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The ultraviolet radiationand the minimal erythemal dose in Maracaibo-Venezuela

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ABSTRACT

The aim of this paper is to perform a statistical descriptive analysis of ultraviolet radiation and theenergy for Erythemal skineffectsin the city of Maracaibo during the period from June 2012 to July 2014. The data was recorded by the meteorological station Meteo Urbe - 1, located at the Universidad Dr. Rafael Belloso Chacin, Maracaibo, Venezuela. The analysis is performed through the Ultraviolet Index (UVI) observed between 6:00 am. and 6:00 pm. The UVI values were located in ranges as high, very high and extreme by the standards set by the World Health Organization (WHO). The energy calculated was over the energy required to produce erythema according to the type of skin for the Minimal Erythemal Dose (MED). Recommendations to be taken by citizens to minimize the effect of this radiation on humans, particularly in children and the elderly persons are made. Also, it was detected an inter-annual increase in the UVI of the area.

KEYWORDS

Ultraviolet radiation;
UVI;
Ultraviolet index;
Ambient;
Maracaibo.

INTRODUCTION

Ultraviolet radiation affects one way or another to all living beings that are exposed to the Sun's rays and also from many non-natural sources used in the industrial sector. Low doses of UV radiation are beneficial to human beings and essential for the production of vitamin D. This radiation is also used to treat various diseases, such as anemia, eczema and psoriasis. Treatments must be carried out under medical supervision and the approval of their advantages over the dangers of exposure to UV radiation is a matter of judgment of the physician. Also UV-C (254 nm) radiation has one important action as agricultural bactericide and on the other hand, it could produce a beneficial effect in tissues in response to low dose or sub lethal according to the concept of "Hormesis"[1]. Another example of the beneficial use of the UV radiation is in the control of microorganisms in food since it is usually used for pasteurization. On the other hand, a non-thermal technology has been applied in food processing to deactivate some types of microorganisms using the radiation UV-

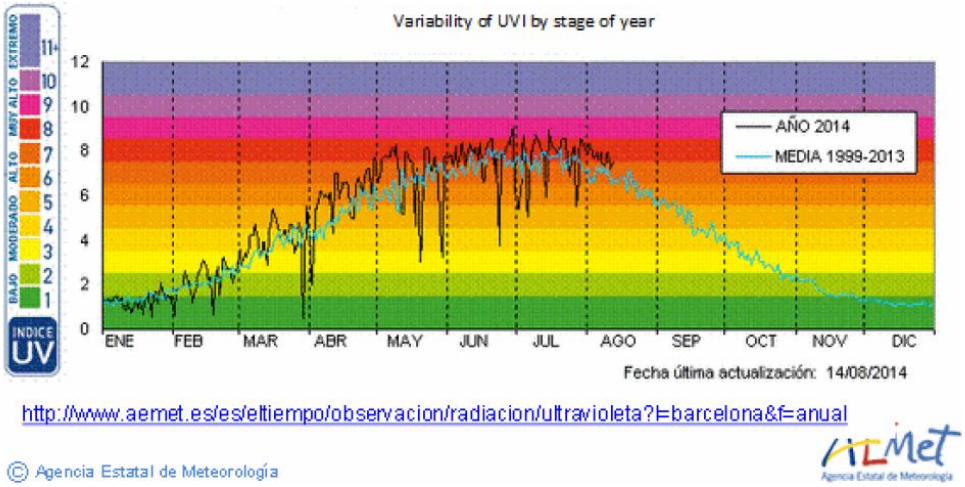

Figure 1 : Variability of UVI by stage of year Barcelona – Spain[5].

C[2].

From the beginning of the 1970's a pronounced increasein the incidence of skin cancer in fair-skinned populations was observed, closely related to the personal habits of exposure to the Sun and its ultraviolet (UV) component, as well as the social perception that tanning is desirable and healthy[3]. Educational programs are urgently needed to learn more about the harmful effects of UV radiation and to drive changes in lifestyles that restrain the increase of skin cancer. UV radiation is also associated with the presence or increase of other types of skin diseases, such as melasma, actinic keratosis and photosensitive diseases like systemic lupus erythematosus, actinic prurigo, and endemic pemphigus[4]. Life as we know would not exist without the ozone layer in the stratosphere to protect us from excessive amounts of UV-B radiation. Living things and their cells are protected from excessive amounts of UV radiation by the chemical called ozone. The layer of ozone in the upper atmosphere absorbs UV radiation and prevents most of it from reaching the Earth.

