
[71] Crookes, 660.

investigating if lighting conditions in museum conservation labs and display spaces have an effect on early aniline dyes, more specifically, magenta. However, a pilot project is underway investigating the use of light filtering systems for light sensitive dyes at the University of Glasgow.[72]

Another gap within the available literature is the lack of consistent information regarding the possible colour change of faded magenta and other synthetic dyes. Generally, early synthetic dyes with poor light fastness have been quoted as becoming "light and duller, and can change to a beige, grey, or reddish shades".[73] It has also been stated that they can fade in different ways. Pellew wrote in 1928 that a red piece of cloth may be bright and then after a few days exposure to sunlight some areas may "turn a yellow, white, or even darker colour."[74] Mills and White have written specifically about magenta stating that it can turn to a mushroom brown when exposed to light, but they do not state the type or duration of the light exposure.[75] Ford mentions the darkening of a Indonesian maroon women's skirt while on display thought to be dyed with synthetic dyes.[76] Recently, Scholler conducted an investigation into understanding and identifying magenta in historic dress collections.[77] In this investigation she looked at examples of dress and early historic dye manuals. During her research she noticed that some samples of magenta within the dye manuals had turned yellow while others appeared to have darkened.[78]

The common thread between all of these examples is that they are not referenced to any other piece of literature or scientific case study and appear as unrefuted fact.

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[72] Quye, "Filtered Light on Light-Sensitive Dyes: A Pilot Project."

[73] Barnett, 72.

[74] Charles Pellew, *Dyes and Dyeing* (London: Sampson Low, Marston &Co., Ltd, 1928), 56.

[75] Mills and White, 130.

[76] Bruce Ford, "Monitoring Colour Change in Textile on Display," *Studies in Conservation*, vol. 27, no. 1 (1992): 5, 9.

[77] Scholler, 40-42.

[78] Ibid.

It leaves many unanswered questions such as: are early aniline dyes, specifically magenta actually so light sensitive that their colour can be bleached in as little as a day? Is it possible for this drastic colour change and fading to happen in a controlled museum environment? Can this happen when magenta dyed textiles are being treated in a conservation lab setting? Or displayed in an exhibition space?

It is possible that the lack of scientific case studies investigating the fading properties of magenta and other early aniline dyes are due to the growing use of an analytical tool called a microfader.[79] The technique of microfading is an accelerated ageing test that can directly measure the potential for light fastness in a material without having to know the identification of the textile dye.[80] The results of microfading can be used to determine how a colour will change and at what level of light exposure the change occurs.[81] This technique is an accelerated ageing technique, which has limitations in its possible comparisons to real fading conditions. This technique only examines physical colour change and does not take into account dye chemical or fibre degradation.

Although limitations exist in the literature there are also many strengths, specifically in regards to Barnett's article. In the conclusion of her article she lays out a range of further research.[82] A particular area she suggests for future research is the investigation and "characterization of fading, colour change, and degradation processes for the most commonly used dyes or dye classes."[83] Since magenta was the second most widely used from the early aniline dyes, it makes it highly likely that textiles using this dye still exist in museum collections. Without an appropriate understanding of how this dye behaves when exposed to light,

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[79] Paul Whitmore, Xan Pan, and Catherine Bailie, "Predicting the Fading of Objects: Identification of Fugitive Colorants through Direct Nondestructive Lightfastness Measurements," *Journal of the American Institute for Conservation*, vol. 38, no. 3, (1999): 396-397.
[80] Ibid.
[81] Ibid.
[82] Barnett, 74-75.
[83] Barnett, 75.

conservators and other museum stakeholders cannot accurately care for these objects. How do you go about assessing lighting criteria when exhibition or other access for a specific object is essential? How many other Empress Eugenie dresses are being safely tucked away in storage for fear that their dye will fade after minutes of being brought into the light? What is the point of keeping these collections if we are too afraid to show them? How can be learn from them without destroying them?

1.5 Research question

An evaluation of the literature has shown that information available regarding the fading and colour change of magenta when it is exposed light is limited and information regarding fading in museum lighting non-existent.

The pertinent question to address is whether magenta is as light sensitive as it as been reported to be. For this dissertation, the research question was: will magenta fade and change chemical composition when exposed to various museum lighting environments that magenta dyed textiles are displayed, cared, and stored in?

1.6 Aims

To answer the research question posed above, 4 aims were developed:

1. What are conservator and curator perceptions of the light-fastness early aniline dyes, specifically magenta?

2. Is magenta light sensitive to indoor lighting typical in a museum and conservation workroom setting?

3. Do indoor lighting environments cause basic magenta to fade and/or change colour?

4. What happens to the dye analysis profile of magenta when it is exposed to different lighting environments?

1.7 Objectives

The aims will be achieved by:

- Asking practicing textile conservators and curators about their attitudes and knowledge of the fading of magenta and other early aniline dyes. This was undertaken by a written questionnaire distributed via electronic mail. Practicing professionals who are directly known to be working on projects dealing with synthetic dyes will be contacted.

- Conducting a light-fastness experiment for six weeks of real-time exposure of silk and wool dyed with magenta to determine if the dye is light fast and the impact of lighting environments such as a museum display area, conservation work rooms, museum offices, and unfiltered sunlight (including outdoor exposure).

- Assessing colour changes and/or fades, in silk and wool dyeing using basic magenta, visually and by measurement with a spectrophotometer to find out how different lighting environments influence changes.

- Analyzing the chemical profile of the light-exposed textile samples of magenta to find out how real-time light exposure affects the chemical composition of the dye.

Chapter 2- Professional perceptions towards the fading of early synthetic dyes

Due to the limited information in the literature, several curators and conservators who are known to be working on projects dealing with synthetic dyes were contacted via email with a short questionnaire (appendix 1). This questionnaire asked about their knowledge regarding the fading of early synthetic dyes, how dyes are identified within their institutions, if their display is impacted when early aniline dyes are present, and what lighting conditions they suggest when working with magenta and other aniline dyes.

Both curators and conservators stated that they have a general awareness that some of the early synthetic dyes have the ability to fade rapidly when exposed to light. One conservator said they were specifically aware of the problems with many of the early purple colours, and that as a whole, not enough is known about early synthetic dyes.

One of the institutions had access to a conservation scientist who is able to undertake dye analysis to positively identify dyestuff. This information gathered from dye analysis was used to develop suitable display protocols and enhances the collection records. Others used mainly documentary evidence that comes from curatorial object records and conduct external dye analyses when funding permits. One conservator stated that it would be useful to have information and guidelines regarding the fading of synthetic dyes and methods of identification that were not costly.

When a textile object is thought, or positively identified to have been dyed with an early synthetic dye, several institutions used shorter display times to minimize risks of light damage. A general consensus of the standard light levels of 50 lux was reported to be used. Interestingly, one institution reported that a bodice chosen for along term display was dyed with magenta. In order to address the issues with long-term display a replica is being made and half will be dyed with magenta and half dyed with a lightfast fabric.

Overall, the questionnaire showed that curators and conservators who are working/have been working on known historical synthetic dye projects are aware generally of the issues with early synthetic dyes, but still require information. The aim of this dissertation is to address a small part of these concerns, by using one early synthetic dye to determine if it is light sensitive in a museum environment. The information gathered from the results of the experimental case study my be used to create protocols regarding the amount of light a textile is subjected to in all aspects of its museum life.

Chapter 3: Magenta

3. Introduction

This chapter aims to provide the reader with background into the history, chemical composition, and use of magenta as a textile dye. This information will be provided in order to show why magenta was chosen for this case study.

3.1 Synthetic dyes

One of the major developments of the mid 19th century was the discovery of the first commercially successful synthetic dye. The invention and use of gas lighting in the early 19th century lead to the production of copious amounts of coal tar, a sticky black waste product.[84] Chemists worked to analyze and understand coal tar to find new uses for it. These investigations lead to the discovery that coal tar contained a number of organic compounds.[85] Among the compounds was aniline (figure 3-1) a colorless product that contained a phenyl group with an amino group attached.

Figure 3-1 Chemical structure of aniline. Figure modified from chemical structure of aniline on ChemSpider. [86]

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[84] Haber, 80-81.

[85] M. Reimann, *On Aniline and Its Derivatives* (London: Logmans, Green, and Co., 1868) p. 2.

[86] "Phenylamine," ChemSpider, http://www.chemspider.com/Chemical-Structure.5889.html (accessed July 5, 2016).

In 1856, Henry Perkin attempted to synthesize quinine, the cure for malaria, by oxidizing aniline dichromate. Instead he accidently formed a purple precipitate that was able to colour fabric.[87] This dye was named mauveine and was known as the first aniline or coal tar dye. Mauveine gained instant popularity because of its bright colour and ease of use. This stimulated others to experiment with aniline, which led to the discovery of a range of other aniline colours.[88] This also created a new understanding and a refinement in the understanding of organic chemistry.[89] Hunt stated in 1861 that when a woman wears a silk dyed with mauveine or magenta she couldn't help but feel "indebted for a new pleasure to the science that produced it."[90]

3.2 Magenta

The second aniline dye discovered and the subject of this dissertation is known as fuchsine or magenta. Several chemists had noted the formation of a red colour when heating aniline and various additives.[91] It was François Emmanuel Verguin who discovered that a brown mass was formed when tetrachloride was added to heated aniline.[92] When this brown mass was added to water it created a red tint.[93] When applied to silk in created a vivid blue-red colour.[94] In many early historic dye manuals magenta is classified as a red dye.[95]

3.3 Naming conventions

Recently, Eve Anne Scholler conducted an investigation into the terminology, appearance, and ways of identifying fuchsine in dress and textile collections.[96] Through this research Scholler uncovered that in both historic and contemporary

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[87] Cooksey and Dronsfield, 179.
[88] Pozza, 281; Aftalion, 37.
[89] Aftalion, 32-48.
[90] Robert Hunt, "Mauve and Magenta," *The St. James Magazine*, (1861): 43.
[91] Cooksey and Dronsfield, 180-181.
[92] Travis, 68.
[93] Ibid.
[94] Cooksey and Dronsfield, 180-181.
[95] Ibid.
[96] Scholler, 79-84.

literature, magenta has been given a number of different names, which depend greatly on the context in which the dye is being described.[97] This presents an issue when attempting to locate and organize all information available. The first name for magenta, was fuchsine, which is the name given in the original product patent. The word fuchsine is thought to be a reference to the red-blue colour of the fuchsia flower (figure 3-2).[98] It has also been termed magenta, as a celebration of the French victory of the Battle of Magenta in June 1859.[99] Magenta is also known as roseaniline, which is its base and aniline red, which is a generic name for magenta and includes variations.[100] With the invention of standardized colour names in 1925 magenta is also known as basic violet and Cl. 42150, just to name a few.[101]

Figure 3-2 Fuchsia flower. ©Michelle Hunter

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[97] Eve-Anne Scholler, et al., "Identifying Fuchsine Visually in Dress and Textile Collections," Poster Presentation at the 33rd Annual Meeting of Dyes in History and Archaeology, University of Glasgow, October 2014; Scholler 79-84.
[98] Cooksey and Dronsfield, 181.
[99] Ibid.
[100] Scholler, 79-84.
[101] Scholler, 79-84; The Society of Dyers and Colourists, *Colour Index Volume 4*. 3rd ed. (North Carolina: American Association of Textile Chemist and Colourists, 1971), 4389.

3.4 Manufacture

Verguin sold his invention to the Renard frères et Franc, a French silk manufacturer in Lyon, France.[102] It was patented it on April 8, 1859 and commercial production began almost immediately.[103] The use of magenta became established within England, and progressed to Germany and Switzerland.[104] Soon the popularity of magenta and other aniline colours began to travel outside of Europe to places like Japan, America, and India.[105]

The original synthesis process of creating magenta involved adding tetrachloride to heated aniline. Other chemists found that magenta could be processed using different mixtures such as, mercury nitrate, arsenic acid, and nitrobenzene, with the arsenic acid process being the most commercially popular as it produced a higher product yield.[106] However, the arsenic acid process began to show a cause of concern as possible health implications began to arise.[107] In the 1870s, a German chemist found trace amounts of arsenic within the fabric that had been dyed with magenta.[108] It was found that the arsenic could leach from the fabric and cause irritations to the skin.[109] Ways of producing magenta that excluded arsenic acid, such as the addition of nitrobenzene, which was originally developed in 1861, took over in the mid 1870s.[110]

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[102] Travis, 67.
[103] Ibid.
[104] Reimann,101-102.
[105] Reimann,102.
[106] Cooksey and Dronsfield, 181.
[107] Rosemary Baker, "Nineteenth Century Synthetic Textile Dyes. Their History and Identification on Fabric" (Doctor of Philosophy Thesis, University of Southampton, 2011), 54.
[108] Henk Van Den Belt, "Why Monopoly Failed: The Rise and Fall of Société La Fuchsine," *The British Journal for the History of Science*, vol.25, no.1 (1992): 57.
[109] Ibid.
[110] William Crookes, "The Production of Aniline Colours without the Use of Arsenic Acid," *Chemical News* (1875), 56.

The first synthesis of magenta was classified as a basic or triphenylmethane dyes, which have been stated, has having poor light fastness properties.[111] Commercial basic forms of triphenylmethane dyes are as cationic salts of hydrochloric acid (HCl).[112] Investigations into the chemical structure of magenta (Figure 3-3) have found that it is a complex composition, with the four main components of pararosaniline, rosaniline, magenta II, and new fuchsine.[113]

Figure 3-3 Chemical structure of basic magenta dye. Modified from the chemical structure for basic aniline on ChemSpider.[114]

Experiments using magenta led to the discovery of a range of new colourants. In 1862, the chemist Hoffman made the discovery that magenta was a salt of a colourless base, which he named roseaniline.[115] Later experiments found that roseaniline could be used as an intermediate to create a range of new synthetic

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[111] Mills and White, *The Organic Chemistry of Museum Objects.* 2nd ed, 153.
[112] Edmund Knecht, et al., *A Manual of Dyeing Volume II* (London: Charles Griffin & Company, Ltd, 1893), 448.
[113] Cooksey and Dronsfield, 180-182.
[114] "Fuchsine," Chemspider, http://www.chemspider.com/Chemical-Structure.10468578.html (accessed July 17, 2016).
[115] Pozza, 281.

colours, such as Methyl Violet, Aniline Blue, and Manchester Brown.[116]

In 1877, a new class of magenta, acid magenta, was created.[117] Acid magenta is the trisulfate from of rosaniline and is anionic.[118] This innovation allowed for acid magenta to be mixed with other acid dyes, however it had about half the tinctorial power of basic magenta.[119] In her research on magenta in dress and textile collections Scholler found acid magenta might have replaced the use of basic magenta on wool after 1877.[120]

The instant popularity of magenta quickly surpassed its predecessor, mauveine, whose production ceased around ten years after it was initially produced.[121] No exact date is known for when fuchsine lost popularity as a textile dye. Forrester and Christie suggest that many early synthetic dyes were "superseded in the 20th century by technically-superior products."[122] This however does not appear to be completely true as Pellew published a dyeing manual aimed towards craftsmen in 1928.[123] This manual, published in the United States, contains instructions and notes on dyeing with basic dyes and a list of basic dyes, magenta being included.[124] It is possible that the commercial production of magenta slowed towards the end of the 19th century, but it was still being used on a smaller scale during the 20th century. Today magenta is still used in medical applications as a biological stain.[125]

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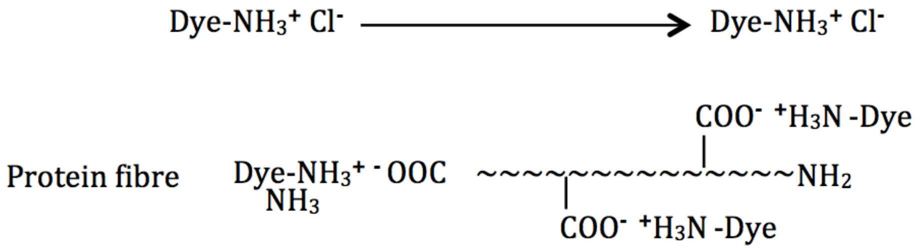
[116] Pozza, 281; Aftalion, 37.
[117] Christopher Rawson, et al*., A Dictionary of Dyes, Mordants, and Other Compounds Used in Dyeing and Calico Printing* (London: Charles Griffin & Company, Limited, 1918), p. 8; Raphael Meldola, *Coal, and What We Get From It* (London: Society for Promoting Christian Knowledge, 1891), 89.
[118] Rawson, et al., 8.
[119] Scholler, 22; Rawson et al., 8.
[120] Scholler, 22.
[121] Micaela Sousa et al., "A Study in Mauve: Unveiling Perkin's Dye in Historic Samples," *Chemistry - A European Journal,* no. 14 (2008): 8507.
[122] Forster and Christie, 10.
[123] Pellew, 1.
[124] Pellew, 140.
[125] Cooksey and Dronsfield, 179.

3.5 Use of magenta

In its raw form magenta is a dark green crystalline powder that is soluble in water. A magenta dye molecule can become a cation by reacting with hydrogen chloride (HCl) to form the NH_2+ (amino) group and creating the chloride salt. Basic dyes are known as cationic dyes as they have the ability to ionize into a cation (positive ion) and have a natural affinity for proteins, such as wool and silk. Cellulose fibres can also be dyed using basic dyes, but require the fibres to be pretreated with a mordant, such as tannic acid or another metallic fixing agent.[126] For the purposes of this research only protein fibers will be discussed.

When the dye is dissolved in a dyebath, the negatively changed carboxyl groups of the protein and the positive charged ion of the dyestuffs to form 'salt linkages'.[127] This process is aided by heating the dyebath, which allows the dye ions to bond to the acidic sites with the protein fibre.[128] The process of colouring wool and silk cloth with magenta is relatively straight forward as the dye can be dissolved in water and the colour takes to the cloth quickly. The process of using magenta as a dye has been highlighted in a number of historic manuals.[129]



$$\text{Dye-NH}_3^+\ \text{Cl}^- \longrightarrow \text{Dye-NH}_3^+\ \text{Cl}^-$$

$$\text{Protein fibre}\quad \underset{\text{NH}_3}{\text{Dye-NH}_3^+\ {}^-\text{OOC}}\ \sim\sim\sim\underset{\text{COO}^-\ {}^+\text{H}_3\text{N-Dye}}{\sim}\sim\sim\sim\sim\sim\sim\sim\sim\overset{\text{COO}^-\ {}^+\text{H}_3\text{N-Dye}}{\sim}\sim\sim\sim\sim\text{NH}_2$$

Figure 3-4 Diagram of the formation of salt linkages between a basic dye and protein fibre. Diagram modified from Tímár-Balázsy and Eastop, 73.[130]

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[126] Knecht, 460.

[127] Tímár-Balázsy and Eastop, 73; James Rice, "The Conservation of Historic Textile Colorants," *Textile Museum Journal,* vol. 1 (1963): 58.

[128] E.R. Trotman, *Dyeing and Chemical Technology of Textile Fibres* (London: Griffin, 1970), 374.

[129] Slater, 110-112; David Smith, *Smith's Practical Dyer's Guide* (London: Simpkin, Marshall & Co, 1880), 125. https://archive.org/details/smithspracticald00smit

[130] Tímár-Balázsy and Eastop, 73.

3.6 Magenta in collections

The popularity and both commercial and domestic availability of magenta means it is likely that textiles dyed with it will end up in museum collections. However, there have only been a few published cases where magenta has been positively identified in museum textiles.[131] Silk, wool, and cotton fabrics dyed with fuchsine, are the main materials that have been found in textile collections. However, other slightly acidic materials such as pineapple fibres have also been dyed with magenta (figure 3-5).[132] Magenta was first commercially produced in France but its popularity saw it spread quickly throughout Europe.[133]

Scholler conducted an investigation into the understanding and identification of magenta in dress and textile collections. She suggests that the known fugitive properties may have impacted the types of textiles that were dyed with magenta.[134] Textiles, such as, high fashion items, embroidery threads, haberdashery, trimmings, and underwear may have been dyed with magenta.[135] Magenta has also been used in historic dyeing ledgers, dyers instruction manuals, and pattern books (Figure 3-6).[136]

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[131] Jing Han, “Jing Han, “The Historical and Chemical Investigation of Dyes in High Status Chinese Costume and Textile of the Ming and Qing Dynasties (1368-1911)” (Doctor of Philosophy, School of Cultural and Creative Arts, University of Glasgow, 2016), 242; M.R van Bommel and AM Wallert, “Analysis of Synthetic Dyes in an Embroidery of Emile Bernard,” in *ICOM CC 14th Triennial Conference 2005 Preprints*, ed. Isabelle Verger, 969-977 (London: James & James, 2005), 976.

[132] “Day dress of piña cloth,” Museum of Fine Arts Boston, http://www.mfa.org/collections/object/day-dress-of-pi%C3%B1a-cloth-584108 (accessed August 1, 2016).

[133] Reimann, 101-102.

[134] Scholler, 51.

[135] van Bommel and Wallert, 976; Scholler, 89-97.

[136] Smith, 125.

Figure 3-5 Day Dress, 1868-1870, pineapple
fibre dyed with fuchsine
Boston Museum of Fine Art, Boston, 50.4042a-b
http://www.mfa.org/collections/object/day-dress-of-pi%C3%B1a-cloth-584108

Figure 3-6 Instructions for dyeing with Magenta along with textile samples from David Smith, *Smith's Practical Dyer's Guide* (London: Simpkin, Marshall & Co, 1880), 125.
https://archive.org/details/smithspracticald00smit

Chapter 4: Light

4. Introduction

Light plays an important role in the life of a historic object. Light is essential to the way humans view colour and has a major impact on the deterioration of heritage materials. This chapter aims to define what light is, how we typically see colour, and how light can cause colour breakdown and fading.

4.1 What is light?

A basic explanation of light states that it is a form of energy that can appear as both a wave and a particle.[137] This energy is generally referred to as electromagnetic radiation and is radiated in units called photons.[138] The different divisions of electromagnetic radiation are divided into what is known as the electromagnetic spectrum (Figure 4-1). The different divisions are placed in order of increasing frequency as the wavelength decreases in size. Within the middle of the electromagnetic spectrum are ultraviolet (UV) (100-400nm), visible (400-700nm), and infrared (IR) (750nm-1mm) light sources. Theses three ranges of the electromagnetic spectrum are of the most concern to museum objects.[139]

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[137] R.L.M Allen, *Colour Chemistry* (London: Thomas Nelson and Sons Ltd, 1971), 1.

