INTRODUCTION

CHAPTER I

INTRODUCTION

"No job is so important and no service is so urgent that we can not take time to perform our work safely"

Health and work have a bidirectional relationship, that is hazardous work can produce negative effects on health in terms of injury and diseases. People who work outdoors are the most likely of all workers to suffer health damage from exposure to hazardous environment. Outdoor workers are one of the most vulnerable segments as they are constantly exposed to multiple hazards. They spend long periods of time outside doing strenuous activity, often with the added burden of heat, exposure to direct sunlight and air pollution in the workplace environment due to diesel exhaust, traffic, industrial operation, wind-blown dust, construction and other sources. These have been found to cause serious occupational health hazards in the tropical and subtropical countries like India. [145]

In recent years the whole world is suffering from all kinds of pollution. Air pollutants such as Choloro-fluorocarbon (CFC), sulphur dioxide, carbon monoxide, CCl_4 etc. present in the atmosphere, have created a deep imbalance in the eco-environment system, consequently the damage in earth protective ozone layer has increased. Ozone layer has got depleted by 5-10% forming the so-called "Ozone hole". With the thinning of the protective ozone layer, the UV radiation contained in sunlight comes closer to the surface of the earth which is carcinogenic. Each one percent decrease in ozone concentration is predicted to increase the rate of skin cancer by two percent to five percent. [131] Thus it is important to protect the skin from excessive exposure to UV radiation.

UV radiation is absorbed in the skin and the adverse health effects that can manifest over both the short and long term are mostly confined to skin and eyes. UVR damage occurs most easily in fair-skinned people and others who burn easily in the sun. Nevertheless, those with black, brown or olive skin must also be concerned about over exposure to the sun. People with naturally dark or tanned skin can still suffer sunburn. The most common forms of skin cancer are basal cell carcinoma (BCC), squamous cell carcinoma (SCC), and melanoma. Each of these has been linked to intermittent and/or chronic sun exposure. [151]

The risk of UV radiation related health effects are independent of skin types. [167], [185] Damage is permanent and irreversible and increases with each exposure. Hence there is critical need to reduce ultraviolet radiation (UVR) exposure in the entire population.

The amount of time spent outside by the workers varies considerably with occupation, although in all occupations, some time is spent outside. They are exposed to sunrays everyday regardless of whether there is cloud coverage or not. The occupations where the highest UVR exposures were observed were the ones where the workers spent most of their time out in the open such as farmers, building and construction workers, telecommunications and utilities workers, postal workers, BSF jawans, physical education teachers, athletes, vendors, fishermen, beach-revelers, road workers, surveyors, traffic policemen, geologists, drivers of taxi, bus and trains, delivery and courier services person, cricketers, etc. It is becoming necessary to protect people who work or play long hours, as they have a greater risk for sun-induced damage than the general population.

The workplace is a major source of exposure for outdoor workers as the causing source (sun and soil) cannot be controlled like other workplace exposure hazards and they are required to spend long periods of time working in open environment under the scorching sun. Pollution and UV rays are some of the factors responsible for deterioration of fabric and skin of outdoor workers. Also accumulations of foreign matter on the fabric surface during wear in polluted and hot environment is one of the important criteria for determining the clothing value of a textile material. Unwanted soiling accumulated on the surface or interiors of fibrous structure often results in discolouration, change in appearance and loss of fabric luster. Daily depositions of soil is difficult to remove by aqueous laundry processes, over the time residual soil builds up on the textiles and causes discolouration, including graying, yellowing, and in some case malodor. However laundering to remove soil and stain consumes energy and reduces the wear life of the garments.

Outdoor workers represent an unaddressed, high-risk population. These workers often use little in the way of protection against hazardous environments. Hence if they have to function safely in wide range of climate condition, in heat and in pollution, there is a felt need for protective clothing, which besides providing protection from UV rays should also trap soil on the surface of the fabric so that it appears clean and gives satisfactory appearance of textiles during wear.

