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A REVIEW ON SUN-PROTECTIVE CLOTHING

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Abstract: *The sun is ultraviolet (UV) radiation source. Damage to skin cells from ultraviolet exposure can lead to the carcinogenic problem such as skin cancer. Clothes and protective agents in cosmetics could be supplied personal protection from UV radiations. The assessment of UV transmittance of clothing and the determination of the UV protection factor (UPF) is crucial for skin cancer. The pathogenesis of epithelial skin cancers causes effects in the human bodies such as squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) and malignant melanoma (MM) could be prevented by suitable UV-protective clothing. UV protective clothes have some characteristic properties such as fiber type, yarn construction, fabric construction, fabric weight and thickness, coloring process, standards and presence of UV radiation absorbers. These parameters have a direct effect on the effectiveness of sun protection and consequently the risk of skin cancer. The increasing of skin cancer rates in past several decades has increased the interest sun-protective clothing. A lot of work has been done around the world on about sun-protective clothes. The aims of this review are to explain properties, standards, and applications of sun-protective clothes, change people's sun behavior and raise awareness for the use of adequate sun-protective clothing.*

Keywords: *Ultraviolet (UV), Ultraviolet Protection Factor (UPF), Sunlight, Absorber, Spectrophotometer*

1. INTRODUCTION

On Earth, the ultimate source of natural light is the Sun. The sunlight consists of infrared, visible light and ultraviolet (UV) radiation. UV radiations damage to skin cells and lead to the development of skin cancer. Sun-protective clothes could be supplied protection against the hazards of UV radiations. Various clothes parameters have an influence on the UPF (Ultraviolet Protection Factor) for being effective broadband protection against the sun. The measurement, properties and standards of UV radiation and UPF affects of clothing are important for the development and application of protective clothing. More detail (UV radiation and its health risks, sun-protective clothes etc.) is given in below sections and subsections of this paper.

2. UV RADIATION

UV radiation on with the wavelengths ranges from 200 to 400 nm, the span of wavelengths shorter than those of visible light but longer than x-rays (400-700 nm). UV radiation has three classifications for wavelengths: UVA (320 – 400 nm), UVB (280 – 320 nm), and UVC (200 – 280 nm) [1].

UVC has been blocked from reaching the Earth's surface by the stratospheric ozone layer. It could extinguish the harmful micro-organisms such as bacteria and viruses by destroying the genetic information in the DNA and use in germicidal lamps. The micro-organisms lose their reproductive capability and are destroyed. Wavelengths of the UVB radiation region are absorbed into the skin, it leads to health problems such as erythema, burns, persistent pigment darkening and so finally skin cancer. UVA has caused carcinogenic problems, speedly aging and wrinkling of the skin because including longer wavelengths than UVB and penetrating more deeply into the skin. UV radiation spectrum and its effects could be seen in Figure 1 [2-3].

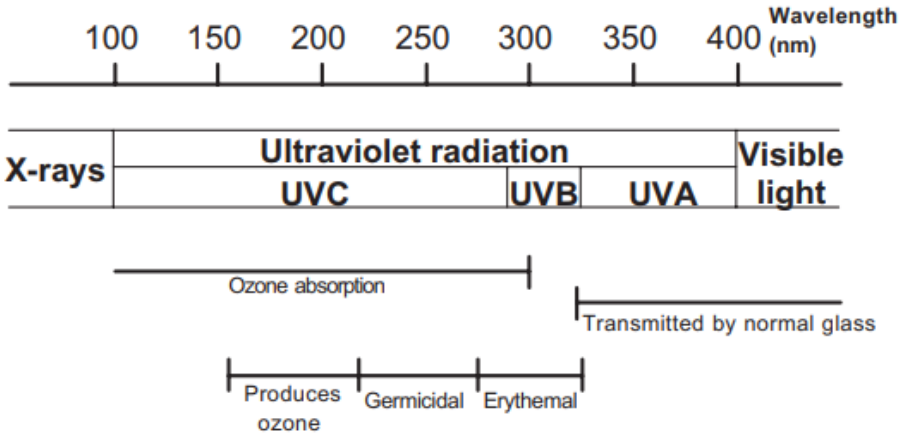

Fig. 1: *UV radiation spectrum and the chemical, physical and biological effects [2]*

3. HEALTHY RISKS OF UV RADIATION

Skin is the structure that will be most affected by cancer in the human body. Direct or indirect UV irradiation causes affect the pathogenesis of epithelial skin cancers such as squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) and malignant melanoma (MM) [2]. Acute UV irradiation leads to DNA lesions such as pyrimidine dimers and (6-4) photoproducts. If they are not repaired, it could be caused to DNA mutations. This mutation must be prevented with DNA repair mechanisms [3].

UV protection against skin cancer has versatile tratments. Researchers have investigated about cell carcinoma on the groups which are beta carotene supplementation, another group sunscreen plus placebo tablets, beta carotene only or placebo only. None of the treatments caused to fall the incidence of BCC, but the incidence of SCC was dramatically lower in the sunscreen group than in the no-sunscreen group [3]. Especially, on white populations, the rising incidence rates of SCC and BCC are composed of increased sun exposure or exposure to ultraviolet (UV) light, increased outdoor activities, changes in clothing style, increased longevity, and ozone depletion [4].
MM is the most dangerous form of skin cancer because it may be developed when unrepaired DNA damage to skin cells. MM is caused by ultraviolet radiation from sunshine and triggered genetic defects. Malignant tumors derive from the pigment-producing melanocytes in the basal layer of the epidermis [5]. MM have different risk factors such as skin color, tendency to freckle, family history of melanoma, the presence of many naevi, increasing age and exposure to UV light [4]. Additionally, especially in childhood, the number of melanocytic nevi is associated with an increased risk of malignant melanoma [3].

