Jack 'n' Jill and their Jaded Jeans

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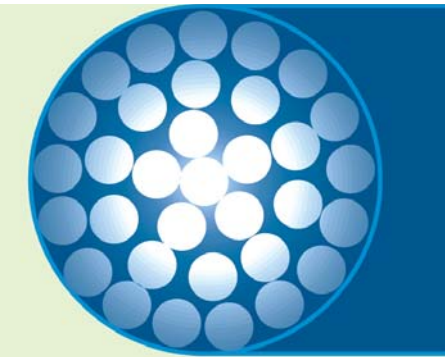
Jack 'n' Jill, after returning from the hill, have grown into adolescent teens. Like any other member of the community, they had taken up to jeans as a symbol of youth.

Things went well for quite some time, as they started with basic denim. Then the new fashion came, where prebleached, faded denims were in vogue. So they bought new pairs. Jack went to town in search of a job while Jill went to the beach with her friends to enjoy her freedom. After one week, when both returned to their village and, to their dismay, both their bleached jeans had turned yellow!

Jill tried to wash them, though she is not supposed to wash jeans at least for one lunar month, but the dirty yellow tinge remained. She discussed the problem with her friends, teachers and learned men and women in village but could not find satisfactory answer.

A visiting consultant told her it was phenolic yellowing, which he had heard about from some other consultant. Finally she approached a professor of textile chemistry. He asked the background details and concluded that this is nothing but Ozone Fading!



Denim is ring dyed.

He narrated his experience and findings, which were fascinating and enlightening to both Jack 'n' Jill.

Indigo dyeing is carried out on continuous ranges, either in sheet form or in rope form. Unlike conventional dyeing, this kind of yarn dyeing is in ring-dyed form, where dyestuff is not allowed to diffuse inside (see picture). The ring-dyed yarn leads to a faded look on usage, because of loss of colour due to abrasion or wear and tear. Fading can also be enhanced artificially in garment form, by either mechanical, chemical or enzymatic assistants.

Unfortunately these fashion garments are prone to yellowing as a result of decomposition of indigo (Isatin and Anthranilinic acid) due to environmental influences. This yellowing is an irreversible phenomenon. The destruction of indigo is due to NOx and oxidants, particularly atmospheric ozone, which is a major cause of yellowing. Ozone is present naturally in air near the seashore, where there are fewer pollutants. Apart from giving a feeling of freshness to the holiday-makers, ozone also silently fades their denims. In industrial cities, chemical smog along with ozone is the main culprit in the yellowing of denims.

Two types of smog have been reported in literature. 'London smog' is caused by soot particles and sulphur dioxide. These particles absorb part of sunlight, making a 'visible' smog. Sulphur dioxide in this smog is capable of destroying indigo. The second type of smog is called 'LA smog' and is invisible. It consists of nitrogen oxides from automobile exhausts. This is also called a 'photochemical smog' and is present usually in the summer months and in populated areas with heavy automobile pollution.

Due to the depleting layer of natural ozone, the sun's UV radiation, mainly shorter wavelengths, increasingly reaches the earth's surface in the summer months. The UV light reacts with nitrogen oxides as well as oxygen in the air to form an ozone molecule, which is unstable. The ozone thus formed destroys indigo. Since ozone generation is continuous process, yellowing continues.

Based on the molecular weight of Ozone and Indigo, theoretically approx 1 gm ozone can destroy 10.9 gm of Indigo. Apart from ozone, nitrogen oxides present in air also destroy indigo. This phenomenon of photochemical smog & decomposition of Indigo is represented in Figs. 1 and 2.
The factors that affect indigo destructions are:

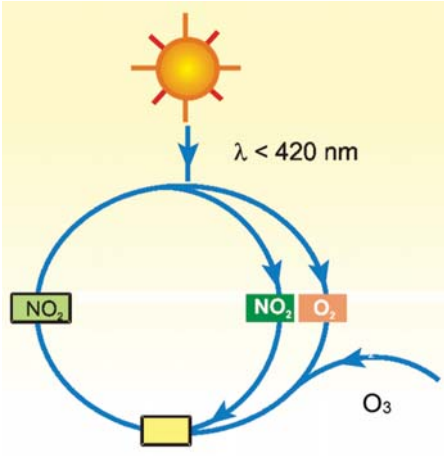


Fig 1 - The effect of UV on fading of Indigo.

