# SUMMARY AND CONCUSSIONS

# CHAPTER V

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In recent years the whole world concern with the environment issues has grown and specially with the thinning of the ozone layer. Till a few years back, the problem of protecting the brown skin from ultra violet radiation was given much thought as it was considered to be a problem only of the white population. However researches are now showing that a tropical country like India also needs to gear up to protect its population from excessive exposure to UV radiation. UV index in most part of the India is 8+, implying that skin damage and burn can occur quickly after 15min (*refer pg. 25*) Data from the various studies have shown that there is need to provide adequate degree of protection against UV radiation in our country.

India being a tropical country, most times of the year its summer and outdoor workers has no choice about the duration of their exposure to the sun. They are exposed to UV radiation both directly from the sun and indirectly as it is reflected or scattered from surrounding surfaces. The review of literature shows that increased occupational exposure to the sun has been a major contributory factor in the rising incidence of skin problem due to sun rays.

In India it is estimated, that there are 400 million workers in the unorganized sector, who have to mostly work outdoors, construction and agricultural workers constituting the largest segment of this population. Recognizing all these facts, it is important to protect the skin of the peoples who are engaged in these outdoor activities, as they constitute a majority of our population, from excessive exposure of UV radiation.

Along with exposure to sun rays, pollution causes soiling problem in the working clothes of the outdoor workers, as they work in the open and are exposed to higher level of dirt and grime. Accumulation of foreign material often results in discolouration, changes in appearance and loss of fabric luster. The best defense against sun-rays and pollution is the constant use of suitable protective clothing

Looking into the above, there seems to be a need to prepare a fabric for clothing which incorporates UV-protection and soil release properties to reduce the dose of

solar UV radiation and soil acquired by outdoor worker while performing their respective jobs.

Hence the present study was formulated by selecting cotton, polyester and polyester/cotton blend, in plain and twill weave, which being the most suitable material for the clothing and was treated with two UV absorbers and two soil-releases finishes. Further, the optimum combination of UV absorber and soil-release finish would be prepared and applied to the selected fabric to provide protection from UV radiation and soil for outdoor workers clothing.

To achieve the purpose of the study, the specific objectives thus framed were as follows:

## 5.1. Objectives

5.1.1. To study the % UVR transmission of commercial UV absorber finishes and natural dye on the selected fabrics with different add-on and concentrations.

5.1.2. To study the effect of selected soil-release finishes for their soil-release and soil-redeposition properties by varying add-on.

5.1.3. To study the influence of fiber type, weave, add-on and concentration on % UVR transmission, soil-release and soil-redeposition properties.

5.1.4. To study the durability of UV absorbers and soil-release finishes to laundry.

5.1.5. To test the selected UV absorber and soil-release finish in combination for their protective performance.

5.1.6. To analyze the effect of various treatments on wear properties of the fabrics under study.

## 5.2. Material and Methods

Selection of the fabrics was based on fiber content and fabric construction 100% cotton, 100%polyester and 67/33% polyester/cotton blend in plain and twill weave were selected for the study. All the fabrics were scoured before the application of finishes.

Fabric parameters including fiber type, mass, fabric count, yarn number, cloth cover factor, thickness, weight per unit area were determined as per standard method.

***The study was divided in three phases***

**Phase I** consisted of providing protection against Ultraviolet radiation. For UV resist property commercial UV absorber 'A' and 'B' and natural colourant Acacia Catechu were used.

The cotton fabrics were treated with commercial UV absorber 'A' using pad dry cure method, polyester fabrics with commercial UV absorber 'B' and polyester/cotton blended fabrics initially with commercial UV absorber 'A' and then with commercial UV absorber 'B'. Pad-thermofixation process was used for polyester and polyester/cotton blend fabrics. Fabrics were padded with commercial UV absorber at 1 %( $U_A$) and 3 %( $U_B$) add-on. Cotton was cured at 130 $^0$C for 3mins, polyester and polyester/cotton blends were dried at 120 $^0$C for 2min on a stenter frame after which it was cured for 30sec and 1min at 180 $^0$C using the oven for plain and twill weave fabrics respectively.

All the fabrics were coloured using exhaust and H.T.H.P. method for cotton and polyester, polyester/cotton blend respectively with Acacia Catechu at 2%($U_C$) and 4% ($U_D$) shades. Alum was used as a mordant for simultaneous dyeing-mordating method. Dyeing was carried out for 45min, using 1:40 MLR at neutral pH. Alum concentration was 10% on weight of the fabric. After dyeing the samples were soaped, rinsed and air-dried.