The Sun's rays identified as ultraviolet (UV) rays are not visible to the human eye and are classified on the basis of its wave length, measured in nanometers (nm), unit of length which corresponds to a billionth of a meter. 'Nano' means one billionth. More short is the wave, more penetrating is the energy of the Sun's rays. The spectrum of non-ionizing radiation comprises all the radiation fields from the UV to the field DC. The optical portion of non-ionizing radiation can be subdivided within the ranges of different wavelengths: They are classified into three types:

1. The UV – A: majority of these rays reach the Earth's surface and comprise less harmful solar radiation. This wavelength is between 320 nm and 400 nm.

2. The UV – B: are largely absorbed by the ozone layer, however, the medium wave rays (between 280 nm and 320 nm) reach Earth's surface. UV-B causes damage at molecular level to the fundamental building block of life— deoxyribonucleic acid (DNA).

3. The UV – C: with wavelengths between 200 nm and 280 nm are absorbed by the ozone layer before reaching Earth's surface. These are potentially dangerous for humans.

Solar UV radiation is manifested in two ways: direct, when it is not altered or modified in its path towards the Earth, and diffused, when it is modified before reachingEarth´s surface. Among others, the causes of its change may be due to:

- TheUVI depends on the solar angle of Zenith whichdependson the stage or season of year. It can be clearly observed in Figure 1.
- The time of the daycan also cause variation on the UVI, as can be seen on Figure 2.
- Wavelength of UV radiation.
- Thickness of ozone layer.
- The amount of UV rays that the ozone layer absorbs differs depending on natural events or the stage of year. Moreover, the ozone layer is thinner than it used to be due to ozone reducing chemicals used in industry and consumer products. These chemicals are being phased out, but the ozone layer is not predicted to heal to

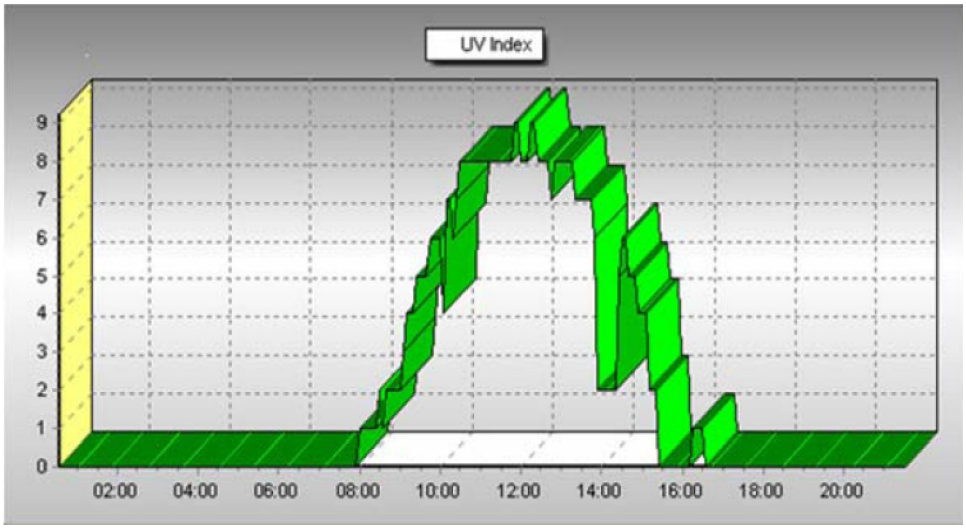

Figure 2 : Index of ultraviolet radiation on a typical day, this chart corresponds to Maracaibo, Venezuela, 22-09-2012 (24 hrs).

pre-1980 levels until mid– to late- century[6].

- Cover by the absorption, scattering and reflection of clouds.
- The altitude above sea level.
- Gas dispersion and absorption on the air, including gaseous pollution.
- The reflective properties of theEarth´s surface.

