TECHNICAL BULLETIN

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OVERVIEW OF FABRIC YELLOWING

This report is sponsored by the Importer Support Program and written to address the technical needs of product sourcers.

INTRODUCTION

Yellowing of textile fabrics is one of the oldest and most widespread quality problems known. The yellowing can be seen directly in the case of market whites, pastel shades or even after-washed denims. However, shade change noticed in darker colored fabrics can often be attributed to chemical change or degradation of the fiber or some chemical agent either purposely applied to the fabric in finishing or inadvertently absorbed by the fabric in its storage and shipment to market or during its end use. As a general statement, yellowing of textile materials is an indication of unanticipated chemical degradation. Very often, as colorless chemicals decompose, they form light to moderate yellowish colors. Of course, if this chemical is a textile finish or additive or has been absorbed by a textile product, this color formation is noted as fabric or garment yellowing. It should also be noted that continued chemical decomposition could form moderate to dark brown colors or, in some extreme cases, even black colors.

It has been suggested by many investigators in the textile, retail, and consumer protection areas that the frequency of occurrence of yellowing of fabrics is actually on the increase. This is understandable because of the wide variety of fibers and fiber blends that compose textile fabrics available in today's market. Additionally, textile finishing chemicals are more numerous and chemically complex than ever before. They often show yellowing tendencies as they age or are subjected to improper storage and cleaning techniques. Also, investigators have suggested that the high concentration of various atmospheric pollutants present today in many parts of the world resulting from a variety of industrial and natural sources are the major reason for the observed fabric yellowing increase.

CAUSES OF YELLOWING

All types of textile products have been subject to yellowing including those made from natural fibers such as cotton wool or silk, as well as those composed of synthetic fibers such as polyester, nylon, or spandex. It should also be noted that in the cases of blended fabrics, at times only one fiber in the blend may be affected by the yellowing. However, at other times several or all fibers in the blend are affected. Specifically, the cause of the yellowing often determines which fiber(s) in the blend exhibit the yellowing. This fact can be used as a diagnostic tool to help determine the source of the observed yellowing and aid in the development of a strategy to prevent future problems.

In recent years, the various causes of these yellowing issues have been studied extensively with the subsequent publication of numerous technical papers and reports. Generally, the causes can be grouped into the following broad categories with the understanding that there can be crossover or combinations of causes that yield observed fabric yellowing:

1. *Fiber Degradation* – Destruction, decomposition, internal change of the fiber structure due to chemical or biological degradation, exposure to excessive heat, intensive or long term exposure to light radiation and/or fiber aging are all primary causes of fabric yellowing. Additionally, specific fiber blends may actually increase the occurrence of these problems.

2. *Chemical Additives or Auxiliaries* – It is well known that the overuse or misuse of chemical finishes such as softeners, lubricating oils, resins, optical brightening agents, or metallic salts can lead to unwanted fabric color change including fabric yellowing.

3. *Atmospheric Pollutants* – As was stated previously, atmospheric contaminants from both natural and industrial sources can lead to pronounced fabric yellowing. The specific pollutants include, but are not limited to oxides of nitrogen, sulfur dioxide, and ozone. The mechanisms for the actual fabric contamination are numerous and varied but are normally directly related to specific fiber or fiber blend content along with fabric finishing processes.

4. *Transferred Contaminants* – The contaminants often are contained in cardboard boxes or dividers, plastic sheets, films, or bags and in auxiliary materials such as pumice stones used for garment after-washing processes. In recent years this type of yellowing has been both frequent and also difficult to minimize.

5. *Consumer Contaminants* – These contaminants include perspiration, chemical residues from such products as perfumes, body lotions, make-up, medical ointments, effects of commercial and domestic laundry products on various textile materials, as well as build-up of chemical additives such as cornstarch added by commercial shirt laundries. This is certainly not a totally complete listing of all the potential causes of fabric yellowing but it does cover the major sources indicated in the technical and trade literature.

