REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

One of the essential prerequisite of any research study is to get acquainted with latest literature on the subject of research. So an attempt was made to review the relevant theoretical literature and researches on UV and soil protection of textiles. The investigator visited and collected the literature from various libraries like SASMIRA (Synthetic and Art Silk Mills Research Association), Mumbai; ATIRA (Ahmedabad Textile Industry's Research Association) and Smt. Hansa Mehta library, T.K Gajjar library and the department library of The M.S.University of Baroda. Another important source of information was the internet.

The review of literature collected was categorized and discussed under the following subsections:

2.1 Theoretical Review

2.1.1. Related terms for protective clothing
2.1.2. UV Radiation and its effects
2.1.3. Textile parameter and finishes for UV protection
2.1.4. Soil and soil mechanism
2.1.5. Soil-releasing method and finishing
2.1.6. Test methods
    2.1.6.a. For quantitative assessments of UV protection of textiles.
    2.1.6.b. Methods of evaluation of soil-release property of fabric

2.2 Research Review

2.2.1 Researches on U.V. Finishes.
2.2.2 Researches on Soil-release Finishes.

2.1.1. Related terms for protective clothing

Protective Clothing:

a. A garment used for the purpose of isolating parts of the body from contact with a potential hazard(157)

b. Protective clothing is clothing designed to protect either the wearer's body or other items of clothing from hazards such as heat, chemicals and infection. Also, special clothes may protect the working environment from pollution and/or infection from the worker, for example in a microchip factory. The protection may also be important in both ways, as with the use of disposable gloves by surgeons and dentists. (146)

c. **Personal protective equipment** (PPE) refers to protective clothing, helmets, goggles, or other garment designed to protect the wearer's body or clothing from injury by blunt impacts, electrical hazards, heat, chemicals, and infection, for job-related occupational safety and health purposes, and in sports, martial arts, combat, etc. body armor is combat-specialized protective gear. In British legislation the term PPE does not cover items such as armour. The terms "protective gear" and "protective clothing" are in many cases interchangeable; "protective clothing" is applied to traditional categories of clothing, and "gear" is a more general term and preferably means uniquely protective categories, such as pads, guards, shields, masks, etc.

PPE can also be used to protect the working environment from pesticide application, pollution or infection from the worker (for example in a microchip factory). The protection may be important in both ways, as with the use of disposable gloves by surgeons and dentists. (142)

Outdoor workers: are those who in the course of their normal duties spend a significant amount of their time in the open (outside of enclosures). It includes staff and students conducting practical work in the field.

2.1.2 . UV Radiation and its effects

2.1.2.a. UV Radiations
2.1.2.b. UV Index
2.1.2.c. Geographical factors effecting UV radiation
2.1.2.d. Ozone layer and its effect
2.1.2.e. Human skin and classification of skin type by sensitivity to UV radiation
2.1.2.f. Health effect of exposure to UV radiation
2.1.2.g. The CPF, UPF, SPF And EPF concept
2.1.2.h. Test Standards for UV protection

2.1.2.a. UV Radiations

The sun provides us with life itself, and with many of its pleasure. However too much sun is not a good thing. Acute or chronic overexposure to sunlight can lead to a variety of deleterious effects. Consequently the damage in earth protective ozone layer has increased. Sun radiation before has a wide spectrum of rays of wavelength for 0.7 to 3000 nm. The fraction of it is up to 175 nm is absorbed into oxygen present above stratosphere (100 Km) where as radiation up to 280 nm is filtered by Ozone layer of stratosphere (15 to 30 Km). It is know as UV- C. Infrared radiation of high wavelengths is also filtered by absorption in water vapor, carbon dioxide etc. (25)

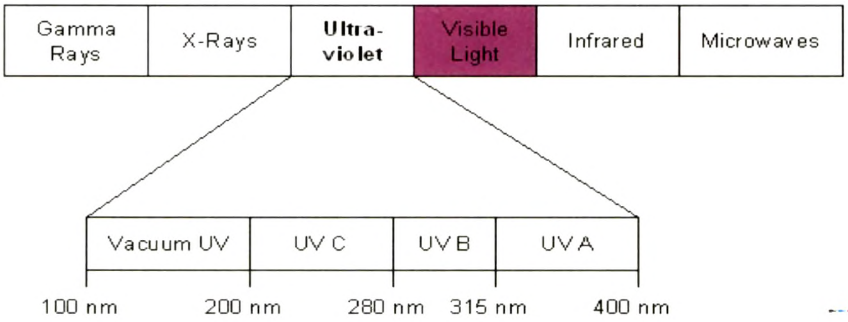


Figure 2.1 - Electromagnetic spectrum

Source: http://www.quawater.com/images/uv_tech_graph_1.png

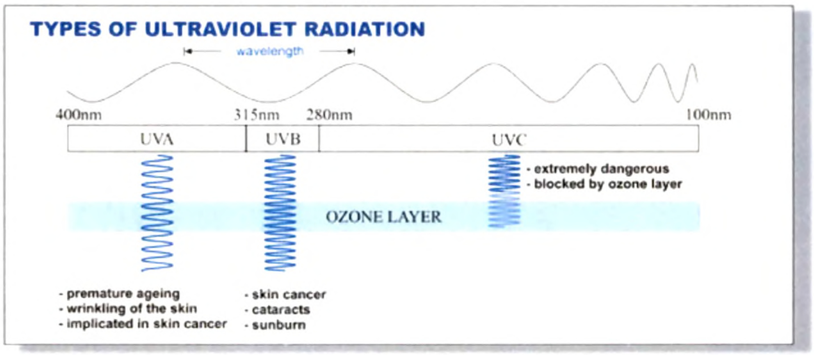


Figure 2.2: Types of ultraviolet radiation

Source: http://www.arpansa.gov.au/RadiationProtection/Basics/uvr.cfm

The spectrum of sun radiations reaching earth's surface constitutes of wavelengths ranging from 100 nm to 3000 nm. The harmful radiations of UV-B and A consists 12% of the total sunrays reaching earth. The presence of ultraviolet radiation on earth and the high exposure to it is the cause of skin cancer and loss in depth of various dyes, colorants, pigments by initiating degradation.

Protection from sun exposure is important all year round not just during the summer or at the beach. Any time the sun's UV rays are able to reach the earth, you need to protect yourself from excessive sun exposure. UV rays can cause skin damage during any season or temperature. Relatively speaking the hours between 10 am to 4 p.m. are the most hazardous for UV exposure. UV rays reach earth on cloudy and hazy days as well as a bright an sunny days. UV Radiation will also reflect off any surface like water, cement, sand and snow.

Malik and Arora (2003) have stated that when ultraviolet radiations fall on matter it is either, reflected or transmitted and scattered, particularly at short wavelength by partials collision. The radiation eventually leaves the medium or is absorbed by an appropriately structured molecule, the chromospheres. These radiations are absorbed and the molecular electron excitation to higher energy orbital takes place. This is the radiation re-emitted to go to the resting stage or chemical change takes place, this chemical change leads to various problems. (80)

2.1.2.b. UV index

The UV index is a scale for measuring the amount of UV radiation reaching the ground and posing danger to humans. On a scale of 0-10, 0 is minimal exposure, 10 is very high exposure. (165)

UV Index was developed by the National Weather Service and the Environmental Protection Agency. It provides a forecast of the expected risk of overexposure to UV rays and indicates the degree of caution you should take when working playing or excursing outdoors.

To determine the UV index, the dose rate, or the amount of UV radiation a person will be exposed to at noon under a clear sky is calculated. The dose rate is then adjusted for the effects of elevation and cloud cover. At a high elevation, the dose rate will increase due to less atmosphere to absorb and scatter UV rays. More clouds will reduce the UV dose rate because clouds screen out some UV rays.

Table 2.1: Different categories of UV-index value [183]

UV-Index level	Exposure category	Recommended sun protection precautions	UV-Index colour code
0 to 2	Low	Most people can stay outside one hour without burning. You can safely stay outdoors with minimal protection. Wear sunglasses on bright days. If outside for more than one hour, cover up and use sunscreen. Reflections off snow can nearly double UV strength. Wear sunglasses and apply sunscreen	Green
3 to 5	Moderate	An average person can withstand a half hour without burning. Take precautions – cover up, wear a hat, sunglasses and look for shade near midday when sun is strongest.	Yellow
6 to 7	High	Protection required - UV radiation damages the skin and can cause sunburn. Reduce time in the sun between 11 a.m. and 4 p.m. and take full precautions - seek shade, cover up, wear a hat, sunglasses and sunscreen	Orange
8 to 10	Very High	Extra precautions required - unprotected skin will be damaged and can burn quickly ; Stay indoors as much as possible otherwise uses all precautions above.	Red
11+	Extreme	Same as for the previous category.	Purple

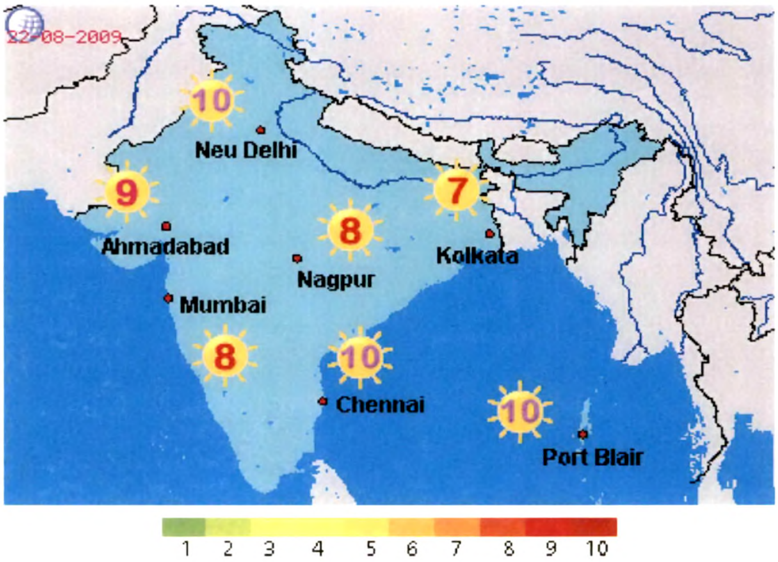


Figure 2.3: India UV-index on 22 Aug 2009

Source:
www.weatheronline.co.uk/weather/maps/forecastmaps?LANG=en&UP=0&R=0&MORE=0&DAY=6&MAPS=uvin&CONT=asie&LAND=II&TOFD=tag

2.12.c. Geographical factors effecting UV radiation

The UVR level and the amount you receive can vary greatly and depends on a number of factors which is reported by the **Singh(2005)** and its also given in the website (112) (150)

- **Sun elevation:** The higher the sun in the sky, the higher the UV radiation level. Thus UV radiation levels vary with time of day and time of year. Outside the tropics, the highest levels occur when the sun is at its maximum elevation, at around midday (solar noon) during the summer months.
- **Time of the day**: UVR levels are highest when the sun reaches peak position in the sky, between 10am and 2pm (11am and 3pm daylight savings time).
- **Time of year:** UV intensity tends to be highest during summer months.
- **Latitude:** The closer to equatorial regions, the higher the UV radiation levels.
- **Cloud cover:** UV radiation levels are highest under cloudless skies but even with cloud cover, UV radiation levels can be high.

  Scattering can have the same effect as the reflectance by different surfaces and thus increase total UV radiation levels.
- **Altitude:** the atmosphere is thinner at higher altitudes and filters out less UVR. With every 1000 meters increase in altitude, UV radiation levels increase by 10% to 12%.

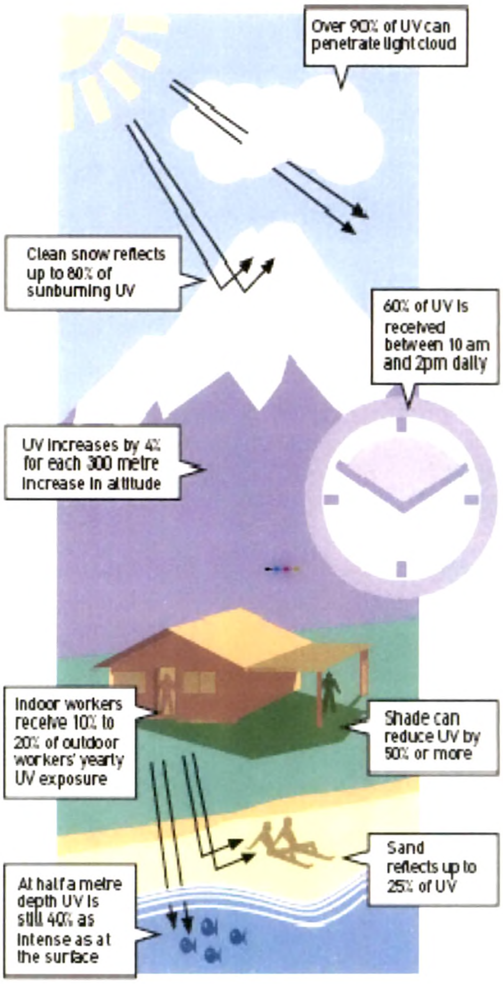


Figure 2.4: Various factors that affect the ultraviolet radiation

Source: www.icnirp.de/documents/SoalrUVI.pdf

- **Sun Height:** When the sun remains high in the sky, the UV radiation found shorter distance to travel through so less UVR is absorbed and more passes to earth.
- **Geographical Position:** If a part of earth is close to the equator, the UV radiation will be more in comparison of other part.
- **Ozone:** Ozone absorbs some of the UV radiation that would otherwise reach the earth's surface. Ozone levels vary over the year and even across the day.
- **Ground reflection:** UV radiation is reflected or scattered to varying extents by different surfaces, some of which can reflect large amounts of UVR onto skin and eyes even when you are in the shade. Most natural surfaces such as grass, soil and water reflect less than 10% of incident UV. However, fresh snow strongly reflects (80%) UV. During spring in higher attitudes, under clear skies, reflection from snow could increase UV exposure levels to those encountered during summer. Sand also reflects (10-25%) and can significantly increase UV exposure at the beach.

2.1.2.d. Ozone layer and its effect (57)

The depletion of ozone layer has caused alarming concern over past decade due to increasing number of skin cancer cases particularly in U.S., Canada, Europe, Australia and New Zealand.

As given by **Holman (2003)** the ozone layer becomes thinner, the protective filter provided by the atmosphere is progressively reduced. Consequently, human beings and the environment are exposed to higher UV radiation levels, and especially higher UVB levels that have the greatest impact on human health, animals, marine organisms and plant life. WHO predict that a 10% decrease in stratospheric ozone could cause an additional 300,000 non-melanoma and 4500 melanoma skin cancers and between 1.6 and 1.75 million more cases of cataracts worldwide every year.

Ozone is the only gas that absorbs UVR, however ozone is present only at a level of 2 ppm and maximum 30 km above the surface of the earth. A well known problem of ozone depletion which arises from the release of Freon's is therefore a matter of environmental concern and holes in the ozone layer can be very large in the Polar Regions

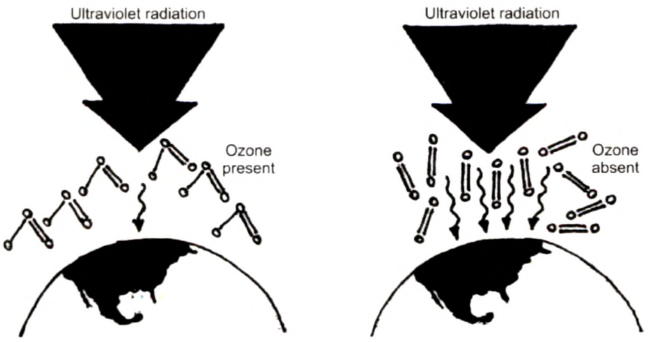


Figure 2.5: Depletion of Ozone Layer

Source: Holme Ian, "UV absorbers for protection and performance", International Dyer,april2003, vol 188, No.4, pp.9-13

In a recent risk assessment document EPA (The US Environmental Protection Agency) predicted that without controls on CFC (chlorofluorocarbon) productions, there would be a 40% depletion of Ozone by 2075. A decrease of 1% in ozone would lead to increase in the solar UVR at the earth's surface and may eventually lead to a 2.3%increase in skin cancer .EPA further concluded that for every 1 percent decrease in ozone, there is a compounded 2 percent increase in the more damaging shorter UVB wavelengths reaching the earth's surface.

2.1.2.e. Human Skin and Classification of skin type by sensitivity to UV radiation

Human skin (44)

Detail of the human skin is given by the Goyal (2005) in his paper. The human skin the largest organ. Its most important feature is its ability to protect our bodies from the many different dangers around us.

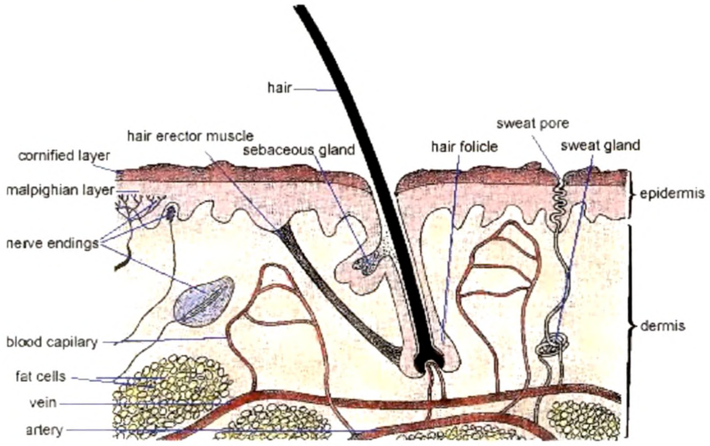


Figure 2.6: The diagram below shows a cross section of a general piece of skin

Source: http://www.sun-togs.co.uk/page.health_issues

The three main layers of human skin from outside to inside are:-Epidermis – (0.1-1.5mm thick), Corium – (4-8mm thick), Sub – Cutis. Each layer has specific components of epithelial, mesothelial and neural origin. The UV radiation is completely absorbed by the first two layers i.e., Epidermis and Corium by nucleic acid. (DNA, RNA), proteins, and chromophores dispersed in the cytosol and membranes.

Skin Types

In terms of sensitivity to light and tendency to pigmentation, there are 6 basic types of skin that demand different levels of UV protection was shown by **Dayal, Aggarwal (1998)** (22) **and Saravanan (2007)** (106) in Table 2.2

Table 2.2: Effect of UV rays on different types of skin

Skin type	**Skin Appearance (unexposed)**	**Critical dose to skin reddening (290-300 nm)**	**Self protection time (min)**	**Risk level**
1	White	15-30	5-10	Burns easily, has the highest risk of premature skin ageing and greatest risk of developing skin cancer
2	White	25-30	8-12	Burn and only rarely tan
3	Brownish	30-50	10-15	Tan and occasionally burn
4	Brown	45-60	15-20	Tan and occasionally burn
5	Brown	60-100	20-35	Sufficient level of melanin and rarely burns, easily tans.
6	Dark brown black	100-200	35-70	Sufficient levels of melanin pigment provide protection. Very rarely burns, easily tan.

The minimal erithemal dose (MED) is apparently consistent with a fair complexion, but shows variation among people of types 3 and 4.

2.1.2.f. Health effect of exposure to UV radiation (44)

Some UV exposure is essential for good health. It stimulates vitamin D production in the body. In medical practice, UV lamps are used for treating psoriasis (a condition causing itchy, scaly red patches on the skin) and for treating jaundice in new born babies.

The ultraviolet component of the terrestrial solar spectrum comprises approximately 5% of the radiant energy; however this component is largely responsible for the deleterious effects of solar exposure have been stated by Goyal (2005). Excessive exposure can damage the skin and the eyes and immune system. The severity of the effect depends on the wavelength (Figure 2.7), intensity, and duration of exposure.

Disorders of the skin (185)

Since the 1850s it has been known that excessive exposure to sunlight can cause skin damage. Observation of boatmen, fishermen, lightermen, agricultural labourers and farmers revealed that skin cancer developed on areas most frequently exposed (e.g. hands, neck and face). The exact process by which exposure to sunlight causes skin cancer was not understood until relatively recently.

Canadian centre for occupational health and safety agency reported the effect of different wavelength of ultraviolet radiation on human skin.

The shortwave UV radiation (UV-C) poses the maximum risk. The sun emits UV-C but it is absorbed in the ozone layer of the atmosphere before reaching the earth. Therefore, UV-C from the sun does not affect people. Some man-made UV sources also emit UV-C. However, the regulations concerning such sources restrict the UV-C intensity to a minimal level and may have requirements to install special guards or shields and interlocks to prevent exposure to the UV.

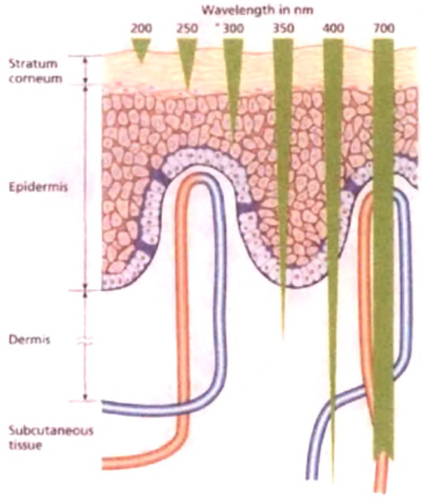


Figure 2.7: The depth of penetration of the skin by UV radiation of different wavelengths

Source: http://www.pgbeautyscience.com/index.php?id=654

The medium wave UV (UV-B) (290-320nm) is a relatively small fraction of total UV radiation (~10% of total UV) it causes skin burns, erythema (reddening of the skin) and darkening of the skin (suntanning). Prolonged exposures increase the risk of skin cancer and photoageing.

UVA wavelengths (320–400 nm) penetrate deep inside the skin causes transformation of melanin precursor, acceleration of skin ageing, production of photodermatosis I.e.; acne, wrinkling, skin allergies and rashes. This radiation has carcinogenic potential and in this segment, there is excitation of pigmentation i.e. tanning without reddening.

However, it takes roughly 1,000 times the doses of UVA to produce sunburn and tanning effects equivalent to those of UVB.

2.1.2.g. The CPF, UPF, SPF And EPF concept (44) (112)

Goyal et al (2005) explained the following concept:

- Clothing Protection Factor - CPF and UPF

  CPF (Clothing Protection Factor) is more commonly displayed as UPF (Ultraviolet Protection Factor) on clothing. Clothing does not always provide as much sun protection as people believe. Protection varies with weave, fabric colour, wetness or dryness, the number of washes a garment has had, elasticity and composition.

  UPF (Ultraviolet Protection Factor): This value is measure of the UVR protection provided by a fabric. The UPF is calculated as follows: assuming that the unpigmented skin of a person reddens after 12 minutes exposure to the non day sun. When wearing a garment with UPF 30, the same person will be able to append 30*12=360 min or 6 hours in the same noonday sun before suffering the same amount of sunburn (or receiving the same amount of UVR).UPF ratings are determined by testing fabric in a laboratory in accordance with Australian Standard AS/NZS4399: 1996.

- SPF (Sun protection Factor): Applied to sunscreen sand it's a measure of the amount of protection against UVR provided by the sunscreen. Sunscreen SPF ratings are determined by testing sunscreens on the skin of human volunteers in accordance with Australian Standards AS2604:1998. It ranges from 2-50^+. SPF 15 will protect you about 75 minutes (15 times longer than you would be without sunscreen). However, be warned, sweating, swimming, toweling etc. can all weaken the coating and leave you open to skin damage. To enjoy adequate protection you must make sure that sun cream is applied evenly to all exposed parts of the body.

- EPF (Eye protection Factor) - A rating scale (1 to 10) applied to sunglasses. EPF 10^+ will provide the 100% blockage against UVR. Sunglasses can block light but let through damaging ultraviolet rays, or they can block both safely. It is NOT the case that the darker the lens the greater protection it will give you. You are reliant on buying sunglasses which state clearly that they block a very high percentage of UVA and UVB. Ideally, the factor should be 100% or at least in the high 90s.