To understand and formulate the objective for the present study and to relate fabric properties to UV protection and soiling the following has been discussed below:

1.1 a. Health risks of outdoor workers associated with UVR in the workplace

1.1.b. Effect of UV radiation and air pollutants on fabric

1.1.c. Effect of fiber composition, fabric construction and surface treatments for protective clothing

1.1.a. Health risks of outdoor workers associated with UVR in the workplace

Godar (2005) reported the UV radiation affects human health. Human exposure to UV radiation causes a few beneficial health effects like vitamin D_3 formation. It also causes many detrimental health effects: sunburn, ocular damage, photoaging, immune suppression, DNA damage and skin cancer. In countries with fair-skinned populations, skin cancer is the most diagnosed of all cancers. In the United States in 2002, there were over one million new skin cancer cases. That means one out of every 285 people get skin cancer. Skin cancer of fair-skinned individuals is increasing at an alarming rate (4–6% per year) around the world and has now reached so-called "pandemic" proportions. Thus, it is important to know what UV doses people around the world get throughout their lives. Overall, outdoor-working adults get about 10%, while indoor-working adults and children get about 3% (2–4%) of the total available annual UV (on a horizontal plane). People's UV doses increase with increasing altitude and decreasing latitude. [(148)]

Ramiez et al (2004) described the relationship between sun exposure, other occupational radiation exposures, and skin cancer. There is an increased risk of skin cancer amongst outdoor workers, such as farmers, welders, watermen, police officers, physical officers, physical education teachers, pilots, and cabin attendants. Although sun exposure is thought to be a common etiologic factor, some studies have suggested alternative explanations, such as irradiation from the welding arc in welders, nonionizing microwave frequency radiation from radar use in police officers, and cosmic radiation in pilots and cabin attendants. Occupation in which there is an increased exposure to ionizing radiation, such as radiation technicians and radiologists, showed an increased risk for melanoma and NMSC (Non-Melanoma Skin Cancer). (100)

A number of previous studies have measured the solar UVR exposures of outdoor workers. **Larko and Diffey (1983)** (76) found that outdoor workers received 10–70% of ambient UVR depending on the amount of work time spent outdoors, whereas indoor workers received 6% of ambient UVR in summer, comparable with a study that found that indoor workers received 2–4% of ambient UVR. **Holman et al. (1983)** (56) examined the anatomical distribution of UVR exposures for five occupations and for a range of outdoor recreational activities. They found that a classroom teacher received 7–11% of ambient UVR, whereas physical education teachers received 30–50% and other outdoor workers (a gardener, a roof carpenter and a bricklayer) received 44–85% of ambient UVR. **Herlihy et al. (1995)** (53) found that gardeners had UVR exposures of 11% of ambient on the chest and 24% on the back, whereas physical education teachers, groundsmen and lifeguards had measured UVR exposures of 8–9% of ambient on the chest. **(1995)**(39) The measured anatomical distributions of solar UVR varied with activity. **(1983,1995)** (39, 56) The measured solar UVR exposures of 90% of the outdoor workers (Pavers-tillers, diggers, traffic controllers, roofers, farm workers, fencers, riggers, laborers, plumbers, steel fixers, carpenters, workers, concreters, bricklayers, supervisors, plant operators, inspectors, painters, cabinet makers) of study done by **Peter and Wright (2003)** (95) were in excess of the Exposure Limit (EL) of the occupational UVR exposure standard, with 50% of the workers exceeding the EL by more than four times.

1.1.a. Effect of UV Radiation on Brown skin

It is a popular misconception that only fair skinned people need to be concerned about exposure to the sun, darker skin has more protective melanin pigment, and the incidence of skin cancer is lower in dark skinned people. Nevertheless, skin cancers do occur with this group and unfortunately they are often detected at a later and more dangerous stage in the darker skinned population. (175) (185)

The risk of UV radiation-related health effects on the eye and immune system is independent of skin type. So, those with black, brown or olive skin must also be concerned about over exposure to the sun. (176) (184)

Gohra and Perez, in their case study revealed that everyone, regardless of skin color, can fall prey to it. Basal cell carcinoma is the most common skin cancer in Caucasians, Hispanics, Chinese, and Japanese Asians, and the second most common skin malignancy in African Americans and Asian Indians. In all races, basal cell carcinoma is usually linked to UV light exposure. Basal cell carcinomas are mainly found on body parts that receive the most sun exposure (Figure 1.1).

Type of Cancer	Primary Predisposing Factor	Most Common Location
Basal Cell Carcinoma	**sunlight**	
Malignant Melanoma (African Americans, Asians, Hawaiians, Native Americans, Darker-skinned Hispanics	**unknown**	
Malignant Melanoma (Lighter-skinned Hispanics)	**unknown**	
Squamous Cell Carcinoma	chronic, non-healing wounds/ ulcerations, scars and chronic inflammatory skin conditions (e.g. discoid lupus, lichen sclerosis, lichen planus)	