THE ULTRAVIOLET INDEX

To better handle the concept of ultraviolet radiation the UV index (UVI) has been defined; it describes the level of intensity of solar radiation to which the Earth's surface is exposed. Also serves as an indicator of the potential harm that can occur in the skin in direct relation to the exposure levels. From there, in almost all developed countries (TABLE 1), this index is now being reported with the weather forecast by the media or via the internet[7]. UV radiation penetrates deep into the skin and acts according to its wavelength, interacting with the cells. The short wavelength ultraviolet radiation (UV-B 280-320 nm) is mostly absorbed in the epidermis and its predominant effects occur in the epidermal cells (e.g.the keratinocytes); while long wavelengthultraviolet radiation (UV-A 320-400 nm) penetrates more deeply and can therefore interact with the epidermal keratinocytes and dermal fibroblasts blood vessels[8].

The UVI was developed on the basis of various studies and independent investigations in several countries to standardize their definitions. It is published as a recommendation of the World Health Organization (WHO), the World Meteorological Organization (WMO), the United *Nations Environment Programme* (UNEP)and the *International Commission* on *Non-Ionizing Radiation* Protection (ICNIRP). In mathematical terms, it is equivalent to 40 times the average effective irradiance (W/m^2). A(1) UVI is equivalent to an irradiance of $1/40 = 0.025\ W/m^2$ for a 5 to 10 minutes interval.

The WHO looks to establish an index (Figure 3) in order to have a simple value to raise awareness about the negative effects that solar UV radiation has on health and to alert citizens about the importance of protecting from such radiation.

There are important works on the UVI measurements and its effects. Values obtained by Sanclemente et al[7] in Medellin - Colombia were considered as "very high", and in villages such as El Retiro were considered to be "high", "very high" and "extreme" starting at 09:00 am. Solórzanoet al[4] reported thatcolombian population is exposed to extreme UVradiation all year round. Colombia, located at the northwest of South America, between latitudes 12° N and 4° S, has extreme levels of UVR during 365 days a year. The UV levels of the 12 largest colombian cities were measured. The UV Index normally reaches higher than 9 points: the very high-extreme category according to the internationally established UV Index scale.

MINIMAL ERYTHEMAL DOSE

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TABLE 1 : UVI values for some areas of the world.[9]

Country (City)	.	J	F	M	A	M	J	J	A	S	O	N	D
Argentine (Buenos Aires)	35°S	9	9	7	4	3	2	2	4	5	7	9	10
Australia (Darwin)	13°S	12	13	12	10	8	8	8	10	11	13	12	12
Australia (Melbourne)	37°S	8	8	6	4	2	2	2	3	5	6	8	9
Australia (Sydney)	34°S	9	9	7	5	3	2	3	4	6	7	9	10
Brazil (Rio de Janeiro)	23°S	12	11	9	7	5	5	5	7	9	10	12	12
Canada (Vancouver)	49°N	1	1	3	4	6	7	7	6	4	2	1	1
Cuba (Havana)	23°N	6	8	9	10	10	11	12	11	10	8	6	5
Falkland-Islands (Port Stanley)	58°S	5	4	2	1	0	0	0	1	2	3	5	5
France (Paris)	49°N	1	1	3	4	6	7	7	6	4	2	1	0
Germany (Berlin)	52°N	1	1	2	4	5	7	7	5	3	1	1	0
Greece (Iraklion)	35°N	3	4	5	8	9	9	10	9	7	4	3	2
Japan (TokYo)	36°N	2	4	5	8	9	9	10	9	7	4	2	2
Kenya (Nairobi)	1°S	12	13	13	12	11	10	11	11	12	12	12	11
Madagascar (Tananarive)	19°S	12	12	11	9	7	6	6	8	11	11	12	12
Mozambique (Maputo)	26°S	11	11	9	7	5	4	4	6	8	10	11	11
Mongolia (Ulan Bator)	48°N	1	2	3	5	6	7	8	6	4	2	1	1
New Zealand (Wellington)	42°S	7	7	5	3	1	1	1	2	4	6	7	8
Panama (Panama)	9°N	9	11	12	12	11	11	12	12	12	11	9	9
Russia (St Petersburg)	60°N	0	0	1	3	4	5	5	4	2	1	0	0
Singapore (Singapore)	1°N	11	12	13	13	11	11	11	11	12	12	11	10
South Africa (Cape Town)	34°S	9	9	7	5	3	2	3	4	6	7	9	10
Spain (Palma de Mallorca)	39°N	2	3	4	6	8	9	9	8	6	4	2	1
Sri Lanka (Colombo)	13°N	8	10	12	12	11	11	12	12	12	10	8	8
Thailand (Bangkok)	14°N	8	10	12	12	11	12	12	12	11	10	8	8
USA (Los Angeles)	34°N	3	4	6	8	9	10	10	9	7	5	3	2
USA (New York)	41°N	2	3	4	6	7	8	9	8	6	3	2	1
Vietnam (Hanoi)	21°N	6	8	10	11	11	11	12	12	10	8	6	6