[138] Tímár-Balázsy and Eastop, 16.

[139] "Agents of Deterioration," Government of Canada, http://canada.pch.gc.ca/eng/1444330943476 (accessed July 3, 2016).

Figure 4-1 Electromagnetic spectrum.[140]

4.2 The cause of colour and how we see it

Humans have the ability to see colour due to a small portion of the electromagnetic spectrum called visible light. Visible light contains wavelengths between 400-700nm. When the human eye observes colour it is witnessing the selective absorption and reflection of electromagnetic radiation.[141]

When a photon of light hits an object, part of the photon is absorbed into the object and some is reflected into the light sensitive part of the human eye.[142] The dominant colour is absorbed into the molecules of the object; this is termed the complimentary colour.[143] This means that an object dyed with magenta absorbs green, as its dominant wavelength is between 510-560nm. The relationship

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[140] "Electromagnetic Spectrum," Cyberphysics http://www.cyberphysics.co.uk/topics/light/emspect.html (accessed August 2, 2016).

[141] Victor Popoola, *The Chemistry of Colours in Dyes and Pigments* (Texas: Wits Publishing, 2015), 48-51.

[142] Popoola, 49.

[143] Popoola, 50-51.

between the colour observed and the complimentary colour was first described by Sir Isaac Newton and has since been studied and summated by others.[144] A table including a list of the relationships of complimentary colours (Table 1), observed colours, and their wavelengths has been included. Colourless products, such as degraded products absorb and reflect outside the UV and infrared absorb energy outside the visible light spectrum. However, both UV and IR can be seen with the assistance of analytical equipment.

Colour observed	**Complementary colour absorbed**	**Wavelength absorbed (nm)**
None (unless fluorescence)	Ultraviolet	<400
Greenish yellow	Violet	400-430
Yellow-orange	Blue	430-490
Red	Blue-green to green	490-510
Purple-red (magenta)	Green	510-530
Violet	Greenish yellow	530-560
Blue	Yellow	560-590
Greenish blue	Orange	590-610
Blue green to green	Red	610-700
None	Infrared	>700

Table 4-1 Table observed colour vs. complementary colour absorbed.

Table adapted from Brill, Popoola, and Tímár-Balázsy and Eastop, 68.[145]

For a dye molecule to be able to absorb a specific part of the visible spectrum its electrons must have the exact energy gaps as the wavelength being absorbed.[146] Once the molecules absorb light, specific electrons within the dye molecule transition from a relaxed state into a higher state of energy and reactivity, known as its excited state.[147] The electron goes back and forth between its excited state And ground, or relaxed state, by releasing energy.[148] This transition back and forth is the fundamental principle of colour.[149]

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[144] Thomas Brill, *Light: Its Interaction with Art and Antiquities* (New York: Plenum Press, 1980), 65.

[145] Brill, 65; Popoola, 51; Tímár-Balázsy and Eastop, 68.

[146] Tímár-Balázsy and Eastop, 68.

[147] Tímár-Balázsy and Eastop, 67-68.

4.3 How dyes are coloured

Within a dye molecule there are specific parts that give it the ability to be seen as a certain colour. These parts are called chromophores and auxchromes. A chromophore is the part of the dye molecule that allows the dye to be coloured. The chromophores present as conjugated systems and these are further described as having alternating single and double bonds. Within the magenta dye molecule this conjugated system is exhibited between carbons within the benzene rings.[150]

Figure 4-2 Benzene ring showing a conjugated system of alternating single and double bonds.[151]

Auxochromes are the functional groups within the dye molecules that influence the colour in terms of its ability to absorb light at a certain wavelength as well as its intensity.[152] There are a number of functional groups that can act as auxochromes with a dye molecule. The auxochromes in magenta are the amino groups ($-NH_2$) found on the end of the aryl groups.[153]

4.4 Fading of dyes

For a dye to appear as a specific colour it must absorb energy. When electrons within the dye molecule transition between the excited state and ground state the excited energy is discarded. This energy can be harmlessly released in the form of

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[148] Ibid.

[149] Ibid.

[150] Brill, 149.

[151] "Benzene," ChemSpider, http://www.chemspider.com/Chemical-Structure.236.html (accessed August 2, 2016).

[152] Brill, 150.

[153] Ibid.

heat or by fluorescence.[154] This generally occurs within colourants that have a high resistance to fading.[155] Some colourants are not able to quickly release this energy and it stays within the molecule, which ends up causing what is known as photochemical deterioration.[156] Exposure to UV radiation is harmful towards most colourants as it contains higher energy, however, visible light is more specific and is only harmful to dyes that are know to be sensitive to it.[157]

Though photochemical degradation processes differ slightly, they all generally involve a dye molecule in an excited state interacting with non-excited parts of a dye molecule, the textile substrate, or both, resulting in damage. The excited dye molecule can break down the chromophoric system causing loss of conjugation by creating smaller parts of dye molecules.[158] This results in colour change and/or colour loss, which is seen in fading.[159] In some instances, like the process of photosensitization, the excited dye molecules can interact with the fibres.[160] This causes both the dye and the fibre to undergo photochemical degradation, which causes fading of the dye and weakening of the fibres. These photochemical processes affect both the visual appearance and the chemical structure of the dye. The latter can only be seen through analytical methods, such as dye analysis.

The amount of time it takes for fading to occur differs depending on the dye, however, Giles suggests that most synthetic dyes follow a similar fading curve.[161] Within this fading curve the initial fading rate is quite quick and then becomes steady.[162] Investigations into fading have shown that a variety of factors other than

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[154] Tímár-Balázsy and Eastop, 88-89.
[155] Ibid.
[156] Ibid.
[157] Brill, 184.
[158] Ibid.
[159] Ibid.
[160] Tímár-Balázsy and Eastop, 88-89
[161] Giles, 15.
[162] Giles, 15.

light affect fading. The presence of oxygen, relative humidity and pollutants can also accelerate photochemical reactions [163]

4.5 What can museums do?

The aim of the museum environment is to minimize potential risks to the long-term preservation of objects. As light is essential in viewing textiles it is not something that can be taken away. Instead, any natural and artificial light sources are monitored and filtered to remove UV. The amount of UV present in light is measured in microwatts of UV radiation per lumen (μW/l), or quantity of visible light.[164] The intensity of the light is controlled and measured in lux. As a rule light sensitive objects, such as textiles, are to be exposed to prolonged light exposure of no more that 50 lux.[165] Stable relative humidity and temperature, along with air filtering are also done to assist in minimizing the potential for fading reactions to accelerate.

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[163] Mills and White, *The Organic Chemistry of Museum Objects*. 2nd ed., 155-156.

[164] Pasty Orlofsky, "Textile Conservation," in *Conservation Concerns: A Guide for Collectors and Curators*, ed. Konstanze Bachman, 79-83 (Washington: Smithsonian Institution Press, 1992), 80.

[165] Ibid.

Part II: Experimental Case Study

Chapter 5: Experimental set up

5. Introduction

This section consists of the experimental methodology that was used to address the research question and aims in chapter 1. Using basic magenta as a case study the following experiential methodology was utilized to assess its fugitive properties:

- The creation of silk and wool basic magenta dyed model test fabrics to assess the colour and chemical changes.

- Silk and wool model test fabrics were placed in six different lighting environments that were reflective of real world examples of where textiles may be viewed, stored, examined, and displayed. The impacts of these lighting environments were assessed to evaluate colour and chemical changes in real time over a six-week period. This was done through:

    - Weekly recordings of perceptible and numerical colour changes both through visual examination and a Spectrophotometer.

    - Undertaking analysis of the dye chemical profile to assess chemical changes to the dye composition.

5.1 Model test fabrics

Wool and silk basic magenta dyed model test fabrics were created at the Centre for Textile Conservation (CTC) to be used to assess colour and chemical changes to basic magenta when it is exposed to a number of different light sources.

5.1.1 Fabrics

Undyed plain woven silk and wool were chosen for this study. 5g of medium weight silk haboui and 20g of volatie fine wool were used. As explained in chapter 3 wool and silk (proteins) have a natural affinity to basic dyes due to its ability to attach to the acid sites within the protein fibre.

5.1.2 Dye

A commercially available basic magenta dye (Cl.42510) was obtained from Kremer pimente GmbH & CO KG. A commercially available dye was chosen, as a historic sample was not available. One depth of shade was used. A recipe for "mid shade" magenta was used as per the quantities set out in Smith's dye manual.[166]

A full account of the dyeing preparations can be found in appendix 2.

5.1.3 Model test sample preparation

Six 75mm x 45mm rectangles of each model test fabrics were cut using a template. The model test fabrics were then attached into a sample holder, which was a piece of acid free card for backing to hold the sample in place and to hide a small section from the light. This was then held together with a piece of *Tyvek*® tape. Each holder was labeled according to its lighting scenario (section 5.5).

5.2 Lighting scenarios

5.2.1 Introduction

To answer the research questions and aims set out in chapter 1, six different light scenarios were chosen to mimic a variety of real world lighting scenarios that textiles may be examined, treated, and displayed in within museum or other heritage institution. These lighting environments were a range of fluctuating and static UV filtered and unfiltered natural and artificial lighting conditions with a range of areas in the CTC and Kelvingrove Museum and Art Gallery. Monitoring was conducted during the experiment and it can be found in section 5.3.

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[166] Smith, 125.

5.2.2 Lighting scenario 1: Workroom 1

Lighting scenario 1 was a bench in a conservation workroom on level 3 at the CTC and was a likely environment in which textiles may be examined and treated in. It was exposed to both UV filtered diffused natural from a window and filtered fluorescent artificial light.

5.2.3 Lighting scenario 2: Workroom 2

This lighting scenario was a conservation workroom on level 3 at the CTC and was a likely environment in which textiles may be examined and treated. It was exposed to UV filtered fluorescent lighting.

5.2.4 Lighting scenario 3: Windowsill

The lighting scenario was a windowsill in a teaching room on level 5 at the CTC. This area was used to provide a ‘worst case scenario’ example of colour and chemical changes as this area was exposed to unfiltered diffused natural light through a window.

5.2.5 Lighting scenario 4: Office

This lighting scenario was an office located on level 3 at the CTC and is a possible environment in which a textile may be viewed or stored. This environment was exposed to a mixture of both unfiltered natural and artificial light.

5.2.6 Lighting scenario 5: Dark store

This lighting scenario was an open shelf in the reference collection storage area on level 3 at the CTC. This area is generally in darkness unless being accessed then it is exposed to UV filtered artificial light. Spot readings were taken to determine the strength of the lights and then a manual log was used to track when the lights were turned on during the experiment.

5.2.7 Lighting scenario 6: Exhibition space

This lighting scenario was an exhibition space within the Scottish Identity Gallery on the second floor of the Kelvingrove Art Gallery and Museum and was a likely space a textile may be exhibited in. In this area there were a range of different objects on display such as: 18th century tartan textiles, paintings, and a range of metal objects. This area is exposed to UV filtered artificial light during opening hours. A spot reading was taken to determine the strength of the lighting.

5.2.8 Lighting scenario 7: Outside

This lighting scenario was the windowsill in my personal residence. This lighting scenario was used to evaluate the prolonged exposure of basic magenta to sunlight. This lighting scenario was initially used as a test, but it provided some interesting maximum fading results so it was included. Only wool was used.

5.3 Monitoring

Over the six week period of the experiment, a variety of monitoring was undertaken to evaluate the strength and amount of the light, presence of UV in light sources, spectral make up of the light sources, and where possible temperature and relative humidity (equipment availability). As the experiments were conducted in real time in real working environments they were subject to fluctuations in the amount and duration of exposure of lighting. For this reason it was not possible to calculate the exact exposure to light. However, the minimum and maximum lux and UV values, relative humidity and temperature (when available) are summarized in the below table. Spectral graphs of the light sources were also taken to assess if there were any wavelength spikes within the light sources. All monitoring data collected can be found in appendix 3.

	Light source	**Lux (min/max)**	**UV (min/max)**	**RH/temp (min/max)**	**Spectral data**
Scenario 1: Workroom1 * This area was monitored using a Hanwell ML400 Lux/UV LuxBug.	Fluorescent (artificial) and diffused natural light	0/1324 lux	0 detected by lux bug.	RH 34.9/67.4% Temperature 18.9/27°C	Intense peaks at 550nm and 620nm.
Scenario 2: Workroom 2 * This area was monitored using a Hanwell ML400 Lux/UV LuxBug.	Fluorescent (artificial)	0/ 580 lux	0 detected by lux bug	Not measured	Intense peaks at 550nm and 620nm.
Scenario 3: Windowsill *This area was monitored weekly using a Elsec hand held monitor as LuxBug does not go abouve 5000 lux.	Unfiltered natural light (diffused through window glazing)	3675/6295 lux	212/430μW/L	July 19th-26th RH 27.4/70.5% Temperature 19/37°C	A broad peak between 350nm and 750nm. Maximum peak height between 500nm-600nm
Scenario 4: Office * This area was monitored using a Hanwell ML400 Lux/UV LuxBug.	Unfiltered natural (diffused through	0/739 lux	0 detected by lux bug	Not measured	Broad peak with only small intensity of light.
Scenario 5: Dark store	Mainly no light	0 –when light off/ 580 lux when on.	0 detected when lights off/on	Not measured	Not measured
Scenario 6: Exhibition Space	Halogen- Track Lighting: Havells Sylvania Torus 100FX fitted with Sylvania 12V 100W GY6.35 UV Stop Capsule Axial Filament lamp	90 lux	0 UV detected with hand held	Not measured	Not measured

Table 5-1 Summary of lighting conditions.

5.4 Experimental time line

The experiment was conducted over the course of a six week period between June13- July 26. Once a week the samples were accessed for their perceptible colour changes, numerical colour values taken using a spectrophotometer, and a sample removed for dye analysis. The schedule can be found in appendix 4.

5.5 Sample names

All samples were named according to their lighting environment, which are highlighted in the table below.

Lighting Environment	**Silk**	**Wool**
Scenario 1: Workroom1	S1	W1
Scenario 2: Workroom 2	S2	W2
Scenario 3: Windowsill	S3	W3
Scenario 4: Office	S4	W4
Scenario 5: Dark store	S5	W5
Scenario 6: Exhibition Space	S6	W6
Scenario 7: Outside		W7

Table 5-2 Sample names according to lighting scenario.

Chapter 6: Colour Change

6. Introduction

The aim of this chapter is to evaluate colour change in the silk and wool samples before, during, and after exposure to various lighting scenarios outlined in the previous chapter.

Each week any colour changes were observed by assessing both visual perceptible changes and numerical colour changes. Perceptible colour changes were observed using the naked eye and recorded on a sheet that can be found in appendix 5. The numerical colour changes were observed using a Konica Minolta CM-2600d spectrophotometer (8 mm aperture, 10° viewing angle, 100% UV, D65/SCI illumination).[167] This Spectrophotometer records colour numerically, as each colour has a unique set of numerical values it is possible to assess colour change this way. Numerical values are assigned using a system called Commission Internationale de l'EclairageLAB or CIE L* a* b* colour space, where L* a* b* values correspond to specific shifts in colour.[168]

The L* is the darkness and lightness value of a colour where 0=black and 100=white. If the numerical difference between two values is closer to 100 this means the sample has become lighter. a* and b* values are responsible for the hue. a* is the balance between green and red. If the numerical shift between two values is positive this indicates a shift towards red and a negative shift indicates a shift towards green. b* is the balance between yellow and blue. If the numerical shift two values is positive this indicates a shift towards yellow and a negative indicates

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[167] "CM-2600d Spectrophotometer," Konica Minolta, http://sensing.konicaminolta.asia/products/cm-2600d-spectrophotometer/ (accessed August 1, 2016); The Spectrophotometer was borrowed from Glasgow Museums.

[168] N.S. Gangakhedkar, "Colour measurement methods for textiles," in *Colour Measurement: Principles, Advances, and Industrial Applications*, ed. M.L. Gulrajani, 221-252 (Cambridge: Woodhead Publishing, 2010), 224.

a shift towards blue. A visual illustration of the CIE L* a* b* system is illustrated in figure 6-1.

Figure 6-1 Visual illustration of the CIE L* a* b* colour system.[169]

The CIE L* a* b* system of measuring colour change has been a common way of measuring colour changes in historic textiles to assess the performance of treatment methods.[170] In 1999, Ford conducted a study monitoring color changes in a range of Asian textiles on temporary display.[171]

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[169] "Colour Perception," e-Flexoglobal, http://www.flexoglobal.com/flexomag/08-September/flexomag-ploumidis.htm (accessed August 10, 2016).

[170] Tímár- Balázy and Eastop, 87; Deborah Bede, "Methodology of Colour Measurement of Historic Textiles," in *The Textile Specialty Group of the American Institute for Conservation of Historic and Artistic Works 1993 Postprints*, ed. Catherine McLean, 19-27 (Washington: American Institute for Conservation of Historic and Artistic Works, 1993).

[171] Ford, 1-11.

6.1 Experimental

Each week three readings were taken of each sample through a template to ensure that the same area was being measured. Prior to taking measurements, the spectrophotometer was calibrated against the supplied white tile.

6.2 Results and discussion

The measurement results were entered into an excel spreadsheet and the average and standard deviation for each measurement calculated. Changes in the L* a* b* and overall colour change (ΔE) were calculated to evaluate the changes week to week along with the changes in the initial vs. final experimental week readings. Only the initial vs. final week readings will be discussed as they hold the most significant results. All data collected was collected and calculated and can be found in appendix 6.

After the experiment the model test fabrics were retained and they can be found in appendix 6 and visually in figure 6-2 and 6-3.

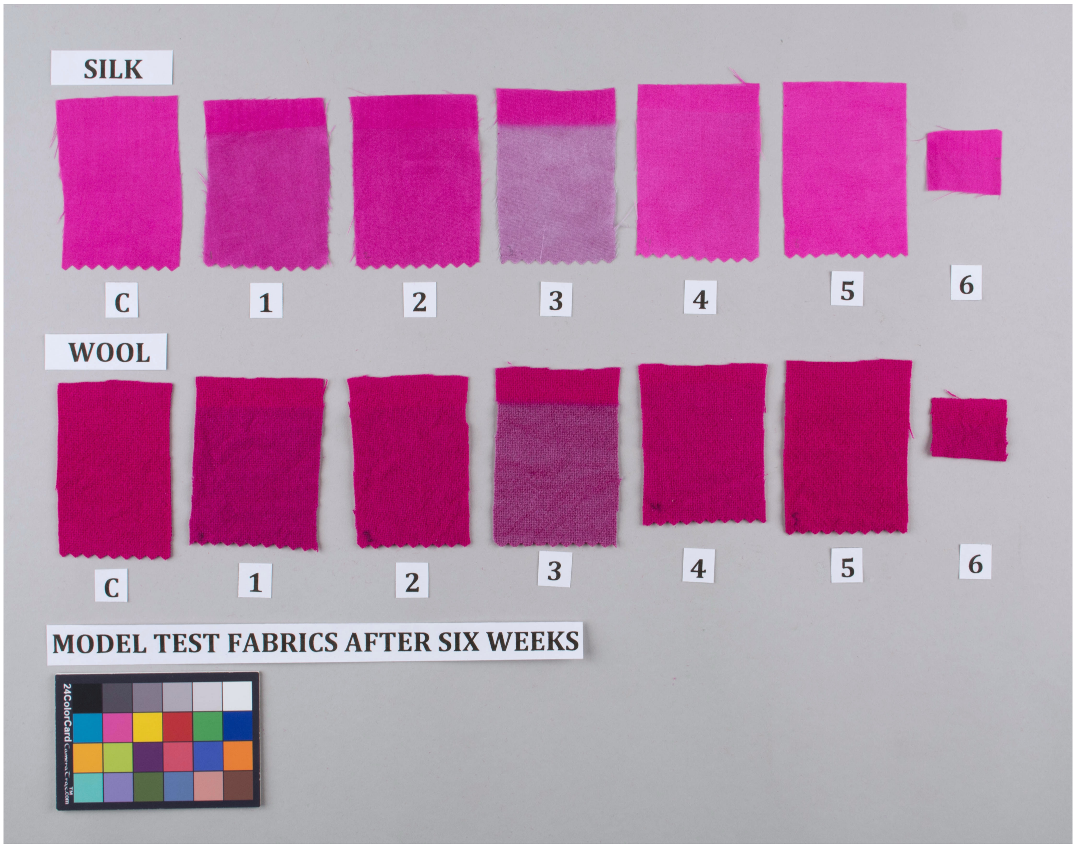

Figure 6-2 All samples after experiment.

Figure 6-3 W7 sample after experiment.

6.2.1 Changes in L* a* b*

The changes in the L* a* b* values were assessed to determine if and how the magenta samples changed over the course of the six week experiment. L* a* b* changes were calculated as follows using L* as an example where wk1 represents the first week compared the following week, etc.[172]

$$\mathbf{\Delta L^*} = L^*_{wk1} - L^*_{wk2}$$

6.2.2 Changes in L* values (ΔL*)

Out of the silk samples only S3 showed a L* change starting at 45.15 and ending on 57.51, which is an overall change of ΔL* 12.36. The shift towards a higher value indicates that the sample is getting lighter/whiter (figure 6-4). This was also observed during the weekly readings. In contrast to the silk, W1 (ΔL*1.8) became lighter and W3 became darker (ΔE-1.47). The samples that have turned lighter were likely due to colour change as a result of a photochemical degradation process.[173]

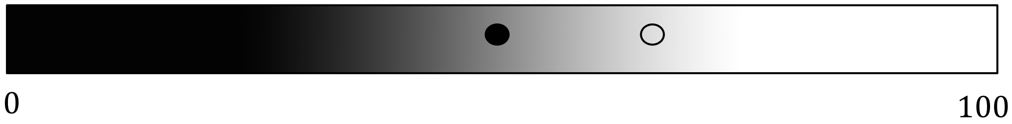

Figure 6-4 Visual illustration of the change in L* values in S3 between initial (●) and end (○) L* values.

6.2.3 Changes in a* values (Δa*)

All silk and wool samples exposed to light exhibited increasing –a* values, indicating a colour shift to green. Magenta has been described as being a red-blue colour. Basic colour theory illustrates that if two complimentary colours are mixed together they begin to dull and the complimentary colour is green.[174] Dullness of

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[172] Tímár-Balázsy and Eastop, 86.

[173] Brill, 178-181.