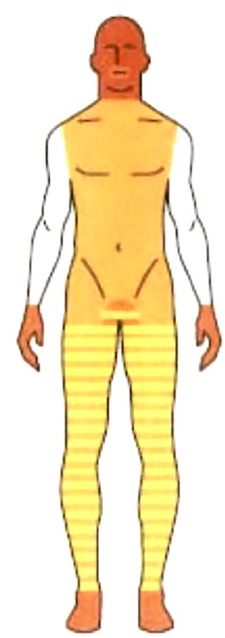

Figure 1.1: Skin cancer and skin of colour

A study from Howard University, Washington, DC, revealed that 89 percent of basal cell carcinomas on naturally brown skin occur on the head or neck. The correlation between UV light and basal cell carcinoma in darker skin types explains the relatively higher incidence of this malignancy among darker-skinned populations living in sunnier climates, such as Hispanics residing in New Mexico and Arizona. [179]

Jin (2003) studied the acute and chronic cutaneous response of UV radiation on brown skin of Asian population, which is more than half the population of earth, differs from those in white skin. As Asian skin is more pigmented, the acute and chronic cutaneous responses to UV irradiation seen in brown skin differ from those in white skin. The study has shown that there is a statistically significant positive association between wrinkling and dyspigmentation. This suggests that people with severe dyspigmentation usually tend to have severe wrinkles, and that wrinkling is a major problem in photoaged Asian skin. The wrinkle pattern and pigmentary changes of photoaged East Asian skins differ from those of Caucasians, and the relative risks of each aggravating factor may also differ. [65]

1.1.b. Effect of UV radiation and air pollutants on fabric:

1.1.b.i) Effect of UV radiation on textile materials

UV radiation is one of the major causes of degradation of textile materials, which is due to excitations in some parts of the polymer molecule and a gradual loss of integrity, and depends on the nature of the fibers. Because of the very large surface volume ratio, textile materials are susceptible to influences from light and other environmental factors. The penetration of UVR in nylon causes photo oxidation and results in decrease in elasticity, tensile strength and a slight increase in the degree of crystallinity. In the absence of UV filters, the loss in tensile strength appears to be higher in the case of nylon (100% loss), followed by wool, cotton and polyester, with approximately 23%, 34% and 44% respectively after 30 days of exposure. Elevated temperature and UVB radiation on cotton plants result in severe loss of bolls. Naturally-coloured cottons contain pigment ranges from light green to tan, brown and inherent long-term UV protection properties with a UPF of 64 and 47, whereas normal cotton shows a UPF of 8. [34]

Gogoi, Baruah and Sarkar (1999) studied the degradation of silk fabric particularly muga (Antheraea assama Ww) and mulberry (Bombyx mori L) silk in the presence of artificial ultraviolet light for 4,8,16 and 24 hours in dry and wet condition on their physical properties i.e. count, GSM, thickness, breaking strength, elongation, abrasion resistance, crease recovery and fabric stiffness. The deteriorating effect was observed more in mulberry fabrics than in muga. As the moisture content weakens the fabric, thereby it creates less resistance to withstand the damage. Hence the change in wet exposure was more than in dry exposure. The deterioration of the fabric increased as the time of exposure increased. Therefore the drying of silk fabrics should not be done directly under the sunlight. [40]

Estimation of crystalline and amorphous regions is very interesting for absorptivity of pigments, humidity, and chemical reactions. In addition, the performance behavior of textile materials depends on a complex interaction of their basic mechanical properties, such as tensile, bending, and shears characteristics. Therefore, the work of **El-Zaher** deals with the study of the variation of crystallinity and amorphosity of dralon fabric exposed to ultraviolet (UV) light irradiation for periods ranging from 0 to 120 h using the X-ray diffraction (XRD) technique. The radiation-induced changes in the optical properties of the fabric, which in turn reflected the damaged sites in the irradiated fabric, were also evaluated using spectrophotometric analysis, and the obtained results are discussed in relation to the mechanical properties of dralon fabric, such as tensile strength and percentage elongation at break. The results indicated the changes in crystallinity, tensile strength, and elongation percentage at break, besides variations in optical properties of dralon fabric after exposure to UV light. These changes may be attributed to the variation caused in the macro- and micromolecular structure of the fabric network due to UV irradiation. [143]

1.1.b.ii) Effect of air pollutants on fabric:

The role of air pollutants in the deterioration of fabrics has received limited attention in outdoor-exposure programmes.

