- ***Short report***

# Measurement of solar ultraviolet radiation in Yazd, Iran

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***Background:*** Ultraviolet (UV) radiation is divided into three regions: $UV_A$, $UV_B$, and $UV_C$. Both the quality and quantity of solar UV radiation vary with various factors including the elevation of the sun above the horizon, as well as absorption and scattering of UV photons by molecules in the atmosphere, notably ozone and clouds. It is clear that whereas a moderate amount of UV exposure is beneficial, too much is detrimental, so there is a need to quantify variations of solar UV on the earth surface, at different time intervals. ***Materials and Methods:*** The measurement of solar UV radiation in Yazd city was achieved by two radiometers: 1) a special $UV_A$ light meter with maximum sensitivity to 365nm in the range of 320-390nm and 2) a radiometer with a probe for 280-320 nm in $UV_B$ radiation. Measurement duration was from 1rst January to the end of December 2008 and from sunrise to sunset, every one hour. ***Results:*** Daily integral $UV_A$ radiation in December with the lowest ($0.38\times10^5 Jm^{-2}$) and July with the highest intensity ($5.26\times10^5 Jm^{-2}$) were found. The minimum and maximum monthly $UV_A$ radiation on the ground level of Yazd city were $25.8\times10^5 Jm^{-2}$ in December and $128.7\times10^5 Jm^{-2}$ in July, respectively. ***Conclusion:*** Based on $UV_B$ /$UV_A$ ratio the $UV_B$ intensity at 12 o'clock is 25 times lower than the $UV_A$. Therefore, the integrated hourly $UV_B$ in this time is equal to 3.13 $kjm^{-2}$ and almost the effective UVB is 1.56 $kJm^{-2}$ so the minimum required exposure time of $UV_B$ radiation for one SDD and MED by hands and head are about 22 and 110 minutes respectively. **Iran. J. Radiat. Res., 2012; 10(3-4): 187-191**

***Keywords:*** *$UV_A$, $UV_B$, solar UV, radiometer, Yazd, broadband meter.*

## INTRODUCTION

The solar UV-spectrum can be divided in $UV_C$ (100-280 nm), $UV_B$ (280–315 nm) and $UV_A$ (315–400 nm) bands [(1)]. The predominant part of the short-wave or destructive UV-spectrum does not reach the earth's surface since the ozone layer of earth's atmosphere absorbs the short-wave up to approximately 310 nm [(1)]. In human skin, $UV_B$ is almost completely absorbed by the epidermis whereas $UV_A$ penetrates deeper into the dermis. Therefore, $UV_B$ can cause skin cancer which occurs in the epidermis and $UV_A$ effects on solar elastosis causing skin ageing in the dermis [(1)]. DNA is an important epidermal chromophore with an absorption maximum of 260 nm, but both $UV_A$ and $UV_B$ can induce structural damage to DNA. Suppression of the skin's immune system has been shown to be another one of the mechanisms by which solar UV radiation induces and promotes skin cancer growth, even at low level doses [(2)]. On the other hand, approximately 90% of the body's needs in vitamin D have to be produced in the skin through the action of solar $UV_B$ radiation. A serious problem, for an association between vitamin D deficiency and various types of cancer (e.g. colon, prostate and breast cancer) has been demonstrated in a large number of studies [(3-5)]. How much vitamin D is necessary to protect against cancer and other diseases? Vieth believes that people need 4000–10,000 IU vitamin D, daily [(5)]. On a sunny summer day, total body sun exposure produces approximately 10,000 IU vitamin D [(6)]. Other researchers agree with 20-25 µg (800 – 1000IU) daily for all adults [(1)]. The variation of ground-level UV irradiance with local time, latitude and season arises primarily from the changing path length

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taken by sunlight through an absorbing and scattering atmosphere as solar elevation varies over time scales ranging from hours to 1 year. Changing optical properties of the local atmosphere, including ozone abundance, clouds, haze and particulates leads to additional variations in UV at a fixed site [7].

Yazd city of Iran lie at 31.9 °N Latitude, 54.4 °E Longitude and 1230m Altitude [8]. This city has desert climate with hot summer. Although monitoring of solar UV radiation is very important, Yazd hasn't achieved that yet, like many of Iranian cites. It is necessary to assess the risk of UV related health effects, especially during growing age as well as decisions on preventive actions. It is also clear that most of the UV energy received on the ground level is $UV_A$ and as the wavelength increases, the receiving UV intensity at the ground level increases [9]. In this survey the dose of $UV_A$ and its relation to $UV_B$ were determined.

