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SUNTEST: a chemical UVB radiation dosimeter

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Abstract

A simple disposable chemical UVB radiation dosimeter with silver–mercury–oxalate suspension, SUNTEST, was developed for use by the general public. Its spectral sensitivity curve closely matches the erythemal action spectrum. SUNTEST takes account of the variables influencing the length of sunbathing. The dose of solar UV radiation can be evaluated from the darkening of the dosimeter, from white to dark brown. On the basis of the results of a 5 min exposure, recommendations are given for safe exposure times (which do not produce sunburn) for different skin types. Regular use of this simple UVB dosimeter will contribute to the prevention of acute adverse effects of solar exposure; like any limitation of UV exposures, it may be expected to reduce also the late adverse effects, including skin malignancies.

Keywords: Chemical dosimeter; UVB; Sunburn; Skin types; Prevention

1. Introduction

Ultraviolet radiation (UVR) of sunlight induces several beneficial and adverse biological effects on human skin [1,2]. An increase in UVB has been observed in Antarctica and elsewhere when there is a considerable amount of ozone depletion. It may be expected that corresponding effects will be found elsewhere, though as yet there are few confirmed observations [3]. As a result there is an enhanced risk of development of both acute and late skin damage [4]. In order to contribute to the prevention of these adverse effects of UVR a simple disposable chemical UVB-sensitive radiation dosimeter, "SUNTEST" (Hungarian patent application no. P92 00766) was developed for use by the general public.

2. Methods and results

The photosensitive layer of SUNTEST is a silver–mercury(I)–oxalate suspension in gelatine (Hungarian patent application no. P92 00766). The format of the dosimeter is as follows: the suspension (inaccurately but commonly called emulsion) is embedded in gelatine and then mounted on a paper strip. It is white in unexposed form, similar to unexposed photographic papers. Increasing UVR/sunlight exposure turns it yellow, brownish then dark brown. Its use as a UVR dosimeter is based on the following chemical changes:

$$2Hg_2(ox) \longrightarrow 3Hg + ox^- + 2CO_2 + Hg^{2+} \quad \text{(photochemical reaction)}$$

$$Hg + Ag^+ \longrightarrow Hg^+ + Ag \quad \text{(colouring effect)}$$

2.1. Densitometric calibration measurements with SUNTEST

The colour changes of SUNTEST produced by different amounts of UVB radiation were measured quantitatively by reflexion densitometer (QUANTALOG, Machbeth, USA). For practical reasons in densitometric experiments a quartz lamp (HgOK 400, Medicor, Hungary), emitting mostly in the UVB spectrum was used as an irradiation source. Different parts of a SUNTEST probe were exposed at fixed geometry for different time intervals and then the reflection density of the separate coloured surfaces was measured. The characteristic curve of the photosensitive suspension displays the reflection density (D_{refl}) as a function of dose. (At constant geometry and constant light source intensity the irradiation time is an exact measure of dose (Fig. 1).) The nearly linearly increasing part of the curve shows the range where the system can be used as a chemical dosimeter. SUNTEST is processed

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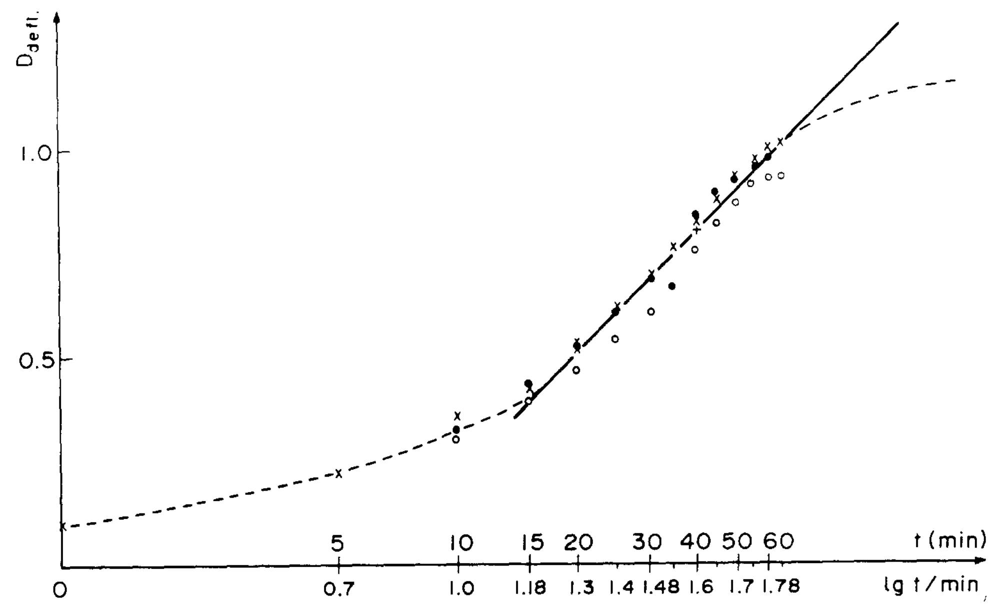

Fig. 1. Characteristic curve of the photosensitive emulsion layer of SUNTEST exposed to UVB spectrum.

in such a way that several minutes exposure in summer sunlight produces a well defined colour change ($0.5 < D_{refl} < 1.5$).

