Photoprotection
Clothing and Glass

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KEYWORDS

• Ultraviolet • Photoprotection • Glass • Window films • Sunglasses • Clothing

KEY POINTS

- Physical methods of photoprotection include glass, window films, sunglasses, and clothing.
- All types of glass block UV-B.
- UV-A transmission depends on the type of the glass.
- Window films added to glass greatly decrease the UV-A transmission of the glass.
- Fabric characteristics can greatly affect the level of photoprotection offered by clothing.

INTRODUCTION

All people are exposed to ultraviolet (UV) radiation (UVR) from the sun. UVR is divided into UV-C (100–290 nm), UV-B (290–320 nm), and UV-A (320–400 nm). All of UV-C and most UV-B (approximately 90%) are absorbed by the ozone layer, which results in mainly UV-A and a small percentage of UV-B reaching the surface of the earth.[1] UVR has known effects on the skin and eyes. With regards to the skin, the acute effects include erythema, edema, pigment darkening, delayed tanning, epidermal hyperplasia, and vitamin D biosynthesis. The chronic effects include immunosuppression, photoaging, and photocarcinogenesis.[2] On the eyes, UVR exposure has been strongly associated with the development of pterygium, photokeratitis, climatic droplet keratopathy, and cortical cataracts.[3] Photoprotection in the form of seeking shade between 10 AM and 2 PM, wearing a wide-brimmed hat, and applying sunscreen is widely promoted to the public. However, little attention is given to educate the public on physical methods of photoprotection, which include clothing, glass, and sunglasses.

PHOTOPROTECTION BY GLASS

Glass is a combination of sand or silica and other components, which are melted together at a very high temperature. At room temperature, it becomes a solid, whereas at higher temperatures, it softens to become a liquid.[4] Flat glass is the basic material used to make industrial and automotive glass. It is produced by the float process. During the float process, sand, limestone, soda ash, dolomite, iron oxide, and salt cake are mixed together with broken glass (cullet). These ingredients are melted at 1600 °C to produce a flat glass.[5] The flat glass is then treated in different ways to produce the different types of glasses that are discussed in the next section (**Table 1**).

Main Types of Glass

Annealed glass is the basic flat glass, which is the first result of the float process. It is the starting material in the glass industry to produce more advanced glass. It breaks into large pieces.[5]

Toughened or tempered glass is produced by heating the flat glass, followed by rapid cooling of the glass surface by air, which results in glass that withstands more compression than flat glass. It breaks into small regular pieces.[5]

Coated glass is made by applying a surface coating to the glass that results in additional advantages, such as decrease in the transmission

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Table 1
Common types of glass

Types of Glass	Comments
Annealed glass	Basic flat glass Breaks into large pieces
Toughened (tempered) glass	Withstands more compression than annealed glass Breaks into small regular pieces
Coated glass	Made by applying a surface coating to the glass Decreases the transmission of light and heat, resistance to scratch, or resistance to corrosion
Laminated glass	Made up of ≥2 layers of glass with interlayers of plastic Decreases transmission of UVR, transmission of sound, and improves security Broken pieces are held together by the interlayer
Patterned glass	Flat glass with a surface that shows a regular pattern

of light or heat, resistance to scratch, or resistance to corrosion.[5]

Laminated glass comprises 2 or more layers of glass with 1 or more interlayers of polymeric material (plastic) such as polyvinyl butyral. It is used in car windshields and facades of buildings. Technology can be incorporated in laminated glass to provide UV filtering, decreasing of sound transmission, adding colors, or resistance to fire. When it breaks, the broken pieces are held together by the interlayer, which provides safety.[5]

Patterned glass is a type of flat glass with a surface that shows a regular pattern.[5]

UV Transmission Through Residential Glass

Almost all glass blocks UV-B radiation, regardless of type or properties of the glass.[6] However, the transmission of UV-A radiation varies according to the type, thickness, and color of the glass. Duarte and colleagues[6] looked at the transmission of UV-A through various types of residential glass (annealed, patterned, tempered [toughened], and laminated). In most studies on glass, UV-A transmission is measured up to 380 nm, because at wavelength greater than 380 nm, glass would have to be opaque or heavily tinted to provide photoprotection. The transmission was measured by a photometer (UV-A-400C, NBC, OH) at zero distance from the UV-A source. These investigators showed that annealed and tempered glass transmit 74% and 72% of UV-A, respectively; patterned glass transmits less UV-A (45%), whereas laminated glass blocks all UV-A. The color of the glass also plays a major role in the transmission of UV-A. Of 5 different colors of patterned glass (green, yellow, wine, blue, and colorless), green was found to be the most protective, followed by yellow. Colorless and wine have similar properties, whereas blue glass offered the least photoprotection.[6] The thickness of the glass has a small effect on the UV-A transmission. Increasing the thickness of the glass 5 times (from 0.2 cm to 1.0 cm) resulted in a modest decrease in the transmission of UV-A, from 76% to 51%.[6]

UV Exposure in Automobiles

People spend approximately 1 to 2 hours per day in their automobiles, based on an epidemiologic study that evaluated 169 individuals from different parts of the United States.[7] When Kimlin and colleagues[8] evaluated UV exposure in cars both with open and closed windows, they found that the exposure is high enough to be considered in calculating the total lifetime UV exposure.

There is some clinical evidence to suggest that UV exposure in automobiles might have a biological significance. Hampton and colleagues[9] found that a 30 to 60 minutes exposure to solar radiation in midday summer in the United Kingdom through automobile tempered glass can reach a dose of 5 J/cm^2, which is sufficient to induce eruptions in patients with severe photosensitivity disorders. Two studies from Australia, which separately evaluated actinic keratosis and lentigo maligna, found these 2 conditions to be more common on the right side (the driver's side in Australia).[10,11] Skin cancers such as basal cell carcinomas, squamous cell carcinomas, melanomas, and Merkel cell carcinomas were found to be slightly more common on the left side from 2 retrospective studies performed in the United States.[12,13]

Automobile Glass

Of the flat glass industry market, 15% to 20% goes to the production of automobile glazing.[5] Automobile glazing is made up of laminated or tempered (toughened) glass. Either type can be tinted to improve the comfort and decrease visible light and infrared transmission. Most automobile glasses are tinted. The most commonly used tint is green, although gray and blue have also been used.[9] Windshields are made up of laminated glass for safety reasons to prevent ejection of the passengers in the event of frontal impacts, whereas side and back windows are usually made up of tempered (toughened) glass.[14]