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**Protection of man against exposure
from solar radiation and UV-irradiation units**

Recommendation of the German Commission on Radiological Protection

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**Schutz des Menschen bei Sonnenbestrahlung
und bei Anwendung von UV-Bestrahlungsgeräten**

Empfehlung der Strahlenschutzkommission

**In the event of any doubts about the meaning,
the German original as published shall prevail.**

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1 Introduction

The Commission on Radiological Protection is greatly concerned about the increase in acute and chronic skin injuries caused by ultraviolet rays, especially about the increased rate of skin cancer.

Electromagnetic waves with wave length of 100 to 400 nanometer (nm) are described as ultraviolet (UV) waves. UV-rays are contained in the sunlight, they are invisible and of higher energy than the rays of the visible light. UV-C-rays (rays with wave lengths of 100 to 280 nm) are nearly completely absorbed by the ozone existing in the upper atmosphere. UV-B-rays (rays with wave lengths of 280 to 315 nm) are also absorbed by ozone, except for a certain percentage, whereby the value is directly depending on the ozone concentration of the atmosphere. With increasing wave length, UV-A-rays (rays with wave length of 315 to 400 nm) are less and less detained by gases in the atmosphere.

UV-rays produce different effects on the skin which are based on the thermal and photochemical energy transition. The curative application of UV-rays may be indicated for certain diseases, especially those of the skin. The most obvious reaction of the skin to UV-radiation is pigmentation. This tanning of the skin can be interpreted as a protection mechanism of the skin, as is the thickening of the skin which begins in the form of "photopathy" after UV-radiation with UV-B-share. No further benefit of tanning is known.

When the radiation exceeds a certain limit value (the so-called threshold erythema dose), which is individually different, acute damages occur. After a latency period of several hours, reddening and formation of edemas of the irradiated skin occur. When the threshold erythema dose is further exceeded, blisters and, finally, surface skin gangrenes develop, i.e. the tissue becomes necrotic. The sensitivity of UV-rays increases in this respect to shorter wave lengths and is at maximum with wave lengths of less than 300 nm, i.e. the sensitivity in the UV-A-range is lesser than in the UV-B-range.

The sensibility of the human skin against UV-radiation varies individually. The reactions to natural solar radiation can be classified as follows:

- skin type I: always rapidly sunburned, hardly any or no tanning, even after repeated irradiations (Celtic type)
- skin type II: nearly always sunburned, moderate tanning after repeated irradiations (fair-skinned European type)
- skin type III: less frequently sunburned, progressive tanning after repeated irradiations (dark-skinned European type)
- skin type IV: rarely sunburned, rapid and obvious tanning (Mediterranean type).

Further acute direct effects of UV-radiation exposure may be phototoxic or photoallergic skin diseases.

After a prolonged exposure to UV-rays (over several years), permanent and irreversible skin changes and late secondary effects may occur. The changes which are characterized as chronic photopathies or premature aging of the skin appear as increases wrinkling, widened pore (follicle extension), blackheads (comedos), vasodilatation (telangiectasia) and damage of the connective tissue (solar elastosis).

The induction of skin cancer is the by far most serious late secondary effect of UV-irradiation. Here it must be differentiated between the basal-cell carcinoma, the spino-cell carcinoma and the malignant melanoma. Especially the incidences of the latter, which is a highly malignant tumor, have increased during the past years.

The carcinogenic impact of frequent UV-irradiation is apparent by the predominant number of basal-cell and spino-cell carcinomas occurring in the area of skin chronically injured by light. This also applies to cases of lentiginous malignant melanoma, a subtype of the malignant melanoma. In contrast to that the other types of malignant melanoma also occur in covered areas of the body. The solar light also plays a key role in melanomatosis, according to epidemiological studies:

- light-sensitive persons are subject to a three times higher melanoma risk than those who are insensitive to light,
- the melanoma risk increases with the geographically increased UV-exposure,
- melanoma patients show a significantly higher incidence of sunburn (especially as a child) in their case histories.

