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Solar Ultraviolet Radiation for Psoriasis Treatment at Nakhon Pathom Province

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ABSTRACT

Psoriasis is one of the long-term (chronic) skin diseases that cause problems to the immune system. Artificial light source in ultraviolet radiation (UV) wavelength, especially in the UV-B band, is one of the standard treatments for psoriasis. Alternatively, natural sunlight is also used for the treatment, called heliotherapy. Consistent solar radiation at a particular location and time is key to successfully giving a safe and effective natural sunlight treatment. Therefore, in this study, solar ultraviolet radiation for psoriasis heliotherapy at a site in Thailand was first investigated to reveal its diurnal and seasonal variations and efficiency in the therapy. A spectroradiometer (DMc150) installed at Silpakorn University, Nakhon Pathom province (13.82 °N, 100.04 °E) was used to measure spectral irradiance and converted to anti-psoriasis irradiance. This irradiance was calculated to obtain the monthly average hourly anti-psoriasis ultraviolet radiation data (2016-2018). The result showed the diurnal and seasonal variations of the anti-psoriasis ultraviolet radiation. The values are relatively high from 10 a.m. to 2 p.m., especially between March and October, and relatively low from November to February. The maximum monthly average hourly values in the summer, rainy, and winter seasons were 77.6, 76.9, and 52.4 mJ/cm^2. In addition, an empirical model for estimating the anti-psoriasis ultraviolet radiation dose was first generated as a linear regression by using the UV index, which is a broader

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measurement. The difference between the data obtained from the model and the measurement is in good agreement with root mean square difference (RMSD) and mean bias difference (MBD) were 12.9% and 1.0%, respectively.

INTRODUCTION

Solar radiation can be divided into three bands, namely, ultraviolet radiation (UV, 280-400 nm), visible light (VIS, 400-700 nm), and near-infrared (NIR, 700-4000 nm). The UV itself can be separated depending on environmental and biological effects, called UV-A (320-400 nm), UV-B (280-320 nm), and UV-C (100-280 nm) [1]. Generally, UV-C cannot penetrate the atmosphere to the earth's surface as it is absorbed by atmospheric constitutions such as oxygen and ozone in the upper atmosphere [2]. Therefore, only UV-A and UV-B reach the earth's surface, and this radiation is only a small portion of the solar radiation [3-4].

UV ranges mainly cause DNA damage to lipid and protein oxidation, which makes clinically seen as tanning for a short-term effect of UV-A, aging, and skin cancers, the long-term during sunburn for the short-term effect of UV-B. Uneven skin color and cataracts are also negative consequences of chronic exposure to a full spectrum of solar radiation [5]. Despite the potential adverse effects of full-spectrum sun exposure, some narrow UV ranges (297-313 nm) can also enormously benefit the living, including the primary source of vitamin D synthesis through the skin. Vitamin D regulates immunity and calcium-phosphorus metabolism, enabling normal bone and muscle function mineralization. This does not only have positive effects on physical health but also on mood balance by providing a sense of security. The narrow-band UV-B's immunosuppressive or anti-inflammatory effects can improve or even clear the lesions of many inflammatory skin diseases. These include psoriasis, vitiligo, and the early stage of cutaneous T-cell lymphoma, making patients with inflammatory sun allergy conditions more tolerant of the sun [6].

UV Phototherapy using artificial light sources is one of the standard treatments for various skin conditions [7]. Phototherapy can also be applied safely to a wide-ranging group of patients. Typical hospital-based phototherapy cabinets contain a bunch of artificial lamps, either broadband (primary emission spectrum 280 – 360 nm, maximum at 320 nm) or narrow-band UV-B irradiation (primary emission spectrum 310-315 nm, maximum at 311 nm) following the well-established knowledge of the most anti-psoriasis effective UV ranges from 304 to 313 nm [8-9]. With national guidelines and standard dosimetry protocols, hospital-based phototherapy equipment provides precisely given safe and effective doses. In Thailand, the number of phototherapy centers and shortage of qualified phototherapy practitioners is limited, and financial concerns for at least twenty treatment sessions are required to see the outcomes [10]. Therefore, natural sunlight treatment is an alternative option. The patients do not need to

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access phototherapy centers often, reducing traveling and treatment costs and spending time. Phototherapy using natural sunlight has been clinically beneficial since the 1890s for a great diversity of health issues [11-13], including skin conditions [14-16]. There have been several clinical studies of successful supervised ambient sun-bathing alone, heliotherapy, however, only in limited regions, mostly from European countries, including the Canary Islands, Spain [17], Helsinki Finland, and Davos, Switzerland [18-23]. One of the most important heliotherapy issues in those countries is inconsistent UV radiation throughout the year. Daily variations in the most suitable spring and summer times for heliotherapy can also be challenging. The key determinants are successfully giving a safe and effective natural sunlight treatment, consistent solar radiation, accurate data of the incident solar spectrum, and dosimetry at a particular location and time. A study of solar UV radiation in Thailand showed that the country generally has sufficient UV radiation despite seasonal variations [24-26].