[174] "Complimentary Colours," Colour Artist Wheel, http://color-wheel-artist.com/complementary-colors.html (accessed July 29, 2016).

S1, S3, W1, and W3 was observed in the visual assessments during the course of the experiments. Below is a table highlighting the changes in a* values for each sample.

Area	Sample	Δ a*	Sample	Δ a*
Workroom 1	**S1**	11.01	**W1**	2.65
Workroom 2	**S2**	4.29	**W2**	0.94
Windowsill	**S3**	51.81	**W3**	20.4
Office	**S4**	5.11	**W4**	0.72
Exhibition Space	**S6**	4.83	**W6**	0.22
Outside			**W7**	60.81

Table 6-1 Table highlighting the Δa*[175]

S3 and W3 showed the highest amount of change. This change is likely caused from exposure to unfiltered UV as UV light has enough energy to break down and change both the chromophores and auxochromes in the dye.[176] Most concerning of all are the changes in the remainder of the silk samples that were exposed to a filtered artificial light source as this shows that irreversible colour change can happen to basic magenta in visible light.

6.2.4 Changes in b* values (Δb*)

One silk sample (S3) exhibited a change in its b* value. This value was positive indicating that the sample had shifted towards yellow. This sample had been exposed to unfiltered natural light which contains both UV and visible light. Silk is highly susceptible to damage from exposure to electromagnetic radiation, particularly UV.[177] The amino acids present in the silk absorb electromagnetic radiation around 220-370nm, which are in the ultraviolet range.[178] It is likely that the yellowing in S3 is from a coloured degradation product from the silk rather than a colour shift in the dye. The wool sample W7 also showed negative b* change.

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[175] The S5 values were deemed not significant based on the standard deviations.

[176] Tímár-Balázsy and Eastop, 89.

[177] Tatiana Koussoulou, "Photodegradation and photostabilization of historic silks in the museum environment- evaluation of a new conservation treatment," *Institute of Archeology*, 10 (1999): 77-78.

[178] Tímár-Balázsy and Eastop, 45.

This sample was observed to have become very light with little dye remaining (Figure 6-3). This sample was also exposed to high amounts of natural light. It is possible that the –b* value shift is due to the break down of the wool rather than a product of the dye break down. Wool samples W1, W2, W3, W4, W6 all showed negative changes in their b* values which indicates a shift in their blue values. Darkening in these wool samples was noted in the weekly observation.

6.2.5 a* and b* changes

Plotting the a* and b* values on a colour saturation graph visually illustrates the colour shifts in the magenta samples after exposure to light. Figure 6-5 illustrates the colour change in S3 and W3, showing that over the course of the experiment they have become duller and have shifter to a more neutral colour. Black= initial and white= end of experiment.

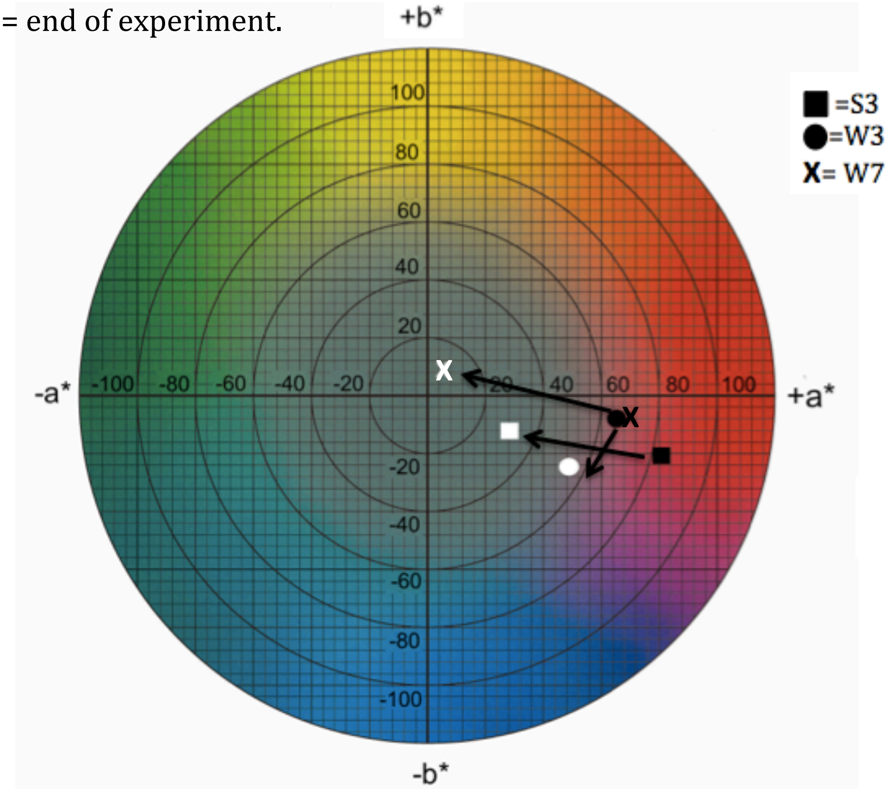

Figure 6-5 Showing the relationship between a* and b* changes and colour change. Image modified from Lumen Technology.[179]

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[179] "CIELAB Colour Space," Lumen Technology, http://sscolor.com/newsshow.asp?sid=29&id=159 (accessed August 2, 2016).

6.2.5 Overall colour change ΔE

The overall change (ΔE) was also calculated to determine which samples shifted the most during the course of the experiment. The ΔE was calculated for each sample using the initial and final values using the follow equation.[180]

$$\Delta E = \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2}$$

Both silk and wool samples were exposed to light during the experiment exhibited some shift in colour change. The silk showed a higher rate of overall change than the wool and this is illustrated in the graph in Figure 6-6. This difference between the wool and silk may be due to the changes in the chemical properties of the fibre rather than the dye. When dyes areas taken in and absorbed within the fibre they do so in the amorphous regions of the fibre.[181] Wool is more amorphous than silk, therefore, wool had a greater potential to absorb dye during the dyeing process.[182]

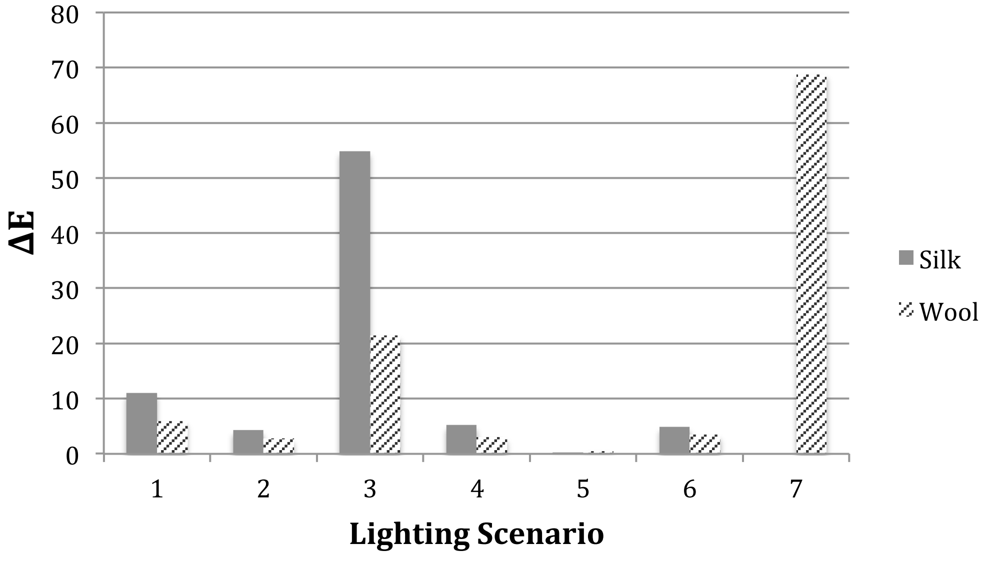

Figure 6-6 Graph illustrating colour ΔE colour change in wool and silk.

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[180] Tímár-Balázsy and Eastop, 86.

[181] E.P.G. Gohl and L.D. Vilensky, *Textile Science: An Explanation of Fibre Properties* (Melbourne: Longman Cheshire Pty Limited, 1983), 82.

[182] Gohl, 82.

Several studies have been conducted investigating ΔE values and their relation to both perceptible and acceptable colour changes in museum objects, specifically to works on works of art.[183] Ashley Smith, et al reported that a change of ΔE 2 is detectable to humans.[184] Recently, Richardson and Saunders conducted an experiment using digitally manipulated images and asked participants to rank what levels of change they found "acceptable."[185] Their preliminary investigation showed 60% of responders felt that a change of Δ4 over a 100 year period is acceptable.[186] The ΔE values for the textile samples exposed to light were between ΔE4.30-54.9 and wool ΔE2.80-21.5 over the course of a six-week period. All samples exposed to light had perceptible change, and based on the preliminary findings of Richardson and Saunders this is could be said to be unacceptable. However, more works is required to determine if these values can be directly applied to textiles.

6.3 Conclusion

The aim of this chapter was to investigate the colour changes of magenta dyed silk and wool in different lighting environments. Observations were recorded using both visually and with a spectrophotometer. Ultimately, the results generated from this chapter demonstrated:

- All silk and wool samples exposed to light showed some kind in either their L*, a*, b* value or a combination of some of these values.

- Silk samples had significant shifts in their a* which is a shift in the green values. They also appeared duller.

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[183] Roxana Rădvan, et al. "Contemporary Art Materials Tests," *International Journal of Conservation Science*, vol. 4 (2013): p. 613-620.
[184] Jonathan Ashley Smith et al., "The continuing development of a practical lighting policy for works of art on paper and other types at the Victoria and Albert Museum," in *ICOM CC 13th Triennial Conference 2002 Preprints*, ed. Roy Vontobel, 3-8 (London: James & James, 2002), 5.
[185] Clare Richardson and David Saunders, "Acceptable Light Damage: A Preliminary Investigation," *Studies in Conservation*, vol. 52, no. 3 (2007): p. 183.
[186] Richardson and Saunders, 183.

- S3 exhibited a positive change in the b* values, which meant the sample, had begun to shift towards yellow. This is likely to be formation of silk degradation products from exposure to high amounts of UV, which can appear yellow as they degradation. This was also seen in the W3 wool sample. The wool samples were visually observed to get darker during the course of the experiment.

- Negative changes in both the a* and b* values meant that the samples were becoming more green and blue respectively. The silk samples appeared to have faded more than the wool samples and is likely due to the chemical structure of the wool being more amorphous than the silk.

- The observed colour changes for the samples exposed to natural light, particularly S3 and W3, appeared to mimic the colour changes for magenta recorded by Crookes in 1874.[187] The wool sample W7 that was exposed to direct sunlight could objectively be noted as the faded 'mushroom' colour suggested by Mills and White.[188] This may be because the front had faded leaving some colour behind, particularly on the back (Figure 6-3).

- Overall, this chapter showed that the effect of the light has impacted the chromophoric system within the molecule causing it to change in some way.

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[187] Crookes, 660.

[188] Mills and White, *The Organic Chemistry of Museum Objects*, 2nd ed., 153.

Chapter 7- Dye analysis

7. Introduction

This chapter investigated the chemical changes to the magenta dyed model test fabrics after they have been exposed to light. As explained in chapter 3 light has the ability to cause photochemical degradation leading in a break down of the chrompohoric system. This means that new, often shorter molecules are made, which can lead to new coloured and non-coloured products being formed. These changes can be seen in the dye chemical profile, which is gathered using ultra high performance liquid chromatography (UHPLC) coupled with photo diode array detection (PDA).

UHPLC is a technique that is able to separate components of a mixture for identification. Since dyes and their degradation products are a unique combination of components separating them allows for these components to be identified.[189] Positive identification of synthetic dyes in historic textiles relies on the comparative analysis of reference samples.[190] For this project the unexposed magenta model test sample will be compared against the samples taken from the exposed model test fabrics. They will be compared against one other and evaluated the results the chemical changes to the dye, if any.

7.1 Ultra High Performance Liquid Chromatography

As stated above, UHPLC is a technique that is able to separate out components of mixtures in order to identify them. This technique utilizes both a mobile and stationary phase.[191] The mobile phase is usually a solvent or ranges of solvents also called eluents.[192] The stationary phase generally consists of a column packed

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[189] Barbra Stuart. *Analytical Techniques in Materials Conservation* (West Sussex: John Wiley & Sons Ltd, 2007), 317-318.
[190] Ibid.
[191] Han, 98-100;
[192] Stuart, 316-317.

with porous polymer particles for separation. In UHPLC, these particles are between 5μm to sub -2μm in size, which allows for a finer separation of the components than traditional HPLC.[193] Analysis of dyes was done at the CTC using a Waters® ACQUITY UPLC® H- class system. This system is composed of a solvent and sample manager flow through needle, a column manager, and a PDA detector.

To be analyzed within the system the dye is extracted from the fibre. The extracted dye sample is injected into the mobile phase and then pumped using high pressure through the stationary phase.[194] A number of different mobile phases can be utilized to obtain the best possible separations.[195] For this particular dye analysis reversed phase ultra high performance liquid chromatography (RP-UHPLC) was utilized as it is able to separate a wide variety of compounds and is therefore the most commonly employed.[196]

RP-UHPLC utilizes a non-polar stationary phase and a polar mobile phase. The non-polar stationary phase is hydrophobic thus attracting the hydrophobic parts of the sample, where as, the polar mobile phase is hydrophilic thus attracting the hydrophilic parts of the sample.[197] A gradient elution system within the mobile phase may also be used as this allows for the polarity of the solvent to be changed throughout the analysis.[198] The use of a gradient elution program additionally allows for a specific system run time to be used, which can be useful when analyzing a compound that contains wide number of components.[199]

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[193] Han, 100.
[194] Han, 98-100; Stuart, 316-318.
[195] Serban Moldoveanu and Victor David, *Essentials in Modern HPLC Separations* (Massachusetts: Elsevier, 2013), 9.
[196] Moldoveanu and David, 9.
[197] "HPLC Separation Modes," Waters, http://www.waters.com/waters/en_GB/HPLC-Separation-Modes/nav.htm?cid=10049076&locale=en_GB (accessed August 2, 2016).
[198] Moldoveanu and David, 6
[199] Ibid.

The amount of time a component from the sample takes to separate through the column and pass onto the detector is known as the retention time. A number of different detectors can be used. The detector the CTC utilizes is a photodiode array detection (PDA), which is a specialist detector for coloured compounds. This technique allows the separated components of the sample to be detected using ultra violet and visible spectra (UV-vis) from 190nm-800nm.[200] PDA can also detect colourless peaks, which can be used to identify non-coloured products within the compound.[201] The retention time along with the results from the PDA allow for unknown components to be measured against known samples in a reference library.[202] The use of the reference database was not used for this project as the unexposed silk and wool samples were used as reference.

The results generated from the PDA are plotted on a graph known as a chromatogram. The x-axis highlights the retention time in minutes for each component in the sample. The y-axis shows the absorbance intensity at the specified wavelength. Below is a chromatogram of magenta silk reference sample at 560nm (figure 7-1) magenta has four main components that elute at 13.03, 13.10, 14.55, and 15.54 minutes.

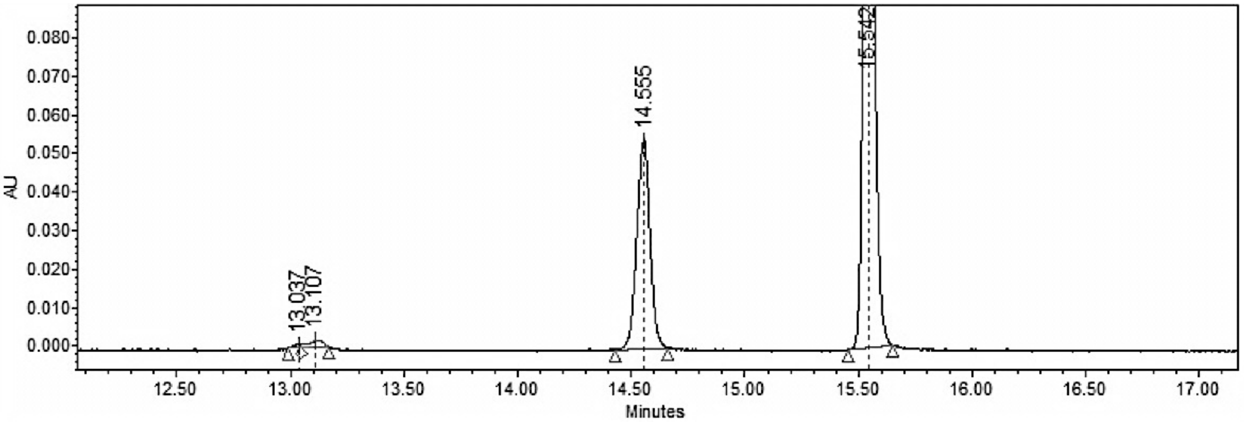

Figure 7-1 Chromatogram showing main components of magenta dyed silk at 560nm.

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[200] Han, 101

[201] Ibid.

[202] Stuart, 318.

7.2 Experimental

A small 2mm x 2mm sample was removed from the model test fabric each week, and to highlight the lighting scenarios with the greatest chemical change, a decision was made to compare the unaged reference samples with the final week samples by UHPLC-PDA.[203]

Sixteen samples were prepared for UHPLC-PDA by extracting the dye from the fibre so it can be injected into the column. The extraction was undertaken using the two step process used at the CTC which involved 75µl DMSO (dimethyl sulfoxide) and 50µloxalic acid solution (0.5M oxalic acid/acetone/water/methanol (1:30:40:30 (v/v/v/v)). The step-by-step instructions for the method used for dye extraction can be found in appendix 8.

The 16 extracted samples were placed in the sample manager and run through the Waters® ACQUITY UPLC® H- class system on 40 minute auto program. This process was supervised by Dr. Jing Han, a postdoctoral researcher at the CTC. Experience with the UHPLC-PDA at the CTC has shown that a 40-minute elution program of 10% aqueous methanol, pure methanol, and 1% aqueous formic acid gives good separation.[204] The particulars of the program can be found in appendix 9.

After the samples were processed the Empower™ software was used to extract chromatograms at 254nm, 350nm, and 560nm with a resolution of 1.2 nm.[205] These wavelengths were chosen, as 254nm is able to detect the generic aromatic structures that are present in both non-coloured and coloured compounds. 350nm

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[203] The samples for the remaining weeks were retained for future research (CTC Project Code 2016.05).

[204] Han, 118-119.

[205] "Empower Software," Waters, http://sites.chem.colostate.edu/diverdi/C431/experiments/high%20pressure%20liquid%20chromatography/references/Empower%20getting%20started%207150 0031203rA.pdf (accessed August 2, 2016).

also shows colourless products but contains less of the peaks from the solvents in the mobile phase. 560nm is it the maximum wavelength absorption of magenta.[206] No extra characteristic components were observed during the examination at 350mn, so it was not included in the results and discussion section below. The chromatogram of retention time between 5 and 28 minutes was integrated as all pertinent peaks were eluted in this timeframe, after the mobile phase solvent front between 0-5 minutes.

7.3 Results and discussion

7.3.1 Silk

At 560nm the chromatograms of the silk magenta samples were compared against one another and the main elution peaks at 13.03, 13.10, 14.55, and 15.54 minutes were found within all samples. However, a decrease in peak sizes was observed. This may be an indication that there is less dye in the sample.

The formation of a new coloured peak at 15.7 minutes was observed in all samples that were exposed to light. The maximum absorptions for this peak were between 560-565nm can be found the below table 7-1.

Area	Sample	Maximum absorption
Workroom 1	S1	560nm
Workroom 2	S2	565nm
Windowsill	S3	562nm (Figure 7-2)
Office	S4	559nm
Exhibition space	S6	560nm

Table 7-1 Maximum absorption wavelengths of the new peak found at 15.17min in all silk samples exposed to light.

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[206] Han, 244.

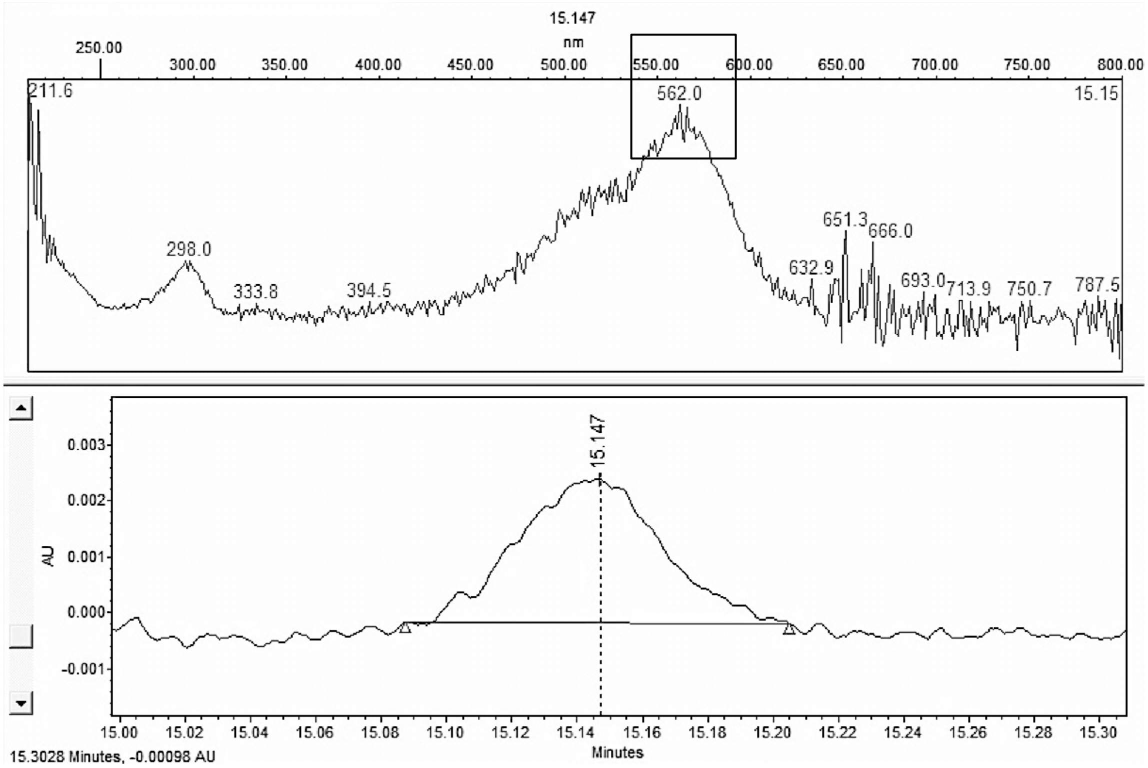

Figure 7-2 Maximum absorption of peak S3 peak at 562nm. Spectral graph top and chromatogram at bottom.