2.1.2.h. Test Standards for UV protection

Kathryn (2003) (50) in his manuscript set forth an overall plan for using the three U.S. UV-protection standards i.e. two by ASTM international ASTM D6603, ASTM D6544 and one by the AATCC Test Method 183, to make a UV-protection claim.

The term "Unprepared" sample which appears only in ASTM D6603 is used to designate specimens in the condition they would be before first use or wearing. There are two Avenues.

Avenue 1 will be taken when the unprepared label UPF value is greater than 15 and Avenue 2 may be considered when the unprepared label UPF value is less than 15.

Avenue 1: It is the commonly used route to making a UV protection claim. The process is to take from the unit of product for which a claim will be made laboratory sample called 'prepared for testing laboratory samples' in ASTM D6544 and D6603. Such laboratory samples are exposed to laundering simulated solar radiation and/or chlorinated pool water, exposures that may result in reduced capability for the fabric to block UV radiation incident on its surface Avenue 1 claim the least amount of protection to be provided. Also the claim reached asserts that both new garment and the garment at the end of two years of 'regular use' perform with a UPF of at least the values stated on the label.

Avenue 2: May be used when the product for which a UV protection claim will be made is labeled 'launder once before using'. The reason for allowing this second avenue is recantation that structural alteration that takes place during tendering may temporarily reduce the UPF value of the fabric, but is restored when the fabric is first washed. This type of claim is more common for knit fabrics and knitwear's than for woven fabrics. It conveys the least protection provided during two years o fuse after the product has been laundered once. A consumer who wears garment before laundering is not protected to the extent communicated on the Label.

Several organizations around the world have developed or have proposed performance standards for UV protections. **Pearson, Mullen, Kathirvelu et al (2009)** in their review paper has summarized the various standards. (93) (69)

1. AS/NZS 4399:1996 Sun Protective Clothing: Evaluation and classification – The standard describes the measurement of UPF rating on dry intentioned fabric.
2. BS 7914:1998 method of test for Penetration of Erythemally weighted Solar UV Radiation through Clothing Fabric – The standard describes UV radiation of dry, intentioned clothing fabric garment design is not considered.
3. BS 7949:1999 children's clothing Requirements for Protection Against Erythemally Weighted Solar Ultra Violet Radiation – The standard is for children between age of 6 months and those which are subjected to VAT' and refers to garment design as well as fabric.
4. BSEN 135758 – 1 2002: Textiles Solar UV Protective Properties, Part I method of Test for Apparel Fabrics – The standard recognizes the effect of wear and usage of clothing on its UV protection particularly the effect of stretching and wetting.
5. BS EN 13758 – 2 :2001: Textiles Solar UV protective Properties Part 2 : Classification and marketing of Apparel – The standard states UV protective clothing will need to have the sun safety logo incorporating the number of the standard, EN 13758 and UV protection factor 30+
6. AATCC Test method 183-2000: Transmittance or Blocking of Erythemally weighted Ultraviolet Radiation through Fabrics. The standard describes a test to determine the UV radiation blocked or transmitted by textile fabrics which are intended to be used for UV protection. The UPF ratings of the tested Fabrics are determined.
7. CEN/TC248/WG14: Apparel fabrics; solar UV protective properties, method of test.

2.1.3 Textile parameters and finishes for UV Protection (44) (112) (80) (55) (104)

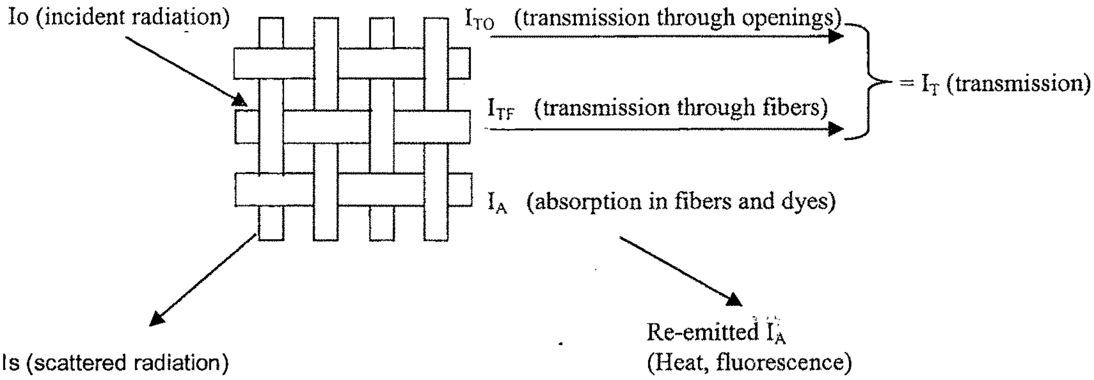
Several researches (2005, 2003, and 2001) have reported various factors on which the UV protective properties of fabrics significantly depends. Those are as follows:

2.1.3.a. UV protection by textiles
2.1.3.b. Fiber characteristics
2.1.3.c.Fabric characteristic
2.1.3.d. Chemical processing to protect fabric

2.1.3.a. UV protection by Textiles

In a study by **Goyal (2005)** it was reported the way UV rays works on fabrics. When incident radiation contacts a fabric, part of radiation is scattered from the surface and the remaining is absorbed by or penetrates/transmits through the fabric. A fraction of the radiation passes through the fibers and spaces between the yarns.

The absorbed radiation is taken by the chromophore in the fibers as well as by other materials present (dyes, de-lusturants, optical brighteners, finishes). Incident light during use may not be perpendicular to the fabric surface, but may contact it at an angle, thereby increasing the scattering and effective cover.



Radiation incident upon a fabric (I_O) is scattered (I_S), absorbed (I_A), transmitted through openings (ITO) or transmitted through the fibers (ITF). The total transmission (IT) is equal to the sum of ITF and ITO. Transmitted rays through the fibers and openings may damage the objects beneath.

Figure 2.8: Process of light transmission through fabric
Source: (Goyal Rakesh, "UV radiation and protection", Colourage, October, 2005, pp.81-87

The extent to which a woven or a knitted fabric transmits, absorbs, or reflects UV radiation determines its sun protection properties. The transmission, absorption, and reflection are in turn dependent on the fiber, fabric construction (thickness and porosity) and finish. Therefore it is transmitted radiation that reaches the skin. Higher is the transmission, or lower is the absorption, lower is the protection offered by the textile for the wearer.

There are two possibilities of reducing UV transmission by factors- by reducing the porosity through modification of construction or by improving the absorption and reflection properties of the fabric. The construction may be improved by determining the optimum relation between the number of yarns in the warp and the weft for a given yarn count. Some parameter that effects the UV absorption characteristics are:

2.1.3.b. Fiber characteristics

Malik, Arora and Singh (2004) have reported that the transmissibility of UV radiation against different textile fiber is different. The raw cotton has higher sun protection factor than bleached cotton because the natural pigments, pectin and waxes act as UV radiation absorber. Wool fiber exhibits maximum protection while silk has intermediate protection value between cotton and wool. Polyamide fibers are less resistance against UV radiation while polyester fibers exhibit high absorption due to its aromatic structure. Acrylic shows low UPF due to the dipole interaction of the nitrile group. (80)

2.1.3.c. Fabric characteristics

Several researches listed various factors which play a role in the amount of protection provided by fabrics.

Weave: The weave or construction of fabrics is the main factor affecting UVR comes through the fabric. The more closely woven fabric the less UVR is transmitted. Twill weave is much denser than satin/sateen weave due to its high compactness. With the same weave structure, the protection factor of the fabric increases with its thickness that is weight. The cover factor of the fabric is the main parameter for UV protection.

Fabric porosity: The number of pores per unit surface reduces then the UPF of the fabric increases.

$$\text{UPF} = \frac{100}{\text{Porosity}} + \frac{100}{\text{100-covering factor}}$$

If UPF is 100, then porosity is 1% and when the porosity increase to 10% then UPF is only 10. So the summer fabrics are required to be open construction for comfort. UPF of 40 is excellent for protection.

Thickness: It is the most useful fabric parameter for explaining difference in UV radiation transmission. Thicker, denser fabric transmitted less UVR than thin fabric. But UVR transmission is not necessarily related to thickness. Thickness is most useful in explaining difference in UVR transmission when differences in percent cover are also accounted for.

Moisture Content: UPF of a wet garment is appreciably lower than that of dry fabric. Water in interstices of fabric reduces the scattering effect and therefore its UV permeability.

Stretch: The UV protection depends on stretch of the fabric also. The greater the tension and stretch lower the UV protection.

Washing: In case of cotton and polyester-cotton fabric, protection increased after first washing and remained high for lifetime of the garments.

Table 2.3. Summary of factors significantly affecting the UPF of apparel textiles*(55)

Fabrics material	UPFs of cotton, viscous, rayon and linen are usually smaller than UPFs of nylon, wool and silk; polyester provides usually high UPFs
Fabric porosity, weight and thickness	UPF increases with decreasing yarn-to-yarn spaces and increasing fabric weight and thickness
Fabric colour	UPF increases with darker colours
UV absorbers	UPF is improved by UV absorbers
Stretch	UPF increases under stretch
Wetness	UPF decreases when cotton becomes wet
Washing	UPF increases for cotton fabrics

* UPF indicates UV protection factor

Table2.4. General recommendations about UV protective clothing for patients with photosensitivity*(55)

Clothing labeled as UV protective with a UPF of at least 30 is preferred
The less transparent a fabric is to visible light, the better the UV protection is.
The darker the colour of the fabric the better the UV protection is.
Polyester or polyester blends usually offer better UV protection.
Stretch and wetness of cotton fabrics significantly decrease their UPF.
Looser fits are preferable; the garment should cover the skin as much as possible.
New clothing especially cotton fabrics, should be washed before wearing, special laundry detergents and fabric conditioners may be used that include broadband UV protective absorbers.
Despite a high UPF, a fabric's UV-A transmission can be significant.

* UPF indicates UV protection factor

2.1.3.d Chemical processing to protect fabric from U.V radiation(44)

Various chemical processes which provide protection against U.V radiation. They are:

2.1.3.d.i. *Influence of TiO_2* - presence of TiO_2 particles in a fabric results in scattering of UV rays and thus makes it less permeable to UV rays.

2.1.3.d.ii. *Application of Dyes* – As the spectral region of all dyes extends to the UV region all dyes act as UV absorbers. Studies show that for a given colour, darker the shades, higher are the protection. In general, navy, black, and olive shades would show a better protection. Some recent studies report, an increase in the UV protection of cotton textiles when dyed with selected direct, vat and reactive dye. However extensive research with dyes of different colours and structures only confirms that the UV absorbing capacity of each dye is unique and hence it is very difficult to generalize.

2.1.3.d.iii. *Application of fluorescent whitening agents (FWAs):* FWAs are applied to fabrics during laundering to enhance the whiteness of textiles by inducing fluorescent by UV excitation and visible blue emission. Most FWAs have excitation maxima in range of 340-400 nm and hence have been known to improve the UPF of textiles. However the efficiency of FWAs can be affected adversely by use of some UV blocking agents, depending on the respective absorption patterns of the two compounds. The improvements in UV absorption by FWAs are an interesting and positive contribution against UVR, though in many cases it does not achieve the desired levels of protection.

2.1.3.d.iv. *Finishing with UV absorbers:* UV absorbers are organic and inorganic substances capable of selectively absorbing short wave solar radiation and of restoring the absorbed energy intact to the environment.

Finishes used as UV-Absorber in the present study were Commercial UV absorbers and Acacia Catechu (*Katha*) a natural colourant

UV absorbers for textiles (57) (102)

Protection of skin against UV radiation is necessary. If fabric cannot offer the required protection than a UV protective finish is advisable. A few finishing agents are available for this purpose which may be applied continuously from aqueous liquors.

Ultraviolet absorbers are organic or inorganic compounds that are characterized by marked absorption of ultraviolet radiation, with virtually no absorption in the visible region, i.e. colourless and have high light fastness. There is a wide variety of UV absorbers but, for application to textiles in wet processing.

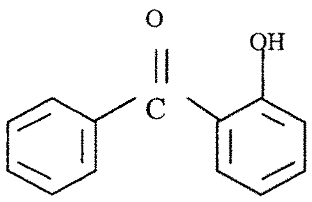
UV absorbers have to be distributing mono-molecularly in the substrate for maximum effect besides; they should meet other criteria such as:

a. Absorb effectively throughout the UV region (280-400nm).
b. Be UV stable itself.
c. Dissipate the absorbed energy in such way so as to cause no degradation or colour change in the medium it protects.

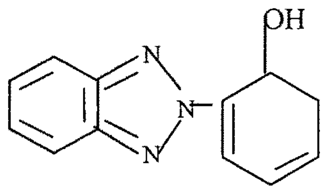
UV absorbers act on the substrate by several ways- by converting electronic excitation energy into thermal energy via a fast, reversible intermolecular proton transfer reaction; functioning as radical scavengers; and functional as singlet oxygen quenchers.

Chemistry of UV absorbers (68)

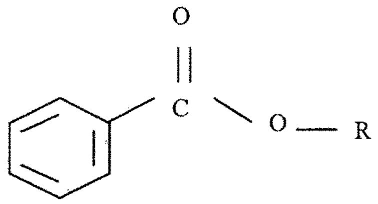
Kanetkar et al (2002) stated about the five most important commercial ultraviolet absorbers those were 2-hydroxy benzophenones, 2-(2'-hydroxyphenyl) benzotriazoles, Salicylic acid derivatives, Aryl dubstituted acrylates and Nickel chilates.



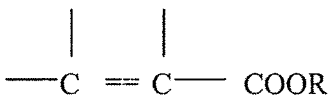
1.2-hydroxy benzophenones



2-(2'-hydroxyphenyl) benzotriazoles



Salicylates



$$-\mathrm{C}=\mathrm{C}-\mathrm{COOR}$$

Substituted acrylates

Photochemistry of UV absorbers

The various additives present in the matrix absorb UV radiation and go to its excitation energy. The reactions are shown below

$$\mathbf{A \rightarrow A^*}$$
$$\mathbf{A^* + P \rightarrow A + P^*}$$
$$\mathbf{P^* \rightarrow Degradation}$$

$$\mathbf{A \rightarrow A^*}$$
$$\mathbf{A^* + P \rightarrow A + P}$$
$$\mathbf{P + O2 \rightarrow auto\ oxidative\ degradation}$$

A= Additives, P=Polymer, A*+Photoexcited state

P*=Photoexcited state, A=Radical, P=Radical

For an effective stabilizer, the excitation energy should be disposed without interaction with the polymer matrix and without undergoing any photochemical reaction, which would destroy its effectiveness.

Examples of the UV absorbers available in the market (48) (57)

Australian researchers have worked out a finish technology that substantially increases the UPF of light garments. **Clarient** is marketing the technology under the name of *Rayosan.* The dyer or finisher can apply the Rayosan process on yarn, knitwear or woven fabrics using the traditional textile finishing process and equipment. Products *Rayosan C. Paste* and *Rayosan CO Liquid* are available for use on cellulosic's, polyamides and wool (with reactive dyes), and *Rayosan P Liq* for the PET and acetate fibers (with disperse dyes). These products reportedly, have no negative effect on the optical brighteners, as they do not absorb the UVR required for the excitation of fluorescence.

Ciba Geigy is marketing UV absorbers for different substrates under the brands *Cibafast* and *Cibatex.* These can also be applied on the fabric by either exhaust or pad batch method. Tinofast Cel is a new product capable of giving a UPF of 40+.

Non reactive UV absorbers based on oxalic anilides, triazine or triazol compounds, salicylic acid esters, substituted acrylonitrile or nitrilo-hydrazones, emulsifying agents, water and polysiloxances.

UV absorbers are versatile products that can be used in variety of applications to improve both personal protection and the performance of textiles.

Acacia Catechu (Katha) Natural colorant

The emergence and popularity of a more natural way of life as reflected in a return to organic farming and natural foods has now extended into textiles where the resurgence of natural dyes is on the increase. In the present study the fabrics were dyed with natural colorants of plant to develop fabrics having anti-UV properties using Acacia catechu (*katha*).

Species identity (162) (169)

Geographic distribution Native: India, Myanmar, Nepal, Pakistan, Thailand.

Botanic description (149)

The generic name, 'acacia', comes from the Greek word 'akis', meaning a point or a barb. It is said that the name 'catechu' was given to it because its bristles resemble the claws of animals of the cat family or maybe because its heart wood contains 'cutch', a tanning extract isolated from its heartwood.

Acacia catechu. 1) flowering branch; 2) branchlet with fruits. From *Prosea* No. 3 "Dye and tanning-producing plants".

Figure 2.9: Leaves of Acacia Catechu (k*atha*)

Source: www.fao.org/docrep/V8879E/v8879e05.htm, http://en.wikipedia.org/wiki/Acacia_catechu

Acacia catechu is a small or medium-sized, thorny tree up to 15 m tall; bark dark grey or grayish-brown, peeling off in long strips, or sometimes in narrow rectangular plates, brown or red inside; branches slender, puberlous when young but glabrescent, with 2 curved, 8-mm prickles at the base of each petiole. Leaves bipinnately compound, with 9-30 pairs of pinnate and a glandular rachis; leaflets 16-50 pairs, oblong-linear, 2-6 mm long, glabrous or pubescent.

Flowers in 5-10 cm long axillary spikes, pentamerous, white to pale yellow, with a campanulate calyx, 1-1.5 mm long, and a corolla 2.5-3 mm long; stamens numerous, far exerted from the corolla, with white or yellowish-white filaments. Fruit a strap-shaped pod, 5-8.5 cm x 1-1.5 cm, flat, tapering at both ends, shiny, brown, dehiscent, 3-10 seeded; seeds broadly ovoid. In India, three varieties, namely: var. catechu, var. catechuoides and var sundra are recognized. (188)

2.1.4. Soil and soil mechanism

2.1.4.a.Defination

Soiling of textiles means unwanted deposition of foreign matter on the surface of the textile material. The foreign matter is called "soil" which can be "particulate" or "oily". Soiling of textiles involve two steps: (1) transport of soil to the fiber surface, and (ii) adsorption of soil by the fiber. (20)

Soil: Soil or dirt refers to the foreign materials that get accumulated as textile fabrics during it use. (108)

Soiling: In textiles, a process by which a textile substrate becomes more or less uniformly covered with/or impregnated with soil.

2.1.4.b.Types of soil

Soil on fabrics can be of three types (84) (123) (116)

- Water borne stains,
- Liquid soils like oil,
- Particulate soils like sand and
- Composite soils made up of both liquid and solid components like used motor oil and containing particulate matter with oily components.

Table 2.5: Composition of the fatty substances secreted by the human skin (128) (170)

Component	% Content
Free fatty acids	22-27
Wax and sterol ester	20-22
Triglyceride	25-35
Diglyceride	6-10
Squalene	10-15
Sterol	2-5
Paraffin	0.5-1.5

Table 2.6: Average composition of road dust (128) (170)

Component	% Content
Water soluble components	10-15
Ether soluble components	8-12
Moisture	2-5
Organic substances (insoluble fats, fibres, soot, etc.)	20-25
Ash containing	50-55
Fe_2O_3	10-12
MgO	1-2
CaO	7-9
SiO_2	23-26

Tomasino and Seastrunk (1982) stated that water–borne stains are hardly a problem since the stains are soluble in the wash water. The removal of dried blood and food stains, although not water soluble, can be facilitated by proteolytic enzymes found in most commercial detergents. (123)

Dry particulate soils such as flour, clay and carbon black are mainly mechanically trapped in the yarn and fabric interstices. Removal of the particulate soil depends on the location of the particle and its adhesion to the fiber surface. Soil-release finishes aid in the removal of particulate soil by reducing the forces of adhesion between the soil particle and the fiber surface, and enhancing the diffusion of the detergent solution to the particle-fiber interface. Even so, mechanical energy must be supplied to physically move the particulate matter away from the interior of the yarn or fabric. Certain hard, non-durable finishes assist in the removal of particulate soils by a "sacrificial flaking" mechanism; however particulate sols imbedded in soft, tacky finishes are extremely difficult to remove.

When two dissimilar materials are brought into intimate contact, the forces of attraction result in a certain amount of adhesion, often described as the "sorption" mechanism by which oil-borne stains adhere to fibers. To satisfactorily remove these oil stains adhere to fibers. To satisfactorily remove these oil stains, the detergent solution must overcome the forces at the oil-fiber interface. The sorptive forces between oils and polyester are particularly troublesome, and stains composed of grease, food fats, sebum and various oils are difficult to completely remove by convention laundering.

- **Particulate-soil/Fiber Interactions** (123)

  The adhesion between particulate soil and the fiber is dependent on the location of the particle, the attractive forces that exist, (mainly Vander Waal's force) and the contact area. Kissa has shown that soiling conditions affect not only the contact area, but also the amount of soil deposited. Both these factors have an effect on the rate of particulate-soil removal. The release of particulate-soil is brought by breaking the adhesive bond and wetting-out the particulate matter and fiber surface. The particle is then carried off to the bulk of the detergent solution.

- **Oil-soil/Fiber Interactions** (128)

  In the case of oily soils, the phenomenon of wettability or relative surface energy is to be considered. If fluid has a lower surface energy than the fabric surface, thermodynamic considerations suggest that the fluid would wet the surface. However, the distribution of a fluid in a fabric is governed by the net effect driving force to maintain a minimum area at the fluid-air interface and by the capillary force influencing the advance of the fluid into the yarn. The capillary pressure is given by -

$$p = \frac{2v \cos\theta_A}{r}$$

Where v is the surface tension of the fluid on the fabric surface, and r is a parameter characterizing the air column separating the fibers in a yarn, and hence depends on yarn construction contact angle θ_A on a continuous surface is dynamic value of the angle made by the fluid as the liquid front is advancing as illustrating in **Figure 2.11.**

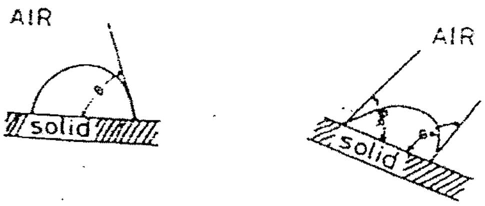


Figure 2.10: Contact angles of a liquid on a solid surface. θ----equilibrium angle; θ_A----advancing angle, θ_R ----receding angle.

θ_A for the fluid will be less than 90^0 if the fluid has a lower surface energy than the fabric surface and grater than 90^0 if the situation is the reverse. In the latter case it is seen from Equation 1 that the capillary pressure is negative, and unless external pressure is applied the oil nerve wets or wicks into the yarn. From the known surface interactions between fluid, air and fabric surfaces one can expect that in the yarn assembly in the dry state the fluid will generally be held by the strongest forces in the surface irregularities of singles fibers and at the fiber junctions or cross-over points, because in these areas a given volume of fluid will present the least interfacial area with air and the capillary forces will have maximum effect.

2.1.4.c. Composition of synthetic soil

The solid particulate widely used included metal oxide, iron oxide, oleic acid, carbon black and vacuum cleaner dirt. The use of dispersions of carbon black as a synthetic soil because a small amount can produce extensive graying of textile similar to that in natural soiling. Some research workers (1987) (62) have applied both solid and oily components in synthetic mixtures to duplicate natural soiling.

2.1.4.d. Soil application

Jacob and Subramaniam(1987) (62) reviewed different ways of applying soil in the laboratory. They are contact soiling tumbling with particulate soils, the use of soiled felt tubes tumbling with dry soil, applying dry soil in an accelerator abrasion tester, immersion technique, padding and spraying, rubbing the test piece with soil, application of soil with abrasion machine soiling in a launder-o-meter with steel balls from a blower, synthetic soil in aqueous dispersion and organic solvent.

2.1.4.d. Fabrics and Soiling (84)

The nature of fabric, especially its hydrophilic/hydrophobic property, appreciably affects its soiling characteristic. Figure shows soiling in hydrophobic textile materials.