## MATERIALS AND METHODS

Although spectroradiometry is the fundamental way to characterize the radiant emission from a light source, radiation output is normally measured by techniques of narrowband radiometry. Narrowband radiometers generally combine a detector (such as a vacuum phototube or a solid-state photodiode) with a wavelength-selective device (such as a color glass filter or interference filter) and suitable input optics (such as a quartz hemispherical diffuser or polytetrafluoroethylene (PTFE) window [10]. In this study, UV radiation measurements were performed using an $UV_A$ radiometer with maximum sensitivity in 365 nm ($UV_A$-365) and band pass of 320-390 nm made in Taiwan (Lutron Co). This radiometer was calibrated by a new similar radiometer which had a valid calibration certification. The UV sensors were stored in dry environment when not in use. The sensor structure was a UV photo diode and UV color correction filter. All the measurements were performed in Yazd city on the ground level with 6 m distance from any disturbing wall and with horizontal position of the sensor. $UV_A$ radiation was measured from sunrise to sunset with an hour period, every day. The measurements were achieved every day, excluding rainy days, for 12 months (from first of January to the end of December 2008). For determination of $UV_A$ relation to $UV_B$ a radiometer made in Germany (Lybold Co) with a probe for $UV_B$ radiation, sensitive to a range of 320-280 nm was used.

## RESULTS

As an example, figure 1 shows the variation of the integrated hourly $UV_A$ radiation throughout a day with clear sky (8th July 2008). Radiation change during day is drastic. It is mostly due to sun rising above the horizon. About 60% of the integrated $UV_A$ in the day results between 11 to 14 o'clock. Figure 2 shows the variation of integrated daily $UV_A$ radiation intensity during different days in Jan 2008 to Jan 2009 with the lowest in Jan and the highest values in July. The highest daily integral $UV_A$ radiation appears in July with intensity value of $5.26\times10^5 Jm^{-2}$ while the lowest intensity value is in January with a value of $0.38\times10^5 Jm^{-2}$. It means that the

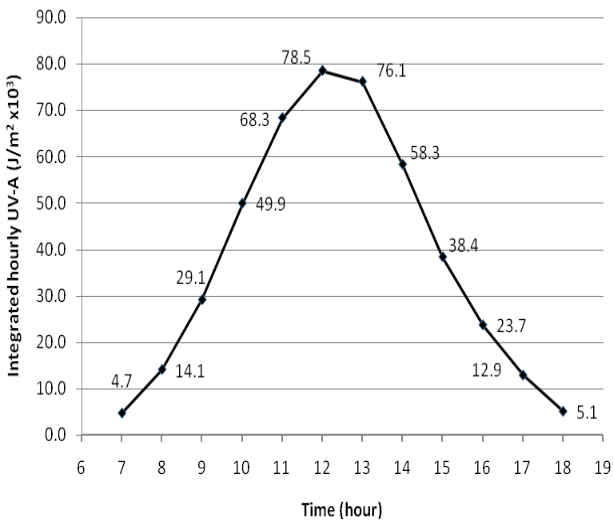


Figure 1. Integrated hourly $UV_A$ (320-390nm) during clear sky 8th July 2008.

amount of $UV_A$ radiation to the body is about 14 times higher in July than January.

The highest monthly integral $UV_A$ radiation appears in July with intensity value of $128.7\times10^5$ $Jm^{-2}$ while the lowest intensity value is in December with a value of $25.8\times10^5$ $Jm^{-2}$ (figure 3). This means that the amount of $UV_A$ radiation absorbed by human body in July is about 5 times higher than in December (figure 3). The intensity of $UV_B$ during one day was averagely determined 30 times lower than $UV_A$ intensity.

## DISCUSSION

Skin cancer cases are still increasing as a result of exposure to both $UV_B$ and $UV_A$ radiation both by acute overdosing and lifelong cumulative exposure, although the mechanistic links to sun exposure are still under investigation [11]. However, the potential health risks due to inadequate UV exposure are being re-evaluated. Vitamin D is synthesized in the skin after exposure to solar $UV_B$ radiation and because only limited types of food contain vitamin D, most people gain the majority of their vitamin D intake from sunlight exposure [11]. The time required to obtain the recommended UV dose for adequate vitamin $D_3$ synthesis in human skin (i.e. 1 Standard Vitamin D Dose (SDD)) depends on the solar elevation angle, as well as the surface and atmospheric conditions. A standard vitamin D dose (SDD) corresponds to the UV equivalent of an oral dose of about 1000 IU vitamin D [11]. For fixed typical atmospheric conditions, a significant variation with respect to season and latitude is evident [11]. Based on the results of Webb and his cooperators, for people with IV type skin (Mediterranean, Asian, who are moderately sensitive to $UV_B$ radiation) such as Yazd residents, 1SDD and 1 minimal erythmal dose (MED) are equal to 83.6 $jm^{-2}$ and 450 $jm^{-2}$ respectively [9]. The action spectrum for the production of vitamin $D_3$ shows some similarity to that for UV erythema. A person exposing hands, face and arms would now make sufficient vitamin $D_3$ with 1 SDD, and will suffer minimal erythema after 1 MED, which by definition is five times the SDD exposure under the reference conditions. This UV exposure of 1 SDD should be achieved approximately every other day [11]. Our results show that the integrated hourly $UV_A$ at 12 o'clock of 8th July 2008, for example, is 78.3 $kJm^{-2}$. Based on $UV_B$ /$UV_A$ ratio (figure 4), the $UV_B$ intensity at 12 o'clock is 25 times lower than the $UV_A$. Therefore, the integrated hourly $UV_B$ in this time is equal to 3.13 $kjm^{-2}$ and almost effective UVB is 1.56 $kJm^{-2}$ so the minimum required exposure time of $UV_B$ radiation for 1 SDD is about 22 minutes if is considered the top of head received about