Rees (1958) have discussed the factors which influence the soiling of textile materials by airborne dirt and the methods for measuring and expressing the extent of soiling of textile materials. An account is given, with experimental data, of the soiling of the textile fabrics by exposure to moving air, by thermal precipitation and by electrostatic attraction of airborne particles, and of the effect of fabric wettability on the appearance of a cotton fabric soiled by exposure to a damp polluted atmosphere. [141]

Mansfield T. (1989) exposed the samples of cotton fabric for eighteen months to environmental conditions at various locations in London. These locations were tested for the ambient level of both smoke and sulphur dioxide. The samples were tested for retained strength in the warp and weft, the percentages of the original warp strength and reflectance were also calculated. No general correlation was observed between the level of air pollutants and the deterioration of the samples. Other factors not tested may be responsible for the deterioration.[81]

1.1.c. Effect of fiber composition, fabric construction and surface treatments for protective clothing

1.1.c.i. Definitions of Protective clothing

(i) Protective textile refers to the garments and other fabric related terms designed to protect the wearer from specified hazards that results in injury or death. [111]

(ii) Protective clothing is a garment, or textile related products that are worn, that prevent a person (or product) from coming into contact with, that protects from and/or reduces the risk of exposure to hostile elements or environments.

1.1.c.ii. Role of cloths in protection

Clothing is one of the basic necessities for the mankind. People choose their clothing depending on their need, purpose, etc. apart from domestic purposed, textiles are also used to protect human beings from a harsh environmental effects which may result in injury or death. The range of hazards and the means of combating them continue to grow and become ever more complex. A consequence of this is the development and exploitation of new textile fibres, structures and clothing systems whose purpose is to provide improved protection, whilst maintaining comfort, efficiency and well being. A number of researches have also shows that the textiles are intrinsically suited for use as protection, as they are able to offer particularly good protection against various hazardous environments.

Some of the hazards to which workers are subjected are:

- Hazard from thermal radiation
- Hazardous environments in warfare requiring bullet proof fabrics.

- Chemical hazards
- Mechanical hazards such as cut, tear, puncture, splash, impact and abrasion
- Electrical hazards when they are working close to power lines and electrical equipments which may cause electric shocks and acute flammability.
- Extreme cold conditions
- Micro-organisms or bacteriological hazards requiring anti-microbial fabrics
- Nuclear radiation

To suit specific requirements, protective clothing's are made from woven, knitted and non-woven fabrics.

1.1.c.iii. Effect of fiber composition for providing protection

Nature of Fibers and UV protection

All fabric products which are used outdoors are exposed to sunlight and hence get degraded by ultraviolet light. It is known as UV degradation, and is one form of polymer degradation. UV absorption leads to chain degradation and loss of strength at sensitive points in the chain structure. Even The problem appears as discoloration or fading, cracking and sometimes, total product disintegration if cracking has proceeded far enough. The rate of attack increases with exposure time and sunlight intensity.

Natural fibers like cotton; silk, and wool have lower degree UVR absorption than synthetic fibers such as PET. Cotton fabric in a grey state provides a higher UPF because the natural pigments, pectin, and waxes act as UV absorbers, while bleached fibers have high UV transparency. Raw natural fibers like linen and hemp possess a UPF of 20 and 10 to 15 respectively, and are not perfect UV protectors even with lignin content. However, the strong absorption of jute is due to the presence of lignin, which acts as a natural absorber. Protein fibers also have mixed effects in allowing UV radiation. Dyed cotton fabrics show higher UPF, and undyed, bleached cotton yields very poor UPF values. Wool absorbs strongly in the region of 280 – 400 nm and even beyond 400 nm. Exposure to sunlight damages the quality of silk's colour, strength and resiliency in both dry and wet conditions. Mulberry silk is deteriorated to a greater extent than muga silk. Bleached silk and bleached PAN show very low UPFs of 9.4 and 3.9 respectively. Polyester fibers absorb more in the UV A & UV B regions than aliphatic polyamide fibers. [34]

Fabric characteristics were examined by **Davis, Capjack, Kerr and Robert (1997)** for their relationship to UVR transmission to determine if certain fabric characteristics such as cover, mass, fiber type, fabric count, could be used to predict the solar-protective performance of fabrics. UVR transmission was measured using a spectrometer fitted with an integrating sphere and a filter to block flurorescence. Twenty-eight fabric i.e. cotton, wool, polyester, nylon, linen, acetate, acrylic, rayon, and two blends, polyester/wool and polyester/cotton were chosen to represent a wide variety of fiber types, fabric weights and woven or knit structure for the study. It was found that the SPF values varied greatly for many fiber types. All white cotton, linen, acetate, and rayon samples had an SPF of less than 15. Polyester and polyester blends fabrics had higher SPF values and offered higher protection than other fiber types in comparably constructed fabrics. 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. The presence of dyes increased protection considerably. [21]

Soiling tendency of different fibers and fabrics

Fibers differ in contour and size as well as their chemical constitution. The surface of the wool is highly serrated by the projecting edges of its epidermal scales, cotton has a convoluted surface and fibrillar fine structure, while silk is smooth and even. Rayon and synthetic nylon, terylene and orlon are extruded materials and are smooth or in same cases have longitudinal serrations. The hydrophobic fiber develops static charges that attract dirt and dust. Being hydrophobic, it has poor wetting property, i.e. difficulty for aqueous wash liquor to enter the fabric. Gradual graying of fabric can also take place.