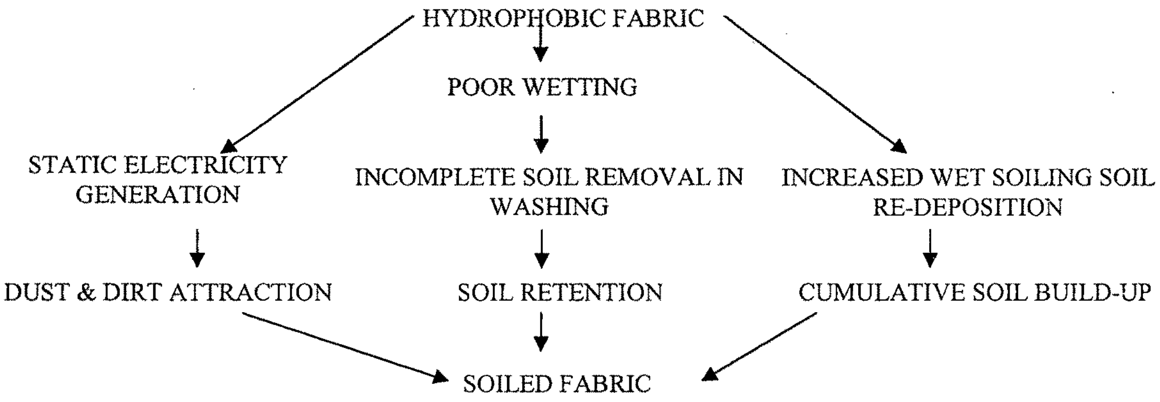


Figure 2.11: Soiling in hydrophobic textiles

The problem of soiling associated with hydrophobic-oleophilic property can be summarized as follows:

1. The oleophilic fabric absorbs oils, fats etc. that are very difficult to remove.
2. Being hydrophobic, it has poor wetting property, i.e.., difficulty for aqueous wash liquor to enter the fabric. Gradual graying of fabric cal also takes place.
3. Being oleophilic. it picks up grease or fatty based dirt from wash liquor resulting in soil re-deposition which again leads to fabric graying.
4. Being hydrophobic, it develops static charges that attract dirt and dust besides garments tending to cling to the body and ride up the legs.
5. Being hydrophobic, garments will not absorb body moisture and the wearer feels discomfort, especially in hot weather.

Moisture regain of fabric plays a significant role in soiling. Those with low moisture regain as in synthetics like polyester and acrylics as well as resin finished cotton show a high tendency for soiling. Fig 18 shows the relationship between soiling and moisture of various natural and synthetic fabrics. (13) (84)

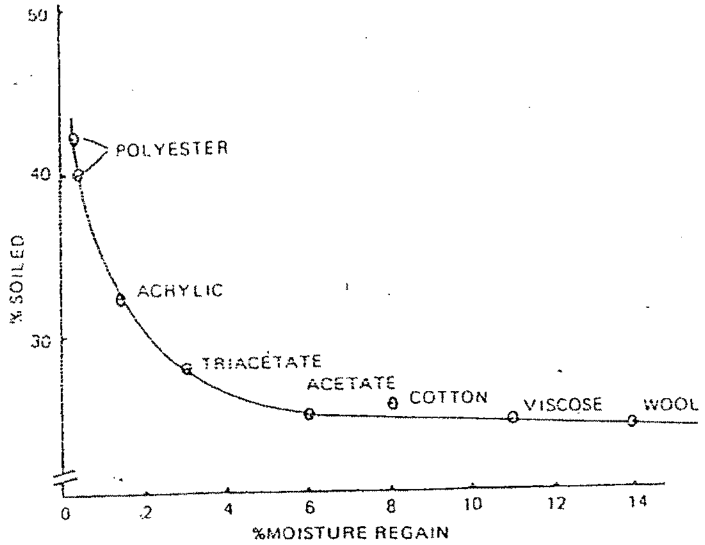


Figure 2.12: Relation of soiling to moisture regain of various natural and synthetic fibers

Treatment of cotton fabrics with nitrogenous resins for obtaining wrinkle-free and durable press properties makes them less hydrophilic and more oleophilic, besides altering their electrostatic properties. Fabrics of cotton blended with oleophilic polyester are prone for easy soiling and difficult soil-removal. Studies have shown that the insoluble carboxymethylated cotton fabric resists soiling and soil re-deposition. Addition of carboxymethylated cellulose in the last rinse water during laundering leads to improvement in soil-release. In these cases it has been suggested that primarily, the electronegative charges on the surface coupled with the hydrophilic nature of carboxymethyl cellulose, contribute to the ease of soil-removal. Increasing electronegative charge on fabric surface will increase the electrostatic repulsion between the fabric and most of the dirt particles that possess a negative charge in aqueous detergent solution.

The interaction between soil and textile materials: (19)

Textile Materials offers an ideal resting place for dirt. Attachment of soil to the host fiber and its removal is a complex phenomenon which is likely to be influenced by a large number of factors. The forces of attraction between soil and the fiber are adsorption force of Vander Waal, dipole or electrostatic nature. Diffusion of soil in fiber, irregularity of fiber surface and pore structure of fiber also may influence the ease of soiling as well as soil removal.

Soiling tendency is closely associated with properties of fiber surfaces. If the fiber surface has large free energy (i.e. zeta-potential), it is thermodynamically unstable and as a result has a strong tendency to attract contaminants which produce low energy and cause a diminution in the zeta-potential.

Cotton has a high surface energy in air but has very low surface energy in water. As a result, it has a high resistance to wet-soiling by hydrophobic soils. Finishing treatments which reduce the high surface energy of cotton detract significantly from the ability of fiber to release oily stains or hydrophobic particulate soils during laundering. Resin treatments detract from cotton's cleanability but the extent to which they do so is less than that cause by film-forming builders and softeners, which are applied along with resins. Furthermore, the uptake of optical brighteners on cotton is considerably reduced by the resin application.

2.1.4.e. Soiling Parameters: (19)

Das and Kulshreshtha(1978) had given various parameters by which the soiling properties of fabrics are evaluated are:

(a) Degree of soiling:

This is the visible amount of dry or greasy soil picked up by the fabric during actual or simulated wear.

(b) Soil-release in washing:

This parameter evaluates how much of the soil picked up during wear can be washed off in actual or simulated washing conditions.

(c) Soiling-redeposit ion in washing:

This parameter evaluates the amount of soil which is picked up by the fabric from the washing liquor during washing. This is essential a form of greasy soiling.

2.1.4.f. Mechanism of soiling (84)

Soiling of fabric is a natural phenomenon, which normally occurs by the following three processes:

- *Direct soiling,* e.g. particulate soil gets deposited on cloth by air currents or a drop of grease falls on cloth (soil particles floating in the atmosphere settle down on the fabric because of gravity or are intercepted by the fabric and finer particles may even diffuse into the fabric structure. Liquids with which the fabric comes into contact may evaporate or be filtered off, leaving behind dissolved or suspended particles).
- *Transfer soiling,* e.g. cloth gets soiled from direct contact with a soiled surface such as contact with soiled hand, skin etc(Through direct contact, simple mechanical forces comes into play to transfer oily and particulate soil directly from soiled surface to the fabric surface) and.
- *Electrostatic soiling* caused by electro-statically charged textile surfaces attracting airborne soil. (In the case of hydrophobic fibers, a large surface density build up on the fiber surface by friction during use or laundering and thereby, soil particles, whether charged or not, are attracted from the atmosphere or the wash liquor).

Factors affecting soiling: (124)(19)

Vaidya et al (1978) had stated various factors that influences soiling of the fabrics, which are as follow:

(a) Physical factors:

Round shaped filaments show the best removal of oily soil. Cotton shows poor oily soil removeability and the poor oily soil-release of polyester/cotton blends is mainly due to the cotton component of the blends. Dry soiling is due to wedging of soil particles in pores of cotton. Mercerization of cotton is effective in improving soil-release properties. Non-crimped yarns show better oily soil-release than crimped yarns.

(b)Choice of washing medium

In aqueous media, hydrophobic fibers soil more easily than hydrophilic fibers. In dry cleaning systems, however, hydrophilic fibers soil more and hydrophobic fibers less.

(c)_Effect of Abrasion:

Abraded cotton fabric retains significantly less oily soil then unbraided fabric. The abrasion damage to a polyester/cotton blend fabric, however, results in a significantly higher retention of oily soil.

(d)_Fiber Type:

The crenulated surfaces of cotton fibers act as traps for particulate soil. Soiling of synthetic fibers on the other hand, is caused by static attraction of dirt.

(e) Size of the soil particle:

Generally soil particles are 0.1 to 10 micros in size. Finer soil particles are attracted more.

(f) Temperature of surroundings:

Between 18 ^{O}C and 75 ^{O}C the rate of soiling is about 8times more at the lower temperature in the range.

(g) Effect of moisture regain:

Soiling of fabric is related to hydrophobic-hydrophilic characteristics of the fiber. In general, fibers having moisture regain above 4% are soiled less. Polyester has the least moisture regain and displays maximum soiling.

(h) The Nature of fabric finish:

DP resins, softeners, catalysts and even the fabric geometry affect soiling. Soft polymeric finishes on cotton are known to contribute to wet soiling especially if they are thermoplastic and soften at elevated laundering temperatures. Soling tendency decreases with increasing hardness of the polymeric film coated on fabric.

2.1.4.g. Mechanisms of Soil Retention (87)

Particulate soils may be held in a number of ways as reported by **Nuessle**:

1. Macro-occlusion or entrapment of particles between yarns and between fibers within the yarns. This mechanism explains why, with increasing twist, soil-retention increases to a maximum and then decrease.

2. Micro-occlusion or entrapment of fine particles in the irregularities of fiber surface. It was found that a sharp increase in the soiling of cotton fibers with carbon black as the particle size dropped below 50mu, in agreement with optical evidence that most of the pores and crevices in the fibers are below that dimension. It was also noted similar effects in case of linen and silk, whereas the soiling of rayon, wool, and nylon were somewhat more regular.

3. Sorption by Vander Waals or coulombic forces, at the surface or within pores and cervices. Montmorillonite, clay in the form of very thin platelets, adsorbs from water dispersion in a continuous layer that completely covers cotton fibers is very difficult to remove. Particulate soils in dirty wash wear will usually compete with each other for adsorption sities but the interactions are quite complex; presence of one particulate soil on the fiber may speed up the adsorption of another.

4. Oil bonding, in which particulate soil is held by layer of oily or fatty materials on the fibers. This is one of the most important causes of soiling of smooth synthetic fibers. However, it is not the only cause, since such fibers can become soiled by re-deposition during dry cleaning, when the oils and fats are in solution. Addition of oil to iron oxide or carbon black did not influence the removal from cotton fabric during laundering.

5. Bonding by finishes, as, for example, in wet soiling of fabrics containing soft thermoplastic polymers. The degree of soiling will vary widely with the type of particulate soil and the conditions of soiling.

2.1.5. Soil-releasing method and finishing

2.1.5.a. Mechanism of soiling release

2.1.5.b. Mechanism of soil redepostion

2.1.5.c. Finishes for Improving Soil-release

2.1.5.a Mechanisms of Soil-Release (128)

- **Soil particle-soil release**

The removal of soil particle adhering to a fiber surface may involve two steps, as shown in figure (1) penetration of a thin liquid layer between the particle and the fiber surface, accompanied by solvation of the separated surfaces of the particle and fiber with adsorption of substances in the wash liquor such as the detergent; and (2) transport of the discharged soil particle into the bulk of the wash liquor.

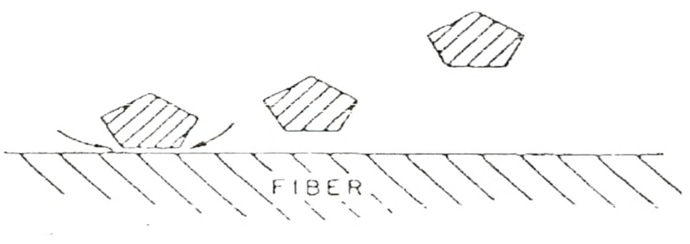


Figure 2.13: Mechanism for particulate soil

- **Oily- Soil release**

To understand the mechanism of soil release, one can consider soiling as a process of wetting or adsorption of fluid soil over the fabric surface, and the phenomenon of soil release as a adsorption process in which the fluid soil is removed from the fabric surface into suspension in a detergent solution. Thus soil release involves the displacement of one interface and the formation of two new interfaces (oil –water and fabric water).

2.1.5.b. Mechanism of soil redeposition

The mechanism of wet soiling is based on the concept that the soil becomes attached to a fiber by displacement of water from the surfaces of both the fiber and the soil. When wet soling takes places, a soil-fiber interface is formed at the expense of water-fiber and soil-fiber interfaces. Thus for easy soil release and wet soil release and wet soil resistant properties, the fabrics should possess not only high respect to the oily soils normally encountered in practice.

The above mentioned theories do not take into account the influence of particulate soil on soiling and soil retention. Also, they do not consider the topography of the fiber and its influence on soiling and soil release. Hence their validity has to experimentally verified.

2.1.5.c. Finishes for improving Soil-release

i) Requirements of a good soil-release finish: (85)

An ideal fabric finish is the one which:

- Provides soil-repellency during fabric wear;
- Helps in soil-removal during fabric laundering;
- Is durable to repeated launderings;
- Will not adversely affect fabric feel;
- Is easy to apply on fabric preferably through incorporation in the regular finishing recipe and processing;
- Is eco-friendly, i.e. not poisonous or harmful.

The choice of finish is determined by the fabric end-use. For instance, a shirting finish should give good soil-release with no loss of the handle or absorbency whereas for DP slacks a slight loss of handle or drape may be acceptable. In fact, an ideal finish would be one which would both resist soiling during use (i.e., soil-repellent) and enable easy release of deposited soil during washing (i.e., soil-release). This ideal cannot generally be met in practice, however.

ii) Various Soil-release methods (85)

Dr. Nair (2004) had listed different methods used for tackling soiling problems in textiles

Table 2.7: Different methods used for tackling soiling problems in textiles

Sr. No.	Method	Details
1	Masking/Camouflaging	Blueing/whitening to nullify fabric yellowing; dyeing/printing to camouflage soiling.
2	Mercerizing/Caustic treatment	Improvement due to fiber turning rounder and smoother by removal of surface irregularities and 'ridges' that contribute in entrapping dirt particles. Caustic treatment of polyester/cotton can improve soil-release properties, achieved through hydrolysis of polyester surface generating hydrophilic carboxyl and hydroxyl groups.
3	Metal oxides and salts	Silica, alumina, titanium dioxide etc of particles size 0.1 to 4.0 microns can fill uneven fiber surface and prevent soiling.
4	Antistatic agents	Usually applied for synthetics such as polyester and nylon to prevent static charge accumulation leading to soiling. An example is an aliphatic hydroxyl-compound containing at least two alcoholic hydroxyl groups in the fully or partially vinylated molecule.
5	Acrylic polymers	Acid acrylics with hydrophilic carboxyl groups, polyacrylamide and its acidic derivatives like sulphonates.
6	Fluorocompounds	Fluorinated ethers quaternary ammonium salts with fluorocarbon compounds etc that are useful as soil-repellents. However, the low water wetting property of these compounds will make soil-removal difficult.
7	Carboxymethyl cellulose	Its inclusion (as low as even 0.25%) in final rinse improves soil-resistance and soil-release, besides preventing soil re-deposition. This action is attributed to its electrostatic repulsive force, its greater affinity towards fiber thus blocking entry of dirt particles and its capacity to envelop dirt particles thereby preventing their re-deposition.
8	Ionizing radiation	This result in rendering fabric surface more hydrophilic Pre-irradiation followed by surface grafting with hydrophilic compounds like acrylic acid, acrylamide etc will produce a better soil-resistance.
9	Other treatments	Treatment with starch or sodium alginate aids in soil-removal while treatments with polyethylene glycol monostearate, partially neutralized stearic acid, maleic a hydride copolymer, polyurethanes etc can render soil-resistance Soiling characteristics can also be improved through partial acetylation and carboxymethylation of cotton fabrics.

iii) Soil release treatments and agents : (86)

Soil release is the property of fabrics to shed or release soil during washing or laundering. Soil-release agents or finishes are those with special functional groups capable of removing soil from the fabric and transfer it to the washing medium. Soil release finishes not only impart improved soil-release but also will prevent soil re-deposition. It confers anti-static and comfort properties on fabrics involve the following approaches:

- Chemical reaction at fiber surfaces such as grafting, hydrolysis, trans-etherification and oxidation.
- Durable physical adsorption of monomolecular amphiphillic compounds like surfactants at fiber surface
- Coating of fiber with soil-releasing polymers like those produce by vinyl polymerization or condensation reactions. Such polymers come under the following structural elements:

  a) **Hydrophilic components** with carboxyl, hydroxyl, alkali metal sulfonate or oxythylene groups. Among these, the carboxyl group being a weak hydrophile can be made strong by converting it to its alkali metal salt.
  b) **Lipophilic components**, viz., alkyl or aryl groups attached either directly to the polymer backbone or through ester or ether linkages such as alkyl acrylates or methacrylates and ester of terephthalic or isophthalic acids. The vinyl polymer backbone is also lipophilic.
  c) **Reactive groups** to insolubilise thereby producing durable soil-release agent on the fiber through cross-links. Examples are N-methylacrylamide, di-isocyanates and glycidyl ethers.
  d) **Fluorocarbon** segments in hybrid soil-release agents.
  e) **Structural elements** to links soil-release agents onto the macromolecules. Such an element can be a polymer backbone by vinyl polymerization of monomer or linkages formed by condensation polymerization of components of soil-releasing macromolecule.
  f) **Pendent lipophilic** groups soluble in fiber made durable trough entering the fiber surface softened by heat or a plasticizer. On cooling, the soil-release polymer gets anchored to the fiber surface.

Soil-release polymers are amphiphilic due to the presence of both hydrophilic and lipophilic groups. The balance between these groups is essential for soil-releasing activity of the polymer besides its water solubility and fiber surface spreading property for pliability of the finish. Soil release agents come as emulsions, dispersions or solutions of compounds that get insolubilised or fibers during the finishing process.

iv) How does a Soil-Release Finish work? (19)

In order to combat soiling and enable soil removal, the forces of adsorption between soil and fabric must be overcome. Most soil-resistant and soil-release finishes operate by increasing the polarity or hydrophilic properties of the fiber surface, by reducing the surface energy of the fiber or by modifying the surface structure physically so as to reduce static charge on the fibers. As a result the SR finish helps to reduce static charge on the fabric and assists the penetration of washing liquors when the soiled fabric is washed. Therefore, accumulated dirt on the fabric is more easily to remove during the washing operation. It has been established that carboxyl-containing finishes are more efficient anti-soil and soil release agents than finishes containing only hydroxyl groups.

The soil removal is very good in the case of hydrophilic fibers because water causes a neutralization of the surface forces, leading to a considerable reduction in the zeta-potential.

v) Fluoropolymer soil-Release finishes (128)

The Soil-Release finishes based on fluorochemicals have found general acceptance for post-cure fabrics. Fluorochemicals have very low surface tensions and because of this have very good oily soil-repellency. Fluorochemicals resin emulsions are used on medium or heavy weight fabrics. These finishes are better than acrylic-based finishes for Soil-release finishing of polyester-cotton blends. Despite their good performance, the fluorochemical treatments are rather expensive. The conventional fluorochemical oil-repellent finishes provide a low energy fabric surface in air but form high energy surfaces in water during fabric laundering. As a result, the finished fabric tends to become contaminated by hydrophobic soils in the aqueous wash medium.

The commercial Soil-Release finishes based on Fluorochemicals are well known. DuPont's "Zepel", 3M Co.'s "Scotchgard" and the "Quarpel" finish developed by the Quartermaster Corps for military purposes are typical example of these. Scotchgard finish is derived from the polymerization of 1, 1-dihydrofluoroalkyl acrylate. The "Quarpel" finish contains a comparatively large proportion of the cheaper water-repellent agent (of the pyridinium type) in a synergistic combination with the fluorocarbon (FC-208). This finish is inexpensive and is fast to washing and dry-cleaning. Fluorocarbon groups can be incorporate in the acrylic or ethylene oxide polymer backbone to obtain SR agents. Other examples of fluorochemical SR finishes are a block copolymer of a sulfonamide fluoroalkyl acrylate and ethylene oxide units, a homopolymer of a fluorinated glycidyl ether, a copolymer of a fluoroalkyl acrylate and acrylic acid, a polyacrylate made by reacting 1,1 dihydroperfluoro octanol with acrylic acid etc. SR finish for DP cotton which is based on the reaction product of THPC and POA (tetrakis hydroxymethyl phosphonium chloride and 1, 1-dihydroperfluorooctylamine).

Developments in the fluorochemical Soil-Release finishes aim at achieving stain repellency as well as soil-release characteristics. Such dual purpose finishing agents are prepared by incorporating within a single hybrid molecule both fluorochemical and hydrophilic segments, each present in a sufficient quantity to confer the desired surface energy in either air or aqueous environment. The examples of such finishes are the reaction product of ethyl perfluorooctanoato and polyethylenimine (EPO-EL finish), sulphydryl-terminated copolymer of tetraethyl glycol dimethyacrylate and copolymer of fluorosilanes and hydrophilic silanes produced by copolymerization in tetrahydrofuran. These can be incorporated in resin-finishes baths for polyester-cotton fabrics.

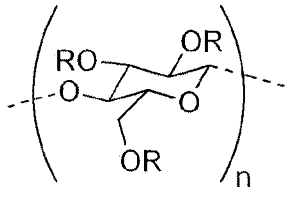
How do they Fluorochemical work?

Copolymers containing fluorine tend to give high Soil-Release ratings because of their oil-repellent nature. Moreover, the oily soil placed on fabrics coated with a suitable fluoropolymer does not penetrate or wick into the fabric structure. It is found that the oil-repellent properties of fluorochemical are proportional to the number of fluorine atoms present. In the SR fluoropolymer, the nature of the polymer backbone controls the durability of the finish whereas the oil-repellency is dependent on the chain length of the perfluoro group.

The dual action fluorochemical Soil-Release finishes work in the following manner: In air, the fluorochemical segment of the finish becomes oriented so as to impart soil repellency to the fabric surface. In an aqueous environment (i.e., during laundering) the surface molecules reorient so that the hydrophilic segment becomes effective and the surface exhibits good soil-release properties. After the completion of laundering and during drying of the fabric, another surface "flip-flop" occurs and the fluorochemical segments reassert dominance at the air interface to provide soil-resistance once again.

vii) Carboxy Methyl Cellulose (C.M.C) (163)

Chemical structure:



R = H or CH_2CO_2H

Carboxy Methyl Cellulose (CMC) is a cellulose derivative with carboxymethyl groups ($-CH_2-COOH$) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. It is often used as its sodium salt, sodium carboxymethyl cellulose

Preparation

It is synthesized by the alkali-catalyzed reaction of cellulose with chloroacetic acid. The polar (organic acid) carboxyl groups render the cellulose soluble and chemically reactive.

The functional properties of CMC depend on the degree of substitution of the cellulose structure (i.e., how many of the hydroxyl groups have taken part in the substitution reaction), as well as the chain length of the cellulose backbone structure and the degree of clustering of the carboxymethyl substituents.

Uses

CMC is used in food science as a viscosity modifier or thickener, and to stabilize emulsions in various products including ice cream. As a food additive, it has E number E466. It is also a constituent of many non-food products, such as K-Y Jelly, toothpaste, laxatives, diet pills, water-based paints, detergents, textile sizing and various paper products. It is used primarily because of it has high viscosity, is non-toxic, and is non-allergenic. In laundry detergents it is used as a soil suspension polymer designed to deposit onto cotton and other cellulosic fabrics creating a negatively charged barrier to soils in the wash solution. CMC is used as a lubricant in non-volatile eye drops (artificial tears). Sometimes it is methyl cellulose (MC) which is used, but its non-polar methyl groups ($-CH_3$) do not add any solubility or chemical reactivity to the base cellulose.