In summary, it can be said that UV-radiation is the most important and predominant cause of skin cancer.

The observations indicate that the relative spectral sensitivity of the UV-radiation spectrum is very similar to that of tanning (melanogenesis), of light irritation (erythema development), and the production of skin cancer (carcinogenesis) as well as a premature aging of the skin (elastosis). Therefore, no radiation may cause a single effect without not simultaneously causing other effects. There is in particular no evidence that tanning by UV-radiation is less hazardous than tanning by exposure to sun light.

The Federal Health Office has published recommendations for the users of solaria and UV-radiation units for domestic use (Federal Health Pamphlet 30 (1), 1987, p. 19-30). In considerations of general and instrument-specific protective measures given here, the risks from UV-radiation (adverse acute and chronic effects) can be diminished.

2 Protective measures against solar irradiation and exposure from UV-irradiation units

The following rules and directions are given, by which the risk caused by solar radiation or by radiation from artificial UV-sources can be diminished.

2.1 Behaviour in the sun

- *The skin should be habituated to extended exposure from solar radiation. When necessary, the hours around noon should be spent in the shadow. The benefit of protective clothing, headwear, etc. should be considered.*

The sunburn sensitivity of the midday sun is several times higher than that of the morning sun or the afternoon sun. For instance, in the summer the time until the unprotected and not sun habituated skin reaches the threshold erythema dose is approximately 30 minutes in Central Europe (in the Mediterranean area approximately 20 minutes around noon). The tanning effectiveness of the indirect (scattered and reflected) ultraviolet radiation of the midday sun is about nearly as great as that of direct UV-radiation of the morning or afternoon sun. Therefore, a tanning can be obtained without direct solar radiation.

- *Suntan preparations with sufficient shielding against light should be used. The use of suntan preparations is, however, no warrant for an excessive sunbathing.*

Suntan preparations should be applied at least 30 minutes before sunbathing. Preparations with light shielding factors of 6 to 10 should be used for skin which is not habituated to light, preparations with light shielding factors of more than 10 should be used for very sensitive skin. After the skin has been habituated to light, the shielding factor can be decreased. If one stays in the sun for a very long time the application should be repeated. For reasons of safety also waterproof suntan preparations should repeatedly be applied after swimming. One should keep in mind that suntan preparations with high shielding factors were developed for the protection of sensitive skin, the use of suntan preparations only in order to stay in the sun for longer periods of time neutralizes the advantages of their application. Additionally, suntan preparations are not a sufficient protection against long-wave UV-A-radiation.

Allergic reactions (with and without influence of light) may occur when suntan preparations are used. The preparation must no longer be used in such a case.

- *Perfume, deodorants and other cosmetics must not be used under solar radiation.*

When applying cosmetics light or dark spots (dyschromias) or irritations of the skin may occur in connection with UV-radiation which often remain for some time.

- *Persons taking drugs should ask the attending physicians's advice prior to "sunbathing".*

Certain drugs increase the skin's sensibility to light and produce allergies caused by light.

- *The number of "sunbaths" shall not exceed 50 per year. A sunburn should always be avoided.*

The term "sunbath" denotes here a UV-radiation of a duration and intensity that will not produce visible reddening of the skin. It is recommended to not expose oneself more than approximately 50 times per year to such a UV-radiation (sun and solarium radiation). More frequent sunbaths are acceptable for correspondingly shorter exposure times.

There are reservations against ante-tanning with UV-A-radiation in solaria as a means against sunburn, because the inherent protective capability of the skin is not increased by radiation with UV-A (no protection via pigmentation or minor callosity is built up by UV-A-radiation). If a habituation of the skin to light is necessary, it should be carried out under medical supervision.

