# MODELING ULTRAVIOLET RADIATION FOR BURGAS MUNICIPALITY

**Zdravka Nikolaeva, Todor Mihalev**
*University "Prof. Dr. Asen Zlatarov" 8010 Burgas, Bulgaria*
z.v.burieva@gmail.com

## ABSTRACT

For calculation of the biologically active ultraviolet radiation for the Municipality of Burgas has been used the formula proposed by Carvalho, who, after many years of calculations, established that a linear connection exists between the UV Index and the total solar radiation.

For calculation of the UV Index by months, for the 8 am to 5 pm time period the method of multiple linear regression is used. For the total hourly solar radiation is taken the average value from four monitoring stations (AIS Dolno Ezerovo, AIS Meden Rudnik, DOAS OPSIS and Mobile station). In the same manner is determined also the total global insulation by hours for a given month of the year.

The coefficient values of determination are high enough to assume that the models are characterized by good quality and reliability, and the values of the F-statistics support their significance.

***Key words:*** *solar radiation, ultraviolet radiation, UV Index, the method of multiple linear regression, coefficient of determination, F – statistics.*

## INTRODUCTION

The UV Index measures the level of solar UV radiation, which reaches the Earth's surface [6]. The impact of the UV radiation on the biological systems is well known (Caldwell et. al., [4]). The concerns regarding this matter are caused mainly by long-term monitoring of the total ozone contents in the atmosphere and its reduction during the last decades [7,8].

In the last couple of years multiple activities and campaigns were carried out aimed at informing the population regarding UV radiation and the related health problems. An example can be given with the recommendation (UNEP, ICNIRP, WHO and WMO [10]) that the solar UV Index (*UVI*) is used as simplified measure of the level of UV radiation, reaching the Earth's surface and being relevant for possible harms to the human skin. One *UVI* is equivalent to 25 $mW/m^2$ erythemal-effective UV radiation, in line with WMO and references of WHO [11]).

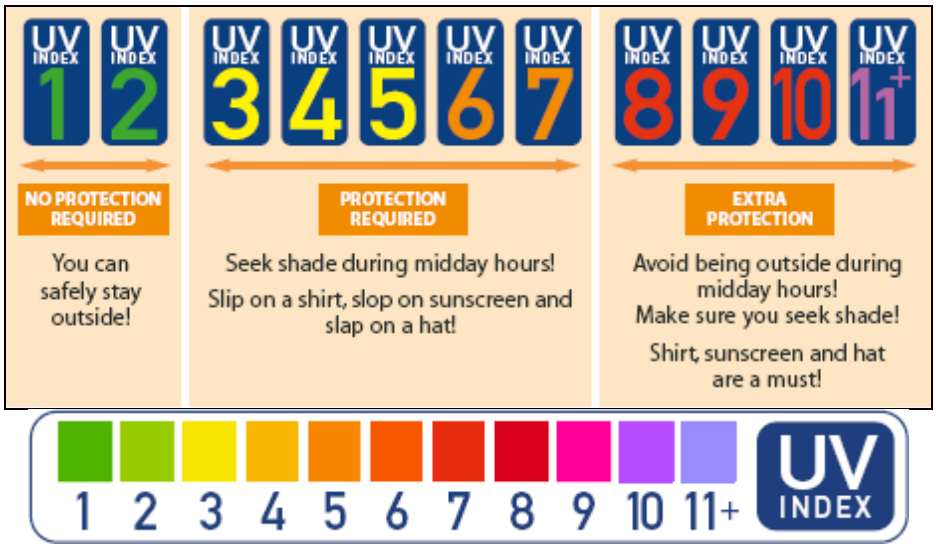



**Figure 1. Presentation of the UV Index according to the generally accepted international standards**

Figure 1 illustrates international methods for presentation of the UV Index and the required measures, which need to be undertaken for protection from the Sun, in conformity with the accepted by the US EPA classifications and colors.