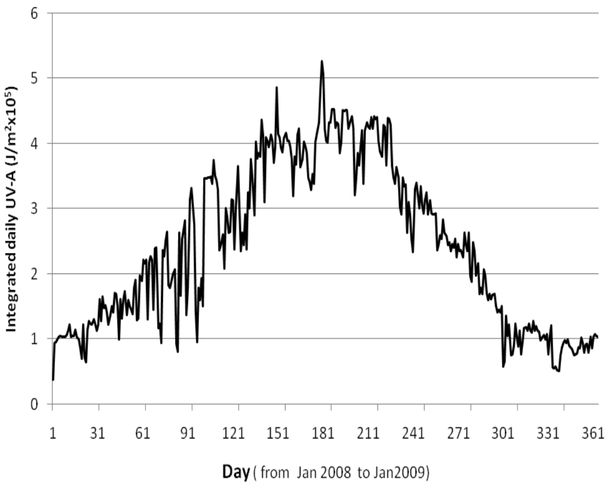


Figure 2. Integrated daily $UV_A$ Intensity from Jan 2008 to Jan 2009.

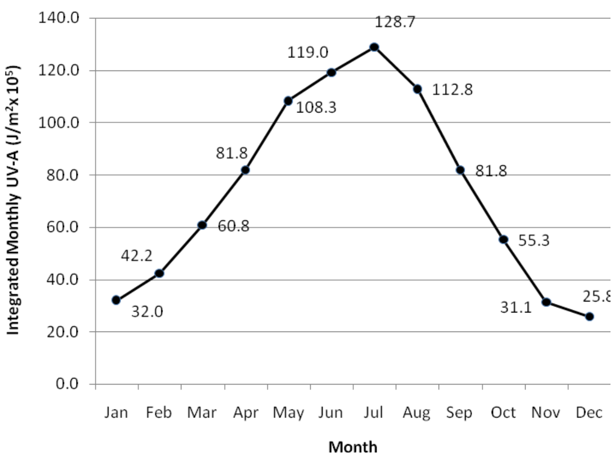


Figure 3. Integrated monthly $UV_A$ Intensity from Jan to end of December 2008.

seventh of the head and face. This time before and after noon, it will be up to 20 times increased and in the other months also be increased. For the $UV_B$ region and lower wavelengths, the radiant exposure in an 8 hour period must not exceed 30 j/m$^2$ for 270 nm that is the most effective $UV_B$ wavelength and 10kJm$^{-2}$ for 315 nm that is lowest effective $UV_B$ wavelength. For the wavelength range 320-400 nm, the total irradiance on the unprotected skin or eye must not exceed 10 Wm$^{-2}$ for periods exceeding 17 minutes. For radiant exposures of shorter durations it should not exceed 10kJm$^{-2}$ [12], so at noon times of July days the maximal allowable time exposure to skin or eye in Yazd is 7 minutes. Although $UV_A$ has much less diverse biological effects on human body than the $UV_B$, its amount is much higher than $UV_B$ (between 25 to 55 in 12th June 2008) and the biological effects are considerable. The $UV_B$/$UV_A$ ratios are variable during day and months. This ratio was reported by Tavakoli, between 6 to 21 [8]. An important factor in $UV_A$ radiation level is sun elevation. The higher the sun in the sky, the higher the UV radiation level will be. The increase in $UV_A$ radiation during a day is drastic (figure 1). These results are mostly due to less attenuation and scattering. As the sun rises above the horizon, the amount of absorption in the stratosphere and scattering in the troposphere is reduced [9]. It is also clear that more than 60% of the integrated UV in the day results between 11 to 14 o'clock (figure 1). These findings are consistent with the results reported by various authors [13, 9, 14]. Radiation levels vary with time of day and year (figures 2 and 3). The highest monthly integral UV radiation appears in July with intensity value of 128.7×10$^5$ Jm$^{-2}$ while the lowest intensity value is in December with a value of 25.8×10$^5$ Jm$^{-2}$ (figure3). So the amount of UV radiation to the body is about 5 times higher in July than in December. The same conclusion has been obtained by Daniela *et al.* for Italy [14] Frederick *et al.* for Chicago [6], Seckmeyer *et al.* for Europe [12], Heikkila *et al.* for Finland[13] and Gholami *et al.* for khorramabad city [15]. The annual integrated value of solar $UV_A$ radiation in Yazd is 879.6×10$^5$ Jm$^{-2}$ which is higher than Isfahan (579×10$^5$ Jm$^{-2}$) which is evident because Yazd city has desert dry climate [9].

