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Designing sustainable colour: *lowering the environmental impact during the wool dyeing process*

A thesis presented in partial fulfilment of the requirements for the degree of Master of Design at Massey University, Wellington, New Zealand

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2013

Abstract:

Synthetic dyeing has been used in the production of coloured textiles since the late 1800s. However, today there is growing awareness that the dyeing process has a huge impact on the environment, causing damage to the earth's climate from high carbon emissions and damage to ecology through discharge of toxic wastewater. Carpets and Rugs of New Zealand Limited (CRONZ) is a small manufacturer of bespoke tufted carpet based in Christchurch, New Zealand who wanted to help combat these environmental problems by offering a sustainable dyeing process as part of their business. They applied for and successfully gained Ministry for Science and Innovation funding for a postgraduate student fellowship to enable this project. The methods of life cycle analysis, traceability, sustainable certification and labelling, along with running many small-scale experiments, including exploration of the new technology of ultrasound waves in the dye bath, are used here to discover strategies to lower energy and chemical use during the hank dyeing process for wool yarns. By gaining an understanding of the hank dyeing process for wool yarns through interviews with industry experts, and documenting energy and chemical use during experiments, the following key solutions for reducing energy and chemical use were found: reducing dye bath time by dyeing lighter colours, as these process faster than dark colours; use of eco-friendly chemicals that do not contain harmful heavy metals; use of agitation of the dye bath as a method to produce level colour, eliminating the need for a chemical levelling agent; and the use of blended un-dyed yarns as an alternative to dyeing the wool fibres. By employing solutions such as these the carpet manufacturing industry would lessen its environmental impact by lowering carbon emissions and discharging fewer chemicals into wastewater streams.

Acknowledgements:

Many thanks to the Ministry for Science and Innovation, since renamed Ministry for Business, Innovation and Employment, for their Education Fellowship funding for this project.

Special thanks to the owners of Carpets and Rugs of New Zealand (CRONZ), John and Helen Wyma for offering me their time, expertise, support and providing equipment for the duration of this project.

Sincere thanks to Massey University, in particular my deep gratitude to Dr Sandy Heffernan and Dr Jessica Payne, my supervisors at Massey University, for their guidance and advice throughout study, and many thanks to Dr Julieanna Preston for all her help and encouragement.

Thank you to the following people for kindly allowing me to interview them:

Dr Rolf Wittlinger (Textile Chemicals, Product Safety) at BASF, Ludwigshafen, Germany for offering an insight into the importance of being able to measure the environmental impact of chemicals used in textiles.

Ray Porter (Textiles Division Manager) at Chemcolour, Auckland, New Zealand for providing the eco-friendly dyeing chemicals used in this project and offering technical support.

Steve McNeil (Senior Textile Scientist) at AgResearch, Lincoln Research Centre, New Zealand for offering technical help and the loan of ultrasonic equipment to CRONZ.

Mick Ingram (General Manager) at Radford Yarns, Christchurch, New Zealand for allowing me to see how felted carpet yarns are made and provide different types of yarn to test with.

Finally, many thanks to all my family and friends for their encouragement, particularly to Janet Carter and Grace Harman for their ongoing support and help.

Notes:

Ethics: This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz.

Paper: ECO100 paper stock has been selected to print this research on due to the environmentally friendly manufacturing process that includes using 100% waste paper in a chlorine free process. Environmental accreditation includes; Blue Angel, Nordic Swan and the Austrian Environmental Label.

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Glossary:

Acid dye: There are three main types of acid dye: levelling dye, milling/super milling dye and pre-metalized dye. Acid dye is usually used on protein fibres lowering the pH of the water in the dye bath so it is slightly acidic (Dharma Trading Co., 2012).

Levelling acid dye creates good strong bright colours but is not totally water fast so cold water wash or dry-clean only is recommended. It creates very even colour and is an excellent dye for wool. Gluabers salt is added as a levelling agent. It is the most acidic dye bath (*Ibid.*).

Milling/Super Milling acid dye (also called Neutral Acid Dye) has excellent wash fastness however the light fastness varies. Does not dye as evenly as levelling acid dyes. Vinegar or Ammonium Sulphate can be added to slow the dyeing process down to allow for a more evenly dyed result (*Ibid.*).

Pre-metalized acid dye uses metals in very small amounts in the dye. These dyes are the most wash fast and lightfast of all acid dyes. Care must be taken to apply very evenly in the dye bath. Ammonium Sulphate is added as a levelling agent. Works best on wool and silk (*Ibid.*).

Auxiliaries: textile auxiliaries describes any chemicals or additives that are used in the pre-treatment of fabric or yarn, added to the dye bath or used as after-treatments. An example of an auxiliary is a chemical that may be added to the dye bath of a wool yarn to stop it from felting while submerged in water at high temperatures during the dyeing process (R. Wittinger, personal communication, March 22, 2012).

Cavitation: This happens when ultrasound is applied in a dye bath. Tiny bubbles are generated and which then collapse causing small ‘hot spots’ where high pressure and temperatures are formed. Cavitation is capable of breaking chemical bonds (Techspan Group, n.d.).

Environment Canterbury Regional Council: Often referred to as ECAN, amongst other things, offers information to businesses on ways to become more sustainable and energy efficient (Environment Canterbury Regional Council, 2009).

Environmental Choice New Zealand: ECNZ is the official environmental labelling system. Offers its own standards and licensing system that businesses can apply to obtain. ECNZ sits under the umbrella of Global EcoLabelling Network, this network adheres to ISO 14024 standards (The New Zealand Ecolabelling Trust, 2012).

Entrophication: This is a problem in agriculture where runoff from the land can sometimes build up in lakes or other bodies of water. This causes high amounts of nutrients resulting in dense plant life, effectively killing animal life due to lack of oxygen (Lyons, 2009).

EPA: Environmental Protection Authority. Lists hazardous chemicals and substances and lists regulations for safe use (Environmental Protection Authority, n.d.).

ETAD: The Ecological and Toxicological Association of Dyes and Organic Pigments Manufacturers. Represents these industries on matters relating to health and the environment (ETAD, n.d.).

Hank dyeing: Hank dyeing is where a fibre is dyed in spun yarn form, rather than as a fibre before it is spun (M. Ingram, personal communication, August 3, 2012).

Mordant: This term is used to describe a substance that is added to dye baths to help the dye adhere to the fabric, rather than wash off when the textile is washed. Examples of this are salt – most commonly used on cellulose fibres or vinegar – most commonly used on silk. Metals are often added to dye baths as a mordant, especially when using natural dyes (Collier & Tortora, 2001).

ISO: International Organisation for Standardisation

Oeko-Textile Standard 100 (Oeko-Tex 100): This is an international certification process that tests for harmful substances and looks at production methods and human contact with textiles (Oeko-Tex Standard 100, n.d.).

Pigment printing: The pigment printing process begins with a paste that is coloured with powder pigments; this paste is then screen-printed onto the fabric (Collier & Tortora, 2001).

Pre-treatment: All yarn dyed in industry is pre-treated often with textile auxiliaries to increase the yarn's ability to take up dye or improve properties of the finished yarn. Pre-treatment includes scouring or bleaching yarn (BASF, 2009).

Reactive dye: These are usually water-soluble dyes that work best on cellulose fibres (although it is possible to get some reactive dyes that work well on either wool or silk). These are used in full emersion dye vats and are alkaline dyes (Collier & Tortora, 2001).

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Introduction:

Growing awareness in New Zealand and internationally about the negative environmental impact of the textile dyeing industry has led to increasing numbers of manufacturers considering sustainable production processes (Quinn, 2010). Carpets and Rugs of New Zealand (CRONZ) is a small manufacturer of bespoke broadloom tufted carpets and rugs situated just outside Christchurch, New Zealand. John and Helen Wyma, owners of CRONZ, are aware of the environmental concerns around the current dyeing process used in the carpet industry and wanted to find strategies that lessen the environmental impact of their current dying process, and enable them to offer sustainable dyeing of wool carpet to their customers. To this end CRONZ applied for and successfully gained Ministry for Science and Innovation funding for a postgraduate student fellowship to enable a project to be conducted that investigated technology for lessening the environmental impact of energy and chemicals in the dyeing process. Because of the specialised nature of the work at CRONZ, there was also the potential to offer a unique colouration system to customers.

The purpose of research was to develop and design a sustainable dyeing process for small scale dyeing of the wool yarns used at CRONZ. Key objectives for the project were: a literature review, set up of equipment and trials, technical experimentation including trialling of the new process of dyeing wool yarn using ultrasound, contemporary colour palette production, analyses and summary of findings, sample rug production (in the form of tufted samples of coloured wool yarn) and the exhibition and presentation of finished designs as well as the written thesis. To allow CRONZ to market a sustainable dyeing process new contemporary colour palettes have been dyed using the newly developed process.

This research project has been a collaboration between CRONZ, the Ministry for Science and Innovation and the student fellow conducting the project for a Masters of Design through Massey University. The collaboration provided the opportunity for the student fellow to gain insight into how new research and technology is informing sustainable dyeing processes for wool yarns, also to see the full production process of carpet, from wool being made into yarn through to the tufting of the coloured yarn that forms the finished carpet. Additionally, collaboration allowed examination of the role process design plays in the manufacturing of carpet.



Figure 1: Selection of carpet created at CRONZ

Context:

Dyeing:

Until the 1900s, colouring textiles usually involved immersing the textile in a water bath with plant materials and occasionally animal materials. During the late 1800s chemical colour dyes were discovered and by 1900 a wide range of chemical colours (called synthetic dyes) were being used to dye textiles (Harris, 1993). The advantages of using synthetic dyes are that colour can be accurately reproduced, there is a wider variety of colour choices available, and synthetic dyes are significantly more light and wash fast than many of the natural dyestuffs (*Ibid.*).

Wool has long been seen as the superior product with which to create carpet and rugs and historically was used for hand woven rugs due to its natural ability to repel water and its warmth (Harris, 1993). When colouring wool yarn for carpet the most important feature of the dye is light fastness. Without this, the lifespan of the carpet may be compromised through fading. The other two key attributes for carpet wool dyes are achieving even colour and good penetration throughout the yarn.

Wool yarn, dyed by full immersion and used for making carpet, is most often dyed before the carpet is constructed at either the stock dyeing stage or the hank dyeing stage. Below are all the possible stages at which wool yarn used for making carpet can be dyed. Full immersion dyeing of the yarn can be done at any one of four stages: the fibre stage (before being carded to spin into yarn), called “stock dyeing”; once the fibre is carded (in sliver form), called “top dyeing”; once the fibre is spun into yarn, called “hank dyeing”; and lastly, dyeing entire carpets or rugs made of felted yarns, called “beck dyeing” (M. Ingram, personal communication, August 3, 2012).

The current textile dyeing process used within the industry is outlined below. The process alters depending on the product being created, so this is a general overview of the process used before implementing any techniques to make the process more sustainable.

Wool yarn that has been spun or felted from fiber is put through any necessary processes such as scouring and bleaching and is then dyed using one of the following dyes: natural dyes, synthetic reactive dyes, synthetic acid, and synthetic basic dyes (Fletcher, 2008). During the commercial dyeing process chemicals, usually referred to as auxiliary chemicals, are typically added to dye powder in a water bath to ensure dye bonds to the fibers, colour goes on evenly and to prevent insects eating the fiber (*Ibid.*).



Figure 2: Current colour selection folder at CRONZ with the seven most popular colours on the right.



Sustainability:

The concept of sustainability is a recent one with measures initially developed in the 1970s to combat climate change and damage to the natural environment and humanity. It is generally agreed that climate change is a result of higher carbon levels in the atmosphere. One of the main contributors to the increase in carbon levels is the manufacturing industry, which started to have the most significant impact following the Industrial Revolution (M. Morris, lecture notes, 14th May 2012).

Sustainability has become a major influencing trend in manufacturing and design. As Andrea Lucena-Orr, colour forecaster for Dulux, states: “Sustainability, environmental care, re-use and recycling are becoming increasingly prevalent in the way we live. The future is about finding better ways to protect and care for our world and its resources” (Dulux New Zealand, February 10, 2011, [video file]). Further, world trend commentators such as Youngsook Park, Chair of UN Future, see design trends associated with solutions to climate change and energy sources as being one of the ways design will continue to develop in the future (2009, June, para. 1).

The environmental concerns surrounding the textile dyeing industry are well acknowledged. An example of this is the study entitled *The Impact of Textile Wet Colouration on the Environment in 2011*, which states: “Wet textile colouration has the highest environmental impact of all textile processing steps. It consumes water, chemicals and energy and produces liquid, heat and gas waste streams” (Hurren, Li, & Wang, p. 540, 2012). The textile industry seeks to improve the environmental impact on current production methods of textiles through finding ways to reduce use of toxic chemicals, energy and water (Fletcher, 2008, p. 46).

According to a comprehensive Canadian study called *Energy Performance: Benchmarking and Best Practices in Canadian Textiles Wet Processing* the wet processing (wet processing covers the pre-treatment, dyeing, printing and finishing of textile production) “is the most energy-intensive aspect of textile production, accounting for 75-85 per cent of plant utility costs” (Canadian Industry Program for Energy Conservation, 2007, p. 2). High-energy use here is usually associated with the high temperatures needed in dye baths (Hurren, Li, & Wang, 2012). Finding sustainable solutions for producing textile products must look at processes that reduce energy use at the wet processing stages.

High chemical use in the dyeing of wool yarn is standard, with the use of chemicals in the production of textiles currently sitting at the same level as petro-chemical production (Quinn, 2010, p. 109). A key environmental issue here is not just the energy and resource consumption to create the chemicals, but the negative effects on eco-systems if textile dye wastewater is not disposed of correctly. A Greenpeace report entitled *Dirty Laundry: Unravelling the corporate connections to toxic water pollution in China*, outlines the hugely damaging effects when chemicals from textile mills in China are not properly treated before disposal into waterways. Current ecological damage to Chinese rivers includes hormone disruptions in eco-systems through chemical build up (2011).

Another researcher, Graham Dickinson, occupational hygiene and environmental consultant in Australia, recommends four affordable measures for improvements in the resourceful colouration of textiles: restrain, repair/refurbish, retrofit and replace (conference lecture notes, March, 2012). The measures offer realistic goals for small companies to work towards.

This research focuses around solutions to reduce the damaging effects to the climate and ecology through looking at strategies to restrain the use of energy and chemical use during the hank dyeing process for wool yarn as used in the carpet manufacturing industry.

Carpets and Rugs of New Zealand:

CRONZ works with a number of interior design and architectural firms in both New Zealand and Australia to create custom broadloom carpets and rugs commissioned for a wide variety of interior spaces (see figures 1 & 3). This year alone CRONZ has manufactured wall-to-wall carpet for large, sophisticated commercial spaces, rugs and hall runners for luxury boutique accommodation and heirloom rugs for family homes. A typical customer is looking for a beautifully bespoke piece that is unique to their business or home.

The current colouration practice at CRONZ is to get wool dyed at either the stock dyeing or hank dyeing stage. Currently the majority of all wool yarn used at CRONZ is sent to Wool Yarns, based in Lower Hutt, New Zealand to be dyed. This research focuses on dyeing wool yarn at the hank dyeing stage, as this is the most appropriate dyeing process for the small-scale sustainable process CRONZ would like to test.

CRONZ's clients currently have two ways of choosing colour for carpet or rugs. They can either choose colours from the CRONZ standard colour range folder (see figure 2) or they can order custom colours. The standard CRONZ colour range is a collection of what CRONZ sees as the most popular and sought after colours within their current Australasian market (Helen Wyma, personal communication, April 4, 2012).



Figure 3: Rug created using the broadloom tufting process at CRONZ

Methods:

There are key methods that can be used to research and assess chemical and energy use in the dyeing process. These are life cycle analysis, traceability, sustainable labeling and certification, and dye process experimentation. Life cycle analysis involves analysing data about the life of a particular product and measuring the environmental impact that the item has on the earth throughout its production and use, with the aim to make improvements to the carbon footprint of a product. Traceability involves tracing a supply or production chain back to include all necessary steps to production of a finished product. The environmental importance of traceability is characterised by the ability to check that proper environmental and health and safety measures are being used throughout production. Sustainable certification and the labeling that goes with it involves meeting national or international standards regarding environmental aspects of the production of a product and allows products that meet the requirements to carry the appropriate labeling. Through repeatedly measuring and testing a current dyeing process it is possible to discover ways to lessen the environmental impact of a process.

Process:

There is a clear need and importance to designing processes and production methods that are sustainable. David Walker, an Auckland-based architect and design leader in New Zealand, discusses sustainable innovation stating: “All design work, engineering work and productive capabilities, should be aligned in the same direction - that is to be more efficient with resources, to consume less energy and to engender really good habits of consumption... everywhere.” (New Zealand Trade and Enterprise Better by Design, n.d., para. 6)

Because the emphasis of this research is on designing a process it is necessary to understand what a typical design-led research process looks like and how it functions. According to the journal article *Action Research and the Practice of Design* by Cal Swann, design research differs from a purely scientific process as it includes a more creative way of problem solving leaving room for “the creation of potential solutions based on individual insight” (Swann, 2002, p. 51). Swann explains how essential reflection is to the development of design processes. A design-led process has stages that flow on from one another, all stemming from the initial problem, as a scientific process

would, along with the revisiting of stages throughout the process, allowing for reflection and modification.