2.2 Behaviour by application of UV-radiation units

When tanning is obtained from commercially operated UV-irradiation units or from units determined for domestic use, the same acute and chronic radiation effects may occur as from tanning by solar radiation. The damaging effect of UV-rays decreases with the increasing wave length, similarly to the tanning sensitivity. On the one hand, high radiation doses are therefore needed in the long-wave UV-range for the production of a certain pigmentation, while, on the other hand the damaging effect of the UV-rays will simultaneously increase. Thus, it leads to the same risk of late effects, regardless whether UV-B or UV-A-ray are used. Therefore filtering out certain wave length ranges will not decrease the risk.

Besides the indicated protective measures against solar radiation, the following further protection guidelines should be observed:

- A physician should be consulted prior to the radiation exposure if there is a skin disease.
- In the presence of pathologic reactions of the skin due to solar radiation UV-irradiation units should not be used.
- If inflammations or skin blisters develop, a physician should be consulted at once.
- Suitable protective glasses should be worn. Persons with a prior grey cataract surgery of the eye lens, should observe the above order to avoid eye injury.
- Cosmetics should be removed, if possible some hours before the radiation occurs.
- No suntan preparations should be applied.

Suntan preparation were developed for the protection of the skin against solar UV-B-ray, because the UV-B-rays are 100 to 1,000 times more effective for erythema than UV-A-rays. The suntan preparations do not protect against UV-A-rays which are mainly emitted by the currently used irradiation lamps.

- Caution with UV-radiation after taking drugs.

There are drugs whereby the side effect increases the UV-sensibility of the skin. The fraction of radiation in the UV-range of some high-capacity emitters can be much higher than of solar radiation. Thus, when taking those drugs, the irradiation threshold time for sunburns, phototoxic and photo-allergic reactions of the skin may become very short (some minutes). Serious, even fatal incidents may thus occur. Examples of such drugs are antibiotics, psycho-pharmacological drugs, diuretics (desiccating drugs). In case of doubt a physician should be consulted. (Substances and drugs which may cause allergic and phototoxic reactions are listed in annex 4.)

- The initial irradiation time as well as the maximum irradiation time marked on the irradiation unit should not be exceeded. These irradiation periods are of different length for individual skin types.

3 Requirements for operators and staff of solarium

It is recommended that the operators and the staff of solarium prove their technical knowledge by corresponding training. Their technical knowledge should be kept current by periodic training. Operators and staff of solarium are obliged to inform and advise. The limits recommended by the International Radiological Protection Association IRPA/INIRC (Health Physics 56, 1989, p. 971-972) should be observed. Sun studios and comparable utilities should be operated in a manner beyond criticism from any hygienic point of view.

Rules and guidelines for operators of solarium:

- a) The legend "Caution, UV-radiation may cause damage to eyes and skin, follow directions for protection" has to be attached to the irradiation units or displayed in the irradiation room in a clearly legible and durable manner.

Furthermore details on exposure rate on the level of effectiveness as well as on the initial and the maximum irradiation time for skin types II, III and IV must be attached to each unit in clearly legible and durable manner.

- b) The text of the protection guidelines (section 2.2), together with the rules and directions c) to i), must be included in the instructions for use. These instructions must be displayed in the irradiation room and be available to the user on request.

As far as instruments for domestic use are concerned, the text of the protection guidelines has to be attached to the instructions for use.

- c) The non-pigmenting skin type I as well as children must basically not be exposed to irradiation from solarium and instruments in domestic use.

The maximum irradiation time for skin type II should only exceed that for other skin types if the skin type is exactly known.

- d) The user's attention must be drawn to circumstances which could possibly forbid the application of solarium, like sun incompatibility, certain diseases of the skin, intake of certain prescribed drugs and use of cosmetics.

- e) The wearing of safety glasses must also be practiced; they are to be provided by the operator.