The pick up of dirty surfaces occurs much more readily if the fabric is rough or hairy. A fabric with dirty surface may look heavily soiled when, in fact, only small amount of dirt has been picked up. But, being concentrated on the surface fibers, it produces a noticeably dirty appearance. A static charge on a fabric will attract dirt, and soil acquired in this way becomes very firmly attaches. Triacetate, polyester, nylon and acrylic fibers develop static charge by rubbing while in use and retain them for a long time. Therefore, they are particularly liable to become soiled in this way. [124]

Soiling depends upon the particular finish applied to the fabric. There are two basic reasons why durable press finishes pick up soil, either in use or during laundering. First polyester fiber, being hydrophobic, tends to pick up oily matter and this tendency is increased by the coating of resin it receives in durable press finishing. The cotton component, although normally hydrophilic, is loaded with resins, which also tend to retain oily stains. Fabrics of cotton blended with oleophilic polyester are prone for easy soiling and difficult soil-removal. It is possible to reduce their soiling tendency by appropriate finishing treatments

The type of fiber and its surface structure, the final form of the woven or knitted textile as well as the treatment given to the fabric, all affect soiling and washing. [123]

Yatagai and Takahashi (2006) did laboratory-soiling tests using iron oxide and carbon black models soils on unfinished and durable press finished cotton, linen and lyocell. Fabrics were durable press finished with citric acid (CA) or 1,2,3,4, -butanetetracarboxylic acid (BTCA), in the presence of sodium hypophosphite (SHP) catalyst. The DP-finished fabrics were tested for soiling as well as for their wrinkle recovery angle 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 fabrics) compared to the untreated control. Both unfinished fabrics showed excellent resistance to soiling with carbon black as compared to control. Improved soil resistance was also observed in BTCA finished linen and lyocell fabrics toward iron oxide or carbon black. [137]

The soiling and soil release behaviour of silk fabric has been investigated by **Kumar and Dave (1983)** using model particulate soil (ferric oxide) under the standard soiling and washing conditions. The results obtained have been compared with those for polyester and cotton fabrics of nearly the same construction. It is observed that the soiling of fabrics of the three different fiber types increase in the order: silk < cotton < polyester, whereas soil release follows the opposite trend, i.e. silk > cotton > polyester. The location and distribution of soil particles on the fiber surface have been examined using the scanning electron microscope, it was found that soil particles are mainly located on the fiber surface and their concentration in the inter-fiber and inter-yarn spaces is relatively low. The kinetics of particulate soil release from fabrics has been found to follow the first order rate process. The effect of washing period and washing temperature on the rate coefficient and the order of soil release process has been also been studied. The value of rate coefficient increases with the increase in wash temperature up to 70 ^{O}C and then decreases with further increase in temperature, whereas the kinetic order of the process follows a decreasing trend.(75)

1.1.c.iv. Fabric characteristics

In woven, knitted and non-woven fabrics, the geometrical spaces between fibers or yarns are determined by the interlacing, interloping or entanglement patterns respectively.

The weave or construction of fabrics is the main factor affecting the amount of UVR that is transmitted 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.

Eight woven fabrics were selected to illustrate the effect of chemical processing on UVR transmission. Fabrics were characterized with respect to fiber chemistry, fabric construction, weight, thickness, and chemical processing history. Influence of fabric characteristics and processing on Ultraviolet protection factor (UPF) were studied by **Sarkar (2006).** Furthermore, a knit bleached cotton T-shirt fabric was treated bio-chemically and the effect of bio-chemical processing on UPF was investigated. Results showed that physical characteristics of fabrics such as thickness, weight and cloth cover were shown to be only partly useful in explaining the UV protective abilities of fabrics in that the data show anomalies when only physical features of fabrics are considered without considering processing history. However, by taking into account the processing history of fabrics, the UPF values obtained can be fully explained. (153)