different types of skin. It is calculated from the measurement of the UV index or its equivalent in MED/ hour, in other words, the effective dose that causes a minimal erythema.

According to Rivas[10], the minimal erythemal dose (MED) is the minimum amount of UV that produces redness 24 h after exposure. Skin type III corresponds to skin that burns and tans moderately and uniformly (MED, 0.30 0.50 kJ/m^2), and skin type IV corresponds to light brown skin that burns minimally and tans moderately and easily (MED, 0.40 0.60 kJ/m^2). Lighter skin as I and II types, transmit more radiation and consequently, the dose and the time that is necessary to induce erythema is less than for darker skin[10].

A MED is also defined as the unit of radiant energy UV-B necessary to produce a barely perceptible erythema in type II skin (light skin) and is equivalent to 210 Joules per square meter (J/m^2). 1 MED/hour is defined as the ratio (irradiance itself)of theUV-B radiation incident on any surface in one hour.[11]

TABLES 2 and 3 present the equivalence in MED/ hr for 15 UV index values and the equivalence of MED units of radiant energy for each type of skin in Joules per square meter (J/m^2). 1 MED = 210 J/m^2. (for light skin)[11].

Also it is important the database and information

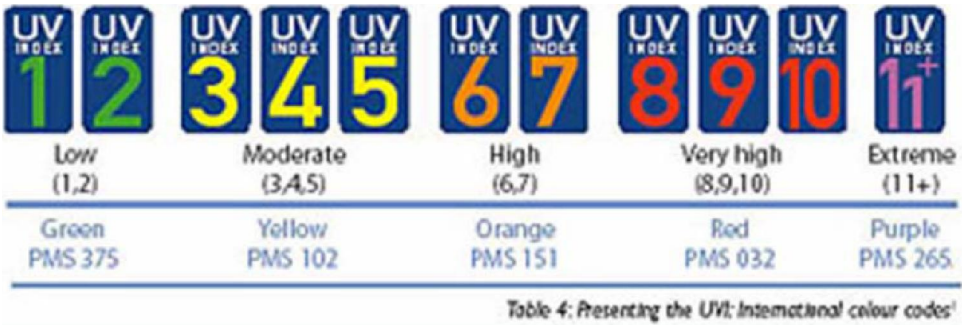

Figure 3 : The global solar ultraviolet (UVI) index. It goes from low (green) to extreme (purple). Taken from WHO World Health Organization (WHO).

TABLE 2 : Equivalence in MED/hr for 15 UV index values.[11]

UVI	MED/hr
0	0
1	0.43
2	0.86
3	1.29
4	1.72
5	2.14
6	2.57
7	3
8	3.43
9	3.86
10	4.29
11	4.72
12	5.15
13	5.57
14	6
15	6.43

that could be obtained at WHO at: http://www.who.int/uv/publications/en/

RESULTS

In our casethe data was registered (every five minutes)by the station Meteo URBE-1 located relatively near the Equator (Figure 4) at Maracaibo – Venezuela; Latitude10° 41' 39" N, Longitude 71° 38' 1" W, Altitude: 30 m. Data was collected since 2012, when the station started to operate. In the absence of a weather station that registered ultraviolet radiation in the city, the university installed Meteo URBE - 1. The climate in Venezuela is characterized by two seasons only: one rainy, badly called winter, and other called summer for having very little rainfall.

The results are analyzed, as mentioned, with reference to the standards set by the World Health Organization.