The fabricated instrument was used to determine percent UVR transmission in the laboratory. Dyed samples were characterized in terms of K/S value using spectrophotometer to determine if a correlation with percent UVR transmission could be established. Other properties like durability of UV absorbers to laundering and perspiration were also studied using standard test method.

**In phase II** all the six fabrics were given soil-release finishing treatment commercial soil-release finish 'C', 'D' ($S_{AB}$) and Carboxy Methyl cellulose.

The cotton fabrics were finished with commercial 'A', polyester fabrics with commercial 'B' and Polyester/Cotton blended fabrics treated with combination of commercial soil-release 'A' and 'B', which were taken as per the percent of the fiber content in the blended fabrics. Cotton fabrics were treated by pad-dry-bake method and

Pad-dry-cure process was used for polyester and its blend fabrics. Cotton was dried at 120-130 °C and cured at 160°C for 3 mins; Polyester and its blends were kept in oven for 30 sec at 180°C for fixation of chemical with fabric.

The fabrics were padded with Carboxy Methyl Cellulose (C.M.C) at 1% ($S_C$) and 3% ($S_D$) add-on. For 3% add-on the fabric was kept soaked in the prepared solution for 5minutes after which padding was done on padding mangle. The padding was done with the help of a laboratory 2-bowl padding mangle by varying the pressure and number of nips and dips according to the fabrics.

The soiling and soil release characteristics of untreated and soil-release treated fabrics were studied. The fabrics were treated with artificial soiling.

Laundering was done in the Launder-o-meter IA 61-1962 according to test method ISO-3. The samples were given 3 washing cycles, each cycles consisted of 45 minutes of laundering. Laundering was carried out at 40 $^0$C. After laundering the samples were removed, thoroughly rinsed in running water and air dried.

The whiteness characteristics were assessed by Hunter Whiteness Index under illuminate D65, 10 degree observer using a Spectrascan 5100 spectrophotometer. The percent soil uptake, percent soil-release and percent soil redeposition were computed by the formulas using the whiteness index value.

In **Phase III,** the optimum combinations of UV absorber and soil-release finishes on selected fabrics was studied. When comparisons were made between the finishes for the UV absorbers Acacia catechu gave the best results. In case of soil release finish CMC showed better soil-release and soil-redeposition characteristics. After analysis of results four optimum combination were purposively selected. The combinations were with lower add-ons as with the higher add-on not much improvement in properties was seen as well as when two finishing treatments were to be given together the higher add-on's would increase the weight of the fabrics under study. However the natural colourant Acacia Catechu higher percent shade of 4% was selected.

The four combinations taken were

$O_A$ : UV absorber 1% add-on + carboxymethyl cellulose 1% add-on

$O_B$ : UV absorber 1% add-on + commercial soil-release finishes

$O_C$ : Acacia catechu dyed 4% shade+ carboxymethyl cellulose 1% add-on

$O_D$ : Acacia catechu dyed 4% shade + commercial soil-release finishes.

Above four combinations were applied sequentially one after the other to the polyester/cotton plain and twill fabrics and treated fabrics were tested for percent UVR transmission, soil behaviour and wear properties and theoretical costing was also done.

S.E.M images and EDS analysis were also carried out on the soiled and samples treated with the combinations.

## 5.3. Result and Discussion

### *5.3.1. Preliminary data of the fabrics*

- Fabric parameters including fiber type, mass, fabric count, structure and cover factor were determined. Confirmation of the fiber type was done through microscopic analysis and chemical solubility test.
- The count i.e. warp x weft per inch was observed almost same in all fabrics.
- The cloth cover and thickness ranged from 21.52 to 28.84 and 0.17 mm to 0.48 mm respectively.
- P/C twill was the heaviest among the six (274 $g/m^2$) and the lightest was polyester plain weave with 94 $g/m^2$.
- The highest yarn count in Tex was observed in P/C twill followed by cotton twill and the lowest was observed in polyester plain weave.

### *5.3.2. Comparison and influence of UV absorbers on performance property of fabrics under study.*

a) Effect of fabric construction

The percent transmission values of the untreated fabrics can be explained in terms of fiber composition and fabric construction. In terms of fiber composition it is known that cellulose is known to be very transparent to UV radiation, hence untreated cotton transmits large amounts of UV radiation even when closely woven, providing little protection. Synthetic materials especially polyester with a large number of aromatic rings in it structure provide very good protection when closely woven.

It was seen that polyester consistently provided higher level of protection and cotton samples showed less protection than other two fabrics. Polyester/cotton blended fabric provided significantly better protection than cotton alone.