1. Indigo concentration and indigo distribution on the substrate

Lighter or bleached denims fade faster than basic unwashed denim.

Table 1 & Fig. 3 show the correlation between indigo concentration, ozone concentrations and the extent of fading. In order to relate laboratory results to actual exposure in a warehouse, a 5-year study was conducted to determine the actual rate of fading under various exposure conditions. The results from these tests are shown in Fig. 3.

2. Air Humidity and Temperature

Higher humidity and higher temperature are known to accelerate yellowing. High humidity gives a thin water film on denim, which increases the absorption rate of ozone. High humidity results in higher moisture retention by the denim fabric, consequently increasing the absorption rate of ozone (Table 2).

3. Finishing Chemicals

Some softeners protect denim while others enhance yellowing. A popular misconception is that silicone emulsions aggravated yellowing. However, a detailed study demonstrated that a surfactant used for emulsification of the silicone oil is the main culprit, rather than silicone oil itself. Silicone oil, irrespective of its viscosity, amine value or modified structure, does not significantly contribute to yellowing. (Figs. 4 & 5)

4. Intensity of UV & NOx in the Environment

Higher UV intensity and higher concentrations of NOx lead to higher concentration of ozone, which in turn leads to quicker yellowing.

5. Duration of Exposure to UV and NOx

The longer the exposure, the greater the yellowing.

6. Packing Material of Garments

Yellowing during storage due to reaction between antioxidant in packing material & NOx (Refer to our article on 'Yellowing of Textiles', which appeared in *International Dyer* – September 2006).

Prevention of Yellowing

It is a known fact that certain finishing chemicals accelerate decomposition of indigo. The extent of decomposition would depend upon the concentration of the finishing chemical on the garment, its chemical nature and the form of its decomposition products. Thus, to protect indigo from destruction, the 'anti-matter', or formulations that have exactly the opposite properties from the destructive species, have been evaluated.

Various formulations were tried, to assess their effect on the destruction of indigo, and suitable formulations were identified and marketed as special finishes for denim to prevent yellowing. These finishes form a protective layer on a substrate and react with ozone as well as NOx simultaneously during exposure.

The preferential reaction of softener or finish formulation with ozone and NOx protects indigo from decomposition.

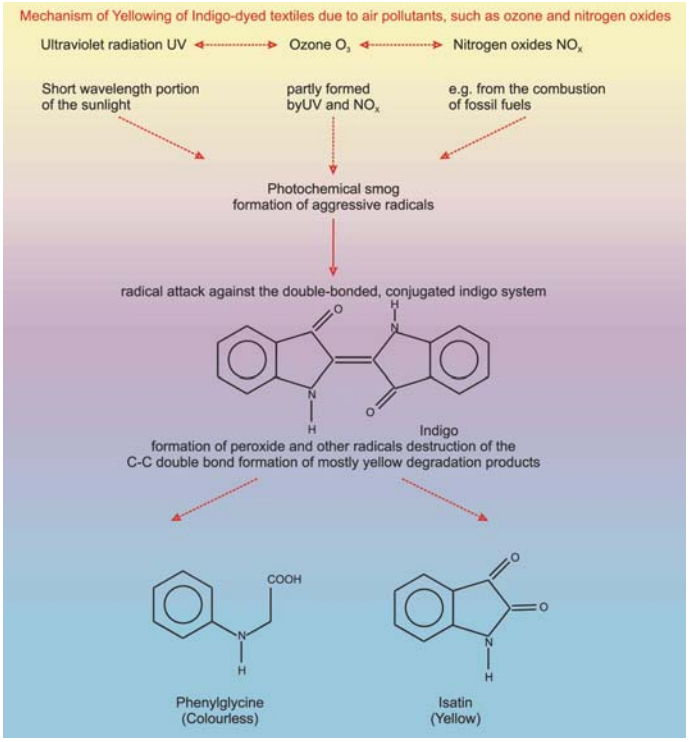


Fig 2 - Mechanism of Yellowing of Denim

Table 1.