The significance of the issue for studying and estimating the detrimental effects on the human beings and their health leads to the necessity of accurate and prompt measurements of the UV radiation as well as forecasting the UV Index by measurements or based on mathematical models.

**RESEARCH METHODS**

For the calculation of the biologically active UV radiation a formula is used, provided by Carvalho [5], who, as a result of many years of calculations established, that a linear connection exists between the UV Index *(UVI)* and the total solar radiation:

$$UVI = b + a\left(\frac{G}{G_o}.UVI_o\right), \quad (1)$$

where: $G$ – total radiation over a unit of area, for a unit of time, $W/m^2$; $G_o$ – total extraterrestrial solar radiation (total global insolation), $W/m^2$; $UVI_o$ – UV Index when the sky is clear of clouds; $a$, $b$ - regression coefficients.

For calculation of the UV Index by months for the time period from 8 am till 5 pm is used the method of multiple linear regression of the following type:

$$UVI = b + a_1.t + a_2.t^2 + a_3.t^3 + a_4.t^4 + a_5.t^5 + a_6.t^6 + a_7.t^7 + a_8.t^8 + a_9.t^9, \quad (2)$$

where: $UVI$ – UV Index; $b$, $a_1$, $a_2$, ...., $a_9$ – regression coefficients; $t$ – time period, $h$ (*hour. hundreds*).

For assessing the quality of the regression models (2) the determination coefficient $R^2$ is used, which determines the level of the linear relation between the included within the model regressive values and the forecasted value of the initial quantity [1-3]. An obligatory condition in this case is to check the significance of $R^2$, for the purpose of which the Fisher criterion is used

$$F = \frac{R^2}{\left(1-R^2\right)}.\frac{\left(N_1-k\right)}{\left(k-1\right)}, \quad (3)$$

where: k – the number of the model's parameters assessed; $N_1$ – the size of the extract of experimental data.

Fisher criterion has a degrees of freedom $v_1 = k-1$ и $v_2 = N_1 - k$.

If $F > F(\alpha, v_1, v_2) = F_{crit}$, the value of $R^2$ is significant and can be used for assessment of the model adequacy. The higher the calculated value of $R^2$ is, the more reliable the derived regression model is at level of significance $\alpha$.

The article contains UV radiation modeling for Burgas Municipality by months for 2012.

**RESULTS AND DISCUSSION**

For calculation of the UV Index for Burgas Municipality the Carvalho equation is used (1). With regard to the total hourly solar radiation, the average value of four monitoring stations is taken into consideration (AIS Dolno Ezerovo, AIS Meden Rudnik, DOAS OPSIS and Mobile station) within Burgas Municipality. In the same manner, by hours for a given month of the year, also the total global insulation $G_o$ is determined. For this purpose data for measured values of the total solar radiation from PVGIS-CMSAF [9] is used for the period 2001-2012. The measured values cover the period 2001-2012 and the time period from 4.87 to 19.87 *h* at an interval of 0.25 *h* (15 minutes).

It can be assumed that the derived models for different months of the year are valid for Burgas Municipality, as the differences between the measured values of the total hourly solar radiation and

the total global insulation for the different stations are too close to each other, i.e. too close also to their average values.

Figure 2 illustrates the relation of UVI / $UVI_o$ with G / $G_o$ for Burgas Municipality, determined by the Carvalho formula (1).