In comparison of fabrics of similar fiber types but different weave structure, twill weave fabrics offer higher protection to UV rays, as compared to plain weave fabrics.

Fabric construction parameters of weight and thickness showed an inverse correlation with percent UVR transmission.

b) Effect of UV absorbers on the fabrics under study

i) Effect of commercial UV absorber

To explore the effectiveness of UV absorber in providing protection against ultraviolet radiation, the commercial UV absorbers 'A' 'B' at two different add-on's, 1% ($\mathbf{U_A}$) and 3% ($\mathbf{U_B}$) were used.

Finished sample of cotton, polyester and P/C blend showed lesser transmission in both weaves than untreated fabrics. As the percent add-on increase only a minimal decrease in the percent UVR transmission value of the fabrics was noticed. Thus fabric having 1% add-on was almost similar to fabrics with 3% add-on in providing protection against ultraviolet radiation. Result also shows that the application of commercial UV absorber on cotton fabrics improved the protection from UVB region as compared to untreated fabric which earlier showed more percent UVR transmission.

ii) Effect of natural colorant Acacia Catechu (*katha*)

To observe the effect of colourant Acacia Catechu were dyed with 2% and 4% shades.

The results showed that percent transmission for colorants applied at higher concentrations gave lesser percent transmission values thus providing more protection against ultraviolet radiation.

The K/S values of the dyed fabrics, which are a measure of colour depth, seemed to support the claim that higher colour depths decreased percent UVR transmission values thus increase the protection against ultraviolet radiation.

c) Effect of launderings on percent UVR transmission of untreated and treated fabrics

The finished fabrics were tested for their durability to washing. Result showed that the mean percent UVR transmission of untreated cotton fabrics decrease after 3 cycles of laundry, thus improve the protection. This was attributed to fabric shrinkage, which in turn, leads to reduce porosity of the fabrics.

But in case of polyester and polyester/cotton blend untreated fabrics it showed a slightly decrease of percent UVR transmission value were observed. The lack of improvement in sun blocking properties following launderings is attributed to the excellent dimensional stability of polyester fabric

Laundry did not alter the percent UVR transmission of Commercial UV absorbers treated and Acacia Catechu dyed, thus the finishes were durable.

d) Effect of perspiration on percent UVR transmission

The effect of wetness due to perspiration on percent UV transmission was also studied, UV transmission when the fabric significantly changed with a marked enhancement of percent transmission observed for fabrics made from cotton and cotton blends. This could be explained by the presence of water in the interstices of a fabric, which reduces optical scattering effects and hence, increases UV transmission of the textiles. It was also seen that alkaline perspiration showed higher percent UVR transmission as compared to acidic perspiration.

### *5.3.3. Comparison and effect of soil-release finishes on the soiling behaviour of the fabrics under study*

After the application of finishes, both the untreated and treated fabrics were subjected to laboratory soil test using 100% artificial solvent soil. They were laundered for 3cycles along with white untreated samples and the whiteness index values of the untreated and treated fabrics at various levels i.e. without soiling, after soiling with artificial soil and after 3 wash cycles were taken and the results were compared with the calculated percent soil-uptake, percent soil-release and percent soil-redeposition.

a) Percent soil uptake

It was observed that the soiling of untreated fabrics increase in the order Cotton<P/C<PET.

The value of percent soiling shows that the untreated fabrics picked up slightly more soil as compared to all the treated fabrics. As the complexity of fabric structure increase the soiling also increases. Twill weave fabrics showed more percent soiling as compared to the plain weave fabrics except in cotton where percent soiling of plain weave was more as compared to twill weave cotton fabric.

There are differences in soil retention by various chemical types of fiber that apparently cannot be related to differences in physical size and shape of the filaments. It was observed that the fabric treated by C.M.C. picked up less soil compared fabric treated with commercial soil-release, except in polyester/cotton blend plain weave fabric.

b) Percent soil-release

After application of Commercial soil- release finish, the percent soil-release of the polyester fabric increased noticeably. Soil-release finishes helped to reduce static charge on the fabric and assists the penetration of washing liquors when the soiled fabric was washed. Therefore, accumulated dirt on the fabric was more easily removed during the washing operation.

The fabrics finished with CMC released more soil in cotton treated fabrics as compared with other two fabrics. CMC at 3% add-on released more soil in all the six fabrics as compared 1% add-on.