De, Sankhe, Chaudhari and Mathur (2005) made an attempt to produce UV-resist, breathable fabrics for use in the cold regions of India as high attitude fabrics. Undyed Nylon 6 fabrics with two different GSM i.e. 60 and 90gms in plain weave were selected. For UV resist property, a dispersion of benzotrial-type derivative and a silicone-based product were taken and perfluoroalkyl type fluorocarbon-based compound and fluorocarbon resin-type compound were used as water-repellent finish. To estimate the performance of each finish on the fabric, these chemicals were applied separately with different concentrations. UV resist were applied by exhaust method were 1 and 2% add-on concentrations. Water-repellent finishes Perfluoroalkyl-type fluorocarbon-based compound was applied in two different concentrations of 15 and 30 gpl and Fluorocarbon resin-type compound was applied in two different concentration of 30 and 40 gpl with 2gpl 30% acetic acid by padding mangle. Treated fabrics were evaluated for breaking strength, strain, tearing strength, water vapour permeability and spray rating. On the basis of test results, the finish and optimum concentration were finalized. After optimization both types of finish were applied sequentially on both the fabrics. The finished sample was then evaluated for various parameters as mentioned above including repeated washing cycles to check the durability of the finish. The benzotriozol derivative for UV-resist and the fluorocarbon resist-type compound for water-repellent finish gave best results and showed good wash fastness. (23)

Crews, Kachman and Beyer (1999) carried out a series of trails to determine the influences of UVR transmission of undyed woven fabrics. They studied forty-three undyed woven fabrics representing a wide range of fibers, fabric type, fabric weight and fabric thickness. Results showed that fabric porosity, as estimated by image analysis was the single best predictor of an undyed woven fabrics UVR-blocking properties. Polyester, silk and wool fabrics exhibited better UVR blocking properties than cotton or rayon when porosity and thickness were taken into account. (15)

As the weight and complexity of fabric structure increases the soiling also increases. Twist and yarn count also effect the soiling of cloth, it was observed that more soil remained on the surface of yarn with higher twist.

The influence on soil retention of filament denier and cross-sectional contour of a series of man-made fibers has been studied by **Weatherburn and Bayley (1957).**

The fibers used included normal acetate (with the usual serrated cross section), circular cross-sectional acetate, nylon, terylene, and viscose rayon. Filament deniers varied from approximately 2 to 16. Soil content was determined by dissolving the soiled fiber in a suitable solvent and measuring the optical density of the resulting suspension. In general, soil retention increases with decreasing filament denier, and for any one type of fiber, e.g., acetate, circular cross-sectional fibers retain less soil than those of similar denier but having a serrated cross section. Soil retention by any one type of fiber is a linear function of the gross surface area of the filaments. There are differences in soil retention by various chemical types of fiber that apparently cannot be related to differences in physical size and shape of the filaments. The influence of static electricity on soiling is not clear, with soil retention showing no correlation with the magnitude of the electrostatic charge. The visual appearance of soiled fibers is not necessarily indicative of the quantity of soil retained. (144)

1.1.c.v. Surface treatments

Different treatments on the fabrics can change the surface properties. It adds or improves functional properties such as protection against UV radiation and soiling.

Chemical processing to protect fabric from U.V radiation

Transmission through the fibers can be effectively reduced by use of selected dyes, fluorescent-whitening agents and by means of UV absorbers. These products have chromophonic system that absorb very effectively in the UV region, enabling them to maximize the absorption of UV radiation on textiles. They are TiO_2, dyes, Fluorescent whitening agents, and UV absorbers. (44)

Gupta et al (2005) have evaluated various natural dye powders i.e. Acacia Catechu (katha), Acacia nilotica, Punica granatum (Pomegranate), Quercus infectoria (Gall nuts), Terminalia chebula (Harda), Kerria lacca (Lac), Mallotus philippinensis (Kamal), Rheum emodi (Dolou), Rubia cordifolia (Madder) and Rumex maritimus for protection against UV radiation and antimicrobial growth on cotton. All the dyed samples show high absorption in the UV region. When mordants are used, the UV screening effect is enhanced. Results show that it is possible to develop cotton fabrics having anti-microbial and anti-UV properties using selected natural dyes. Tannin based dye Q.infectoria shows good protection against both UV radiation as well as common microbes. [47]

Sarkar (2004) studied the impact of three natural colourants, i.e. two from plants and one from insect origin [madder (Rubia Tinctorum), indigo (Indigofera tinctoria) and cochineal (Dactylopius coccus)] on three cotton fabrics. Fabrics were characterized with respect to fabric construction, weight, thickness and thread count. Ultraviolet Protection Factor (UPF) was measured using a labsphere UV-a00F Ultraviolet transmission analyzer. The effect of colourant concentration on the UPF was examined via colour strength analysis. A positive correlation was observed between weight of the fabric and their UPF values. Similarly thicker fabrics offered more protection from ultraviolet rays. Thread count appears to be negatively correlated with UPF. Dyeing with natural colourants dramatically increased the protective abilities of all fabrics. Additionally, within the same fabric type UPF (ultraviolet protection factor) values increased with higher depth of shades. [107]