UV-rays as well as the light emission from UV-irradiation lamps (especially in the blue range) may lead to a damage of the eyes (e.g. inflammations, dullness of the eye lenses and retinal damages). In order to avoid such injuries, suitable safety glasses according to DIN 4647, part 2, protective stage 3-3 or 3-4 should be provided. Persons with a prior grey cataract surgery of the eye lens must by all means wear safety glasses in order to avoid exposure of the retina.

- f) UV-rays may damage the skin acutely (erythema, blisters, necroses) and chronically (elastosis, carcinoma).

The spectral impact function for the development of erythema according to IEC (see annex 3) has to be taken as a basis for the assessment of late effects, i.e. the UV-erythema is regarded as an indicator for occurrence of chronic changes of the skin induced by UV-radiation. In particular, irradiations producing sunburns increase the risk of skin cancer. The threshold irradiation for erythema must therefore not be exceeded during an irradiation.

If irradiation units with high UV-A-exposure rates are used, the threshold exposure time may be very short for phototoxic and photoallergic reactions of the skin.

- g) When there are defects, the irradiation unit must not be put into operation (for instance when the timer or the filter are defect).
- h) Repair work has to be carried out professionally. The values for the erythema-effective exposure rate of the initial and maximum irradiation time must be recalculated after repair and after lamps and filters are changed, and the data of the irradiation unit are correspondingly to be corrected.

4 Requirements on equipment safety

For all UV-irradiation units the manufacturer should provide information on the use of the equipment. Especially recommendations referring to the duration of irradiation and the time-interval between irradiations need to be mentioned. The factual contents of the corresponding standards must be observed in labelling the units as well as in the content of the instructions for use.

For each UV-irradiation unit (equipment type) the erythema-effective exposure rate E_{er} must be calculated by means of the spectral impact function on the level of impact as well as the threshold irradiation time for erythema development $t_{s, er}$ (maximum irradiation time). These data must be attached to the unit for skin types II, III, IV in clearly legible way. For the determination of the maximum irradiation time the erythema-effective exposure rate of the unit and the erythema-effective threshold irradiations (250 Jm^{-2} for skin type II, 350 Jm^{-2} for skin type III and 450 Jm^{-2} for skin type IV) have to be taken as a basis.

With regard to the use of UV-irradiation units there must be a distinction between instruments accessible to the public and those for domestic use (home solarium). The first require constant supervision and maintenance of the units, irradiation under the supervision of technical personnel as well as specific information for the users by the technical personnel. The suppositions concerning home solariums are quite different. Specific information for the users with regard to acute and chronic radiation risks can only be provided by means of guidelines as part of the instructions for use. In order to reduce physical radiation risks when using home solarium, it is thus necessary to limit the erythema-effective irradiation impact of these instruments more strictly than of units where the use and operation is supervised by technical personnel. Therefore it is recommended as follow:

- UV-irradiation units which are operated and supervised by technical personnel must not exceed an erythema-effective exposure rate of $E_{er} = 0.3 \text{ Wm}^{-2}$ on the level of impact that

corresponds with a solar erythema factor of 1. The total exposure rate of an UV-irradiation unit must not exceed $1,200 \text{ Wm}^{-2}$ on the level of impact.

- UV-irradiation units for domestic use must not exceed an erythema-effective exposure rate of $E_{\text{er}} = 0.1 \text{ Wm}^{-2}$ on the level of impact that corresponds with a solar erythema factor of 0.33.

Annex 1: Terms and Definitions (from DIN 5050, draft, 1988/89)

1. Erythema-effective exposure rate E_{er}

The erythema-effective exposure rate E_{er} is the exposure rate which is assessed corresponding to the relative spectral biological sensitivity $s(\lambda)_{er, rel}$ of the erythema impact reaction that has been looked at.

$$E_{er} = \int_0^{\infty} E_{\lambda}(\lambda) \cdot s(\lambda)_{er, rel} \cdot d\lambda$$

Unit: Wm^{-2}

Where:

E_{er} erythema-effective exposure rate

$E_{\lambda}(\lambda)$ spectral exposure rate

$s(\lambda)_{er, rel}$ relative spectral sensitivity of the erythema impact.