Apart from heliotherapy, there are several options for skin treatment, e.g., pill or topical therapy. The topical therapy is recommended for mild skin disease, and pill treatment may have side effects. Additionally, heliotherapy in Thailand is seemingly promising as a systemic treatment alternative where patients effortlessly receive sun-bathing treatments from their homes whenever they are convenient.

In Thailand, there is no report on UV data for psoriasis treatment. Therefore, this study aims to investigate the natural UV sunlight for the psoriasis treatment at a study site in Nakhon Pathom, the central region of Thailand, where the measurement is available. The diurnal and seasonal variations of the UV dose were analyzed using three years of data covering 1 January 2016 to 31 December 2018. In addition, as the lack of UV data for the psoriasis treatment, an empirical model to estimate the UV dose for psoriasis treatment from the UV index data, a broader measurement, was first developed and validated in this work.

MATERIALS AND METHODS

A spectroradiometer (Bentham Instrument, model DMc150) installed at Silpakorn University, Nakhon Pathom province (13.82 °N, 100.04 °E, 39.4 msl), was used to measure solar spectral irradiance covering the wavelength of 260-420 nm with the spectral resolution of 1 nm. The pictorial view of the instrument is presented in Figure 1.

The input optics is located on a rooftop of the science building of Silpakorn University. These input optics are connected to the double monochromator, the photomultiplier, and the detector. The electronic signals from the detector were transferred and displayed on a processing computer, and Benwin+ software was installed on the processing computer to control the system and for the data acquisition. This instrument was calibrated using a deuterium standard lamp once per month.

Figure 1 A pictorial view of the spectroradiometer installed at Nakhon Pathom a) input optics b) the monochromator and detector

To obtain the UV data responding to psoriasis treatment, the current signals recorded in the processing computer every ten minutes were converted to spectral irradiance using its sensitivity retrieved from the calibration. This spectral irradiance was converted to effective doses for the anti-psoriatic effect of ultraviolet radiation using the following expression.

$$\mathrm{Dose}_{\mathrm{ANTIPSOR}}(t_2, t_1) = \int_{t_1}^{t_2} \left(\int_{280\mathrm{nm}}^{400\mathrm{nm}} I_\lambda(t,\lambda)\, R_\lambda d\lambda \right) dt \quad (1)$$

where $\mathrm{Dose}_{\mathrm{ANTIPSOR}}$ is an anti-psoriasis-weighted dose in the period t_1 to t_2, $I_\lambda(t,\lambda)$ is spectral irradiance at time t and wavelength λ, and R_λ is anti-psoriasis action spectrum function.

The anti-psoriasis action spectra are defined as follows Krzyscin et al. [10]:

$$R_\lambda = \begin{cases} 0.6504 \times 10^{-0.6304(296-\lambda)} & \lambda < 296 \text{ nm} \\ 1.0000 \times 10^{-0.0467(300-\lambda)} & 296 \le \lambda < 300 \text{ nm} \\ 1.0000 \times 10^{-0.1067(\lambda-300)} & 300 \le \lambda < 304 \text{ nm} \\ 0.3743 \times 10^{-0.1571(\lambda-304)} & 304 \le \lambda < 313 \text{ nm} \\ 0.0144 \times 10^{0.08233(313-\lambda)} & 313 \le \lambda < 330 \text{ nm} \\ 0.0057 \times 10^{0.00937(330-\lambda)} & 330 \le \lambda < 400 \text{ nm} \end{cases} \quad (2)$$

An example of the spectral irradiance and anti-psoriasis action function is presented in Figure 2, which can be seen that the most effective spectral irradiance for anti-psoriasis is in the UV-B wavelength.