A new approach to a UV-blocking treatment for cotton fabrics is developed by **Xin, Daoud, Kong (2004)** using the sol-gel method. The treatment forms a thin layer of titania on the surface of cotton fibers, and the treated fabrics show much improved protection against UV radiation, with a UPF factor of 50+ or excellent protection according to the Australian/New Zealand standards. The treated fabrics are also tested for washfastness. The results show that the excellent UV protection rating of the treated fabrics can be maintained even after 55 home launderings, indicating a high level of adhesion between the titania layer and the cotton. A bursting strength test of the treated fabrics shows no adverse effect from the treatment. [135]

Ghosh, Bajaj and Kothari (2003) has been studied the effect of different dyes and finishes on UV protection property of jute/cotton union fabrics. Two reactive dyes i.e. Monochlorotriazinyl reactive dye Cibacron Red FAL and Solophenyl Turquoise Blue BRLE dye and two UV absorbers namely Cibatex UPF from CIBA Speciality Chemicals and Rayosan C from Clariant (India) Limited, were also used along with titanium dioxide TiO_2. The samples were bleached, dyed and treated with finishes. The samples were evaluated for UV protection by an indirect method and results lead to the conclusion that 100% grey jute fabric provided higher protection than both grey and bleached jute / cotton union fabrics. It is observed from spectral analysis that the monochlorotriazinyl reactive dye with cyanuric chloride nucleus such as Cibacron Red FAL, is quite effective in UV protection. From the UV-visible spectral analysis, Cibatex UPF is found to be a suitable finishing agent for rendering sufficient UV protection to the jute/cotton fabric. Simultaneous dyeing and finishing with Cibacron Red FAL and Cibatex UPF provides higher UV protection. The treatment of jute/cotton fabric with titanium dioxide also provides satisfactory protection against UV rays. [38]

Soil release treatments and agents

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.

Different methods used for tackling soiling problems in textiles are masking/ camouflaging, mercerizing/caustic treatment, metal oxides and salts, acrylic polymers, flurocompounds, carboxylic cellulose, etc. [85]

Easter and Bruce (2004) conducted a "Comparative study on soil repellent finishes and dual action fluorocarbon finishes on cotton blends". A dual action stains repellent / stain release technology functions by repelling water based stains while at the same time allowing soils that become stains when they penetrate the finish to be released. The objective of the research project was to compare the appearance and performance characteristics of both finishes. The aesthetic and functional characteristic of fluorocarbon treated khaki pants was evaluated. The properties of water repellency, oil repellency, soil release, colourfast, smoothness appearance and edge abrasion were evaluated at wash / dry intervals of 10, 20 and 30 cycles. The effects of a fabric softener and ironing on the aesthetic and functional performance of the finish were factors included in the research design. Two fabric finishes: soil repellent treated 60% cotton / 40% polyester and dual-action soil repel / release treated 60% cotton / 40% polyester was used.

The performance characteristics of smoothness, colour and edge abrasion were evaluated. The sample were also evaluated for their water – stain repellency and stain release properties. In every performance test except the spray test, the repel / release fabric out performed the repel-only fabric. Most notably, the colour retention, the performance in the alcohol test for stain repellency and the release of the dirty motor oil stains was substantially better for the repel / release fabric. [30]

Obendorf and Borsa (2001) using electron microscopy and radiotracer techniques studied soiling and soil removal from cotton fabrics that had been chemically modified by mercerization and carboxymethylation. The distribution of soil in specimens before and after laundering was determined. Both the chemical and physical changes of the cotton resulted in differences in soiling and soil removal of lipid soil. The results of this experiment indicate that chemical accessibility and hydrophilicity of the fiber structure influence both soil deposition and soil removal of lipid soils. Soil removal of these modified cottons is enhanced by multiple mechanisms: (i) the decrease in small crevices and the crenulation or small capillary along the fiber, (ii) the increase in pore volume that enhances chemical accessibility and thus detergency within the fiber structure, (iii) the increase in hydrophilicity that enhances soil removal from the surface by the roll-up mechanism, (iv) the increase of mechanical action due to enhanced swelling of the carboxymethylated cotton, and (v) the reduction of soil redeposition on carboxymethylated surfaces. [181]

Czech, Pavlenyl and Sabia (1997) study resulted in the development of two silicon softeners by blending the terpolymer with Magnasoft plus (amino-silicone) and with a novel (AB)n in linear, polydimethylsiloxane aminopolyalkyeneoxide block copolymer called magnsoft SRS, which provides substantially improved fabric softness without degrading the soil release properties provided by the fluorocarbon treatment.