TABLE 3 : The energy required to produce erythema according to the type of skin.[11]

The energy required to produce erythema according to the type of skin MED		
Skin type	**MED**	**J/m²**
• Skin very clear (extra sensitive)	0.80	168.0
• Skin clear (sensitive)	1.00	210.0
• light brown skin (normal)	1.25	262.5
• Dark brown skin (normal)	1.56	328.1
• Dark skin (insensitive)	1.95	410.2
• Very dark skin (insensitive)	2.44	512.7

DISCUSSION

A typical daily behavior of the UVI for the city of Maracaibo is shown in Figure 5. Evidently, the UVI value vary with the sun position, beginning approximately at 06:00 am, it increases until noon and then decreases until the 06:00 pm. In this particular day it is observed that the maximum value was 12, corresponding for this particular day, to an extreme value according to the WHO. From TABLE 2 it corresponds to 5.15 MED/hour (an exposure of 1081.5 J/m^2 per hour). From TABLE 3for light brown skin (most of the Maracaibo population)the MED is 1.25, meaning an exposure four times the energy required to produce erythema.

The annual distributions for 2012, 2013 and 2014 are shown in Figures 6a, 6b and 6c, respectively.

In 2012 the maximum values were between 7 (high) and 10 (very high). Lower values correspond to rainy periods. In average it was 9, corresponding to a very high value. With 3.86 MED/hour meaning almost 3 times the energy required to produce erythema. In 2013 the

Figure 4 : Location of Maracaibo-Venezuela.

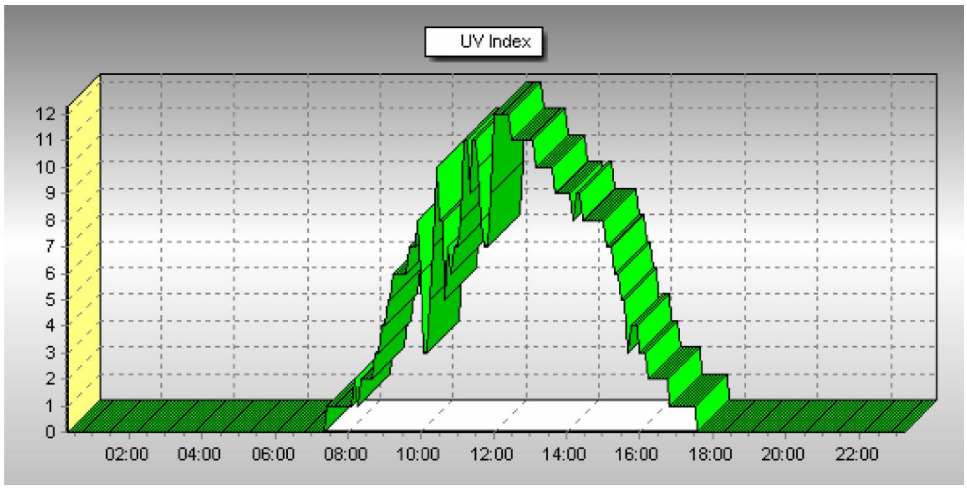

Figure 5 : One day ultraviolet radiation index (UVI) in Maracaibo, 08/02/2013. Latitude 10° 41' 39" N, Longitude 71° 38' 1" W, Altitude: 30 m.

maximum values oscillate between 9 and 13 and the average was 11 equivalent to 4.72 MED/hour higher than the obtained in 2012. For 2013 year the maximum UVI values show a very high and extreme values corresponding to figure 3.

In the three first quarters of 2014 the maximum values of UVI registered were in between 12 and 14, giving an extreme condition and 5.57 MED/hour. 4.5 times higher the maximum allowed for light brown skin (normal).

One of the most remarkable facts, as observed in Figure 7, is the increase of the UVIdaily maximum between 2012 and 2014. On average, the daily maximum values registered, were greater than 8 UVIfor 2012, 10 for 2013 and 12 for 2014. The reason of such inter annual increase is not yet understood. Nevertheless therainfall in those years is in similar proportion to the UVI values obtained for these periods. For the year 2014 from the month of January there have been very few rains and authorities have declared a "state of emergency" and have established a program of rationing for water supply.