2. Erythema-effective radiation (dose) H_{er}

The erythema-effective radiation H_{er} is the integral of the erythema-effective exposure rate E_{er} over the time t (t_i : duration of the irradiation procedure).

$$H_{er} = \int_0^{t_i} E_{er} dt$$

Unit: Jm^{-2}

3. Erythema-effective threshold irradiation $H_{s, er}$

The erythema-effective irradiation H_{er} which causes a threshold reaction which is just perceptible is referred to as erythema-effective threshold irradiation $H_{s, er}$.

For the value of the erythema-effective threshold dose for the human body (fair-skinned European, skin type II) the following is determined:

$$H_{s, er} = 250 \text{ Jm}^{-2}$$

4. Threshold irradiation time for the erythema development $t_{s, er}$

The threshold irradiation time for the erythema development $t_{s, er}$ is the irradiation time after which the threshold irradiation $H_{s, er}$ is reached with a given erythema-effective exposure rate E_{er} .

$$t_{s, er} = H_{s, er} / E_{er}$$

5. Solar erythema factor SEF

The solar erythema factor SEF is the relation of the erythema-effective exposure rate $E_{er, unit}$ to the erythema-effective exposure rate $E_{er, Gl}$ of the global radiation on the reference solar day with the sun's altitude $\gamma = 90^\circ$.

$$SEF = \frac{E_{er, unit}}{E_{er, Gl}}$$

This factor equals the inverse ratio of the erythema-effective threshold irradiation time for the irradiation unit and the global radiation on the reference solar day.

6. Reference solar day

When comparing the photobiologically effective irradiation by UV-irradiation units with the natural global irradiation, the values according to table 1 have to be set up as maximum values of the erythema-effective exposure rates of the global irradiation.

Table 1: Maximum values of the erythema-effective exposure rates of the global irradiation

γ [°]	E_{er} [Wm ⁻²]
10	0.0053
30	0.054
60	0.21
90	0.30

Where:

γ sun's altitude
 E_{er} erythema-effective exposure rate.

As reference solar day a day is referred to on which these maximum values of the erythema-effective exposure rates of the global irradiance are present. They depend on the season and the geographical latitude, see e.g. table 2