The chemical used were the scotch guard FC-248, a 30% fluroaliphatic ester emulsion, was the fluorocarbon soil release agent, a DMDHEU resin was the durable press resin. Four chemically different silicones and a blend were evaluated. The fabrics treated were bleached, mercerized 100%cotton and 65/35 polyester/cotton broadcloth bleached fabric. The results obtained shows that on the 63/35 polyester/cotton at the 0.5% silicone application level, all silicones reduced soil release after one wash by 0.5 soil release units as compared to the fabric treated with fluorocarbon and resin only. The copolymer and the terpolymer had the same soil release performance as the fluorocarbon/resin alone treatment.[18]

Some of the effects which can be obtained on cotton through the combined use of a fluorochemical textile finish and conventional water-repellent products were studied by **Harman (1961).** The types of water repellents included in this study are quaternaries, stearamide-resin dispersions, silicones, aluminum salt-wax emulsions, zirconium salt-wax emulsions, and a cationic thermosetting compound. The effects studied, and for which data are presented, include dynamic absorbency, spray ratings, soil resistance, whiteness, and mildew resistance. The properties obtained are also evaluated for their resistance toward laundering, dry cleaning, weathering, and abrasion. The result showed that the resistance that fluoro-chemicals provide permits ready removal by blotting most of the stains during use. Stains, which were allowed to remain on the fabrics until launderings, were superficially attached to yarn surfaces in a state where they were readily accessible to the detergent solution. [(49)]

1.2. PURPOSE OF THE STUDY

From the above cited literature and research studies it was clear that fabric type (content), fabric construction and finishing of textiles if used in proper combinations can prove to make effective protective clothing for outdoor workers

In recent years the concern with environmental issues has grown, especially with the thinning of the ozone layer. Till a few years back, the problem of protecting the brown skin from ultra violet radiation was given much thought as it was considered to be a problem only of the white population. However researches are now showing that a tropical country like India also needs to gear up to protect its population from excessive exposure to UV radiation. This has been further confirmed by a joint study by scientists of the IIT, Kanpur and George Mason University, Virginia which assessed the trend of total ozone column (TOZ) over the Indian subcontinent and adjacent region during 1997-2003. The study showed an increase in the rate of decline of TOZ at several locations over the western, eastern and central parts of Indo-Gangetic basin. [(176)]

UV index in most part of the India is 8+, implying that skin damage and burn can occur quickly after 15min (pp from ROL). Data from the various studies have shown that there is a need to provide adequate degree of protection against UV radiation in our country. [(182)]

India being a tropical country, most times of the year its summer only and outdoor workers have no choice about the duration of their exposure to the sun. They are exposed to UV radiation both directly from the sun and indirectly as it is reflected or scattered from surrounding surfaces, such as concrete, glass, metal surfaces (such as steel decks and roofing materials), sand, grass, snow and large bodies of water. So there is need to wear sun protection even in the shade for maximum protection. The review of literature shows that increased occupational exposure to the sun has been a major contributory factor in the rising incidence of skin problems.

In India it is estimated, that there are *400 million* workers in the unorganized sector, who have to mostly work outdoors. [(182)] Construction and agricultural workers constituting the largest segment of this population.

Recognizing all these facts, it is important to protect the skin of the people who are engaged in the agricultural sector and construction work, as they constitute a majority of our population. Although skin cancer caused from excessive exposure to UV radiation, has not reached a pandemic proportion in India, but this needs to be addressed with great concern.

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

There is requirement of a textile, which incorporates UV-protection and soil release properties, in order to reduce the risk of exposure to UV radiation as well as accumulation of soil on the clothes of outdoor workers while performing their respective jobs.

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

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

1.3. Objectives

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

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

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

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

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

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

1.4. Delimitation of the study

1.4.1. Study was limited to three fiber types i.e. cotton, polyester and polyester/cotton blend in plain and twill weave that is the total of six fabrics.

1.4.2. Study was also limited to the use of two selected finishes as UV absorber i.e. Commercial UV absorbers and natural colouring agent Acacia Catechu (*Katha*) and two finishing agent as anti soiling i.e. Commercial soil-release finishes and Carboxy Methyl Cellulose.

1.5. Scope of the study

- If given an UV absorber finish along with soil release treatment such textiles can be used for protective clothing of outdoor workers.
- The aim of these fabrics is to provide protection with comfort to the outdoor workers.