The characteristic curve of SUNTEST exposed to sunlight at different times of the day (10.00 and 13.15 h) is shown in Fig. 2.

The other crucial feature of a photosensitive system is its spectral sensitivity. For our purposes only, a UVB selective system is suitable. It must not be sensitive to visible light, but only, or mainly to, UVB radiation. It is best if spectral sensitivity of the dosimeter is very close to the action spectrum

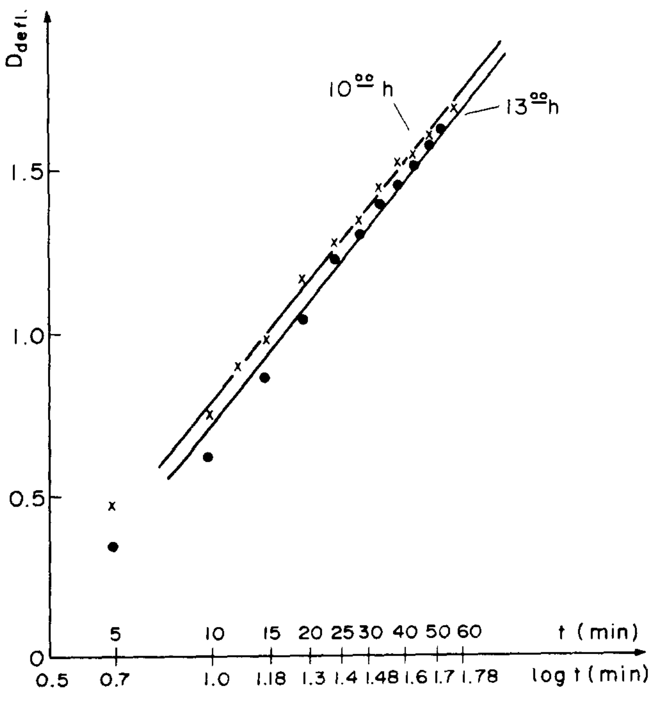

Fig. 2. Characteristic curve of SUNTEST exposed to sunlight.

for UVB-induced erythema. Fig. 3 presents the spectral sensitivity of SUNTEST and the CIE action spectrum for UVB-induced erythema [5]. The agreement is quite good for our purposes.

2.2. *Biological effectiveness of SUNTEST*

Measurements were performed with both the above-mentioned UV lamp and sunlight on the skin of the back of 24 healthy volunteers of different skin types [2]:

Group A: type 1: always burns, never tans
type 2: always burns, sometimes tans
Group B: type 3: sometimes burns, always tans
type 4: never burns, always tans

Parallel tests were carried out to establish the minimal erythema dose (MED) with the above-mentioned UV lamp and sunlight exposure on the back of the volunteers. The SUNTEST strip was placed on the back and was irradiated simultaneously with the same exposure times used for the MED determination. In evaluating the results, the darkening of the SUNTEST was correlated with the average MED in each skin type group. On the basis of the results obtained, recommendations were given for safe exposure times (which do not produce sunburn) for the different skin types (Table 1).

3. Discussion

The intensity of UVR in sunlight is subject, among other things, to such factors as the time of day, the season, the geographical conditions and the air pollution [6]. In addition, owing to the changes in the protective stratospheric ozone layer, the intensity of UVR has increased recently in certain parts of the world, resulting in an enhanced risk of development of both acute (sunburn, exacerbation of different cutaneous and internal diseases) and late skin damage (premature ageing, development of skin cancers) [4,7,8].

The sensitivity of human skin to UVR may be influenced by several factors, such as age, certain drugs, contact with chemicals or skin type [2]. Certain individuals are more predisposed to develop skin sunburn than others. Based on the skin sensitivity to sunlight, people can be classified into several groups. Skin type 1 is particularly at risk; such people always burn but never tan. Most Caucasians belong to groups 2 and 3 but there are a considerable number of them in group 1. In groups 1 and 2 especially, it is often difficult to determine acceptable sun exposure times which do not produce sunburn.