At 254nm the reference sample was observed to have a range of peaks missing along with the formation of several new peaks. A peak eluting at 7.80 minutes was observed in the reference sample, however this peak was missing in all samples that had been exposed to light. Additionally, a peak at 8.91 was observed in the reference sample that is present in samples aside from S3. In samples S1 and S2 there is a wide and board peak at 11.39. The purity angle is much higher than the threshold meaning that this may be a co-elution with another component.[207]

S3 was also observed to have a range of 5 new peaks between 6.80 and 7.68 minutes. S3 was exposed to natural light containing a large amount of UV, which is likely to have caused both photochemical degradation to the dye and the fibre

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[207] Han, 119.

through photo-sanitization.[208] It is possible these peaks may correlative with the protein break down of silk substrate or may be a component of the dye.

7.3.2 Wool

At 560nm the chromatograms of the silk magenta samples were compared against one another the main elution peaks at 13.03, 13.10, 14.55, and 15.54 minutes were found within W1, W2, W3, W4, and W6. However, a decrease in the peak size in all samples exposed to light was observed.[209] In W7 the elution peaks at 13.03 and 13.10 are missing completely and the peaks at 14.55 and 15.54 were observed to be significantly smaller (Figure 7-3). The decreased peak size and in particularly in W7 the missing peaks are an indication that there is a loss of colour within these samples.

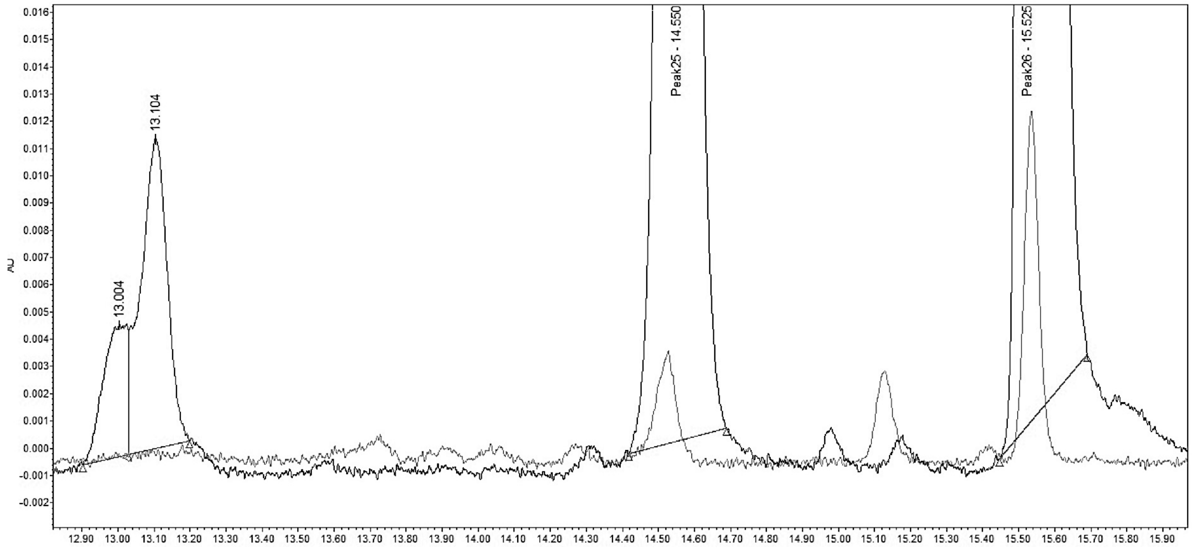

Figure 7-3 Figure showing significant decrease in peak height between reference sample and W7. Black lines indicate reference sample and grey indicates sample W7.

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[208] Tímár-Balázsy, 90.

[209] Wool reference sample was processed in different batches and their retention times differ slightly.

W3 was observed to have gained several new small coloured peaks at 13.70, 13.90, and 14.80 minutes. These peaks have a maximum absorption between 560nm and 565nm. Like the silk samples a new peak at 15.17 minutes observed in all wool samples exposed to light. The maximum absorption of each of these new peaks were examined to and indicate that there name be a small shift towards the blue part of the visible spectrum. These values can be found in table 7-2.

Area	**Sample**	**Maximum absorption**
Workroom 1	W1	559nm
Workroom 2	W2	559nm
Windowsill	W3	565nm
Office	W4	555nm
Exhibition space	W6	559nm
Outside	W7	565nm

Table 7-2 Maximum absorption wavelengths of the new peak found at 15.17 in all wool samples exposed to light.

At 254nm the main elution peaks within the samples exposed to light were observed to be much lower. Elution peaks at 14.95, 16.50, and 17.50 minutes within the reference sample were missing in all samples exposed to light.

W3 has a new peak formation at 15.15 minutes. Like the silk sample S3, W3 has formed 5 new peaks at 6.80 and 7.68 minutes. W7 also has these peaks, however, at 254nm they have a much higher absorbance (Figure 7-4). Given that these new peaks exist in the samples that have been exposed to high amount of unfiltered ultraviolet and visible light and sample W7 has little remaining colour it is likely that these peaks are degradation products.

7.3.3 Silk and Wool

When comparing the results generated from the silk and wool samples exposed to light at 560nm all showed lower in the main elution peaks and in some cases, as in W7, several of the main elution peaks were missing. At 560nm is the maximum absportion of magetna and thereofre at this wavelegnth the colour components could be seen. In both silk and wool samples exposed to light at new peak at 15.17 was formed. The decreasing, missing peaks, and new peak could indicate that there has been in a change in the amount of dye present in the sample compared to that of the reference sample. This is likely to have been caused from a decrease or in the chromophoric system caused by photochemical degradation.

In sample S3, W3, and W7 at 254nm new peaks at 6.80, 6.90, 7.51, 7.60, and 7.68 minutes were formed. As they exist in all samples exposed to uv light is possible that the formation of these colourless peaks are due to the break down of the protien fibres. Considering that W7 has hardly any dye left it is likley that is is the substrate.

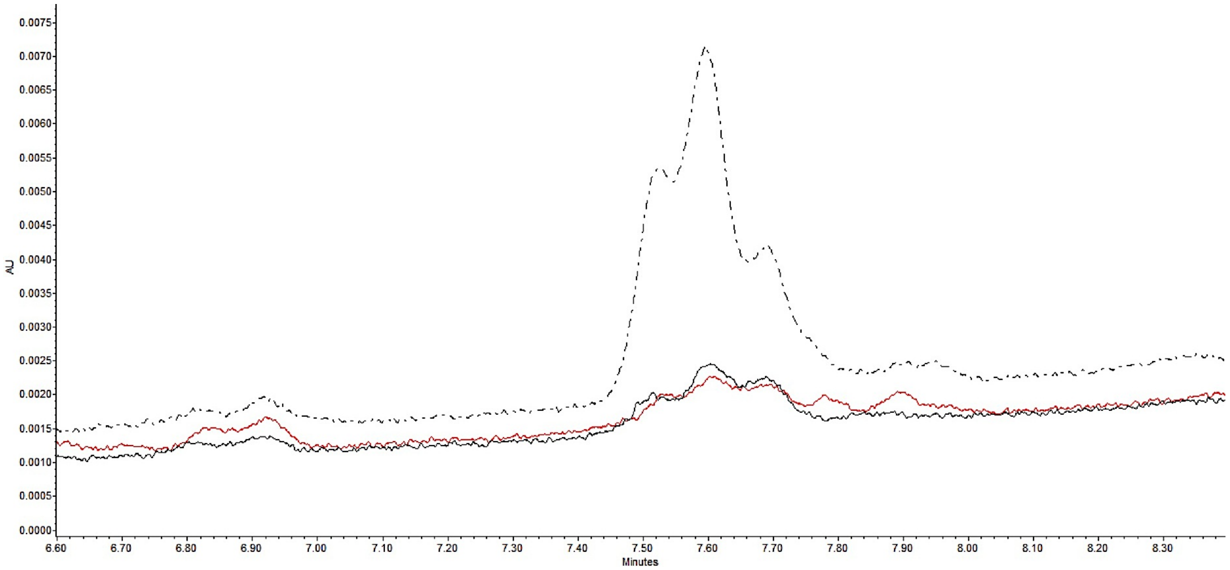

Figure 7-4 Chromatogram at 254nm showing the range of new peaks between 6.80 and 7.68 minutes. Grey dotted line W7, W3 black line, and S3 is red line.

7.4 Conclusion

The aim of chapter 7 was to investigate the chemical changes to the magenta dyed silk and wool samples before and after exposure to light using UHPLC-PDA. Dyes were extracted from each sample using a 2 step extraction process of 75µl DMSO and 50µloxalic acid solution. Samples were run through the Waters® ACQUITY

UPLC® H- class system and chromatograms at 254nm and 560nm were extracted using the Empower™ software.

Overall, both the silk and wool samples either show new, missing, or decreased peaks at both 254nm and 560nm. However, the identification of these products was outside the scope of this project. Ultimately, the results of the dye analysis show that when these samples are exposed to light it causes irreversible changes within the structure of the dye. This impacts not only the appearance of the dye, but has implications for the understanding of the chemical composition in historic textiles.

7.5 Colour change vs. chemical change

Results from the colour change (chapter 6) and chemical change (chapter 7) were compared to attempt to draw a correlation between the two. The following was found:

- Both silk and wool samples a* values shifted towards green. Within these samples a new peak at 15.17 at 560nm was also during dye analysis.

- S3, W3, and W7 all had significant changes in their ΔE values. Samples S3, W3, and W7 show the formation of a range of 5 new peaks at 6.80 and 7.68 minutes at 254nm. These areas were all exposed to high amounts of UV and could be break down products from the protein of the silk and wool.

It is possible that there may be a correlating relationship between colour change and chemical change, but more research is required to definitively say so.

Chapter 8- Conclusion

Magenta was first synthesized in 1858 and quickly became the most commercially successful synthetic dye. Magenta was first synthesized and classified as a 'basic' dye because of its positively charged (cationic) chemical structure. Historically, dyes from this class have been described as being incredibly light sensitive. Magenta has been recorded being bleached from a fabric in a matter of hours when exposed to sunlight. To date there has been no information addressing the fugitive properties of early aniline dyes within a museum environment. The research question of this dissertation was: will basic magenta fade and change chemical composition when exposed to various museum lighting environments? To address the research question the following four aims were created:

1. What are conservator and curator perceptions of the light-fastness early aniline dyes, specifically magenta?

2. Is magenta light sensitive to indoor lighting typical in a museum and conservation workroom setting?

3. Do indoor lighting environments cause magenta to fade and/or change colour?

4. What happens to the dye analysis profile of magenta when it is exposed to different lighting environments?

The first aim was to gather results from a questionnaire sent to a range of curators and conservators who are known to be working on projects that have worked directly with early aniline dyes. The results generated from the questionnaire showed that the curators and conservators contacted had a general awareness regarding the historic fugitive issues with early aniline dyes. However, the general consensus is that not enough information is known. The results from the questionnaire along with the literature review highlighted the need for this research.

To investigate if magenta was as light sensitive as historically described, six lighting scenarios were chosen to mimic likely lighting scenarios textiles may be exposed to during display, examination, and treatment. Silk and wool model test fabrics dyed with magenta were used to assess the impact of these light scenarios on colour and chemical change over the course of six weeks. These changes were evaluated using visual examination, a spectrophotometer, and dye analysis using UHPLC-PDA.

To examine the if indoor lighting environments cause magenta to fade and/or change colour visual examination and the use of a spectrophotometer was used. The results showed changes in all samples that were exposed to light. Silk showed a negative change their a* indicating a green shift. Whereas, wool showed a negative b*, indicating a blue shift. Overall, both wool and silk showed ΔE values of between 2.8- 51.81. Perceptible colour changes were observed throughout the course of the experiment in samples S1, S3, W3 and W7. All took on a bluer and duller appearance. Samples S2, W3, S4, W4, S6, and W6 were also found to have perceptible colour change, but not until they were removed for their sample holder.

To determine what happens to the dye analysis profile of magenta after light exposure, dye analysis was undertaken using UHPLC-PDA. Dyes were extracted from the fibres using a 2 step extraction process and run through the Waters® ACQUITY UPLC® H- class system. Chromatograms at 254mn and 560nm were extracted and assessed to observe both non-coloured and coloured components. Ranges of new peaks, along with missing and decreased peaks were observed. This indicates that all samples exposed to light under went irreversible chemical changes within the structure of the dye. However, it was outside the scope of this project to identify them.

The results of this dissertation show that magenta does undergo both a colour and chemical change when exposed to both UV and filtered visible light. What was most concerning were the changes in the model test fabrics that were exposed to visible light in areas what were concerned safe for textiles.

This adds another layer to an already challenging situation of trying to strike a balance between preserving a textile and providing access, whether it is for study, conservation treatment, or display. Knowledge and awareness that colour and chemical changes *will* occur in magenta within a museum workroom environment are the first steps in addressing the problem. The questions is, now that magenta is known to have the ability to fade in an indoor lighting environment, what can be done to minimize it? Should we 'let there be light'? More research is needed to address this, but perhaps it is time to take a step back and evaluate the lighting used within these spaces and develop protocols for exposure outside of display areas.

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Appendix 1: Synthetic Dye Questionnaire

My name is Michelle Hunter and I am a second year student in the MPhil textile conservation program at the University of Glasgow. I am currently completing dissertation research investigating the fading characteristics of an early synthetic dye. Historic literature has expressed that many early synthetic dyes fade quickly when they are exposed to light. However, this has been not been proven through scientific research. For this project the early synthetic dye Fuchsine (Magenta) was chosen. Fuchsine was discovered in 1858 and is an aniline derived direct dye that can be used to colour wool, silk, and cotton fabrics. The aim of this research project is to answer the following questions:

- Does Fuchsine fade quickly when exposed to light?
- What environment had the most impact on the dye?
- What happens to the dye molecule when it is exposed to light?
- What happens to the colour when it exposed to light?

These aims will be answered using an experimental methodology, which will involve the creation of model test fabrics, light fast testing, and analyzing the samples using dye analysis and colorimeter readings.

In order to gain an understanding how textiles dyed with early synthetic dyes are investigated, viewed, and displayed in a museum environment I hoping to gather information from museum professionals through a questionnaire. The following are the questions in the questionnaire.

1. What do you know about the fading of textiles dyed with early synthetic dyes?
2. How are early synthetic dyes identified in your museum/institution?
3. If a textile is found/thought to have been dyed with an early synthetic dye does this have an impact on its display?
4. If a textile dyed with an early synthetic dye is to be display, what are the lighting conditions?
5. Any other information you wish to add.

If you are interested in participating I have attached a copy of the questions and the consent to use data form required by the University of Glasgow. The questionnaire and signed consent form or any other queries can be emailed to 2128673H@student.gla.ac.uk. Alternatively I can arrange a time to contact you by telephone at your convenience. I am hoping to gather responses by Friday June 24, 2016.

Thank you for your involvement in this project.
Synthetic Dye Questionnaire
Dissertation Research

Name:
Museum/institution:

1. What do you know about the fading of textiles dyed with early synthetic dyes?

2. How are early synthetic dyes identified in your museum/institution?

3. If a textile is found/thought to have been dyed with an early synthetic dye does this impact display?

4. If a textile dyed with an early synthetic dye is to be display, what are the lighting conditions?

5. Any other information you wish to add.

Appendix 2: Dyeing of Experimental Model Test Fabrics

Model test fabrics for the experiment were created at the Centre for Textile Conservation in the chemistry lab on level 3. Silk and wool fabrics were used as magenta is a basic dye and has a natural affinity for proteins. Cellulose fibres require a mordant and this was not undertaken as a way of elevating variables.

Materials

- Plain woven silk habotai medium (5g)
- Plain woven Voltaire wool fine nautral (20g)
- Commerical fuchsin dye (Cl.42510) from Kremer pigmente. (**This dye is a known carcinogen. Read COSSH carefully before beginning).**

Method

Step 1: Glass wear was cleaned with ultrapure water and methanol to remove an possible contaminants.

Step 2: Samples were scoured in a solution of sodium bicarbonate (ph9) (Acros Organics 99.7 ACS reagent) in 800mL of ultrapure water (around 25 spoonfull). This was brought to a boil for 15 minutes. Samples were then rinsed with ultra pure water.

Step 3: Fuchsin dye (Cl.42510) Kremer pigmente GmbH &CO KG dyestuff was used. One depth of shade was used. A 'mid' shade magenta was chosen based on a recipe found in David Smith's practical dyer.[210] Silk and wool were dyed in different baths. 0.0125g of magenta dye powder was used for the silk and 0.05g of magenta dye powder was used to dye the wool. Each of these were then added to 800mL of ultrapure water.

Step 4: Dye was added to bath at 50°c and then filtered through cotton lawn.

Step 5: Dye bath was slowly heated to 60-70c. Fabric was put into the bath at 40-50. Placed in the bath for 40 minutes . Fabric quickly look up dye. Very little left in bath after approx. 10 minutes. All dye was exhausted after 40 minutes.

Step 6: Samples were rinse x4 using ultrapure water. Dye bath and all rinses were disposed of in non-cholorated waste.

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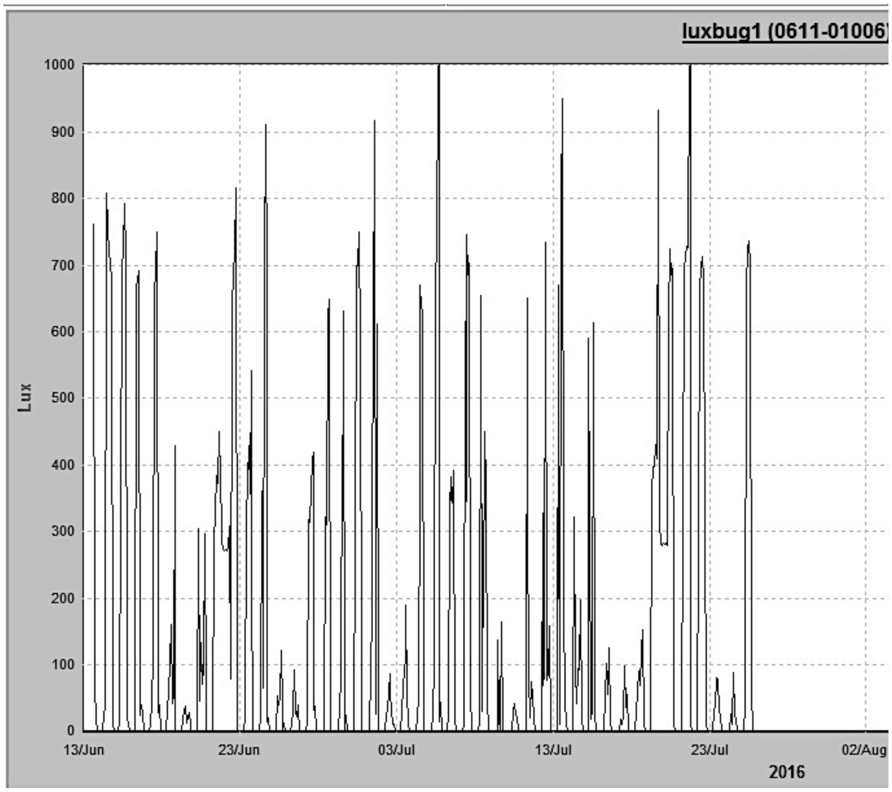
[210] David Smith, *Smith's Practical Dyer's Guide* (London: Simpkin, Marshall & Co, 1880), 125.

Appendix 3: Lighting Scenario Monitoring Data

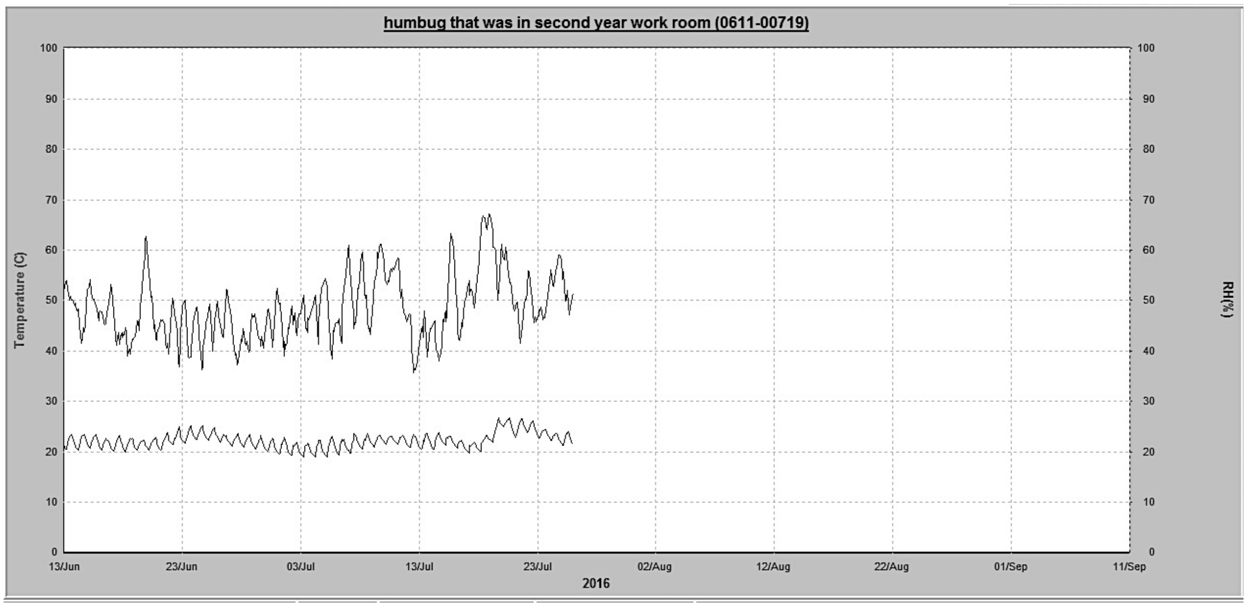
Lighting scenario 1: Workroom 1

Lighting scenario 1 was a bench in a conservation workroom on level 3 at the CTC and was a likely environment in which textiles may be examined and treated in. It was exposed to both UV filtered diffused natural from a window and filtered fluorescent artificial light. Monitored with a Hanwell ML400 Lux/UV LuxBug.