Table 2: Erythema-effective irradiances on 21st June

Φ_N [°]	H_{er} [kJ m ⁻²]
23.5	6.5
50	5.6

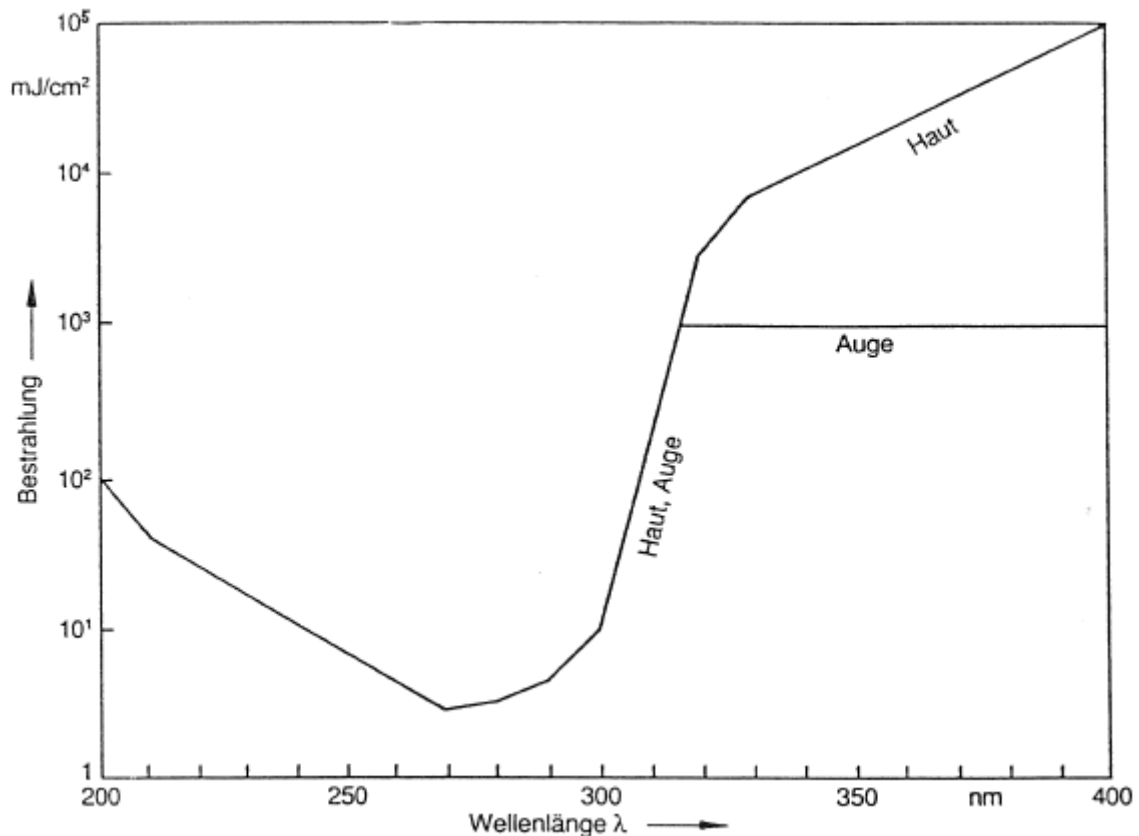
Where:

Φ_N geographical latitude north
 H_{er} erythema-effective irradiation.

7. Light protection factor

The light protection factor is a measure for the sensitivity of the suntan preparation. The factor indicates how much longer than without the preparation the user may expose himself to the radiation with the same exposure rate and the same skin reaction.

Annex 2: Limit values for occupational exposure



Values of exposition for general or occupational 8-hour-UV-irradiation in order to avoid harmful effects on skin and eyes (unprotected).

For broad-band UV-irradiation sources the effective irradiation has to be determined making use of the values of relative spectral sensitivity given in the table (IRPA/INIRC Guidelines, Health Physics 56(6): 971-972, 1989).

Limit values of exposition for ultraviolet radiation over an 8-hour-period as well as relative spectral sensitivity $s(\lambda)_{er, rel}$. For the UVA-range between 315 and 400 nm the total irradiation for the unprotected eye within an 8-hour-period should not exceed a value of 10 kJ/m² (1 J/cm²).

Wave length ^{a)} [nm]	Limit value of exposition		Relative spectral sensitivity $s(\lambda)_{er, rel}$
	J/m ²	mJ/cm ²	
180	2,500	250	0.012
190	1,600	160	0.019
200	1,000	100	0.030
205	590	59	0.051
210	400	40	0.075
215	320	32	0.095
220	250	25	0.120
225	200	20	0.150
230	160	16	0.190
235	130	13	0.240
240	100	10	0.300
245	83	8.3	0.360
250	70	7.0	0.430
254 ^{b)}	60	6.0	0.500
255	58	5.8	0.520
260	46	4.6	0.650
265	37	3.7	0.810
270	30	3.0	1.000
275	31	3.1	0.960
280 ^{b)}	34	3.4	0.880
285	39	3.9	0.770
290	47	4.7	0.640
295	56	5.6	0.540
297 ^{b)}	65	6.5	0.460
300	100	10	0.300
303 ^{b)}	250	25	0.190
305	500	50	0.060
308	1,200	120	0.026
310	2,000	200	0.015
313 ^{b)}	5,000	500	0.006
315	$1,0 \times 10^4$	$1,0 \times 10^3$	0.003

