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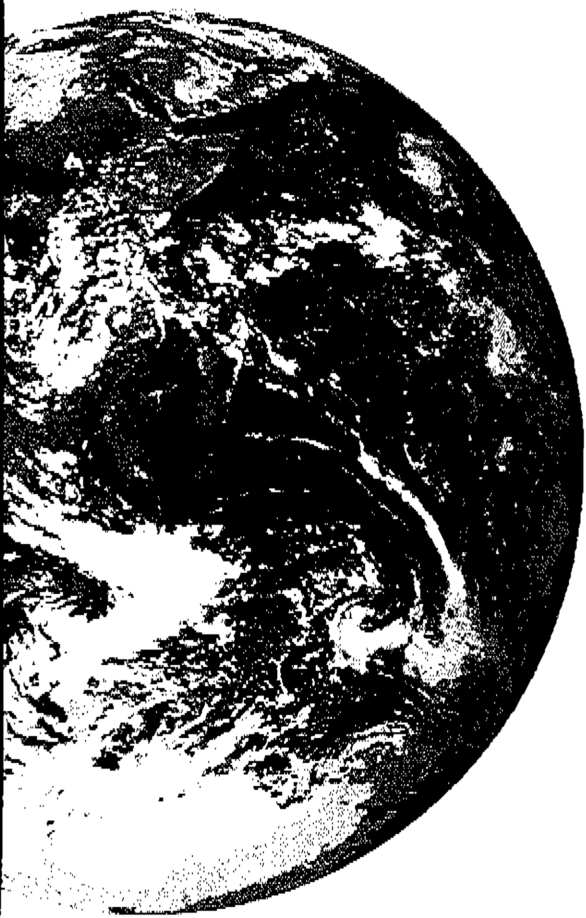

ULTRAVIOLET RADIATION EXPOSURE DOSIMETRY OF THE EYE

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ULTRAVIOLET RADIATION OCULAR EXPOSURE DOSIMETRY OF THE EYE

A Report to the World Health Organization and United Nations Environment Programme

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ABSTRACT

A careful study of ocular exposure to environmental sunlight demonstrates that it is not at all simple to accurately determine the level of solar ultraviolet radiation exposure of the human eye. Epidemiological studies of cataract depend heavily upon realistic and reasonably accurate dosimetry of UVR exposure. Unfortunately, most past attempts to measure or calculate UVR exposure of the eye for such studies have generally relied upon monitors to measure the ambient UVR in sunlight falling upon a horizontal surface (i.e., the global UVR). This approach is insufficient to properly assess the large role of ground reflection, the horizon sky contribution, the degree of lid opening and the extreme lateral component of UVR incident on the eye. Current dosimetric estimates may lead to incorrect assignment of lifetime exposures to different cohorts.

This report summarizes a series of recent ocular dosimetry studies undertaken to assess all of these factors. An algorithm is developed for calculating ocular exposure for a given environment. Additionally, the value of different types of eye protection is shown to vary widely depending upon frame design. The dosimetry studies can be confirmed by a biological dosimeter – the human cornea. Because the action spectrum and threshold for the human cornea are well defined, the living cornea actually serves as a biological dosimeter to calibrate this method for calculating ocular exposure. More accurate dosimetric methods are expected to aid in the resolution of the current controversy as to the etiologic role of UVR in cataract and other ocular diseases. Concerns about the depletion of stratospheric ozone and the related increase in terrestrial UVR exposure have emphasized the importance of resolving this controversy.

KEY WORDS: Ultraviolet radiation, eye, cataract, UV dosimetry

I. INTRODUCTION

1.1 Purpose

The objective of this study was to evaluate the geometrical, physiological and environmental exposure factors which play a role in determining the actual ultraviolet radiation (UVR) exposure of the lens to a person when outdoors in daylight, and to provide an algorithm for calculating exposure in a given environment.

1.2 Background

The prevalence of the blinding disease of cataract worldwide exceeds 50 million. Prevention or slowing the progress of lenticular opacities is an important objective in public health [1]. Despite the fact that animal experiments clearly show that ultraviolet radiation (UVR) can produce cataract under acute laboratory exposures [1-8], refined epidemiological studies show an increased risk of cortical cataract with UVB (280-315 nm) exposure [9], and the derivation of ocular exposure guidelines based upon these studies [10], the clear role of UVR in cataractogenesis is still debated. Some experts argue that UVR plays a major role [11] and others suggest that UVR does not [12]. To a large extent, the controversy is fuelled by poor ocular dosimetry. The goal of the studies reported here was to enlarge our understanding of the relative importance of several factors that determine the ocular dose from UVR in sunlight.

1.3 Ambient UVR Exposure

The ambient out-door UVR constantly changes during the day. Because these substantial changes are not directly proportional to the much less dramatic changes in visible light, we are subjectively largely unaware of the degree of these changes. For example, the summertime terrestrial solar spectral irradiance at a wavelength of 300 nm is ten times greater than at either three hours before or three hours after solar noon. An untanned person with fair skin would receive a mild sunburn in 25 minutes at noon, but would have to lie in the sun for at least two hours to receive the same dose after 3:00 (standard time) [13-15]. The integrated total exposure dose of biologically-weighted UVR falling on a horizontal surface (the global UVR exposure) occurs primarily during the midday hours, and 70% occurs during the four hours cantered on noon-time zenith as shown is Table 1 [13].

Because short-wavelength UVR is strongly scattered by atmospheric molecules, it is quite possible to receive a sunburn while lying in the shade, if exposed to a large segment of the sky. Although most visible light is not strongly scattered, and well over 85% of the light received at ground level on a clear sunny day are direct rays, more than 50% at 300 nm is scattered and diffused. Due to the strong scattering factor in the UV spectrum it has been conventional to distinguish between the direct and the diffuse components in sunlight. The sum of the global and diffuse components – the total falling on a horizontal ground surface, is termed the *global radiation*, as shown in Figure 1. If one could see at 300 nm and see only this radiant energy, the sky would appear perpetually in a heavy haze, and shadows would probably not be noted. For epidemiological studies of skin cancer and for atmospheric science, normally the global UVR has been used. This is clearly unacceptable for studies of ocular exposure, since the eyes are only exposed to diffuse, horizon UVR and to ground reflections.

Table 1. Calculated ACGIH Effective Global UV-B and Total UV-A Exposure