Following the initial reaction the resultant mixture produces approximately 60% CMC plus 40% salts (sodium chloride and sodium glycolate). This product is the so-called Technical CMC which is used in detergents. A further purification process is used to remove these salts to produce pure CMC which is used for food, pharmaceutical and dentifrice (toothpaste) applications. An intermediate "semi-purified" grade is also produced, typically used in paper applications.

CMC is also used in the oil drilling industry as an ingredient of drilling mud, where it acts as a viscosity modifier and water retention agent. In this field it is referred to as poly-anionic cellulose or PAC.

Insoluble microgranular carboxymethyl cellulose is used as a cation-exchange resin in ion-exchange chromatography for purification of proteins. Presumably the level of derivatization is much lower so that the solubility properties of microgranular cellulose are retained while adding sufficient negative charged carboxylate groups to bind positively charged proteins.

Carboxy Methyl Cellulose (CMC) as soil-release and preventing soil-redeposition agent (116)(124)

CMC when applied on the surface of the fabric, physically block the soil particles from penetrating deeper into fabric. The action of CMC may also be due to the electrostatic repulsive force which develops between negatively charged soil particle and negatively charged cotton surface (due to the presence of carboxylic group in CMC).

2.1.6. Test methods

2.1.6.a. For quantitative assessments of UV protection of textiles.

2.1.6.b. Methods of evaluation of soil-release property of fabric.

2.1.6.a. For quantitative assessments of UV protection of textiles.

Given the increasing interest in sun protection, recreationally and occupationally, test methods and a rating scheme for clothing were needed that would ensure sufficient UV protection. The Australian/New Zealand Standard (AS/NZS) was the first normative publication offering test methods to be used for determining UV protection factor (UPF) and a classification scheme. Clothing with UV protection ratings has been available in Australia for several years, particularly recreational wear such as beachwear and elastane bodysuits for small children. A worldwide effort has been under way to study factors that affect the UV protection provided by clothing. However, systematic research to quantify the effect of various manufacturing techniques is difficult, as these variables are rarely independent.

Test methods for quantitative assessment of UV protection of textiles

i) In Vitro (69)(71)

Direct and diffuse UV transmittance through a fabric is the crucial factor determining the UV protection of textiles. Radiometric UV transmission tests use a broadband UV light source filtered for UV-B or combined UV-A and UV-B spectral regions to illuminate a fabric sample. The total UV transmission through the textile is measured by a radiometer. For correct measurement, this test method requires a UV source that closely matches the solar spectrum, with detectors that respond similarly to human skin. Nevertheless, this technique is simple and suitable when a relative variation in UPF needs to be measured. Spectroradiometers or spectrophotometers collect transmitted and scattered radiation with the aid of an integrating sphere positioned behind a textile sample. Although spectrophotometers fitted with a double monochromator have a large dynamic range and high accuracy, regular scans of the UV source (deuterium or xenon arc lamp) are required to provide reference data.

As suggested by the AS/NZS and European standard, the spectrophotometer should be fitted with a UV radiation transmitting filter for wavelengths of less than 400 nm (UG-11 filter; Schott, Mainz, Germany) to minimize errors caused by fluorescence from whitening agents. The spectrophotometric measurements are performed in the wavelength range of 290 to 400 nm, in 5-nm steps or less. For UPF determination, at least 4 textile samples must be taken from a garment, 2 in the machine direction and 2 in the cross-machine direction. To determine the in vitro UPF, the spectral irradiance (of the source and transmitted spectrum) is weighted against the erythemal action spectrum, as follows:

$$UPF = \int E_\lambda S_\lambda d_\lambda \; / \int E_\lambda S_\lambda T_\lambda d_\lambda ,$$

where $\lambda$is the wavelength in nm; $E\lambda$, relative erythemal spectral effectiveness; $S\lambda$, solar spectral irradiance of the source in watts per square meter; $d\lambda$, bandwidth in nanometer; and $T\lambda$, spectral transmission of the sample. The integrals ($\int$) are calculated over the wavelength range of 290 to 400 nm.

The definition of *UPF* is that it is the ratio of the average effective UV irradiance calculated for unprotected skin to the average effective UV irradiance calculated for skin protected by the test fabric. Intercomparison measurements of different testing laboratories have shown that spectrophotometry is an accurate and reproducible test method for determining UPF.

ii) In Vivo (71)

With human volunteers, use of the sun as the UV source is impracticable to test the UPF of fabrics. Generally, xenon arc solar simulators are used, with filters to absorb wavelengths below 290 nm and to reduce visible and infrared radiation. Stanford and Gies and their co-workers described in vivo test methods based on MED testing. However, the most frequently performed in vivo test method is in vivo confirmation of the UPFs measured in vitro. Based on skin phototype, MED is determined using incremental UV-B doses on the upper back of a subject and is read after 24 hours. To measure the MED of protected skin, a textile is placed over the skin on the other side of the back. The incremental UV-B doses for determining the MED of unprotected skin are multiplied by the UPF determined in vitro, with the product being the incremental UV-B doses for MED testing of the protected skin. The in vivo and in vitro methods are in agreement if the ratio of the MED of protected skin to the MED of unprotected skin results in the original in vitro UPF. Several studies, however, have shown that UPFs determined using the in vivo "on skin" method are significantly lower than the UPFs obtained in vitro. Again, as with the in vitro test method, the actual UPF of a garment would probably be much higher than the UPF determined using the in vivo test method. Cost and impracticability are limitations of the in vivo test methods. Some in vivo tests have used polysulfone dosimeters as small portable badges monitoring UV doses on mobile subjects Ravishankar and Diffey concluded that the actual protection provided by textiles worn in sunlight is, on average, 50% higher than that measured by conventional in vitro testing using collimated radiation beams. Similar results were found in studies of a biological UV-detector film using *Bacillus subtilis*

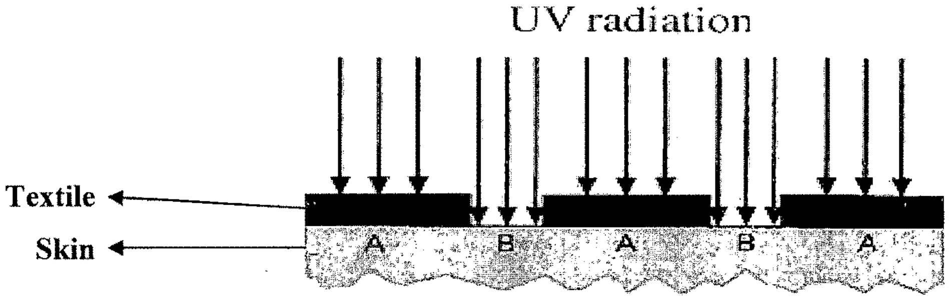


Figure2.14. In vivo `on skin' test with collimated ultraviolet (UV) radiation (A, non-irradiated skin; B, irradiated skin). After passing the spaces between the yarns of the textile the UV radiation directly hits the skin.

Source: T.Gambichler, A.Avermaete, A.Bader, P.Altmeywer and K.Hoffmann, " Ultraviolet protection by summer textiles. Ultraviolet transmission measurements verified by determination of the minimal erythema dose with solar-simulated radiation" British Journal of Dermatology, 2001; pg 484±489.

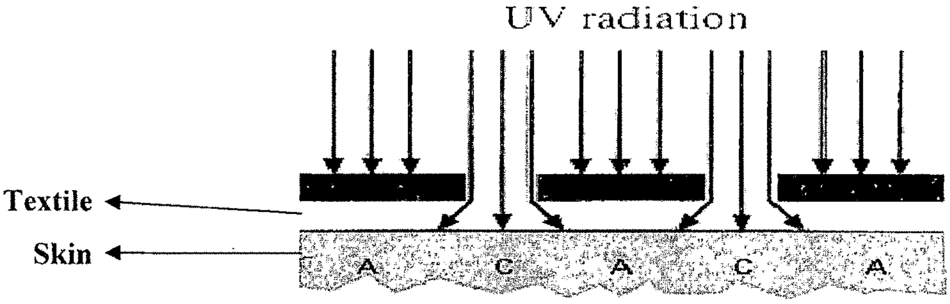


Figure2.15. In vivo 'off skin' test with collimated ultraviolet (UV) radiation (A, non-irradiated skin; C, irradiated skin). After passing the spaces between the yarns of the textile the UV radiation becomes more diffuse due to scattering; the irradiated sites (C) are greater than in 'on skin' testing

Source: T.Gambichler, A.Avermaete, A.Bader, P.Altmeywer and K.Hoffmann, " Ultraviolet protection by summer textiles. Ultraviolet transmission measurements verified by determination of the minimal erythema dose with solar-simulated radiation" British Journal of Dermatology, 2001; pg 484±489.

iii) Percent transmittance (69)

The calculation of total UV percent transmittance for a fabric is the ratio of the amount of radiation transmitted to the amount of radiation directed perpendicular to the fabric swatch surface. The calculation of the percentage of UVB transmitted through the fabric is the same, except only the data from the UV rays in the UVB region are used. Likewise, the calculation of the percentage of UVA transmitted involves only the data when UVA was directed at the fabric surface. Percent transmittance data do not take into account that certain wavelengths in the UV range are more responsible for skin damage than others.

2.1.6.b. Methods of evaluation of soil-release property of fabric

Venkatesh (1974) (128) reviewed various methods that have been used to measure the degree of soiling and soil removals are:

(i) Reflectance Measurement

The amount of soil deposited during soiling can be estimated by chemical methods and reflectance measurements made on the soiled samples. The most popular method for estimating the amount of soil released during laundering is the reflectance method. The reflectance values of the fabric swatches are measured before soiling, after soiling, and after laundering, with a suitable spectrometer. The degree of soiling or soil removal is calculated using the Kubelka Munk equation:

$$K/S = \frac{(1-R^2)}{2R}$$

Where R is the reflectance and K and S are the absorption and scattering coefficients, respectively.

The degree of soiling and the degree of soil release are given by equations:

$$\text{Degree of soiling DS} = (K/S)_S - (K/S)_{US}$$

$$\text{Degree of soil removal} = (K/S)_S - (K/S)_{SW}$$

Where $(K/S)_S$, $(K/S)_{US}$, and $(K/S)_{SW}$ refer to K/S values (usually measured at a wavelength of 550 mμ) of soiled, unsoiled, and laundered samples, respectively.

For routine evaluation this equation has been modified as follows

$$DS = \frac{R_{UU} - R_{SU}}{R_{SU}} * 100$$

$$DSR = \frac{(R_{SW} - R_{SU}) - (R_{UW} - R_{UU})}{(R_{UU} - R_{SU})} \simeq \frac{(R_{SW} - R_{SU})}{(R_{UU} - R_{SU})}$$

Where R_{uu}, R_{su}, R_{sw}, and R_{uw} refer to the reflectance values of the fabric samples: (1) not soiled and unwashed, (2) soiled and unwashed, (3) soiled and washed, and (4) not soiled but washed, respectively.

However, the actual amount of soil in textiles as determined above does not seem to correlate well with the visual ranking. In such cased the evaluation of soling is done by colour difference. The X, Y, Z tristimulus values are measured with a colorimeter. Then the colour difference is given by

$$\Delta C = [(\Delta X)^2 + (\Delta Y)^2 + (\Delta Z)^2]^{1/2}$$

Where ΔX, ΔY and ΔZ represent the differences in X, Y, Z values of the soiled and unsoiled samples. The degree of soiling of the ith sample is given by Equation

$$DS_i = \frac{\Delta C_i}{\Delta C_O} * 100$$

Where ΔC_i is the colour difference of the ith sample and ΔC_o is the colour difference of the sample showing the least amount of soil on it.

A radioactive tracer technique has been employed for determining the amount of soil deposited or released from the fabric surface. By determining the amount of radioactive soil present, one can calculate the degree of soiling or soil release. An approximate idea of the amount of soil can also be obtained by using fluorescent dyes.

ii) Other experimental techniques

Different experimental techniques which give useful information about the physico-chemical and mechanical aspect of soiling and soil release are discussed below.

- **Microscopic Techniques-** Optical and electron microscopic techniques have been employed to study the nature, location and distribution of soil retained on the fabric surface as well as the manner and efficiency of soil removal under various conditions of soiling and laundering and also to assess the influence of fabric and yarn construction, fiber morphology, and surface characteristics in promoting entrapment and retention of soil.
- **Surface Energy-** The surface energy of the fiber-soil interface is an important parameter which cannot be measured directly on the fabric. However, the relative surface energies can be determined from contact angle measurements employing the method developed by Zisman. In this method, contact angles of a number of liquids of different surface tensions on the fabric surface under investigation are determined. A plot of the cosine of the contact angle against the surface tension of the liquid is a straight line which, when extrapolated to cosine1 ($\theta = 0^0$), gives the critical surface energy of the surface. Since the fabric surface is not flat, the fabric geometry (yarn and fabric to the surface) and the capillarity of the fabric in addition to the surface energy. Hence the contact angle of the liquid of the lowest surface energy that does not wet the surface and the contact angle of the liquid of the highest surface energy that does wet the surface should give the critical surface energy of the fabric surface. The values of the oil-air interfacial energy of

the fluids obtained in air should be useful as a guide to the resistance of the fabric to fluid soiling; and the values of the critical surface tension for wetting in water, as a guide to the phenomenon of wet soiling and ease of soil removal. Contact angles are measured with a telescope goniometer. The critical surface tension for wetting of the fabric in air is determined by placing on the fabric drops of several liquids of different surface energies, while the critical interfacial tension for wetting of fabrics in water is determined in an analogous manner by using a series of liquids having different interfacial tensions against water.

- **Work of Adhesion-** Equally useful information can be obtained by determining the work of adhesion W from the Young-Dupre Equation using some suitable oils as reference material.

$$W=v\,(1+\cos\theta)$$

Where v is the surface tension of the oil in air or the interfacial tension of the oil against water, and θ is the contact angle. It is, however, necessary to use an oil with a contact angle greater than 90^0 in air, because if it is less, it will wet the fabric surface. As the soiling increases, the work of adhesion in air decreases, indicating difficulty in wetting the fabric surface with water. A decrease in the work of adhesion of oil in water, on the other hand, indicates good detergency, since soil becomes easily removable in the detergent solution.

- **Wettability Test-** In order to get good soil removed, complete wetting of the fabric is very essential for the effective interaction with the wash liquor. Simple test (AATCC-17-1952) can be carried out by noting the time taken by the test fabric to become wet with distilled water. Increased wettability, i.e., a decrease in the time taken to wet the fabric surface, indicates better detergency.

- **Zeta Potential-** Under the conditions encountered in practice, most soil particles are charged. As a result there is an interaction between the electrical double layers of the fabric and soil particles in water and this interaction has an important effect on detergency. Since the electrical potential of soil particles is essentially constant, the relative interaction potential between fabric and soil is obtained from the zeta potential of the soiled fabric. The zeta potential in and aqueous electrolytic solution is determined by the streaming potential measurement. One g of fabric is plugged between the electrodes of the cell, the streaming potential is measured with an electrometer. The zeta potential is calculated from the equation

$$S = \frac{4\pi\eta}{D} \, \frac{E_S . S}{P_S}$$

Where E_S, is the streaming potential for the applied pressure P_S (Cms. of mercury), D and n are the dielectric constant and coefficient of viscosity, respectively, and S is the streaming cell constant. A decrease in the negative zeta potential indicates good detergency action.

Two forces which interact between the soil and fabric in the detergent solution are London-Van der Waal's attraction an electrical double layer interaction. The work of adhesion is based on London-Van der Waal's attraction, and the zeta potential is based on electrical double layer interactions. The combination of work of adhesion and the zeta potential correlates well with the detergency curve.

- **Hardness-** Another basic parameter in adhesion is the area of contact between the soil and the fabric. Since the strength of the bond depends on surface interactions at the interface, its overall strength will be proportional to the area of contact. A large area of contact between the soil particles and the fabric would result if the fiber surface is soft so that the soil particles could get embedded in it. Studies have shown that the embedding of soil particles in the soft surface coatings on the fabrics treated with thermoplastic finishes is responsible for soil retention. Hence, it would be useful to know the hardness of a fabric surface which has been chemically treated to impart durable press and soil release properties at laundering temperatures. Unfortunately, the hardness of a fabric surface cannot be measured directly, but measuring the hardness of films of these finishes. The changes in the hardness of these films and the adhesion of pigment particles are to be studied as a function of temperature. Earlier studies have shown a rough qualitative correlation between fabric soiling and temperature as well as the hardness of the films.

- **Capillary Rise-** Capillary rise has been found to be the physical property most closely associated with soil release. Liquid columns rise either between fiber in a yarn or within the interyarn spaces. In the capillary rise method small oil drops are applied at one end of the yarns removed from the fabric under investigation.

These yarns re suspended vertically from a horizontal support and lowered into a suitable dye solution. The ratio of the colored length for the untreated yarn to that for the treated yarn had been found to correlate well with the soil release properties. As the value of the capillary rise ratio decreased, the soil release property improves.

To assess the importance of the hydrophilicity of fibers, the following properties are studied: surface charge density, dielectric constant, conductivity, moisture regain, and permeability of the fabric to air and water.

2.2 Research Review

2.2.1. Researches, Textile parameter and finishes for UV Protection

Summer clothing is usually made of cotton, viscose, rayon, linen, polyester, or combinations thereof. Other types of materials, such as nylon or elastane, are also found in bathing suits, nylon stockings, and other garments. Consumers generally consider lightweight no synthetic fabrics (cotton and linen) to be the most comfortable for summer wear. Comparison of the UPF of different types of material is difficult and possible only in limited situations. This is because certain production steps (dying and finishing) vary based on the material, resulting in a comparison of the "material-color-finish" combination and not of the material itself. In the case of synthetic fibers, such as polyester and polyamide, an analysis is even more difficult because the UV protection of these materials depends on the type and quantity of additives to the fiber, such as antioxidants or UV stabilizers. In accordance with most studies, the type of fiber used to construct a textile can have a substantial effect on the UPF.

Menter and Hatch (2003) reviewed about clothing as solar radiation protection. The sun is essential for life. Yet, sunlight can also be a source of such deleterious effects as sunburn, and suntanning, as well as premalignant and malignant lesions. These may all occur in individuals with normal responses to sunlight. or visible wavelengths. (83)

Hoffmann et al (2001) in his article has updated information on test methods and standards for determining the UV protection of apparel textiles and on factors affecting UV protective properties of fabrics, from dermatological and textile technological viewpoints. Articles from dermatological and textile technological journals published from 1990 to 2001 were identified from MEDLINE, *Excerpta Medica*/EMBASE, *World Textiles*, and *Textile Technology Digest*. Peer-reviewed dermatological articles, textile technological research articles, and normative publications were selected. Independent data extraction was performed by several observers. Spectrophotometry is the preferred method for determining UV protection factor of textile materials. Various textile qualities affect the UV protection factor of a finished garment; important elements are the fabric porosity, type, color, weight, and thickness. The application of UV absorbers in the yarns significantly improves the UV protection factor of a garment. With wear and use, several factors can alter the UV protective properties of a textile, including stretch, wetness, and degradation due to laundering. Standards in the field exist in Australia and Great Britain, and organizations such as the European Standardization Commission in Europe and the American Association of Textile Chemists and Colorists and the American Society for Testing and Materials in the United States are also establishing standards for the determination and labeling of sun protective clothing. Various textile qualities and conditions of wear and use affect UV protective properties of apparel textiles. The use of UV blocking fabrics can provide excellent protection against the hazards of sunlight; this is especially true for garments manufactured as UV protective clothing. (55)

Nature of Fibers and UV protection

The ability of natural pigment in cotton to absorb UV radiation by eliminating the effect of construction was studied by **Gorensek et al (2007).** Plain weave, raw, lightweight cotton fabric was used. Desizing, blank bleaching, blank dyeing and bleaching and dyeing processes were performed. To confirm the presence of the natural pigment in cotton by simple-whiteness hue detection using CIE equation. Cover factor was calculated using the results of image analysis. Waxes and pectin's on raw cotton fabric were determined using FTIR analysis. UV transmittance was determined on Varian Cary IE UV/Vis spectrometer. The results showed that the desizing stage had the greatest effect on the increase of the cotton fabric cover factor. The whiteness hue, and the higher UPF value of blank-bleached dyed cotton fabric versus the UPF value of bleached dyed cotton fabrics, indicated the presence of a natural pigment in raw and blank-treated samples. The presence of the natural pigment in cotton enhanced UV protection. Despite the lower cover factor, the raw sample had a UPF value of 13.3. with a decreasing concentration of the natural pigment, UV absorbance decreased and was almost four times less on bleached samples than on raw cotton. (41)

Malik and Arora (2003) in their study illustrated the effect of UV radiations on different fibers such as:

Silk – Silk comprises of various amino acids like Glycine, tyrosine etc. and they are linked by the polypeptide linkages. As the silk is exposed to UV radiations the quality of damage was assessed in terms of its colour, strength and resiliency.

Wool – When exposed to UV radiation wool fabrics undergo photo tendering. There is loss in tensile strength and abrasion resistance as per the exposure time but the tear strength decreases much faster at the same level of exposure. Also, there can be photo yellowing of wool fabric.

Cellulosics – The effect of UV radiation on cellulosics leads to the free radial formation reaction. The chemical reactivity depends upon the degree of crystallinity of samples and type of crystalline lattice.

Polyester – PET is degraded rapidly by direct UV radiation exposure due to the present of ester carbonyl group. Exposure of PET to light results in the cleavage of ester groups and the production of carboxylic, phenolic and ethylenic groups, carbon monoxide and carbon dioxide.

Polyamide – Irradiation at wavelengths less than 300 nm causes direct photolysis of amide groups and especially in the absence of oxygen.

Polypropylene – Irradiation of isotactic polypropylene leads to the rapid production of hydroperoxide and carbonyl groups and to the scission of polymer chains, resulting in decrease in tensile strength and elongation at break. (80)

Gambichler et al (2001) investigated 236 apparel textiles of different fiber type, construction and colour of the spring/summer collections 2000 and 2001. Cotton, wool, linen, viscose, polyamide, polyester and different mixture of polyester, linen, viscose and cotton fabrics. In accordance with the forthcoming European standard the UV protection factor (UPF) of the fabrics was determined spectrophotometrically. Results showed that seventy-eight (33%) fabrics had UPF < 15, 45 (19%) had UPF = or > 15 and < 30, and 113 (48%) had UPF = or > 30 (30+). More than 70% of the wool, polyester, and fabric blends, and only less than 30% of the cotton, linen, and viscose fabrics had UPF values of 30+. Fabrics with black, navy-blue, white, green, or beige colours provided most frequently UPF values of 30+. (37)

Davis S. and et al (1997) examined the effectiveness 28 fabrics for their relationship to UVR transmission to determine if certain fabric characteristics (independent variables), such as cover (the degree of closed versus open space in a fabric), mass, fiber type, fabric, count, structure or colour [specimens from each of the four cotton fabrics were dyed blue using Procion M Midnight Blue fiber reactive dye (3% shade based on fabric weight, 50:1 liquor ratio)], could be used to predict the solar-protective performance of fabric. The fiber type tested were cotton, wool, polyester, nylon, linen, acetate, acrylic, rayon, and two blends, polyester/wool and polyester/cotton. The dependent variable, UVR transmission, was measured using a spectrometer fitted with an integrating sphere and a filter to block fluorescence.

It was found that all white cotton, linen acetate, and rayon samples had an SPF less than 15. Polyester fabrics had higher SPF values and offered higher protection than other fiber types in comparably constructed fabrics. Polyester blends significantly increase a fabric's SPF.

Fabric SPF generally increased with increase in mass or weight, but the relationship was not linear. Fabrics which are closely woven or knit with small spaces between yarns have a higher SPF than those which are loosely woven or knit. In the few cotton samples tested, it was noted that the addition of dyestuff increased the protectiveness of the fabric from solar UVR. (21)

Genkoy and Atmazo examined 75 fabrics to determine whether a difference in UVR transmission existed between fabrics made from nylon, polyester, cotton and cotton blends. They concluded that a fabric's UVR permeability to ultraviolet radiation than natural fibers.