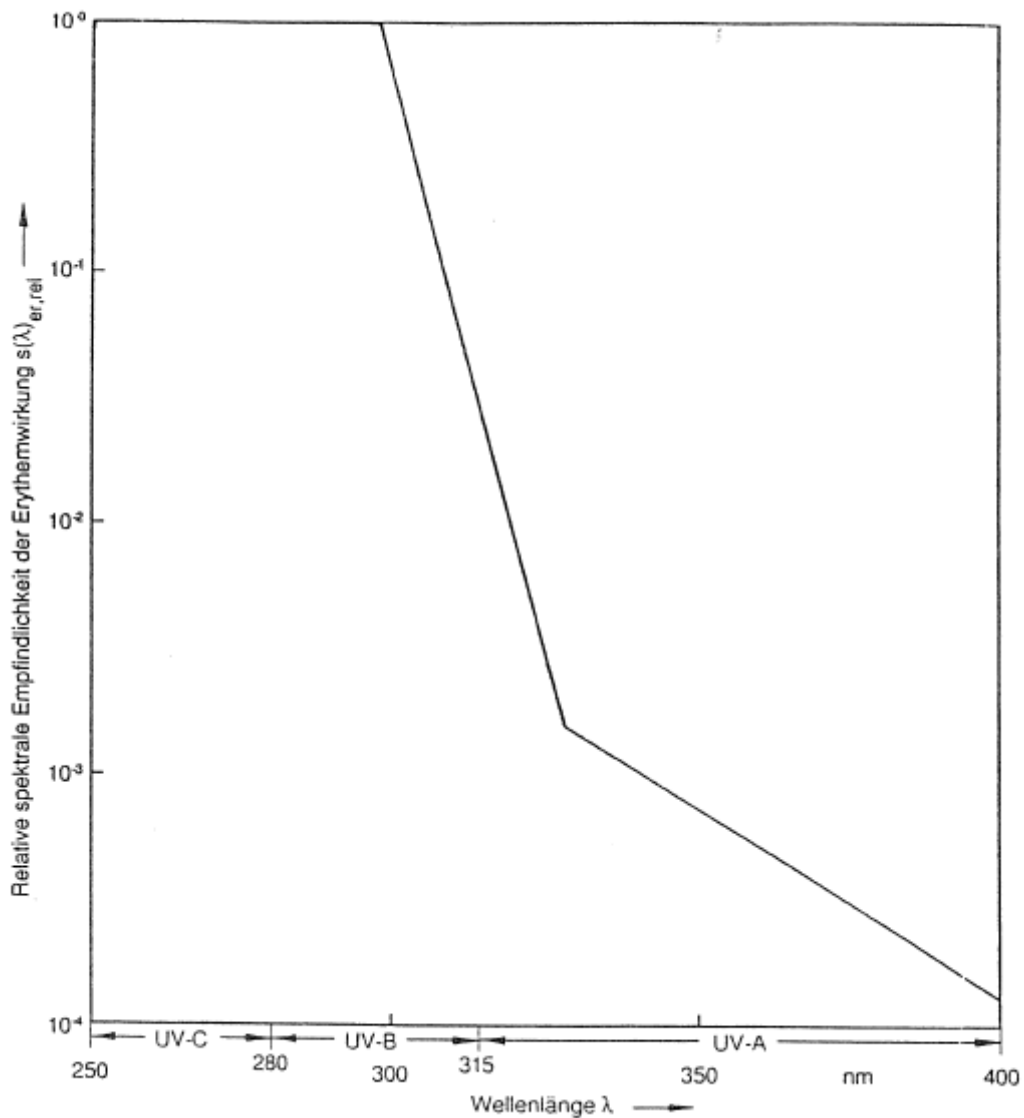
a) Selected wave lengths, limit values of exposition for other wave lengths can be determined by interpolation.

b) Emission lines for a mercury-vapour discharge spectrum.