Below is the basic design-led process as discussed by Swann (Swann, 2002, p. 53):

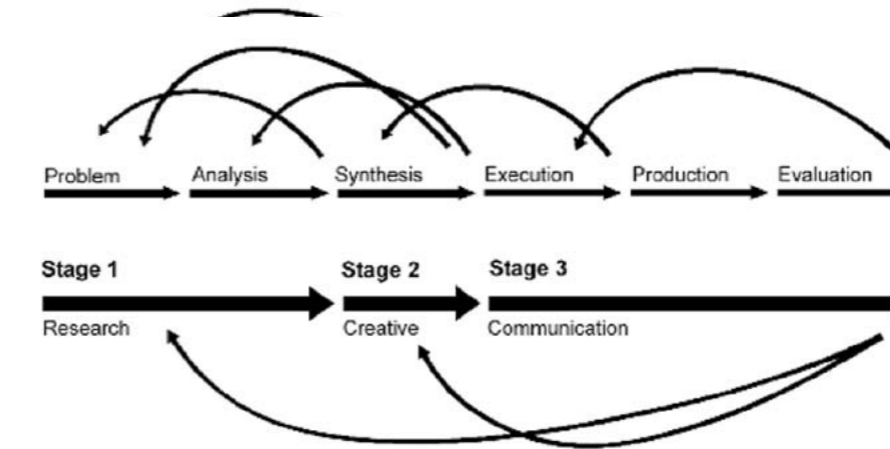


Figure 4: Design-led model. (2002), Swann, C.

The design-led model places the emphasis on the creation of form, rather than placing the emphasis on the end form (Ingold, 2010, p. 2). The importance of design-led research here is that the process itself becomes the mechanism for transparency of the environmental goals of reducing the impact of energy and chemical use in the colouration of wool yarn. Carrying out the physical process of dyeing the wool yarn allows for a much more complete understanding of the process. This in turn allows for the type of reflective and intuitive alterations to the process that Swann speaks of.



Figure 5: Home page of CRONZ website. (n.d.). Screenshot of CRONZ homepage.

Marketing sustainable products:

In addition to the environmental benefits of sustainability, there are also significant marketing advantages. The branding used at CRONZ plays on an association between the land and beauty of New Zealand and the wool carpet made at CRONZ using wool grown in New Zealand. This can be seen in the company tagline: *The beauty of New Zealand on the floors of the world*. By associating the land and beauty of New Zealand with the wool carpets made at CRONZ, consumers are not only buying the carpet but the idea of the natural beauty of the land in which the wool is grown and where the carpets are manufactured. So by reducing the impact that the wool carpet produced at CRONZ is having on the land, there would be a stronger association between product and place.

Another marketing advantage is that CRONZ could offer a sustainably superior product that authenticates how CRONZ cares for the beauty of the land that the wool carpet comes from. Key features of authentication are being able to offer comprehensive information to customers on the environmental impact of production methods used at CRONZ through the use of life cycle analysis and traceability. Identifying key certification and labelling that CRONZ would be eligible to use offers a clear visual alert to customers as to the point of difference – that steps have been taken to reduce the impact on the earth. While the carpet would have the same highly lightfast qualities there would be an added benefit to the customer of lessening chemical and energy use, therefore customers would have a healthier product that uses less of the earth's resources. In turn these measures strengthen the current branding association used at CRONZ.

Strategies to lessen the environmental impact of energy and chemicals in the dyeing process of wool yarns for carpet

Life cycle analysis:

As noted in the introduction, life cycle analysis (LCA) is one model of measuring the environmental impact that a product has on the earth throughout its production and use. A standardised system measures the impact through use of resources (such as water, energy, chemicals) in production along with environmental impact (such as damage to waterways) taking into account the expected life of the product and its disposal. The aim in using this type of model is to pinpoint areas of production that have the highest impact on the environment and then find ways to reduce the impact these areas make (Rajagopalan, Bilec & Landis, 2012). LCA models should follow the ISO rules and be peer reviewed to ensure the model is of high quality (Klöpffer, 2012). The New Zealand Merino Industry has published a life cycle assessment looking at *Merino Wool Total Energy Use and Carbon Dioxide Emissions* and the Australian Wool Innovation is currently working on a comprehensive Life Cycle Analysis (Lyons, 2009). Reducing energy use and chemical use are the key areas of interest to this study, therefore that is where examples are focused.

The New Zealand Merino Industry's life cycle assessment was published in March 2006, but unfortunately does not include the dye process and does not take a cradle to grave approach, as its goal was to establish information about wool only until fabric formation. Australian Wool Innovation also produced a LCA, however they felt that there were too many problems with the data produced and are planning on publishing

a new report in March 2013 that will include greenhouse gas emissions, carbon sequestration, water usage/water footprint, entrophication and land use (Lyons, 2009, p. 101).

Finding a relevant comparative LCA that includes the full colouration and production of wool carpet is difficult. This is partly due to the ISO continuing improvements to the standards of LCA. While these improvements are necessary it makes it difficult to compare older studies with newer studies (see appendix 2 for additional information). For this reason the focus here is on finding reports and data about textile colouration that point to methods of reducing energy and chemical use in the dyeing process.

Reduce energy:

The highest use of energy in textile production is during wet processing as dye bath temperatures of 98°C are required for dye chemicals to work correctly (Hurren, Li, Wang, 2012)). Ege Carpet, a Denmark-based yarn and carpet manufacturer has very strong environmental policies around energy use. They employ a continued dye system to colour carpet, which uses natural gas as the energy source (ege Carpet, 2012, July). A key energy goal for ege Carpet is to “reduce energy consumption by 20% over the period 2006/7 – 2014” (ege Carpet, 2012, para. 3). Jan Ladefoged, Quality and Environment manager at ege Carpets, discusses how energy savings are planned to be made through ventilation control and use of residual energy (*Ibid.*).

Key aims:

Key aims of this project are to use the methods of life cycle analysis, traceability, sustainable labeling, and certification to research strategies that have the potential to reduce the environmental impact of energy and chemicals in the dyeing process of wool yarns for carpet. Then to find suitable ways to implement the strategies identified, through running different experiments of dye baths, continually modifying and refining this experimentation process as required to develop a sustainable small scale dyeing process for the wool yarns used at CRONZ. The overarching aim is for the newly developed dye process to offer clear environmental improvements for CRONZ. The environmental improvements can then be used to strengthen CRONZ's marketing.

Results:

The results of this project are described in two sections. The first section describes the findings from researching strategies to lessen the environmental impact of energy and chemicals in the dyeing process of wool yarns for carpet while the second section describes the experimentation method, process and findings. This section also includes findings from the ultrasound testing.

An extensive study entitled *Energy Performance: Benchmarking and Best Practices in Canadian Textiles Wet Processing* gathered data from 22 textile plants with the overall discovery that energy management is key to improving energy conservation. This study defines six different areas as being important to manage energy use.

1. Corporate Energy Policy
2. Organization
3. Skills and Knowledge
4. Information Systems
5. Marketing and Communications
6. Planning and Investment

Weak areas were skills and knowledge along with marketing and communications, with the report recommending incremental changes to improve these areas. Additionally, of the twenty-two plants monitored, none measured and recorded energy use during production, meaning there was a lack of understanding around energy use and no data to compare energy use year-to-year. Therefore, understanding and communicating energy information along with monitoring and recording energy use is key to its reduction (Canadian Industry Program for Energy Conservation, 2007).

One organisation that does track energy use successfully is BASF, a large international chemical company, who use a six point system with their own developed LCA as a way to reduce energy use in textile colouration systems. The six point system measures: energy consumption, emissions, toxicity potential, risk potential, use of resources and use of area/space in factory. When interviewed about reducing energy use, Dr Rolf Wittlinger, BASF's textile chemist in the area of product safety, explained that pigment printing is both environmentally and economically more efficient than reactive printing because pigment printing uses less energy (see appendix 3 for transcript). Reactive printing requires more steam, washing and drying (R. Wittlinger, personal communication, March 22, 2012). While it appears that pigment printing is generally more energy efficient than the reactive dyeing process, immersion-dyeing processes such as reactive dyeing or acid dyeing are used in industry for the dyeing of yarns to ensure the dye fully penetrates the yarn.

Much of the wool yarn used at CRONZ is manufactured at Radford Yarn, a Christchurch-based company. Radford Yarn has made changes to their energy source for the most energy intensive part of the felting process, heating the water. In an effort to “to ensure [their] products support New Zealand’s “clean, green” international reputation and to reduce [their] carbon footprint” they have installed a wood pallet fuel system to heat the water used for felting (Radford Yarn, 2012).

Recent scientific research has shown introducing ultrasound waves into dye vats could be a possible way to reduce energy by allowing a reduction in the temperature used for dyeing. High frequency ultrasound waves have traditionally been used to clean hard surfaces through an action known as cavitation (Guyson, n.d.). It is thought that this same action could help the yarn dyeing process through encouraging the dye into the yarn at lower temperatures (Ferrero and Periolatto, 2011). Traditionally temperatures of around 98°C are held for up to 120 minutes in the dye vat. Finding ways to reduce this temperature could contribute to making the dyeing process more energy efficient, and on a practical level reduce the risk of damaging the wool fibres through keeping them at this high temperature (Ferrero & Periolatto, 2012, p. 602).

John Wyma, owner of CRONZ, is interested in testing the new and emerging technology of ultrasound as part of a sustainable dyeing

process. CRONZ are looking for technology that can be altered and individualised to their specific needs (personal communication, November, 2011). The ultrasound system is also very compact and therefore quite a feasible size for the small scale dyeing CRONZ anticipates doing.

Researchers from AgResearch in Christchurch, New Zealand have explored possible environmental advantages to using ultrasound during pre-treatment of small handfuls of wool fibres and then in the dyeing process of the wool using reactive and acid milling dyes as a way to reduce energy and chemical use. Overall there were mixed results. It seems that the use of ultrasound at the scouring and bleaching phases of pre-treatment improved effectiveness of these processes. However, the wool that had been pre-treated with ultrasound was slower to uptake the synthetic dyes (McNeil & McCall, 2010, p.405).

Following the study done at AgResearch, one aim of experiments in this research is to compare time taken to uptake dye with and without the use of ultrasound in order to find the more energy efficient option. One limitation of current research in the area of dyeing textiles with ultrasound is the very small amounts of yarn tested per batch, so this research aims to increase the sample size to achieve more commercially-applicable results.

Reduce chemicals:

Reducing chemical use in the wool yarn dyeing process is critical to solving environmental issues around ecological damage through wastewater disposal, with the added environmental benefit of reduced production of these chemicals. In New Zealand the largest volume of waste is wastewater (Ministry for the Environment, 2012). In the standard hank dyeing process for wool yarn the yarn is added to a water bath at a ratio of 1:15 (Clariant, n.d.). Common chemicals added to the water bath are: dye powders, salt, and acid, along with auxiliary chemicals to ensure qualities such as longevity and even colour on the yarn. Both the Südwole Group and Rubia Natural colours show that it is possible to reduce chemical use during the yarn colouration process, therefore reducing pollutants in wastewater and the need for certain chemicals to be produced.

The Südwole Group, a German-based manufacturer and dyer of yarn, is committed to reducing chemical use during the colouration of yarn. A yearly report for the company, entitled Ecobalance, explains the Südwole Group's commitment to reducing the use of chemicals through the use of their own digital colouration system called Dyeco, which uses the motto *less is best*. Chemical use is broken down into chemicals, dyestuff and auxiliaries. In 2009 the use of chemicals was at its highest at 250 kilograms per ton but by 2011 this had been reduced to 100 kilograms per ton (2012).

Rubia Natural Colours is a Dutch-based firm that specialises in creating textiles with a focus on reducing chemical use during the colouration of yarn by using natural vegetable dyes, rather than synthetic dyes (see figure 6). They specialise in extracting the colour known as Rubia red from a vegetable root called madder. The process has been used to colour woollen carpet for office interior applications (Rubia Natural Colours, 2011). The success at Rubia Natural Colours is due to having access to substantial quantities of madder root grown in Holland. New Zealand does not grow madder root meaning that this would not be such a good commercial dye option for CRONZ, therefore the research conducted here uses synthetic dyes.



Figure 6: Rubia dyed carpets. (n.d.), Rubia Natural Colours.

Chemical use in the dyeing of textiles is a specialist area and during an interview, BASF textile chemist Dr Rolf Wittlinger outlined the role that education plays in the correct use of the dye auxiliary chemicals BASF develop and sell. “The textile mill or textile producer can do what he learnt and this is to produce textiles, this is patterns, fabric production and special weavings, but they usually have very limited experience in the application of chemicals. They need consultancy and technical support...” BASF offers expert help with the chemicals they sell as a way to combat misuse of the chemicals (personal communication, March 22, 2012). This highlights the need to understand chemical use through safety data sheets, technical information and expert help.

Particularly harmful chemicals used during the hank dyeing of wool yarn for carpet are pre-metalized acid dyes for wool yarn and insecticides. Pre-metalized dyes contain harmful heavy metals such as zinc, lead and copper (United Nations Environment Program, 1993) and these can reach ecosystems via wastewater. In Christchurch, New Zealand, a key regulation for disposal of trade wastewater is that water must not contain colour when disposed (Christchurch City Council, 2006). Clariant, a Swiss-based chemical company, produces a range of eco-friendly dyes called the Optilan® MF range. These are suitable for dyeing 100% wool yarn using the hank dyeing process and do not contain heavy metals (see appendix 4 for suppliers declaration). They also allow for a near 100% exhaustion rate, meaning that there should be very little colouration residue in the waste water (R. Porter, personal communication, June 7th, 2012).

After careful consultation with Ray Porter (Textiles Division Manager) at Chemcolor, the Clariant Optilan® MF dye range has been selected for use in this research. This choice is based on both the environmental benefits and availability of the dye, as CRONZ needs to run testing with a product that is readily available in New Zealand.

Moth treatments are generally added in the form of an insecticide to increase the longevity of carpet and have the potential for danger to both the environment and human health (National Pesticide Information Centre, 2011). The usual moth treatment added to wool yarn dyed for CRONZ is Larvanil SB-5, containing the insecticide Bifenthrin (H. Wyma, personal communication, July 23, 2012). Bifenthrin is known to be highly toxic to aquatic life as it has the ability to build up in fish (National Pesticide Information Centre, 2011). Additionally Bifenthrin is known to cause

respiratory problems in humans if inhaled (Material Safety Data Sheet: Larvanil SB-5, 2005) and the US Environmental Protection Authority cites Bifenthrin as being a possible human carcinogen (*Ibid.*). Due to these environmental and safety hazards, no insecticide has been used in dye process testing in this research. The Pesticide Action Network UK suggests regular vacuum cleaning and steam cleaning as safer alternatives (2006).

A common auxiliary chemical used for dyeing wool yarn is Lyogen MF Liquid (Lyogen). Lyogen works to slow down the time taken for the dye to absorb into the yarn, creating level or even colour on the yarn. While this chemical is not dangerous to the environment (Safety Data Sheet: Lyogen MF Liquid, 2010), any reduction in auxiliaries benefits the environment by reducing the need for the chemical and thereby saving resources.

In addition to examining use of chemicals in the colouration of the yarn, chemical use has also been examined in the yarn making stage in order to gain a more complete understanding of chemicals in a finished carpet. Radford Yarn is the Christchurch yarn-manufacturing company who supply CRONZ with the majority of the 100% New Zealand wool yarns used for textured carpets and rugs. At the yarn making stage of production, natural spinning oil is added to the wool fibres along with a biodegradable industrial detergent (see appendix 5 for the full yarn making process). There are no chemical differences between types of yarn produced at Radford Yarn and bleach is not used to lighten the

yarn colour (M. Ingram, personal communication, June 19, 2012). (See appendix 6 for chart of yarn types and treatments).

Radford Yarn produce ranges of natural undyed yarns for the European market, eliminating the additional energy and chemical requirements of the dyeing process. Proportions of natural white wool fibre are mixed with natural black wool fibre yarn to produce undyed grey yarn. These yarns are produced in graduated ranges, offering customers a wide choice of neutral undyed coloured yarns (M. Ingram, personal communication, June 19, 2012). One example is the 3600 tex grey yarn produced at Radford Yarn (see figure 7). CRONZ currently offers customers the option of one natural undyed yarn, however, Radford Yarn shows that there may be the option to extend the natural undyed yarn range. In addition, it may be possible to develop a range of yarn where only a small percentage of the yarn is dyed; for example, by mixing 20% synthetic dyed wool fibres with 80% natural undyed wool fibres resulting in a reduction in chemical use.



Figure 7: 3600 tex grey yarn produced at Radford Yarn.

Using the concept of life cycle analysis, information has been collected regarding energy and chemical use in the manufacturing and dyeing of wool yarn for carpet in order to discover strategies to lessen the environmental impact. The following key strategies have been discovered: tracking data with the aim to reduce energy used, testing the time yarn takes to absorb dye with and without ultrasound to see if there is potential to reduce energy, use of eco-friendly chemicals, reducing additional auxiliaries, and seeking to further incorporate natural undyed wool fibers in colour ranges.