Welsh and Diffey compared several samples of cotton, nylon, polyester and wool fabrics. They concluded that with the exception of cotton, fiber type has little effect on UVR transmission of a fabric. They explained that cotton fabrics generally offer better UVR protection than knitted nylon or polyester because cotton fabrics lend to be tightly woven.

Fabric construction and UV protection

Gabrijelčič et al (2009) analysed the influence of the fabric surface cover factor and fabric colour values on the degree of UV ray transmittance and the UV protective factor (UPF). The research was carried out on lightweight coloured fabrics woven in sateen weave with different densities of warp and weft threads and with different colours in the weft. Measurements of the UPF were performed using the "in vitro" method in the range of UVA and UVB ray wavelengths, from 280 to 400 nm. The results of the research confirmed the importance of the fabric surface openness for the UV protective factor and exposed the influence of the fabric face and reverse sides as well as of colour values L*, C*ab, hab of warp and weft threads on the UPF in sufficiently closed woven constructions. Namely, the higher the surface openness, the lower or more negligible the influences of other factors on UPF values are. The colour of a fabric plays an important role in UV ray protection in the samples with a sufficiently closed surface. Especially black and blue colours exhibit high absorbance in the UV wavelength range and provide excellent protection when the samples are highly closed (compact). Other chromatic colours, such as red, yellow and green also offer adequate (very good) protection against UV radiation. Comparison of the influence of such colour values as the lightness L*, chroma C*ab and hue hab on UPF values highlighted that only lightness can be directly mathematically connected with the UV protective factor. In the research, chroma and hue did not show sufficient correlation with UPF values. The construction of a fabric in sateen weave provides different types of protection against UV radiation with dependence on the openness/closeness of the face side and colour combination on the face and reverse sides. This fact should be considered when samples with interchanging colours on the face and reverse sides, following the pattern, are designed. The colour white does not provide good protection against UV radiation regardless of the constructional parameters of the samples. (34)

Various chemical processing to protect fabric from U.V radiation

Ibrahim et al (2009) dealt with enhancing the UV-protecting properties as well as the antibacterial activity of knitted cotton fabrics against two kinds of bacteria: gram-positive bacteria (G +ve), i.e., *Staphylococcus aureus (S. aureus)*, and gram-negative bacteria (G -ve), i.e., *Escherichia coli (E. coli)*. Results showed that the extent of improvement in the UPF values are determined by: the fabric structure, i.e., Interlock > Pique > Parasol, pretreatment history, i.e., gray > scoured > bleached, type of softening agent, incorporation of the UV-absorber in the softening bath as well as sequence of addition, in addition to the nature of the deposited metal-oxide, i.e., Cu > Zr > Zn ⋙Al ≈none. On the other hand, the antibacterial activities of the treated substrates against G +ve and G -ve bacteria are outstandingly improved by using the proper: fabric structure, i.e., Parasol > Interlock > Pique, state of the untreated substrate, i.e., bleached > gray, finishing additives and regime, i.e., soft finishing (using polysiloxame softener - Adasil® SM) and UV-protecting (using UV-absorber, Tinofast® CEL) in one step > Tinofast® CEL-finish > Adasil® SM-finish > full-bleaching, as well as deposited metal oxide, i.e., Zn > Cu > Zr > Al > none. Combined soft-finishing and UV-cutting as well as *in* situ deposition of proper metal oxides, onto and/or within the knitted substrates, options exhibited both an excellent UV-protection and prominent antibacterial activities. (60)

The effects of cover factor, double layers of fabric were investigated by **Gorensek etal (2007)**. Furthermore, the influences of monofluoro-s-triazine reactive dyes with azo and formazan chromogens on the UPF of single and double layered, lightweight, cotton fabric were examined. Lastly, the influence of UV absorber Tinofast CIE applied by an exhaust dyeing process on the UPF was determined. In the study cotton bleached, unmercerized, lightweight cotton fabric was used. Three dyes Cibracron yellow F-4G, Cibacron Red F-B and Cibacron Blue F-R applied at a concentration of 0.5% o.w.f and 3% o.w.f. The yellow and red dyes were azo dyes and the basis of the blue dye was metalcomplex-formazan. Reactive groups were monofluoro-s-triazine. UV transmission and reflectance were measured according to AATCC test method 183-1998 on a Varian Cary 1E spectrophotometer. Bleached cotton fabric was subjected to the dyeing process to account for dimensional changes during dyeing. The result showed that yellow, red and blue reactive dye used at a concentration of

0.5% owf caused a slight increase in the UPF of the dyed fabrics, but the UPF remained low. The fabrics dyed at 3% owf with red and blue reactive dyes had good UPF values. Tinofast CIE with reactive dyes resulted in mostly good UPF values not only on dyed fabrics, but also on a blank-dyed fabric. Considerably higher UPF values were achieved when a blank-dyed fabric was combined with a dyed fabric. Greater UV protection resulted when the blank-dyed fabric was facing the source of UV radiation and the dyed layer facing the skin. (43)

To enhance the UV-protective property of cotton fabrics an attempt has been made by **Zheng et al (2007)** to use ZnO nanosol as a finishing agent in combination with pigment dyeing. ZnO nanosol was successfully prepared and dispersed uniformly in the pigment dye liquid bath using a specified dispersant and dispersive method. The distribution and configuration of ZnO nanosol on the fabric was observed using scanning electron microscopy and changes in the performance properties (dry wrinkle recovery angles, tensile strength, tear strength of the treated fabrics were investigated. To investigate ZnO nanosol durability on the fabric UPF value evaluation were made before and after 0, 10, 20, 30 laundering cycles in the automatic washer. Colourfastness to crocking, light and washing were also measured. The results showed that the UPF of the finished fabrics reached 50+. The use of the adhesive increased the washing durability of ZnO nanosol and pigment on the fabric. After 30 laundering cycles, the UPF values of the treated fabrics decreased slightly. Fabric physical properties, K/S values, and colourfastness teats on the treated fabric showed no negative effects from the fabric treatment. (139)

Grancaric et al (2006) studied the influence of various cotton damask fabric pretreatments, as well as the influence of Fluorescent Whitening Agents, on the Ultraviolet protection factor (UPF). Cotton damask fabric was enzymatically scoured and bleached under industrial conditions, then mercerized with or without zeolite addition, cationized and treated with FWA and UV absorber. Breaking force, breaking elongation, relative fluorescence intensity, degree of whiteness, and UPF was determined. The influences of pretreatments on the mechanical properties of the cotton fabric were investigated as well. The results showed improved mechanical properties after mercerization, but no significant change for additional treatments during mercerization. In general, cotton fabrics that have been mercerized have higher relative intensity of fluorescence values than mercerized fabrics. Fabrics with the UV absorber show somewhat lower fluorescence than untreated ones, with the exception of two cationzed samples. Increasing the FWA concentration beyond the optimal level causes a decrease in fluorescence intensity to occur. The whiteness of cotton damask fabrics treated with FWA and UV absorber show the same effect, but the degree of whiteness is slightly lower than for fabrics treated only with FWA. UPF of EB (Enzymatically scoured and bleached) fabric was relatively low. Pretreatment increased the UPF, but the values are still low, ranging from a UPF of 10.95 for EBM (enzymatically scoured, bleached and mercerized) to 13.84 for EBMZ (Enzymatically scoured, bleached and mercerized samples with zeolite added). In every wet treatment of cotton, the fibers swell, leading to fabric shrinkage, shrinkage and changes in fiber structure during mercerization process especially with the addition of a cationic compound and zeolite increased UPF as well. Cotton fabrics with the highest relative intensity of fluorescence also have the highest UPF. For fabrics treated with FWA concentration higher than 0.60% owf, all mean UPF values are significantly higher than 40, which is considered excellent protection. Treatment of optically brightened damask fabrics with UV protective agents resulted in excellent protection for the whole range of FWA concentrations. (45)

Rosinkaya et al (2005) studied the effect of properties, concentration and ratio of the dyes in the ternary mixtures on the UV-protection ability of the dyed cotton fabrics.

For the study reactive manochlorotriazine dyes i.e. Procioness (BASF), Yellow HE4R, Red HE3B, HE7B, Cibacrones (CIBA): Golden yellow RE, Yellow GE, Brillant Red 4GE, Red FB, Blue FGF, Brown 4RRA, Navy HEXL, Violet 2RD, Turquoise Blue GL were used for dyeing them individually at the concentrations: 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2% o.w.f., and in the ternary mixtures at the total concentration:0.3, 0.6, 1.0, 1.2% o.w.f, ratio of components in the mixture was 1:1:1, 2:1:1, 1:2:1, 1:1:2, 4:1:1, 1:4:1, 1:1:4. were used.

The experiment included two stages.

a. Dyeing with the chosen reactive dyes individually at all the mentioned concentrations.

b. Dyeing with the ternary mixtures of the mono chlortriazine dyes at aforementioned conditions.

The measurement of transmittance and calculation were done. Results stated the comparison of the values UVA, UVB – transmittance and UPF for the fabrics dyed with individual dyes and their ternary mixtures, shows that in the first case may be higher or lower than the second, because the first ones are dependent only upon the properties of the dye itself. Since the compatibility does not influence on ht UV-protection ability of the dyed may display additively in the UV-protection action. In the case of mixture if the total quantity of the dye in one of comparable substrates is higher, its UPF also must be higher. It was found that UV protective action is due to the covalent bond between the dyes and cellulose fiber and intermolecular interaction of the linked dyes. (103)

Titanium hydrosol was prepared by **Peng et al (2005)** to enhance the ultraviolet protection factor (UPF) of cotton fabrics. The cotton surface morphology was determined using JSM 5600LV Scanning Electron Microscopy operating at 10KV. The UPF was measured using a UV1000F transmission analyzer according to AS/NZZ 4399-96. The UV transmittance of treated fabrics decreased considerably after hydrosol treatment because the nanoscale titanium gel particles on the fibers could strongly block the UV rays. Hydrosol, assisted by a fluorescent whitening agent (FWA), further improved the UV protection property and eliminated the yellowing incurred by sol treatment. The use of adhesive could increase both the washing durability and UV protection property of the fabric. The UPF of the treated fabric increased further after 60 home launderings from 240.49 to 291.36 while the UPF of the fabric untreated with adhesive decreased from 221.02 to 177.72 with washing. Strength testing (tensile and tear strength) of the treated fabric showed no negative effects from the treatment on the fabrics. (94)

Algaba, Riva and Grews (2004) made an attempt to investigate the effect of fiber type and fabric porosity on UPF of fabrics. Fabrics taken for the study were cotton, modal and treated modal. Fabrics were constructed in plain weave combining three different warp and weft yarn numbers and three weft threads counts. Each set was composed of 27 fabrics covering a wide range of porosities. After weaving the fabric were designed and bleached. Five specimens were taken at random from each set.

Percent cover was determined using an image analysis system. From the results it was concluded that the UPF of the fabric was influenced by their porosity. UPF values increased when percent cover values increased. UPF was influenced by fiber type also.

Bleached cotton fabrics proved to be very transparent to UV radiation even for very compact fabric structures. Undyed modal used in this study provide better sun protection than bleached cotton tested and the treated modal fabrics proved to be very protective as compared to other two. Fabrics porosity has significant effect on UPF values. (2)

The influences of conventional acid and alkaline high temperature dyeing procedures on fabric construction were investigated by **Gorensek and Sluga (2004)** in their study. The effects of weave construction, orange, red, and blue disperse dyed, double layer of fabrics and UV absorber on the UPF of polyester fabrics, satin weave has been done. A spectrophotometer with an integrating sphere is used to measure the UV transmittances of polyester fabric according to an AATCC test. The results stated that a very low difference in the weight of polyester fabrics after blind acid or alkaline dyeing has a definited influences on their UV transmittance. Pale orange and blue dyed fabrics shoed a high enough UPF, while pale red dyed fabric does not reach such values. Deep dyed and doubled layered fabrics and fabrics after treated with UV absorber reach high UPF values. (42)

Haerri and Harenzi (2002) described an experiment in which application by discontinuous (batch) process – where bleached cotton fabrics, including heavy, closely woven varieties like awning material have a fairly low UPF. Very small amount of "Tinofast CEL" leave cotton textiles of suitable porosity with substantially improved UV screening power. Continuous application by Pad dry thermo fixation process – although the highest degree of fixation – and consequently also the highest UPF – is achieved by exhausting, the absorber can also by applied by padding.

Cold pad – batch process – "Tinofast CEL" can be applied together with "Cibacron C" dyes in a cold pad – batch process. Polyester / cotton blend 50/50 – upto to 2% "Tinofast CEL" can be successfully applied by the falling high temperature one – bath dyeing methods.

Polyamide – The absorber significantly increases the UPF of polyamide and polyamide elastane blends – preferably applied by exhaustion, it can be used in conjunction with acid dyes (48)

Veatch and Gatewood (2002) examined the relationship between dye fading, UV transmission and UPF values. They determine if a change in the UPF value of dyed fabrics occurs once colour has been lost or has shifted due to light exposure in 22 direct, 11 reactive, 31 acid and 19 disperse dyes applied to cotton and spun nylon 6,6 plain weave fabrics. All dyes were applied at a concentration of 0.5% owf. Dyed samples were exposed to xenon light in an WeatherOmeter. Transmittance was measured by spectrophotometer. Results showed that all the dyes except C.I. Acid yellow increased the UPF of cotton and nylon fabric greater than 15%. Most of the direct and reactive dyes increased UPF values greater than 30. Even though many of the direct and reactive had appreciable colour change in the visible region after exposure to xenon light. The acid and disperse dyes were somewhat less effective inn increasing the UPF of nylon fabric, but most of the UPF values were greater than 15 and somewhere greater than 30. The Xanthenes and triarylmethane dyes exhibited substantial fading with colour difference values greater than 40 and 80 AFUs, whereas many of the other dye types had substantially less colour change or fading. Some of these dyes had almost a complete colour loss. Many of the xanthenes and triarylmethane dyes also exhibited a reduction in UV protection after extend light exposure on the nylon fabric. (127)

N. Abidi, et al (2001) worked on the UV transmission of woven and knitted cotton fabric, the most common textile for summer clothes. They investigated the effects on the UV permeability of: (1) fabric structure, (2) dyeing with reactive and direct blue, using the conventional dyeing method for direct and hot reactive dye, and (3) chemical cross-linking with an UV absorber Rayosan, which was applied by the exhaustion method. The concentration of rayosan on the weight of the fiber (wof) was varied between 1 and 10 %. Results show that undyed and untreated fabrics (woven or knitted) have high UV transmission and, therefore, little protection. However, when dyed, the dyed fabrics could provide better protection than undyed fabrics. This protection depends on the type of dye, its concentration and the type of fabrics. The chemical cross-linking of undyed fabric with UV-absorber appears to be the best way to increase its UPF and to provide an excellent UV protection. (1)

Sharma and Singh (2001) in their study have used cotton fabrics to develop sun-protective textiles. Three types of cotton fabrics one in plain and two in drill weaves were selected. UV study of eight reactive dyes i.e. R/F/Supra red HRBL, Reactofix Red ME4BL, Reactofix Red HE7B, R/F-Navy blue MEBL, Supra black HBL, R/F-Golden Yellow MERL, R/F-Golden yellow HER and R/F3-Gold yellow HRNL was also conducted to see absorbance in the UV region. These dyes were applied in two concentrations to cotton fabrics by exhaustion method. The fabrics were also treated with Rayosan C and optical brightener. The UPF values were measured on 1000F UV analyzer. Results clearly indicated that tight fabric construction offers higher protection as compared to lighter ones, Reactive red 141 and reactive black 5 were found to be quite effective in cutting UV rays. Darker shade imparts higher protection against UV rays compared to lighter one. Finishing with UV absorber and Optical brightening agent treated fabrics also imparts good UV protection to the fabrics. (110)

Several factors influence a material transmission properties, including weave, weight and type and colour of the dyes used. The effects of stretch, wetting and repeated wash cycling on a range of fabric samples are studied by **Clark et al (2000).** To assess the effect of different treatments, a range of commonly used fabrics were selected. The effect of dyes on the spectral transmission was investigated by dyeing, dyed used were yellow, red, royal blue and almost black. Fabric stretched in all directions or primarily in one direction to investigated the effect of areal and linear stretch. In all the cases the CPF decreased with stretching, with knitted fabrics. The samples washed with water only, non-biological and biological detergents were done with and without a conditioner added. To investigate any difference that might occur between an experimental wash programme and a real-life situation, a T-shirt was used in a wash/wear test. It was concluded from the study that in general, dyeing a fabric decreases the transmission of UVR and therefore increase the CPF. The composition and fiber content play a major role in determining the spectral transmission of a fabric. Wetting a fabric generally decrease its CPF but occasions increases have been observed, washing a fabric generally increases the CPF. The amount of change observed is affected by the detergent used and whether or not conditioner was present in the final rinse. When a garment is worn and then washed in repeated cycles it was observed that, after the initial wear almost all of the increase in CPF was due to washing. (12)

Zhou and Crews (1998) studied eight fabrics, fabric type included 100% cotton sheeting, 100% cotton broadcloth, 100% cotton knit, 50/50 PET/cotton, 50/50 PET/cotton knit, 100% PET, 100% nylon, 100% supple nylon. Fabric samples were subjected to 20 home launderings using detergents with and without an optical brightening agent (OBA) and dried according to the AATCC guidelines for standardization of Home Laundering Test conditions. The results showed that laundering clothing with detergents containing an OBA is an effective medium for improving the UV-blocking of cotton fabrics and polyester/cotton blend fabrics but not 100% nylon polyester fabrics. The implication of this finding is that the UPF rating of a cotton or polyester/cotton fabric not only be maintained but can be significantly enhanced by repeated laundering of the garment in a detergent containing OBA. (104)

Work on the sun protection factors (SPF) of cotton, wool, silk, polyester, polyamide and polyamide/elastan fabrics and their improvement by the means of UV absorbers was described by **Reinert et at (1997)**. A fabric's SPF is determined by the chemical structure of its constituent fibers and the substances present on and in them and by its structural characteristics (porosity, thickness, dimensional stability, elastic properties etc.). Fabric of cotton, silk, polyamide and polyamide/elastan (these last two with only a low delustrant content), particularly in pale shades, were found to give too little protection against intense UV radiation. If they are close woven or knitted, that is if their porosity is low, their performance can be improved by treatment with UV absorbers. (101)

UV absorbers and antioxidants topically applied to upholstery fabrics to reduce fading, separately and in conjunction with soil repellent finish formulations containing UV absorbers, were evaluated by **Patricia et al (1990)**. Over fifty upholstery fabrics were initially evaluated and fourteen were selected for further study. The fabrics were then topically treated with commercially available soil repellent finishes (a fluorocarbon and a silicone finish) containing UV absorbers or immersion-treated with one of thirteen UV absorbers or antioxidants. Following light exposure, color changes were evaluated visually and instrumentally. The results showed that neither the fluorocarbon nor silicone- based soil repellent finishes containing UV absorbers significantly reduced fading in the upholstery fabrics. Furthermore none of the UV absorbers and antioxidants applied to the upholstery fabrics improved lightfastness properties substantially, so they cannot be recommended as additives to soil repellent finish formulations. (92)

Effect of wetness on UV protection

Crews and Zhou (2004) determined whether wetting fabric in distilled water, sea-water or chlorinated pool water resulted in significantly different UVR transmission values. Thirteen undyed woven fabrics of five different fiber contents (rayon, nylon, cotton, silk and polyester) were selected. UPF transmission was evaluated in dry state and in wet state. Results showed that water type does not significantly affect the UVR transmission or the UPF values of a given fabric. The results showed that no compelling needs to measure fabrics wet out in all three types of water-pool, sea and distilled – when evaluating them for UV – protection labeling. The polyester fabrics included in this study exhibited slightly higher UPF values when wet than dry. (14)

Due to limited data about the effect of fabric wetness on UPF, **Gambichler et al (2002)** undertaken the study to investigate the following: (a) the effect of saturating a variety of fabrics with tap water and with salt water on fabric UPF and (b) whether wetted-fabric UPF values reflect only the fact that the fabric is wet during testing or the fact that the skin is hydrated and the fabric is wet. For objective a, 69 summer fabrics were spectrophotometrically (*in vitro*) assessed when "dry" and when saturated with tap and salt water. *In vitro* UPFs, percent UVA transmission and percent UVB transmission values were calculated from the transmission data. For objective b, 100% cotton and 100% polyester fabrics were tested *in vivo* to determine *in vivo* UPF values. The minimal erythema dose (MED) was determined for each of the 12 subjects on unprotected "dry" skin and on "hydrated" unprotected skin. $\text{MED}_{\text{protected}}$ was determined when the subject's skin was covered with "dry" and with saturated fabric. *In vivo* UPFs were calculated using this data. Student's paired *t*-tests were used to determine the effect of wetting.

With one exception, *in vitro* UPF values were the same when the fabrics were saturated with tap water and when they were saturated with salt water. However, saturating the fabrics with water had different effects on the UPF, UVA transmission, and UVB transmission values. For linen, viscose and polyester fabrics, UPF significantly increased. For the cotton fabrics and the polyester + TiO_2 fabrics, UPF significantly decreased. For the modal + TiO_2 fabrics and the polyester crepe + TiO_2 fabrics, UPF significantly increased. From the *in vivo* testing, the MED of the "hydrated unprotected" skin was not different than the MED of "dry unprotected skin." Values obtained from subtracting dry-fabric *in vivo* UPF values from dry-fabric *in vitro* values and subtracting wet-fabric *in vivo* UPF values from wet-fabric *in vitro* values are not different. (36)

Wang et al (2001) determined the UV protection factor (UPF) of two types of white cotton fabrics (cotton T-shirt and mercerized cotton print cloth) used in the manufacture of summer T-shirts and to explore methods that could improve the UPF of these fabrics. Fabrics were given four treatment i.e. (1) water-only (machine washed with water), (2) detergent-only (washed with detergent), (3) detergent-UV absorber (washed with detergent and a UV absorber), and (4) dyes (dyed fabrics). Ultraviolet transmission through the fabrics was measured with a spectrophotometer before and after laundry and dyeing treatments. Based on UV transmission through these fabrics, the UPF values were calculated. *The Result showed that b*efore any treatments, the mean UPFs were 4.94 for the T-shirt fabric and 3.13 for the print cloth. There was greater UVA (320-400 nm) than UVB (280-320 nm) transmission through these fabrics. After 5 washings with water alone and with detergent alone, UPF increased by 51% and 17%, respectively, for the cotton T-shirt fabric by causing fabric shrinkage. . Washing the T-shirt fabrics with detergent plus the UV-absorbing agent increased the UPF by 407% after 5 treatments. Dyeing the fabric blue or yellow increased the UPF by 544% and 212%, respectively. Similar changes in UPFs were observed for the print cloth fabric. (118)

Test methods for quantitative assessments of UV protection of textiles

The effect of fabric type, colour, fit and wetness on transmission of solar erythemal ultraviolet radiation through garments was investigated by **Wilson and Parisi (2006)** using laboratory testing and during simulated wear using a multivariate experimental design. Transmission of UV through two knit fabrics cotton/elastane jersey and polyester eyelet in each of two colours (black and white) and two states of wetness (dry and wet) was determined under laboratory conditions using a spectrophotometer. Garments were also evaluated under conditions of simulated use in Queensland Australia using polysulphone dosimeters. Dosimeters, placed against the skin at selected sites on the torso and on the adjacent outer-surface of the covering garment, were used to measure solar UVB. During simulated wear the fabric type, fit colour were the main variables affecting UVB transmission through the garments. To optimize protection, dark fabrics with good cover should be constructed into garments with positive design ease, and be selected and worn as loosely-fitting styles that maximize the surface area covered. (134)

The different correlation between in vitro and in vivo measurements of the UPF may be due to the optical, geometrical properties of textiles and the different amount of direct and diffuse radiation passing through the spaces between the yarns. **Gambichle et al (2001)** compared the relationship between in vitro tests and in vivo tests of UPF using solar simulators for determination of the minimal erythema dose (MED), applied to 30 different summer textiles. Thirty summer textiles were spectrophotometrically assessed, and UPFs were calculated with respect to the International Commission on Illumination (CIE) erythemal action spectrum. Based on the in vitro UPFs `on skin' and `off skin', in vivo testing was performed using a solar simulator for the determination of the MEDunprotected and MEDprotected. Researcher found out that the UPFs obtained from in vivo `on skin' testing were significantly (r à 0'95; P, 0'001) lower than the predicted in vitro UPFs. This disparity was also confirmed by chromometric assessment of the MED testing; the erythemal responses measured after textile protection were significantly (P, 0'001) higher than those obtained without protection. However, the in vivo `off skin' UPFs did not significantly (r à 0'98; P. 0'05). differ from the in vitro UPFs; comparison of the chromometrically assessed erythemal responses was also insignificant (P. 0'05).It was concluded from the study that the in vitro test method provides `safe' UPF values representing a `worst-case scenario'. In contrast to in vitro testing, in vivo methods are much more expensive and time-consuming. Thus, with respect to practicality, spectrophotometric measurements seem to be most suitable for the evaluation of UV protection of textiles. (135)

Parisi et al (2000) measured the personal solar UV exposure to the skin through a common summer garment, namely a T-shirt at a number of different human anatomical sites in a field situation during wear and during outdoor activities. The garments employed were 100% cotton black and 100% cotton white T-shirt both in dry and wet conditions. The UV spectrum and the UV spectrum transmitted through each of the materials were measured with a spectroradiometer based on a dual holographic grating (1200 lines/mm). The erythemal UV exposures to a number of anatomical body sites underneath the garment material and erythemal UV exposures above the garment material have been measured with polysulphone dosimeters. T-shirts were wet when they were initially placed on manikin and then wet at approximately 30 minutes intervals for the duration of the exposure period from approximately 9:00 EST to 15:00 EST. Researcher has found a relatively high erythemal UV exposure to the skin below the garment for the wet white T-shirt. For the late spring to summer period, the exposure exceeded a MED at some anatomical sites in summer for a two hour period. An erythemal exposure of 1.7 MED was measured for the white garment during swimming. This is in excess of the occupational limit for the UV exposure. The stretch of the garment over the body while it is worn alters the UPF. This stretch was a result of the garment while being worn and for the swimming activity due to drag of the garment through the water. Additionally, the UPF for the black garment in the wet and dry state was higher than that for the white garment, however, while jogging, the UPF measured on the human in the field while jogging for the black garment was less than that for the white garment.