Before discussing specific examples of circumstances of fabric yellowing, it is worth mentioning the importance of the light used to evaluate a textile fabric or garment for this type of quality problem. It should be noted that the choice of light source and lighting circumstances such as surroundings are extremely critical when judging the shade, whiteness, or yellowness of textile fabrics. The American Association of Textile Chemists and Colorists has published specific recommendations for both visually and instrumentally judging the color of textile fabrics. One should be aware that each light source available such as simulated daylight, incandescent (home light bulb), various fluorescent tubes, xenon arc, or even sunshine will differ in the energy output distribution of the light wave lengths across the visible light spectrum. For instance, an incandescent light has very high energy output in the yellow, orange, and red wavelength region but is deficient in the energy output of the blue wavelengths. A textile fabric viewed under incandescent would exhibit yellow more vibrantly since it is rich in yellow, orange, and red but deficient in blue. The same fabric would show much less yellowing under a simulated daylight light source, since these have much higher blue wavelength energy and much lower yellow, orange, and red energy than the incandescent source. In practice, color evaluation should be conducted under controlled and consistent circumstances that are agreed to by the buyer and seller. Sunshine should never be used as a sole evaluation light source because of its inevitable variability depending on factors such as geographic location, time of year, time of day, cloud cover, and pollution load in the atmosphere.

FIBER DEGRADATION

As mentioned earlier, normally fiber degradation is not considered a major source of fabric yellowing but there have been studies that do indicate that this does occur. These investigations have shown that natural fibers such as cotton degrade and show yellowing, as well as synthetic fibers such as nylon. This fiber yellowing is normally accelerated by exposure to excessive heat, especially in the presence of high humidity, high exposure to ultraviolet light, or long term storage so that the fibers age. M. Yatagai from Tokyo Gakuex Women's College reported that in aged cotton fabric there is yellowing, a loss of breaking strength, a decrease in moisture regain and a decrease in dye uptake. It is well known that nylon and polyester fabric have a tendency to yellow upon storage over long time periods or in high heat containing warehouses. Greige spandex blend fabrics are notorious for their poor storage stability and normally should be finished within two months of their manufacture.

CHEMICAL ADDITIVES OR AUXILLARIES

Textile finishing of modern textile fabrics employs varied and complex chemical formulations depending on the end use requirements for the textile products. One of the most widely used chemical additives are textile softeners because they can be added in home or commercial laundries, as well as by the textile manufacturer. The source of these chemicals can be natural products such as chemically modified animal fats and oils, vegetable fats and waxes or synthetic products such as hydrocarbon waxes or silicone materials. Because of the chemical composition of these materials many of them are subject to yellowing due to exposure to high heat, long time storage, or incorrect chemical formulation. Additionally, because of their oily, greasy nature, heavy application of these softeners leads to excessive attraction of oily dirt by the fabric surface, which in turn creates a tendency toward yellowing.

Because yellowness within a fabric can be considered as minus blue, a traditional method to improve apparent "whiteness" in home or commercial laundry is to add fugitive blue tints to the wash-bath. In practice, this method generally leads to dulling of the textile fabrics. A group of textile chemical additives called optical brightening agents (OBAs) or fluorescent whitening agents have been developed to replace the fugitive blue tints. These unique chemicals have the ability to absorb invisible ultraviolet light and emit this light in the blue region. This has the two-fold benefit of adding blue energy to cancel out yellowness and adding increased light energy so that the fabric appears brighter. These compounds are used in almost all laundry detergent formulations. However, it has been shown that some of these materials dull certain colored fabrics and in certain specific instances, actually contribute to fabric yellowness. As an example, gray threads sewn or woven into a blue fabric tend to appear as yellow threads to the human eye. Many optical brightening agents intensify the yellowish appearance. Additionally, some of these materials are sensitive to aging, their chemical environment, atmospheric pollutants or excessive heat. This sensitivity may cause degradation or change such that the OBA's may yellow the fabrics themselves.