Traceability:

Traceability involves tracing the supply or production chain back to include all necessary steps in producing a finished product. Environmentally the importance of traceability is characterised by having good sustainable production standards in place during farming and manufacturing (Opara, 2003). By tracing a product back to where it is being produced it is also possible to make decisions that reduce the carbon footprint made during production. Wools of New Zealand and Banks Peninsula Farms are two examples of New Zealand-based companies that offer customers extensive information about the origins of wool used for carpets as part of an environmentally sound production chain.

Wools of New Zealand is a carpet manufacturing company who enable customers to trace their wool carpet back to the farm gate as a way of guaranteeing the product has been produced under the strict sustainable guidelines marketed as the Laneve brand (see figure 8). Information is given about the farm that the wool comes from along with the textile mills that carry out production. A farming collective called Banks Peninsula Farms also offer a traceable system. As the name suggests, this is a group of 19 farmers located in the Banks Peninsula region of the South Island of New Zealand who raise sheep for strong wool used in carpets. The collective is able to offer carpet manufacturers assurance that their wool is grown in the region of the Banks Peninsula and guarantee that sustainable farming practices are used. In both cases customers are assured of the sustainable farming practices and manufacturing of carpet through use of a transparent system.

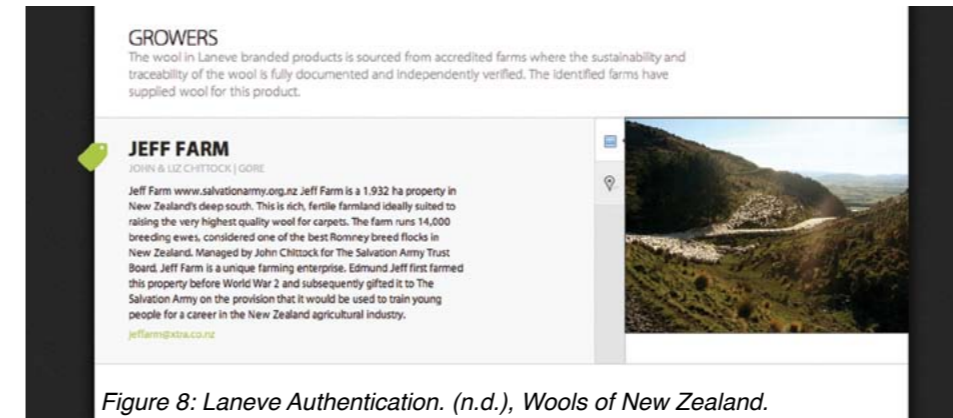


Figure 8: Laneve Authentication. (n.d.), Wools of New Zealand.

The sustainable transparency offered through traceability would be highly beneficial to CRONZ. Currently the carpets and rugs manufactured at CRONZ are made primarily from New Zealand 25-micron strong wool fiber (John Wyma, personal communication, November, 2011). CRONZ uses two suppliers for wool yarn: Radford Yarn, located in Hornby, Christchurch and Woolyarns located in Lower Hutt, Wellington (Helen Wyma, personal communication, May 23rd, 2012). Since the majority of

yarn studied here comes from Radford Yarn it was necessary to trace where the wool used in their factory comes from. The scoured wool is delivered in approximately 400kg-sized bails and sourced from farms all over New Zealand. Mick Ingram, General Manager at Radford Yarn, explained that while it would technically be possible for Radford Yarn to trace wool back through batch numbers to a group of approximately 50-80 sheep stations within New Zealand, they do not currently have the technology to pinpoint exactly where the wool comes from (personal communication, June 19, 2012). Radford Yarn has never been asked to supply this information so it is not current company practice and at this stage would be too time consuming to implement.

In addition to the environmental benefits of offering greater transparency of production through tracing the wool used at CRONZ back to where it comes from there are marketing benefits. A 2012 study entitled *Green Growth: Opportunities for New Zealand* discusses the international perception of New Zealand as a place, stating; “there is a near-universal recognition that New Zealand’s clean, green brand is valuable” (Vivid

Economics and Energy Centre, University of Auckland Business School, p. 10). Both Laneve and Banks Peninsula Farms embrace this perception by offering scenic images via websites (see figure 9) that work to associate the geographic place within New Zealand where the wool is grown with the environmental benefits. Wool from Banks Peninsula Farm is branded as *Pure New Zealand Wool: grown on Banks Peninsula Farms* (Banks Peninsula Farms, 2010). CRONZ already has a branding story that associates their wool carpets with New Zealand, therefore being able to show a clear manufacturing trail back to the wool origins would work to strengthen the current branding story.

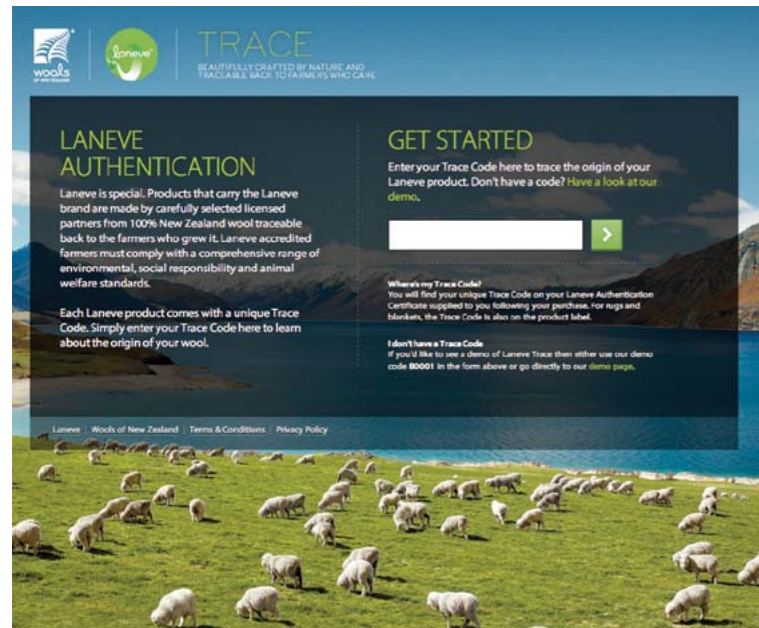


Figure 9: Laneve Authentication. (n.d.), Wools of New Zealand.

Government schemes are also being developed to help educate about environmental issues. Under the Australian government portfolio *Sustainability, Environment, Water Population & Communities*, a scheme called Caring for our Country has a focus on offering greater protection of the country's natural resources as well as working as a teaching mechanism offering help to improve sustainable practices to farmers (Australian Government Department of Agriculture, Fisheries and Forestry and the Department of Sustainability, Environment, Water, Population and Communities, 2012, para. 1). Schemes to educate give consumers greater awareness when selecting products.

Certification and labeling:

Qualifying for sustainable certification and labeling is important as it offers companies another form of authoritative transparency around sustainable production systems used, such as traceability. Unfortunately there is yet to be a worldwide-standardised system for comparing sustainable qualities of dye pigments. At present there are two common international textile environmental labelling systems: Oeko-Tex® Standard 100 and Bluesign® standard. Oeko-Tex® Standard 100 (Oeko-Tex® 100) looks at harmful chemicals used from the production stage through to the end-use (Oeko-Tex® Standard 100, n.d.). Bluesign® standard focuses on eliminating chemicals that are hazardous to the environment and health and safety during textile production (Bluesign®, n.d.). New Zealand adheres to a different system called Environmental Choice New Zealand (ECNZ). This is the official New Zealand environmental labelling system and it offers its own certification system (The New Zealand Ecolabelling Trust, 2012).

Certain dye chemicals qualify for sustainable certification if manufactured according to strict criteria. BASF has certification to use the Oeko-Tex® 100 labelling. Clariant, the company who produces the Optilan® MF dye chemicals used in this research, is certified with the Bluesign® standard. The Optilan® MF range also meets standards for the ECNZ environmental labelling system. Through choosing to use the Optilan® MF range in this research, both international and national environmental labelling systems are applicable for CRONZ's Australasian market.

There is also a marketing advantage to CRONZ from using environmental labelling on its products. The consumer survey entitled *Price, packaging and perception: Global results from the 2011 ImagePower Green Brands Survey* discusses how 48% of consumers in Australia look to a type of green certification mark to help decide whether to buy a product. Packaging and word of mouth are the also key factors in buying a green product (Ibid, p. 32). Although it is noted, that the wide range of green certification marks used in some countries can become confusing (Ibid, p. 10), this is not a current issue for the New Zealand and Australian market.



Figure 10: Equipment and chemicals used for dye testing.

Experimentation: method, process and findings

This section describes the steps and processes taken during experimentation. It is written in temporal sequence with issues, new learning's at each stage, and modifications highlighted as they occurred. It follows a design-led-process with an iterative methodology used to prove that the refined process is repeatable for a small company like CRONZ. Throughout the physical process of dyeing wool yarn, key documentation tools were observation (written, photographic and video) and analysis (tracking data, aesthetics of colour) as methods to improve and refine environmental aspects of the dyeing process.

Sustainable aims for dye bath experimentation:

1. Follow industry best practice where possible.
2. Use eco-friendly dye + chemicals.
3. Aim for complete use of dye chemicals (100% exhaustion of colouration chemicals in dye bath).
4. Document energy and chemical use as a tool to find areas where chemicals and energy could be lowered or eliminated.
5. Test the use of ultrasound in the dye bath to see if it helps yarn absorb colour faster as a possible method to reduce energy use.



Figure 11: Yarn used for dye testing: 3 ply 740 tex, 1300 tex felted yarn, 3600 tex natural black and white flecked wool (left to right/top to bottom).

Method:

The method used has taken the industry best practice process for hank dyeing of wool yarn using Clariant MF Optilan dye (see figure 10) for setting up a repeatable dyeing process for small batches of yarn (50 – 250 grams yarn) as the benchmark before tailoring the process to the specific aims of this project. All yarns used were 100% wool with the following thicknesses: 1300 tex felted yarn, 3 ply 740 tex yarn and 3600 tex natural and black neps yarn. The first two yarns were selected by John and Helen Wyma because they are the most popular yarns used at CRONZ and are quite different in thickness. The difference was important for developing a colouration process, as the process needs to work for a variety of yarn types. The third yarn is a 3600 tex natural undyed grey yarn that is not currently used at CRONZ but manufactured at Radford Yarn. Yarn has been selected from one particular batch number in each instance to keep the process consistent. Yarn has been dyed in minimum batches of 50 grams of yarn and maximum batches of 250 grams of yarn.

The Clariant Optilan® MF industry method has been used as a starting point to ensure the correct process and auxiliary chemicals were used (see appendix 7 for dye procedure card). Auxiliary chemicals used initially were: Lyogen, Glauber's salt and vinegar as a weaker alternative to acetic acid. No insecticide was added.

In order to properly record all data about each dye bath the following information was documented: yarn type, supplier and composition, along with water temperature, pH level, energy use, dye type and amount (worked out as a percentage), water ratio and auxiliaries used. Any changes in the technique used and evaluation notes were made for every dye bath (see appendix 8 for examples of this).

The process for dyeing wool yarn in hanks for Clariant Optilan® MF dye range:

1. Fill vat with water and add wool.
2. Add a wetting agent and run 5 minutes.
3. Add dyeing auxiliaries and run 5 minutes.
4. Check pH level and adjust.
5. Add the dye and run 5 minutes.
6. Raise temperature at 1.5 degree per minute to 98 degrees (lowered to 94/5 degrees for this experiment due to equipment).
7. Run at this temperature for 45 minutes (or up to 60 mins if needed).
8. Cool and sample shade.
9. Rinse (dark shades warm water rinse and cold water rinse, light shades 2 x cold water rinses).

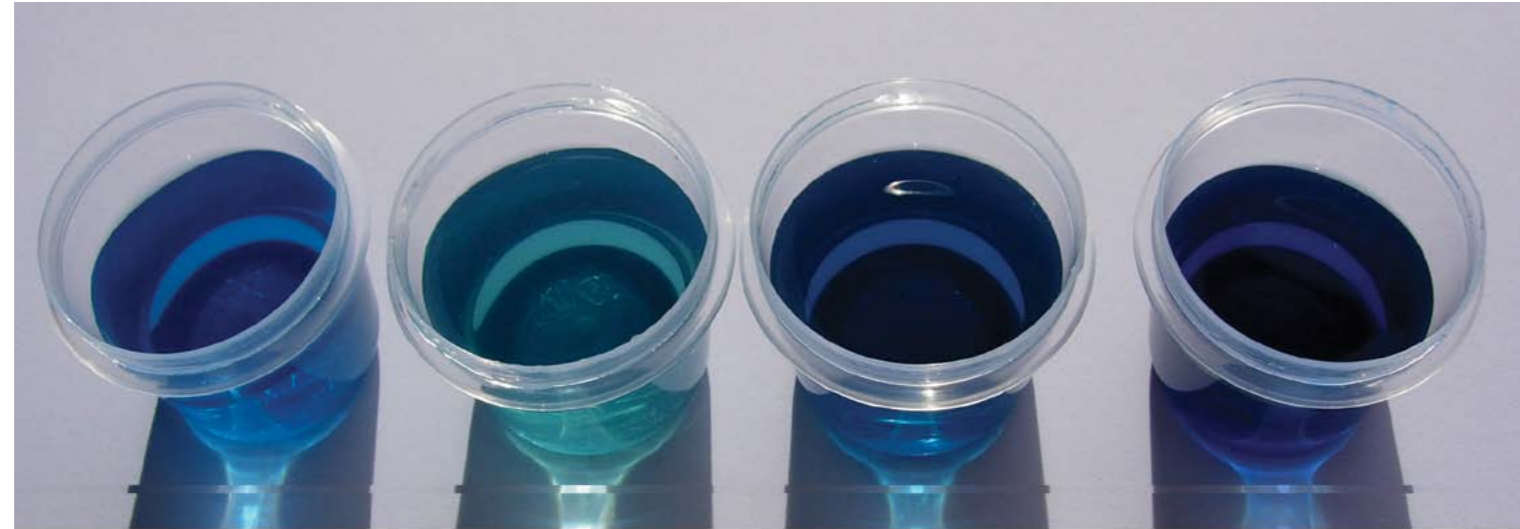


Figure 12: Attempts at exhausting dye bath

An Agee Preserver, acting like a bain-maire, was used to contain the dye bath (see figure 10 for equipment set up). A thick woollen carpet was wrapped around the outside of the Agee Preserver to prevent unnecessary heat-loss (see figure 10). Throughout testing, a stock solution of dye powder was used to mix colours from. An energy meter was set up in order to track energy use per dye bath.

A major issue during early experiments was that the dye was not exhausting, so instead of clear water left at the end of the dye bath, the water was coloured. It was important to solve why this was happening, as a key aim was complete extraction of dye chemicals. The percentage of dye powder added to the dye bath was checked ensuring that the recommended amounts of dye powder were being added. Ray Porter, contact and supplier of the dye chemicals at Chemcolour New Zealand, advised that correct temperature, correct pH levels and consistent agitation of the yarn in the dye bath water were needed for full exhaustion of the dye powder. On this recommendation, temperature levels and pH levels were tracked and charted.

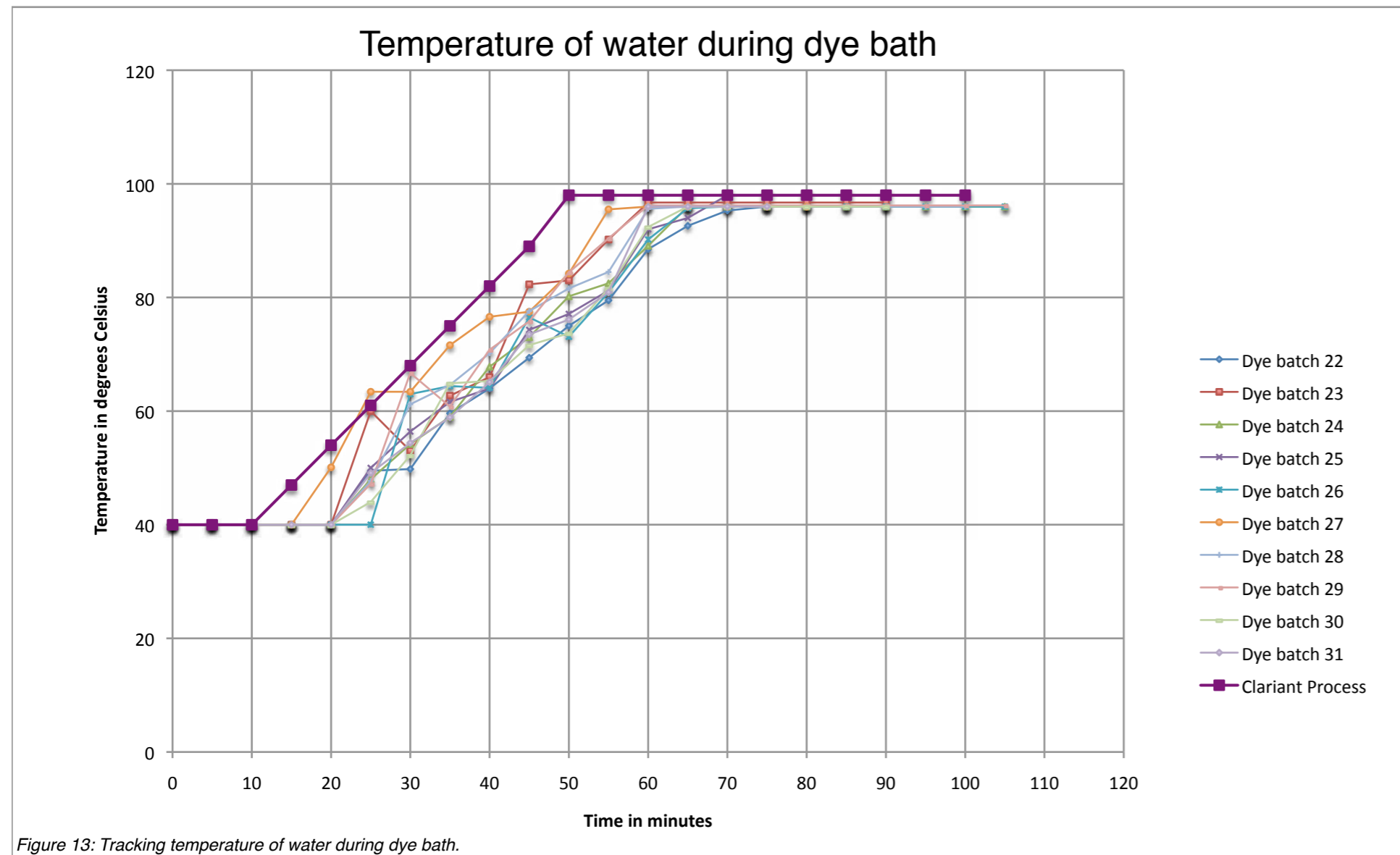


Figure 13: Tracking temperature of water during dye bath.