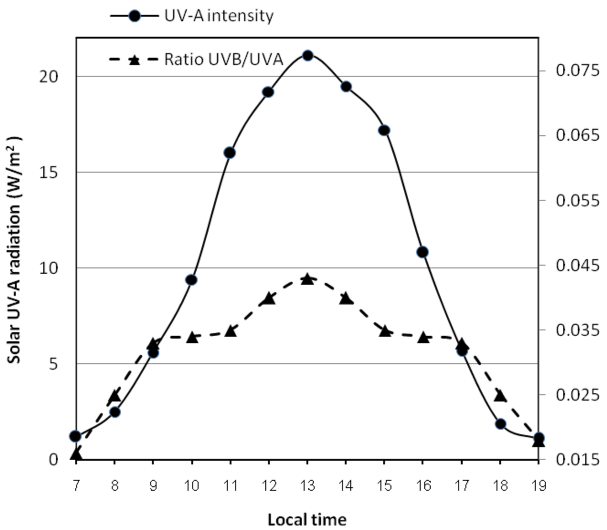


**Figure 4.** Diurnal variation of the solar $UV_A$ intensity in 12th June 2008 (solid line) a cloudless sky day, ratios of $UV_B$ to $UV_A$ irradiance (right axis). The ratio $UV_B$ /$UV_A$ become high in 13 o'clock (dashed line).

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## REFERENCES

1. Reichrath J (2006) the challenge resulting from positive and negative effects of sunlight: How much solar UV exposure is appropriate to balance between risks of vitamin D deficiency and skin cancer? *Progress Biophysics Molecular Biology, 92: 9–16*
2. Garland CF, Comstock GW, Garland FC (1989) Serum 25-hydroxyvitamin D and colon cancer: eight year prospective study. *Lancet, 2: 1176–1178.*
3. Gorham ED, Garland FC, Garland CF (1990) Sunlight and breast cancer incidence in the USSR. *Int J Epidemiol, 19: 614–622.*
4. Grant WB (2002) An estimate of premature cancer mortality in the U.S. due to inadequate doses of solar ultraviolet-B radiation. *Cancer, 94: 1867–1875.*

5. Vieth R (1999) Vitamin D supplementation, 25-hydroxyvitamin D concentrations, and safety. *Am J Clin Nutr, 69: 842–856.*
6. Frederick JE, Slusser JR, Bigelow DS (2000) Annual and interannual behavior of solar ultraviolet irradiance revealed by broadband measurements. *Photochem Photobiol, 72: 488-496.*
7. Sabziparvar AA (2007) A simple formula for estimating global solar radiation in central arid deserts of Iran. *Renewable energy, 33:1002-1010.*
8. Tavakoli MB and Shahi Z (2007) Solar ultraviolet radiation on the ground level of Isfahan. *Iran J Radiat Res, 5: 101-104.*
9. Webb AR and Engelsen O (2006) Calculated ultraviolet exposure levels for a healthy vitamin D status. *photochem photobio, 82: 1697–1703.*
10. Diffey BL (2002) Sources and measurement of ultraviolet radiation. *Methods, 28: 4–13.*
11. Suess M and Morison DB (1989) Nonionizing Radiation Protection, WHO Regional publication European Series No. 25
12. Seckmeyer G, Pissulla D, Glandorf M, Henrigues D, Johnsen B, Webb A (2008) Variability of UV irradiance in Europe. *Photochemistry and Photobiology 84: 172-179.*
13. Heikkila A, Tanskanen, Karha P, Hanhi K (2007) Adjusting timing of weathering test to account for seasonal variations in UV exposure. *Polymer Degrada Stabil, 92: 675-683.*
14. Daniela M, Giusepp RC, Siani AM, Palmiri S, Cappllan F (2000) Solar UV dose pattern in Italy. *Photochem Photobiol, 71: 681-690.*
15. Gholami M and Yoosefi L (2009) Solar ultraviolet-B radiation monitoring in Khorram Abad city in Iran. *Iran J Radiat Res, 7: 171-175.*