Yellowing of Textiles

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A common problem with light and white shades in textiles is yellowing of textile in use or during storage. Gradual yellowing of textile in use is related to the accumulation and oxidation of the residual soil mainly sebum and nitrogenous soil. Unsaturated compounds in sebum, unsaturated fatty acids and their esters form dark coloured oxidation products. Some of the yellowing in cellulose based textiles is also due to oxidation of cellulose.

This yellowing phenomenon has been discussed under the following classes as they are more frequent in their occurrences:

- Yellowing during wear
- Yellowing of Wool
- Yellowing on storage

**Yellowing During Wear:** This is caused by insufficient light fastness, Perspiration and urine, combined with the effects of dry cleaning and laundering due to auxiliary residues including optical brightening agents which have been removed, insufficiently fixed or have altered fastness properties and are generally more visible after finishing treatments (ironing, pressing and mangling). For measuring techniques: the grey/whiteness measurement using whiteness measuring devices is not sufficient, as deposits which tend to be yellow to brown play a
significant role in the altered fabric appearance as “yellowing”. It is universally observed that a
grey with a blue cast appears more pleasing “whiter” (optical brightening agent) to the eye than
grey with a yellow cast with the same degree of graying. To be able to measure both graying
and yellowing of a strip of test fabric, this is graded on a blue-grey-yellow scale. It is neutral
grey if it reflects light of different wavelengths to an equal degree, i.e. it has a constant degree
of whiteness when various filters are placed in front of it.

**Yellowing of Wool:** Environmental influence on fibrous material include: solar radiation,
artificial light sources etc: (light exposure damage), temperature, oxygen, water (water
sorption, water vapour etc).

Various harmful pollutants e.g. pollutant gases (ozone, nitrogen, sulphur oxide etc, various
solvents.

All the above factors may occur in a wide range of combinations and at varying intensities and
exert different effects on wool. The physical values of radiation and temperature are the primary
functions for the photochemical changes to the wool fiber. By thermal exposure of wool, the
extremely damaged scale structure of the fibers can be clearly identified.. Table - I below shows
the distribution of the energy radiation of the sun and its effect on wool. Here two apparently
opposite process can be observed, wavelengths of approximately 280-400 nm result in yellowing
and fiber degradation, whereby the short wavelength, higher energy portion of 280-330nm
(blocked by window glass) has a significantly more damaging effect than the range of
approximately 330-400nm. The wavelength range of 400-460nm has a photo bleaching effect, on
wool. When wet wool is exposed to radiation, photo bleaching and photo radiation is accelerated.
The absorption of solar radiation in the visible range changes depending on the dyestuff, optical brightener etc. applied on the substrate but a similar phenomenon also occurs in the UV and IR range. Heat alone tends primarily to have a yellowing effect on wool and fiber degradation is comparatively less.

In practice wool tends to be dyed and its absorption spectrum for radiation is therefore altered to a greater or lesser extent. Temperature measured on woolen fabrics, which have been dyed with various metal complex dyes was found to be different. These differences in temperature are caused by the altered radiation absorption of the fabrics in particular in the visible, longer wavelength range and near infrared. Heat accelerates the photochemical degradation process of wool.

The mechanisms and chromophores arising in connection to photochemical yellowing and fiber degradation are largely unknown. The amino acid analysis of carefully irradiated wools demonstrates characteristic changes in the cases of amino acids, tryptophane, tyrosine, hystidine, cystine and methionine. Strong irradiation causes almost all amino acids to deteriorate. Numerous mechanism are known in relation to photo yellowing on the one hand, reactions of the amino acids altered on radiation and on the other the occurrence of ketone compounds, double bonds or reaction in the non protein areas.

The aim of protecting wool against the negative effects of light in particular against yellowing i.e. improving the light fastness of wool and its dyes in the uv range have been achieved by means of UV absorber of the o-hydroxy-phenyl-benzotriazole type.
Table I: Strength of Vertical Incidence Global Radiation and its Effect on Wool

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Intensity of Irradiation (W/m²)</th>
<th>Proportion (%)</th>
<th>Range</th>
<th>Effect on wool</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 280</td>
<td>0</td>
<td>0</td>
<td>Ultra violet</td>
<td>Photochemical effect</td>
</tr>
<tr>
<td>280 - 400</td>
<td>68</td>
<td>6.1</td>
<td>Ultra violet</td>
<td>Yellowing, Fibre Degradation</td>
</tr>
<tr>
<td>400 - 720</td>
<td>493</td>
<td>44.0</td>
<td>Visible</td>
<td>400-450 nm has a photobleaching effect</td>
</tr>
<tr>
<td>720 - 3000</td>
<td>559</td>
<td>49.9</td>
<td>Infrared</td>
<td>Acceleration of the Photochemical Process, thermal effect</td>
</tr>
</tbody>
</table>

**Yellowing on Storage:** A commonly occurring problem encountered in the garment retail shops is yellowing that typically takes the form of bright yellow patches or bands on the folded edges of garments stored for long periods in cardboard boxes.; It can also occur on other substrates and in other modes of storage not associated with cardboard. It is caused by the interaction of atmospheric nitrogen oxides with certain phenolic substances present in, for example, storage materials. The resulting compounds, which are nitrated phenols, which are colourless in acid media but yellow in alkaline; can sublime in the acid form and migrate at room temperature through protective plastic films, to be fixed in the yellow, alkaline form on fabric., or on other substrates contaminated by alkaline residues. Yellowing of textiles is very often a result of the presence of phenol-based antioxidants (butylated hydroxy toluene derivatives).