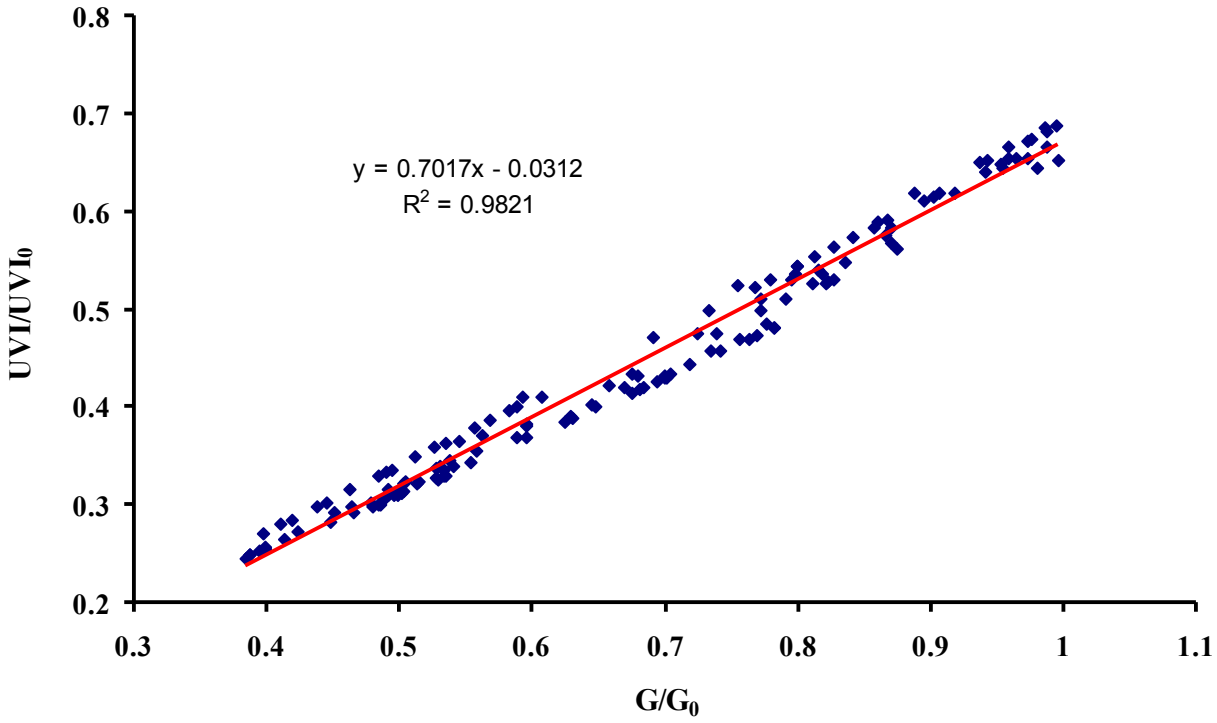



**Figure 2. Relation of UVI / $UVI_o$ with G / $G_o$ according to Carvalho formula**

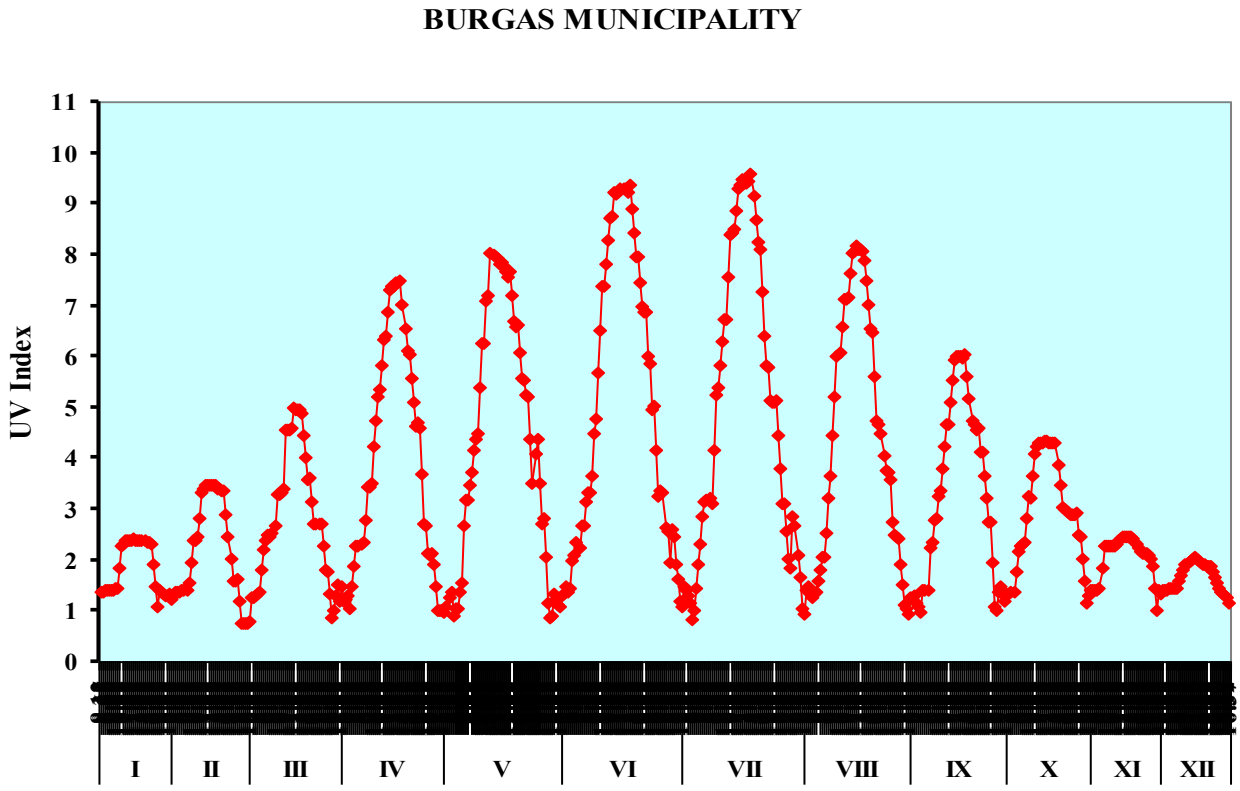
**Table 1. Statistical parameters of the model quality (2) for Burgas Municipality by months**