When we compared the fabrics treated with chemical finishes and CMC, the results showed that cotton fabrics when treated with CMC showed the double amount of soil-release as compared with chemical finishes cotton fabrics, but soil removal was reduced in CMC polyester treated fabrics as compared with Commercial soil release finished fabrics. In P/C blended fabrics soil-removal is almost same with both the treated agents.

c) Percent soil-redeposition during laundering

The results showed that the soil-redeposition on cotton was less as compared to polyester, which showed the maximum soil redeposition tendency as compared to other fabrics; hence it has been found that the soil-redeposition is greatly influenced by fabric types. When the unsoiled fabric laundered together with the soiled fabrics in the same bath, the affinity was high between the oleophilic fabrics, such as polyester or its blends and the oleophilic soils, which was carbon black. Being oleophilic, it picked up grease or fatty based dirt from wash liquor resulting in soil re-deposition, which again leads to fabric graying.

The three fabrics were treated with commercial soil release and CMC with two different add-on. It was observed that the CMC treatment reduced the amount of percent soil-redeposition on the fabrics as compared to commercial soil release finished fabric and in case of commercial soil release treated polyester soil-reposition was more as compared to fabric treated with CMC.

### *5.3.4 Results of optimum combination of UV absorber and soil-release finishes on selected fabrics*

i) Percent UVR transmission

a) Comparison and influence of finishes in combination on percent UVR transmission.

After the application of various finishes in combination, polyester/cotton blend plain weave fabrics showed lesser transmission than the untreated fabric, thus providing better protection.

It was also seen that when the fabrics was treated with the four combination finishes they gave better protection than the fabrics treated with the UV absorber individually.

Result also shows that the applications of UV absorbers with CMC ($O_A$ and $O_C$) on polyester/cotton fabrics have more protection against ultraviolet radiation as compared to combination of UV absorbers with commercial soil-release finish ($O_B$ and $O_D$).

b) Effect of launderings on percent UVR transmission of untreated and treated fabrics with combination of finishes on polyester/cotton blend plain weave fabric

The result showed that when the treated polyester/cotton plain weave fabric was laundered there was no noticeable change seen in the percent UVR transmission. Similar results were seen when the combination finishes were compared to the UV absorber finishes when studied individually. However the combination with Acacia Catechu ($O_C$ and $O_D$) gave better results as compared to combination $O_A$ and $O_B$.

c) Effect of perspiration on the percent UVR transmission of untreated and treated polyester/cotton blend plain weave fabric with finishes in combination

Result of the percent UVR transmission of all the fabrics under study exhibited significantly lower protection when wet (with perspiration) as compared to fabric in dry state. The commercial UV absorber treated fabrics with commercial soil-release finishes ($O_B$) have less percent transmission as compared to commercial UV absorber + CMC ($O_D$) treated fabrics. Even in dyed samples same pattern was observed. It was also observed that even though percent UVR transmission increased in various combinations, treated fabrics still provided moderate protection as compared to untreated fabric which showed poor protection in wet state.

ii) Soiling behaviour

a) Percent soil-uptake

When the percent soiling of the four finishes in combination were compared it was seen that the combination with CMC ($O_A$ + $O_C$) took more soil as compared to the combination which has commercial soil-release finish ($O_B$ + $O_D$). Also the commercial UV absorber combination i.e. $O_A$ and $O_B$ picked up more soil as compared to natural colorant in combination i.e. $O_C$ and $O_D$.

b) Percent soil-release property

All the four finish combination gave better percent soil release as compared to untreated fabrics. It was also observed that after the application of $O_A$ i.e. UV absorbers + CMC percent soil-release noticeably increased in both the weaves as compared to the application of $O_B$ i.e. UV absorber + commercial soil-release

finished. The soil-release performance of the Acacia catechu with CMC ($O_C$) showed maximum value as compared to the other combination for both the fabric.

c) Percent soil-redepostion characteristics

The fabric treated with the same chemical composition was stitched and laundered alone with soiled fabric of same chemical composition, to evaluate the soil redepostion.

All the combination gave good readings for percent soil redposition and it was seen from the Table 4.27 that after treatments the percent soil redeposition was considerably reduced when compared with the untreated fabric samples.

The least soil redepostion occurred with the combination of acacia catechu and CMC ($O_C$), 1.18 and 1.44 in plain and twill weave respectively.

d) SEM studies of untreated and treated polyester/cotton twill weave soiled fabrics before and after laundry

The Scanning Microscopic studies showed that in the case of untreated polyester/cotton blend twill weave fabric, much larger amount of soil particles were ambient forming clusters and hills on the fiber surface, where as in the case of combination of U.V absorber and CMC treated fabric, such detrimental effect was not visible, soil was distributed evenly on the fiber surface and fibrous structure.