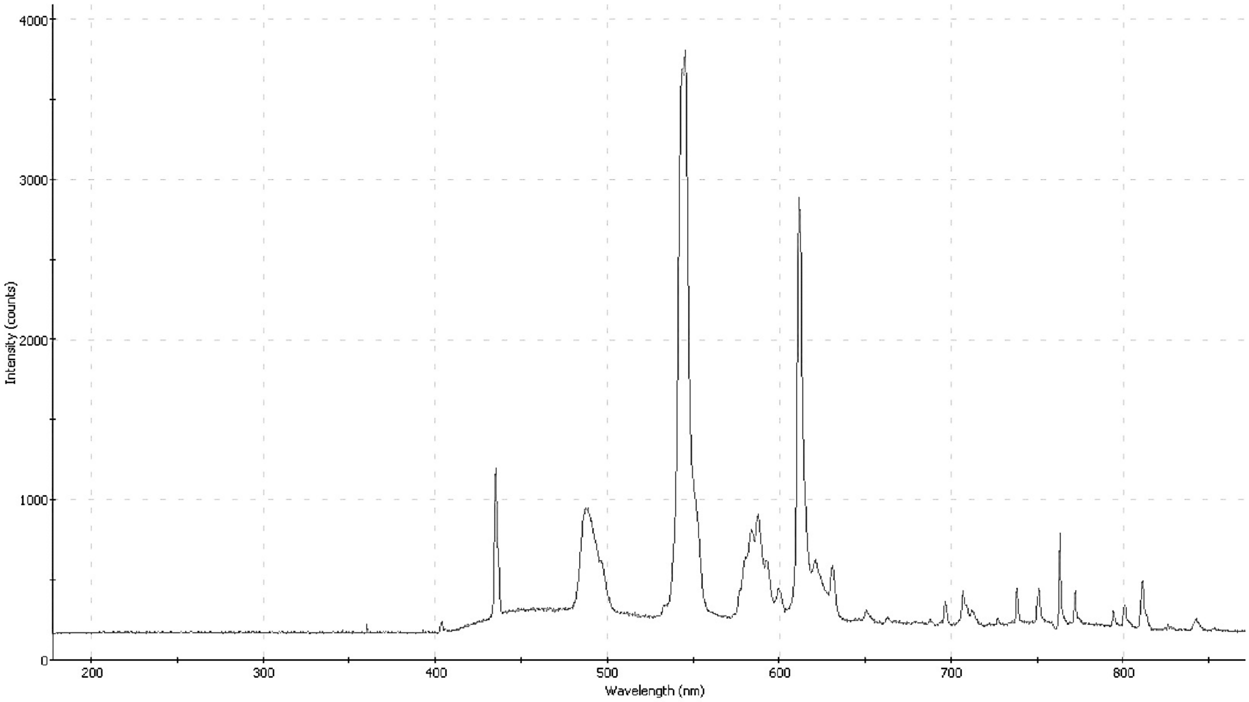
Light Source: Filtered Artificial Fluorescent and diffused natural light
Lux: 0-1324lux max
UV: No UV was detected.
Relative Humidity: 34.9/67.4%
Temperature: 18.9/27. 18.9/27°C



LuxBug data for Workroom 1 during course of experiment. (June 13-July26)



Temperature and relative humidity graph of Workroom during course of experiment.



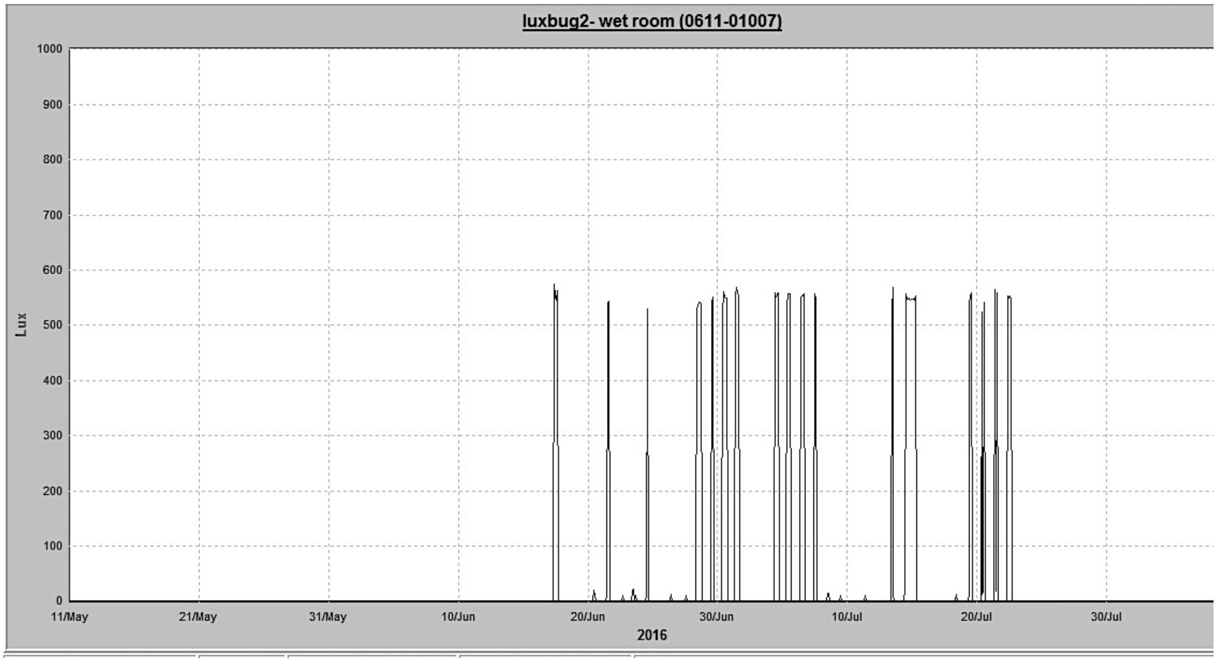
Spectral graph for fluorescent light in Workroom 1. Biggest spike in the visible wavelength is around 550nm, which is around the maximum absorption of magenta.

Lighting Scenario 2: Workroom 2

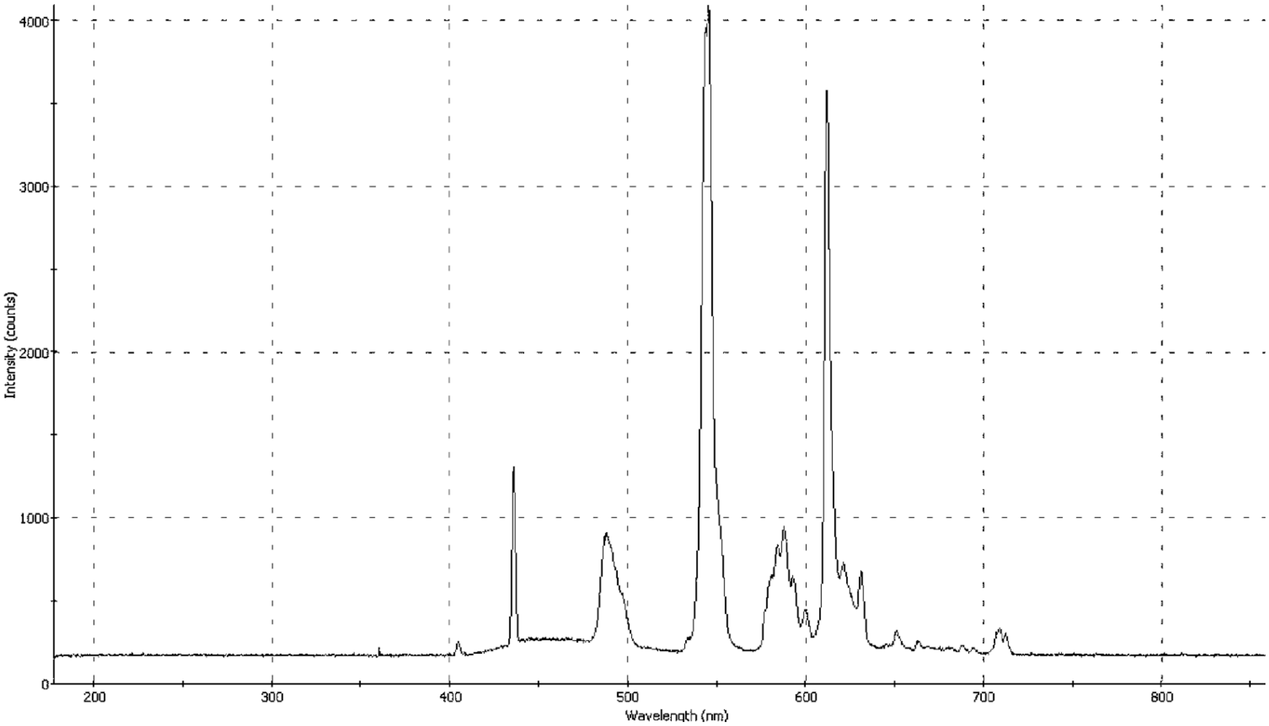
This lighting scenario was a conservation workroom on level 3 at the CTC and was a likely environment in which textiles may be examined and treated in. It was exposed to UV filtered fluorescent lighting. Area monitored with a Hanwell ML400 Lux/UV LuxBug.

Light Source: Filtered Artificial Fluorescent light.

Lux: 0-580 lux.
UV: No UV was detected.



LuxBug data for Workroom 2 during course of experiment (June 13-July 26)



Spectral graph for fluorescent light in Workroom 2. Biggest spike in the visible wavelength is around 550nm, which is around the maximum absorption of magenta.

Lighting scenario 3: Windowsill

The lighting scenario was a windowsill in a teaching room on level 5 at the CTC. This area was used to provide a 'worst case scenario' example of colour and chemical changes as this area was exposed to unfiltered diffused natural light through a window. This area was monitored weekly using an Elsec hand held lux/UV monitor as the Hanwell ML400 Lux/UV LuxBug was only able to measure up to 5000lux.

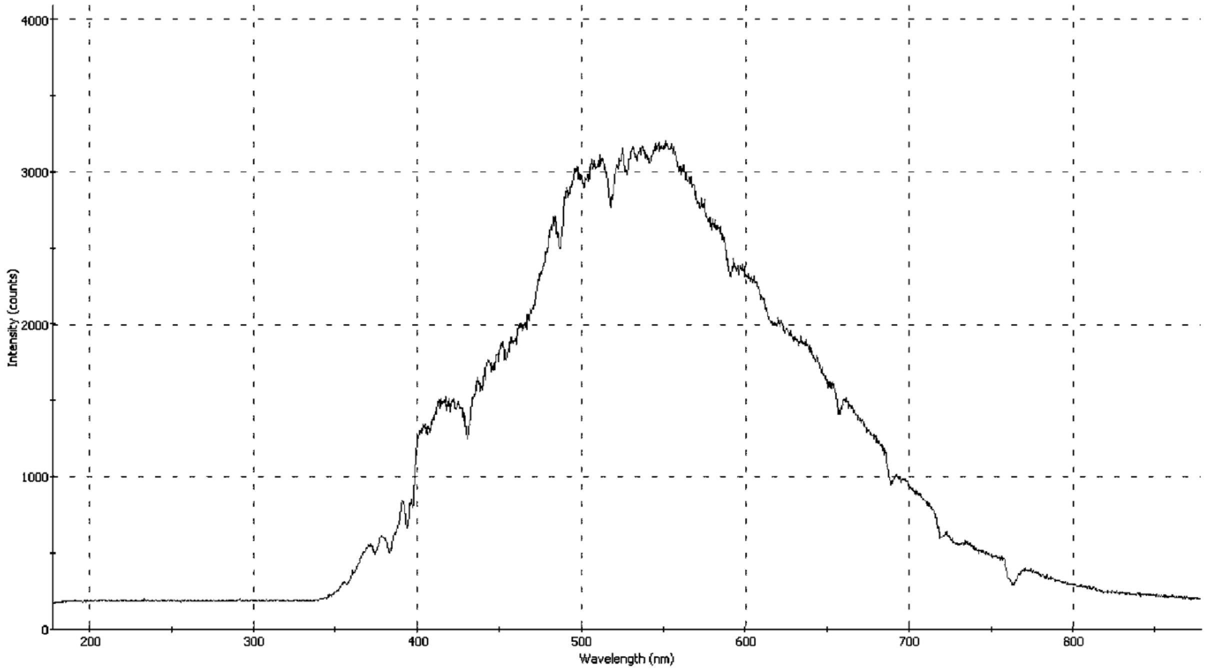
Light source: Unfiltered natural light (diffused through window glazing)

Lux: 3675- 6295lux.

UV: 212/430 μW/L

Week	**Environmental readings**
Week 1- June 12 *Initial week	6295 lux 272 μW/L *Reading taken at 11.30. Sunny outside.
Week 2- June 21	4724 lux 312 μW/L *Reading taken at 11.45am overcast day.
Week 3- June 38	5343 lux 212 μW/L *Reading taken at 11.30. Overcast day.
Week 4- July 5	3955 lux 326 uW/L *Reading taken at 11.20. Cloudy environment.
Week 5- July 12	3675 lux 289 μW/L *Reading taken at 11.45. Cloudy day.
Week 6- July 19	4737 lux 730 μW/L *Reading taken at 11.25. Sunny day.
Week 7- July 26 *Final day	4717 lux 383 μW/L *Reading taken at 11.50. Sunny day.

Table showing spot readings during the course of the experiment.



Spectral graph for natural light in windowsill. A broad peak between 350mn and 750nm. Maximum peak height between 500-600nm.

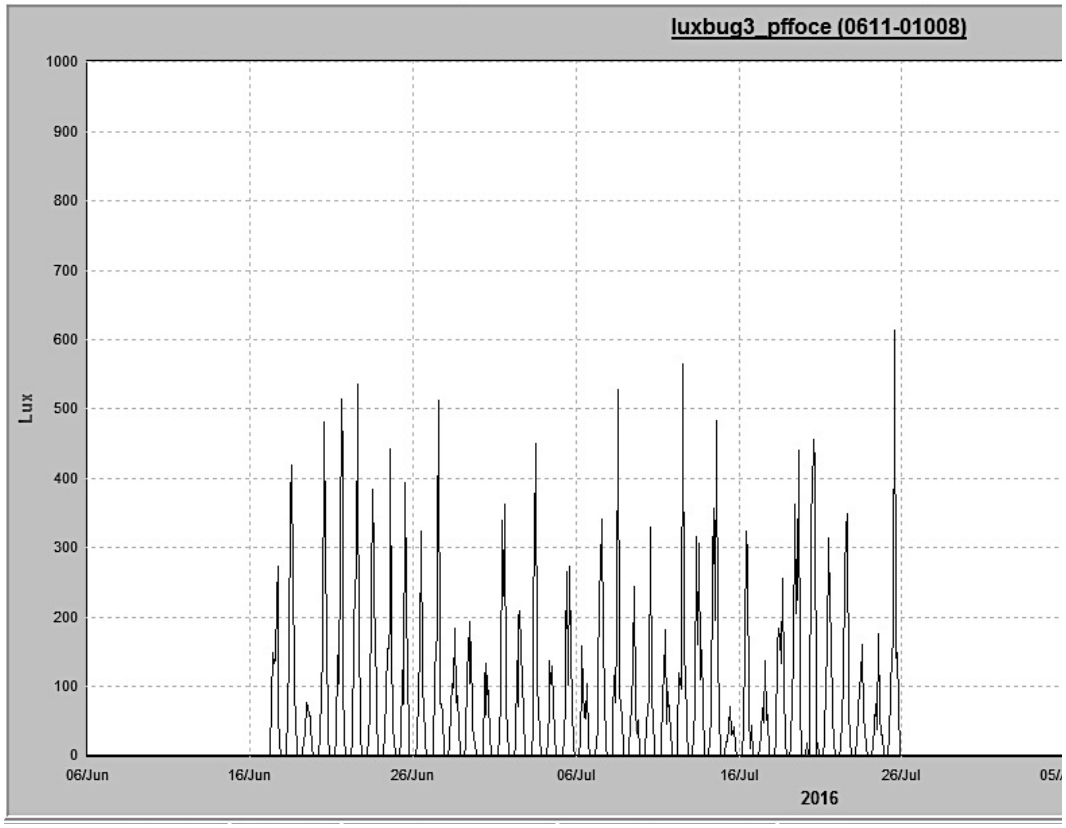
Lighting scenario 4: Office desk

This lighting scenario was an office located on level 3 at the CTC and is a possible environment in which a textile may be viewed or stored on. This environment was exposed to a mixture of both unfiltered natural and artificial light. This area was monitored using a Hanwell ML400 Lux/UV LuxBug

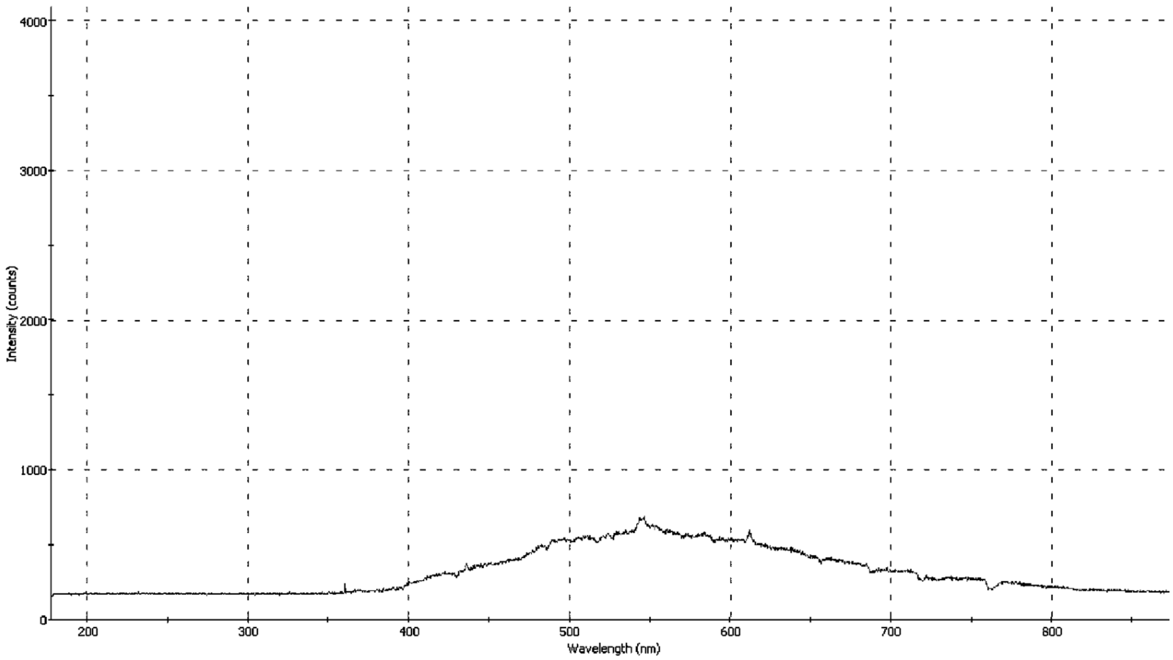
Light source: Unfiltered natural (diffused through window glazing)

Lux: 0/739 lux.

UV: 0 detected.



Lighting scenario 4- Office: Luxbug data showing lux monitored throughout experiment. No UV was detected.



Spectral graph of Lighting scenario 4- Office light source. Taken when cloudy.

Lighting scenario 5: Dark Store

This lighting scenario was an open self in the reference collection storage area on level 3 at the CTC. This area is generally in darkness unless being accessed then it is exposed to UV filtered artificial light. Spot readings were taken to determine the strength of the lights and then a manual log was used to track when the lights were turned on during the experiment. The lights were turned on a total of 15 minutes during the course of the experiment.

Lighting scenario 6: Exhibition space

This lighting scenario was an exhibition space within the Scottish Identity Gallery on the second floor of the Kelvingrove Art Gallery and Museum and was a likely space a textile may be exhibited in. In this area there were a range of different objects on display such as: 18th century tartan textiles, paintings, and a range of metal objects. This area is exposed to UV filtered artificial light during opening hours. A spot reading was taken to determine the light strength was 90 lux with 0 detectable UV.

Lighting scenario 7: Outside

This lighting scenario was the windowsill in my personal residence. This lighting scenario was used to evaluate the prolonged exposure of basic magenta to sunlight. No monitoring of this space was undertaken.

Appendix 4: Experimental Schedule

Week	**Colorimeter reading**	**Samples taken for dye analysis**
Week 1- June 13 *Initial week June 14- samples placed in Kelvingrove	Initial readings taken	No samples taken
Week 2- June 21 *Weekly readings/sample days switched to Tuesdays due to software availability.	Readings taken	Samples taken
Week 3- June 28	Reading taken	Samples taken
Week 4- July 5	Readings taken	Samples taken
Week 5- July 12	Readings taken	Samples taken
Week 6- July 19	Readings taken	Samples taken
Week 7- July 26 *Final week	Readings taken	Samples taken

Appendix 5: Weekly recordings of perceptible colour change

Lighting scenario 1: Workroom 1

Week	Silk	Wool
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	No noticeable colour change.	No noticeable change.
Week 3- June 38	No noticeable colour change.	No noticeable change.
Week 4- July 5	No noticeable colour change.	No noticeable change.
Week 5- July 12	No noticeable colour change.	No noticeable change
Week 6- July 19	No noticeable change.	No noticeable change.
Week 7- July 26 *Final day	Silk appears to be bright, but maybe a little darker around the edges. When removed from the sample holder a significant difference between the exposed and unexposed was observed. Appears to be both darker and bluer.	Appears slightly darker around the edges. When removed from the sample holder a significant difference between the exposed and unexposed was observed. Appears to be both darker and bluer.

Lighting scenario 2: Workroom 2

Week	Silk	Wool
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	No noticeable colour change.	No noticeable colour change.
Week 3- June 38	No noticeable colour change.	No noticeable colour change.
Week 4- July 5	No noticeable colour change.	No noticeable colour change.
Week 5- July 12	No noticeable colour change.	No noticeable colour change.
Week 6- July 19	No noticeable colour change.	No noticeable colour change.
Week 7- July 26 *Final day	When removed from the sample holder a small noticeable difference between the exposed and unexposed was observed. Appears to be both darker and bluer.	When removed from the sample holder a small noticeable difference between the exposed and unexposed was observed. Appears to be both darker and bluer.