By tracking the temperature it was possible to see that the water was heating slower and coming up to temperature more inconsistently than industry procedure. This was due to the lack of an industrial dye vat. In industry the water dye bath temperature should reach and maintain 98°C. The results of the testing here show the dye bath maintaining between 96°C and 98°C for the second part of the dye bath, and according to Porter, this should be sufficient to exhaust the dye powder.

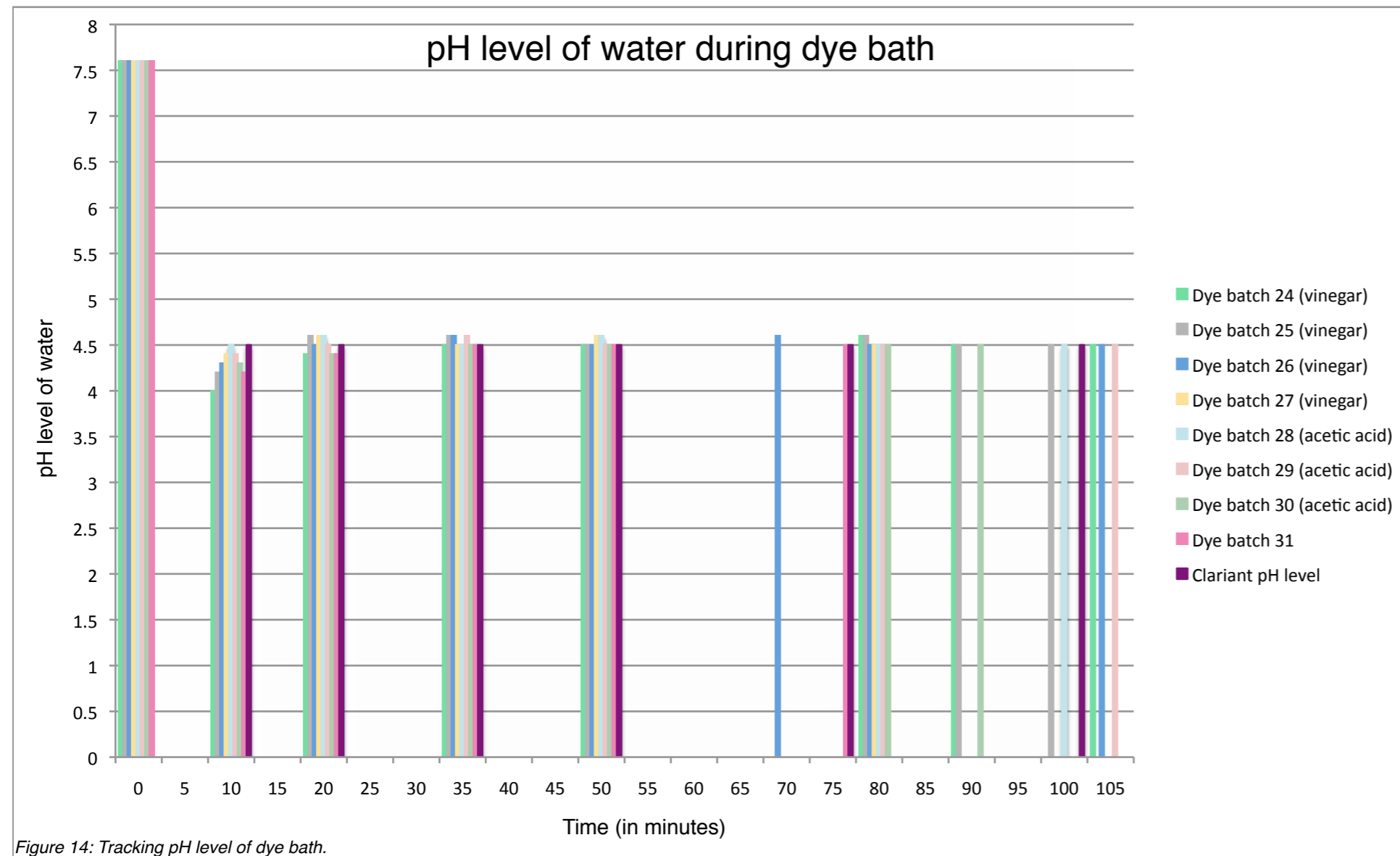


Figure 14: Tracking pH level of dye bath.

The pH level was initially inconsistent - ideally it needed to be lowered from the normal pH level of tap water to 4.5 and stay at this level throughout the dye bath to help the bonding of the dye chemicals to the wool. Porter had advised using vinegar as a diluted form of acetic acid for early trials. However, further research suggested that vinegar can vary in strength and was not a consistent form of acetic acid (Burch, 2012). As a result, vinegar was substituted for a 10% solution of acetic acid. When compared with dye baths using vinegar it can be seen that the acetic acid consistently held the dye bath at the optimal pH level of 4.5. Monitoring and correcting the pH level made the process more consistent with industry standards but did not resolve the issue of the dye powder failing to exhaust.



Figure 15: Over-agitation of dye bath resulting in felted yarn.



Figure 16: Coiling yarn before dyeing resulted in yarn curling up.



Figure 17: Twisted yarn before and after dyeing.



Agitation of the yarn in the dye bath water was the next process analysed as a potential cause of the dye bath failing to exhaust. Correct agitation, or movement, of the yarn through the dye bath is important. Not enough agitation results in yarn that is uneven (or not level) in colour; too much agitation results in yarn that begins to felt together. During initial trials the yarn had been felting through over-agitation (see figure 15), but this was eventually resolved by first coiling the yarn when dyeing, then lightly twisting it to agitate without re-felting (see figure 17).

However, examining and altering the process in relation to the temperature, pH level and agitation was not producing complete dye exhaustion. So the next step was to re-examine the dye process as a whole. The chemicals in the dye bath had all been checked except for Lyogen, a dye auxiliary that helps achieve level colour through slowing down the time the dye takes to absorb into the yarn (Clariant, n.d.). A decision was made to run testing without Lyogen, using only water agitation to achieve level colour. These tests were very successful in finally achieving the desired clear water at the end of the dye bath period and allowed for the elimination of the chemical Lyogen going forward, resulting in a reduction of chemicals in wastewater.



Figure 18: Example of uneven colour resulting from incorrect agitation of dye bath



Figure 19: Left jar contains Navy dye powder that did not exhaust properly in the dye bath, right jar contains the same Navy dye powder properly exhausted at the end of the dye bath.

In addition to eliminating Lyogen from the dyeing process used here, further research revealed it would be beneficial to soak the wool yarn in water overnight prior to running the dye baths (Dharma Trading Company, 2012). Yarn used for carpet is comparatively thick and early observations during testing showed that the yarn seemed to take 15 to 20 minutes to absorb water at the start of the dye bath. Therefore it made sense to trial soaking the yarn overnight to ensure it was primed to absorb the dye chemicals during a full dye bath, each running between 100 to 120 minutes. Through eliminating the chemical Lyogen and soaking the yarn overnight all dye baths immediately began to exhaust completely (see figure 19), resulting in the desired clear water finish.

In a further effort to reduce chemical use, 3600 tex grey yarn has been tested. Proportions of natural white wool fibre are mixed with natural black wool fibre yarn to produce the undyed grey yarn. Through dyeing just the natural white wool fibre then mixing these with the natural black wool fibre a coloured yarn could be created containing less dye chemicals. While it was not possible to test dyeing the fibre itself, the grey yarn was successfully dyed a light blue colour to test the finished appearance.

Energy use was also tracked across a number of dye baths (see chart below). It became apparent that, in general, it is more energy efficient to dye lighter shades of colour than dark shades of colour due to the shorter dye bath time needed for light colours. For the process used in these experiments it is recommended that the average dye bath run for 120 minutes. Water has to be heated during the first 100 minutes of the dye bath and after 50 minutes the water temperature needs to be held at 98°C. During experiments dye chemicals for light colours were observed to completely exhaust in a shorter period of time than dark colours usually requiring a full dye bath time of 100 minutes. For extremely dark colours (such as black) a dye bath time of up to 130 minutes is required. Shorter dye bath times equate to lower energy use.

Energy use per dye bath

Date	Batch number	Length of dye bath (mins)	Energy used (kWh)	Shade of colour
28/08/12	23	90	4.1	medium
28/08/12	24	105	5.8	dark
29/08/12	25	100	4.6	medium
29/08/12	26	105	4.5	dark
29/08/12	27	80	3.2	medium
30/08/12	28	100	4.5	dark
30/08/12	29	105	4.4	dark
30/08/12	30	90	4.4	medium
30/08/12	31	75	2.8	pale

Results:

Resolved Process (see appendix 9 for images of this process):

1. 40°C water poured over weighed yarn and left in pot overnight to soak.
2. When dye bath begins, raise temperature of water and yarn back up to 40°C.
3. Add Glaubers salt, dissolving first in a small amount of the dye bath water that is heated above 40°C to ensure proper dissolution.
Gently agitate for 5 minutes. Aim to keep water at 40°C.
4. Add initial acid portion (based on records from previous dye baths).
Gently agitate for 5 minutes. Aim to keep water at 40°C.
Test pH level and adjust, leave 5 minutes and re-test.
5. Add the dye and agitate for 5 minutes. Agitation is critical at this stage to avoid variation in the shade of colour on the yarn. Aim to keep water at 40°C.
6. Begin to gradually increase the temperature to 96°C over a 40-minute period. Record the temperature every 5 minutes to ensure heating is as even as possible.
7. After heating for 35 minutes, place lid on the stainless steel pot and leave on to heat to 96°C.
8. Leave at 96°C for 30 - 60 minutes (depending on the shade of colour dyeing).
9. Cool yarn in pot for 20 minutes with lid remaining on pot, then leave for a further 20 minutes with lid off.
10. Rinse yarn twice: first with warm water, then with cold.
11. Carefully hang the yarn and leave to dry overnight, placing onto cones as soon as possible.

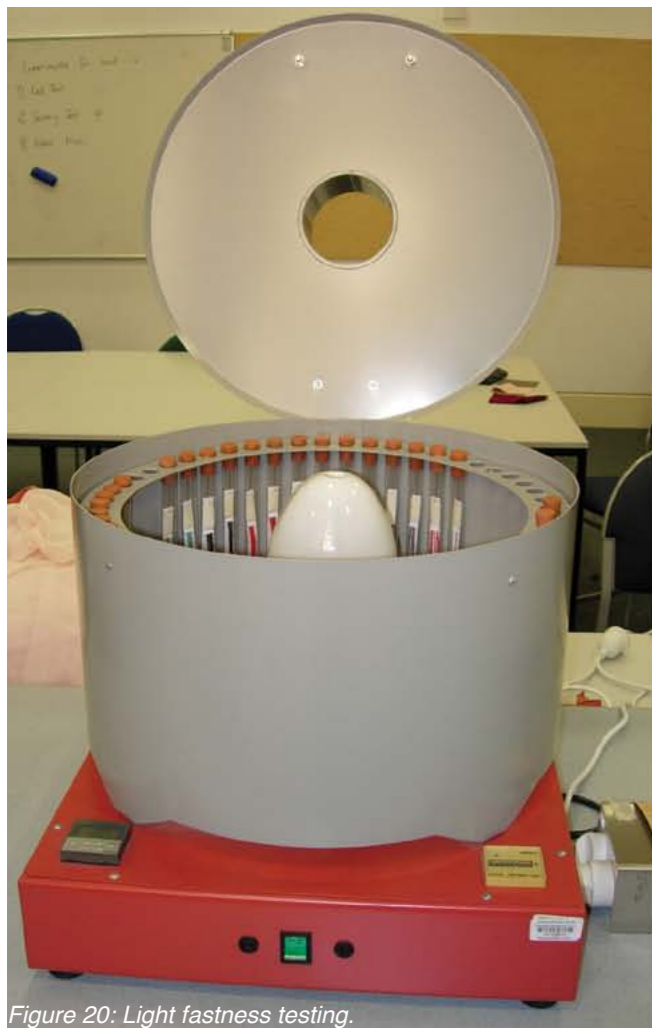
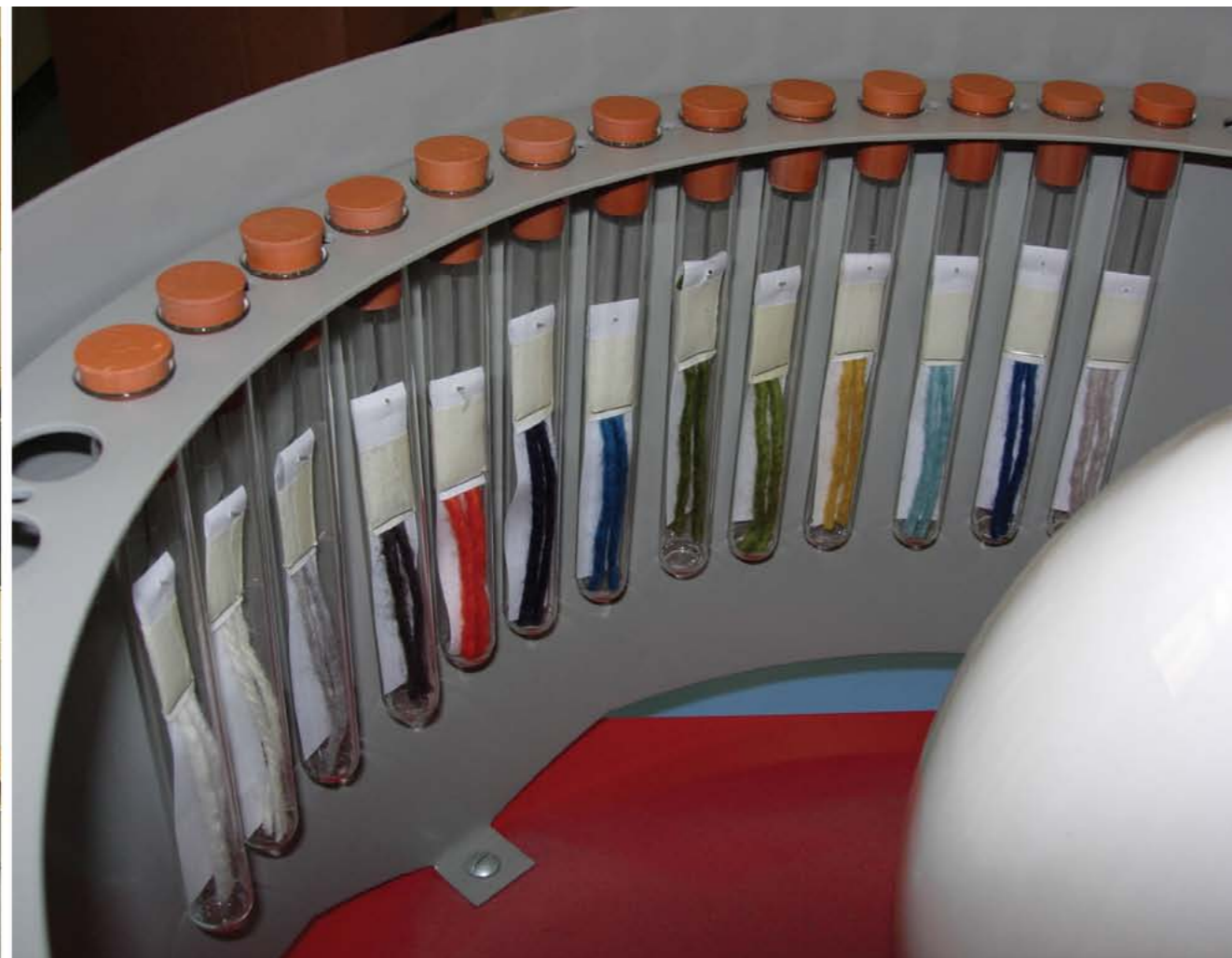


Figure 20: Light fastness testing.