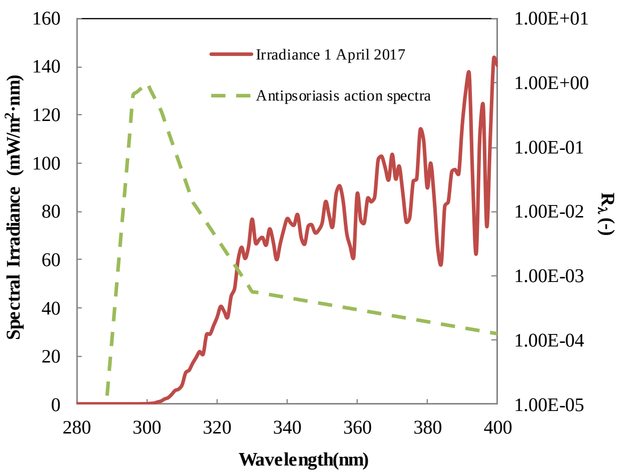

Figure 2 An example of spectral UV irradiance at a given time on 1 April 2017 at 8 a.m. and the anti-psoriasis action spectra ($R\lambda$)

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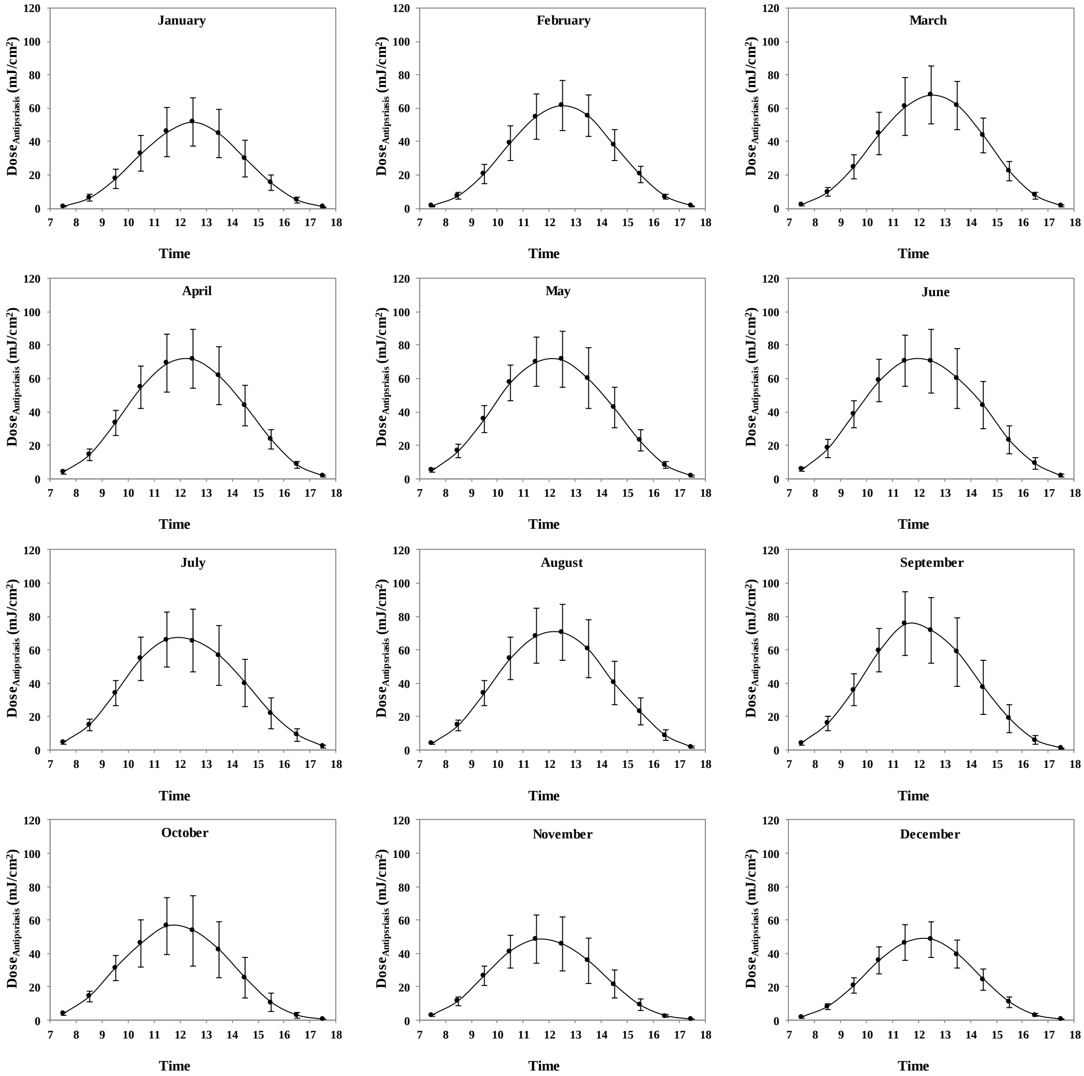

Figure 3 The diurnal variation of anti-psoriasis UV doses at Nakhon Pathom during 2016-2018

RESULTS AND DISCUSSION

In this study, the anti-psoriasis weighted doses retrieved from the spectroradiometer were used for three years, from 1 January 2016 to 31 December 2018. The dose within an hour was obtained from 7 a.m. to 6 p.m. At each month, the hourly anti-psoriasis UV doses at the same period were averaged to obtain monthly average hourly data and then plotted against the local time to investigate the diurnal variation. For the seasonal variation analysis, the monthly data were plotted against the month for each period.