One of the most prevalent chemicals textile fabrics are exposed to is chlorine. It is used as a disinfectant in household and industrial process water, in swimming pools and in some medical

applications. Sodium hypochlorite is one of the oldest and most commonly used textile bleaches. Chlorine in textile process waters has been called the "unseen assailant" and is a common source for fabric yellowing. Chlorine is retained from process or wash water by many textile resin finishes used for cotton, rayon, or lyocell, slowly building over time to finally yellow and weaken the fabrics. Chlorine attacks and yellows protein based fibers such as wool and silk. It also exhibits yellowing effects on nylon. Chlorine based chemical treatments can be beneficial on certain textile fabrics but these must be applied selectively and carefully.

Any type of chemical additive for either fibers, yarns, fabrics, or garments which is not applied correctly or that is sensitive to storage conditions, environmental conditions, heat, biological attack or chemical environment has the potential to yellow the textile fabric. Industrially applied chemicals such as fiber finishes, yarn lubricants, knitting oils, warp sizes, and many different fabric chemical finishes not previously discussed fall into this category. For synthetic fabrics such as nylon and polyester, as well as their fabric blends, over heat setting leads to fabric yellowing and tear strength loss. Any residual chemicals left on these fabrics during heat setting also contribute to the yellowing potential.

ATMOSPHERIC POLLUTANTS

Studies have shown that one of the most potent agents for causing yellowing comes from atmospheric pollution (from both natural and man-made sources). The single biggest source of yellowing has been identified as oxides of nitrogen. For example, these oxides are formed by the action of lightning in the atmosphere. Man-made sources include the burning of gasoline and diesel fuel in tow motors, automobiles, trucks and trains, gas- and oil-fired heating systems, and various types of industrial and commercial processes. The most prevalent pollutant, nitrogen dioxide, may react with small amounts of chemical residues, oils or greases on the fabric surface. High concentration of nitrogen dioxide has been shown to yellow nylon fiber directly.

Other gaseous pollutants shown to induce fabric yellowing include sulfur dioxide, hydrogen sulfide, and ozone. It must be emphasized that fabric yellowing in the presence of these atmospheric contaminants is usually the result of a chemical interaction between the specific pollutant and some chemical components on or near the fabric surface. For factories or warehouses, it is important to ensure that gas or oil-fired heating systems are well maintained. Proper air ventilation within the facility is also very important, especially if emissions from tow motors can concentrate within fabric or garment storage areas.

TRANSFERRED CONTAMINANTS

Twenty-five years ago, the frequency of fabric or garment yellowing while in storage markedly increased. This was a particular problem for white and pastel shades. The problem was not particularly uniform, in that, within a carton of rolls of fabric, some rolls would exhibit severe yellowing while other rolls showed no yellowing at all. After many attempts to isolate and identify the problem over several years, researchers determined the source of the problem to be what is now known as phenolic yellowing resulting from fabrics wrapped in polyethylene film or bags. Many reports and papers have been published which explain the chemistry and reaction mechanisms of the yellowing formation. However, the essence of these studies have shown that

phenolic antioxidants, most notably butylated hyroxytoluene (BHT), blended into the polyethylene film as a protectant and preservative react with nitrogen dioxide from atmospheric pollution to form yellowing on the fabric surface. This yellowing can be in patches and is normally reversible. It often can be removed by an acidic scouring of the fabric or exposure of the fabric to direct sunlight. This phenolic yellowing has since been discovered to be much more widespread throughout fiber-textile-cut & sew-retail chain than anyone initially believed. For instance, these phenolic antioxidants have been found to be in polyethylene wrap and bags, cardboard, brown paper, and other wrapping and packaging materials. In textile processing, these antioxidants have been used as additives in the fiber extrusion process, as fiber finish additives, as preservatives in textile softeners, coning oils, knitting lubricants, and various other textile finishes. In the cut and sew industry, these phenolic antioxidants have been found in foam paddings, interlinings, fabric adhesives, and stitch lubricants. Obviously, to prevent this type of fabric yellowing, materials should be chosen which do not contain these phenolic antioxidants. However, because of the widespread use of these compounds in many necessary textile auxiliaries and supplies, it becomes difficult to completely eliminate these antioxidants from all potential exposure scenarios. Therefore, to minimize yellowing in storage, warehouse areas should be well ventilated to remove nitrogen dioxide and temperature controlled. Also, if possible, gas-fired tow motors should not be used in storage areas.

