UV – Radiation Properties at the Dead Sea

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Abstract
The Dead Sea, a salt lake located between the Judean mountains in Israel and Moab mountains in Jordan, is one of the saltiest bodies of water known, containing 345 g mineral salts per liter. It is situated at the lowest terrestrial point on earth, approximately 400 m below mean sea level. The Dead Sea area is recognized as a natural treatment facility for patients with psoriasis, atopic dermatitis, vitiligo and other skin and rheumatic diseases. A research project was initiated in 1994 to determine if the Dead Sea basin is indeed characterized by a unique ultraviolet radiation spectrum, which contributes to the success of photoclimatherapy of psoriasis and other skin diseases. A meteorological station was established at the Dead Sea basin (Neve Zohar) to continuously monitor solar global, UVB and UVA radiation, measure spectral selectivity within the ultraviolet spectrum and investigate other relevant bio-climatological parameters. The same parameters were also monitored continuously at a second meteorological station in Beer Sheva, which is located in the southern Negev region of Israel at a distance of approximately 65 km west of the Dead Sea and an altitude of ~315 m above mean sea level, i.e., about a 700 m altitude differential between the two sites.
The results of this on-going study can be summarized as follows:

- The UVB and UVA solar radiation intensities at the Dead Sea are both attenuated relative to Beer Sheva; the UVB to much a greater extent than the UVA.
- The degree of attenuation is inversely proportional to the wavelength. The erythema wavelength range (ca. 300 nm) is attenuated to greatest extent, whereas the degree of attenuation is lower in the therapeutic wavelength range (ca. 311 nm) with regard to psoriasis.
- Consequently, the incident solar UVB has a higher ratio of therapeutic to erythema radiation relative to other sites.
- The ratio of the therapeutic to erythema radiation has a minimum value at solar noon (diurnal minimum optical path length).

These findings have been applied to revise the psoriasis treatment protocol at the Dead Sea with the goal of reducing the cumulative sun-exposure time without affecting treatment efficacy.

Key words: UVB, UVA, Solar Global Radiation, Relative Attenuation of Solar Radiation, Photoclimatherapy, Dead Sea, Beer Sheva, Israel.

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Propiedades de la radiación UV en el Mar Muerto

Resumen
El Mar Muerto, un lago salado situado entre las montañas de Judea en Israel y las montañas de Moab, en Jordania, tiene una de las aguas conocida más salada, contiene 345 g de sales minerales por litro. Se sitúa en el punto más bajo de la tierra, a unos 400 m por debajo del nivel del mar. La zona del Mar Muerto es reconocida como un tratamiento natural para pacientes con psoriasis, dermatitis atópica, vitíligo y otras enfermedades de piel y reumáticas. Un proyecto de investigación se inició en 1994 para determinar si la cuenca del Mar Muerto se caracteriza de hecho por un espectro de radiación ultravioleta único, lo que contribuye al éxito de la foto-climatoterapia de la psoriasis y otras enfermedades de la piel. Una estación meteorológica se estableció en la cuenca del Mar Muerto (Neve Zohar) para monitorear de forma global y continua la radiación solar UVB y UVA, medida selectividad del espectro ultravioleta e investigar otros parámetros relevantes bioclimáticos. Los mismos parámetros se controlaron también de forma continua en una segunda estación meteorológica en Beer Sheva, que se encuentra en el sur de la región de Negev de Israel, a una distancia de aproximadamente 65 km al oeste del Mar Muerto y una altitud aproximada de 315 m sobre el nivel del mar, es decir, una diferencia de alrededor de 700 metros de altitud entre los dos sitios.
Los resultados de este estudio en curso se pueden resumir como sigue:

- Las intensidades de la radiación solar UVB y UVA en el Mar Muerto están atenuadas en relación a Beer Sheva, la UVB en mayor medida que los rayos UVA.
- El grado de atenuación es inversamente proporcional a la longitud de onda. El rango de longitud de onda para el eritema (aprox. 300 nm) se atenúa en mayor grado, mientras que el grado de atenuación es menor en el rango de la longitud de onda terapéutica (aprox. 311 nm) teniendo en cuenta la psoriasis.
- En consecuencia, la radiación UVB solar incidente tiene una mayor proporción de radiación terapéutica que de radiación eritematosa, en relación con otros lugares.
- La relación entre la radiación terapéutica y la radiación eritematosa tiene un valor mínimo durante el mediodía solar (mínima longitud del camino óptico diurno).

Estos resultados se han aplicado para revisar el protocolo de tratamiento de la psoriasis en el Mar Muerto con el objetivo de reducir la exposición solar acumulada sin afectar la eficacia del tratamiento.

Palabras clave: UVB, UVA, Radiación Solar Global, Atenuación Relativa de la Radiación Solar, Foto-Climatoterapia, Mar Muerto, Beer Sheva, Israel.

REFERENCE STANDARD
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INTRODUCTION

Over the past 50 years, tens of thousands of psoriatic patients from all over the world have undergone photoclimatherapy at the Dead Sea medical spas. The success rate measured in terms of partial (i.e., significant improvement) to complete clearance after 4 weeks of treatment, under strict medical supervision, exceeds 85 per cent[1-5]. These clinical findings were presumed to be associated with a unique ultraviolet radiation spectrum present at the Dead Sea basin[6-8] as a result of it being located on the lowest terrestrial site on the earth, i.e., -400 m below mean sea level.

A research project was initiated in 1994 to examine the ultraviolet radiation in the Dead Sea basin. The goal of this investigation was to determine if the incident ultraviolet radiation has unique properties that might contribute to the success of Dead Sea photoclimatherapy in the treatment of psoriasis and other skin diseases. A meteorological station located at the Dead Sea basin (Neve Zohar) was established to monitor continuously solar global, UVB and UVA radiation, measure spectral selectivity within the UV spectrum and investigate other relevant bio-climatological parameters. The same parameters were also monitored continuously at a second meteorological station located in Beer Sheva, which is situated in the southern Negev region of Israel at a distance of approximately 65 km west of the Dead Sea and an altitude of ~315 m above mean sea level, i.e., about a 700 m altitude differential between the two sites. The two sites provided a basis for an inter-comparison of the measured parameters.

The attenuation of terrestrial solar radiation with optical path length (i.e., the distance the sun's rays traverse through the earth's atmosphere prior to being incident on its surface) is well documented. The terrestrial radiation is attenuated by two different phenomena, (i) atmospheric scattering by air molecules, water vapor and aerosols, and (ii) atmospheric absorption by mainly ozone, water and carbon dioxide. Scattering by air molecules, water vapor and aerosols, which results in the attenuation of the beam radiation, has been the subject of numerous studies and approximate correlations have been developed to estimate the magnitude of the effect[9-10]. Air molecules are small compared with the wavelength (λ) of radiation significant in the solar spectrum. Scattering of solar radiation by air molecules is in accordance with the theory of Rayleigh, which predicts that the degree of scattering varies approximately as λ^{-4}. The scattering of solar radiation by water molecules is a function of the amount of precipitable water (i.e., the amount of water vapor in the air column above the observation site) and an empirical scattering coefficient for water vapor that varies as λ^{-2} has been proposed. An empirical coefficient for aerosols has been developed[9], which varies approximately as $\lambda^{-0.75}$. In all cases, the degree of attenuation by scattering is an inverse function of the wavelength, i.e., attenuation decreases with increasing wavelength. Absorption of solar radiation in the atmosphere is due mainly to ozone in the ultraviolet range and water vapor, in specific bands, in the infrared range ($\lambda > 780$ nm) of the solar spectrum. Carbon dioxide absorbs at specific bands in both the visible and infrared range of the solar spectrum.

The ultraviolet radiation spectrum has been divided into three types as a function of their wavelength range: (i) UVC, with a spectral range from 100 to 280 nm, which is completely absorbed by the stratospheric ozone layer, (ii) UVB, with a spectral range from 280 to 320 nm, which is mostly absorbed by the stratospheric ozone layer and virtually no solar radiation below 295 nm is incident on the earth's surface, (iii) UVA, with a spectral range from 320 to 400 nm, where stratospheric ozone layer absorption is minimal. Ozone absorption decreases with increasing λ, and above 350 nm virtually no absorption exists except for a weak ozone absorption band in the visible range of the solar spectrum, at about 600 nm.

The potential increase of exposure to UVB radiation is a cause of mounting concern regarding the thickness of the stratospheric ozone layer, because the solar UVB, or erythemal UV, radiation is most sensitive to the changes in the total ozone content of the atmosphere. It is generally assumed that an increase in UVB radiation at the earth's surface would be detrimental to the well being of both plant and anima1 life. The problems of increased sunburn, skin cancer (melanoma and non-melanoma) and eye diseases (cataracts, melanoma) are usually emphasized for humans, while the general destruction of plant tissue and living cells is also being investigated. The annual growth rate of the incidence of malignant melanoma cases has been estimated at 4% since 1973[11]. The harmful effects of exposure to UVB radiation are partially compensated for by some beneficial factors, which include germicidal action, the production of vitamin D for the prevention of rickets, and the photoclimatherapy treatment of various skin diseases such as psoriasis, atopic dermatitis and vitiligo.

The health-associated effects of UVA exposure include photo-ageing of the skin, immuno-suppression of the skin immune system, and potential enhancement of the negative effects of UVB exposure. The treatment of psoriasis by UVA radiation in conjunction with psoralen (PUVA) has also been widely used in the past but has recently come under scrutiny as potentially increasing the risk of cancer[12].

In recent years, the improvements in the quality of life of the people living in the developed countries have changed to a significant degree their behavioral patterns. They now have much more free time for recreation and vacations, which, in general, translates to an increased exposure to solar radiation and its UV components with increasing availability of outdoor leisure time. This is especially so with regard to vacations, the majority of which are taken in regions having relatively high UV radiation environments. These two factors, viz., the enhanced UV radiation intensity due to global depletion of stratospheric ozone and the increased cumulative sun-exposure of the public, are of major concern due to the deleterious health-associated effects of increased exposure to UV radiation.

The attenuation of ultraviolet radiation with altitude (i.e., optical path length) has been studied previously but only for sites above sea level. Bener[13], Reiter et al[14], Blumthaler[15-16] and Piazena[17] have observed the attenuation of ultraviolet radiation intensity with decreasing altitude in the Alps and Andes mountains and that the UVB is attenuated much more than the UVA.

The Dead Sea basin offers a unique site to study the attenuation of the solar ultraviolet radiation because it is situated at the lowest terrestrial point on the earth, about 400 m below sea level. In view of its being an internationally recognized center for photoclimatherapy, it is of interest to study both its ultraviolet radiation intensity and attenuation as a function of wavelength relative to other sites. An analysis of the solar UVB, UVA and global radiation databases, the relevance of these findings with regard to the success of photoclimatherapy at the Dead Sea medical spas and the application of these findings to optimize the photoclimatherapy treatment protocols at the Dead Sea medical spas will be discussed in the following sections.

MEASUREMENTS

The radiation data on which this paper is based are being monitored at two meteorological stations. One station is located at Neve Zohar in the Dead Sea basin and the other on the campus of the Ben-Gurion University of the Negev in Beer Sheva. Neve Zohar is situated in the Judean desert and is on the western shore of the Dead Sea. Beer Sheva is located in the southern Negev region of Israel, a semi arid zone. The site parameters for the two stations are listed in Table 1. These two meteorological stations are part of the national network of meteorological stations and are connected via modem to the Israel Meteorological Service, located at Bet Dagan.

Table 1 - Site parameters for the two meteorological stations.

	Latitude	**Longitude**	**Altitude (m mean sea level)**
Neve Zohar	31º 12’ N	35º 22’ E	-375
Beer Sheva	31º 15’ N	35º 45’ E	+315

Broad-band measurements

The global radiation is measured by a Kipp & Zonen, Model CM11, at Neve Zohar and by an Eppley, Model PSP, at Beer Sheva. The global radiation measurements were initiated at Neve Zohar in January 1995, whereas in Beer Sheva the global radiation has been continuously monitored since September 1976. The global radiation instruments undergo annual field calibration checks by the Israel Meteorological staff using an absolute standard. The accuracy of both pyranometers, which are secondary standard instruments, is ± 3%.

The instrumentation utilized to measure the UV radiation at both sites is identical and consists of a Solar Light Co. Inc., Model 501A UV-Biometer for the measurement of UVB and a Solar Light Co. Inc., analog UVA version of Model 501A UV-Biometer for the measurement of UVA. The UVB and UVA measurements were initiated at Neve Zohar in February 1995 and the radiation has been monitored continuously except for interruptions; both scheduled to enable annual factory calibration checks and random ones caused by power failures. The UVB measurements were inaugurated at the Beer Sheva site in May 1994 and that for UVA in June 1995 and have been monitored continuously except for the abovementioned interruptions.

The Model 501A UV-Biometer measures UVB radiation in units of Minimum Erythema Dose per hour (MED/h). This unit is calculated by the cross-multiplication of the irradiating flux in the UVB spectral range and the Erythema Action spectra, cf., McKinley and Diffey[18]. Consequently, the UVB biometer has a spectral response normalized to that at 297 nm (i.e., the normalized spectral response at 297 nm is equal to unity) and the logarithm of the normalized spectral response degrades linearly with wavelength and is ~ 0.01 at 320 nm and ~ 0.001 at 330 nm. One MED/h is defined for this instrument as that dose which causes incipient redness of the average skin type II after one hour of irradiation. The effective power of 1 MED/h is equivalent to 0.0583 W/m^2 for an MED of 21 mJ/cm^2. The accuracy of the measurement is ± 5% for the daily total.

The analog UVA version of Model 501A UV-Biometer measures the irradiating flux in the UVA spectral range in units of W/m^{-2}. The relative spectral response is normalized to that at ~ 370 nm and is > 0.2 in the range of 320 nm $\leq \lambda \leq$ 390 nm; decreasing rapidly outside this range. The accuracy of the measurement is also ± 5% for the daily total.

A Campbell Scientific Instruments data-logger, located at each site (a Model CR21 at Neve Zohar and a Model CR10 at Beer Sheva), monitors and stores the data at 10-minute intervals (i.e., the meters are scanned at 10 second intervals and average values at 10 minute intervals are calculated and stored). The data is downloaded via modem periodically from the data-loggers to a desktop computer in Beer Sheva.

The individual databases have undergone an extensive analysis to give statistical evidence to the correctness of the calculated monthly average daily values. This was done by determining the coefficient of autocorrelation function and then using these values to determine the standard errors of both the monthly average daily values and the monthly average daily standard deviations. It was determined that the standard errors are less than the inherent measurement error for all instruments in this study. Consequently, the monthly average daily and hourly radiation intensities are representative of the two sites, cf., Kudish et al[19].

Narrow-band measurements

Sporadic measurements utilizing a narrow-band spectroradiometer, UV-Optronics 742, to scan from 295 to 380 nm at 1 nm intervals (the instrument's band pass is 1.5 nm, as per the manufacturers' specifications) were also performed. Such measurements could not be carried out concurrently at the Dead Sea and Beer Sheva, since there was only a single spectroradiometer. In order to overcome this obstacle, the broad-band ultraviolet measurements at both sites were utilized to ascertain that the overall radiation flux densities were similar prior to performing an inter-comparison between spectroradiometer measurements performed on two different but consecutive days. In addition, the horizontal global radiation intensity values measured at both sites were compared. They provide a better criterion for the justification of the inter-comparison of the narrow-band spectra because they are least affected by the different optical path lengths (i.e. site altitudes) associated with both sites due to their higher wavelength spectral range. The spectroradiometer and its peripheral equipment were transported to the Neve Zohar (Dead Sea) site approximately once every two to three weeks for a day of measurements. The latter consist of a single scan through the ultraviolet range (i.e., 295 to 380 nm) once an hour from about 9:30 until 15:30 (Israel Standard Time). An identical set of measurements were performed at the Beer Sheva site on a number of days both before and after the measurement day at Neve Zohar in order to enhance the probability of obtaining two very similar days for the purpose of inter-comparison. Again, the spectral radiation intensities referred to that on a horizontal surface.

Microtops II

A third set of measurements, providing further insight as to the nature of the ultraviolet radiation environment in the Dead Sea basin was initiated in March 1998 with a Solar Light Co., Inc. Microtops II, Ozone Monitor-Sunphotometer. This is a portable meter consisting of three narrow-band light filters measuring the UVB radiation intensities at three wavelengths of the UVB spectrum, viz., 305.5 ± 0.3, 312.5 ± 0.3 and 320.0 ± 0.3 nm. Its primary intended use is to determine the stratospheric ozone layer thickness, which is calculated as a function of the relative intensities of the three narrow-band UVB readings utilizing an algorithm programmed into the instrument. The analysis of these measurements is highly significant with regard to photoclimatherapy at the Dead Sea, as they enable one to determine optimum time intervals for sun-exposure.

DATA ANALYSIS AND RESULTS

Broad-band measurements

Monthly average daily radiation. The results and inter-comparison of the broad-band solar radiation intensity measurements at both sites are reported in Table 2-4 for the global, UVB and UVA, respectively. The database utilized in this analysis

Table 2 - Monthly average daily solar global radiation intensities in the Dead Sea Basin and Beer Sheva and their relative difference.

Month	Neve Zohar Global (kWh/m^2)	Days	Beer Sheva Global (kWh/m^2)	% Relative attenuation
J	3.12	495	3.03	2.89
F	3.96	477	3.79	4.47
M	5.30	521	5.15	2.87
A	6.28	490	6.27	0.19
M	7.30	527	7.37	-0.93
J	7.95	504	8.06	-1.34
J	7.69	521	7.76	-0.95
A	7.10	495	7.11	-0.21
S	6.13	503	6.09	0.73
O	4.72	518	4.67	1.16
N	3.63	481	3.58	1.41
D	2.97	493	2.90	2.21

Table 3 - Monthly average daily solar UVB radiation intensities in the Dead Sea Basin and Beer Sheva and their relative difference.

Month	Neve Zohar UVB (MED)	Days	Beer Sheva UVB (MED)	% Relative attenuation
J	5.89	360	6.00	-1.78
F	8.91	321	9.24	-3.55
M	13.25	512	14.10	-6.04
A	16.87	490	18.65	-9.58
M	20.79	527	23.54	-11.65
J	24.36	507	27.84	-12.50
J	23.47	521	26.95	-12.92
A	21.25	496	24.02	-11.53
S	17.28	481	19.35	-10.72
O	11.67	505	13.10	-10.89
N	7.52	416	8.34	-9.82
D	5.46	353	5.88	-7.11

consists of only those days for which intensity values existed for the specified solar radiation parameter at both sites from January 1995 through December 2011. The solar radiation intensities are reported as monthly average daily values, the number of days in each monthly database is reported in column 3 and the relative attenuation, reported in column 5, is defined as

$$\% \text{ relative attenuation} = (X_{NZ} - X_{BS})*100/X_{BS}, \quad (1)$$

where X refers the type of solar radiation, i.e., either global, UVB or UVA. The subscripts NZ and BS refer to Neve Zohar and Beer Sheva, respectively.

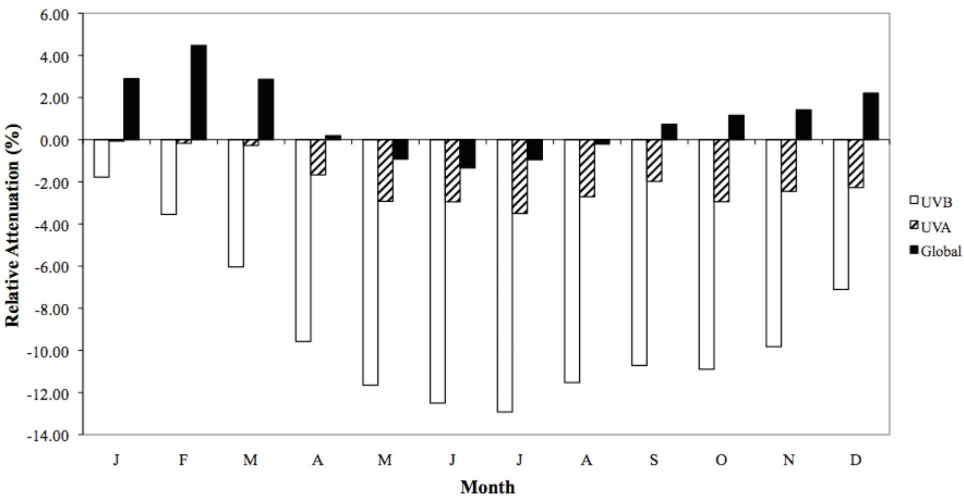
The magnitudes of the monthly average daily solar global radiation intensity at the two sites, cf. Table 2, are very similar. The % relative attenuation is < 2% for all months with the exception of January, February, March and December. This is most likely due to differences in local climatic conditions, i.e., the clouds move eastward from Beer Sheva and may be broken up as they pass over the Judean mountains prior to reaching the Dead Sea basin, since the attenuation of solar radiation within the global spectral range due to the difference of altitude between the two sites by scattering phenomena is negligible. This is supported by the fact that Beer Sheva exhibits a higher degree of cloud cover relative to the Dead Sea basin and its the mean annual rainfall is approximately five times greater than in the Dead Sea basin[20].

Table 4 - Monthly average daily solar UVA radiation intensities in the Dead Sea Basin and Beer Sheva and their relative difference.

Month	Neve Zohar UVA (Wh/m^2)	Days	Beer Sheva UVA (Wh/m^2)	% Relative attenuation
J	141.36	361	141.45	-0.07
F	183.97	330	184.28	-0.17
M	246.19	458	246.87	-0.27
A	298.66	461	303.74	-1.67
M	350.99	490	361.57	-2.93
J	390.42	487	402.29	-2.95
J	375.36	513	388.98	-3.50
A	346.05	477	355.67	-2.71
S	293.70	481	299.63	-1.98
O	219.68	518	226.34	-2.94
N	164.79	481	168.93	-2.45
D	132.42	411	135.50	-2.27

The greater magnitude of the corresponding monthly values for the percentage relative attenuation for UVB compared to that for UVA, cf. Table 3 and 4, is a result of the attenuation being inversely proportional to the wavelength and, thereby, greater for the shorter UVB wavelengths as discussed in a previous section. The variation in the monthly percent relative attenuation values for a particular UV type of radiation is also influenced by site climatic conditions, similar to the case of the global radiation discussed above. This explains the relatively low magnitude of the percent relative attenuation during the months of January and February, since the higher incidence of partially cloudy and cloudy sky conditions in Beer Sheva results in an enhanced attenuation of the UV radiation relative to the Dead Sea basin. The percent relative attenuation is also presented graphically for the three solar radiation types in Fig. 1.

Figure 1 - Monthly average daily % relative attenuation of radiation intensities [% (Neve Zohar - Beer Sheva)/Beer Sheva]

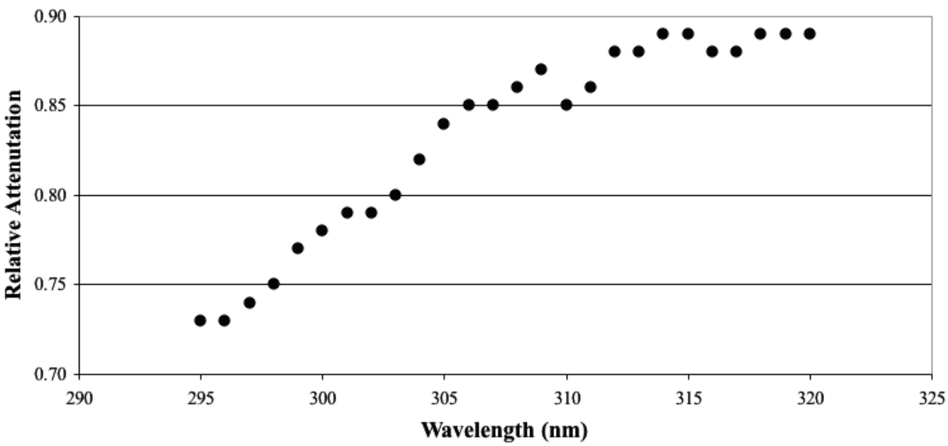


It should be noted that the relatively smaller databases corresponding to the months of January, February and December for both the UVB and UVA measurements are the result of the factory calibration that the UV meters undergo annually. These months are chosen because they correspond to that time interval which is not suitable for photoclimatherapy at the Dead Sea as they have relatively low daily solar UVB radiation intensities.

Narrow-band measurements

The results of these measurements are shown in Figs. 2 and 3 for the UVB (295 to 320 nm) and UVA (320 to 380 nm) spectral ranges, respectively. These data refer to measurements performed on two consecutive days during the month of August, i.e., one day of measurements at each site, Dead Sea and Beer Sheva, and are representative of these types of measurements. As mentioned previously, the criteria for inter-comparison was based primarily on the relative magnitude of their horizontal global radiation intensities, viz., its approach to unity. The graphs depict the ratio of the radiation intensities at the two sites (Dead Sea:Beer Sheva) as a function of wavelength throughout the UVB and UVA spectral ranges. A marked spectral selectivity is observed for the case of the UVB radiation, viz., the degree of attenuation decreases as the wavelength increases. In the vicinity of the peak erythema action spectra, ca. 300 nm, the degree of attenuation is in the range of 0.73 to 0.79 (27%-21%), whereas in the spectral range of the UVB beneficial to psoriasis, ca. 312 nm[21] the degree of attenuation is 0.85 to 0.89 (15%-11%). The degree of attenuation in the case of the UVA radiation is less than that for the UVB radiation and its spectral selectivity is much less marked, it varies in the range of 0.89 to 0.95 (11%-5%). The scatter of the measured data is not unexpected considering the very low radiation intensities being measured by the spectroradiometer.

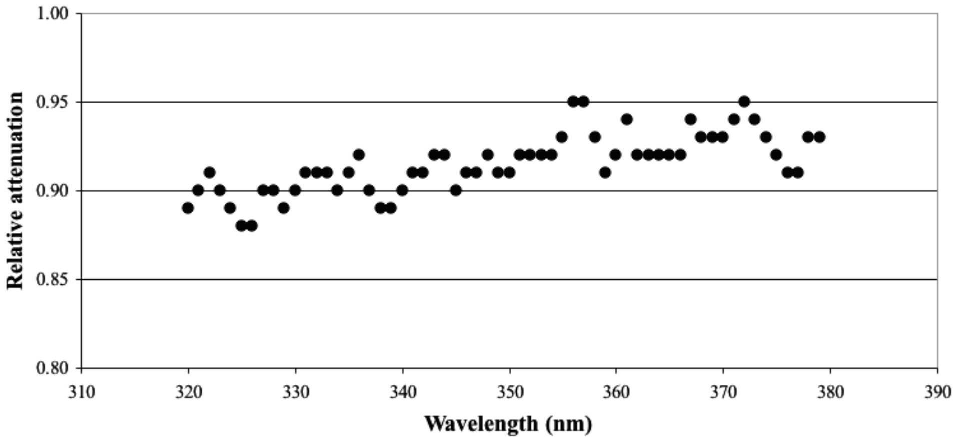
Figure 2 - Relative attenuation of solar UVB radiation within spectral range for Neve Zohar:Beer Sheva



Microtops II

The Microtops II, Ozone Monitor-Sunphotometer, has been utilized to perform sporadic measurements of the ratio of the solar UVB radiation intensities at three narrow-band wavelengths as described previously. The solar UVB radiation intensity ratio measured at 305.5 nm and 312.5 nm are of particular importance to the treatment of psoriasis at the Dead Sea medical spas. The former wavelength is within the erythema spectral range, whereas the latter is within the therapeutic spectral range with regard to the treatment of psoriasis.

Figure 3 - Relative attenuation of solar UVA radiation within spectral range for Neve Zohar:Beer Sheva

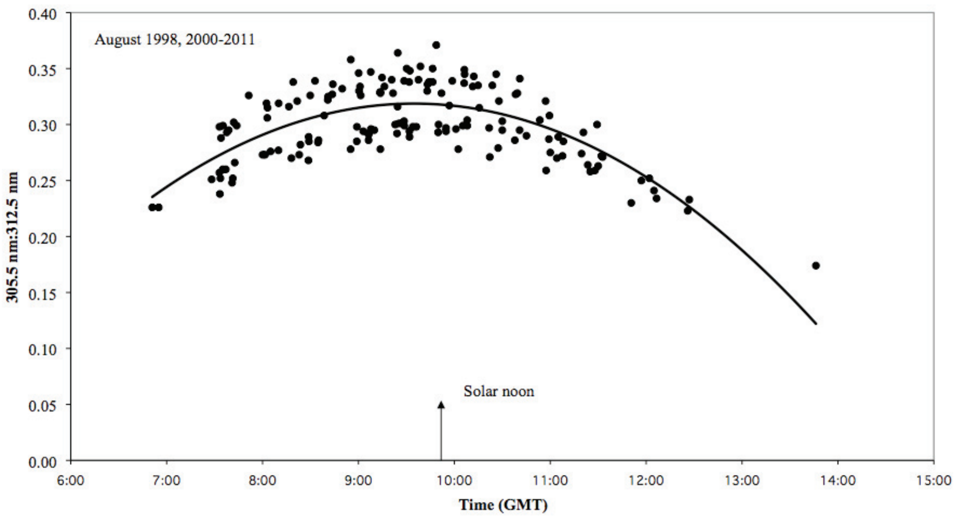


The sporadic measurements, initiated in March 1998, using the Microtops II at the Dead Sea have been analyzed on a monthly basis, viz., monthly databases are being constructed. An example of such a database is shown in Fig. 4 for the month of August. The radiation intensity ratios are presented as a function of time of day, referred to GMT, and attain a maximum at solar noon. Israel Standard Time (IST) is equivalent to GMT + 2 hours and during the month of August solar time precede local time by about 15 minutes. The optical path length varies diurnally and attains its daily minimum at solar noon and increases towards sunrise and sunset. As a result, the shortest optical path length during the month of August occurs at approximately 9:45 GMT, i.e., 11:45 IST, as attested to by the minimum attenuation of the 305.5 nm relative to 312.5 nm radiation intensity, i.e., the highest ratio. Consequently, the degree of attenuation and resultant spectral selectivity varies in the same manner, viz., the minimum in daily attenuation occurs at solar noon. The longest optical path length occurs after sunrise and before sunset. Consequently, the fraction of the incident UVB radiation within the erythema spectral range is lowest at these time intervals, viz., after sunrise and before sunset.

RELEVANCE TO PHOTOCLIMATHERAPY

The treatment protocols for photoclimatherapy of psoriasis define patient sun-exposure time intervals in order to ascertain that the patient receive the prescribed daily and cumulative doses, i.e., the total dose received by the patient during his

Figure 4 - Ratio of hourly solar UVB radiation intensities at 305.5 nm and 312.5 nm for Neve Zohar for August.



stay at the Dead Sea, of UVB radiation. Based on the observed significant attenuation of solar UVB radiation at the Dead Sea, patients undergoing photoclimatherapy at the Dead Sea would require longer periods of sun exposure in order to obtain the prescribed dose of UVB radiation relative to other locations. Consequently, the significant attenuation of the solar UVB radiation dose not bestow upon Dead Sea photoclimatherapy an overt advantage, unless this attenuation exhibits wavelength selectivity within the UVB radiation spectral range. Viz., a demonstrated spectral selectivity that causes a change in the relative intensities of the radiation within the erythema spectral range and the therapeutic spectral range beneficial to psoriasis.

The wavelength selectivity with regard to the relative attenuation within the solar UVB spectral range has been demonstrated by the narrow-band measurements described previously. It is observed, cf., Fig. 2, that the attenuation within the UVB spectral range at the Dead Sea basin decreases significantly with increasing wavelength relative to Beer Sheva. Once again, the range of relative attenuation within the peak erythema spectral range, ca. 300nm, is from 27% to 21%, whereas within the therapeutic spectral range beneficial to psoriasis, ca. 312 nm21, it decreases from 15% to 11%. Consequently, the UVB spectrum at the Dead Sea basin contains less of the shorter more deleterious erythema rays, since the narrow-band measurements show that the UVB radiation incident at the Dead Sea basin is attenuated to a much greater degree at the shorter end of its spectrum, i.e., lower wavelengths. On the other hand, the wavelengths within the therapeutic spectral range for psoriasis are also attenuated but to a lesser degree. Therefore, as a result of this wavelength selectivity at the Dead Sea basin the solar UVB spectrum has a lower proportion of the shorter erythema wavelengths in the incident UVB radiation, relative to other sites, i.e., the solar UVB radiation is less harmful. This is a direct consequence of the Dead Sea basin being situated at the lowest terrestrial point on the earth. It should be noted that the number of hospital clinics that treat psoriasis with UV lamps employing narrow-band lamps, with an intensity peak at about 312 nm, is increasing rapidly.

It is observed from the measurements performed with the Microtops II, Ozone Monitor-Sunphotometer, cf., Fig. 4, that the relative radiation intensities within the UVB spectrum between erythema and the therapeutic wavelengths are also a function of time of day. The relative radiation intensities (i.e., the ratio of the 305.5 nm to the 312.5 nm radiation intensities) exhibit a peak at solar noon and decrease towards sunrise or sunset. Therefore, psoriasis patient sun-exposure time intervals should be scheduled for early morning or late afternoon hours in order to reduce their exposure to the deleterious erythema rays, viz., to avoid the midday hours. This is accordance with the general instructions given to the public-at-large regarding sun-exposure. The prescribed time interval for sun-exposure is, of course, contingent to the availability of sufficient solar UVB radiation in accordance to the prescribed daily dose.

These findings have been applied to the psoriasis treatment protocol by defining the optimal monthly sun-exposure time intervals based upon the monthly average hourly UVB radiation intensities and those hours having relatively low ratios of the erythema to therapeutic radiation intensities, i.e., 305 nm/312 nm. An example of such is reported in Table 5 for a patient with skin type II during the month of April. The sun-exposure time intervals are chosen such that the there is sufficient UVB radiation intensity and the fraction of erythema radiation is relatively low. The goal of this study is to minimize cumulative patient sun-exposure without affecting treatment efficacy.

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Table 5 - Sun-exposure protocol for skin type II patient for April.

Day	**Daily MED**	**Dose mJ/cm2**	**Sun Exposure**	
			Morning	**Afternoon**
			8:00-8:25	14:40-15:00
1	0.4	10	9:45-10:00	13:00-13:15
			8:00-8:35	14:30-15:00
2	0.6	15	9:40-10:00	13:00-13:20
			8:00-8:45	14:20-15:00
3	0.8	20	9:30-10:00	13:00-13:25
			8:00-9:05	14:05-15:00
4	1.1	27.5	9:20-10:00	13:00-13:35
			8:00-9:10	13:55-15:00
5	1.3	32.5	9:15-10:00	13:00-13:45
			8:00-9:15	13:50-15:00
6	1.5	37.5	9:05-10:00	13:00-13:50
			8:00-8:50	14:15-15:00
7	1.7	42.5	9:30-10:00	13:00-13:30
			8:00-8:55	14:10-15:00
8	1.9	47.5	9:25-10:00	13:00-13:30
			8:00-9:00	14:05-15:00
9	2.1	52.5	9:20-10:00	13:00-13:35
			8:00-9:05	14:00-15:00
10	2.3	57.5	9:20-10:00	13:00-13:40
			8:00-9:10	14:00-15:00
11	2.5	62.5	9:15-10:00	13:00-13:40
			8:00-9:15	13:55-15:00
12	2.8	70	9:10-10:00	13:00-13:45
			8:00-9:20	13:50-15:00
13	3.1	77.5	9:05-10:00	13:00-13:50
			8:00-9:25	13:45-15:00
14	3.4	85	8:55-10:00	13:00-13:55
Total UVB Dose	**25.5**	**637.5**		

Application of table:

- Days 1 – 6

1. Daily sun-exposure can be scheduled for either the morning or afternoon hours, i.e., only a single sun-exposure session is required for days 1-6.
2. Choose either a single morning or afternoon sun-exposure time interval.
3. Prefer a single sun-exposure time that starts either early in the morning or relatively late in the afternoon; e.g., in the case of April for skin type II this translates to either a sun-exposure time interval beginning at 8:00 or finishing at 15:00.

- Days 7 – 14

1. Daily sun-exposure is scheduled for both the morning and the afternoon hours, viz., the daily dose is divided into two sun-exposure time intervals, morning and afternoon for days 7 -14.
2. Choose a single sun-exposure time interval in the morning and a single sun-exposure time in the afternoon, i.e., a total of two sun-exposure time intervals.
3. Prefer the sun-exposure times that either start early in the morning or relatively late in the afternoon; e.g., in the case of April for skin type II this translates to a morning sun-exposure time interval beginning at 8:00 and an afternoon sun-exposure finishing at 15:00.

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