The diurnal variation

The diurnal variation of the anti-psoriasis UV doses averaged during 2016-2018 are presented in Figure 3. The results indicate that the UV doses increase from the early morning to reach the maximum value during noontime and decrease until evening. This is mainly influenced by the position of the sun. In the morning and evening, the sun is relatively low, and thus path length of solar radiation in the atmosphere is relatively large compared to the noontime. As a result, the maximum anti-psoriasis UV doses are 77.6, 76.9, and 52.4 mJ/cm^2 in the summer (February-May), rainy (June-October), and winter (November-January) seasons, respectively.

Seasonal variation

The seasonal variation of the hourly anti-psoriasis UV dose averaged during 2016-2018 is shown in Figure 4 from 7 a.m. to 6 p.m. In addition, the threshold dose (i.e., 45 mJ/cm^2) used for the treatment of psoriasis proposed by Krzyscin et al. [10] was also drawn in the figures to present the potential of the solar UV dose for the psoriasis treatment in Thailand.

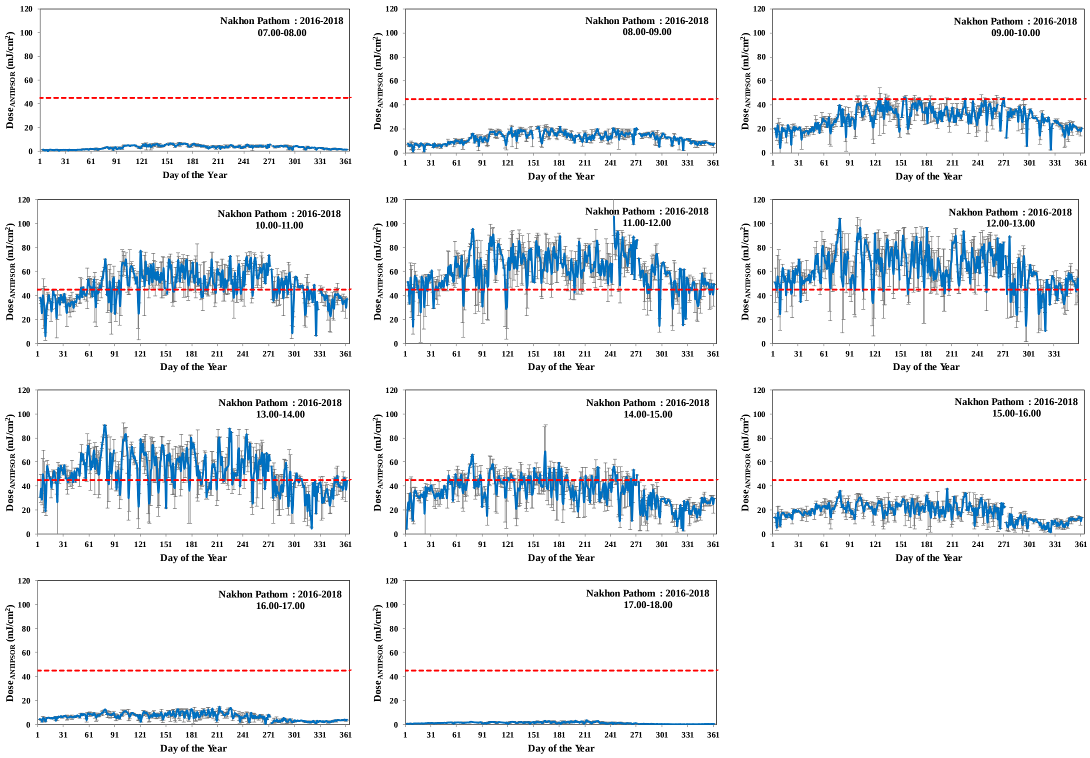

Figure 4 The seasonal variation of hourly anti-psoriasis UV doses from 7 a.m. to 6 p.m. at Nakhon Pathom (The red dash line indicates the threshold of UV dose for the treatment)