This fact arouses an investigation as this phenomenon is functioning: (a) there is some alteration in the ozone layer of the area which increases ultra-violet radiation and therefore heats the area of such magnitude that it prevents or blocks the condensation of clouds? Or there is some change in the inter tropical convergence of the Caribbean area, as a result of climate change, which has altered the cloud cover in the area and as a result of it, has occurred this year an increase of ultraviolet radiation that reaches the Earth layer caus-

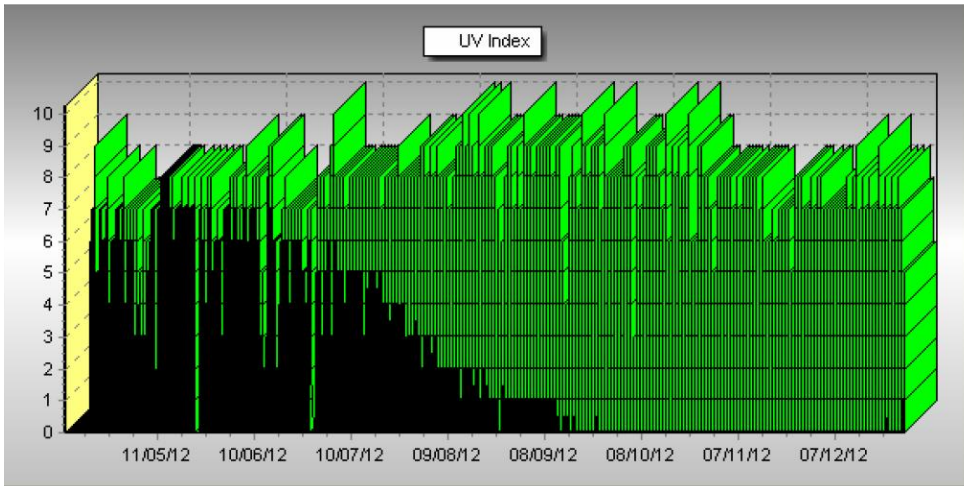

Figure 6(a) : Ultraviolet radiation index (UVI) in Maracaibo, January – December 2012.

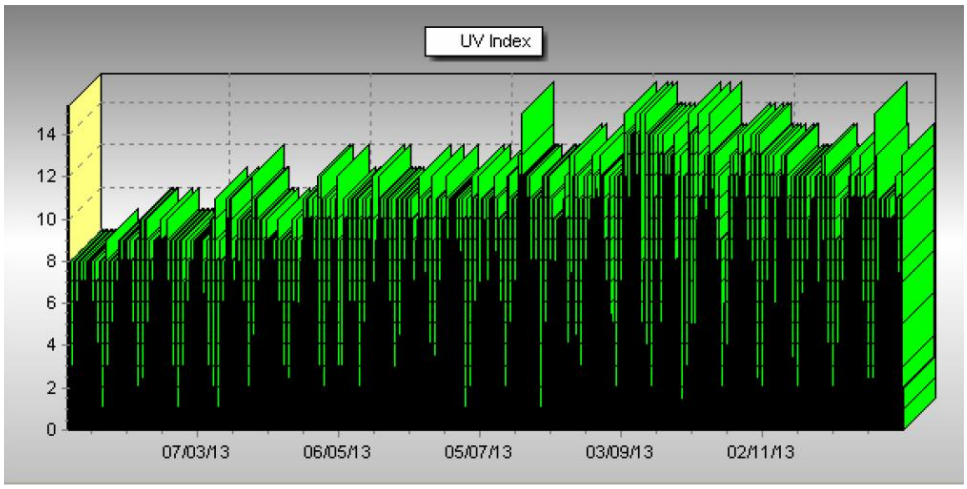

Figure 6(b) : Ultraviolet radiation index (UVI) in Maracaibo, January – December 2013.

