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DESIGN AND IMPLEMENTATION OF AN UV RADIATION MONITORING SYSTEM TO THE NEIVA-HUILA MUNICIPALITY

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ABSTRACT

Overexposure to solar Ultraviolet (UV) radiation is one of the main causes of skin cancer in people; in that sense, knowing the levels of radiation during the course of the day is of vital importance for all outdoor activities. Therefore, in this work we developed an ultraviolet radiation monitoring system, which allows knowing in real time the index of ultraviolet radiation in the municipality of Neiva. The system recorded the measurements made in a database and deployed through a web application; it allows knowing all present and past records captured by the system. In addition, through a mobile application this information can be accessed in real time and create alarms that alert users when the UV radiation index exceeds a predefined value by the user. Finally, in order to corroborate the reliability of the system, a validation of the system was carried out, comparing the data obtained by the designed system with the data from the Institute of Hydrology, Meteorology and Environmental Studies (in Spanish IDEAM) automatic weather station, generating high expectations in the operation of the designed system under normal environmental conditions.

Keywords: UV radiation; monitoring; UVI; SDI.

INTRODUCTION

Ultraviolet radiation (UV) is a type of ionizing energy that covers wavelengths between 100 and 400 nanometers (nm) in the electromagnetic spectrum, its main source is the sun and is classified into three bands: UVA (320-400nm), UVB (280-320nm) and UVC (100-280nm) (MINAMBIENTE, 2018). It is important to notice that the UVC band is the most energetic fraction and therefore, the most harmful, and this band is fully retained by the atmosphere. Whereas, the UVB and UVA bands have the ability to reach the earth's surface and affect human skin causing burns and direct damage to the DNA of cells (CHILE, 2018).

With regard to the last statement, it is important to emphasize that there is an indicator that associates the UVB radiation incident with the possible negative effects on the skin, called Ultraviolet Radiation Index or UVI. When there is greater danger of skin and eye damage, the UVI increases in a range of 0 to 11 (Ionizante, 2018), this index has been developed as a measure of guidance aimed at promoting good habits of sun exposure among general population. Faced with this, the WHO (World Health Organization) created a color code and pictograms, which differentiate and standardize the values of UVI (MINSALUD, 2014).

Under these problems, the developed research consists in the design of a system that allows monitoring the incident UV radiation, in which was integrated a GPS, a computer Raspberry Pi reduced plate and photo detector sensors that measure UV radiation and UVI directly. The system was designed so that anyone interested in the state of the biosphere, knows in real time the information captured by the sensors, and can access it through a web application and a mobile application, which have useful tools for users such as alarms, histograms, real time data, and information of interest. In the present project, a system validation process was carried out, acquiring and comparing data within an automatic meteorological station of the -IDEAM-.

BACKGROUND

The human eye by simple inspection does not have the ability to perceive the spectral light of ultraviolet radiation, therefore, it requires a specialized equipment or instrument that detects and quantifies this variable. Currently, there are several techniques that allow measuring the intensity of UV radiation, which lie in the handling of physical or empirical models that have a specific spatial, temporal and spectral range, which may vary depending on the technology implemented. The following is a series of works on UV radiation that allows a clearer understanding of the precedents of the research topic, as well:

- **Evaluation of solar radiation in Bogota from images of the GOES satellite** (Suárez, 2013), this work explains a way of knowing the spatial and temporal characteristics of global solar radiation in the city of Bogota, obtained from satellite images of the visible channel and acquired by the GOES E satellite. Thus, to obtain the results, four intervention maps were made. The first was based on the quarterly average of global solar radiation; the second is the accumulated average of solar radiation for 2011; the third and fourth had as a research focus, the average accumulation of global radiation.
- **GEUL Mobile** (Carlos A., 2013). In this work, a system was designed to measure UVI radiation in real time in the whole territory of Montevideo, Uruguay. Therefore, the data collection of the system was made directly by setting up UVI monitoring equipment on transport vehicles, locomotives, and fixed points in the country. Therefore, the main objective of this work was to generate a database of UV radiation over

time, which would allow the definition of areas and times with greater risk of disease due to solar exposure.