Clothing must form an important component of a UV protection strategy. However, it must be realised that total UV protection is not provided and significant UV exposure may be received beneath the garment, particularly for a white garment in the wet state. This re-enforces the necessity of a combination of several UV prevention strategies to minimize UV exposure. (91)

2.2.2 Related review for soil-release properties

(a) Researches on starch as barrier

Starch act as pesticide trap and reduce contaminated area and also reduce the pesticide transfer by rubbing. As well as starched cotton fabric enhances removal of pesticide by laundering. **Obendorf, Rocz and Borsa (1998)** studied the carboxymethylate cotton for pesticide protective clothing. It was found that when outer layer of clothing system is carboxymethylate, 30 to 45% more pesticide is trapped by the layer as compaired to untreated. Also carboxymethylate reduces residual pesticide on the cotton fabric after laundering to less than half that of the control fabrics.

Franz diffusion experiments with human skin combined with work-clothing fabric have shown that skin exposure to pesticides is reduced by the presence of traditional nonbarrier textiles. This study was undertaken **Csiszar, Borsa, Racz, Obendorf (1998)** to obtain further information about the reduction in exposure using traditional work-clothing fabrics that had chemical finishing to increase the sorption properties. The effects of a renewable starch finish and chemical modification by carboxymethylation on cotton fabrics on the pesticide (methyl parathion) retention, transfer, and decontamination by laundering were investigated. Two weights of work clothing fabrics made of 100% cotton were used, one appropriate for shirts and the other for pants. The amount of pesticide observed on human skin was reduced by the presence of clothing fabric. Carboxymethylation of the shirt fabric reduced the amount of pesticide observed on the human skin. This treatment also resulted in less pesticide being transferred to a second fabric layer within a clothing system. No pesticide penetrated to the second fabric layer when the heavier pant fabric was used as the outer layer. The lighter weight shirt fabric did not retain as much pesticide as the pant fabric. The pesticide retained on the shirt fabric was increased by the application of a renewable starch finish and by carboxymethylation; both of these finishes were found to be effective in enhancing the decontamination of cotton fabrics by laundering. (17)

Because many pesticide handlers persist in wearing and reusing conventional work clothes, a renewable functional finish that enhances the pesticide-protective qualities of fabrics would be useful. **Obendorf et al (1991)** investigated the ability of starch to act as a pesticide trap, preventing transfer and increasing removal by laundering, and the effect of carboxymethyl cellulose on release of pesticide in laundry. The retention and distribution of methyl parathion (MeP) on 65% polyester/35% cotton fabric was studied with four finishes: starch and carboxymethyl cellulose (CMC) as nondurable finishes; durable press resin (DP) and durable press/carboxymethyl cellulose

(DP/CMC) as durable finishes. Starching with an add-on of 8% (w/w) effectively reduced the area of contamination and enhanced the removal of methyl parathion from polyester/cotton fabrics. Residual pesticide values for CMC, DP, and DP/CMC finishes were similar to that of the unfinished fabric. While distribution profiles of methyl parathion throughout the yarn and fiber structures were similar for all the finishes, lower concentrations of pesticide were observed on the cotton fibers from the starched fabric. Starch reduced the pesticide transferring by rubbing from both 100% cotton and 65% polyester/cotton fabrics. These studies support the intriguing theory that starch can act as a pesticide trap on the fabric surface to decrease pesticide transfer and to enhance pesticide removal. Extensive penetration studies, field studies, and additional investigation of fiber, yarn, and fabric parameters are needed to further quantify the effects of starch. (89)

(b) Researches on Anti-soiling Finishes

Yatagai Mamiko and Takahashi Yui (2006) study the effect of polycarboxylic acid-based durable press (DP) finishing on the particulate soiling properties of cellulosic fabric under laboratory testing condition. Citric acid (CA) and 1,2,3,4-butanetetracarboxylix acid (BTCA) was applied to cotton, linen and lyocell fabrics in the presence of sodium hypophosphite (SHP) catalyst. Laboratory soiling testes were carried out onunfinished and finished fabrics using iron oxide and carbon black (which a different in hydrophilicity) as soil models.The finished fabrics were tested for wrinkle recovery angle (WRA) and yellowness. The degree of fabric soiling was evaluated by reflectance measurements and K/S calculations before and after soiling.

The CA-finished cotton fabric picked up significantly more iron oxide (less so for BTCA-finished cotton fabric) compared to the untreated control. Both finished cotton fabrics showed excellent resistance to soiling with carbon black compared to the control. Improved soil resistance was also observed in certain finished linen and lyocell fabrics toward iron oxide or carbon black. Generally finishing with BTCA in the presence of SHP resulted in excellent wrinkle recovery and almost negligible fabric yellowing.(137)

Soiling of nylon 66 carpets was studied by **Petrick et al (2006)** to investigated the effect of spin finishes with and without fluorocarbons finishes and in addition, the use of a secondary extraction process was examined to determine the effect of removing residual spin finish oils. Two types of residential carpet of intimate blend trilobal fibers with two modification ratios were evaluated: one had fluorocarbons in the spin finish with an additional topical mill-applied fluorocarbon. The second carpet had no fluorocarbons in the spin finish, but had topical mill-applied fluorocarbon finish so that both carpets had a target of 250 to 300 ppm fluorine. Acetone extraction was used to remove the spin finishes from the carpets. Both the carpets with or without extraction were soiled with particulate soil in the laboratory. Visual ratings and colour difference measurements indicated more soiling on the carpets that had been extracted. Fluorine analysis showed that fluorcarbons were removed from both carpet types with the acetone extraction. Electron microscopy indicated the deposition of soil in the V-groove of the filaments with the higher modification ratio. Furthermore, fiber surfaces near the face of the carpet exhibited higher levels of soil than surfaces located near the carpet blacking. (96)

Vukusic, Katovic and Grgec (2004) studied "The effects of microwave treatment on fluorocarbon finishing". A new device for microwave planar treatment of textiles was constructed. Results of water- and soil-repellency obtained on planar microwave apparatus had been compared with the ones using conventional curing treatment. Microwave technology in textile finishing offers better effects than conventional curing. Only in case of durability to washing, cotton materials treated with microwave showed a decrease. Lower effects, primarily caused by disorientation of fluorocarbon chains, had been improved with thermal re-activation performed after washing and dry cleaning. The greatest advantage of microwave device is that it was constructed at lower production costs, and the elimination of separate drying procedure. Microwave technology was successfully used in the study for the processes of drying and curing, during which different interactions occurred providing an increase in water and oil repellency and lower tensile strength loss. (129)

Upholstery constitutes an important group of fabrics where discoloration from soil is common, appearance is of greatest concern, and cleaning is difficult. Fluorochemical (FC) finishing of upholstery fabrics is a common practice. **Raheel and Hwang (1990)** explored the effectiveness of FC repellent finish on soiling and soil release properties of upholstery fabrics having various fiber contents and fabric geometry toward particulate as well as oily I particulate composite soils. Soiling propensity and soil release properties were evaluated using laboratory techniques as well as visual examination. Results indicate that FC finish affected soiling and soil release properties of fabrics to different extents. Also, overall soiling due to composite soil increased in all fabrics but more prominently in cellulosic fabrics. (97)

Electron beam microanalysis provides information about soiling and soil removal by defining the distribution of residual soils on fibers. Elemental analysis of X-ray emissions from natural soils, such as clay and unsaturated oily soils that have been tagged with osmium tetroxide, yields valuable data on deposition, penetration and retention/removal. Using these techniques, residual oily soil on naturally soil collars and on laboratory soiled fabrics was observed by **Obendorf (1988)** in the inter fiber spaces of the yarn bundle and on cotton and polyester fabric surfaces. Electron microscopy was also used to determine the effectiveness of five commercial detergents in removing oily soil from fabrics. Additionally, the effects of fiber blend levels and durable press/soil release finishes on polyester/cotton were investigated. Oil was found in the crenulatons, secondary wall, and lumen of cotton fibers. Little or no oil was on the polyester fibers except on a few highly damaged fibers. He further stated that particulate soil was not homogeneously distributed rather, it was aggregated on the fiber surfaces, particularly in the cervices between the filament on the yarn surface. Oily and particulate soils were detected in the same location, indicating that they form a multicomponent or composite soil. It was further found that the effectiveness in removal of particulate soil was related to the surfactant/builder system, with the phosphate-built anionic powder detergent being the most effective than the built liquids being more effective than the unbuilt liquid detergent. The study revealed that the addition of an acrylic acid based soil-release finish on durable press finished 63/35 polyester/cotton fabrics reduced the concentration of oil on the surface of the polyester fibers and within the inter fiber capillaries. (88)

A study was undertaken by **Jayashree (1988)** to study the effect of certain pretreatments on physical properties, soiling and soil removal characteristic of resin finished Seri silk. The fabrics were pretreated with 1) 3% Thio-urea, ii) 10% Polyethylene glycol, iii) 1%Ammonium thiocyanate, iv) 2%Formic acid, Physical properties like tensile strength, elongation dry crease recovery angles and stiffness were determined following the standard test methods. Abrasion was carried out by modifying the pilling tester. Both the treated and untreated samples given finishing treatment. Whiteness charcterstics, soil pick-up and soil removal was assessed by measuring the reflectance's. The finishing agents used were Dimethylol dihydroxy ethylene urea and Ahuracryl TX, Polyethylene glycol-600 was used as an additive in the resin bath. The catalyst used was Magnesium chloride. For the study it can be generalized that losses in physical properties (namely tensile strength and stiffness encountered after the finishing treatments can be greatly minimized by appropriate pretreatments, it was observed that among four pretreatments employed best results were given by 3% thio urea and 10% polyethylene glycol. Following the above pretreatments, when the silk fabric was finished with Dimethyloldihydroxy ethylene urea combined with polyethylene as an additive, enhanced the overall performance (64)

Deshpande and Chavan (1983) study the situ polymerization of acrylic acid, acrylamide and their mixture onto polyester/viscous blend fabrics (80:20 and 48:52) and transfer printing with disperse dyes on such modified fabrics. The soil release properties of such modified fabrics have also been studied. Crease recovery angle, breaking strength and bending length were tested. The result showed that stiffness was more in acrylic acid treatment than acrylamide treatment for the same application period. The stiffness of treated samples depends on the time interval between the preparation of the padding bath and the actual padding process. The higher was the interval, the stiffer was the fabrics. The fabrics treated with acrylic acid acrylamide and their mixtures were found to be stained with methylene blue giving medium to heavy shades. The untreated and only resin-treated samples showed faint or negligible tinting. It was observed that the prints on 80/20 blend fabrics were brighter and deeper than those on 48/52 blend fabrics. Transfer prints were evaluated before and after washing. It was found that polymer deposited fabrics show better fastness to washing as compared to untreated and only resin treated fabrics. The cyclic N-methylol compounds, used with the acid polyacrylate soil releasing agents, contributed to permanency of the soil release effect. The staining after washing was less on modified fabrics as compared to that on untreated and only resin-treated samples. The carboxyl groups of deposited polymer provide hydrophilic character to polyester/viscous blend fabrics. The hydrophilic hydroxyl and carboxyl groups promote soil release and thus impart one additional property to the treated fabrics. (26)

The cotton component of cotton-polyester blend fabrics was partially carboxymethylated under different conditions to control the CO_2H content prior to durable-press finishing with dimethyloldihydroxyethyleneurea [1854-26-8] in the presence of $MgCl_2.6H_2O$. The susceptibility of the modified blend fabrics before and after cross linking to aqueous and non-aqueous oily soiling and the ability of the fabrics to release the soil was studied by **Hebeish et al (1982)**. Introduction of carboxymethyl groups into the molecular structure of the cotton component imparted soil release characteristics to the blend provided that the condition of partial carboxymethylation was not accompanied by profound changes in the microstructure of the cotton component or in the polyester content of the blend and that the carboxymethyl content was not too high. The anionic nature of the modified cotton component of the blend during washing helps in repelling the negative charged soil particles. In addition, a reduction in the interfacial tension at the soil, water interface assists in rolling up the soil for subsequent removal. This behavior is reversed if the electrostatic repulsion is masked through the creation of a soft and swollen environment by significantly increasing the carboxymethyl content, decreasing the polyester content, and(or) increasing the accessibility of the cotton component of the blend. (184)

One of the disadvantages of synthetic fibers is their rather strong tendency of soiling. It is a well known fact that the soil once removed from the textile may be redposited on the fibers from the washing bath. **Varga et al(1981)** investigated the effect of various hydrolysis parameters on the soil release property, as well as on the tenacity of polyester and polyester cotton weaves of a given fabric structure. It was found that the soil release ability of fabrics containing polyester fibers may be considerably improved by an alkaline treatment. By the proper selection of the parameters of the alkaline treatment, the decrease of tensile strength may be neglected. (126)

Sello and Stevens (1981) study the effect of Interfacial polymerization technique for deposited polyamide, polyurea and polyurethane coatings on texturized woven polyester. The effect of the coating on soiling characteristics was found to be highly dependent on the specific monomers employed. The most significant improvements in soiling characteristics were obtained with a polyamide coating formed via the polycondensation of piperazine and adipoyl chloride. Soil release problems are associated not only with 100% polyester textiles, but also with polyester/cellulosic blends, especially those treated with durable press resins. Anionic copolymers, perfluoroacrylates containing hydrophilic segments and topical finishes composed of combinations of these are the most effective in enhancing the soil release properties of such blends. (109)

With the advent of synthetic and resin treated cotton fabrics, soiling and soil release behaviour of textiles has become an important criterion for consumer acceptance. To evaluate these properties a reliable soiling method is essential. As part of the programme on development of soil release finishes for resin-treated cotton fabrics, work on the methods of soiling was taken up in ATIRA. **Dave et al (1980)** soiled the cotton by direct and transfer methods using ferric oxide. The soiling conditions for the accelerator method were: 5% soil on the weight of the fabric; 1600 rpm speed and 60 seconds of rotation. For the tumbler method 5% o.w.f, 40 felt cubes and 14 soiling cycles of 10min each (= 140min) were employed). The extent of soiling was determined by measuring the reflectance of the sample using reflection spectrophotometer and was represented by soiling value. Fabrics soiled by the two methods observed under scanning electron microscope.

The following conclusions were drawn from the study:

i. Although accelerator method and tumbler methods were both dynamic methods of soiling, the former simulates natural soiling to a greater extent than the latter method.
ii. Distribution of soil on the fabric was more uniform by the accelerator method as compared to the tumbler method.
iii. Reproducibility of soiling was better with the accelerator than with the tumbler.
iv. Controlling the amount of soil applied to the fabric was easier by the accelerotor method. This was rather difficult by tumbler method.
v. Soiling by accelerator takes only few minutes soiling by the tumbler requires as long as 3.5 hours.

It can be concluded that the accelerotor method of soiling with particulate soils was superior to the FIRA tumbler method. (20)

Cotton and 50/50 polyester/cotton fabrics, untreated and with four formaldehyde crosslinking treatments and two resin finishes, were soiled with oily and nonoily soils and an oily stain. Extent of soiling, ease of soil and stain removal, and the development of yellowness were determined after repeated laundering in a Launder-Ometer by **Reeves et al (1980)**. Soiling and soil removal were influenced more by type of soil, fiber content, process of producing crosslinks, and catalyst than by the chemical composition of the crosslinking agent, although chemical composition did produce some effects. Development of yellowness of untreated and crosslinked fabrics during laundering was attributed to swelling of cotton fiber and cotton content of polyester/cotton blend fabrics. Cross-linking of cotton and cotton/ polyester fabrics by a pad-dry-cure process retarded the development of yellowness. Yellowness developed in both oily and nonoily soiled fabrics. Yellowness was not related to amount of soil on the fabrics. (133)

In a study of the soil removal and soil redepositon tendency of different fabrics by **Bansal (1974)** the following results were reported.

1. When the length of washing period was long equilibrium was established between desoiling and wet soiling tendency of different fabrics. An increase in concentration up to 0.2 percent of cleaning solution had relatively less influence on desoiling and wet soiling tendency, because any influence on desoiling due to the increase in concentration up to 0.2 percent was neutralized by redeposition of soil.

2. Presence of another fiber did not have much influence on soil removal. Very high redeposition of soil took place on nylon and terylene followed by rayon and minimum redepositon of soil takes place on cotton fabrics.

3. When the length of washing period was short, soil redeposition (High) took place only on nylon and terylene while that on other fabrics was nil or negligible during this short period.

4. Effective cleaning depends upon the soil suspending power of the cleaning solution. For effective cleaning, concentration above 0.2 percent soap was found to be necessary. (4)

The soiling behavior in a specific wet-soiling technique of cotton treated with different reactant-type crosslinking agents and metal salt catalysts under different conditions by means of the pad-dry-cure technique has been investigated by **Fiebig and Rezk (1973)** to study the influence of the amounts of reagents and catalysts used in the impregnation solution and bound to the fabric after finishing. Up to about N contents of 1.4% and dry crease-recovery angles of 140°, there was found only slight increase in soiling, but fabrics, which were unnecessarily heavily resinated, showed much worse soiling. An inverse relation was detected between soiling and moisture regain of finished fabrics. The catalyst residues after-found finishing seems to have no influence on soiling. (31)

East and Ferguson (1973) study the soil pick-up and retention of eight common man-made fibres. The fibres (all of which were of 3 den (3.3 dtex) and 1 7/16 in staple) were spun into yarns of a common linear density, which were woven onto a common cotton warp in an identical sateen construction. The fabrics were soiled by the felt-block method, and the results are interpreted in terms of the absorbing and scattering powers of the fabrics as calculated from the Kubelka-Munk equations. It is shown that the most important parameter governing the appearance of white fabrics after soiling is the scattering power, although differences in soil pick-up are also observed. (172)

The soiling behaviour of nylon 66, terylene, polypropylene, tricel, dicel, courtelle cotton, cupraammonium rayon and terycot, tery-vincel blends in aqueous and dry-cleaning media containing fatty and particulate soils is described by **Byrne (1972)**. In aqueous media hydrophobic fibers generally soil more than hydrophilic fibers. In dry cleaning media the opposite is true. The individual contributions to the soiling of textiles are fatty soil, air borne particulate soil and the organic components of air-borne soil were assessed. The water soluble components of air-borne soil are largely responsible for yellowing of nylon in acqueous media. (9)

Yoshiaki and Mino (1970) have studied the difficulty or ease of soil removal from soiled fabric. Cotton, nylon, polyester and wool fabrics were studied with soiled with five oily soils were used with carbon black: Liquid paraffin, squalene, olive oil, lanolin and palmitic acid and were laundered with eight different detergents under various washing conditions.

Variable bath components were surfactant types, water hardness, detergent concentrations and bath temperatures.

The contributions of such fabrics, soil, detergents and bath conditions were estimated by the analysis of variance.

Surfactants are classified by pattern analysis, based on the detergent contribution of the various factors in detergent systems as follow: (1) sulfate group (normal and branched alkyl types) (2) sulfonate group (3) nonionic group (138)

Bubl (1970) study the effect of the variables, detergent type and temperature, on the removal of an artificial soil from cotton fabric during repeated launderings. In six university laboratories in the Western region of he United States, white 80-square cotton fabric was repeatedly soiled with a synthetic sebum and clay. The swatches were laundered in automatic home-type equipment using the following conditions: a built nonionic cold water detergent at both 70^0 and 140^0F wash water temperatures; a built nonionic detergent normally used in heated water at both 70^0 and 140^0F wash water temperature. Swatched that had not been soiled were included in each laundering to study soil redepostion. Samples were withdrawn for gravimetric analyses and reflectance measurements after 6, 12, 18 and 24 soiling and launderings.

Evidence of a buildup of soil on all samples was obtained from the increase in extracted oil and ash content, the decrease in reflectance (R_d values) and the increase in yellowness ("b" values). The mean percentages of total soil removed varied among the laboratories. Clay soil was removed more readily than oily soil. More soil was removed by laundering at 140° than at 70°F. The regular detergent had better detersive action than the cold-water detergent. Water temperature was more important than detergent type in soil removal. Redeposition of soil onto unsoiled laundered fabrics was negligible.

Extraction and ashing gave a better indication of total residual soil than reflectance measurement.

Use of novial filter during reflectance measurement indicated the effectiveness of optical brighteners in whitening fabrics. (63)

The manner in which fluids and particulate soils interact with textiles in actual use, and then respond to normal laundering has been briefly reviewed by **Smith and Sherman (1969).**

It is proposed that the response to laundering of textiles soiled with a water insoluble fluid is a complex function of the viscosity of the fluid stain (or carrier); the intrinsic surface energies of the detergent solution, the fluid and the fibers; as well as the geometries of the fibers and yarns. The effects of a more complicated substrate geometry is to cause a hysteretic change in the dynamic surface interactions of the detergent solution, soiling fluid, fibers in a manner which retards the soil release process.The soiling process which ensues following the contact of a textile with a soiling fluid is a function of many of the same variables as the soil release process. Thus, the degree of the rate of soiling in the dry state has been seen to be a function of the fluid viscosity and the intrinsic surface energies of fluid and fibers and the geometries of the fibers and yarns. The major complication to the view that soiling and soil release are truly reversible processes stems from the change in environment from air (soiling process) to the detergent solution (soil release points).

Dry particulate soiling of textiles appears to involve “geometric” and sorptive” bonding mechanisms. Fluids frequently act as carriers which bond particles to fibers and composite soils of the type respond to laundering (at least in part) as the fluid does in the absence of the particles.