In unbleached cardboard the phenolic precursors are decomposition products of lignin. In the absence of cardboard the yellowing is attributed to other substituted phenols such as antioxidants that may have been added deliberately, or may be present as residual traces in, for example, dyed
fabrics. Normally, white phenol based antioxidants (PA) turns yellow even under slightly acid conditions, due to the cationic character of the free amino end-groups of PA, which interact with the antioxidant derivatives.

PA chemistry is widely used as it is low in cost and highly effective. Due to its low vapour pressure, it is volatile and can be transferred to textile goods easily. Products of this type are commonly used as stabilisers in fibre production, further textile processing, and packing materials (eg, polyethylene wrapping films, packing material in general). As long as such antioxidants are used, it is virtually very difficult to prevent such yellowing.

The most likely source of nitrogen oxides is exhaust fumes from motor vehicles. In the wide majority of cases of white goods yellowing on storage, three yellow compounds were found. These yellow components occurred individually or in varying blending ratios. These yellow components occurred individually or in varying blending ratios. These yellow compounds have been identified as 1) nitro phenol derivatives and 2) quinone compounds. These yellow body forms easily due to the effect of nitrogen oxides on the sterically hindered phenol 2,6, di-tert butyl-4-nitrophenol. The formation of compound 1 is possible if there is a substituent in the p-position, however, compound 2 is formed on oxidation of compound 1 with potassium hexa cyanoferrall in a caustic alkaline solution and also under mild reaction conditions. Identification of the yellowing component also gave insight into the reaction mechanism of yellowing on storage. According to this yellowing which occurs when ultra white or pastel coloured textiles are stored is due to reaction products in the storage atmosphere, and generally due to oxidation or nitration with sterically hindered phenols, and also applies to other phenols.
Oxidation of sterically hindered or other phenols is known and has been investigated in depth. Sterically hindered phenols are widespread as antioxidants and anti-agers and may therefore cause a yellow cast on textiles through packaging materials such as foils or rubber threads which come into contact with textiles.

One phenol compound often used as antioxidant for polyethylene foil is sterically hindered 2,6-ditert butyl-4-methyl phenol, generally known as “butylated hydroxy toluene” or “BHT”. BHT as actually an intermediate product in the formation of stilbene quinone due to its low stability, and has been isolated from garments, which have yellowed on storage. It has also been observed that only the polyester sewing threads yellow on storage, rather than the made up garment, and it opined that the sew ability improver on the sewing thread is much more likely to be able to absorbing and retaining volatile phenol compounds than the base fabric which has no final finishing. The phenol compounds therefore yellow due to the effect of nitrogen oxide in the atmosphere.

**Measures to minimize phenolic yellowing:**

- Finished the textile in an acid medium with a non volatile acid such as citric acid as the presence of alkali constitute an additional factor to convert BHT to stilbene quinone.
- Use of Phenol free cardboard boxes for packaging or recycled synthetic packaging.
- Minimizing the content of nitrogen oxide in the storage room.
- Packaging material coming into direct contact with the textile material should not contain volatile phenol based antioxidants.
• Whenever possible the use of finishing agents having minimal affinity for volatile phenol compounds.

• Warn customers to ensure that fibres and auxiliaries are free of phenolic antioxidants

**Phenolic Yellowing Test:**

This is a simple, predictive test, typically used to assess the potential of white or pastel-coloured textiles to transit or storage yellowing. The test is specific to phenolic yellowing that is the discolouration of textiles caused by the action of oxides of nitrogen on yellowable phenols. It is not intended to deal with the many other causes of discolouration, e.g. the migration or fading of optical brightening agents, gas fume fading, the oxidation of fabric lubricants and so on.

Based on a technique originally developed by *Courtaulds Research*, Phenolic Yellowing Test Kit is provided by the manufacturers of testing equipments is an effective means of controlling the quality of white and pastel-coloured goods and has considerably reduced the incidence of yellowing complaints arising from storage yellowing.

The Phenolic Yellowing Test Kit has today become established as the benchmark industry standard and is widely specified by a number of major retailers.

The risk of phenolic yellowing is evaluated by a contact test. Each test specimen is folded between a phenol-impregnated test paper. The test package consists of 5 test specimens and one standard control fabric wrapped and sealed in BHT – free polythene film. Constant
pressure on the package is maintained by the Perspirometer, and the specified environmental conditions are provided by the Incubator.

On removal from the Incubator the specimens are compared with their originals and the intensity of yellowing assessed using the standard Grey Scale for Staining.

References:
