Dead Sea & Arava Science Center
מרכז מדע ים המלח והערבה
under the auspices of Ben Gurion University of the Negev
בחסות אוניברסיטת בן גוריון בנגב

THE MEASUREMENT AND ANALYSIS OF UV RADIATION AND ITS USE IN OPTIMIZING TREATMENT PROTOCOLS FOR PHOTOCLIMATHERAPY OF PSORIASIS AT THE DEAD SEA MEDICAL SPAS

Avraham I. Kudish*

ABSTRACT

The Dead Sea basin offers a unique site to study the attenuation of solar ultraviolet radiation, as 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 of various skin diseases, it is of interest to study both its UV intensity and attenuation as a function of wavelength relative to other sites. In order to provide a basis for inter-comparison of the solar radiation intensity parameters measured at the Dead Sea, a second set of identical parameters are measured simultaneously at a second site (Beer Sheva), located at a distance of ca. 65 km to the west and situated above sea level. The existing database consists of measurements from January 1995 to the present. The results of this on-going research project are discussed on three levels: (1) a detailed description of the analysis of the solar UVB, UVA and global radiation databases; (2) the relevance of these findings with regard to the success of photoclimatherapy at the Dead Sea medical spas and (3) the application of these findings to optimize the photoclimatherapy treatment protocols at the Dead Sea medical spas.

Keywords: Dead Sea; Beer Sheva; Israel; UVB; UVA; solar global radiation; relative attenuation of solar radiation; photoclimatherapy.

Introduction

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[1,2]. It is situated at the lowest terrestrial point on earth, approximately 400 meters 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[3-7]. Over the past 40 years, mainly psoriasis patients have been treated at the Dead Sea medical spas8. The success rate measured in terms of excellent to complete clearance after 4 weeks of treatment exceeds 85 per cent[5,9]. These clinical findings were presumed to be associated with a unique spectrum of ultraviolet radiation present at the Dead Sea basin[10-12].

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. 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

* Blaustein Institutes for Desert Research,Ben-Gurion University of the Negev, ED Bergmann Campus, Beer Sheva 84105, Israel and The Dead-Sea and Arava Science Center, Tamar Regional Council, Newe Zohar, Dead-Sea mobile post 86910, Israel ● e-mail: akudish@bgu.ac.il

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[13,14]. 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[13], 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[15]. 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[16].

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[17], Reiter et al.[18], Blumthaler[19,20] and Piazena[21] 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.

The results of this on-going research project will be discussed on three levels: (1) a detailed description of the analysis of the solar UVB, UVA and global radiation databases; (2) the relevance of these findings with regard to the success of photoclimatherapy at the Dead Sea medical spas and (3) the application of these findings to optimize the photoclimatherapy treatment protocols at the Dead Sea medical spas.

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. It is about 65 km to the west of the Dead Sea and is 315 m above mean sea level. 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 also connected via modem to the Israel Meteorological Service, located at Bet Dagan. All measurements refer to Israel Standard Time (GMT + 2).

Table 1. Site parameters for the two meteorological stations

Site	Latitude	Longitude	Altitude (m m.s.l.)
Neve Zohar	31°12'N	35°22'E	-375
Beer Sheva	31°15'N	34°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 due to scheduled 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[22]. Consequently, the UVB biometer has a spectral response normalized to that at 297 nm 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 the dose that 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. This effective power of 1 MED was utilized to convert the measured UVB radiation to W/m^2 when calculating the corresponding UV Index. 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 $\le \lambda \le$ 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.[23].

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 during the time interval 1995-1997. 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 the two sites due to their longer 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 into 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 relative intensity measurements is highly significant with regard to photoclimatherapy at the Dead Sea, as will be discussed in the section on photoclimatherapy.

Data analysis and Results

Broad-band measurements

Monthly average hourly 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 consists of only those days for which intensity values existed for the specified solar radiation parameter at both sites from January 1995 through August 2008. 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

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

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.

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

Month	Neve Zohar (kWh/m^2)	Days	Beer Sheva (kWh/m^2)	% Relative attenuation
J	3.09	402	3.00	3.15
F	3.98	393	3.80	4.66
M	5.27	432	5.11	3.04
A	6.28	407	6.26	0.29
M	7.32	434	7.41	-1.19
J	7.95	414	8.06	-1.44
J	7.68	428	7.77	-1.05
A	7.09	404	7.12	-0.37
S	6.17	383	6.13	0.59
O	4.72	403	4.68	0.88
N	3.61	390	3.56	1.47
D	2.95	385	2.89	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 (MED)	Days	Beer Sheva (MED)	% Relative attenuation
J	5.75	268	5.97	-3.75
F	9.01	262	9.56	-5.71
M	13.19	423	14.34	-8.01
A	16.97	407	19.08	-11.06
M	20.85	434	24.14	-13.61
J	24.42	417	28.45	-14.20
J	23.38	428	27.46	-14.86
A	21.14	405	24.51	-13.74
S	17.14	361	19.85	-13.65
O	11.48	390	13.30	-13.67
N	7.42	340	8.41	-11.82
D	5.35	245	6.05	-11.48

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

Month	Neve-Zohar (Wh/m^2)	Days	Beer Sheva (Wh/m^2)	% Relative attenuation
J	138.91	268	138.93	-0.01
F	184.78	246	186.54	-0.95
M	244.82	394	246.05	-0.50
A	297.34	378	303.75	-2.11
M	350.00	397	364.21	-3.90
J	388.24	397	402.75	-3.60
J	372.39	420	388.94	-4.26
A	343.53	386	355.45	-3.35
S	292.32	361	301.04	-2.90
O	217.80	403	226.91	-4.01
N	163.38	390	168.10	-2.81
D	131.52	315	135.32	-2.81

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 < 3% for all months with the exception of January, February and March. 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[24].

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, February and March, 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 Figure 1.

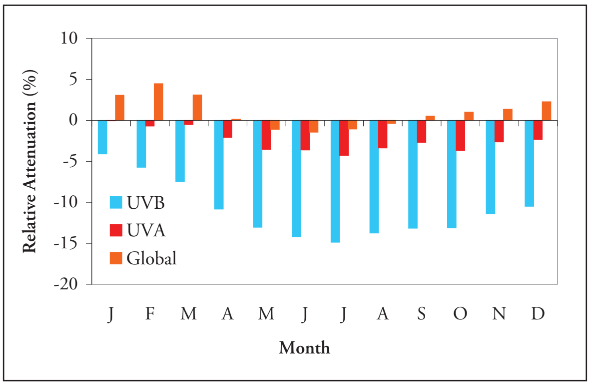

Figure 1. Relative attenuation of solar global, UVB and UVA radiation for Neve Zohar and Beer Sheva

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 that is not suitable for photoclimatherapy at the Dead Sea, as they have relatively low daily solar UVB radiation intensities.

UV Index

The database utilized in this analysis consists of all available hourly values for UVB radiation from January 1995 through August 2008 for both sites. The hourly UVB radiation values were first converted to W/m^2 and then multiplied by 40 to determine the corresponding UVI values. The monthly average hourly UVI values throughout the day are reported in Figs. 2 and 3 for Neve Zohar and Beer Sheva, respectively. The UVI values on the ordinates have been separated into four ranges according to the generally accepted classification of the UVI values, viz., extreme, UVI ≥ 9; high, 7 ≤ UVI < 9; moderate, 4 ≤ UVI < 7 and low, UVI < 4. A UVI < 2 is considered negligible. In terms of sun exposure time to achieve incipient redness for a skin type II (sometimes burns, sometime tans) these four ranges of UVI values translate into < 15 minutes, 20 minutes, 30 minutes and more than 1 hour, respectively.

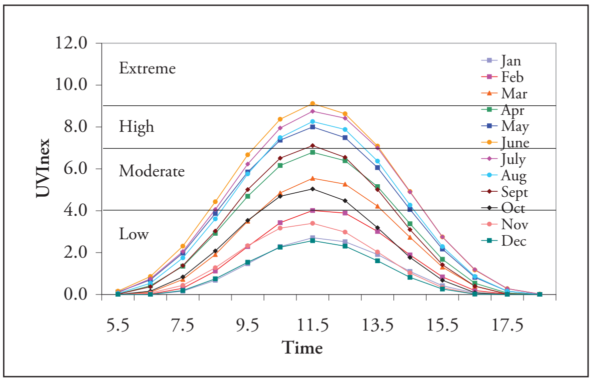

Figure 2. Monthly average hourly UV Index values for Neve Zohar (Israel Standard Time)

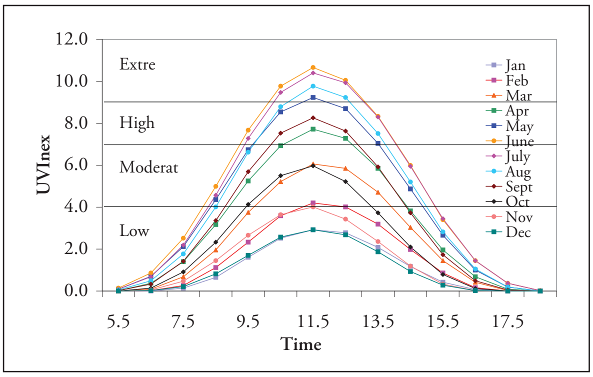

Figure 3. Monthly average hourly UV Index values for Beer Sheva (Israel Standard Time).

The most striking observation from Figs. 2 and 3 is that only a single average hourly UVI value, midday in June, enters in the 'extreme' range at Neve Zohar, whereas at Beer Sheva the midday hours from May through August exhibit extreme UVI values. This is a reflection of the relative attenuation of the solar UVB radiation at the two sites. Consequently, it will take longer to achieve incipient redness (erythema) at Neve Zohar than at Beer Sheva under very similar solar global radiation intensities.

Narrow-band measurements

The results of these measurements are shown in Figures 4 and 5 for the UVB (295 to 320 nm) and UVA (320 to 380 nm) spectral ranges, respectively.

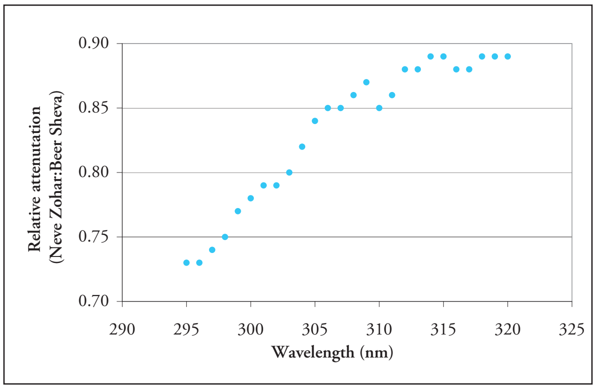

Figure 4. Relative attenuation of solar UVB radiation within spectral range; Neve Zohar divided by Beer Sheva

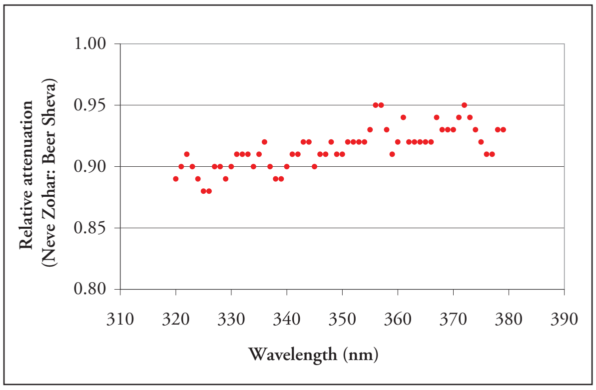

Figure 5. Relative attenuation of solar UVA radiation within spectral range; Neve Zohar divided by Beer Sheva

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[25] 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.

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. The application of these measurements to photoclimatherapy will be discussed in a following section.

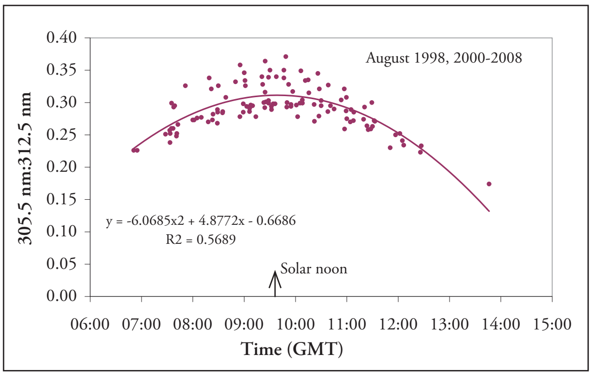

Figure 6. Ratio of hourly solar UVB radiation intensities at 305.5 nm and 312.5 nm for Neve Zohar for August

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 Figure 6 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 precedes 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. The degree of attenuation and resultant spectral selectivity vary in the same manner, viz., the minimum in daily attenuation occurs at solar noon.

Relevance to photoclimatherapy

The results from the broad-band measurements of the solar UVB and UVA radiation, as summarized in Tables 3 and 4, show a general attenuation of both UVB and UVA radiation intensities at the Dead Sea basin relative to that at Beer Sheva, with the UVB radiation attenuated to a much greater extent than the UVA. The annual average daily attenuation for Neve Zohar relative to Beer Sheva is 11.3% and 2.6% for UVB and UVA, respectively. The maximum attenuation of the solar UVB radiation is 14.9% in July, whereas the minimum is 3.8% in January. In the case of solar UVA radiation the maximum attenuation is 4.3% in July, whereas in January the solar UVA radiation intensities at the two sites are essentially identical.

As to be discussed in the following section, treatment protocols for photoclimatherapy of psoriasis define patient sun-exposure time intervals in order to ascertain that the patient receives the prescribed daily and cumulative doses, i.e., the total dose received by the patient during his 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., Figure 4, 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. 300 nm, is from 27% to 21%, whereas within the therapeutic spectral range beneficial to psoriasis, ca. 312 nm[25], 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., Figure 6, 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.

Photoclimatherapy treatment protocols

The question relating to the safety of patient exposure to both solar and artificial phototherapy has been raised in recent years,[26] and a reduction in the cumulative UVB exposure dose during photoclimatherapy could reduce the possible dangerous side effects[27,28]. Consequently, our goal is to reduce the cumulative dose of the UVB radiation that a patient receives during photoclimatherapy at the Dead Sea to a minimum and thereby reduce the risk of possible deleterious side-effects. This must be achieved without affecting treatment efficacy; viz., the cumulative dose of UVB radiation from sun exposure must be sufficient to treat successfully the patient's skin diseases.

In the framework of our regional research and development program at the Dead Sea, we endeavor to improve the efficiency of the photoclimatherapy protocol for the treatment of psoriasis at the Dead Sea clinics. The suggested revisions in the treatment protocols, presented as guidelines, are based upon the scientific information retrieved from our on-going research activities, mainly the continuous measurement of the UVB radiation intensity.

As described previously, the solar UVB radiation at the Dead Sea has been monitored since January 1995 and the existing database has been tabulated (and continuously up-dated) as monthly average hourly UVB radiation values. In addition, sporadic measurements of the diurnal variation of the ratio of the UVB radiation at two wavelengths, 305.5 and 312.5 nm, have been performed since March 1998. These wavelengths correspond to the erythema and therapeutic (for psoriasis) wavelengths ranges, respectively. The data from these measurements have also been tabulated as monthly average hourly values. These two sets of data have been cross-referenced in order to prescribe patient sun-exposure time schedules, i.e., sun-exposure protocols that assure that the patient receives the adequate dose of UVB radiation, while minimizing patient exposure to radiation within the erythema wavelength range. It is important to emphasize that the risk of side effects increases as the radiation wavelength decreases, i.e., within the erythema wavelength range.

The procedure used to achieve the suggested, optimal sun-exposure treatment protocols for psoriasis patients at the Dead Sea is described in the following paragraphs.

Minimum Erythema Dose

Extensive studies have been performed on the application of photoclimatherapy of psoriasis at the Dead Sea medical spas. These studies have resulted in a quantitative definition of the optimal dose of UVB radiation, both daily and cumulative, that the patient of a particular skin type should be exposed to during his stay at the Dead Sea. This dose is defined in units of MED's. The MED can be individually evaluated but is defined, approximately, as a function of patient skin type as follows[29]:

Skin type II	1 MED = 25 mJ/cm^2
Skin type III	1 MED = 35 mJ/cm^2
Skin type IV	1 MED = 45 mJ/cm^2

The recommended cumulative dose of UVB radiation to which a patient should be exposed during a 2-week stay at the Dead Sea, based upon clinical experience, is as follows:

Skin type II 25.5 MED = 637.5 mJ/cm^2
Skin type III 27.5 MED = 962.5 mJ/cm^2
Skin type IV 33.5 MED = 1507.5 mJ/cm^2

Monthly Average Hourly UVB Radiation

The tabulated monthly average hourly UVB radiation values provide information regarding the hours that have sufficient UVB radiation and should be allowed for the ***prescribed*** patient sun exposure. The hours with excessive UVB radiation (≥ 2 MED) should be ***proscribed*** for patient sun exposure. The data for the three skin types are reported in Tables 5 a-c only for those months that have sufficient UVB radiation to achieve the prescribed dose.

The average hourly values reported in Tables 5 a-c have been grouped into three different categories:

Blue: hours with sufficient UVB radiation for patient sun exposure; hours that can be prescribed.

Red: hours with excessive UVB radiation (≥ 2 MED); hours to be proscribed.

Green: hours with insufficient UVB radiation. The threshold value for useful sun exposure has been set at > 0.60 MED. The exception to this being the case of Skin Type IV during the month of September. This is due to the relatively low UVB radiation available in terms of MED's for Skin Type IV.

UVB Dose and Sun-Exposure Times

As mentioned previously, the goal of these guidelines is to minimize the risks of possible dangerous side effects to the patients during photoclimatherapy at the Dead Sea. This has to be accomplished by choosing sun-exposure hours that provide the prescribed dose of UVB radiation and, at the same time, having a preference for those hours that have a lower ratio of erythema to therapeutic radiation. This information is provided by the tabulated monthly average hourly ratios of the 305.5 to 312.5 nm wavelengths, viz., the ratio of the erythema to therapeutic UVB radiation. The results of this on-going study can be summarized as follows: the ratio decreases as the hour is further removed from midday. Consequently, the prescribed hours should be as early/late in the day as possible; contingent on the availability of sufficient UVB radiation to comply with the suggested daily dose.

The hourly UVB radiation received from the sun varies with both time of day and month of the year, cf. Tables 5 a-c. These factors must be taken into consideration when developing a sun-exposure protocol for the photoclimatherapy of psoriasis. The 2-week stay at the Dead Sea has been split into two

Table 5. Monthly average hourly UVB radiation (MED) as a function skin type

Skin type II										
Month/hour	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Mar	0.25	0.67	1.22	1.70	1.94	1.86	1.48	0.95	0.46	0.14
Apr	0.48	1.02	1.65	2.18	2.41	2.27	1.83	1.20	0.60	0.19
May	0.70	1.37	2.07	2.60	2.81	2.64	2.14	1.44	0.76	0.29
June	0.81	1.56	2.35	2.97	3.22	3.04	2.49	1.72	0.97	0.41
July	0.71	1.40	2.18	2.78	3.06	2.94	2.44	1.71	0.96	0.40
Aug	0.61	1.27	2.02	2.63	2.89	2.76	2.23	1.49	0.79	0.29
Sept	0.48	1.08	1.77	2.30	2.51	2.31	1.76	1.08	0.50	0.14
Oct	0.30	0.73	1.26	1.66	1.78	1.58	1.13	0.62	0.24	0.03
Skin type III										
Month/hour	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Mar	0.18	0.48	0.87	1.21	1.39	1.33	1.06	0.68	0.33	0.10
Apr	0.34	0.73	1.18	1.56	1.72	1.62	1.31	0.86	0.43	0.14
May	0.50	0.98	1.48	1.86	2.01	1.89	1.53	1.03	0.54	0.21
June	0.58	1.11	1.68	2.12	2.30	2.17	1.78	1.23	0.69	0.29
July	0.51	1.00	1.56	1.99	2.19	2.10	1.74	1.22	0.69	0.29
Aug	0.44	0.91	1.44	1.88	2.06	1.97	1.59	1.06	0.56	0.21
Sept	0.34	0.77	1.26	1.64	1.79	1.65	1.26	0.77	0.36	0.10
Oct	0.21	0.52	0.90	1.19	1.27	1.13	0.81	0.44	0.17	0.02
Skin type IV										
Month/hour	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17
Mar	0.14	0.37	0.68	0.94	1.08	1.03	0.82	0.53	0.26	0.08
Apr	0.27	0.57	0.92	1.21	1.34	1.26	1.02	0.67	0.33	0.11
May	0.39	0.76	1.15	1.44	1.56	1.47	1.19	0.80	0.42	0.16
June	0.45	0.87	1.31	1.65	1.79	1.69	1.38	0.96	0.54	0.23
July	0.39	0.78	1.21	1.54	1.70	1.63	1.36	0.95	0.53	0.22
Aug	0.34	0.71	1.12	1.46	1.61	1.53	1.24	0.83	0.44	0.16
Sept	0.27	0.60	0.98	1.28	1.39	1.28	0.98	0.60	0.28	0.08
Oct*	0.17	0.41	0.70	0.92	0.99	0.88	0.63	0.34	0.13	0.02

* There is insufficient UVB radiation available during October for the treatment of patients with skin type IV.

parts based upon the suggested levels of the daily dose of UVB radiation. Days 1–6 of sun exposure are characterized by relatively low daily doses, whereas days 7-14 require higher doses of UVB radiation. Consequently, days 1–6 require sun exposure during either the morning (pre-noon) or afternoon hours, whereas days 7-14 require sun exposure during both morning and afternoon hours. The initially low and gradual increase of daily UVB doses is due to the necessity for conditioning the patient's skin, i.e., to prevent severe sunburn.

Monthly Sun-Exposure Protocol

It should be emphasized that the suggested 2-week sun-exposure protocol presented in these guidelines for photoclimatherapy of psoriasis at the Dead Sea is based upon a database consisting of monthly hourly UVB radiation intensity values measured at the Neve Zohar since January 1995. It was developed in accordance with both the daily dose of UVB radiation required by each skin type and the monthly variation in the hourly UVB radiation intensity available at the Dead Sea. It adheres to the principle of a gradual increase of sun exposure and achieves the suggested required dose of UVB radiation at the end of 14 days of photoclimatherapy at the Dead Sea.

If the photoclimatherapy treatment exceeds 2 weeks, it is recommended that the daily UVB dose should not be increased beyond that dose received on day 14, viz., the patient should continue to receive the same dose received on day 14 until the completion of his stay at the Dead Sea.

The actual guidelines consist of monthly tables for each skin type, e.g., Table 6. They provide a detailed monthly sun-exposure protocol for each skin type (II, III and IV), respectively, and contain the following parameters:

Column 1: day number (1-14);

Column 2: daily dose in MED units;

Column 3: daily dose in mJ/cm^2;

Column 4: days 1-6, morning sun-exposure time interval required to obtain total daily dose; days 7-14, morning sun-exposure time interval required to obtain half the daily dose;

Column 5: days 1-6, afternoon sun-exposure time interval required to obtain total daily dose; days 7-14, afternoon sun-exposure time interval required to obtain half the daily dose.

It is **highly recommended** that the longer sun-exposure time interval be preferred, since they correspond to those hourly time intervals further removed from midday. This preference is a result of the fact that the ratio of the erythema to therapeutic radiation decreases as the sun-exposure time interval is further removed from the midday hours (11:00 – 13:00).

Table 6. Sun-exposure protocol for skin type II patient for April

Day	Daily (MED)	Dose (mJ/cm2)	Sun Exposure Morning	Sun Exposure Afternoon
1	0.4	10.0	8:00-8:25 9:45-10:00	14:40-15:00 13:00-13:15
2	0.6	15.0	8:00-8:35 9:40-10:00	14:30-15:00 13:00-13:20
3	0.8	20.0	8:00-8:45 9:30-10:00	14:20-15:00 13:00-13:25
4	1.1	27.5	8:00-9:05 9:20-10:00	14:05-15:00 13:00-13:35
5	1.3	32.5	8:00-9:10 9:15-10:00	13:55-15:00 13:00-13:45
6	1.5	37.5	8:00-9:15 9:05-10:00	13:50-15:00 13:00-13:50
7	1.7	42.5	8:00-8:50 9:30-10:00	14:15-15:00 13:00-13:30
8	1.9	47.5	8:00-8:55 9:25-10:00	14:10-15:00 13:00-13:30
9	2.1	52.5	8:00-9:00 9:20-10:00	14:05-15:00 13:00-13:35
10	2.3	57.5	8:00-9:05 9:20-10:00	14:00-15:00 13:00-13:40
11	2.5	62.5	8:00-9:10 9:15-10:00	14:00-15:00 13:00-13:40
12	2.8	70.0	8:00-9:15 9:10-10:00	13:55-15:00 13:00-13:45
13	3.1	77.5	8:00-9:20 9:05-10:00	13:50-15:00 13:00-13:50
14	3.4	85.0	8:00-9:25 8:55-10:00	13:45-15:00 13:00-13:55
Total UVB Dose	25.5	637.5		

It is of the utmost importance to emphasize:

- These tables were prepared for the medical staffs of the Dead Sea medical spas in order to provide both them and their patients with a safe photoclimatherapy treatment protocol. Any changes in the sun-exposure protocol should be done under medical supervision and in accordance to specific patient reaction to sun exposure.
- The occurrence of sunburn requires the interruption of the sun exposure or reduction of daily dose, i.e., decrease daily sun-exposure time, at least for the involved skin areas.

It should be noted that it was **Dr. M. Harari** (DMZ Medical Center, Ein Bokek and the Dead Sea Center for Research, Development and Study, Neve Zohar) who first proposed the monthly sun-exposure protocol tables as a function of skin type and developed them together with the author.

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.

Acknowledgments

The author wishes to express his gratitude to the Dead Sea Institute for Research, Development and Study for funding this on-going study under research grants 85422101-601, 86754101-801 and to the Israel Meteorological Service for their aid in both the design and maintenance of the meteorological stations. He is especially grateful to all his co-investigators, who have made significant contributions to the research studies presented in this manuscript.

References

1. Steinhorn I, Gat JR, The Dead Sea, *Sci Am* **249**, 84-91, 1983.
2. Even-Paz Z, Efron D, The Dead Sea as a health spa resort, *Isr J Med Sci* **32(Supplement),** 4-8, 1996.
3. Dostrovsky A, Sagher F, The therapeutic effect of the Dead Sea on some skin diseases, *Harefuah* **57,** 143-145, 1959.
4. Avrach WW, Niordson AM, Treatment of psoriasis at the Dead Sea, *Ugeskr Laeg* **13,** 2687-2690, 1974.
5. Abels DJ, Kattan BJ, Psoriasis treatment at the Dead Sea, *J Am Acad Dermatol* **12,** 639-643, 1985.
6. Sukenik S, Spa treatment for arthritis at the Dead Sea area, *Isr J Med Sci* **30,** 919-921, 1994.
7. Even-Paz Z, Efron D, Kipnis V, Abels DJ, How much Dead Sea for psoriasis, *J Dermatol Treat* **7,** 17-19, 1996.
8. Abels DJ, Kipnis V, Bioclimatology and balneology: A Dead Sea perspective, *Clinics Dermatol* **16(6):** 695-698, 1998.
9. Harari M, Shani J, Demographic evaluation of successful anti-psoriatic climatotherapy at the Dead Sea (Israel) DMZ Clinic, *Int'l J Dermatol* **36,** 304-308, 1997.
10. Kushelevsky AP, Slifkin MA, Ultraviolet light measurements at the Dead Sea and at Beer Sheva,, *Isr J Med Sci* **11,** 488-490, 1975.
11. Kushelevsky AP, Kudish AI, Inter-comparison of global, ultraviolet B and A radiation measurements in the Dead Sea region and Beer Sheva, *Isr J Med Sci* **32 (Supplement),** 24-27, 1996.
12. Abels DJ, Even-Paz Z, Efron D, Bioclimatology at the Dead Sea in Israel, *Clinics Dermatol* **14,** 653-658, 1996.
13. Moon P, Proposed standard solar radiation curves for engineering use, *J Franklin Inst* **230,** 583-617, 1940.
14. Thekaekara MP, Data on incident solar energy, *Supplement to the Proc. of the 20th Annual Meeting of the Inst. for Environmental Science* **21,** 1974.
15. ACS, Cancer facts and figures, *Publication 95-375*, Atlanta, GA, American Cancer Society, 1995.
16. Felipe P, Emerit I, Youssefi AA, Levy A, Cernjavski L, Freitas, J, Cirne de Castro JL, Oxyradical-mediated clastogenic plasma factors in psoriasis: increase in clastogenic activity after PUVA, *Photochemistry and Photobiology* **66,** 497-501, 1997.
17. Bener P, Final technical report no. DAJA 37-68-C-1017 (Europ. Res. Office, U.S. Army), 1972.
18. Reiter R, Munzert K, Sladkovic R, Results of 5-year concurrent recordings of global, diffuse and UV-radiation at three levels (700, 1800 and 2999 m a.s.l.) in the Northern Alps, *Arch Met Geophy Biokl Ser. B* **30,** 1-28, 1982.
19. Blumthaler M, Rehwald W, Ambach W, Seasonal variations of erythema dose at two Alpine stations in different altitudes, *Arch Met Geophy Biokl Ser. B* **35,** 389-397, 1985.
20. Blumthaler M, Ambach W, Rehwald W, Solar UV-A and UV-B radiation fluxes at two Alpine stations at different altitudes, *Theoretical Applied Climatology* **46,** 39-44, 1992.
21. Piazena H, The effect of altitude upon the solar UV-B

and UV-A irradiance in the tropical Chilean Andes, *Solar Energy* **57,** 133-140, 1996.

22. McKinlay A, Diffey B, A reference action spectrum for ultraviolet induce erythema, in human skin. In: Passchler WR, Bosnajokovic BFM, editors. *Human Exposure to Ultraviolet Radiation: Risks and Regulations*, Elsevier Science Publishers B.V., Amsterdam, pp.83-87, 1987.
23. Kudish AI, Lyubansky V, Evseev EG, Ianetz A, Statistical analysis and inter-comparison of the solar UVB, UVA and global radiation for Beer Sheva and Neve Zohar (Dead Sea), Israel, *Theoretical and Applied Climatology* **80,** 1-15, 2005.
24. Bitan A, Rubin S, *Climatic Atlas of Israel for Physical and Environmental Planning and Design*, Israel Ministry of Infrastructure, Division of Research and Development, 2000
25. Parrish JA, Jaenicke KF, Action spectrum for phototherapy of psoriasis. *J Invest Dermatol* **76,** 359-362, 1981.
26. Kushelevsky AP, Harari M, Kudish AI, Hristakieva E, Ingber A, Shani J, Safety of solar phototherapy at the Dead Sea. *J Am Acad Dermatol* **38,** 447-452, 1998.
27. Stern RS, Thibodeau LA, Kleinermann RA, Risk of cutaneous carcinoma in patients treated with oral methoxsalen photochemotherapy for psoriasis *N Engl J Med* **300,** 809-813, 1979.
28. Morison WL Photoimmunology, *J Invest Dermatol* **77,** 71-76, 1981.
29. Vanicek K, Frei T, Litynska Z, Schnalwieser A, *UV-Index for the Public, COST-713 Action (UV-B Forecasting),* Office for official Publications of the European Communities, Luxumberg, 27 pp., 2000.

Appendix

How the daily time intervals for sun-exposure have been calculated in Table 6. E.g.: Skin type II, Day 6, recommended daily dose = 1.5 MED

From Table 5(a) determine which hour or combination of hours have at least 1.5 MED; hour(s) furthest removed from midday are preferred.

Recommended time interval is determined as follows:

- Sun exposure from 8:00-9:00 provides 0.67 MED
- Sun exposure from 9:00-10:00 provides 1.22 MED but require only an additional 0.83 MED, viz., 1.5 MED – 0.67 MED
- Additional sun-exposure time interval required beyond 9:00 is calculated by the following equation:

  0.83 MED/1.22 MED=X min/60 min

  X=(0.83 MED/1.22 MED)*60 min=41 min

  Total sun-exposure time interval=101 min~100 min

  Recommended sun-exposure time interval is then 8:00 to 9:40.

Journal of Dead-Sea and Arava Research (2009) Vol 1: 1-13
מחקרי ים-המלח והערבה (2009) כרך 1: 1-13

Dead Sea & Arava Science Center
מרכז מדע ים המלח והערבה
under the auspices of Ben Gurion University of the Negev
בחסות אוניברסיטת בן גוריון בנגב

מדידה וניתוח של קרינת אולטרא-סגול ושימושיה לאופטימיזציה של פרוטוקולים לטיפול פוטו-אקלימי של חולי פסוריאזיס במרחצאות ים המלח**

אברהם קודיש*

תקציר

ים המלח מהווה אתר ייחודי לבצוע מחקרים הבודקים את הפחתת העוצמה של קרינת האולטרא-סגול של השמש, וזאת משום שהוא נמצא במקום היבשתי הנמוך ביותר על פני כדור הארץ, 417 מטרים מתחת לפני הים. לאור העובדה שאזור ים המלח משמש כאתר מרפא בפוטו-קלימתרפיה לשורה של מחלות עור, יש חשיבות רבה לחקור את העוצמה של קרינת האולטרא-סגול באזור זה ולהשוותה למצוי במקומות אחרים. ידוע כי העוצמה של קרינת האולטרא-סגול מופחתת ביחס הפוך לאורך הגל. עבודה זו מפרטת את נתוני קרינת האולטרא-סגול שנמדדו במשך שנים באזור ים המלח בהשוואה לעוצמת הקרינה שנמדדה בבאר שבע, בגובה 315 מטרים מעל פני הים. מאגר הנתונים הקיימים מכיל מדידות החל מינואר 1995 עד היום. תוצאותיו של המחקר המתמשך נותחו בשלוש רמות:

1. תאור מעמיק של ניתוח המדידות של הקרינה הגלובלית, וקרינת האולטרא-סגול A ו-B.
2. חשיבותן של המסקנות המבוססות על ניתוח התוצאות להצלחת הטיפול הפוטו-אקלימי בים המלח.
3. יישום תוצאות המחקר בפיתוח פרוטוקול אופטימאלי לטיפול פוטו-אקלימי בפסוריאזיס בים המלח.

ניתן לסכם את התוצאות העיקריות של המחקר כדלהלן:

1. עוצמת קרינת ה-UVB באזור ים המלח מופחתת באופן משמעותי ביחס לאתרים הנמצאים בגובה מעל פני הים.
2. היות וכמות ההפחתה של קרינת ה-UVB היא פונקציה הפוכה של אורך הגל של הקרינה, עוצמת הקרינה בתחום ה-erythema (300 nm) מופחתת יותר מהקרינה בתחום אורך הגל המשפיע על הפסוריאזיס (311 nm)
3. על סמך ניתוח התוצאות של עוצמות הקרינה הממוצעות ניתן לקבוע לוח זמנים לחשיפה לקרינת אולטרא-סגול כפונקציה של חודש הטיפול וסוג עורו של המטופל. כאשר המטרה היא להגיע למינימום חשיפה לקרינת אולטרא-סגול מבלי להפחית ביעילות הטיפול הפוטו-אקלימי ובהצלחתו.

על סמך תוצאות המחקר ניתן לקבוע שקיימים באזור ים המלח תנאי אקלים מיוחדים לטיפול פוטו-אקלימי במחלות עור, בעיקר כתוצאה מהעובדה שקיים סינון בורר של קרינת אולטרא-סגול כפונקציה של אורך-גל.

* המכונים לחקר המדבר ע"ש בלאושטיין, אוניברסיטת בן-גוריון בנגב, קריית ארנסט דוד ברגמן ומרכז מדע ים-המלח והערבה, מועצה אזורית תמר, נווה זוהר דואר-נע ים-המלח 86910 ● דוא"ל: akudish@bgu.ac.il
** המאמר מפורסם במקורו באנגלית.