Lighting scenario 3: Windowsill

Week	**Silk**	**Wool**
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	Appears to be developing a blueish tint.	Appears to be developing a blueish tint.
Week 3- June 38	Silk appears to be loosing lustre and turning darker/bluer.	Appears to be turning darker and turning darker.
Week 4- July 5	Still has a blue hue. Looks as if it is getting darker and duller.	Appears to be turning darker/more blue.
Week 5- July 12	Silk has become significantly lighter and less blue.	Wool is muddled. Darker and lighter areas. The edges are darker and overall the sample is taking on a bluer tone.
Week 6- July 19	Dull, on both sides. Less blue. Becoming more white than pink.	The sample is a lot darker and non uniform. Muddled surface. This may have affected the readings. This discolouration only appears on the surface, whereas, the silk appears to be all the way through.
Week 7- July 26 *Final day	Very light- less blue than previous weeks.. When removed from the sample holder a significant difference between the exposed and unexposed was observed.	Lighter and less muddled. Edges on back beginning to darken. When removed from the sample holder a small noticeable difference between the exposed and unexposed was observed. Appears to be both darker and bluer.

Lighting scenario 4: Office

Week	Silk	Wool
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	No noticeable colour change.	No noticeable colour change.
Week 3- June 38	No noticeable colour change.	No noticeable colour change.
Week 4- July 5	No noticeable colour change	No noticeable colour change.
Week 5- July 12	No noticeable colour change	No noticeable colour change.
Week 6- July 19	No noticeable colour change.	No noticeable colour change.
Week 7- July 26 *Final day	Throughout the experiment there was no noticeable colour change, however, a small difference between the exposed and unexposed was observed.	Throughout the experiment there was no noticeable colour change, however, a small difference between the exposed and unexposed was observed.

Lighting scenario 5: Dark Store

Week	Silk	Wool
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	No noticeable colour change	No noticeable colour change
Week 3- June 38	No noticeable colour change	No noticeable colour change
Week 4- July 5	No noticeable colour change	No noticeable colour change
Week 5- July 12	No noticeable colour change	No noticeable colour change
Week 6- July 19	No noticeable colour change	No noticeable colour change
Week 7- July 26 *Final day	No noticeable colour change between the exposed and unexposed area.	No noticeable colour change between the exposed and unexposed area.

Lighting scenario 6- Exhibition Space

Week	Silk	Wool
Week 1- June 12 *Initial week	Bright pink/blue with high lustre.	Medium pink/blue.
Week 2- June 21	No noticeable colour change	No noticeable colour change
Week 3- June 38	No noticeable colour change	No noticeable colour change
Week 4- July 5	No noticeable colour change	No noticeable colour change
Week 5- July 12	No noticeable colour change	No noticeable colour change
Week 6- July 19	No noticeable colour change	No noticeable colour change
Week 7- July 26 *Final day	Small noticeable colour change between the exposed and unexposed area.	Small noticeable colour change between the exposed and unexposed area.

Appendix 6: Spectrophotometer data

Week 1- Initial (June 13)			
Name	L*	a*	b*
s1_wk1_1	44.04	79.41	-33.11
s1_wk1_2	43.25	80.58	-33.37
s1_wk1_3	44.05	80.22	-33.72
Average	**43.78**	**80.07**	**-33.4**
STDEV	0.45	0.59	0.30

OVERALL Δwk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
-0.23	**11.01**	**-0.46**	**11.02**

Week 2- June 21			
Name	L*	a*	b*
s1_wk2_1	43.52	76.95	-33.25
s1_wk2_2	42.88	78.14	-33.48
s1_wk2_3	43.61	77.75	-33.77
Average	**43.33**	**77.61**	**-33.5**
STDEV	0.39	0.60	0.26

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.48	2.46	0.1	2.5

Week 3 (June 28)			
Name	L*	a*	b*
s1_wk3_1	43.14	74.87	-33.6
s1_wk3_2	42.53	76.05	-33.93
s1_wk3_3	43.13	75.6	-34.18
Average	**42.93**	**75.5**	**-33.9**
STDEV	0.34	0.59	0.29

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.43	2.11	0.4	2.18

Week 4 (July 5)			
Name	L*	a*	b*
s1_wk4_1	43.24	73.08	-33.53
s1_wk4_2	42.51	74.38	-33.81
s1_wk4_3	43.14	73.87	-34.16
Average	**42.96**	**73.77**	**-33.83**
STDEV	0.39	0.65	0.31

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.03	1.73	0.07	1.76

Week 5 (July 12)			
Name	L*	a*	b*
s1_wk5_1	43.34	72.19	-33.27
s1_wk5_2	42.57	73.3	-33.48
s1_wk5_3	43.39	72.66	-33.81
Average	**43.1**	**72.71**	**-33.52**
STDEV	0.45	0.55	0.27

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
-0.14	1.06	-0.31	1.17

Week 6 (July 19)			
Name	L*	a*	B*
s1_wk6_1	43.89	71.28	-32.73
s1_wk6_2	43.15	72.5	-32.99
s1_wk6_3	43.56	72.19	-33.45
Average	**43.53**	**71.99**	**-33.05**
STDEV	0.37	0.63	0.36

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.4	0.72	0.47	1.1

Week 7 (July 28)			
Name	L*	a*	b*
s1_wk6_1	43.92	68.46	-32.62
s1_wk6_2	43.18	69.79	-32.97
s1_wk6_3	43.57	68.95	-33.23
Average	**43.55**	**69.06**	**-32.94**
STDEV	0.376	0.67	0.30

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
-0.02	2.93	-0.11	2.93

Week 1- Initial (June 13)			
s2_wk1_1	44.27	79.45	-33.19
s2_wk1_2	44.16	79.53	-33.35
s2_wk1_3	45.14	78.89	-33.38
Average	**44.52**	**79.29**	**-33.30**
STDEV	0.53	0.348	0.10

OVERALL Δwk1-7*			
0.24	**4.29**	**-0.32**	**4.3**

Week 2 (June 21)			
Name	L*	a*	b*
s2_wk2_1	43.86	78.7	-33.3
s2_wk2_2	44.18	78.23	-33.42
s2_wk2_3	44.86	77.54	-33.35
Average	**44.3**	**78.15**	**-33.35**
STDEV	0.51	0.58	0.060

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.22	1.14	0.05	1.16

Week 3 (June 28)			
Name	L*	a*	b*
s2_wk3_1	43.78	78.44	-33.31
s2_wk3_2	43.75	78.55	-33.58
s2_wk3_3	44.81	77.41	-33.46
Average	**44.11**	**78.13**	**-33.45**
STDEV	0.60	0.62	0.13

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.19	0.02	0.1	0.21

Week 4 (July 5)			
Name	L*	a*	b*
s2_wk4_1	43.79	76.91	-33.53
s2_wk4_2	44.12	76.36	-33.48
s2_wk4_3	44.51	76.27	-33.66
Average	**44.14**	**76.51**	**-33.55**
STDEV	0.36	0.34	0.09

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.03	1.62	0.1	1.62

Week 5 (July 12)			
Name	L*	a	b*
s2_wk5_1	43.69	77.09	-33.32
s2_wk5_2	43.72	76.83	-33.28
s2_wk5_3	44.77	75.94	-33.33
Average	**44.06**	**76.62**	**-33.31**
STDEV	0.61	0.60	0.02

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
0.08	-0.11	-0.24	0.27

Week 6 (July 19)			
Name	L*	a*	b*
s2_wk6_1	44.02	76.51	-32.93
s2_wk6_2	44.04	76.29	-32.84
s2_wk6_3	44.85	75.49	-33.15
Average	**44.30**	**76.09**	**-32.97**
STDEV	0.47	0.53	0.15

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.24	0.53	-0.34	0.67

Week 7 (July 28)			
Name	L*	a*	b*
s2_wk7_1	44.03	75.23	-32.83
s2_wk7_2	43.99	75.49	-33.02
s2_wk7_3	44.84	74.28	-33.1
Average	**44.28**	**75**	**-32.98**
STDEV	0.47	0.63	0.13

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.02	1.09	0.01	1.09

Week 1- Initial (June 13)				**wk1-7***			
Name	L*	a*	b*	**wk1-7* ΔL***	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
s3_wk1_1	45.16	78.91	-33.78	**-12.36**	**51.81**	**-13.65**	**54.9**
s3_wk1_2	44.49	79.53	-33.66				
s3_wk1_3	45.82	78.65	-34.03				
Average	**45.15**	**79.03**	**-33.82**				
STDEV	0.66	0.45	0.185				
Week 2 (June 21)				**wk1***			
Name	L*	a*	b*	**wk1* ΔL***	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
s3_wk2_1	44.64	66.8	-32.98	0.03	12.42	-0.85	12.44
s3_wk2_2	44.13	67.3	-32.89				
s3_wk2_3	45.79	65.75	-33.06				
Average	**44.85**	**66.61**	**-32.97**				
STDEV	0.85	0.79	0.08				
Week 3 (June 28)				**wk2***			
Name	L*	a*	b*	**wk2* ΔL***	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
s3_wk3_1	46.82	54.41	-30.72	-2	12.18	-2.25	12.54
s3_wk3_2	45.99	55.22	-30.78				
s3_wk3_3	47.75	53.67	-30.67				
Average	**46.85**	**54.43**	**-30.72**				
STDEV	0.88	0.77	0.05				
Week 4 (July 5)				**wk3***			
Name	L*	a*	b*	**wk3* ΔL***	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
s3_wk4_1	48.97	47.69	-28.2	-2.32	6.74	-2.24	7.47
s3_wk4_2	48.56	48.1	-28.25				
s3_wk4_3	49.98	47.29	-28.27				
Average	**49.17**	**47.69**	**-28.24**				
STDEV	0.73	0.40	0.036				
Week 5 (July 12)				**wk4***			
Name	L*	a*	b*	**wk4* ΔL***	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
s3_wk5_1	51.81	39.25	-25.17	-2.82	8.36	-2.99	9.31
s3_wk5_2	51	40.49	-25.59				
s3_wk5_3	53.19	38.25	-25.01				
Average	**52**	**39.33**	**-25.25**				
STDEV	1.10	1.12	0.29				
Week 6 (July 19)				**wk5***			
Name	L*	a*	b*	**wk5* ΔL***	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
s3_wk6_1	56.06	31.83	-22.24	-3.98	7.3	-2.93	8.81
s3_wk6_2	56.15	31.85	-22.26				
s3_wk6_3	55.75	32.43	-22.47				
Average	**55.98**	**32.03**	**-22.32**				
STDEV	0.20	0.34	0.12				
Name	L*	a*	b*	**wk6* ΔL***	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
s3_wk7_1	57.31	27.36	-20.2	-1.53	4.81	-2.15	5.48
s3_wk7_2	56.58	28.2	-20.54				
s3_wk7_3	58.66	26.12	-19.78				
Average	**57.51**	**27.22**	**-20.17**				
STDEV	1.05	1.04	0.38				

Week 1- Initial (June 13)

Name	L*	a*	b*
s4_wk1_1	45.51	79.39	-34.3
s4_wk1_2	46.2	78.77	-34.3
s4_wk1_3	47.18	78.29	-34.45
Average	**46.29**	**78.81**	**-34.35**
STDEV	0.83	0.55	0.08

wk1-7*

wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
-0.05	**5.11**	**0.92**	**5.19**

Week 2 (June 21)

Name	L*	a*	b*
s4_wk2_1	45.53	78.25	-34.11
s4_wk2_2	46.36	77.36	-34.11
s4_wk2_3	46.87	77.25	-34.22
Average	**46.25**	**77.62**	**-34.14**
STDEV	0.67	0.54	0.06

wk1*

wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.04	1.19	-0.21	1.2

Week 3 (June 28)

Name	L*	a*	b*
s4_wk3_1	45.23	77.55	-34.21
s4_wk3_2	46	76.61	-34.23
s4_wk3_3	46.42	76.49	-34.29
Average	**45.88**	**76.88**	**-34.24**
STDEV	0.60	0.58	0.04

wk2*

wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.37	0.74	0.1	0.83

Week 4 (July 5)

Name	L*	a*	b*
s4_wk4_1	45.31	76.76	-34.08
s4_wk4_2	46.24	75.42	-34.05
s4_wk4_3	46.58	75.58	-34.3
Average	**46.04**	**75.92**	**-34.14**
STDEV	0.65	0.73	0.13

wk3*

wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.16	0.96	-0.1	0.97

Week 5 (July 12)

Name	L*	a*	b*
s4_wk5_1	45.22	76.49	-33.97
s4_wk5_2	46.25	75.1	-33.83
s4_wk5_3	46.93	74.8	-34.1
Average	**46.13**	**75.46**	**-33.96**
STDEV	0.86	0.90	0.13

wk4*

wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
-0.09	0.46	-0.18	0.5

Week 6 (July 19)

Name	L*	a*	b*
s4_wk6_1	46.12	75.53	-33.37
s4_wk6_2	46.71	74.5	-33.36
s4_wk6_3	47.25	74.11	-33.56
Average	**46.69**	**74.71**	**-33.43**
STDEV	0.56	0.73	0.11

wk5*

wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.56	0.75	-0.53	1.07

Week 7 (July 28)

Name	L*	a*	b*
s4_wk7_1	45.54	74.78	-33.48
s4_wk7_2	46.49	73.42	-33.38
s4_wk7_3	47	72.92	-33.53
Average	**46.34**	**73.70**	**-33.46**
STDEV	0.74	0.96	0.07

wk6*

wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.35	1.01	0.03	1.06

Week 1- Initial (June 13)			
Name	L*	a*	b*
s5_wk1_1	47.8	77.01	-34.28
s5_wk1_2	48.13	76.75	-34.3
s5_wk1_3	46.13	78.88	-34.34
Average	**47.35**	**77.54**	**-34.30**
STDEV	1.07	1.16	0.03

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
0.03	**-0.1**	**-0.27**	**0.28**

Week 2 (June 21)			
Name	L*	a*	b*
s5_wk2_1	47.63	77.1	-34.09
s5_wk2_2	44.39	75.42	-33.13
s5_wk2_3	46.43	78.59	-34.1
Average	**46.15**	**77.03**	**-33.77**
STDEV	1.63	1.58	0.55

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
1.2	0.51	-0.6	1.43

Week 3 (June 28)			
Name	L*	a*	b*
s5_wk3_1	47.44	77.29	-34.2
s5_wk3_2	48.01	76.74	-34.17
s5_wk3_3	46.17	78.85	-34.19
Average	**47.20**	**77.62**	**-34.18**
STDEV	0.94	1.09	0.01

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
-1.05	-0.59	0.41	1.27

Week 4 (July 5)			
Name	L*	a*	b*
s5_wk4_1	47.6	77.25	-34.14
s5_wk4_2	47.97	76.59	-34.06
s5_wk4_3	46.13	78.91	-34.14
Average	**47.23**	**77.58**	**-34.11**
STDEV	0.97	1.19	0.04

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.03	0.04	-0.07	0.08

Week 5 (July 12)			
Name	L*	a*	b*
s5_wk5_1	47.76	76.87	-34.07
s5_wk5_2	48.11	76.63	-34.14
s5_wk5_3	46.21	78.81	-34.16
Average	**47.36**	**77.43**	**-34.12**
STDEV	1.01	1.19	0.04

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
-0.13	0.15	0.01	0.19

Week 6 (July 19)			
Name	L*	a*	b*
s5_wk6_1	47.77	77.16	-33.99
s5_wk6_2	48.42	76.64	-34
s5_wk6_3	46.31	78.97	-34.03
Average	**47.5**	**77.59**	**-34.00**
STDEV	1.08	1.22	0.02

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.14	-0.16	-0.12	0.24

Week 7 (July 28)			
Name	L*	a*	b*
s5_wk7_1	47.79	77.01	-34
s5_wk7_2	48.12	76.77	-34
s5_wk7_3	46.05	79.14	-34.11
Average	**47.32**	**77.64**	**-34.03**
STDEV	1.11	1.30	0.06

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.18	-0.05	0.03	0.18

Week 1- Initial (June 13)				**wk1-7***			
Name	L*	a*	b*	**wk1-7* ΔL***	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
s6_wk1_1	44.73	78.77	-33.33	**-0.82**	**4.83**	**-0.28**	**4.89**
s6_wk1_2	43.87	79.02	-32.81				
s6_wk1_3	44.14	79.07	-33.22				
Average	**44.24**	**78.95**	**-33.12**				
STDEV	0.43	0.16	0.274				
Week 3 (June 28)				**wk2***			
Name	L*	a*	b*	**wk2* ΔL***	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
s6_wk3_1	43.63	78.18	-33.19	0.33	0.73	0.25	0.52
s6_wk3_2	44.2	78.27	-33.55				
Average	**43.915**	**78.22**	**-33.37**				
STDEV	0.40	0.06	0.254				
Week 5 (July 12)				**wk4***			
Name	L*	a*	b*	**wk4* ΔL***	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
s6_wk5_1	43.65	76.52	-33.02	0.43	2.23	-0.25	2.28
s6_wk5_2	45.04	75.45	-33.22				
Average	**44.345**	**75.98**	**-33.12**				
STDEV	0.98	0.75	0.14				
Week 7 (July 28)				**wk6***			
Name	L*	a*	b*	**wk6* ΔL***	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
s6_wk7_1	45.22	74	-32.8	-0.72	1.86	-0.28	2.01
s6_wk7_2	44.9	74.25	-32.88				
Average	**45.06**	**74.12**	**-32.84**				
STDEV	0.22	0.17	0.05				

Week 1- Initial (June 13)			
Name	L*	a*	b*
w1_wk1_1	25.73	66.32	-13.09
w1_wk1_2	26.45	66.98	-13.43
w1_wk1_3	26.41	67.14	-13.53
Average	**26.19**	**66.81**	**-13.35**
STDEV	0.40	0.43	0.23

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
1.8	**2.65**	**5.02**	**5.95**

Week 2 (June 21)			
Name	L*	a*	b*
w1_wk2_1	25.08	65.61	-14.71
w1_wk2_2	25.68	66.12	-15.14
w1_wk2_3	25.92	66.62	-15.52
Average	**25.56**	**66.11**	**-15.12**
STDEV	0.43	0.50	0.40

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.63	0.65	1.77	2

Week 3 (June 28)			
Name	L*	a*	b*
w1_wk3_1	24.29	64.65	-15.74
w1_wk3_2	24.94	65.18	-16.38
w1_wk3_3	25.11	65.61	-16.51
Average	**24.78**	**65.14**	**-16.21**
STDEV	0.43	0.48	0.41

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.78	0.97	1.09	1.65

Week 4 (July 5)			
Name	L*	a*	b*
w1_wk4_1	24.28	64.51	-16.67
w1_wk4_2	24.82	64.92	-17.33
w1_wk4_3	24.96	65.31	-17.4
Average	**24.68**	**64.91**	**-17.13**
STDEV	0.35	0.40	0.40

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
0.1	0.23	0.92	1.08

Week 5 (July 12)			
Name	L*	a*	b*
w1_wk5_1	24.13	64.24	-16.78
w1_wk5_2	24.75	64.77	-17.49
w1_wk5_3	24.97	65.2	-17.79
Average	**24.61**	**64.73**	**-17.35**
STDEV	0.43	0.48	0.51

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
0.07	0.18	0.22	0.29

Week 6 (July 19)			
Name	L*	a*	b*
w1_wk6_1	24.68	64.71	-16.62
w1_wk6_2	25.32	65.27	-17.52
w1_wk6_3	25.54	65.68	-17.82
Average	**25.18**	**65.22**	**-17.32**
STDEV	0.44	0.48	0.62

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.57	-0.49	-0.03	0.81

Week 7 (July 28)			
Name	L*	a*	b*
w1_wk7_1	24.01	63.87	-17.86
w1_wk7_2	24.58	64.33	-18.64
w1_wk7_3	24.6	64.3	-18.63
Average	**24.39**	**64.16**	**-18.37**
STDEV	0.33	0.25	0.44

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.79	1.06	1.05	1.68

Week 1- Initial (June 13)			
Name	L*	a*	b*
w2_wk1_1	26.11	66.84	-13.65
w2_wk1_2	26.71	67.33	-14.36
w2_wk1_3	26.94	67.46	-13.63
Average	**26.58**	**67.21**	**-13.88**
STDEV	0.428	0.26	0.33

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
0.73	**0.94**	**2.54**	**2.8**

Week 2 (June 21)			
Name	L*	a*	b*
w2_wk2_1	25.74	66.43	-14.9
w2_wk2_2	26.23	66.89	-15.18
w2_wk2_3	26.59	67.16	-14.74
Average	**26.18**	**66.82**	**-14.94**
STDEV	0.42	0.36	0.22

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.63	0.65	1.77	2

Week 3 (June 28)			
Name	L*	a*	b*
w2_wk3_1	25.58	66.31	-14.95
w2_wk3_2	26.12	66.73	-15.45
w2_wk3_3	26.3	66.79	-14.54
Average	**26**	**66.61**	**-14.98**
STDEV	0.37	0.26	0.45

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.18	0.21	0.04	0.27

Week 4 (July 5)			
Name	L*	a*	b*
w2_wk4_1	25.27	65.92	-15.72
w2_wk4_2	25.74	66.17	-16.23
w2_wk4_3	26.09	66.64	-15.76
Average	**25.7**	**66.24**	**-15.90**
STDEV	0.41	0.36	0.28

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.7	0.37	0.92	1.21

Week 5 (July 19)			
Name	L*	a*	b*
w2_wk5_1	25.36	66	-15.6
w2_wk5_2	25.88	66.31	-16.2
w2_wk5_3	26.13	66.6	-15.63
Average	**25.79**	**66.30**	**-15.81**
STDEV	0.39	0.30	0.33

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
-0.09	-0.06	-0.09	0.14

Week 6 (July 19)			
Name	L*	a*	b*
w2_wk6_1	25.86	66.39	-15.83
w2_wk6_2	26.43	66.8	-16.38
w2_wk6_3	26.48	66.89	-15.56
Average	**26.25**	**66.69**	**-15.92**
STDEV	0.34	0.26	0.41

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.46	-0.39	0.14	0.61

Week 7 (July 28)			
Name	L*	a*	b*
w2_wk7_1	25.37	65.85	-16.07
w2_wk7_2	25.92	66.34	-16.68
w2_wk7_3	26.27	66.63	-16.52
Average	**25.85**	**66.27**	**-16.42**
STDEV	0.45	0.39	0.31