CONSUMER CONTAMINANTS

Many times, once the textile end product is in the hands of the consumer, fabric yellowing can be directly attributed to the actions of the consumer. For instance, fabric yellowing can occur by the improper cleaning and removal of body lotions, perfume and cologne, hair spray, make-up, perspiration, and other oily dirt absorbed into the fabric or garments through normal use. The International Fabricare Institute Bulletin has identified these and other consumer caused contaminants as typical sources of fabric yellowing. In many cases, such as around collars or underarms of blouses or shirts, the contaminants which lead to fabric yellowing slowly build-up over time until they reach a point where the garment appearance and performance is negatively affected. A good example of this is the build-up of aluminum chloride from certain deodorants, which imbeds into the fabric in the underarm area. It is very difficult to remove in laundering and over a period of time builds to a level that severely affects the garment.

The textile consumer can contribute to fabric yellowing in other ways. The particular choice and use of detergents and fabric softeners can be a factor. Over-drying of laundered garments can lead to yellowing. Exposure of textile fabrics to smoke and soot from fireplaces, pipes, cigars, cigarettes, and improperly maintained gas- and oil-fired furnaces within the household can all contribute to fabric yellowing. In commercial laundering, overuse of starch or hot pressing garments containing too much alkali can lead directly to yellowing.

As a final item, the yellowing of denim garments, specifically stone/bleach after-washed jeans has been a major topic of study. This yellowing occurs as large patches throughout the garment as well as at the folded edges of the garment. Studies have shown that the yellow formation is due to decomposition products of indigo dye, namely isatin and anthranilic acid. The published mechanism shows that yellow formation occurs when isatin interacts with nitrogen oxide pollutant gases. Anthranilic acid has been shown to develop yellow color on exposure to natural

sunlight or on interaction with ozone. Other decomposition products may lead to yellow formation but at this time, they do not seem to be major contributors to the observed yellowing problem. Yellowing of denims can be minimized by making sure that jeans are thoroughly scoured after stone washing where possible to remove these indigo decomposition products from the garment. Practices used to minimize atmospheric pollutant gas contamination are strongly recommended.

SUMMARY

The following is a general but not complete list of measures to take to minimize yellowing of textile fabrics:

- Use chemical finishing agents, especially softeners, which do not contain phenolic-based antioxidants and preservatives.
- Minimum amounts of softeners, particularly cationics, should be used since they may intensify yellowing by attracting dirt and oils and by storing phenolic compounds.
- Maintain a slightly acidic pH of around pH six or below for the finished fabric.
- Where possible use packaging and wrapping materials and boxes free from phenolic antioxidants. Use gas impermeable wrapping films.
- Avoid the use of vehicles powered with internal-combustion engines in warehouses, storage areas, and processing facilities.
- To ensure the removal of harmful gases, maintain good ventilation in storage areas, and processing facilities.
- Ensure that garment components such as shoulder pads or interlinings do not contain phenolic compounds, which have a tendency to yellow.

As can be seen from this overview, there are a wide variety of causes for yellowing of textile garments and fabric. Wherever possible, steps should be taken to prevent yellowing formation rather than trying to remove or "fix" it. Once fabric is yellowed, the cause of the yellowing often dictates what the possibilities for remedy may be. In some cases, fabric yellowing indicates fabric degradation, in which instance; the fabric may not be able to be restored to its original condition. Careful analysis of the sources of fabric yellowing and attention to detail in the handling and treatment of textile fabrics are the keys to minimizing losses from yellowing.

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Selected technical issues have been identified by importer members as relevant to their business. This report is a condensed, less technical report of those issues intended to provide the reader with basic, yet useful information on the topic.

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