Marked inflammation of the cornea (keratitis solaris) is often observed after exposure to strong solar radiation, especially in high altitudes and snow-covered terrain. Using the action spectrum and the solar spectrum, the radiant exposure causing keratitis solaris was calculated for a horizontal surface. The parameters selected were altitude, season, ozone content and albedo. The radiant exposure of the eye increases approximately 16-fold, comparing terrain without snow-cover and terrain with snow-cover. Radiant exposures in clinically observed cases of keratitis solaris were calculated to range from 1200 to 5600 Jm⁻². A discussion on these figures with regard to threshold doses shows a significant difference between long-term exposure to solar radiation and short-term exposure to artificial sources. Invest Ophthalmol Vis Sci 28:1713–1716, 1987

Data of threshold radiant exposure for keratitis photoelectrica after short-term exposure to artificial sources are given by Pitts¹,² as amounting to 40 Jm⁻² relative to 270 nm. In the present paper it is shown that this value is hardly applicable for solar radiant exposure. In order to examine the threshold radiant exposure for keratitis solaris, the radiant exposure for individuals with keratitis solaris was estimated by model calculations.

Materials and Methods. The model calculations are based on the action spectrum of keratitis photoelectrica,³ which is normalized to 100% at 270 nm (Fig. 1a), and on the spectrum of global radiation on a horizontal surface given by Bener⁴ (Fig. 1b), whose data are based on extensive spectral measurements. The parameters selected were altitude, ozone content and solar elevation. The calculation results in a keratitis-effective solar spectrum (Fig. 1c). The hourly course of keratitis-effective irradiance in different seasons was calculated in order to determine the radiant exposure of clinically observed cases of keratitis solaris.

![Graph](https://via.placeholder.com/150)

Fig. 1. (a) Action spectrum of keratitis. (b) Spectrum of global radiation for different solar elevations at an ozone content of 0.24 cm (unbroken line) and 0.40 cm (broken line). Both curves are identical for λ > 340 nm. (c) Keratitis-effective spectrum. The curves apply to different solar elevations, with unbroken lines for 0.24 cm ozone and dotted lines for 0.40 cm.
**Results.** Figure 2 shows the keratitis-effective irradiance of a horizontal plane at noon versus altitude for equinoxes and solstices, based on the ozone content for 47° latitude. Because of the higher ozone content in spring, the keratitis-effective irradiance is 23% lower at the spring equinox than at the autumn equinox. For altitudes of 0 to 3000 m, the average altitude gradient of keratitis-effective irradiance in spring, summer and autumn is 16% per 1000 m.

Experience shows that keratitis Solaris is triggered by radiant exposures that occur within just a few hours during the course of the day. The hourly course of keratitis-effective irradiance is characterized by a steep increase in the morning and a corresponding steep decrease in the afternoon. This is due to the changing optical thickness of the ozone layer.

In calculating the keratitis-effective radiant exposure for the human eye, the albedo of the terrain is of decisive importance. The eye is taken as the detector directed towards the reflecting ground. Calculations were performed for an albedo of 6% and 95% respectively, representing average values in the UV-B range for snow-free and snow-covered terrain. These albedo values differ considerably from those for global radiation, which amount to approximately 20% for snow-free terrain and 80% for snow-covered terrain. The values of the albedo on which the calculations are based are results from authors' measurements, they agree with extrapolations of data from Dirmhirn and are close to values measured by Slukey.

Figure 3 shows the hourly course of keratitis-effective irradiance relevant for the human eye at equinoxes and solstices for elevations 0 m, 2000 m and 4000 m above sea level (ASL), when the eye observes a horizontal, snow-covered terrain with an albedo of 95%. The keratitis-effective irradiance from a snow-free terrain is lower by a factor of 15.8 than that of a snow-covered terrain, due to the differences in albedo.

The daily total of keratitis-effective radiant exposure was determined by integrating the hourly course of the irradiance. Table 1 lists these daily totals at equinoxes and solstices in the cases of snow-free and snow-covered terrain at 3000 m ASL. A significant difference in the daily total radiant exposure of the eye results when comparing winter and summer conditions. Data differ by a factor of 21 with surfaces of the same albedo. Usually surfaces are snow-covered.
in winter and snow-free in summer; in this case the daily total radiant exposure of the eye is higher in summer than in winter only by a factor of 1.35. Table 1 also shows the percentage share of the daily total accounted for hourly intervals. For example, 6 hr from 9 AM to 3 PM in spring account for 87.2% of the daily total, i.e., 3209 Jm$^{-2}$ over a snow-covered terrain.

Figure 4 shows the changes in keratitis-effective irradiance versus changes in ozone content. For example, with a 25% decrease in the ozone content of the atmosphere, keratitis-effective irradiance increases by 35% for a solar elevation of 40° and by 70% for 20° solar elevation. This relation is of interest considering natural variations of ozone content and possible antropogenic variations due to contamination by trace gases.

Results from Figure 3 allow one to calculate the keratitis-effective radiant exposure for clinically observed cases of keratitis Solaris. For this purpose, patients treated at the outpatients' department of the Clinic of Ophthalmology in Innsbruck were questioned with regard to their exposure time to solar radiation. From 1984 to 1986, 32 patients were registered during the months March to May. All patients had spent several hours in snow-covered terrain between 2000 and 3000 m ASL while skiing. No one had used protective goggles and in all cases the weather was sunny with only sporadic clouds. From the stated duration of exposure the radiant exposures were calculated for snow-covered terrain at an altitude of 3000 m. The radiant exposures of the 32 patients varied between 1200 and 5600 Jm$^{-2}$.