The resolved process is the result of running close to 50 dye baths with a focus on fulfilling the following aims:

1. Follow industry best practice where possible
2. Use eco-friendly dye and chemicals
3. Aim for complete use of dye chemicals (100% exhaustion of colouration chemicals in dye bath)
4. Document chemical and energy use as a tool to find areas where chemicals and energy could be lowered or eliminated

Solving the issue of why the eco-friendly Clariant Optilan® MF dye was not exhausting properly became essential to gaining a full understanding of the wool dyeing process and resulted in successfully reducing the environmental impact of the dye process. Once the dye process had been resolved the dye colour completely absorbed resulting in clear water at the end of the dye bath. Chemical use was lowered through the elimination of the use of Lyogen. There is the possibility of further

reducing chemical use through trialling the success of dyeing natural white fiber for grey yarn. Through documenting energy use it was possible to see that dyeing light colours requires a shorter dye time, which corresponds to lower energy use.

All dyed yarn has been tested successfully for light fastness and passed with readings more than suitable for use in carpet (see figure 20).

Evaluation:

In summary, through fully using dye chemicals the wastewater became clear, fulfilling part of the necessary criteria for disposal of wastewater. By eliminating the use of Lyogen, the chemical is no longer part of the life cycle of carpet made using the resolved process for Clariant Optilan® MF dyes. Further reductions in chemical use could be explored by dyeing only a percentage of the fibre mixed to create grey yarn. Finding solutions to shorten the dye bath period enables a reduction in energy use; so selecting lighter colour shades was explored as one option for reducing energy use.



Figure 21: Dye bath set up with ultrasonic equipment.

Ultrasound testing:

Having refined a dyeing process in which chemical use is reduced and energy use monitored the process of introducing ultrasound waves into the dye bath can be tested as a possible way to further reduce energy use.

Aim: To observe the rate at which dye exhausts with and without the use of ultrasound in the dye bath as a way to discover the best process for reducing energy impact.

Method & Equipment set up:

An ultrasound-cleaning tank was modified for use as a dye bath (see figure 21) to enable the same resolved dye process to be used here. Dye baths were run with and without the use of ultrasound and the results were compared to discover if the dye exhausted faster with the addition of the ultrasound. Unlike with previous testing it was not possible to manually agitate the water bath when using ultrasound waves due to safety (S. McNeil, personal communication, September 24, 2012). Two different methods for agitating the dye bath were tested, with the slightly faster agitation method being selected for use throughout testing.

The following colours and dye powders were selected:

- A light blue (here the main base colour is Blue MFGL with small amounts of Navy MF-RLD 200 and Yellow MF-2GLA added)
- A medium green (mixed from Golden Yellow MF-RL and Blue MF-GL with smaller amounts of Yellow MF-2GLA, Navy MF-RLD 200 and Red MF-GRLN added) this colour was the most complex colour tested

- A dark orange (mixed from Red MF-GRLN and Golden Yellow MF-RL with a very small amount of Navy MF-RLD 200 added)
 - A dark purple (mixed from Dark Red MF-BR 150 and Blue MF-GL)
- Three out of four of the colours selected included yellow in their makeup, as previous testing revealed that yellow dye powder can be difficult to fully exhaust.

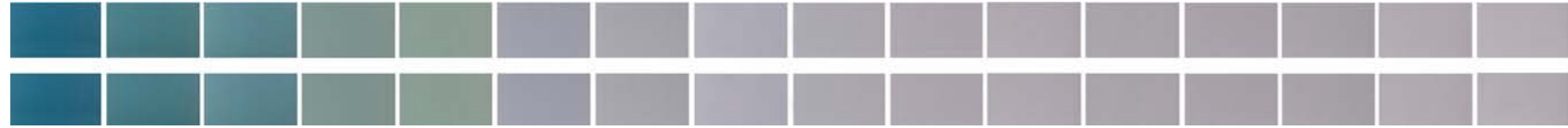
Identical wool yarn to earlier testing was used here: a 1300 tex felted yarn and a 3 ply 740 tex yarn.

Documentation sheets were again used to record data. Thirty-five mls of dye bath liquid was withdrawn from the dye bath at five-minute intervals to be observed and photographed, then 30 mls was returned to the dye bath. Five mls was reserved, set aside and labelled in ice cube trays to allow for a direct comparison between dye baths run with and without the use of ultrasound. Lighting was controlled to ensure photographs were accurate.

Results:

Observations during initial testing of the ultrasound equipment noted that ultrasound cavitation was occurring in distinct areas (see appendix 10 for images of how this was occurring). This did not appear to cause a problem with the levelness of the yarn tested; however, newer technology called the Sweep system evenly distributes the ultrasound waves (Techspan, n.d.). During testing in this study there was not access to ultrasonic equipment containing the Sweep system, however, if CRONZ ran tests in the future with ultrasound the Sweep technology would be strongly recommended for best distribution of sound waves.

Below are images of the comparison between the dye baths, dye baths using ultrasound sit on the top row.



LIGHT BLUE: the blue dye exhausted very quickly during testing. Thirty-five minutes after the dye had been added only a tinge of colour remained both with and without the ultrasound. After 45 minutes both dye baths were very clear and by 75 minutes (the end of the dye bath) both dye baths were extremely clear. The light blue colour exhausted at a very similar rate with no noticeable differences in the way in which the colour exhausted.



MEDIUM GREEN: both dye baths, with and without the introduction of ultrasound, seemed almost completely exhausted by 45 minutes. There was no discernible difference in the rate of colour exhaustion throughout the testing.



DARK ORANGE: this was the only test that displayed a discernible difference in the rate of exhaustion. After 30 minutes the dye bath without ultrasound had exhausted slightly faster and was therefore lighter in colour. Interestingly this dye bath continued to stay this way with the Golden Yellow MF-RL in the base exhausting noticeably faster without the use of ultrasound.



DARK PURPLE: here the rate of exhaustion of colour was very similar throughout, with no discernible differences.

Evaluation:

Results from testing indicate that the Clariant Optilan MF dyes used here exhaust at a very similar rate with and without the introduction of ultrasound to the dye bath. One of the four tests conducted showed a faster rate of exhaustion without the introduction of ultrasound.

Dark colours were significantly easier to test as they were easier to observe. The 3 ply 740 tex wool yarn was easier to test with as it absorbed the dye better than the felted yarn and did not require soaking overnight (thus removing the variable of time left soaking).

The use of ultrasound in the dyeing of yarn is a very new and emerging technology and not yet ready to be directly applied to industry as all studies (including this one) have only explored aspects of small scale testing using ultrasound technology in the dyeing process.

Possible areas for future research:

Repeated testing of small-scale studies would be recommended with a view to increasing the scale of the technology. Testing would need to be repeated to discover if there is any benefit to the exhaustion rate of dye used either with or without ultrasound. The new technology of the Sweep system would need to be implemented to ensure uneven distribution of ultrasound waves did not affect testing. This study focused on a unit with a non-adjustable ultrasonic frequency of 35 kHz; further work needs to be done to assess whether a different frequency would be more effective.



Figure 22: Process of using dyed yarn tufted into samples with frames and photography to see how colours could be used together.

Colour palettes:

Aim: In order to promote a sustainable dyeing process to their customers, CRONZ asked that new contemporary colour palettes be created appropriate for their current market and using the refined sustainable process.

Method:

Trend prediction information along with knowledge from CRONZ of their current Australasian market was key to selecting colours (see appendix 11 for current colours from the CRONZ standard colour range folder). Trend prediction information was selected in consultation with Helen Wyma and from here three trend colour palettes were selected:

1. Blue bases with one contrasting colour;
2. Green bases with one contrasting colour;
3. Neutrals.

Next colour chips from paint charts were matched to colour trend information as a method to find suitable new colours for CRONZ that worked well proportionally together. All yarns used were 100% wool with the following thicknesses: 1300 tex felted yarn, 3 ply 740 tex yarn and 3600 tex natural and black neps yarn. Coloured yarn from every dye bath was discussed with Helen Wyma. Here colour was selected based on best match to colour chips and altered only if it was not working well with the rest of the palette. When selecting colours from dyed yarn the yarn was viewed from above, mimicking the natural point of view for carpet.

An initial problem was that dyed yarn colours were dull and very flat on the yarn. One example is early dyed batches of green. Through trial and error it was discovered that by mixing a more complex base for a colour (for instance using two different yellows for a green, rather than one yellow) the colour became richer on the yarn. This technique was then used to continue to mix more complex bases for each colour.



Figure 23: Colour palettes tufted into samples.

Results:

Dyed yarn has successfully been developed into colour palettes for use as a marketing tool at CRONZ (see figure 23). Mixing complex base colours resulted in yarn that appeared particularly rich, saturated and three dimensional in strong sunlight, ideal for the harsh light conditions in New Zealand and Australia. Through testing three different types of yarn it became apparent that both the thickness of the yarn and the yarn type affected the finished colour and texture of the yarn. Because felted yarn has an additional washing process during its production, the yarn colours appear a little richer and more intense when compared with the 3 ply 740 tex yarn used. The 3 ply 740 tex yarn is fine and allows for detailed textured tufting, while the 1300 tex felted yarn is thick, giving a more cushioned feel underfoot, and is best suited to simple tufted patterns.



Figure 24: Example of colour difference depending on the direction of the fiber in the yarn

Figure 25: The 3600 tex yarn undyed (above) and dyed (below).

Because the direction that the wool fibres sit once tufted into a carpet affects the colour of the yarn, all colours selected have been tufted into small samples. Through tufting selected coloured yarn into squares of both cut and loop pile, customers can fully appreciate how the cut pile of the yarn is always a little darker in colour than the loop pile; meaning for every yarn dyed there are two possible shades of colour (see figure 24). The thickness and fibre mix of the yarn also affects the colour. Here the 3600 tex natural and black neps yarn takes on a pearly glow in sunlight due to its thickness and because it is a blend of both black and white wool (see figure 25).

In summary, through creating colour palettes and tufted samples it has been possible to show how CRONZ could use carpet samples as a selling tool to market a sustainable dyeing process, educating customers on ways to lessen the environmental effects of the dyeing process used to colour wool carpet.



Figure 26: Colour palettes in Masters of Design exhibition February 2013.

Conclusion:

In conclusion, while this research has concentrated on finding sustainable solutions to the hank dyeing process for CRONZ, a very small carpet manufacturing company, it seems that the key objectives for designing a dyeing system that reduces the environmental impact of energy and chemical use are the same regardless of the size of the company: understanding the overall process, excellent communication between textile mills and chemical suppliers (or textile chemists), and documentation of energy and chemical use. Documentation is very important as it allows for energy and chemical use to be measured as a mechanism for change.

Key methods used to discover the environment impact of energy and chemical use during the hank dyeing process were: life cycle analysis as a concept to discover where energy and chemical use could be reduced, traceability to understand the sustainability of the supply chain, sustainable certification as a way to authenticate sustainable steps taken and as a visual cue to customers. Experimentation has been conducted using the dyeing process as a method to track energy and chemical use. Techniques used to reduce chemical use were: use of eco-friendly chemicals and good agitation of the yarn during dyeing allowed for removal of the chemical Lyogen. Experimentation showed the potential to further reducing chemical use through mixing natural undyed wool yarn with dyed wool fibres. Energy use was reduced when dyeing lighter shades of colour, as the time taken was shorter than for dark shades of colour. The new technology of ultrasound waves in the dye bath was also explored, with no new energy or chemical advantages discovered. Experimentation during research focused on small-scale hank dyeing of wool yarn, meaning that discoveries may not yet directly be applicable to an industrial system, however, they aim to point to possible solutions to environmental issues.

I see the future of sustainable colouration of wool yarns for carpet continuing to use tools such as life cycle analysis and traceability to ensure sustainable production methods and supply chains are in place. Certification and labelling will only remain a sustainable tool if the market is not flooded with options, thereby confusing customers. Through continually seeking to find methods of production that allow for elimination of chemical use, as shown here with the elimination of Lyogen, and development of new colorants that contain no harmful chemicals the industry will be able to greatly reduce damage done to ecology through wastewater discharge. Technology developments, such as the reduction in temperature required for dye baths when using ultrasound waves, will need to be utilised in future dyeing processes. Encouraging greater public awareness of the environmental benefits to selecting light to medium shades of colour in wool carpet will result in a reduction of energy use, hereby lowering carbon emissions. I also believe there will be a continual shift towards blending of natural coloured wool fibres as a way to reduce the environmental impact of both energy and chemical use during the dyeing process.



Figure 27: Visualisation of dye powder fully exhausting, Masters of Design exhibition February 2013.



Figure 28: Dye powders used for process, Masters of Design exhibition February 2013.

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26 March 2012

Rebekah Harman
570 Sandy Knolls Road
RD 5
CHRISTCHURCH 7675

Dear Rebekah

Re: Sustainable Yarn Dyeing Processes and Colour Palette Creation for CRONZ

Thank you for your Low Risk Notification which was received on 12 March 2012.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research."

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz."

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and Director (Research Ethics)

cc Dr Sandy Heffernan
Institute of Design for Industry and Environment
Wellington

Mr Rodney Adank, HoI
Institute of Design for Industry and Environment
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www.massey.ac.nz



MASSEY UNIVERSITY
COLLEGE OF CREATIVE ARTS
TOI RAUWHARANGI

Sustainable yarn dyeing processes and colour palette creation for CRONZ

PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree ~~to~~ ^{not} agree to the interview being sound recorded.

I ~~agree~~ ^{do not} agree to images/photographs being taken (as stated in the information sheet the if these were these were used permission would be sought from the individual before using). ^{on site}

I agree ~~to~~ ^{do not} agree to quotes being used (as stated in the information sheet the if these were used permission would be sought from the individual before using). ^{in this study.}

Signature: *Rodney Adank*

Full Name (printed): *Prof W. Heffernan*

Date: *22.03.12*



Sustainable yarn dyeing processes and colour palette creation for CRONZ

PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree/~~do not agree~~ to the interview being sound recorded.

I agree/~~do not agree~~ to images/photographs being taken (as stated in the information sheet the if these were used permission would be sought from the individual before using).

I agree/~~do not agree~~ to quotes being used (as stated in the information sheet the if these were used permission would be sought from the individual before using).

Signature: Steven Meil

Full Name (printed): Steven Meil

Date: 11 June 2012



Sustainable yarn dyeing processes and colour palette creation for CRONZ

PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree/~~do not agree~~ to the interview being sound recorded.

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I agree/~~do not agree~~ to quotes being used (as stated in the information sheet the if these were used permission would be sought from the individual before using).

Signature: Michael Ingram

Full Name (printed): Michael Ingram

Date: 19 June 2012

Appendix 2:

For example a paper published called *Life-cycle assessment of four types of floor covering* in The Netherlands investigates which of the following floor coverings (used domestically) are more environmentally friendly; cushion vinyl, linoleum, tufted carpet with a woollen pile and tufted carpet with a polyamide pile. This covers the production, use and disposal of these floor coverings (Potting & Blok, 1995, p. 201). The study concludes, “the most environmentally favourable floor covering is linoleum” (Potting & Blok, 1995, p. 211). Being published in 1995 this would not have had the same strict peer review process that is now in place (Klöpffer, 2012), so this is difficult to know how reliable and through the system of assessment used is compared to contemporary studies.

Appendix 3:

Interview Transcript

Interview date: Thursday 22nd March 2012 2pm

Interview conducted at: BASF Headquarters, Ludwigshafen, Germany

Interviewer: Rebekah Harman (RH), Interviewee: Dr Rolf Wittlinger (RW)

RW: BASF was established about 140 years ago in 1865, it started with dyes and textile chemicals; today it is a small share which is remnant, but the focus of BASF has changed totally. BASF is busy in a lot of industry sectors, about all are covered by materials from BASF and then their company goal is not only economic success, this is important, but in the same rank is the social responsibility and the protection of the environment. The sales are huge, 63 billion euros. 1 euro is about 1 dollar, or a little bit more at present – so about 80 billion dollars, I don’t know how you count in New Zealand? Do you have pounds?

RH: We have New Zealand dollars, so at the moment I think 1 New Zealand dollar is worth about ,50 Euro’s.

RW: So it’s twice, we have to double it for New Zealand. And running a seven billion euro business, this sometimes makes problems. When we rise the prices customers do not understand why we raise the prices despite these huge earnings. This is an art in itself for the sales team. The employees are 109,000 this is huge in a lot of locations.

RH: It is. So is about half that number in Germany?

RW: No, ah, employees is about 40 – 45,000 per year so less than half in Germany. The rest is in USA, China, India and Antwerp is a big site. Good question, I’ve never seen a list about how many people are in each country. The biggest outside of Germany is probably the USA. Then South America perhaps, this also a huge site, because there is oil processing industry and [unclear...2.35 minutes] plastics, so Brazil is very important.