Appropriate textile finishing appears to offer the following virtue with regards to soiling and soil release properties. Elimination or substantial reduction of the surface irregularities of the fibers in the case of a film forming finish. Reduction of the surface energy of the yarn to prevent spontaneous fluid staining by the use of fluorochemical oil repellent finishes. Increasing the surface hydrophilicity of the fibers with high energy, film-forming finishes to increase the likelihood of achieving spontaneous soil release on laundering. (144)

Fort, Billion and Sloan (1966) studied fibers taken from cotton fabrics (clean, use-soiled, and laundry-soiled) and polyester fabrics. Electron microscopic examination of filament surfaces and cross-sections identified both organic and inorganic particulate soil, distributed according to treatment the soiled fabrics had received. The distribution of dirt on use-soiled and laundry soiled polyester fibers is somewhat different. Use-soil is concentrated on the filaments at the exposed surface of the fabric, while laundry soil is distributed over each filament and concentrated at fiber-fiber junction points. In all cases a sheath of organic material appears to spread over the fiber surfaces, with particulate material embedded in the sheath. This fact implies that the surface to which the particulate soil adheres is usually not polyester or cotton but, rather an organic soil film which has previously coated the fibers. This suggested that a deposition of fatty material could be prevented, or if a wash process could be devised which would completely remove the oily constituent of natural dirt, the particulate constituent might give little trouble. Evidence was obtained for the binding of particulate soil to fiber surfaces with a fatty soil adhesive. (32)

Julian et al (1965) determined the relation between the surface energy of cotton finishes, their tendency to become soiled, and the case with which soil is removed from them. The surface energy of finishing materials was characterized by wetting measurements. The critical surface tension for wetting of finishing agents and of the corresponding finished fabrics was determined. The critical surface tension for wetting by organic liquids of these same materials immersed in water was also determined. Cellulose has a high critical surface tension for wetting in air (high surface energy), but it has an extremely low critical surface tension for wetting in water. Due to this low 'surface energy in water, cellulose has a high resistance to wet soiling by hydro phobic soils. Similarly, hydrophobic soils are relatively easily removed from cotton. Silicone and fluorocarbon finishes have low surface energy in air but form high-energy surfaces in water. This leads to a strong tendency for these finishes to become contaminated in water by hydrophobic soils and, correspondingly, these soils are difficult to remove by laundering. (67)

MATERIAL AND METHODS

CHAPTER III

MATERIALS AND METHODS

This was an experimental study on functional clothing for protection against ultraviolet radiation and soiling. The main aim of the study was to compare the performance of selected fabrics according to their fiber content and weave. Present study was also planned to analyze the performance of UV absorber and soil-release finishes with different add-on and concentrations on selected fabrics. And finally to test the selected fabrics treated with a combination finish of UV absorbers and soil-release finishes for their performance against UV rays and soiling.

This chapter deals with materials and methods followed for fulfilling the objective of this study.

The experimental procedure has been discussed under the following sections.

3.1. Selection and composition of the materials used

- 3.1.1. Selection of the fabrics
- 3.1.2. Selection of the finishes for UV protection and soil release

3.2. Preliminary data of the fabrics used.

3.3. Procedure for the application of the finishes

- 3.3.1. Scouring of the samples
- 3.3.2. Application of UV absorber finishes
- 3.3.3. Application of soil-release finishes
    - a. Preparation of artificial soil and preparation of soiled samples
    - b. Preparation and application of soil-release finishes

3.4.Testing of untreated and treated fabrics using relevant standard methods

- 3.4.1. Testing of UV absorbers
    - a. Determination of percent UVR transmission of untreated and treated fabrics.
    - b. The effect of colorant concentration on the percent UVR transmission.

c. Determination of percent UVR transmission of finished and unfinished samples after laundering.

d. Determination of percent UVR transmission of untreated and treated fabrics after exposure to artificial perspiration.

3.4.2. Testing of Soil-release finishes

a. Determination of the whiteness index of the fabric before soiling, after soiling and after laundering.

b. Evaluation of soil-release finishes by calculation of % soil-release and soil-re-deposition.

c. Determination of fiber surface characteristics of treated fabrics using scanning electron microscope.

3.5. Application of optimum combination of UV absorber and soil-release finishes on selected fabrics

3.5.1. Application of combination of UV absorber and soil-release finishes

3.5.2. Determination of percent UVR transmission, whiteness index and wear properties of the finished fabrics using relevant standard methods.

3.5.3. Costing of the finished fabrics.

3.6. Evaluation of wear properties of untreated and treated fabrics

3.6.1. Determination of stiffness of fabrics

3.6.2. Determination of crease recovery angle of fabrics,

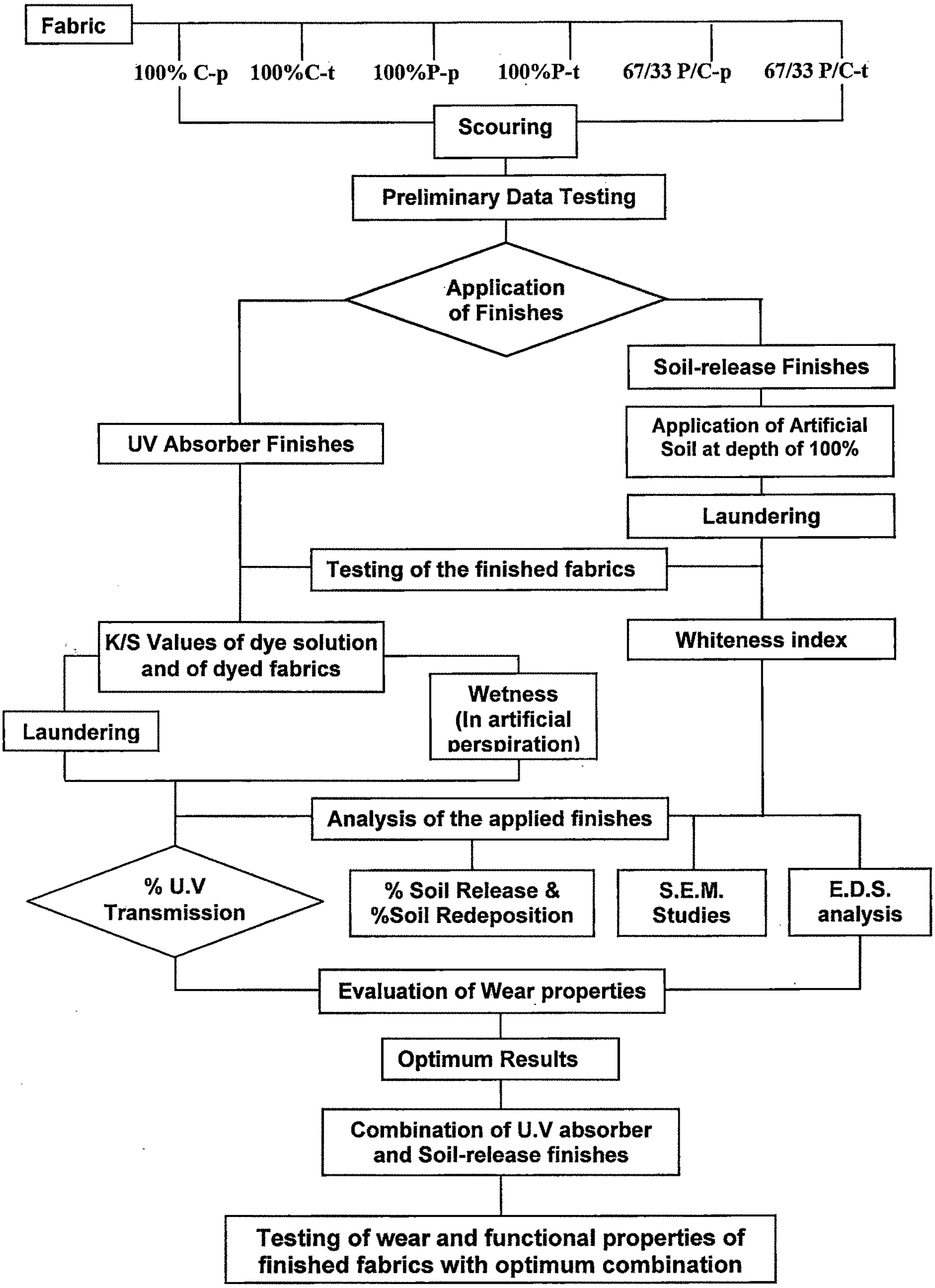
3.6.3. Determination of tensile strength and elongation of fabrics

3.6.4. Determination of air-permeability of fabrics

3.7. Determination of fiber surface characteristics of treated fabrics using scanning electron microscope.

3.8. E.D.S. analysis of the samples treated with UV absorbers and soil-release finishes.

Research design:



3.1. Selection and composition of the materials used

3.1.1. Selection of the fabrics

Selection of the fabric was based on their utility and suitability as per the climatic condition of the country for the upper and lower garment of the outdoor workers.

Three fiber type i.e. 100% cotton, 100%polyester (PET) and polyester/cotton (67/35 blend) in two different weave, plain and twill, that is the total of six fabrics were chosen to cover the gamut of basic fiber content and weaves. All fabrics were in white colour.

Table 3.1: Fabric code given to the fabrics used in the study

Name of the fabrics	Weave	Fabric Code
Cotton	Plain	C-p
Cotton	Twill	C-t
Polyester	Plain	P-p
Polyester	Twill	P-t
Polyester/Cotton blend	Plain	P/C-p
Polyester/Cotton blend	Twill	P/C-t

3.1.2. Selection of the finishes for UV protection and soil release

To provide protection against ultra-violet radiation and soiling, two UV-absorber finishes and two soil-release finishes were selected for study.

3.1.2.a. For UV protection

Two finishing treatments were given to the fabrics under study for UV protection- one being a commercial UV absorbers- Clariant product and the second a natural colourant *Acacia Catechu*. The details of which have been given below

I. The UV absorbers used for the study was from Clariant International Ltd. Commercial UV absorber ‘A’ for cellulosic fibers and Commercial UV absorber ‘B’ for polyester. The literature given by the company has been cited below.

a) Commercial UV absorber ‘A’

This is for the finishing of cellulosic, polyamide. The product can be applied normally as a finishing process, that is, after any bleaching and/or dyeing. It was a white viscous liquid having an anionic character with a pH of 6.

Commercial UV absorber ‘A’ is a heterocyclic compound and reacted with the hydroxyl groups of cellulosic fibers and forms covalent bonds with the fibers exhibits very high fastness level to repeated home launderings and care conditions. It absorbs principally in the UVC and UVB regions but very little in the UVA regions and therefore has no or little influence on the optical brighteners contained in the fiber. It does not affect the shade or the fastness properties of dyed textiles.

b) Commercial UV absorber ‘B’

This product is principally designed for finishing PES and acetate fibers and their blends and can be applied alone or together with dispersed dyes by the exhaust method (at high temperature or at the boil with carriers) and pad-thermosol continuous processes. Commercial UV absorber ‘B’ was an aqueous dispersion of a substituted benzotriazole. It was yellowish with pH ranging between 5 and 6 having anionic character.

It exhibits a very high absorbing effect over the whole ultraviolet region and therefore ensures very high UVR protection of fabrics.

Commercial Auxiliary ‘A’

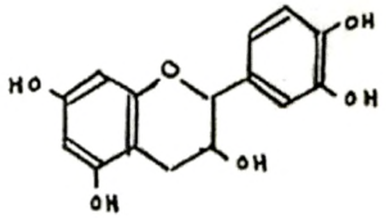
Application and properties	low foaming, non-retardant wetting agent for dyeing with sulphur, reactive and vat dyes.
Ionic character	anionic
Chemical base	aliphate ester

Commercial Auxiliary 'B'

Application and properties	highly efficient, low foaming wetting agent.
Ionic character	anionic
Chemical base	alkyl sulphonate and organic phosphate

II. Natural Dye: *Acacia Catechu (katha)*

This natural dye is prepared from the heartwood of the tree *Acacia catechu*. It is composed mainly of catechu-tannic acid with catechin, catechu red, quercetin and a gum as minor components.



catechin

Figure 3.1: Structure of Catechin

Bond-formation between Acacia Catechu and Fabric

"*Katha*" as it is locally known is a brown semi-crystalline substance, which contains catechin and its isomers and can be used in coloration of cotton, silk, wool, nylon and polyester, as it has a unique mechanism of dyeing. CI name of Acacia Catechu was natural brown.

Its attachment to cotton may be via hydrogen bonds between the phenolic groups of the dye and the hydroxyl groups of cellulose. Further on treatment of the dye with alum (Aluminum Potassium sulphate) some-dye metal-complex is formed that is precipitated in the pores of the fiber.

In the case of polyester the phenolic groups of the dye may act as lubricant breaking the inter molecular bond between the individual chains of polyester thus acting as carrier. Once inside the fiber the dye may be deposited as precipitated alum-dye complex. The dye can also have hydrophobic interactions and Vander Waals force acting to hold the dye in the fiber. (Dr. M.L.Gulrajani)

3.1.2.b. For Soil-release:

Here again two finishes were studied for their soil release properties, i.e. Commercial soil-release finishes and Carboxy Methyl Cellulose.

1. For the study Resil Chemicals Pvt Ltd. products i.e. commercial soil-release finish 'C' was tested on cellulosic fibers and commercial soil-release finish 'D' on polyester and its blends. The following was the literature given by the company

   - Commercial soil-release finish 'C'

     It s Fluorocarbon based wickable stain release finish. It was a non-flammable, pale yellow liquid. It imparts soft hand than other conventional stain-release agents. it is non-flammable and having low VOC(volatile organic compound). Its pH ranged between 2 and 4 with a specific gravity of 1.08 at 25 ^{0}C.

   - Commercial soil-release finish 'D'

     Commercial soil-release finish 'D' is acid donor to set pH=5. It was a hydrophilic polymer that can be applied on polyester and its blends during finishing. It was an off white coloured liquid; having pH ranging from 4 to 6. This durable treatment imparts the following properties:

     Inhibits formation of static charge

     Enhances wear comfort drastically

     Improves wetting action of polyester

     Soil release effect: this makes polyester extremely easy to clean by releasing oil based stains and soils and preventing deposition of stains

Commercial Auxiliary 'C'

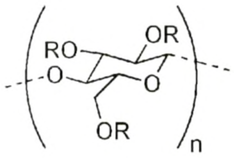
Butyl isocianate based extender for Florocarbon. It is an extender which improves the durability of finish.

Commercial Auxiliary 'D'

It is resin modified DMDHEU based product.

2. Renewable soil-release finish C.M.C. The fabrics under study were finished with soluble Sodium-Carboxy Methyl Cellulose (CMC).

Chemical structure:



R = H or CH_2CO_2H

Carboxy Methyl Cellulose (CMC) is a cellulose derivative with carboxymethyl groups (-CH_2-COOH) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. It is often used as its sodium salt, Sodium Carboxy Methyl Cellulose

CMC when applied on the surface of the fabric, physically block the soil particles from penetrating deeper into fabric.

3.2. Preliminary data of the fabrics used.

Preliminary data of the fabrics was determined as per standard procedures given below:

3.2.1. *Determination of fiber content of the fabrics*

Confirmation of the fiber type was done through microscopic analysis and chemical solubility tests.

3.2.2. *Determination of thread count of fabrics*

Thread count (the number of yarns/cm^2) helped to describe the tightness of the weave. Fabric count was determined according to ASTM D3775-98.

The fabric count was determined by counting the number of threads in one square centimeter in the warp and in the weft directions.

3.2.3. *Determination of yarn number of the fabrics*

Cotton yarn number was calculated using Beesley's balance. To facilitate comparisons, yarn number was calculated using cotton count system equation for polyester and polyester/cotton blend.

3.2.4. Determination of cloth cover of the fabrics

Cloth cover, a measure of the fraction of area covered by both the warp and weft threads in a given fabric, was calculated using thread count and yarn number (cotton count system) for respective fabric. (7)

Equation for calculating cloth cover

$$\text{Cloth Cover} = \text{Cover factor}_{\text{warp}} + \text{Cover factor}_{\text{weft}} - [\,(\text{Cf}_{\text{warp}} \text{ X } \text{Cf}_{\text{weft}})/28]$$

$$\text{Where cover factor (Cf)} = \text{threads per inch}/ \sqrt{\text{Yarn number}}$$

Although this formula for estimating cloth cover was developed for plain weave cotton fabrics, it was applied to all fabrics included in this study. Some simplifying assumptions were made: first, the formula would be equally valid for fabrics of twill weaves and for fabrics of non-cotton fiber contents; second filaments converted to cotton counts would yield reasonable estimates of cover factor using the equation. (15)

3.2.5. Determination of thickness of the fabric

Compressometer was used to determine the thickness of the fabric. Fabric thickness was measured according to ASTM Test Method D1777-96.

3.2.6. Determination of fabric weight per unit area:

The mass units (g/m^2) were measured according to ASTM Test Method D3776-96.

3.3. Procedure for the application of the finishes

3.3.1. Scouring of the samples

The fabrics were first scoured to remove any impurities in form of grease, dust or foreign matter before application of any finish.

Cotton and Polyester/Cotton blends fabrics were scoured with 2g/l of commercial detergent and 2g/l soda ash in a material liquor ratio of 1:40 for 1hr at 80 ^{0}C and were then washed thoroughly and air-dried.

Polyester fabrics were given a mild scouring treatment using 2g/l of mild liquid detergent for 1hr at 80 ^{0}C with material to liquor ratio 1:40. The fabrics were thoroughly washed and then air dried.

3.3.2. Application of UV absorber finishes: Chemical UV absorbers and Natural Colourant (Acacia Catechu (*Katha*)).

3.3.2.1. *Procedure for the preparation and application of commercial UV absorber finishes 'A' and 'B'*

A pilot study was conducted to determine optimum conditions for the application of the finishes to get add-on of 1% and 3%. Different pressures, number of dips and nips were tried to standardize the procedures. Finishes selected for the study was commercial UV absorber 'A' for cotton and commercial UV absorber 'B' for polyester fabric. The recipes for the finishes were as per the company's recommendation.

- ***Commercial UV absorber 'A' for 100% Cotton***

Heterocyclic compound based commercial UV absorber 'A' using the recipe given below was applied to the fabric sample by the padding method. Cotton fabrics were treated using Pad Dry Cure method.

Recipe of commercial UV absorber 'A' for 100% Cotton:

Padliquor	40 gm/l
Sodium Carbonate/ Soda ash	(3.75 + 0.123*40) g/l
Urea	60 gm/l

Cotton fabrics were padded with 4% of commercial UV absorber 'A' maintaining add-on of 1% and 3%. The finish was applied on the fabric with the help of padding mangle. To achieve 1% and 3% add-on on plain and twill weave fabrics the following conditions were maintained

For 1% add-on:

100% C-p	one dip two nip at 2kg/ cm^2
100% C-t	two dip two nip at 1.5kg/cm^2

For 3% add-on:

For 3% add-on, the fabric was kept soaked in the prepared solution for 5 min after which padding was done on padding mangle with decided nips and dips.

100% C-p	two dip two nip at 1kg/cm^2
100% C-t	three dip three nip at 1kg/cm^2

Padded materials were cured at 130 ^{0}C for 3mins. All the fabrics were given hot and cold rinse thereafter and then air-dried.

- ***Commercial UV absorber 'B' for 100% polyester fabrics***

Commercial UV absorber 'B' was applied in concentration of 30g/l. This finishing was carried out by pad thermo-fixation process.

Recipe of commercial UV absorber 'B' for 100% Polyester:

Padliquor	: 30 g/l
Commercial Auxiliary 'A'	: 20 g/l
Commercial Auxiliary 'B'	: 1 g/l

The finishes were applied on the fabric with the help of padding mangle. To achieve 1% and 3% add-on on plain and twill weave fabrics the following conditions were maintained

For 1% add-on:

100% P-p	One dip one nip at 2kg/cm^2
100% P-t	two dip two nip at 1.5kg/cm^2

For 3% add-on:

100% P-p	two dip two nip at 1kg/cm^2
100% P-t	Three dip three nips at 1kg/cm^2

The treated fabrics were dried at 120^{0}C for 2 min on a stenter frame after which it was cured for 30s and 1min at 180°C for plain and twill weave respectively using the oven.

- ***Commercial UV absorber 'A'& 'B' for 67/33% for Polyester/Cotton Blend:***

Polyester/cotton blended fabrics were first treated with commercial UV absorber 'A' and then with the Commercial UV absorber 'B' keeping the same conditions and recipes as above described.

Application Procedure:

The finishes were applied on the fabric with the help of padding mangle. The procedure applied for each fabric was as follow:

For 1% add-0n

For Commercial UV absorber 'A'

67/33% P/C-p	one dip one nip at 2kg/cm^2
67/33% P/C-t	two dip two nip at 1.5Kg/cm^2

Padded materials were cured at 130 ^{0}C for 3mins. All the fabrics were given hot and cold rinse and then air-dried.

For Commercial UV absorber 'B'

67/33% P/C-p	one dip one nip at 2kg/cm^2
67/33% P/C-t	two dip two nip at 1kg/cm^2

The treated fabrics were dried at 120 ^{0}C for 2min on a stenter frame after which it was cured for 1min at 180 ^{0}C using the oven.

For 3% add-on

For Commercial UV absorber 'A'

67/33% P/C-p	one dip one nip at 1kg/cm^2
67/33% P/C-t	three dip three nip at 1Kg/cm^2

Padded materials were cured at 130 ^{0}C for 3mins. All the fabrics were given hot and cold rinse and then air-dried.

For Commercial UV absorber 'B'

67/33% P/C-p	one dip one nip at 1kg/cm^2
67/33% P/C-t	three dip three nip at 1kg/cm^2

The treated fabrics were dried at 120 ^{0}C for 2min on a stenter frame after which it was cured for 1min at 180 ^{0}C using the oven.

3.3.2.2. *Application of Natural Colourant: Acacia Catechu (Katha)*

Dyeing with Acacia Catechu

In order to examine the effects of colour on Ultraviolet radiation transmission, all the samples were coloured with *Acacia Catechu* at 2% and 4% shades with 10% Alum o.w.f. as the mordant. The simultaneous method used for mordanting and dyeing of samples for the six fabrics.

Method of extraction

According to the shade i.e. 2% and 4% catechu were taken and then it was pasted with little amount of water. Remaining calculated water was poured in the content and the same was kept at 80^{0}C for 30mins. Finally it was filtered and the filtrate was used as dye solution.

(i) Cotton Fabric

Cotton materials were coloured using exhaust method with *Katha* at 2% and 4% shades.

Recipe:

Dye : 2%, 4% o.w.f.
Alum : 10 % o.w.f.
M:L:R : 1:40
Temp. : 80 ^{0}C
Time : 45 min
E.D.T.A : 1g/l of water

Simultaneous-mordanting method:

In this method the mordant and dye are applied simultaneously in the same bath.

Alum as a mordant used for simultaneous dyeing-mordanting. Dyeing was carried out at 80^{O}C for 45min, using 1:40 MLR at self-pH. Alum concentration was 10% on weight of the fabric. After dyeing, the samples were rinsed in water then washed using non-ionic detergent at 40^{O}C for 10min, then rinsed again in water and air-dried.

(ii) Polyester Fabric

High Temperature High Pressure method for polyester and its blend with Acacia Catechu at 2% and 4% shades were used.

Recipe:

Dye : 2%, 4% o.w.f.
Alum : 10 % o.w.f.
M:L:R : 1:40
Temp. : 130 ^{O}C
Time : 45 min
E.D.T.A : 1g/l of water

Simultaneous Mordanting method:

Dyeing of 100% polyester and polyester/cotton blend was dyed on laboratory glycerin dye bath machine, Model No. 25000 x 12 of Tex-Fab Engineers (India) Pvt. Ltd. Dyeing was carried out in Modern Petrofil, Por, Baroda, Gujarat. The material liquor ratio was 1:40. The dyeing was started at 60 ^{O}C and the temperature rose to 130 ^{O}C and maintained there for 45mins in closed pots. Degree of increment was 1^{O}C/min. The fabric were then removed after 45min, washed with cold water, soaped at 40^{O}C for 10min with non-ionic detergent, rinsed and air-dried.