Indigo Dips	Gms. Dye / 100 gm. Fabric	Gms. Dye Destroyed	% Dye Destroyed
6	3.00	0.125	4.0
2	0.50	0.125	25.0
½	0.25	0.125	50.0

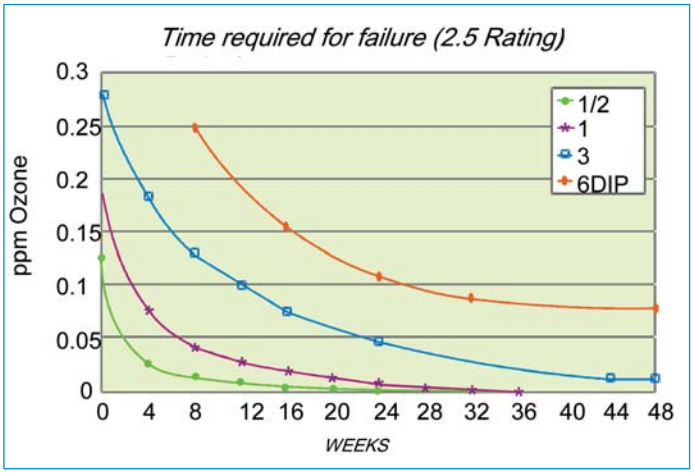


Fig 3 - Ozone fading of indigo dyed denim as related to Ozone concentration.

Table 2

Time to failure (2.5 rating on AATCC grey scale)

Percent Relative Humidity	Ozone Level	
	0.20 ppm	0.90 ppm
90	12 hrs.	9 hrs.
85	16 hrs.	14 hrs.
80	34 hrs.	24 hrs.

A protective softener undergoes degradation, sacrificing itself with ozone, thereby preventing destruction of indigo. Primary oxidation takes place at the free amine group in the softener, whereas secondary oxidation takes place in the main structure, which will vary depending upon the chemistry of softener. However, the softener can slow down degradation of indigo but cannot prevent it completely.

Those finishers who are ignorant about this phenomenon choose softeners based on 'hand' feel alone and thus may compromise on yellowing.

After listening to the story, we at Sarex decided to help Jack and Jill to overcome the yellowing of denims without compromising softness or yellowing. We took desized, medium and fully bleached denim garment and subjected them to a softening treatment with Sarasoft-OZ (Conc) in a drum washer at 40º - 45ºC for 20-30 minutes; pH 4-5 with acetic acid, MLR 1:10. This was followed by hydro-extraction and then tumble drying.

The treated and untreated garments were then tested for Ozone fading by the AATCC 109 Test Method for 2 cycles and the following results were obtained.

Sample	Untreated	Treat
Cycle 1	2	4
Cycle 2	1.5	3.5

Rating 1 – 5
1 - Very Poor
5 - Excellent

As shown above, the garment treated with Sarasoft-OZ (Conc) gives an increase in Ozone Fade Rating by 1 to 1 ½ units, which is the internationally accepted norm by garment merchandisers.

Apart from selection of a suitable softener, Sarasoft-OZ (Conc), the following measures will also prevent destruction of indigo.

1. Prevent back-staining during desizing, biofading or stone washing. Loose indigo on undyed weft is prone to yellowing.

2. Proper rinsing before finishing to eliminate residues of surface-active agents and other chemicals, which will interfere in the protective action.

3. Removal of Mn+2 residues by treatment with Saraquest-W or suitable sequestering agent if potassium permanganate is used for fading.

4. Avoiding softeners/finishing chemicals that accelerate indigo decomposition. Initial screening in laboratory is recommended.

5. Dry the garments as quickly as possible, as wet garments are more prone to yellowing.

6. Use suitable packing material to avoid phenolic yellowing. Avoid packing materials containing BHT (Butylated Hydroxy Toluene).