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.4	0.42	0.5	0.76

Week 1- Initial (June 13)			
Name	L*	a*	b*
w3_wk1_1	26.03	66.6	-12.78
w3_wk1_2	26.49	66.99	-13.27
w3_wk1_3	26.2	66.73	-12.71
Average	**26.24**	**66.77**	**-12.92**
STDEV	0.23	0.19	0.30

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
-1.47	**20.04**	**7.85**	**21.5**

Week 2 (June 21)			
Name	L*	a*	b*
w3_wk2_1	23.58	63.31	-18.15
w3_wk2_2	24.39	64.15	-18.32
w3_wk2_3	23.95	63.75	-17.43
Average	**23.97**	**63.73**	**-17.96**
STDEV	0.40	0.42	0.47

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
2.27	3.04	5.04	6.3

Week 3 (June 28)			
Name	L*	a*	b*
w3_wk3_1	22.61	60.74	-20.98
w3_wk3_2	23.48	61.67	-21.17
w3_wk3_3	22.94	61.2	-20.43
Average	**23.01**	**61.20**	**-20.86**
STDEV	0.43	0.46	0.38

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.96	2.53	2.9	3.9

Week 4 (July 5)			
Name	L*	a*	b*
w3_wk4_1	23.24	59.57	-22.07
w3_wk4_2	24.04	60.61	-22.09
w3_wk4_3	23.62	60.06	-21.89
Average	**23.63**	**60.08**	**-22.01**
STDEV	0.40	0.52	0.11

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.62	1.12	1.15	1.32

Week 5 (July 12)			
Name	L*	a*	b*
w3_wk5_1	23.84	55.93	-22.93
w3_wk5_2	24.6	57.22	-22.91
w3_wk5_3	24.12	56.83	-22.73
Average	**24.18**	**56.66**	**-22.85**
STDEV	0.38	0.54	0.11

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
-0.55	3.42	0.84	3.56

Week 6 (July 19)			
Name	L*	a*	b*
w3_wk6_1	25.95	51.09	-21.93
w3_wk6_2	26.29	53.14	-22.06
w3_wk6_3	25.44	54.58	-21.96
Average	**25.89**	**52.93**	**-21.98**
STDEV	0.42	1.75	0.06

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-1.71	3.73	-0.87	4.19

Week 7 (July 28)			
Name	L*	a	b*
w3_wk7_1	28	44.56	-20.38
w3_wk7_2	27.74	48.01	-21.04
w3_wk7_3	27.4	47.43	-20.89
Average	**27.71**	**46.67**	**-20.77**
STDEV	0.30	1.84	0.34

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
-1.82	6.27	-1.21	6.63

Week 1- Initial (June 13)			
Name	L*	a*	b*
w4_wk1_1	26.47	66.82	-13.38
w4_wk1_2	27.3	67.32	-14.19
w4_wk1_3	26.89	67.18	-13.98
Average	**26.88**	**67.10**	**-13.85**
STDEV	0.41	0.25	0.42

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
0.64	**0.72**	**2.91**	**3.06**

Week 2 (June 21)			
Name	L*	a*	b*
w4_wk2_1	26.43	66.87	-14.59
w4_wk2_2	27.19	67.2	-15.47
w4_wk2_3	26.64	67.05	-14.87
Average	**26.75**	**67.04**	**-14.97**
STDEV	0.39	0.16	0.44

wk1*			
wk1* ΔL*	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
0.63	0.65	1.77	2

Week 3 (June 28)			
Name	L*	a*	b*
w4_wk3_1	25.96	66.41	-15.14
w4_wk3_2	26.53	66.57	-15.69
w4_wk3_3	26.24	66.67	-15.52
Average	**26.24**	**66.55**	**-15.45**
STDEV	0.28	0.13	0.28

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.51	0.49	0.48	0.85

Week 4 (July 5)			
Name	L*	a*	b*
w4_wk4_1	25.93	66.3	-15.45
w4_wk4_2	26.61	66.59	-16.45
w4_wk4_3	26.35	66.68	-16.21
Average	**26.29**	**66.52**	**-16.03**
STDEV	0.34	0.19	0.52

wk3*			
wk3* ΔL*	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
-0.05	0.03	0.58	0.58

Week 5 (July 15)			
Name	L*	a*	b*
w4_wk5_1	25.87	66.24	-15.65
w4_wk5_2	26.63	66.64	-16.7
w4_wk5_3	26.23	66.54	-16.16
Average	**26.24**	**66.47**	**-16.17**
STDEV	0.38	0.20	0.52

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
0.05	0.05	0.14	0.15

Week 6 (July 19)			
Name	L*	a*	b*
w4_wk6_1	26.4	66.75	-15.78
w4_wk6_2	27.05	67.04	-16.5
w4_wk6_3	26.51	66.79	-15.91
Average	**26.65**	**66.86**	**-16.06**
STDEV	0.34	0.157	0.38

wk5*			
wk5* ΔL*	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
-0.41	-0.39	-0.11	0.57

Week 7 (July 28)			
Name	L*	a*	b*
w4_wk7_1	25.93	66.21	-16.26
w4_wk7_2	26.54	66.44	-17.03
w4_wk7_3	26.27	66.49	-17
Average	**26.24**	**66.38**	**-16.76**
STDEV	0.30	0.14	0.43

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
0.41	0.48	0.7	0.94

Week 1- Initial (June 13)				**wk1-7***			
Name	L*	a*	b*	**wk1-7* ΔL***	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
w5_wk1_1	26.03	66.43	-12.71	**0.03**	**0.2**	**0.51**	**0.54**
w5_wk1_2	26.14	66.56	-12.94				
w5_wk1_3	25.35	65.89	-11.79				
Average	**25.84**	**66.29**	**-12.48**				
STDEV	0.42	0.35	0.60				
Week 2 (June 21)				**wk1***			
Name	L*	a*	b*	**wk1* ΔL***	**wk1* Δa***	**wk1* Δb***	**wk1* ΔE**
w5_wk2_1	26.05	66.54	-13.16	-0.07	-0.13	0.38	0.4
w5_wk2_2	26.17	66.62	-13.25				
w5_wk2_3	25.51	66.11	-12.18				
Average	**25.91**	**66.42**	**-12.86**				
STDEV	0.35	0.27	0.59				
Week 3 (June 28)				**wk2***			
Name	L*	a*	b*	**wk2* ΔL***	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
w5_wk3_1	25.91	66.43	-13.12	0.14	0.11	0.08	0.19
w5_wk3_2	26.02	66.51	-13.41				
w5_wk3_3	25.38	66	-12.31				
Average	**25.77**	**66.31**	**-12.94**				
STDEV	0.34	0.27	0.57				
Week 4 (July 15)				**wk3***			
Name	L*	a*	b*	**wk3* ΔL***	**wk3* Δa***	**wk3* Δb***	**wk3* ΔE**
w5_wk4_1	26.01	66.54	-13.16	-0.02	-0.01	-0.05	0.05
w5_wk4_2	26.02	66.5	-13.32				
w5_wk4_3	25.36	65.94	-12.19				
Average	**25.79**	**66.32**	**-12.89**				
STDEV	0.37	0.33	0.61				
Week 5 (July 12)				**wk4***			
Name	L*	a*	b*	**wk4* ΔL***	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
w5_wk5_1	25.92	66.46	-13.31	-0.19	-0.19	0.63	0.68
w5_wk5_2	26.02	66.54	-13.63				
w5_wk5_3	26.02	66.53	-13.63				
Average	**25.98**	**66.51**	**-13.52**				
STDEV	0.05	0.04	0.18				
Week 6 (July 19)				**wk5***			
Name	L*	a*	b*	**wk5* ΔL***	**wk5* Δa***	**wk5* Δb***	**wk5* ΔE**
w5_wk6_1	26.22	66.77	-13.33	-0.03	-0.08	-0.48	0.48
w5_wk6_2	26.2	66.76	-13.36				
w5_wk6_3	25.62	66.26	-12.45				
Average	**26.01**	**66.59**	**-13.04**				
STDEV	0.34	0.29	0.51				
Week 7 (July 28)				**wk6***			
Name	L*	a*	b*	**wk6* ΔL***	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
w5_wk7_1	25.86	66.42	-13.5	0.2	0.2	0.51	0.58
w5_wk7_2	26.08	66.58	-13.96				
w5_wk7_3	25.51	66.19	-13.19				
Average	**25.81**	**66.39**	**-13.55**				
STDEV	0.28	0.19	0.38				

Wool | scenario 6

Week 1- Initial (June 13)			
Name	L*	a*	b*
w6_wk1_1	25.68	66.14	-13.82
w6_wk1_2	25.04	65.5	-12.43
w6_wk1_3	25.4	65.99	-12.43
Average	**25.37**	**65.87**	**-12.89**
STDEV	0.32	0.33	0.80

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
-0.07	**0.22**	**3.5**	**3.5**

Week 3 (June 28)			
Name	L*	a*	b*
w6_wk3_1	24.97	65.57	-14.5
w6_wk3_2	25.34	65.91	-14.4
Average	**25.155**	**65.74**	**-14.45**
STDEV	0.26	0.24	0.07

wk2*			
wk2* ΔL*	**wk2* Δa***	**wk2* Δb***	**wk2* ΔE**
0.22	0.13	1.56	1.58

Week 5 (July 12)			
Name	L*	a*	b*
w6_wk5_1	24.9	65.31	-15.18
w6_wk5_2	24.76	64.96	-14.77
Average	**24.83**	**65.13**	**-14.97**
STDEV	0.098	0.24	0.28

wk4*			
wk4* ΔL*	**wk4* Δa***	**wk4* Δb***	**wk4* ΔE**
0.32	0.61	0.52	0.86

Week 7 (July 28)			
Name	L*	a*	b*
w6_wk7_1	25.34	65.52	-16.31
w6_wk7_2	25.54	65.79	-16.47
Average	**25.44**	**65.65**	**-16.39**
STDEV	0.14	0.19	0.11

wk6*			
wk6* ΔL*	**wk6* Δa***	**wk6* Δb***	**wk6* ΔE**
-0.61	-0.52	1.42	1.63

Wool | scenario 7

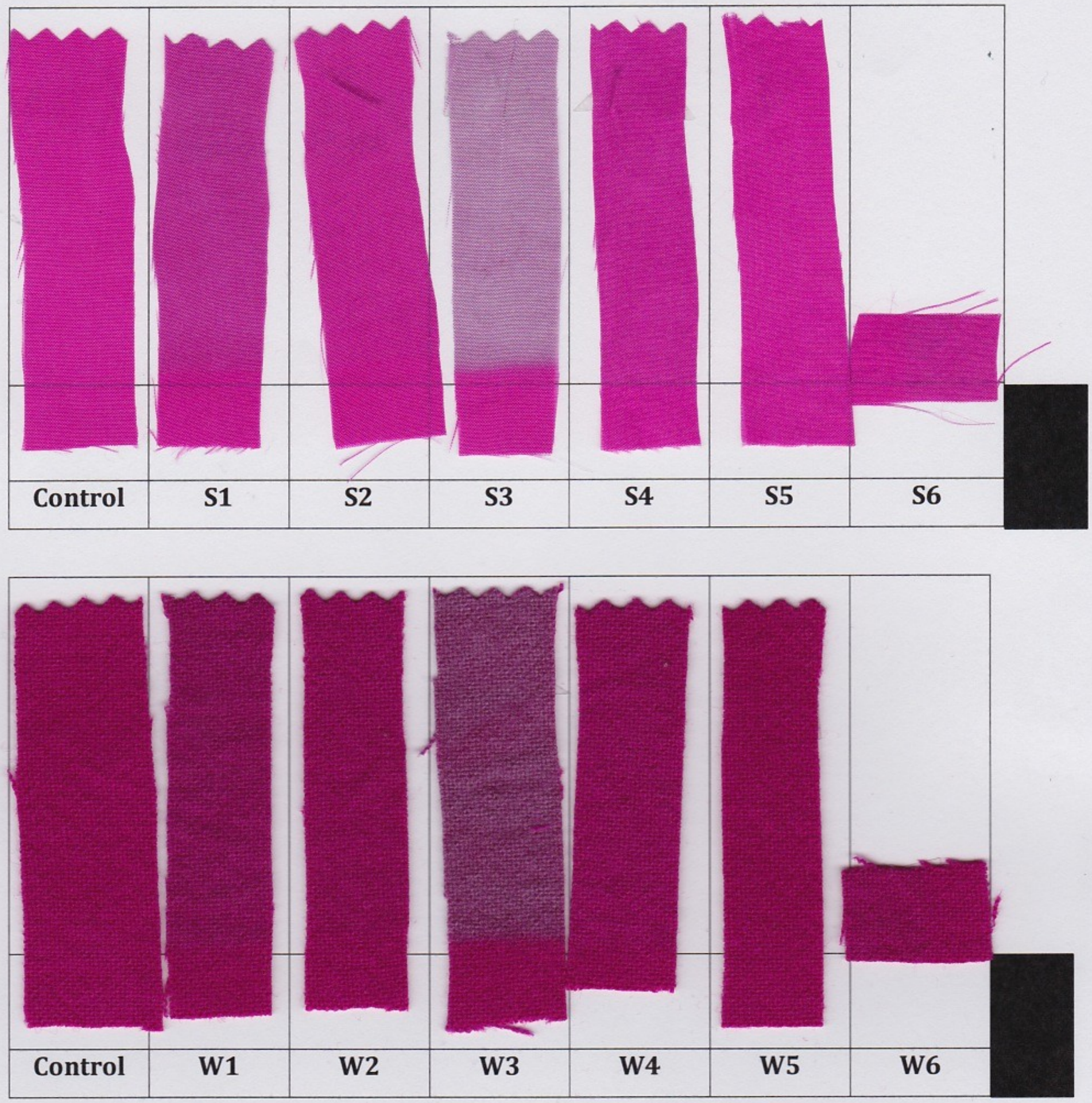
Week 1- Initial (June 13)			
Name	L*	a*	b*
w7_wk1_1	25.68	66.14	-13.82
w7_wk1_2	25.04	65.5	-12.43
w7_wk1_3	25.4	65.99	-12.43
Average	**25.37**	**65.87**	**-12.89**
STDEV	0.32	0.33	0.80

wk1-7*			
wk1-7* ΔL*	**wk1-7* Δa***	**wk1-7* Δb***	**wk1-7* ΔE**
-26.72	**60.81**	**-17.96**	**68.8**

Week 3 (June 28)			
Name	L*	a*	b*
w7_wk7_1	51.91	5.03	4.95
w7_wk7_2	52.75	4.75	5.34
w7_wk7_3	51.62	5.41	4.35
Average	**52.09**	**5.06**	**4.88**
STDEV	0.58	0.33	0.49

Appendix 7: Model Test Fabrics After Experiment

Silk and wool model test fabrics after six week exposure to light. The black rectangle denotes where the sample was hidden from light during the experiment.



Appendix 8: Extraction of dye components from samples for UHPLC analysis

The dye extraction method carried out on the sixteen samples utilized a two step process developed at the Centre for Textile conservation (Jing- did you develop this?) The step-by-step method s used to extract the thirteen samples, two reference samples, and solvent blanks can be found in Dr Jing Han's doctoral thesis investigating dyes in high status Chinese costume and textiles of the Ming and Qing Dynasties (1386-1911).[211]

Step 1: The 2mm x 2mm sample was removed from the model test fabric and transferred into a 1ml flat bottom glass vial. 50μl of DMSO (dimethyl sulfoxide) was added to the vial and then heated at 80 °C for 10 mins in a Talboys block heater. By heating the DMSO all vat dyed and direct dyes are extracted from the sample. The DMSO extract is then transferred using a micropipette with a disposable tip into a vial insert. Keep this aside.

Step 2: Second step of the extraction process 75μl of oxalic acid solution, composed of a mixture of 0.5M oxalic acid / acetone / water / methanol (1:30:40:30 (v/v/v/v)) was added to the fibre sample remaining in the vial. The sample was heated for 15 minutes at 80 °C. The extract was then evaporated using a BUCHO R-215 Rotavaatpor at 15-18mbar for 30 minutes or until the sample is completely evaporated.

Step 3: The dried extract was reconstituted using the first DMSO fraction, thereby combining the extracts from the two steps. The extract is then filtered through a 0.2 μm Angilent Premium Syringe Filter into glass vial, which fits into the UHPLC auto sampler.

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[211] Jing Han, "Jing Han, "The Historical and Chemical Investigation of Dyes in High Status Chinese Costume and Textile of the Ming and Qing Dynasties (1368-1911)" (Doctor of Philosophy, School of Cultural and Creative Arts, University of Glasgow, 2016), 117.

Appendix 9: Analysis of samples by UHPLC: system conditions

The 16 extracted samples were placed in the sample manager and run through the Waters® ACQUITY UPLC® H- class system on 40 minute auto program. This process was supervised by Dr. Jing Han, a postdoctoral researcher at the CTC. The following process was followed and taken from Dr. Jing Han's doctoral thesis on page 118-119.[212]

Extracted samples were placed in the vial support located in the sample manager chamber. 4 ml was injected by an auto-sampler for each analysis. A Waters C18 BEH shield VanGuard pre-column (5 ×2.1 mm I.D., particle size 1.7 μm) was installed in front of the C18 BEH shield column to prevent the column from being blocked by potential particles in samples. A gradient elution programme involving water, methanol and formic acid was used. The mobile phase was composed of 10% aqueous methanol (v/v) (solvent A), pure methanol (solvent B) and 1% aqueous formic acid (v/v) (solvent C) and a 40-min gradient elution programme was set for each analysis. Column temperature was set at 40 °C and the flow rate was 0.2ml/min. The initial eluent composition was 80% A : 10% B : 10% C and held till 1.33 min; this ratio changed linearly to 74% A : 16% B : 10% C from 1.33 to 2.33 min, then to 55% A : 35% B : 10% C from 2.33 to 5.33 min. This composition was held till 9 min, changed linearly to 30% A : 60% B : 10% C from 9 to 14 min, to 5% A : 85% B : 10% C from 14 to 25 min, and then to 100% B from 25 to 26 min. The ratio remained till 30 min, returned linearly to the initial ratio of 80% A : 10% B : 10% C from 30 to 32 min and held for 8 minutes till 40 min. UV-Vis data was collected in the range of 190 to 800 nm with the resolution of 1.2 nm and was monitored at 254 nm.

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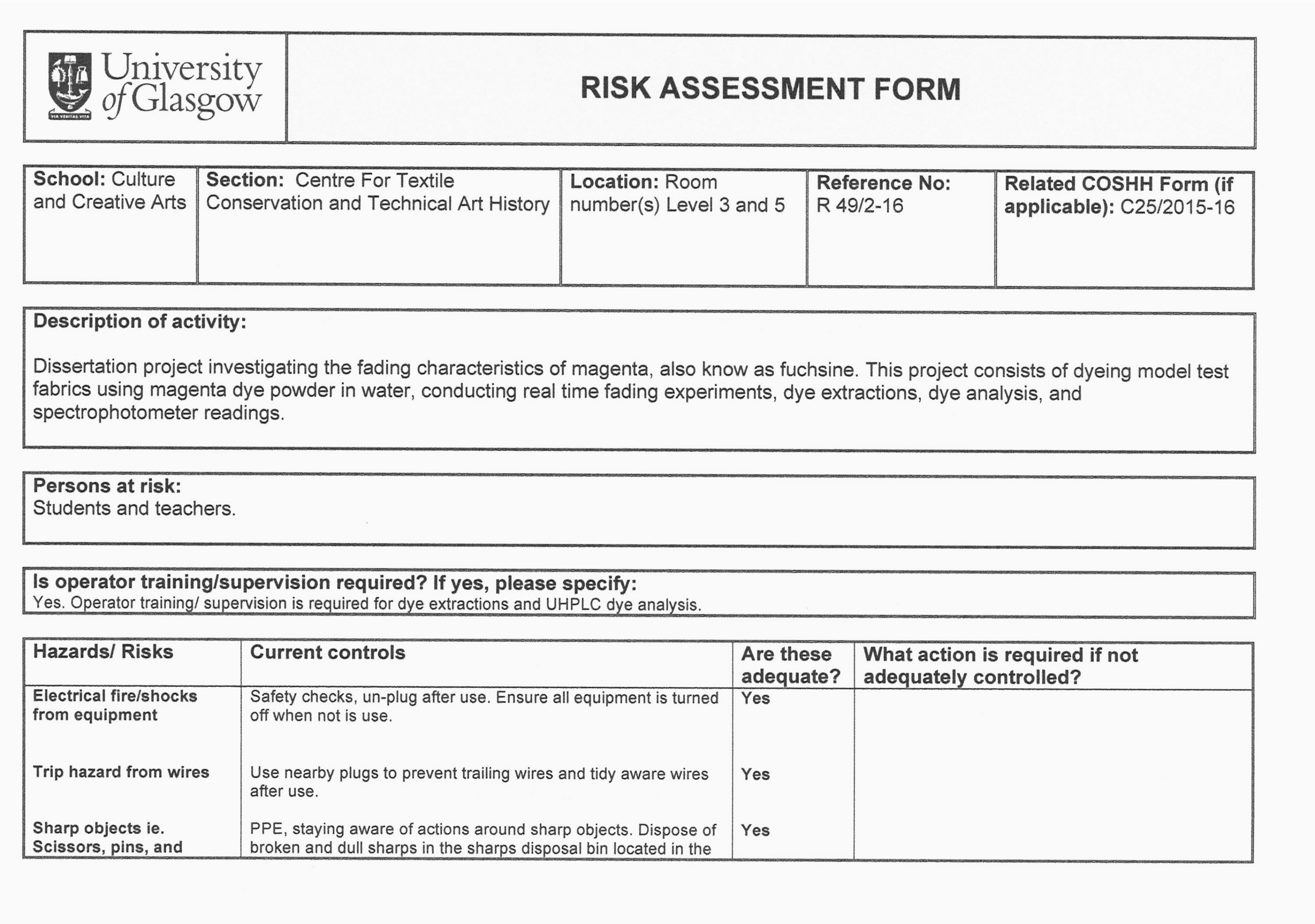
[212] Han, 118-119.

Appendix 10: Risk Assessment and COSSH Forms



University of Glasgow

RISK ASSESSMENT FORM

School: Culture and Creative Arts	**Section:** Centre For Textile Conservation and Technical Art History	**Location:** Room number(s) Level 3 and 5	**Reference No:** R 49/2-16	**Related COSHH Form (if applicable):** C25/2015-16

Description of activity:

Dissertation project investigating the fading characteristics of magenta, also know as fuchsine. This project consists of dyeing model test fabrics using magenta dye powder in water, conducting real time fading experiments, dye extractions, dye analysis, and spectrophotometer readings.