BASF does research and has 30, 100 patents, and has six big sites; these are called Verbund sites. Verbund means that you have an assembly of plants and an assembly of people and you transfer the goods from one plant to the next plant. So plant by plant, and you can have 5-6 processing steps on one site, it helps to reduce the costs for logistics because you simply pump it through one hose. Also for the reuse of waste, so the waste can often be reused in chemistry at another site, but then you need the equipment. And if you then have the distance of 10,000 kms you can’t reuse waste, but if it reused at the same plant you can do it. This is a Verbund site, so you have an assembly of 50 or 100 plants and this is one of the key knowledge when you manage one of these sites, because if one is failing then whole site has a problem. If one plant stops then you have to reduce something else in the plant receiving the chemicals. And if you have a split production at different sites, then you pay for the storage and for the logistics, but in the case of failure of one plant you can continue to produce, because you can buy on the market, or you have in stock for three months. It makes life more difficult, but it saves money because not only is the stock lower, but the reuse of waste is high. Due to the mergers and acquisitions of BASF, BASF bought a lot of companies, for example; Ciba, Cognis, Engelhard Catalysts, Johnson Polymers in the last few years and a small water treatment called Inge – that’s what I have in mind [unclear...4.50 minutes]. There is an inflation of production sites at present. There are 390. This is growing very rapidly because each acquisition brings in 10 or 20 production sites or even more.

The activities are spread over several segments. The basic chemical sales, then the plastics, then the performance products. These are products that you cannot see as a end-user product, you will have the have the additives, dyes, pigments and things that you put into other products, stabilizers.

RH: When I think of performance products I think of things added to fabrics at the end of their production.

RW: But you see the performance products are 12 billion and the textile and leather business together is 400 million so it's a small share. So textile and leather is 400 million of 63 billion so less than 1% of the company. [Going back to the division of activities at BASF] Oil and gas, agricultural chemicals (they are well working now) lastly functional solutions (for example; food additives and cosmetics).

The foundation of BASF was 1865 and it started with dyes, very famous indigo and Indanthrene blue RS. These are BASF inventions. BASF also created the high-pressure synthesis for fertilizers; first fertilizers were produced from potassium nitrate from Chile, then BASF developed the synthesis of ammonia in Ludwigshafen. After the Second World War plastics were the focus, ABS, polystyrene, polyethylene, polypropylene, polyamide. Today BASF still has ABS, polyamide and [polystyrene has been sold recently. Polyethylene and Polypropylene were sold more than 10 years ago. The next is the walk away from Ludwigshafen to the world. Today BASF is around the globe everywhere. And from 2000 on it was sustainability got a company goal and an aid to sell the products and to come to future products.

Six business sectors, sixteen divisions and 73 business units and the strategy is prepared differently for 86 business units, one is textiles for example. And we have original divisions that look for original business and then there is the centralized overhead that is expansive; three central divisions, five corporate departments and nine competence centers? One competence center is for example the environment, health and safety, the scientific documentation is competence center, too. health department is a competence center, too. Engineering is also this division, which designs the plants. The segments are broken down again by chemicals. We have organics, petro-chemicals and intermediates. At the plastics we have an arbitrary split to polymers, performance polymers and polyurethanes. The performance products are e.g. dispersion and pigments, care chemicals, paper chemicals, textiles, leather.

Crop protection is a very separate business because there is about no link to other businesses, but the core protection is very different. The main focus of them is to have the registration in time and to have the appropriate climate that the product can be sold well, that it is needed. If you have a lucky summer you will not need any core protection, if the summer is late or dry you need more – so this is quite different from the other businesses. And oil and gas drilling this is also quite different, because there you need equipment and expertise and luck. And here you need expertise about chemicals, there you have to be an geologist (11.20) to know where you have to drill. This business also part of BASF.

The Verbund sites are in Ludwigshafen, very important then Europe – one is in Istanbul and the headquarters for Turkey is in Istanbul. But in each country something. Not in Africa, in Africa we are busy with dealers, you can buy a textile chemical in each country in Africa but they are dealers there. And there are four locations in Australia, one in New Zealand.

RH: Auckland?

RW: Ja, we can check. [laughs] You caught me not knowing all! [Looks it up online]

RH: So have you been working for BASF for quite a long time now?

RW: Yes, I have been here since 1988, this is 20 years, it's going to get to 24 years. I'm a chemist by profession and I did my PhD Thesis at Ulm, this is a city about 200 kms from here. I was working here for environmental protection to do the analysis of the sludge treatment plant and the emissions to air from the site. . Then moved to the Existing Substances reports and the European program for existing substances there and the eco-efficiency analysis for six years. Then I've been about 9 years in the textiles department. And doing the Product [unclear...14 minutes]Sewardship for textiles. If someone is asking about an eco textile, or if it is a

fit for Nike we can give an answer.

[Finds information on location of BASF in New Zealand]

Ah they are in Auckland, two sites are there; Airpark Drive in Manukau City and William Pickering Drive in Albany. What are these areas like?

RH: The one in Manukau City is right by the airport, so quite an industrial area. Albany is a suburb further out of the city. Most of Auckland is right by the water, because of how it is shaped, so most buildings are tucked around this water area.

RW: So I'll just continue on, so BASF's strategy is divided into four areas, to earn money frankly spoken. To help the customers to be more successful. This is for example for textile chemicals; the hope is that if textile mills buy BASF chemicals they will be competitive in the market. This means good quality, efficient processes, well-documented support and information. We form the best team in industry, means that the team itself is capable to withstand their market and to show to the customers the advantages of the product.

And sustainable development means that environmental aspects and social aspects are on the same rank as financial aspects. [So the financial aspects] are not more important than the development of the stuff and the social welfare of the staff. And in the long term the strategy for the shareholders to get higher share prices and to get nice earnings.

BASF has a set of values and core guidelines for how the business has to be managed. The values are sustainable profit with the performance added – you have to earn money but not only tomorrow but in the long term. Innovation for the success of our customers means the product must help the customers to be successful otherwise you will lose the customer usually mid-term, then a responsibility for safety, health and the environment, then personal and professional competence so well educated, well trained staff. Mutual respect and open dialogue and integrity. This is diversity, today it's called diversity means you have to face the problem that the employees are worldwide, so you have to deal with Chinese, with Indian, with North-American and they are different inhabitant culture and you have to respect this. This is considered to be a change that you have different cultures each bringing benefits and so on. And in the sum your company will act better. It does it really.

RH: This must be quite interesting then being able to work with people in so many other countries?

RW: Yes, you have contact each day with Chinese and Indians. We always seem to get a lot of visits because here is the headquarters here. So we have training and meetings, so you see a lot of overseas people here.

Then integrity, this is also very important BASF obeys all the laws where it is active, it is legal for each site we have a permit or license to operate and BASF does not accept any corruption or bribery. It's allowed for the trade unions to be active here, and they are active. And BASF pays at least minimum legal wage here, usually more. These are the advantages of integrity.

BASF is very big and so well known. BASF collects awards from the world in area of sustainability and responsibility for the environment. Here is one, BASF is one of the green companies of China; BASF is a member of the Carbon Disclosure Membership Index. And BASF got ranked in this DOW Jones sustainability index – usually around the top position, sometimes the top one. But it's changing.

RH: I was looking on the website and there seems to be a large list of all the awards around sustainability.

RW: Ja, ja. And you can get an award for carpet users and innovative textiles and so on. Responsible care, a worldwide initiative of the textile industry, BASF is supporting that, and here you see a picture – you can read more about this on the Internet.

BASF has some donation projects; if there is an emergency around the world or catastrophe then BASF gives donations to support the people. Usually they are also where the sites are. It is better to channel the money because there are a lot of locally available know-how there already.

RH: And helping the communities that it is already involved in?

RW: Ja. Ok looking for the textile chemicals. Again textiles are the beginning of the company. BASF is part of the textiles community but never produced textiles, only some fibers. Until 10 years ago BASF produced fibers, polyamide fibers. This has been stopped.

Consumer safety and environment protection are top priorities for new products and we try to check the future of the textile industry with clever and innovative products. The goals [are] putting future into textiles. We have three areas of innovation, this is consumer safety, resource saving and climate protection. Consumer safety is that the garment you buy is safe when produced with BASF chemicals. The next one is to save resources; that the textile mill can use less water for a designed garment. The third one is climate protection; climate protection means that you emit less carbon dioxide. This is more or less synonymous with less energy input into the textile mill and we help with clever products to use the energy at the textile mill very efficiently. They need less steam to produce the designs, fabric or comparable fabric.

The areas where we are busy is along the textile chain. So BASF is busy with raw materials for fibers, with the polyTHF for spandex fibers, this is booming, absolutely booming this business. The Ultramide, this is stable and nice money. Do you know these fibers? I think you know all these fibers. Spandex is an elastic yarn that is added to jeans or shirts to keep it in form despite its flexible weave. So flexibility to the garment but the shape is kept. Ultramide is for sportswear and underwear, usually it's called nylon or perlon. We are selling the raw material, not the fibers.

Then the textiles chemicals (the department where you are at now), this department is busy at weaving, pretreatment, dyeing, printing, finishing, coating – these are the areas that we sell the chemicals for. And the finishing is also a part of the product range. This is easy care, non-iron, smooth handle and water repellent. And we sell hang-tags and labels.

[Shows me types of hang-tags]

For example this one [hands me one to look at]. They are German and English.

RH: Great, so the hang-tags are just little tags that would sit with a garments labels.

RW: If you want to use them you have to agree on a license agreement and then you need some proof that you produce BASF textile chemicals, that the technology of the yarn fits to criteria then you can use these labels.

RH: Arh, I see.

RW: But it's not successful in industry frankly spoken because when you have Levi's or Nike they will not put a chemical label on, never. They have their brand name and nothing else. Puma usually put their own label on. The only exception is Teflon, by Dupont who really breaks this barrier.

And we support with marketing and consultancy with our customers.

So next, here are the products that we have, as you are in textiles I think you will know them all and you are a dyer. Products for the weaving, detergents, wetting agents, extracting agents, bleaching agents for the pretreatment of cotton mainly, but also for dyeing and leveling and printing... here are the brand names. Printing binders, pigments, synthetic thickeners and emulsifiers. And for the coating and finishing: resins, catalysis's, repellants and coating compounds.

RH: It's a big range of products and areas.

RW: It's not that big – it's very streamlined I would say. Competitors have a much broader range. We have about 500 products – this is not much, so very efficient and streamlined. There were some pruning activities during the last few years and now we are very streamlined.

RH: Is that like how you were saying before, how BASF is trying to make overall production more efficient in the Verbund sites?

RW: Ja, production of the chemicals – ja, this really saves.

Next, 6, no 7 areas of activities, the next are the highlights we have at present running for the sales team and for press campaigns, what we do. The first one is free of formaldehyde; formaldehyde is a hot topic in the textile industry. I do not know if you are aware of this in your dyeing area? It's not such a big problem in the area of dyeing.

RH: No, I have heard about it, but your right, it isn't such a concern at the dyeing stage.

RW: But it is very important for the sales product, they are often finished and in finishes you often have formaldehyde as a curing agent or when you do a pigment print you have a curing agent and this can be usually it's based on formaldehyde. We have a textile print that is used that is free of formaldehyde. We are working with a resin finish that is free of formaldehyde. And it fulfills the requirements of the Oeko-textile naturally. This is our benchmark. Oeko-textile 100 is mandatory for all products. European Union eco-label most of these brands: or all of them in this case and of the retailers.

I'll show you a sample of this...sorry I don't have it here. Sorry I just have the brochure, not the product.

RH: That's ok

RW: No it is not ok. It is a pity. Here is the brochure, the demonstration material is in the office and the office is closed.

This is a common print, a pigment print this is produced with a common binder and a fixing agent, and the curing agent is a formaldehyde and you can replace it with a formaldehyde free one.

RH: And get the same result?

RW: Ja, and get the same result. This is a common pigment print, not for you a designer [commenting on the very dated 1990s style of textile print used on the sample fabric]? [Laughs]

RH: [Laughs]

RW: When you have a company you have to design these things too! Then you have the Eco-Soft printing system. I'll show you how we evaluate this. BASF has this so-called eco-efficiency analysis.

So you have a raw textile and want to print it. For that you need a print-house. And then for the printer to get the ink you need mining, where you drill for oil, extract the oil from earth – extract sodium chloride for other chemicals and extract sulfur for sulfuric acid and you the raw materials from the mining process and you go to a company that produces textile chemicals from these raw materials – for that you need energy. And for the print-house you need some electricity and some steam to run. For that you need a company like Exxon or Shell they send you the fuel and another company sends you the gas and the electricity. They use fuel oil or something like that or coal to bring the electricity to the print-house. You have transport – this means the truck is driving around and in it is some carbon dioxide and uses some fuel for running around. So the print-house itself has some emissions and it's working. The sum of all these activities has an environmental impact. If you can calculate this environmental impact in so a called life cycle assessment or eco-balance. And we did that for the comparison of two printing processes. One is the pigment print. You need a paste, you need a textile, you print, you dry and fix and then you get a printed textile – like this one [holds out a sample]. If you go to a reactive print you need a textile, you need a paste, you print, you dry, you steam, you wash, you dry again and then you also have a printed textile like this one [holds out another sample] – this is a reactive print. So you have two different technologies coming to the same. And then we, at BASF, have developed a method where you chart the environmental impact – this is the outcome of the eco-balance or life-cycle assessment – the best is on top, the worst is on the bottom and you draw the cost for the process. The cheapest process is here [points to chart] the most expensive process is here [points to a different area on chart] and the average is here. If you have something that is average then you are here. If you see the green bubble is the pigment print. The pigment print is cheaper and lower in environmental impact, the cost, the pigment print is cheaper and the reactive print is more expensive, it also is higher in environmental impact because...coming back...you need energy for the steaming and for the washing.

Pigment print is more eco-efficient because there are reasons for this, lets look at the results. This is counted in Euros, for 1 square meter. For this you need some:

- dye or pigment
- Auxiliaries, for the pigment print you need more auxiliaries, meaning they are more expensive
- Mix the colour in the color kitchen
- Print – the pigment print is a little bit cheaper because the machine can run faster. So the same machine, same stuff produces more prints.
- The drying process is the same
- For the pigment print you only need hot air, rather than steam for the fixation – so cheaper.

For the reactive print:

- Printing more expensive
- Auxiliaries are less, so cheaper than for pigment print
- Steaming – this is expensive, you have to have an expensive machine and a lot of fuel to produce the steam
- and you have to wash in an expensive washing machine
- and you have to dry one more time.

So the cost difference is not at the dyes, not at the chemicals, but the main cost drivers are the steaming, washing and drying for the reactive print. As you are a textile designer what do you think, what do you know about the market penetration? For bedding? It could be tinted or dyed, but if it's printed?

RH: Well from this it seems that the pigment printing process is much better.

RW: Probably you have already bought some bedding – is it a pigment print or a reactive print?

RH: Well there are a lot of pigment prints now for bedding, but it is fashion led and that is quite interesting. There is a printing process for that type of thing traditionally, is led by trend prediction in terms of what people like. So at the moment there have been a lot more of graphic, intricate printing which is better with pigment printing, rather than reactive printing. But that is what I'm interested in finding out with this project as well – does the consumer dictate what you end up producing?

RW: No they will not, they cannot. If you are in a shop it is very difficult to find out if it is pigment or reactive dye.

RH: Yes it is.

RW: And about 90% of the bedding is printed with pigments – so the market takes this up and has realized already the advantage of the pigment.

RH: That's great.

RW: And if you see these [has two different fabric samples, both a similar cotton drill fabric coloured a light khaki colour], the handle is a little bit different, but it is also the fabric type that is causing this.

We plot environmental impact on a polygon with six axis:

Energy consumption
Emissions
Toxicity potential
The risk potential
The use of resources
The use of area

The worst is one, and the better ones are reduced to less than one. And here you see pigment print has an advantage in the admissions, because you have less energy consumption meaning you have less carbon dioxide going to the atmosphere. It uses less energy; this is often linked energy and emissions – but not always. The area used of the print-house can be smaller because you have less equipment. You need less resources, this means about comparable resources for the chemicals and the pigments or dye, but less resources for the fuel – because you have less fuel you have less resources. The risk of the installation is reduced slightly. So you see here you need more stuff, here you need less stuff here to manage this and if you have less stuff you have less risk for accidents. This is the risk reduction.

RH: But the toxicity potential is similar. What is the toxicity actually measuring?

RW: The toxicity potential we have a scheme which is published where you check if you handle toxic substances, so you have three areas of consideration. The first is the production of the textile; there you check the chemicals you bring in because the textile itself is not toxic. So checking if the chemicals you bring in are hazardous. This is done with these rectangles – if there is a skull and bone or something like that, a warning. Then we have this scheme and we take them from this scheme, arbitrary points system, you count in points that are attributed to the chemicals. So if you have a lot of chemicals that are harmful for human beings you have a high number of points and you get worse here. So this means to reduce the amount of toxic chemicals or harmful chemicals no dangerous chemicals, they

are dangerous chemicals. Because in a textile-mill it is quite common that you have substances that are labeled with some of these warning symbols. Do you know them?