| Month | *F* | $R^2$ |
|---|---|---|
| ***January*** | 117.42 | **0.9635** |
| ***February*** | 401.42 | **0.9866** |
| ***March*** | 249.77 | **0.9770** |
| ***April*** | 885.96 | **0.9928** |
| ***May*** | 567.62 | **0.9874** |
| ***June*** | 1255.46 | **0.9942** |
| ***July*** | 718.27 | **0.9899** |
| ***August*** | 1243.00 | **0.9947** |
| ***September*** | 327.02 | **0.9813** |
| ***October*** | 380.95 | **0.9856** |
| ***November*** | 220.56 | **0.9783** |
| ***December*** | 220.56 | **0.9783** |

Figure 2 shows, that the determination coefficient $R^2$ has very close value to 1 ($R^2$= 0.9821), which shows, that (1) can be used for calculation of the UV Index for Burgas Municipality.

Table 1 provides the calculated values for F-criterion and the determination coefficient of the model (2) for Burgas Municipality by months.

We can see from table 1 that the determination coefficient values are high enough to assume, that the models are characterized by good quality and reliability, while the F-criterion values confirm their significance.




**Фигура 3.** Ултравиолетов индекс за Община Бургас по месеци

Figure 3 illustrates the graphically calculated by formula (2) values of the UV Index by months from 8 am to 5 pm, which is approximately the lowest average monthly duration of the solar shining. Naturally, the largest values are observed during the months of June and July, when the total solar radiation is most intense.

The method can be used for investigation of the relation between the UV Index and the total solar radiation for Burgas Municipality.

## CONCLUSIONS

1. It can be assumed that the derived models for the different months of the year are valid for the Municipality of Burgas, as the differences between the measured values of the total hourly solar radiation and the total global insulation for the different stations are too close to each other, i.e. too close to their average values as well.

2. The conducted research shows us, that the determination coefficient $R^2$ has a very close value to 1 ($R^2$= 0.9821), which indicates, that the Carvalho formula can be used for calculation of the UV Index for Burgas Municipality.

3. The UV Index is calculated by months for the time period from 8 am to 5 pm by the extended multiple linear regression model. The determination coefficient values are high enough to assume, that the models are characterized by good quality and reliability, and the F-criterion values support their significance.

4. The method can be used for studying the relation between the UV Index and the total solar radiation for Burgas Municipality.

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