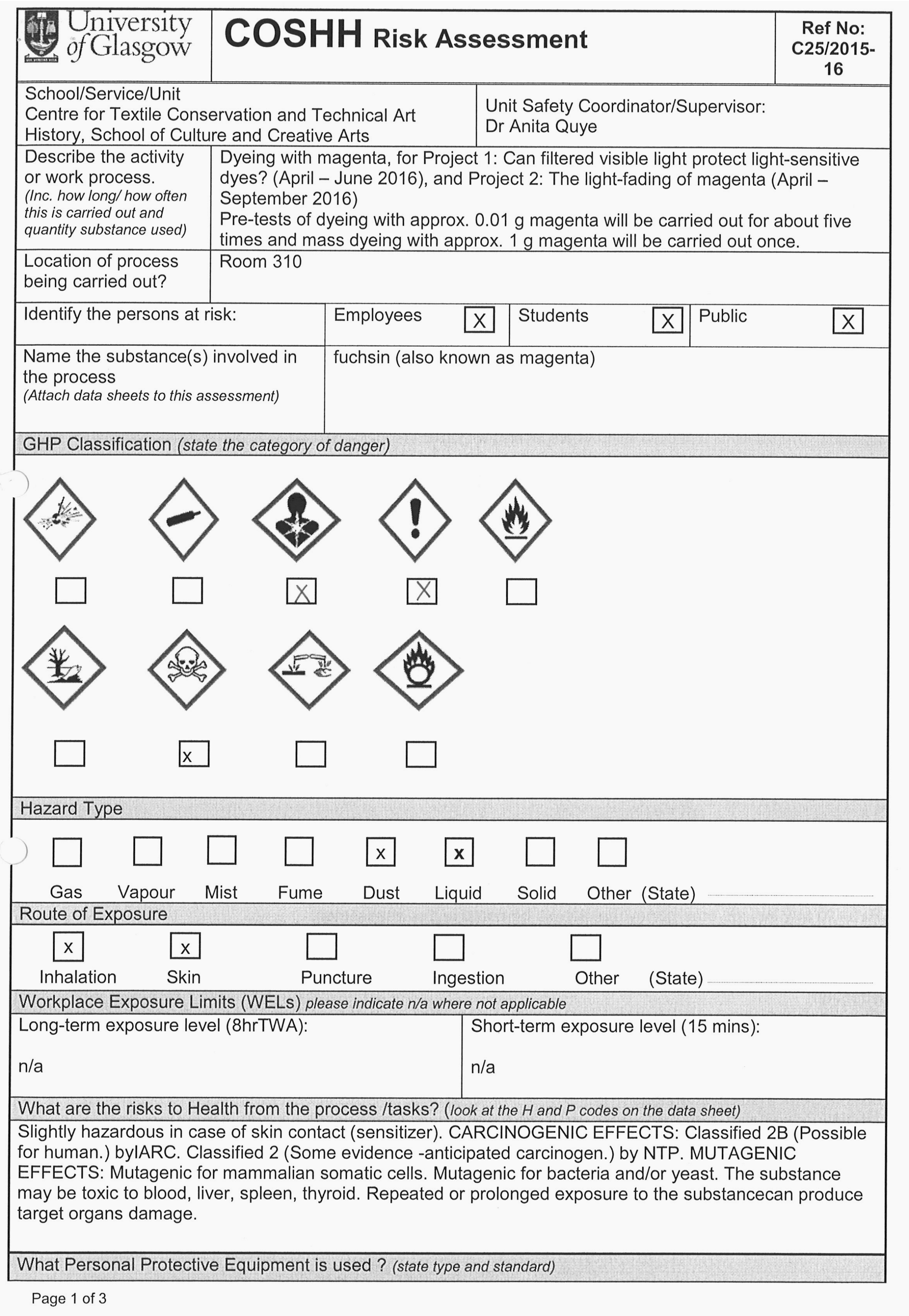
Persons at risk:
Students and teachers.

Is operator training/supervision required? If yes, please specify:
Yes. Operator training/ supervision is required for dye extractions and UHPLC dye analysis.

Hazards/ Risks	Current controls	Are these adequate?	What action is required if not adequately controlled?
Electrical fire/shocks from equipment	Safety checks, un-plug after use. Ensure all equipment is turned off when not is use.	Yes	
Trip hazard from wires	Use nearby plugs to prevent trailing wires and tidy aware wires after use.	Yes	
Sharp objects ie. Scissors, pins, and	PPE, staying aware of actions around sharp objects. Dispose of broken and dull sharps in the sharps disposal bin located in the	Yes	

needles	Chemistry Lab.		
Spillages **- liquid and solid**	Take care and stay aware of actions when handling both liquid and solids. Mop up any spills right away and dispose of according to COSSH.	**Yes**	
Broken Glassware	Take care and stay aware of actions when handling glassware. Safely and carefully sweep up broken glassware and dispose in yellow glassware disposal bin located in the Wet Lab.	**Yes**	
Chemicals **- Fuchsine dye powder** **- Dye extraction and analysis**	Use PPE when working with fuchsine dye powder and chemicals for dye extraction and analysis. Mop any spillages right away. Follow and COSSH controls required. See COSSH assessment attached. Emergency contact numbers and telephone located in chemistry lab.	**No**	**See COSSH forms attached.**
Heat Injury **-Boiling Water for dyeing** **- Dye extraction**	Use heat-proof PPE and care when handling. First aid kit located in room 307. Emergency contact numbers and telephone are located in the Chemistry Lab.	**Yes**	

Completed by (print name and position, and sign): Michelle Hunter	Michelle Hunter, Student (MPHIL TEXTILE CONSERVATION)	**Date: May 31, 2016**
Approved by (print name and position, and sign):	Anita Quye Senior Lecturer Textile Conservation	**Date: May 31, 2016**



University of Glasgow	**COSHH Risk Assessment**	**Ref No: C25/2015-16**

School/Service/Unit Centre for Textile Conservation and Technical Art History, School of Culture and Creative Arts	Unit Safety Coordinator/Supervisor: Dr Anita Quye

Describe the activity or work process. *(Inc. how long/ how often this is carried out and quantity substance used)*	Dyeing with magenta, for Project 1: Can filtered visible light protect light-sensitive dyes? (April – June 2016), and Project 2: The light-fading of magenta (April – September 2016) Pre-tests of dyeing with approx. 0.01 g magenta will be carried out for about five times and mass dyeing with approx. 1 g magenta will be carried out once.
Location of process being carried out?	Room 310

Identify the persons at risk:	Employees ☒	Students ☒	Public ☒
Name the substance(s) involved in the process *(Attach data sheets to this assessment)*	fuchsin (also known as magenta)		

GHP Classification *(state the category of danger)*

☐ ☐ ☒ ☒ ☐

☐ ☒ ☐ ☐

Hazard Type

☐ Gas ☐ Vapour ☐ Mist ☐ Fume ☒ Dust ☒ Liquid ☐ Solid ☐ Other (State) ....

Route of Exposure

☒ Inhalation ☒ Skin ☐ Puncture ☐ Ingestion ☐ Other (State) ....

Workplace Exposure Limits (WELs) *please indicate n/a where not applicable*

Long-term exposure level (8hrTWA): n/a	Short-term exposure level (15 mins): n/a

What are the risks to Health from the process /tasks? (*look at the H and P codes on the data sheet)*

Slightly hazardous in case of skin contact (sensitizer). CARCINOGENIC EFFECTS: Classified 2B (Possible for human.) byIARC. Classified 2 (Some evidence -anticipated carcinogen.) by NTP. MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. Mutagenic for bacteria and/or yeast. The substance may be toxic to blood, liver, spleen, thyroid. Repeated or prolonged exposure to the substancecan produce target organs damage.

What Personal Protective Equipment is used ? *(state type and standard)*

Page 1 of 3

☒ Dust mask		☐ Visor	
☐ Respirator		☒ Eye wear	
☒ Gloves		☒ Overalls	
☐ Footwear		☐ Other	

Assessment of the process/task

(List the summary of controls already in place and identify any gaps)

Engineering controls: Carry out dyeing in a fume cupboard.
Personal Protective Equipment: Wear gloves, safety glasses and a lab coat all the time. Use a respirator when weighing fuchsin outside of the fume cupboard.
Management measures: Keep the container tightly closed. Keep away from heat. Ensure all containers of fuchsin pigments, dye solutions and dyed samples are labeled with toxic.

Now rate the overall rating with the controls you have listed

High ☐ Medium ☐ Low ☒

List the new controls that need to be in place to give adequate control *(consider the need for monitoring as well as changes to the task or substitution of chemicals used)*

Ensure that the protective measures are carried out properly. Check before, during and after the experiment.

Final check: Has the risk rating been reduced to as low as possible with the new controls?

yes ☒ Note any monitoring that may be needed………………………………….

Emergency Plans and procedures (this will apply to carcinogens, mutagens or similar health risks)

Are plans in place to deal with spillages or emergencies? Yes ☒ N/a ☐

Refer to any first aid emergency that should be noted in this assessment

Eye Contact:Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15minutes. Cold water may be used. WARM water MUST be used. Get medical attention.
Skin Contact:In case of contact, immediately flush skin with plenty of water. Cover the irritated skin with an emollient. Remove contaminatedclothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.
Serious Skin Contact:Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek medical attention.
Inhalation:If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medicalattention.
Ingestion:Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconsciousperson. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Has waste disposal been considered and established Yes ☒ N/a ☐

Is there a requirement to carry out health surveillance?
Yes ☐ No ☒

Assessed by: Jing Han Date: 5 April 2016 Review Date: 4 April 2017

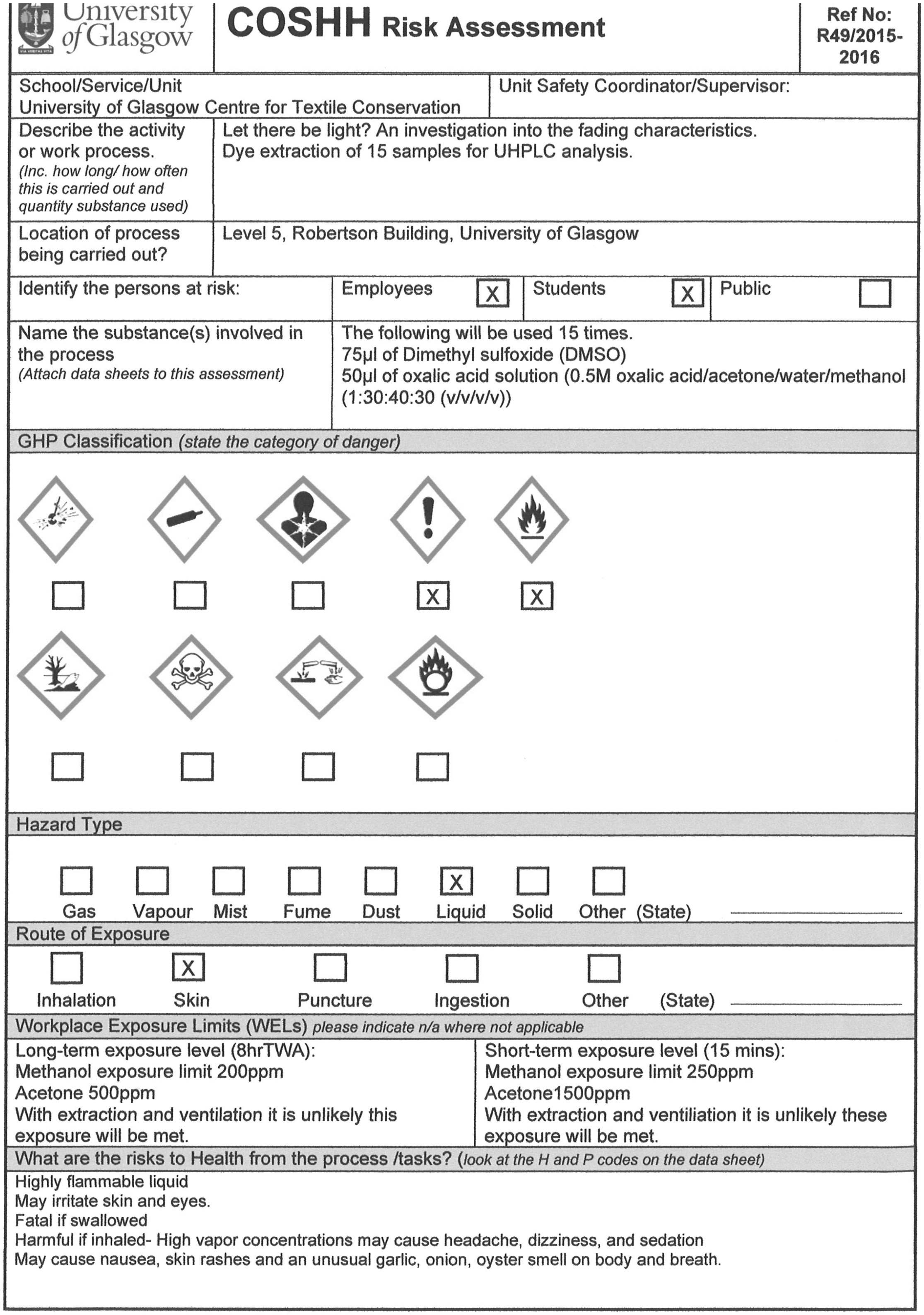
Approval by: Anita Quye Date: 5 April 2016

Anita Quye

Sign off Sheet of Understanding

I have been taken through the COSHH assessment for the listed task/process and understand the safety controls and responsibilities to ensure I work safely.

NAME	Signature	DATE
Jing Han	Jing Han	6 April 2016
Michelle Hunter		May 23/2016



University of Glasgow

COSHH Risk Assessment

Ref No: R49/2015-2016

School/Service/Unit University of Glasgow Centre for Textile Conservation	Unit Safety Coordinator/Supervisor:
Describe the activity or work process. *(Inc. how long/ how often this is carried out and quantity substance used)*	Let there be light? An investigation into the fading characteristics. Dye extraction of 15 samples for UHPLC analysis.
Location of process being carried out?	Level 5, Robertson Building, University of Glasgow
Identify the persons at risk:	Employees ☒ Students ☒ Public ☐
Name the substance(s) involved in the process *(Attach data sheets to this assessment)*	The following will be used 15 times. 75µl of Dimethyl sulfoxide (DMSO) 50µl of oxalic acid solution (0.5M oxalic acid/acetone/water/methanol (1:30:40:30 (v/v/v/v))

GHP Classification *(state the category of danger)*

☐ ☐ ☐ ☒ ☒

☐ ☐ ☐ ☐

Hazard Type

☐ Gas ☐ Vapour ☐ Mist ☐ Fume ☐ Dust ☒ Liquid ☐ Solid ☐ Other (State) ____________

Route of Exposure

☐ Inhalation ☒ Skin ☐ Puncture ☐ Ingestion ☐ Other (State) ____________

Workplace Exposure Limits (WELs) *please indicate n/a where not applicable*

Long-term exposure level (8hrTWA): Methanol exposure limit 200ppm Acetone 500ppm With extraction and ventilation it is unlikely this exposure will be met.	Short-term exposure level (15 mins): Methanol exposure limit 250ppm Acetone1500ppm With extraction and ventiliation it is unlikely these exposure will be met.

What are the risks to Health from the process /tasks? (*look at the H and P codes on the data sheet)*

Highly flammable liquid
May irritate skin and eyes.
Fatal if swallowed
Harmful if inhaled- High vapor concentrations may cause headache, dizziness, and sedation
May cause nausea, skin rashes and an unusual garlic, onion, oyster smell on body and breath.

Page 1 of 3

What Personal Protective Equipment is used ? *(state type and standard)*

☐ ☐ Dust mask		☐ ☐ Visor	
☐ ☒ Respirator	Work within the hume cupboard.	☐ ☒ Eye wear	
☐ ☒ Gloves	Nitrile gloves	☐ ☒ Overalls	Lab coat
☐ ☒ Footwear	Close toe shoes	☐ ☐ Other	

Assessment of the process/task

(List the summary of controls already in place and identify any gaps)
Only small quantities of solvents will be used and are dispensed in small bottled. Activity carried out in fumecupoard.

Now rate the overall rating with the controls you have listed

High ☐ Medium ☐ Low ☒

List the new controls that need to be in place to give adequate control *(consider the need for monitoring as well as changes to the task or substitution of chemicals used)*

Final check: Has the risk rating been reduced to as low as possible with the new controls?

yes ☒ Note any monitoring that may be needed……………………………………

Emergency Plans and procedures (this will apply to carcinogens, mutagens or similar health risks)

Are plans in place to deal with spillages or emergencies? Yes ☒ N/a ☐

Refer to any first aid emergency that should be noted in this assessment

Has waste disposal been considered and established Yes ☒ N/a ☐
Yes. Small quantities of solvents used and will be allowed to evapourate
In fume cupboard.

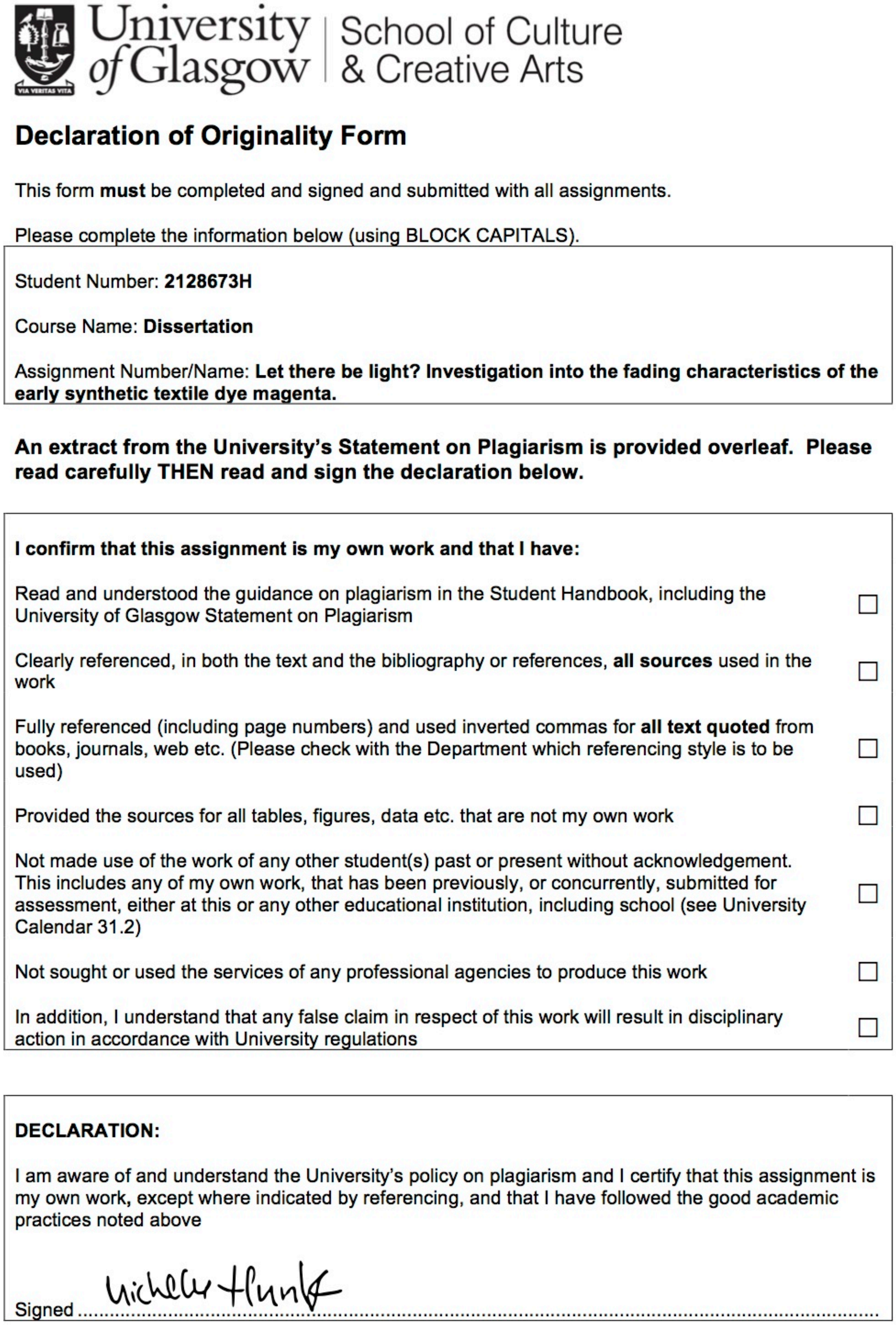
Is there a requirement to carry out health surveillance?

Yes ☐ No ☒

Assessed by: Date: May 31, 2016 Review Date:

Approval by: Date: May 31, 2016

Appendix 11: Declaration of Originality Form



University of Glasgow | School of Culture & Creative Arts

VIA VERITAS VITA

Declaration of Originality Form

This form **must** be completed and signed and submitted with all assignments.

Please complete the information below (using BLOCK CAPITALS).

Student Number: **2128673H**

Course Name: **Dissertation**

Assignment Number/Name: **Let there be light? Investigation into the fading characteristics of the early synthetic textile dye magenta.**

An extract from the University's Statement on Plagiarism is provided overleaf. Please read carefully THEN read and sign the declaration below.

I confirm that this assignment is my own work and that I have:

Read and understood the guidance on plagiarism in the Student Handbook, including the University of Glasgow Statement on Plagiarism ☐

Clearly referenced, in both the text and the bibliography or references, **all sources** used in the work ☐

Fully referenced (including page numbers) and used inverted commas for **all text quoted** from books, journals, web etc. (Please check with the Department which referencing style is to be used) ☐

Provided the sources for all tables, figures, data etc. that are not my own work ☐

Not made use of the work of any other student(s) past or present without acknowledgement. This includes any of my own work, that has been previously, or concurrently, submitted for assessment, either at this or any other educational institution, including school (see University Calendar 31.2) ☐

Not sought or used the services of any professional agencies to produce this work ☐

In addition, I understand that any false claim in respect of this work will result in disciplinary action in accordance with University regulations ☐

DECLARATION:

I am aware of and understand the University's policy on plagiarism and I certify that this assignment is my own work, except where indicated by referencing, and that I have followed the good academic practices noted above

Signed Michelle Plunk...