- **Quantification and characterization of solar radiation in the department of La Guajira-Colombia by calculating atmospheric transmissibility** (M. Vanegas, 2015). Within this study was possible to establish the analysis made during more than five years in the department of La Guajira, through analysis of the meteorological records to quantify and characterize the UV radiation. Moreover, to identify the zones of the department that presents greater potential for the development of different solar technologies, that could guarantee the energy supply in a sustainable way and environmentally acceptable, providing the energy necessities of the region.
- **Measurements of UV irradiance within the area of one satellite pixel** (Weihs, 2008). This research compares the UV radiation index data obtained by a satellite model, and those obtained by six stations whose radius is 30Km, being equivalent to the area of a satellite pixel. In any case, the analysis found a series of discrepancies of five percent on clear days, and 200% in cloudy conditions, establishing that satellite information despite having the advantage of simultaneously analyzing large areas of terrain, presents inconsistency in certain climate scenarios.

Measurements and estimates of UV radiation

Within the measurements or estimates, it is important to recognize that UV radiation on a surface is referred as "irradiance", which in synthesis refers to the power density of the solar radiation incident on a surface, and expressed instantly in units of measurement: watts per square meter $(\mathrm{w/m^2})$.

Additionally, these systems can also express it in integrated form under the unit of measurement: watts per hour and per square meter (wh/m^2) known as "irradiation", (MINAMBIENTE, 2018). Also, it is important to highlight that UV solar radiation reaching the surface of the earth can be assessed in three different ways: experimental measurements, satellite observations or estimates using models. (M., 2007).

The estimation of UV radiation through mathematical or physical models is used when experimental data is not available and good spatial and temporal coverage of information is desired. Then, physical laws that explain the interaction of UV solar radiation with the atmosphere, are applied, or mathematical laws based on the main modulating factors of UV radiation such as the position of the sun and stratospheric gases. (VARGAS, 2013).

Basically, satellite observations use remote sensing equipment to make measurements of the UV energy that is dispersed through the atmosphere. In this way, with the help of some physical model, it is possible to estimate the amount of UV radiation that reaches the surface of the earth. The estimates of the satellite observations make it possible to complete the surface measurements and to have a more global idea of the behavior of the energy emitted by the sun (Diez, 2012)

In the case of experimental measurements, it is possible to evaluate UV radiation using an instrument or equipment that detects this variable. Thus, this technique estimates in detail the intensity of UV radiation, and the UVI with a minimum error, in its temporal variability, and with a spatial limitation, considering that in order to have greater coverage more equipment or instruments are required that fulfill this function. (VARGAS, 2013).

The most commonly used instruments in meteorological stations that evaluate UV radiation directly are:

- **Heliograph:** Heliographs are used to measure the duration of sunlight, and thus, allow the consolidation of the time interval during which the solar disk has been seen, in addition to measuring the periods of the day where the intensity of direct radiation is above a certain threshold, which recognized worldwide and corresponds to 120 W/m, (Diez, 2012).
- **Pyrheliometer:** this instrument is able to measure the energy that comes directly from the sun, avoiding diffuse radiation from other directions; therefore, it is always oriented to the solar disk. In addition, the sensor consists of a black plate whose temperature is measured with a system of thermo-domes that vary proportionally with the direct solar radiation, which reaches the plate, (Meruane, 2005)
- **Pyranometer:** the pyrometer has the function of measuring the global solar flux, both from direct rays and from scattered rays. This instrument consists of a thermopile, which is responsible for generating an electrical voltage proportional to the flow of heat from the radiation that receives its capsule, the body is composed of a cylindrical piece of bronze protected by a disk guard, there houses the electronic circuitry and serves as a heat sink for the cold junction of the thermopile. This instrument is widely used due to its simplicity and ease of calibration; 90% or more of the solar data over the world have been collected using some type of pyranometers, (Meinel, 1982).
- **Albedometer:** made up of two pyranometers opposing, the first is oriented towards the sky and the other towards the earth. The one oriented upwards measure the global radiation (direct + diffuse) affecting the ground, while the one oriented downwards measures the global radiation reflected by the ground. (Gisiberica, 2016)