The results show seasonal variation in which the anti-psoriasis UV doses are relatively high from March to October and relatively low from November to February. This is mainly because of the position of the sun in the sky. The solar zenith angle is relatively high from March to October, resulting in small solar path length and solar extinction [25-27]. In addition, the figure represents that the potential periods to treat psoriasis using sunlight within 1 hour are from 10 a.m. - 2 p.m. from March to October when the value of UV dose is above the threshold value. However, patients can exposure the sun at other times for a longer period depending on the

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direction of their dermatologists. It is noted that the threshold used in this work was defined in Krzyscin et al. [10] for mid-latitude at San Diego (32.77°N, 117.20°W) and high-latitude at Belsk (51.83°N, 20.78°E), which may not perfectly suit for Thailand. This threshold then should be further justified for low-latitude as Thailand. Moreover, excessive exposure is harmful. Therefore, the optimal exposure time for psoriasis treatment should not exceed the time leading to hazardous health [28].

The empirical model

According to the limitation of the ground-based spectroradiometer, they can be used to measure the UV doses to treat psoriasis. In contrast, UV index (UVI) has been measured broadly. Therefore, a simple model used to estimate the anti-psoriasis UV doses is needed. In this study, an empirical model was developed and validated. UVI was calculated following the method in [29] using the DMc150 spectroradiometer at the same site. Then hourly anti-psoriasis UV dose was plotted against the UV index using 2016 and 2017. The graph between the anti-psoriasis UV dose and the UV index is shown in Figure 5, and the linear least square expression can be written as follows:

$$\mathrm{Dose_{ANTIPSOR}} = 6.5713\mathrm{UVI} \qquad (3)$$

$\mathrm{Dose_{ANTIPSOR}}$ is the anti-psoriasis UV dose (mJ/cm^2), and UVI is the UV index (unitless).

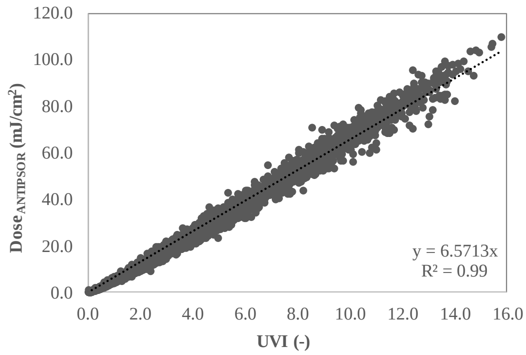

Figure 5 The relationship between anti-psoriasis UV dose ($\mathrm{Dose_{Psoriasis}}$) and UV index (UVI) in 2016 and 2017

For the model validation, the anti-psoriasis UV doses calculated from the proposed model were compared with those measured from the spectroradiometer in 2018. The validation result presented in Figure 6 shows that the model can estimate the anti-psoriasis reasonably compared to a method in Krzyscin et al. [30] that used the satellite data approach.

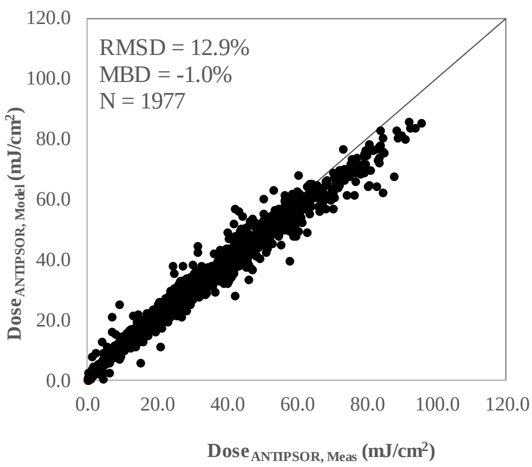

Figure 6 The comparison between the anti-psoriasis UV dose from the model ($\mathrm{Dose_{ANTIPSOR,\ Model}}$) and the measurement ($\mathrm{Dose_{ANTIPSOR,\ Meas}}$)

CONCLUSION

The anti-psoriasis effective UV dose at Nakhon Pathom was investigated. The results show that the UV dose was diurnal and seasonal variations and relatively high from 10 a.m. to 2 p.m., especially between March and October. Therefore, this period is likely to have the potential for treating psoriasis and several inflammatory skin conditions. However, the UV doses in other regions may differ depending on the location, geography, and atmospheric conditions. Therefore, the UV dose in other regions of Thailand should be further investigated for the extended development of a national heliotherapy protocol for psoriasis in Thailand. In Thailand, Heliotherapy using a sustainable abundance of solar energy would transform medical practice on light-based treatments, which is considered enormously beneficial but time-consuming and required commitment into perhaps one of the supervised primary aids at home.

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