RH: Yes

RW: The consumer is also exposed to chemicals. Some chemicals are remnant in the textile, some that are washed off are not considered but you have residues in. For example when the finishes are bought in by intention, intentionally brought in and then you, the consumer is exposed to the chemicals of the garment. There you need two requirements, the first one is to have a high fastness, so if it is a dye or tinted chemical or if it is a non-colourful chemical then you have to look for low-release. This is the case for example with formaldehyde that is part of the Oeko-tex 100 and all these brands. The third part is the rubbish, if the textile is at the end of its life you have to dump it somewhere or you have to incinerate it and if you make toxic gases it is worse toxicity potential.

The method also allows for if you change something, for example if the bedding weight is not 120 grams but 150 grams, so if this changes there is no change of the potential. Pigment print is sturdy and eco-efficient.

Coming back to this chart. The big sell in Asia is this pigment print, Eco-soft. Not in Europe in Asia it is called Eco-soft – this pigment print range. Based on formaldehyde curing agents. The formaldehyde-free is called Helizarin Binder CFF and Helizarin Fixing-Agent LF. Then we sell the Lurotex-range, this is a stain repellent. And this helps because you don't have to launder so much. If you have a stain repellent you can reduce the number of washes because the garment keeps better, the dirt keeps off. I have a sample of this.

This is the shirt that has the stain repellent on it [opens a bag with a white men business shirt in it]. So here if we put some water on it you can see it repels the water droplets.

RH: [laughs] It's like a duck isn't it! So even after washing it this repellent property will stay?

RW: Yes it will stay. I also have an awning case, but it got lost.

RH: So this type of product, do people use it in the interiors industry as well as the fashion industry?

RW: For the fashion industry it is seldom used, it is used more for outdoor wear and raincoats. For raincoats it is quite common. Awnings are usually equipped with this. So this shirt is not usual. Because a shirt is not expensive enough so you simply wash it. It would be about 10 Euros more expense with this finish on it. Unfortunately, because we would like to sell more.

RH: But you could see a good application for application for interiors fabrics.

RW: Yes they are often equipped with stain repellency, car seats and furniture seats. I don't think in the cheap range though, say if you buy a chair for 20 Euros probably not. But if you buy a more expensive chair, or a car chair, car chairs are always equipped with repellency and stain release. The repellency means you repel the dirt or the water and the release means if you have some mud on it you can erase it with a rubber or sheet of fabric you can wash it off. So car interior trim is usually fitted with this. With awnings it is common to have water repellency.

RH: Yes that is great, because how often to you wash your car seat cover? You don't.

RW: Yes, because it repels perspiration and stains. So if you got in the shower with all your clothes on, you shower once and all the dirt is washed off. So your clothes are washed and you yourself are washed. And then you need a microbial additive then you do not perspire – or you do not smell. So you only go in the shower for cleaning the outerwear. This is the future. The company should support this, because then you work more because you save money from showering and from washing clothes.

RH: Yes it is a good idea, I worked for a company in New Zealand selling clothes. They produced merino knitwear. Merino naturally helps repel perspiration – not to the extent of what you are talking about.

RW: But it lets past moisture I think?

RH: Yes it does. So we tried to tell people that they didn't need to wash it after every wear.

RW: But they do it anyway.

RH: Yes this is true, but you do get the opposite extreme, so some people still wash it anyway, then one person came in and said 'I've had this for seven years and I wear it all the time and I've never washed it' – and I thought hmmm – maybe you should have washed it a couple of times!

RW: The next is what we also do to help reduce the carbon footprint, similar measures.

We did two projects with this t-shirt here. We improved the dyeing process with Cyclone XC-W New, a simply reactive dye t-shirt of Puma and we could reduce, by using Cyclone XC-W New, we could reduce the carbon dioxide emissions by 9% with improving the dyeing process. If you come here there is a poster showing this.

[57 minutes - discusses chart showing this improvement in emissions, then return to discussing Puma t-shirt]

RH: So is this a cotton fabric? Ah, yes 100%. So the saving for that t-shirt was 9%?

RW: Yes 9%.

RH: That's a great result isn't it?

RW: Yes and we did trials with a company – Viyellatex in Bangladesh. So we had to have external consultants to calculate the savings. [59.49 minutes – discussion around folding up the garments again]

RW: To give you an impression this is a pure pigment so it is a jump back. I also wanted to present to you, this is a pure pigment [unclear 60 minutes]...so it is very strong colours. Deep shades. This is the red; this is the pure pigment red 170.

RH: So it's a very rich colour, but it does affect the handle of the fabric doesn't it?

RW: Ah, this is for trials in the lab to see the colour shade for the production. Each production batch we have to print it once and check the colour shade then adjust

the colour shade by dilution or by mixing some blue or some orange or yellow. This is called finishing, you have to finish each pigment preparation and this is what is used to check the colour shade.

And next what we did – this is leisure wear clothes and it is reactive dye to penetrate and this is pigment dyed, if you didn't know you wouldn't find the difference is my expectation. Usually pigment dyeing is called to be harsh handle and you feel the binder and so on.

RH: But it's actually the opposite if anything with these examples [referring to the pigment dyed example feeling softer than the reactive dyed example].

RW: Ja, but it is the same fabric, two different dyeing steps. This is even mercerized a little bit [referring to the reactive dyed fabric being mercerized]. And this was not mercerized [referring to the pigment dyed fabric example]. So this is the pigment dye process and this is the reactive dye process [again referring to samples].

RH: Do they have to print on each side?

RW: No, it's a padding process, not a coating. I will show it to you. Pigment dyeing is you take the fabric – not as a trouser, it's not garment dyeing, it's fabric dyeing – usually, but I think you could also do garment dyeing. You take the fabric, you go to the padder – can you see it, or is it too small?

RH: Yes I can see it that is fine.

RW: Then you go to a pre-dryer and you dry and you cure and that's all. Small equipment, nice beautiful equipment. So the pad-steam dyeing, but sorry this is for polyester cotton, so it is a little bit different from pure cotton...so you will pad the polyester dye, the disperse dye, you dry, you thermosol to fix the dye, then you cool down, you pad the vat dye or the reactive dye, then you steam (for reactive dye), you rinse off the excess dye, you dry and then thermosol again, then you dry and put a finish on. So you have huge machinery, and here you have all your small machine. Here the finish means you can put in some waxes or silicone oils for soft handle or some repellency, water repellency. This can be mixed into this dye liquor here already, so you do need to separate the finishing.

RH: So you're doing it all at once?

RW: Ja, and if you check the costs this pigment dyeing, we call it colour fast finish process is 400,000 euros for the machinery. You need two persons to manage this machinery – two men on shift. For the big machine you need an investment of around three million euros this is eight times that of the pigment dyeing process, you need 3 persons, 1 person more because the machine is more difficult and the speed is the same, or the production speed is the same. If you then look at this eco-efficiency analysis it is very clear you can save some money because the equipment is cheap, smaller and the environmental impact is smaller. Going back – here you need a lot of hot water and here you need only some hot air, here you need also hot air for the drying, here you have a dryer and here you have a lot of hot water. So the effect is not if you have a reactive dye or pigment dye, it's the after treatment or curing step that is what decides what is more energy efficient.

If you look at a plot of the costs, you see here are the costs for steam, here you need a lot of steam, this costs a lot of money, for the reactive and disperse dyeing process you need much more chemicals, because there are two dyeing steps, the disperse dyeing step and the reactive dyeing step. You'll need an expensive machine and you'll need one person more – so it's more expensive. You pay, instead of 25 euros per hundred kg of textiles using pigment dyeing and if you use a reactive or disperse dyeing process you pay 70 euros per hundred kg of textiles. I showed you the trousers are about the same.

Then we have solutions for finishes; water and oil repellency and we have Mincor, this is water repellency for awnings. I do not find my awning so I cannot show it to

you. This is nano-technology it looks similar to this. We work hard to have textiles that are very comfortable and doing the functions that it is intended to do. Ja, this is the touch and feel, the look and feel, this is more or less what we offer for the daily routine of the textile mill. But I can also show you – at the beginning – we also support labels, we are dealing with labels, such as eco-tex and so on. We do not support this bluesign – this label here – because we do not think it is a add-on that is worth paying the money. BASF chemicals are good in itself and fulfill the needs. Ok, so that was what we do – now you questions?

RH: So basically with these things that you are producing you then market them to company's to help encourage them to create a better product, hopefully for them, but also a more sustainability product by cutting down on...

RW: Ja, we have documentation for the sale team, we have documentation – these flyers – for example here it is explained for a textile mill how you can apply the pigment dyeing, the colour shade and the chemicals you need. And that is eco-efficient and so on. This is the one that we do advertise – if you read some of these journals, you will find advertising. We also have a technical service that comes to mills to train them on how to use BASF products. You can take these brochures – this one on water repellency and one on ecological topics – I wrote this.

RH: Have you found that companies are quite excited to use this type of technology? Because it is something that a consumer can't actually see the difference in what they are buying a lot of the time.

RW: If you come with a new technology – it is very difficult to replace it. Because the textile industry is medium sized companies, very flexible, changing product range each day more or less. For example they print one pattern one day, and the next half-day they print the next pattern and each day they have different raw material – so they do not have two fabrics the same. Even in work suits, each work suit is different so if you produce for Lufthansa this is quite different for what you need for air force and so on. Or here you have this BASF clothes you produce it in one day, all the fabric that you need for one year – so you do not have an optimized process, it is a very inflexible process so it is very difficult to change something because then you don't know what you do. It might fit, it might not fit – this is the first problem.

The next problem is that of all these ideas they have fixed equipment and each change is expensive – and staff is so low, there no degree of freedom to try and test something.

The next problem is if they can save money then they immediately do it. And they also have clever ideas; they do not wait until BASF comes. So if you have products that are good they penetrate into the market very quickly – if they are really a step ahead. And if a product doesn't fit you will never sell it. You can recommend it, but they do trials and then they neglect it. The easier way is when you have the same process and the same machinery but improved chemicals. Then it goes very quickly – if you have a good idea you can sell a lot. You cannot produce as much as you could sell. But when there are legal requirements, or requirements of this brand then it takes two or three years. For example when they must produce [textiles] free of alkylphenols [1.13.57 minutes], the check and potential exchange of all chemicals lasts up to two years. As long the textile mills still uses alkylphenols so this is very long lasting. First the mills try to avoid the change because the change cost money, then the exchange consumes time.

And even more difficult is when you go for example from reactive dye to pigment dye because the purchasing department in Hong Kong is sitting in Hong Kong, they go out and look for reactive dye trousers, they do not have the degree of freedom to say we want to have a trouser that looks like this – they know we need reactive dye, we need cotton with tear strength and fabric weight and so on. And then they go directly to the plant where they know to go and they tell them we need another batch of this, no change possible at the sourcing company or the sourcing office in Hong Kong or Shanghai or in Thane (nearby Mumbai) in India or Bangladesh. This would only happen if the headquarters accepted these changes.

We are also busy, we have one lady dealing with these brands and she is advertising the new techniques and traveling around and presenting the latest developments of chemicals. But it is really long lasting and difficult to penetrate with a new chemical into the market. Not impossible – some products are frankly spoken 50 years old, but a lot of products have been developed in the last five years. The industry is willing to accept, but you really need a benefit, so you need to consider the special needs of this industry. It's not well defined the process. They need processes that are very flexible and if you have a colouration process that they try and it doesn't work, they simply have to go through and do it a second time.

RH: I think in New Zealand there are some consumers, the end user of a product – so wear the garment – who do look at labeling now for any special features that that company is promoting in terms of being more sustainable and reducing the amount of carbon dioxide emissions and things like that. Which is quite good, because I think it can help encourage companies' to take on board ideas and new systems [around sustainability]. But I think, as you say, it is difficult – just in the initial research that I have been doing so far some of the larger companies – Nike, Levi's – they have been introducing sustainable ways of dyeing their products which is great. But I think a lot of very small companies it is very difficult for them to A: do the research to be able to offer a sustainable option and B: be able to afford to produce things in a way that they would like.

RW: I wouldn't say that small companies cannot do much. This is not true. The textile mill or textile producer can do what he learnt and this is to produce textiles, this is patterns, fabric production and special weavings, but they usually have very limited experience in the application of chemicals. They need consultancy and technical support and if they have somebody who is a textile engineer who is capable to look at chemicals he is totally occupied with this business of the company. But they usually rely on the expertise of the chemical producer – that we have chemicals that can optimize it. They surely optimize it, when you say you have to reduce 1 gram, they will try to reduce it 1.9, 1.8, 1.7 and then they find the optimum for their processes. And this may change, for a simple process this might be 1.5, for a difficult cloth this might be 2 or 2.5 grams. This is what they can do locally, but they will never buy chemicals, mix them to be textile chemicals and try to optimize that. This is out of the capacity of the textile mill and they smaller ones, I know very well, they are even more flexible because they are in niche's – they have more experience in and they have a surprisingly high knowledge about what chemicals can do, but their focus is always shades and weaving effects and these things. They usually do not take care of the chemicals. The chemicals have to sit for the full production range, usually they understand only that if they have a heavy cloth they have to use more, or the retention is higher and you need more of the aftersoaping agent or something like that but they do not differentiate the chemical name, we do not tell them the chemical names.

RH: So it is about making sure that they get the right scientific knowledge, so that they get the best understanding?

RW: Yes, what we do offer customers [pauses while looking for power-point to illustrate this].

RH: So for people who buy your products can you offer some training and some more expert advice?

RW: Yes, we offer training. So we have one problem in the textile chain, we are selling textiles and we ship products to the mill and we ship information to the mill. But the mill has to transfer information for the consumers. The textile mill is sending garments to the consumers – and the garment has some information. For example the hangtags or on the Internet. For example if you take Levi's or Nike whichever online...or lets take a German one which you don't know [goes to a website for a small German clothing manufacturer] – if you are lucky you will find some information on sustainability – here not [on the clothing website] and you can find a lot of information here so you see here so the sizes, a description about what it is and so on. And sometimes if you are lucky you will find something more. With this brand probably not, and if you look here (oh but it's in German) you will not find anything about sustainability, if are lucky you will find it somewhere quite hidden. This is a smaller one they don't take care much.

They have a [unclear 1.25.17] I well know, they are asking a lot but here you can see there is a bank account where you can send the money, you can...this is a customer card – here in the name, this is the company where you might find something...what do you find...an advertisement for a festival on YouTube.com and you

will not find something for sustainability. This is what you usually find.

And they get for the mill or the dealer, who is speaking for the mill, you get the garment – and the consumer is asking, if it is a more serious company like Levi's you will a lot on sustainability this is no child labor, fair wages, no dangerous chemicals and so on. But we do not send the information they need because we do not inform about a fabric, we inform about a chemical and the mill has to transfer that. We can only offer information for chemicals and for chemicals we have the label on the container, we have the safety data sheet, we have technical information and we give confirmation and we have product specification and personal consultation. This is the label – what would you say to this label? Ah you are from New Zealand. You still accept it.

RH: It just looks like a standard label.

RW: This is what the mill is getting. And they produce this...fabric...we do wet dyeing with hydro – this could be wet dyed. This is the label they get. And they have to transfer this into a label that goes on the garment, like Puma. Here is it [get's out Puma t-shirt] you have to transfer it to such a label. Do you find somewhere information about hydro [unclear... 1.27.55] at BASF and that it is harmful? No. So they need someone who tells it to them. And we give the consultancy. We tell them how they have to depict it. When we give them safety sheet – this is the top header of the safety sheet – 15 chapters – about hazardous properties and physical chemical properties and advises for emergencies and workplace exposure. We give technical information sheets, this is about 6 or 8 or 10 pages or 2 pages, it depends on how important it is. How you have to apply the chemical and we give certificates that the product can be used to process textiles and they can send them sales man. The sales man will listen to the questions and tell the textile mill how to apply the chemicals to and explain it. He will come back also with some questions that he cannot solve locally. And we put some information to the public on the internet, here you can find it – here is the address www.basf.com/textiles - this is if you want to produce for Adidas for example – it doesn't matter which one. Then you will see that the textiles can be used for the processing of textiles they meet the requirements of this editors group and then you find some mandatory things that you have to apply BASF's recommendation and so on. And here is a long list of products that fit totally – you can find in New Zealand on the Internet. Then there are products, they are catalysts, they contain formaldehyde so you have to apply special measures to reduce the formaldehyde level and these are other products and so on, it shows the limitations. High levels of formaldehyde 300 ppm (ISO14184-1) – this is allowed for outerwear sometimes and those which contain carbon black or orange then you have to apply special cautionary measures too. You should not mix black and orange – ja. This is the information that we give to a mill and the mill has to transfer this into these fine label. This a problem and they need support and training – this is what I do and the purpose that I am here.

RH: It's great, so that that information gets transferred at every point along the line.

RW: Ja, this is the next problem, we cannot support much, if you have 5 mills, one is weaving, the next is pre-treatment or dye house, print house, finisher, maker then you have to ensure that the information is transferred along the textile chain. No help. This is responsibility of the dealer then if he puts enough pressure on that the corporation works. Or they deny it and then you simply have some garment looking nice. But may harm their consumer. This is also very dangerous when you sell a garment in the USA that you do not know what you sell, it might get very expensive. And some clients get an allergy and you have to pay for it, and then if you do that knowingly then it is 10 times more expensive. This is what we do.

Now we can have a look at the visitors centre.

RH: That would good; this has been excellent, very interesting and very informative as well about what you do and what can be achieved. Thank you for your time.