DATA COLLECTION SYSTEM

In the data collection process, electronic equipment that integrates modules and sensors to quantify the UV radiation that reaches the surface was used. This equipment has a Raspberry PI motherboard that can read three different signals, the first, from GPS NEO 6M, which delivers a digital signal by serial port with the location of the system, the second from the photo detector sensor TOCON ABC6 SiC, which delivers an analog

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signal with a resolution of 2.8 $mV/uW/cm^2$, sensitive to UV rays between 227nm and 360nm,and the third from the TOCON E2 sensor that delivers to the system a voltage signal proportional to the UVI it receives, with a resolution of 170mV/UVI, with a operating range of 0 to 30 UVI in accordance with international standards on lighting (CIE). (Sglux, 2017). The incorporation of the two TOCON sensors makes it possible to measure UV radiation in two different formats, one in: (mW/cm^2) to quantify the energy that reaches the surface of the planet in one unit of area, and another: UVI, to determine an index the erythematous irradiance caused by solar exposure.

In order to ensure that the Raspberry Pi card reads the signals coming from the analog sensors correctly, it was necessary to incorporate a converter into the equipment. A/D ADS1115, which delivers information in digital format via the I2C interface. Figure-1 shows the diagram of the data collection system.

Data acquisition and management

The information that use the system is based on the data acquired through TOCON sensors and GPS, complemented with the date and time of the system, providing support to both the web application and the mobile application. After the data collection, these are stored in a database system that has two tables: one in charge of consigning the credentials of users who register in the web application called "user", and another to consign the registration of the data collected by the system called "track", with which it is possible to manage the information in a detailed way.

Figure-2 describes the graphical schema of the database and the relationship between the different fields and tables that compose it.

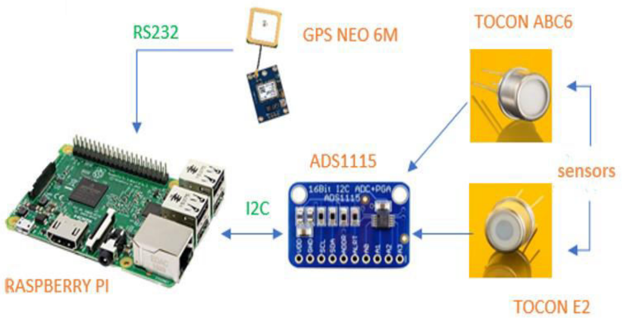
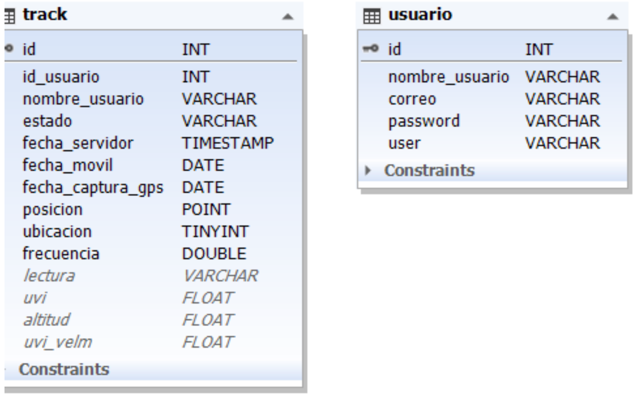


Figure-1. Data collector system.



track	
id	INT
id_usuario	INT
nombre_usuario	VARCHAR
estado	VARCHAR
fecha_servidor	TIMESTAMP
fecha_movil	DATE
fecha_captura_gps	DATE
posicion	POINT
ubicacion	TINYINT
frecuencia	DOUBLE
lectura	*VARCHAR*
uvi	*FLOAT*
altitud	*FLOAT*
uvi_velm	*FLOAT*
Constraints	

usuario	
id	INT
nombre_usuario	VARCHAR
correo	VARCHAR
password	VARCHAR
user	VARCHAR
Constraints	

Figure-2. Database table.