**Discussion.** For the threshold radiant exposure, the smallest calculated radiation exposure (1200 Jm$^{-2}$) that led to keratitis Solaris is relevant. However, this radiant exposure should be considered as a maximum value of the threshold radiant exposure, since the effective exposure time for the human eye may be less than the exposure time stated by the patients. Skiers typically spend some time in buildings or in lift gondolas, thus reducing the exposure time for the eyes. Based on our experience with skiing in the specific sites, we estimate the reduction in the exposure time to be at most 20%.

Furthermore, it is of less importance whether the eye is looking at snow-covered terrain or at the sky, because of the significantly high diffuse sky radiation in the UV-B range. This is also expressed by Sliney, who describes the snow-covered ground and the sky as an integrating sphere. In the UV-B range, even some cloud cover does not significantly reduce the diffuse sky radiation.

A slight discount of the effectiveness of the sky as a function of angle must be taken into account due to the shading action of the brows, eyelids, etc. and the glancing angle on the cornea. Another factor reducing the radiant exposure of the eye is the partial closure of the eyelids due to blinking and squinting in snow-covered surroundings. Although it is very difficult to quantify the influence of this behavior, we estimate that the reduction of the radiant exposure of the eye is at most 50%.

Table 1. Keratitis-effective radiant exposure of the eye at 3000 m ASL

<table>
<thead>
<tr>
<th></th>
<th>Winter solstice</th>
<th>Spring equinox</th>
<th>Summer solstice</th>
<th>Autumn equinox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily total Jm$^{-2}$ (snow-free)</td>
<td>30</td>
<td>233</td>
<td>649</td>
<td>335</td>
</tr>
<tr>
<td>Daily total Jm$^{-2}$ (snow-covered)</td>
<td>480</td>
<td>3680</td>
<td>10260</td>
<td>5300</td>
</tr>
<tr>
<td>11 AM–1 PM</td>
<td>46.2%</td>
<td>37.9%</td>
<td>30.2%</td>
<td>36.7%</td>
</tr>
<tr>
<td>10 AM–2 PM</td>
<td>79.1%</td>
<td>66.7%</td>
<td>55.8%</td>
<td>65.0%</td>
</tr>
<tr>
<td>9 AM–3 PM</td>
<td>95.2%</td>
<td>87.2%</td>
<td>75.7%</td>
<td>85.6%</td>
</tr>
<tr>
<td>8 AM–4 PM</td>
<td>100.0%</td>
<td>97.0%</td>
<td>88.7%</td>
<td>96.1%</td>
</tr>
</tbody>
</table>
As far as the annual course is concerned, the first occurrence of keratitis solars is observed during March. Thus, radiation exposures in January and February are below the threshold dose. However, the individual behaviors of people in winter in response to the lower temperatures, such as wearing spectacles more frequently, may contribute to the non-appearance of keratitis solars in winter months.

All of the above considerations lead to a rough estimation of the threshold radiant exposure for keratitis solars to be less than the lowest calculated radiant exposure by a factor of 2 to 4. Thus, a threshold radiant exposure of 300 to 600 Jm$^{-2}$ is estimated.

So far, threshold radiant exposures for keratitis quoted in the literature$^{1-3,12}$ are based on extremely intensive short-term radiation of a few minutes’ duration, such as occurs during welding work. The threshold radiant exposure for such short-term radiation is quoted as 40 Jm$^{-2}$. This value is several times lower than the threshold dose for solar radiation exposure estimated in this study, even if all the above discussed influences are considered. It is therefore concluded that the threshold radiant exposure for keratitis may depend on the intensity of the radiation and increases with decreasing intensity. Further clinical observations will be carried out to permit a more accurate assessment of threshold dose for solar radiant exposure.

Key words: keratitis solars, action spectrum, solar radiation, threshold radiant exposure

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References

The Effect of Corneal Contact Lenses on the Oxygen Tension in the Anterior Chamber of the Rabbit Eye

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The oxygen tension in the aqueous humor in the anterior chamber of rabbit eyes was measured continuously with a polarographic electrode. The normal oxygen tension in the anterior chamber was 23 ± 2 mm Hg (mean ± SD, n = 4). A contact lens was then placed on the cornea for at least 10 min and the drop in oxygen tension recorded. A hard polymethylmethacrylate lens reduced the oxygen tension by 16 ± 4 mm Hg, and a larger hydroxyethylmethacrylate soft lens (Soflens®) decreased oxygen tension by 17 ± 4 mm Hg (mean ± SD, n = 4). Comparable statistically significant decreases were seen with the Permalens®, Polycon II®, and Silicon® lenses. Only the elastofilcon A lens (Silsoft®) did not decrease the oxygen tension in the anterior chamber significantly. Invest Ophthalmol Vis Sc 28:1716–1719, 1987

Previous studies have shown that corneal contact lenses can reduce the oxygen tension in the anterior chamber of rabbits$^{1}$ and cats.2 However, the contact lenses used in previous experiments are not comparable with those in current clinical use. The aim of the present study was to determine whether corneal contact lenses, which are used clinically, affect the intraocular oxygen tension. Six types of lenses were tested ranging from a hard polymethylmethacrylate lens with poor oxygen permeability to the highly oxygen-permeable silicone lenses.

Materials and Methods. Four adult New Zealand red rabbits (2–4 kg, either sex) were anesthetized with