Untreated fabric after laundering shows that surface area was much uniform but the fibrous structure still contains some soil particles, it was not completely removed. In case of treated fabric with combination $O_A$ when washed greater was the release of soil from the fabric and increase the brightness.

iii) Effects of finishes in combination on the wear properties of the fabrics under study.

Finish in combination given to fabric did not alter noticeably the wear properties like thickness, weight per unit area, air permeability, stiffness, crease recovery and tensile strength. Therefore it could be said that the comfort properties were not altered after the treatments were imparted.

iv) Theoretical Costing of the fabrics

The theoretical cost per liter of the finishes in combination was calculated it is seen that the prices was almost similar for all the four combination. The cost of the OC combination is least among four combinations of finishes even though this combination gave better protection against UV rays and soiling as compared to other combinations

### *5.3.5. Determination of fiber surface characteristics of treated fabrics using scanning electron microscope.*

The SEM images of the treated fabrics showed the modifications in the fibrous structure by application of combination of finishes on polyester/cotton fabrics and commercial Soil-release finish and CMC finishes, in case of cotton and polyester fabric. Fabrics treated with CMC in combination of finishes showed the accumulation of layer of starch along with the globules on the surface of the treated fabrics. Combination of commercial UV absorber and commercial soil-release finishes showed shiny needle like attachment on the fiber surface. Cotton twill with CMC showed a thick layer of CMC with no cracks on the layer of the fabric.

### *5.3.6. E.D.S. analysis of the finished samples with UV absorbers and soil-release*

The E.D.S analysis was undertaken in the present study shows that all the element present in finishing recipes were present in permissible limits.

## 5.4. Conclusion:

The influences of fabric parameters and UV absorbers and soil-release finishing, on UVR transmission, soil-release and soil-redeposition were examined for cotton, polyester and P/C blend (67/33). It was concluded from the study that

1. Fiber content was an important factor followed by weave type, weight per unit area, fabric count, cloth cover and thickness of the fabric in predicting the percent UVR transmission.
2. Tight fabric construction offers higher protection to UV rays, as compared to lighter ones. It was seen that twill weave fabrics compared to plain weave showed lower UVR transmission.

3. Both, Commercial UV absorber finish and Acacia catechu improved the UV protection substantially for all the six fabrics under study.
4. Lower add-on gave protection as effective as higher add-on
5. Depth of dyeing increases protection values. (Increase in depth of colour decreased the percent transmission of UVR and hence provided better protection).
6. All fabrics exhibited increase in percent UVR transmission when wet with artificial perspiration, except for the polyester fabrics.
7. After laundering all samples showed reduced percent transmission. This could be attributed to the swelling and shrinkage of fabrics.
8. All the four finishing treatments studied were durable to laundry and showed good wash fastness
9. The soiling and soil retention of fabrics of the three different fiber types were in the order: Cotton < P/C < polyester.
10. All the three treated plain weave fabrics released more soil after laundering as compared to the twill weave fabric.
11. The application of commercial soil-release finish ($S_{AB}$ ), noticeably imp the soil-release response of the fabrics. The result shows that maximum redeposition of soil on untreated fabrics is dependent on the soil-release capacity of the respective fiber and the soil pick-up tendency of the same.
12. The fabrics finished with commercial soil-release finish ($S_{AB}$ )showed more percent of soil-release and less percent soil-reposition in polyester fiber; while CMC treated fabric shows more percent of soil-release in cotton fabrics.
13. Combination of Acacia catechu with CMC ($O_C$) gave maximum protection against UV rays as well it remove maximum soil after laundering with minimum theoretical cost as compare to other finishes in combination.
14. Treatments given to fabric did not alter noticeably the wear properties like air permeability, stiffness, crease recovery and tensile strength. This indicated that after finishing the comfort properties of the fabrics were maintained.

It can be theorized that clothing constructed from polyester/cotton blend, treated with Acacia catechu and soiling release finishes could provide protection against UV radiation and soiling. For white colour clothing commercial UV absorber with commercial soil release finish is suitable.

Hence these treated fabrics with finishes in combination would be useful for clothing of outdoor workers.

### 5.5. Recommendation

Outdoor workers are exposed to heat, dust and perspiration during long hours of work. Looking into their need an antimicrobial finish along with ultraviolet radiation protection, could be studied for the clothing of outdoor workers.

Other natural colourant could be tried for their anti UV properties on different blends like Polyester/Wool, Polyester/viscose etc. These blends would be useful for uniforms and clothing for the workforce

Theoretical costing has been done in this study, but if this fabric needs to be commercialized practical costing could be carried out by preparing a prototype.