Wave length ^{a)} [nm]	Limit value of exposition		Relative spectral sensitivity $s(\lambda)_{er, rel}$
	J/m ²	mJ/cm ²	
316	1.3×10^4	1.3×10^3	0.0024
317	1.5×10^4	1.5×10^3	0.0020
318	1.9×10^4	1.9×10^3	0.0016
319	2.5×10^4	2.5×10^3	0.0012
320	2.9×10^4	2.9×10^3	0.0010
322	4.5×10^4	4.5×10^3	0.00067
323	5.6×10^4	5.6×10^3	0.00054
325	6.0×10^4	6.0×10^3	0.00050
328	6.8×10^4	6.8×10^3	0.00044
330	7.3×10^4	7.3×10^3	0.00041
333	8.1×10^4	8.1×10^3	0.00037
335	8.8×10^4	8.8×10^3	0.00034
340	1.1×10^5	1.1×10^4	0.00028
345	1.3×10^5	1.3×10^4	0.00024
350	1.5×10^5	1.5×10^4	0.00020
355	1.9×10^5	1.9×10^4	0.00016
360	2.3×10^5	2.3×10^4	0.00013
365 ^{b)}	2.7×10^5	2.7×10^4	0.00011
370	3.2×10^5	3.2×10^4	0.000093
375	3.9×10^5	3.9×10^4	0.000077
380	4.7×10^5	4.7×10^4	0.000064
385	5.7×10^5	5.7×10^4	0.000053
390	6.8×10^5	6.8×10^4	0.000044
395	8.3×10^5	8.3×10^4	0.000036
400	1.0×10^6	1.0×10^5	0.000030

- a) Selected wave lengths, limit values of exposition for other wave lengths can be determined by interpolation.
- b) Emission lines for a mercury-vapour discharge spectrum.

Annex 3: Effective functioning of UV-radiation



The shown graph corresponds to the relative spectral sensitivity $s(\lambda)_{er,rel}$ according to IEC 335-2-27 of 1984 and according to PrEN 60 335-2-27^{*)}. It is determined as follows:

$$\begin{aligned}
 s(\lambda)_{er,rel} &= 1 && \text{for } \lambda \leq 298 \text{ nm} \\
 s(\lambda)_{er,rel} &= 10^{0.094(298-\lambda/\text{nm})} && \text{for } 298 \text{ nm} < \lambda \leq 328 \text{ nm} \\
 s(\lambda)_{er,rel} &= 10^{0.015(139-\lambda/\text{nm})} && \text{for } 328 \text{ nm} < \lambda \leq 400 \text{ nm}
 \end{aligned}$$

^{*)} This European norm (EN) conforms to the german norm DIN-VDE 0700, part 27

Annex 4: Selection of drugs which may cause an increased sensitivity to UV-radiation (phototoxic and photoallergic reactions)

Short terms/ classes of substances	Pharmacological group of substances	Trade name
External application Tar components Halogen salicylamides Furocumarines (ammoidine)	Dermatics Antimycotics Photochemotherapeutical remedy	Multifungin® Meladinine® (also internally applied)
Internal application Sulfonyl ureas Sulfonamides Quinolones (Gyrasis inhibitor) Tetracyclines Chloroquini sulfas Mefloquine Phenothiazines Hydrochlorothiazides Diphenylethanolamines	Antidiabetics Chemotherapeutical remedy Antibiotics Antibiotics Antimalarial drugs/ Antirheumatic agents Antimalarial drugs Neuroleptics/ Antihistamines Diuretics Antihistamines Antitussives	Euglucon®, Rastinon® Tarivid®, Ciprobay®, Nogram® Resochin® Lariam® Atosil®, Neurocil®, Psyquil®, Melleril®, Taxilan® Esidrix®, Dytide® H, Moduretik® Soventol® Benadryl®

® = registered trademark

The mentioning of the commercial preparations only occurs exemplarily, partly the statement of single trade names is not appropriately possible due to the great amount of preparations.