7. Avoid exposure of garments to light and atmospheric ozone and NOx.

8. Have proper ventilation in store rooms to avoid build-up of NOx. Avoid fuel-based trucks and forklifts. Instead, use electrically operated vehicles to avoid build-up of exhaust fumes in warehouses.

9. Avoid storing and display in highly polluted areas having higher photochemical smog.

Always remember, any protective finishing chemical can improve rating to ozone fading test by only 1-1.5 rating and that for 2 cycles. Sarasoft-OZ (Conc) can help you precisely reach there. We can offer a cure but not a miracle! ❍

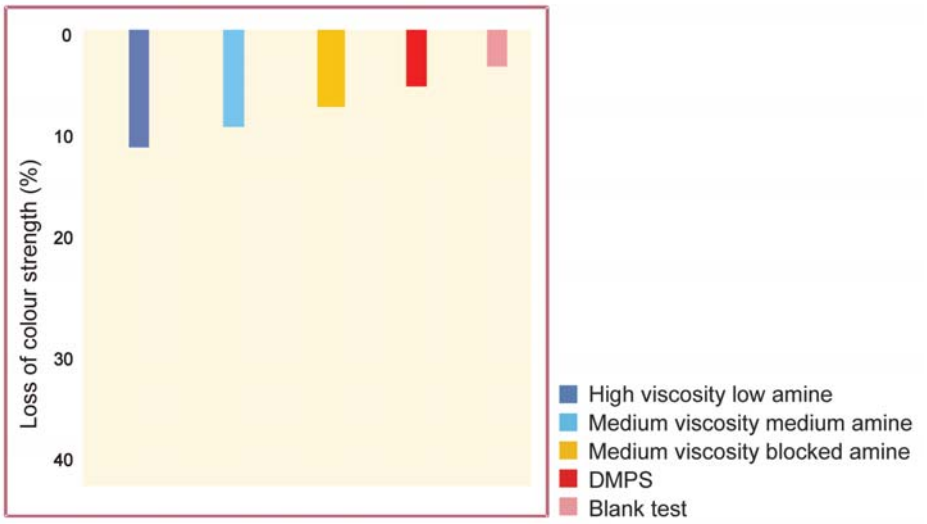


Fig 4- Loss of colour strength after Ozone and NOx exposure of denim treated with various silicone softeners

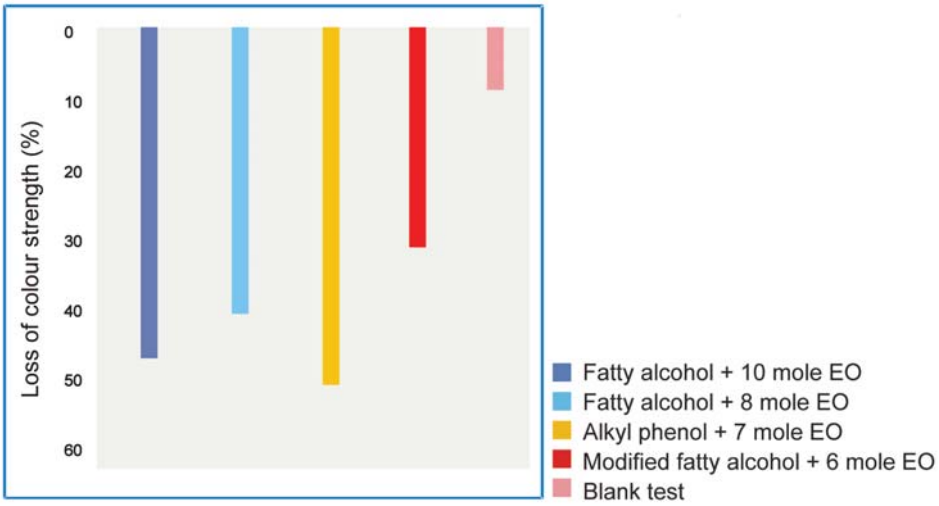


Fig 5- Loss of colour strength after Ozone & NOx exposure of denim fabric treated with various emulsifiers