Appendix 4:

SUPPLIERS DECLARATION

I/We supplier of the dye **Sandolan Blue MF-2RLA sgr** (specify product name) declare that:

X The product does not contain:

alkylphenolethoxylates (APEOs)
linear alkylbenzene sulfonates (LAS)
bis(hydrogenated tallow alkyl)
dimethyl ammonium chloride (DTDMAC)
distearyl dimethyl ammonium chloride (DSDMAC)

di(hardened tallow)
dimethyl ammonium chloride (DHTDMAC)
ethylene diamine tetra acetate (EDTA)
diethylene triamine penta acetate (DTPA)

X The levels for ionic impurities in the dye are not exceeding:

Ag 100 ppm	Co 500 ppm	Hg 4 ppm	Se 20 ppm
As 50 ppm	Cr 100 ppm	Mn 1000 ppm	Sb 50 ppm
Ba 100 ppm	Cu 250 ppm	Ni 200 ppm	Sn 250 ppm
Cd 20 ppm	Fe 2500 ppm	Pb 100 ppm	Zn 1500 ppm

X The dyestuff is not based on pigments

X The dyestuff is not a metal complex dye

X The dyestuffs do not cleave to any of the aromatic amines:

4-aminodiphenyl (CAS No.92-67-1)	3,3'-dimethyl-4,4'-diaminodiphenylmethane (CAS No. 838-88-0)
4-chloro-o-toluidine (CAS No.95-69-2)	p-cresidine (CAS No. 120-71-8)
2-naphthylamine (CAS No. 91-59-8)	4,4'-methylene-bis(2-chloroaniline) (CAS No. 101-14-4)
o-amino-azotoluene (CAS No. 97-56-3)	4,4'-oxydianiline (CAS No. 101-80-4)
2-amino-4-nitrotoluene (CAS No. 99-55-8)	4,4'-thiodianiline (CAS No. 139-65-1)
p-chloroaniline (CAS No. 106-47-8)	o-toluidine (CAS No. 95-53-4)
2,4-diaminoanisol (CAS No. 615-05-4)	2,4-diaminotoluene (CAS No. 95-80-7)
4,4'-diaminodiphenylmethane (CAS No. 101-77-9)	2,4,5-trimethylaniline (CAS No. 137-17-7)
3,3'-dichlorobenzidine (CAS No. 91-94-1)	4-aminoazobenzene (CAS No. 60-09-3)
3,3'-dimethoxybenzidine (CAS No. 119-90-4)	o-anisidine (CAS No. 90-04-0)
3,3'-dimethylbenzidine (CAS No. 119-93-7)	6-amino-2-ethoxynaphthalene
4-amino-3-fluorophenol	

X The dye or dye preparation does not contain any of the following dyes: C.I. Basic Red 9, C.I. Disperse Blue 1, C.I. Acid Red 26, C.I. Basic Violet 14, C.I. Disperse Orange 11, C.I. Direct Black 38, C.I. Direct Blue 6, C.I. Direct Red 28, C.I. Disperse Yellow 3

X No dye substance or dye preparations contains more than 0.1% by weight of substances that are assigned or may be assigned at the time of application any of the risk phrases R40, R45, R46, R49, R60, R61, R62, R63 or R68

as laid down in Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, and its subsequent amendments.

- 1 -

INSTYLE CONTRACT TEXTILES
LIFE Textiles™ Specification - Version 1

Appendix 5:

Radford Yarns produce their felted carpet yarns in the following way:

1. Raw materials arrive (this is scoured wool that arrives highly compacted)
2. The wool is then carded (Radford Yarn add a natural spinning oil to the fibers and aerate them before carding). The aim here is to bring the wool off in nice even slivers.
3. Next the wool goes through the gilling process (here the yarn is mixed and aligned as straight as possible).
4. The wool is put through the roving machine (here a light twist is put in the yarn to hold it together. Radford Yarn can put a slub in the yarn at this stage).
5. The yarn is then felted (hot water and a biodegradable detergent are used to bind the fibers together).
6. The yarn is dried (hot air is gently blown over the yarn).
7. The yarn is then wound (usually either onto hanks or cones depending on the way it is to be dyed).
8. The yarn is then dispatched.

(M. Ingram, personal communication, June 19, 2012)

Appendix 6:

The chart below shows chemicals added to Radford Yarn wool yarns used at CRONZ:

Yarn type	Felted	Composition	Supplier	Pre-treatments	Chemicals added during yarn production	Used
780 tex	Yes	100% Merino wool	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	No
1300 tex	Yes	100% wool	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	Yes
2500 tex	Yes	100% wool	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	No
3000 tex	Yes	100% wool*	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	No
3600 tex	Yes	100% wool	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	No
3600 tex	Yes	100% wool**	Radford Yarns	Scoured	Natural spinning oil, biodegradable detergent	Yes

*this yarn is natural white with a black wool core

**this yarn is grey with black neps, the grey is produced by mixing natural undyed white and black wool fibres, the black neps have been dyed before felting yarn together

Appendix 7:

Optilan MF
 N = change of shade
 Wo = stain on wool
 Co = stain on cotton
 SD = standard depth

		Xenon lamp IWS TMS 1/3 SD	1/1 SD	Perseparation alkaline ISO E04	Domestic Laundering ISO 105 C06 A25 40°C
Yellow MF-2GLA 1.60%	6	N Wo Co	4-5 4-5 4-5	4-5 4-5 4-5	
Golden Yellow MF-RL 0.85%	5	N Wo Co	4-5 4-5 4-5	4-5 4-5 4-5	
Scarlet MF-GL 130 1.10%	4-5	N Wo Co	4-5 5 4-5	5 5 4-5	
Red MF-GRLN 1.70%	5	N Wo Co	5 4-5 4-5	5 4-5 4-5	
Brill.Red MF-BG 125 1.00%	3-4	N Wo Co	4-5 3-4 4	4 4 4-5	
Brill.Red MF-3B 140 0.8%	3	N Wo Co	4-5 4-5 4	4-5 5 5	
Dark Red MF-BR 150 1.00%	1/1SD 3-4	N Wo Co	4-5 4-5 4-5	4-5 5 5	
Blue MF-GL 2.10%	5-6	N Wo Co	5 4 4-5	4-5 4-5 5	
Blue MF-2RLA 2.00%	5	N Wo Co	5 3-4 4	5 5 5	
Dark Blue MF-2B 300 0.45%	3-4	N Wo Co	5 4-5 4-5	5 5 4-5	
Navy MF-RLD 200* 3.60%	6	N Wo Co	4-5 4 3-4	4 5 4-5	
Black MF-BR* 3.50%	6	N Wo Co	5 4 3-4	5 5 4	

* in SDD fastness properties in 1/1SD, but Black, Navy in SDD

Optilan MF
 N = change of shade
 Wo = stain on wool
 Co = stain on cotton
 SD = standard depth

		Xenon lamp IWS TMS 1/3 SD	1/1 SD	Perseparation alkaline ISO E04	Domestic Laundering ISO 105 C06 A25 40°C
Yellow MF-PL 140 1.15%	5	N Wo Co	4-5 3-4 4	4-5 4-5 4	
Red MF-PL 150 1.00%	5-6	N Wo Co	4-5 3-4 4	4-5 4-5 4	
Blue MF-PLA 125 1.30%	5-6	N Wo Co	4-5 3 4	4-5 3 4	
Blue MF-PRL 200 0.95%	5	N Wo Co	4-5 3-4 4-5	4-5 3-4 4-5	

Dyeing process:

Dyes: Optilan MF x%

Auxiliaries: Lyogen MF liq 0-1%
 Na₂SO₄ 5.0%
 NaAC 1.0g/l
 HAC pH 4.5

L.R: 1:15


Appendix 8:

Date:	Time:
Technique used:	Water temperature:
Yarn type:	
Yarn Supplier	Yarn Composition:
Weight of dry yarn (grams):	pH of water:
Dye used:	
Colour number (if a mix of dyes):	
% shade:	Vinegar (mls):
Lyogen (mls):	Glaubers salt (grams):
Water (mls):	Total liquid in dye bath:
Time in dye bath:	Sample:
Energy used:	
Evaluative notes:	

Time:	Bath time:	Dye steps:	Chemicals:	Water temp:	pH level:	Power meter:
		40°C water (this will cool down) + wool left to soak overnight				
		Raise temperature of water + wool back to 40°C and begin dye bath		40°C		
	0 minutes	Add Glaubers salt	Glaubers salt	40°C		
	5 minutes	Agitate bath		40°C		
		Add acid, agitate for 5 minutes	Acid	40°C		
	10 minutes	Check pH level adjust if necessary		40°C		
	15 minutes	Add dye, agitate for 5 minutes	Dye	40°C		
	20 minutes	Re-check pH level, adjust if needed		40°C		
	20 minutes	Raise temperature over 40 minutes, agitating throughout				
	25 minutes	Check temperature				
	30 minutes	Check temperature, prep pH in 5 minutes				
	35 minutes	Check temperature + pH				
	40 minutes	Check temperature				
	45 minutes	Check temperature, prep pH in 5 minutes				
	50 minutes	Check temperature + pH level				
	55 minutes	Check temperature, leave pot in Agee for last 5 minutes of heating				
	60 minutes	Dye bath should now be at 96°C, agitate with lid on				
	75 minutes	Take small amount of dye out and leave to cool				
	80 minutes	Check pH of cooled dye out of dye bath, then replace dye				
	90-105 mins	Leave yarn to cool for 20 minutes				
		Take yarn out of dye bath and rinse yarn				
		Test pH level of remaining dye bath and correct	Baking soda			

Examples of dye documentation sheets in practice:

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Date: 21-08-12	Time: Salt in @ 10:20am	<input checked="" type="checkbox"/> Salt <input checked="" type="checkbox"/> vinegar <input checked="" type="checkbox"/> dye
Technique used: Twisted uprn. Soaked overnight, no Lyogen. used spatula like pedal to move yarn around	Water temperature: Aye in @ 10:20am -11:40@96°C	
Yarn type: 1300T Felted <small>is not fully submerged</small>	Yarn Composition:	
Yarn Supplier: Radfords	pH of water:	
Weight of dry yarn (grams): 100g	Dye used: 5mls Golden Yellow stock solution, 4mls Blue MFGL stock solution, 2.4mls navy stock solution, 2.4mls Red MF-GLN	
Colour number (if a mix of dyes): recipe 2 for green but no lemon yellow + less Golden Yellow.		
% shade: 1.445% / 1.445g dye	Vinegar (mls): 30mls + 6 + 4 + 10 + 6	
Lyogen (mls):	Glaubers salt (grams): 5g	
Water (mls): 21000mls	Total liquid in dye bath: <small>Removed equivalent of dye stock solution before adding salt or vinegar</small>	
Time in dye bath:	Sample:	
Energy used:		
Evaluative notes: Fully exhausted		

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Time:	Bath time:	Dye steps:	Chemicals:	Temp:	pH level:	Extra acid:	POWER AGEE METER
3:40pm		40°C water (this will cool down) + wool left to soak overnight					
		Raise temperature of water + wool back to 40°C and begin dye bath		40°C			
3:40pm	0 minutes	✓ Add Glaubers salt	Glaubers salt	40°C			
3:45	5 minutes	Agitate bath		40°C			
		✓ Add acid, agitate for 5 minutes	Acid	40°C			
3:50	10 minutes	Check pH level adjust if necessary		40°C	4		
3:55	15 minutes	Add dye, agitate for 5 minutes	Dye	40°C			
4pm	20 minutes	Re-check pH level, adjust if needed		40°C	4.4	236	12.1
4pm	20 minutes	Raise temperature over 40 minutes, agitating throughout					
4:05	25 minutes	Check temperature					48
4:10	30 minutes	Check temperature, prep pH in 5 minutes					54.2
4:15	35 minutes	Check temperature + pH					59
4:20	40 minutes	Check temperature			4.5	233	13.2
4:25	45 minutes	Check temperature, prep pH in 5 minutes					67.8
4:30	50 minutes	Check temperature + pH level					73
4:35	55 minutes	Check temperature, leave pot in Agee for last 5 minutes of heating			4.5	235	13.9
4:40	60 minutes	Dye bath should now be at 96°C, agitate with lid on					80.2
4:55	75 minutes	Take small amount of dye out and leave to cool					82.5
5pm	80 minutes	Check pH of cooled dye out of dye bath, then replace dye			4.6		89.1
5:30pm	105 minutes	Leave yarn to cool for 20 minutes					
	125 minutes	Take yarn out of dye bath and rinse yarn					
	130 minutes	Test pH level of remaining dye bath and correct	Baking soda		7.4		

Total = 5.8kwh



1. Weigh out yarn



2. Coil yarn



3. Place yarn in stainless steel container



4. Begin documentation



5. Measure out water at 40 degrees C



6. Cover yarn in water and leave to soak overnight



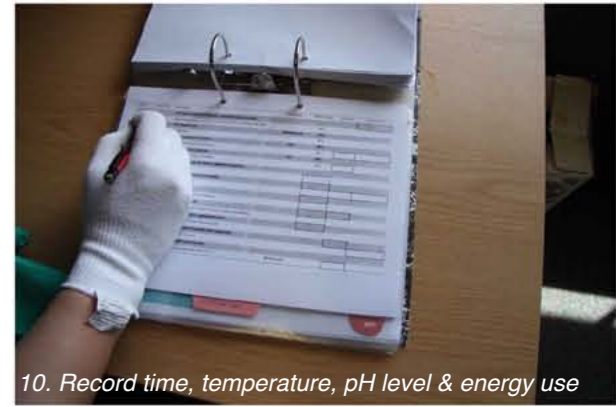
7. The next day heat dye vat, measuring energy



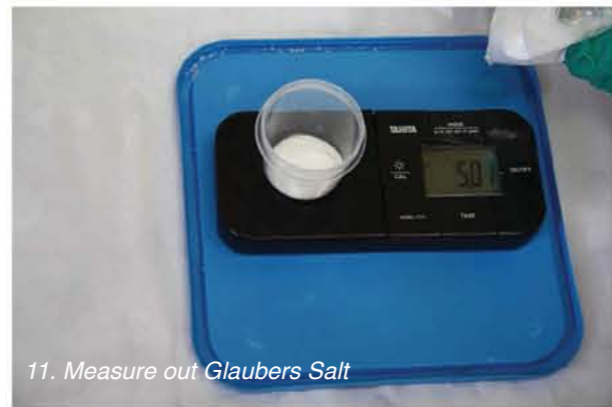
8. Set out equipment



9. Bring yarn in dye bath back up to 40 degrees C



10. Record time, temperature, pH level & energy use



11. Measure out Glaubers Salt



12. Remove water from dye bath to mix salt into



13. Add Glaubers Salt to dye bath



14. Mix Glaubers Salt well into dye bath



15. Measure out acetic acid



16. Add acetic acid to dye bath



17. Agitate to mix acid into dye bath



18. Check pH level



19. Weigh out dye powder



20. Remove water from dye bath and use this to mix dye powder



21. Add dye powder into dye bath



22. Mix dye powder in well and agitate dye bath



23. Re-check pH level



24. Agitate dye bath



25. Begin to raise temperature of dye bath



26. Check temperature and record data every 5 minutes



27. Continue to agitate dye bath



28. Continue to gradually heat dye bath



29. Take temperature



30. Continue to agitate and heat dye bath



31. Take a sample of the dye bath and test pH level



32. Remove sample of dye bath to check exhaustion then replace





33. Once dye bath reaches 96 degrees C keep on heat



34. Periodically remove dye bath water to check colour is exhausting correctly



35. Coloured yarn with clear water at end of dye bath



36. Clear dye bath liquid at end of dye bath



37. Yarn dyed and rinsed out



38. Add baking soda to neutralise acidic dye bath before disposal



39. Dry dyed yarn

Appendix 10:

Here tinfoil was used to measure the strength of the cavitation for 5 minutes over 5 dye baths. Below is a tinfoil example, from test 12, of how the strength of the cavitation ate away at the tinfoil. Opposite is a composition where overlapping coloured areas show the areas of strongest cavitation.



Appendix 11:



Image credits:

Unless otherwise stated all images, graphs and charts are the work of Rebekah Harman. Please note that print colours may differ from original work.

Figure 4: Swann, C. (2002). Design-led model. Chart.

In Action Research and the Practice of Design. *Design Issues*, 18(2), 49-61. Used with permission from The MIT Press

Figure 5: CRONZ. (n.d.). *CRONZ home page* [Screenshot of website]. Retrieved from <http://www.cronz.co.nz/> Used with permission from CRONZ

Figure 6: Rubia Natural Colours. (n.d.). *Rubia dyed carpets*. Images used courtesy of Rubia Natural Colours: The Netherlands.

Figure 7: Wools of New Zealand: Laneve. (n.d.), *Laneve Authentication* [Screenshot of website]. Retrieved from <http://www.woolsnz.com/laneve/batch/S5213/view.aspx> Used with permission from Wools of New Zealand

Figure 8: Wools of New Zealand: Laneve. (n.d.), *Trace: Laneve Authentication* [Screenshot of website]. Retrieved from <http://www.woolsnz.com/laneve/> Used with permission from Wools of New Zealand

Figures 23, 26, 27 & 28: Images taken by Amber Griffin. (2013). Used with permission.