UVB is considered to be biologically the most effective spectral region of the UVR range. It has also been established that the erythemal action spectrum for untanned skin and for non-melanoma skin cancers is similar [9,10]. In order to prevent the adverse effects of UVB there have been a number of different kinds of erythemal dosimeters reported [9,11–16]. There are three important requirements for a UVB radiometer to measure the erythemal reaction to sunlight:

(1) rejection of the relatively intense longer wavelength UV and visible solar radiation;

(2) a spectral response closely matching the erythemal action spectrum [9], and

(3) a monotonic response as the UV dose increases [11].

The simple disposable UVB sensitive radiation dosimeter, SUNTEST, presented here is based on a silver–mercury–oxalate suspension. It meets the requirements of a UVB dosimeter. According to the spectral sensitivity curve its spectral response approximates the erythemal action spectrum, i.e. the peak response of the product occurs at UVB, whereas its sensitivity to longer wavelength UV is not significant in practice. The application of SUNTEST is very easy, the dose of the UVR radiation can be evaluated from the darkening of the dosimeter, comparing it with the calibration scale. The permissible time for sunbathing without sunburn can also be determined easily, i.e. the strip, which is provided in a film can with a calibration scale, is exposed for 5 min and compared with the scale. In addition, SUNTEST takes account of the variables influencing the length of sunbathing (type of skin, latitude, season, time of day, surrounding environment, etc.).

Regular use of this simple disposable UVB dosimeter, SUNTEST (produced by Forte Photochemical Company, Hungary for use by the general public) will contribute to the

Table 1
Exposure times allowed for safe sunbathing for different skin types expressed as a function of the discolouration of SUNTEST exposed to sunlight of different intensity for 5 min

Degrees of intensity	D_{refl}	Permitted exposure time to sunlight without sunburn (in min for skin type)	
		A [a]	B [a]
I	0.22	35	70
II	0.43	25	50
III	0.62	15	30
IV	0.78	10	20

[a] 12 persons.

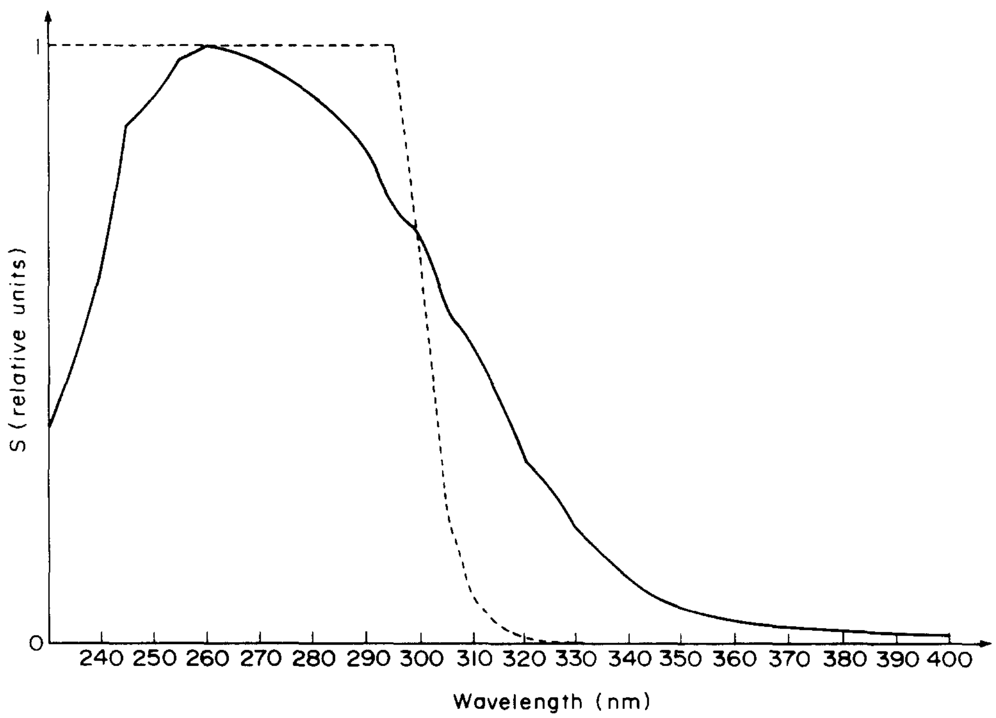

Fig. 3. Spectral sensitivity of SUNTEST (solid line) and action spectrum for UVB-induced erythema (dotted line).

prevention of acute adverse effects of solar exposure; like any limitation of UV exposures, it may be expected to reduce also the late adverse effects, including skin malignancies.

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