3.3.3. Application of soil-release finishes: Commercial soil-release finishes and Carboxy Methyl Cellulose (C.M.C)

3.3.3.a. Preparation and application of soil-release finishes

3.3.3.b. Preparation of artificial soil and its application

3.3.3.a. Preparation and application of soil-release finishes

All six fabrics under study i.e. 100%cotton, 100% polyester and 67/33% Polyester/Cotton in plain and twill weave, were scoured and then finished with two finishes Commercial soil-release finishes 'C' & 'D' and Carboxy Methyl Cellulose (C.M.C)} by varying the add-on i.e. 1% and 3%. The uniform procedure was followed for each of the six fabrics. Commercial soil-release finishes 'C' & 'D' and commercial auxiliary 'C' & 'D' was sponsored from Resil chemicals Pvt Ltd. (Ahmedabad). To get desired add-on fabrics were treated with different number of dips and nips with different weights.

3.4.3.a.i. Finishing with commercial soil-release finishes

The cotton fabrics were finished with commercial soil-release finish 'C', polyester fabrics with commercial soil-release finish 'D' and Polyester/Cotton blended fabrics treated with combination of above chemicals, which were taken as per the % 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.

Commercial soil-release finish 'C' for cotton

Application guideline:

Commercial soil-release finish 'C' : 40g/l
Commercial Auxiliary C : 2.7g/l
Commercial Auxiliary D : 20g/l
Mgcl$_2$ (Magnesium Chloride) : 5g/l
IP (Isopropyl Alcohol) : 5g/l

Application conditions:

1dip 1nip at the weight of 2kg/cm^2
Pick-up :75%
Dry at 120 ^{O}C for 130 ^{O}C
Cure at 160^{O}C for 3min

Commercial soil-release finish 'D' for polyester

Recipe:

Commercial soil-release finish 'D' : 20g/l

Application conditions:

The weight was maintained at 1.5kg/cm^2

Polyester and Polyester/cotton blends were kept in oven for 30sec at 180^{O}C for fixation of chemical with fabric.

For polyester/cotton blend fabrics

Calculations of commercial soil release C, D and auxiliary were done as per the percent of fiber content in the fabric.

Commercial soil-release finish 'C' for cotton

Recipe:

Commercial soil-release finish 'C' : 13.3g/l
Commercial Auxiliary C : 0.8 g/l
Commercial Auxiliary D : 9.9 g/l
Mgcl$_2$ (Magnesium Chloride) : 3.3 g/l
IP (Isopropyl Alcohol) : 1.65g/l

Commercial soil-release finish 'D' for polyester

Recipe:

Commercial soil-release finish 'D' : 13.4g/l

Commercial soil-release finishes C and D where combined and applied to the fabrics with 1dip 1nip at $2g/cm^2$ and then fabrics were kept in oven for 30sec at 180^OC for fixation of chemical with fabric.

ii. Finishing with Carboxy Methyl Cellulose (C.M.C)

A pilot study was conducted to determine optimal concentration of the finish and to get add-on in between from 1% and 3% for the finish. For 3% add-on the fabric was kept soaked in the prepared solution for 5minutes after which padding was done on padding mangle.

To get desired add-on fabrics were treated with different number of dips and nips with different weights.

Recipe:

Carboxy Methyl Cellulose : 2% (8g)
Water (to make the volume 400ml) : 400ml

CMC was insoluble in water at room temperature. A homogeneous mixture of 2% Carboxy Methyl Cellulose (C.M.C) at boil was prepared in distilled water. The fabrics were padded with the solution to get 1% and 3% add-on. 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.

Sample were subsequently dried at room temperature and then cured at 100^OC for 5min.

Application of C.M.C.

The finishes were applied on the fabric with the help of padding mangle. The procedure applied for each fabric was as follow:

For 1% add-on

All the six fabrics, fabrics were treated with solution at 1%, 1 dip and 1nips. The weight was maintained at $1.5kg/cm^2$ except for cotton plain weave it was kept at $2kg/cm^2$

For 3% add-on

Plain weave fabrics were treated at 1dip and nip and twill weave fabric treated at 2dips, 2nips. The weight maintained for plain and twill weave fabrics at 1kg/ cm^2.

3.3.3.b. Preparation of artificial soil and its application

i. Preparation of artificial soil solution

The scoured samples were soiled using particulate solvent soil; the composition of soil was as follows: (10)

Carbon Black (Jai Kajal) : 2 g
Coconut Oil : 5 ml
Stearic acid : 2 g
Oleic acid : 10 ml
Carbon tetrachloride : 85 ml

100

Carbon black was mixed thoroughly with coconut oil; a fine paste of stearic acid and oleic acid were prepared with vigorous stirring using a mechanical stirrer. Then the two parts were mixed together. Carbon tetrachloride was then added and stirred well to get even soil suspension. This mixture was used for preparation of soiled samples.

Purpose of the ingredients:

1. Carbon black is used as a grey coloured pigment to indicate grayness. (Jai Kajal manufactured by Western India Chemical Co., Mumbai.)
2. Coconut oil is used because it does not leave any ageing effect and its helps in dispersing pigments in the solvent.
3. Oleic acid is used as it helps in even dispersion of soil particles.
4. Stearic acid is similar to oleic acid and simulates wax.
5. Carbon tetrachloride is used as a solvent.

ii. Procedure of soiling

Soiling was done by passing the scoured sample through the soil solution, taken in an enamel tray. The sample was removed from tray and laid flat on a blotting paper and was covered with another blotting paper and passed through paddling mangle. This process removes excess solution. Samples were hung in air for drying.

iii. Laundering of soiled samples

Sample Preparation:

The soiled samples were cut to 2.5 inch X 5 inch and were stitched to white (scoured) fabric of same size (This was done to see if during washing there was any staining or re-deposition of the soil on the white fabric.). Then prepared samples were washed in a launder-o-meter.

Laundering procedure:

Laundering of the soiled samples was carried out in laboratory launder-o-meter IA 61-1962 according to test method ISO-3. Soap solution was poured into the 250ml glass jars containing 15 steel balls (1/4 inch diameter of each). Stitched samples were put into these glass jars. The jars were then fixed to the rotatory mechanism of the launder-o-meter and it was run for 45 min at 40 ^{0}C. The steel balls were to provide abrasion as jars turned. The material liquor ratio taken was 1:60 and soap solution 5g/l. The samples so washed were removed from the jars after 45mins and were rinsed thoroughly in water, two to three times and dried in air.

3.4. Testing of untreated and treated fabrics using relevant standard methods

3.4.1. For UV absorbers

a. *Determination of percent UVR transmission of untreated and treated samples, using, an instrument, which was fabricated, based on direct optics using UV diode in the laboratory.*

When UV radiation hits a textile surface, it causes the UV radiation to be broken down into several components. Part of the radiation is reflected, another part is absorbed by the sample *that is converted to a different energy form.* Yet another part of the radiation, which travels through the fabric and reaches the skin, this part is referred to as the transmission. Transmitted radiation that reaches the skin, cause the harmful effect on the skin.

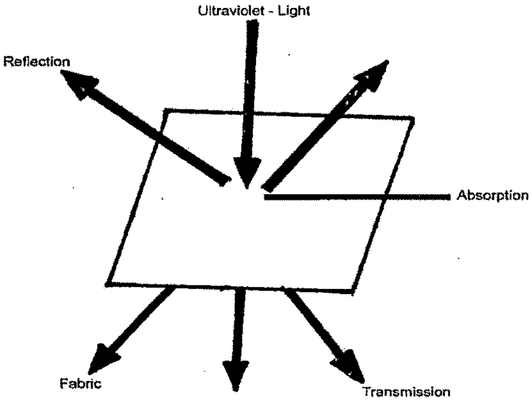


Figure 3.2: Incident UV Light on Textile Material

Source: (Goyal Rakesh, "UV radiation and protection", Colourage, October, 2005, pp.81-87)

Fabrication of the instrument for testing UV transmission of the fabrics

An instrument was fabricated in the Department of Applied Physics, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Vadodara for the testing of the percent UVR transmission.

Principle:

The instrument is based on direct optics. It states that light passes through the monochromator and the monochromatic light is directed to the object. Finally the detector measures the reflected or transmitted light.

Working:

The working of the instrument was very simple. The UV light was generated by the source, it passes through the monochromator, then through optical chopper and than via several mirror reaches the fabric sample. The detailed method of working has been given in Figure 3.3.

The instrument was based on direct optics. Light was generated through a tungsten halogen lamp (its intensity is closely matches the solar spectrum) The light passes through the monochromator input slit of grating. 'Range of grating' is 0-1500 nm at 0.2 nm resolutions. Monochrometer only passes UV rays with particular wavelength. The output from diffraction grating of monochromator is continuous light beam. Optical chopper converts this UV rays into pulses. The Alternating Current passes through the concave mirror to focus the light, the use of concave mirror gives spherical wavefront, and to convert it back into the plane wave front plane mirror is placed. Thus, the light is directed towards the sample. From this the light passes on the fabric where the transmitted light is detected by a UV diode. A lock in amplifier amplifies that signal to certain level, which converts 0-5v signal to computer.

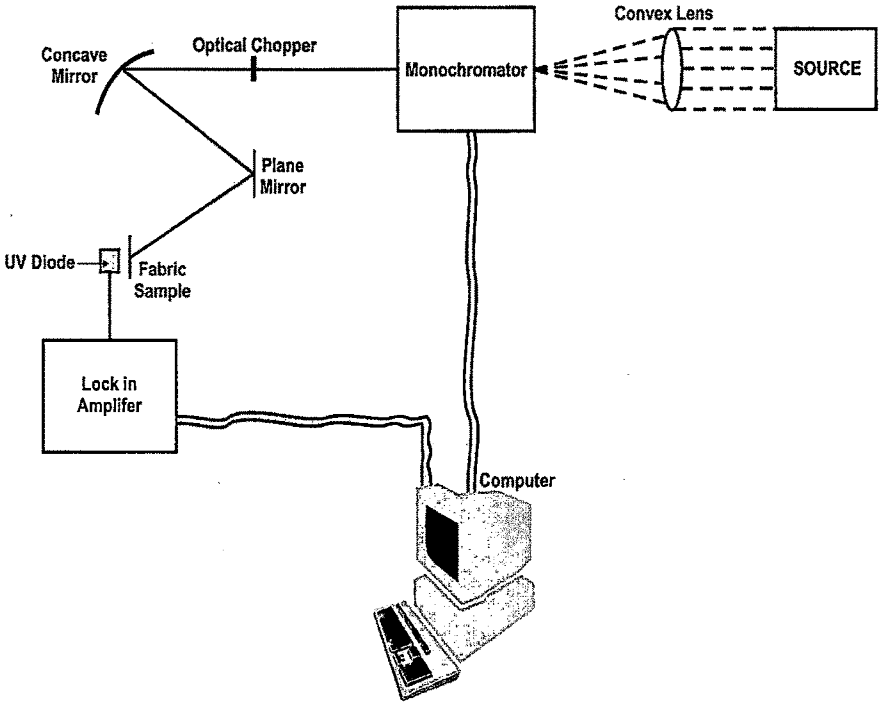


Figure 3.3: Schematic diagram of fabricated Instrument for testing percent UVR transmission

The fabric sample was placed 0.05 cm away from the UV diode. The whole set up was programmed on the computer by the Lab view 7.1 software. The computer screen directly showed the graph between wavelength and transmittance. Hence transmittance percentage was calculated by the following formula:

$$\text{UVR Transmission \%} = \frac{\text{Transmission obtained by Fabric}}{\text{Transmission of Direct Light}}$$

Percent UVR transmission was then converted to UPF value and protection categories to analyze the effect of the finishes under study were done according to the AS/NZ 4399:1966.

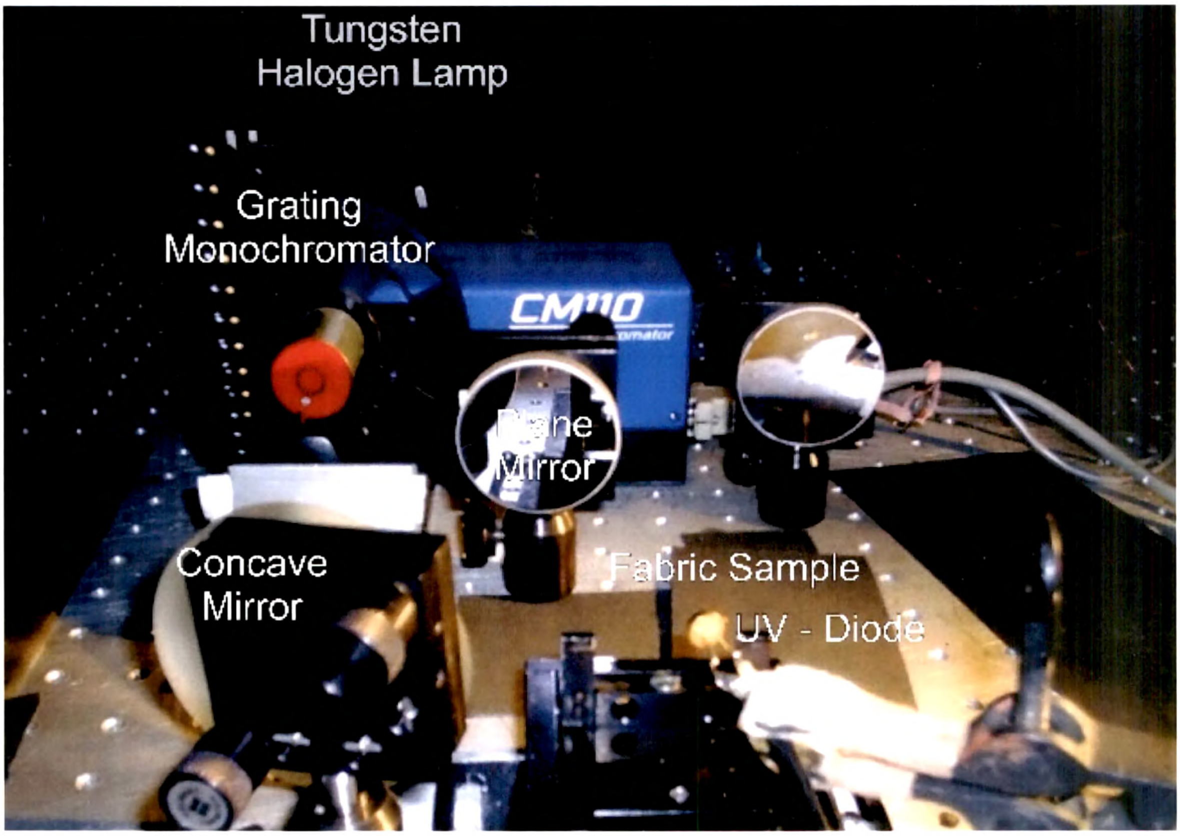


Plate 3.1: Fabricated instrument for testing percent UV transmission.

Table 3.2: Classification of UPF and percent UVR transmission as per AS/NZ 4399:1996 classification of sun-protective clothing

UPF	Protection Categories	Duration of Protection (hrs)	UV Protection (%)	UVR Transmitted (%)
10	Moderate	2..5 – 5.0	90 – 95	10 – 5
20 – 29	High	5.0 – 7.5	95 – 96.5	5 – 3.3
30-40	Very High	7.5-12.5	96.7-98	3.3-2.0
50+	Maximum	>12.5	>98	<2

b. The effect of colorant concentration on the percent UVR transmission was examined via color strength analysis.

Measured percent transmission values were also correlated to the colour strength of the dyed fabrics. Colour strength was evaluated using K/S values generated by a Premier Colourscan spectrscan 5100 spectrometer using CIE 100 observer and D65 illuminant. K/S is a function of colour depth and is represented by the equation of Kubelka and Munk.

$$K/S = \frac{(1-R^2)}{2R}$$

R was the reflectance of the dyed fabric;
K the sorption coefficient,
S the scattering coefficient.

c. Determination of percent UVR transmission of untreated and treated fabrics after laundering.

Laundering of the finished samples was carried out in laboratory launder-o-meter IA 61-1962. The fabrics were cut into rectangular swatches.

The specimens were placed in the airtight glass jar, the necessary amount of soap solution was added to (It contain 2g/ml of non-ionic detergent) previously heated at

40 ^{0}C to give a liquor material ratio of 1:40 with 10 stainless steel balls. The specimen was treated for 45min at 40 ^{0}C in the launder-o-meter. The process was repeated 3 cycles, and then it was rinsed and dried in air. It was followed by the evaluation of percent UVR transmission.

Transmission measurements were done before and after treatment, so that each swatch served as its own control.

d. Determination of percent UVR transmission untreated and treated fabrics after exposure to artificial perspiration

The clothing worn by outdoor workers would be exposed to perspiration during wear and so it was thought to study the effect of perspiration on the UV protection of the finished fabrics. The moisture content of a fabric's which can increase during its wearing may decrease the fabric's capability of protecting the skin from solar UV radiation, that is higher percent UV transmission. The water absorption of the fabric depends on the fiber content like cotton, polyester and acrylic etc.

Therefore the effect of fabric wetness due to artificial perspiration on UV percent transmission through the fabric was investigated.

Procedure:

Samples of 10 X 4cm were taken from the finished fabrics to be tested.

Recipes for the preparation of alkaline and acidic solution:

1) Alkaline Solution:

Distilled water : 1l
1-histidine-mono-hydro-chloride-mono-hydrate
($C_6H_9O_2N_3HCl.H_2O$) : 0.5g
Sodium chloride : 5g
Disodium-hydrogen-orthophosphate-do-deca-hydrate
($Na_2HPO_4.12H_2O$). : 5g

The solution was brought to pH8 by adding 0.1N sodium hydroxide solution and stirred well.

2) Acidic Solution:

Distilled water : 1L
1-histidine mono hydro chloride mono hydrate ($C_6H_9O_2N_3HCl.H_2O$) : 0.5g
Sodium chloride : 5g
Sodium di hydrogen orthophosphate dihydrate ($NaH_2PO_4 . 2H_2O$) : 2.2g

The solution was brought to pH of 5.5 by adding 0.1N acetic solution and stir well.

Method:

The untreated and treated fabrics were immersed in the separate bath of acid and alkali solution at room temperature for 30min with occasional agitation to ensure thorough wetting out. The material liquor ratio was 1:40. The wetted samples were then passed through the padding mangle to remove excess moisture.

3.4.2. For Soil-release finishes

a. Determination of the whiteness index

The amount of soil deposited during soiling can be estimated by chemical methods and reflectance measurements made on the soiled samples. The most popular method for estimating the amount of soil released during laundering is the reflectance method. The reflectance values of the fabric swatches were measured before soiling, after soiling, and after laundering, with a suitable spectrometer.

Using Spectrascan 5100 spectrometer, manufactured by Premier Colourscan, the whiteness-index of the fabrics were assessed by Hunter Whiteness Index under illuminate D65, 10 degree observer. Whiteness index measurements were performed according to AATCC test method 110. Three measurements were obtained for each sample and average value was calculated and recorded.

b. Evaluation of soil-release finishes by measuring percent soil-release and percent soil-re-deposition using the formula

Percent soiling, percent soil-release and percent soil-deposition values of test fabrics were calculated using value of whiteness-index and were calculated using the following formula:

$$\% \text{ Soiling} = \frac{Ro-Rs}{Ro} \times 100$$

$$\% \text{ Soil-release} = \frac{Rsw-Rs}{Ro-Rs} \times 100$$

$$\% \text{ Soil-deposition} = \frac{Ro-Rww}{Ro} \times 100$$

Where Ro=Original sample, Rs=soiled sample, Rsw=soiled and washed sample and Rww=white and washed sample.

c. The scanning electron microscopic studies

The Scanning Microscopic studies were carried out to examine the effect of finishes on the fiber surface characteristics, soil affinity, location of soiled area in the fabric and distribution of soil on the surface area of fiber. Fabrics were previously treated with soil-release finishes, and then coated with artificial soil (Carbon black) with standard procedure. All the samples were viewed under a Scanning Electron Microscope (Joel JSM-5610V S.E.M) at different magnification. The untreated and soiled samples after washing were also examined for comparison purpose.

3.5. Evaluation of wear properties of untreated and treated fabrics

3.5.1. Determination of stiffness of fabrics

Stiffness or bending length was measured using "Bending Cantilever Test method" ASTM No. 1388-55T on "Shirley" Stiffness Tester.

3.5.2. Determination of crease recovery angle of fabrics

The dry crease recovery was determined by "Shirley Wrinkle Recovery Tester" manufactured by T.J.Edward Inc., USA using AATCC standard test method 66 option

2. The total wrinkle recovery angles were recorded as the added total of warp and weft averages.

3.5.3. Determination of tensile strength and elongation of fabrics

The tensile strength and elongation of the fabrics with varying treatments were determined on Instron, Model 1121, 10KN Testing Instrument using ASTM Test method D5035. The instrument was based on the principle of CRE (Constant Rate of Extension).

3.5.4. Determination of air-permeability of fabrics

Air permeability or porosity is an important property of fabrics used in the clothing industry, principally from the viewpoint of the hygiene. The porosity of the textiles provides the perspiration of the human body to evaporate, thus being contributory to the "comfort feeling" of the wearer.

It is the measure of the resistance of fabrics to passage of air through them. The Metefem Air-Permeability Tester was used to determine the air permeability of fabrics. Average of three reading was taken and reported in $m^3/mt^2/m$.

3.6. Application of combined finish (UV absorbers and soil-release finishes)

3.6.1 Application of combination of UV absorber and soil-release finishes

Experiments were broadly divided into three parts-

In part I separately two UV absorbers and two soil release finishes were applied on the fabrics under study. Commercial UV absorber 'A' and 'B' were applied maintaining add-on between 1% and 3% on six fabric samples. All the samples were coloured with natural UV absorber (Acacia catechu (*Katha*)) at 2% and 4% shades. After finishing and dyeing the treated fabrics were evaluated for percent UVR transmission, performance and wear properties. On the basis of test results, the add-on and percent shades providing the optimum protection were finalized as a UV absorber.

In the II part, two soil-release finishes i.e. Commercial soil-release finish 'C', 'D' and Carboxymethylcellulose with add-on 1% and 3% on cotton, polyester and polyester/cotton blended fabrics in plain and twill weave were applied. After finishing percent soil-uptake, percent soil-release and percent soil-re-deposition, properties were tested. On the basis of test results, the optimum conditions for protection against soil were selected for further study.

In part III fabrics after treated with UV absorber and soil-release finishes, fabrics providing optimum performances were selected for the further work.

Based on result of optimum performances combination of both types of finishes were applied sequentially (first UV absorber then soil-release finish) on optimum selected fabrics.

3.6.2. Determination of percent UVR transmission, whiteness index and wear properties of the finished fabrics using relevant standard methods.

The selected fabrics treated with optimum combination of the two finishes were then evaluated for percent transmission before and after laundry, after exposure to artificial perspiration, whiteness-index, percent soil-release, percent soil-redeposition, SEM and EDS analysis

The wear properties of treated fabrics were also estimated by testing for stiffness, crease recovery, air permeability and tensile strength.

3.6.3. Costing of the finished fabrics

The fabrics if they have to be commercialized the cost of finishing the fabrics would have to be calculated and so the costing was done for the optimum finishes in combination.

Theoretical cost was under taken by calculating the cost of individual finishes and auxiliaries as per the recipes for one liter of finish.

3.7. Determination of fiber surface characteristics of treated fabrics using scanning electron microscope.

SEM analysis was performed to analyze the topographic features of the fabrics used in the present study and to compare the morphological characterization of cotton, polyester and polyester/cotton blend fabrics before and after the application of various treatments i.e. soil-releases finishes individually on cotton and polyester fabrics and four combinations of finishes on polyester/cotton blend plain and twill weave fabrics.

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

E.D.S. analysis was carried out to identify the elements present in the applied finishes, in Department of Metallurgy, Faculty of Engineering and Technology, The Maharaja Sayajirao University of Baroda, Vadodara.