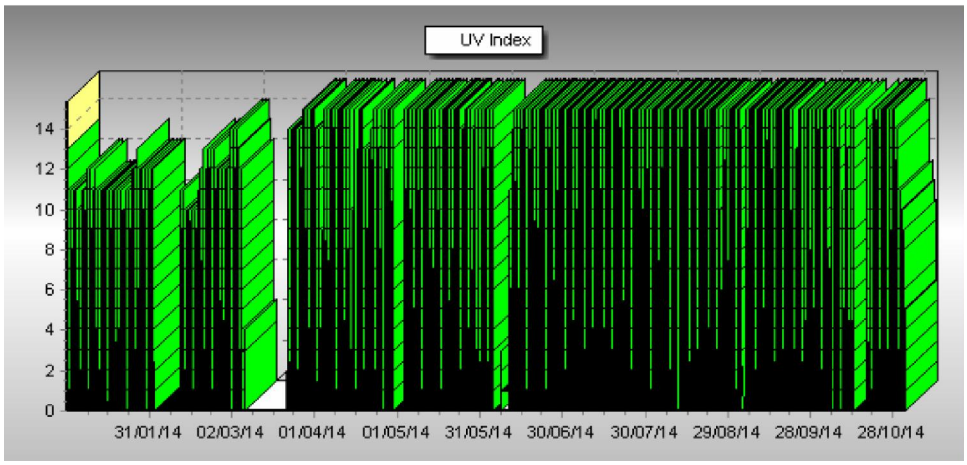

Figure 6(c) : Ultraviolet radiation index (UVI) in Maracaibo, January – December 2014.

ing overheating and therefore a decrease of the rainfall on the area? These two hypotheses require further study and research.

Also, It is clear the influence of the stage of the year for countries with four seasons, if compare the Figure No.1 Variability of UVI by stage of year Barcelona – Spain with 4 season clearly defined the up and down of the UVI for each seasonin contrast with the city of

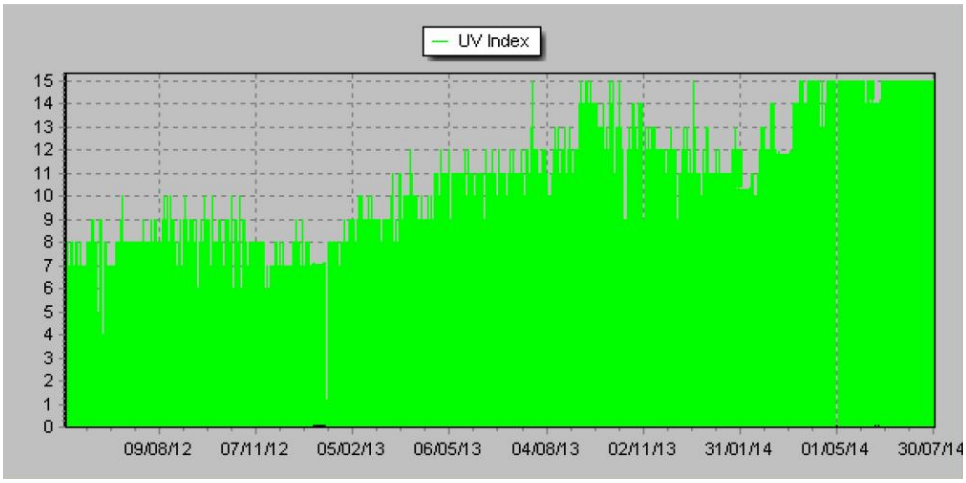

Figure 7 : Variation of the ultraviolet radiation index (UVI) from 2012 to 2014. Latitude 10° 41' 39" N, Longitude 71° 38' 1" W, Altitude: 30 m.

Maracaibo with a constantly increase variation of the UVI year-round Figure 6(b).

CONCLUSIONS

In this work were observed, for the city of Maracaibo, values of the UVI highly above the standards of the World Health Organization and other specialized agencies.

Also, it was detected an inter-annual increase in the UIV in the area of Maracaibo city. However, it is recognized that the weather station is relatively young and does not record enough data to make definitive inferences or predictions about the behavior of the involved parameters forforecasts of the coming years.

Also the calculated energy based on the UVI widely over the minimum energy requiredto produce erythema (MED) according to the type of skin. Shuch energy was also yearly increasing from 2013 to 2014.

Despite this last, it is necessary to continue observing this behavior and evaluate hypotheses that relate this performance with the rainfall in the place.

Finally, it is recommended to promote campaigns on the benefits, but also dangers of ultraviolet radiation according to guidelines established by the World Health Organization. This activity should be directed towards children and older people.

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