Fig. 2: *Most Common Types of Skin Cancer [6]*

4. SUN-PROTECTIVE CLOTHES

Clothes and protective agents in cosmetics could be supplied personal protection from UV radiations. Fabrics provide protection against UV radiation, but it isn't enough to sufficient UV protection. Sunlight protective fabrics are evaluated by UV protection factor (UPF), which could be range from 15 to 24 for good protection, 25 to 39 for very good protection and 40 to 50 or more for excellent protection [7]. UPF factor can be measured with the spectrophotometer using an in vitro method. It collects both transmitted and scattered radiation with the aid of an integrating sphere positioned behind the textile sample [8] UV protective clothes must have some parameters such as UPF, fiber type, yarn construction, fabric construction, fabric weight and thickness, finishing process, coloration process, and presence of UV radiation absorbers [9]. Their protection effects represent with detail in Table 1.

Table 1: *Characteristics of Sun-Protective Clothes [10]*

Characteristic	**Good Protection**	**Poor Protection**
Fabric Construction	Tightly woven/knitted	Loosely woven/knitted
Fabric Weight	Heavy	Light
Type of Fiber	Wool, polyester	Cotton, silk, polyamide, polyacryl
Textile Color	Dark, bold	White, light, pastels
Moisture	Dry	Wet
Fit	Loose	Tight

4.1. Fiber and Yarn Parameters

It is affected of the base fibre material on the UV absorption causing the fluctuations up and down in the UV transmittance, but the UV reflectance trend is the same [11]. Polyester or polyester blends may be the most suitable fabric type for UV protection clothes because they provide relatively low UVB transmission probably due to a large conjugated system in the polymer chains. Bleached cotton and viscose rayon are transparent to UV so they can grant low portection to UV radiation [12].

Fine fibres in fabrics have both the high UV protection and good tactile comfort. The yarns with the fine fibre diameter, the large yarn linear density, low twist and large refractive index could supply the high UV protection [11].

4.2. Fabric Parameters

For fabric construction, both yarn-to-yarn spaces in the fabrics are smaller and less fabric's porosity results less UV radiation which is transmitted. For suitable fabric in UV protection must have fiber content and fabric construction, an increase in weight per unit area is associated with a decrease in fabric porosity and the spaces between the yarns could be smaller in a heavier textile, therefore less UV radiation is transmitted. Additionally, denser fabrics transmit less UV radiation and so fabric thickness is most useful in explaining differences in UV transmission [12]. Similarity, for the weight of the fabric, varies from 80 to 300 g/m^2, and this greatly affects the UPF [13].

The value of porosity in a good quality fabric is below 10% while that in a bad quality fabric may be above 30% [13]. The ideal fabric determined that the yarns which are completely opaque to ultraviolet radiation and the pores between the yarns are very small. Porosity of the ideal fabric as showen in equation 1 [14].

$$UPF = \frac{100}{Porosity\%} \quad (1)$$

4.3. Coloring Parameters

Generally, dark colors provide better UV protection due to increased UV absorption. UV absorbers are colorless compounds that absorb in the wavelength range 280-400 nm. Titan dioxide is frequently used as a UV blocking substance in fabrics. The absorptive and scattering properties of titan dioxide particles in the UVA wavelength range are different and depend mainly on the particle size and geometry [11]. UV-blocking treatment for cotton fabrics is used with the sol-gel method. A thin layer of titanium dioxide is formed on the surface of the treated cotton fabric, so it provides excellent UV-protection and this effect can be maintained after 50 washing [15]. The proportion of UVA wavelengths could be absorbed by the dye decreasing transmittance over part of the spectrum and increasing protection. Color depth affects both the absorption and the reflectivity of UV photons by the fabric with dye molecules and it has an important role [16].

4.4. Standardization of Sun-Protective Clothes

For determining UV protection in European Standards, European, draft standard prEN 13758-1, İt is used a spectrophotometric method with an integrating sphere. The method is used for clothing fabrics which are worn in close proximity to the skin but not on the skin. According to the method, UPF on clothing must be larger than 30 for being UV-protective. For determining UV protection in United Kingdom Standards, referred to as BS 7914 "Method of Test for Penetration of Erythemally Weighted Solar Ultraviolet Radiation Through Clothing Fabrics", it is used of a photospectrometer equipped with an integrating sphere. The first requirement of standard is the design of the clothing. Another requirement is a maximum UV penetration of 2.5%. This method is suitable for UV-protective apparel of children older than 6 months [17]. American Standarts have three categories for the testing and labeling of UV-protective textile products such as ASTM D 6544 "Standard Practice for the Preparation of Textiles Prior to UV Transmission Testing", AATCC 183 "Test Method for Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation Through Fabrics", and ASTM 6603 "Standard Guide to Labeling

of UV-protective Textiles" [18].

5. CONCLUSION

The sunlight consists of infrared, visible light and ultraviolet (UV) radiation. UV radiation has some carcinogenic properties on human skin. The use of sun-protective clothes can provide excellent protection against the hazards of sunlight. Sun-protective clothes play a significant role in the prevention of skin cancer. They depend on a number of parameters, including fibre material, yarn and fabric construction, type, weight, thickness, coloring processes, standardizations, and UV-absorbing substances additives. This paper could be useful to understanding parameters and raise awareness for the use of adequate sun-protective clothing.

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