User table:

- **Id:** *int* type field that stores the user unique identifier within the database.
- **Password:** *string* type field containing the access password of each registered user.
- **User name**: the name provided by the user to identify it within the system.
- **Email:** identifier provided by the user to confirm acceptance of registration and log in.

Track table:

- **Id:** *int* field type used to identify the record within the entire database server.
- **User Id:** *int* field type used to differentiate and set data captures for some specific users.
- **State:** *varchar* type field, used to differentiate the state of the unit inserting the data.
- **Server Date:** date-type field, used to keep track of the time in which the data inserted.
- **Mobile date**: date type field, used to record the date of the mobile station.
- **Date, Capture and GPS**: Date type field, used to set the GPS capture.
- **Position:** *point* type field, used to establish the position where the information captured.
- **Location**: small *Int* type field, used to set when a reading has location.
- **Frequency:** *double* type field, used to establish the frequency at which data will be capture from the sensors incorporated in the system.
- **Reading**: *varchar* field type, used to set the reading of the analog sensor TOCON_ABC6.
- **UVI:** field type *float*, is used in the input of the information captured by the sensor TOCON_E2.
- **Altitude**: *float* type field, used to establish information about the altitude from which the data capture was made.

The Integrated Development Environment (IDE) of NetBeans 8.2, was used to developing the *Back-End* of the system, this is responsible for organizing the information acquired and insert it into the database. In addition to validating the credentials of users registered in the web application, it has the ability to provide

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information to the mobile application and manage the deployment of present and past readings of the system. In this sense, Figure-3 represents the interactions of the server.

The classes implemented in the server called *Track* and *User*, are used as entities for the management of information in the database, also help to model the objects that intervene in the system. In Figure-4, you can detail the class diagram, with their respective relations.

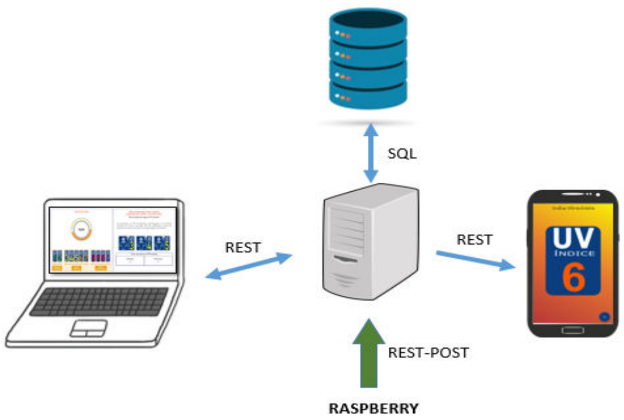

Figure-3. Data administration.

DISPLAYING THE INFORMATION

The UV radiation monitoring system designed, aims to provide a reliable tool and easy access for the entire community in general, therefore, two applications were developed that allow access to information and are at the hand of any user, which are described in detail below:

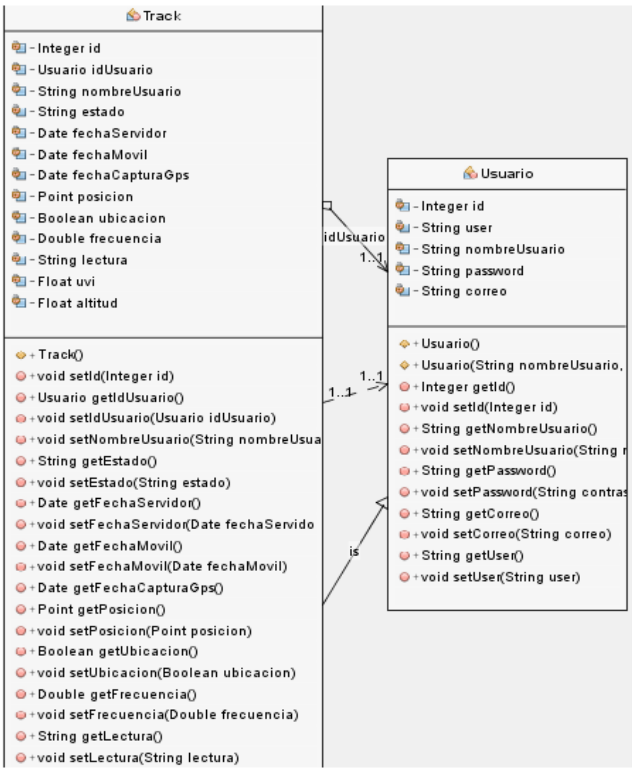

Figure-4. Class diagram.

Web platform: the web platform allows users to access UV, UVI and GPS data in real time, as the system updates the records and graphs every five minutes, allowing the user to choose the range of data they want to know, in periods of last day, last week or last month. Figure-5 shows the main screen of the web application, which includes a side menu that makes it easier to navigate between basic concepts of UV radiation, gallery, credits, and the main page.

Thus, on the second screen of the web application, shows a dynamic diagram that changes color and fills according to the present values of the UVI, as can be seen in Figure-6. Later, on the third screen displays the news of interest section published by IDEAM, the Ministry of Health and the American Cancer Association, as shown in Figure-7.

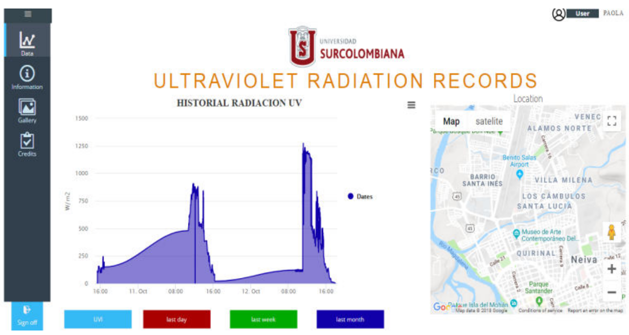

Figure-5. Web platform's main page.

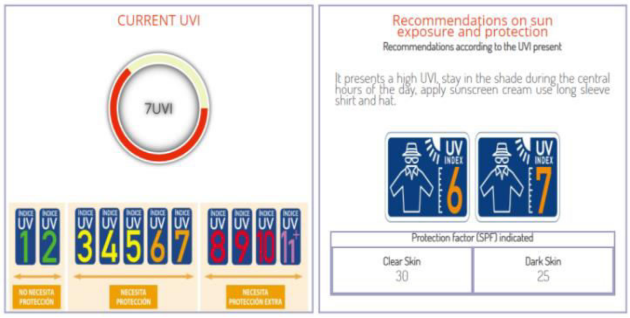

Figure-6. Second screen web application.

Figure-7. Web Platform news screen of interest.

After the above, is important to clarify that to access the web application, the user must be previously registered, from filling out a small form with the credentials of the name, email and password, and then the

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user can log in, in Figure-8 and Figure-9, you can see the screen Login and Registration, respectively:

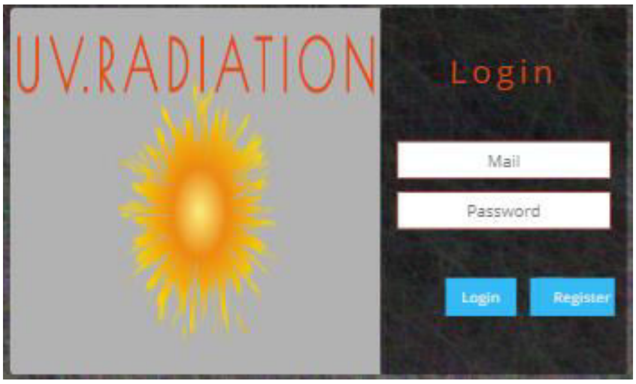

Figure-8. Home Session web platform.

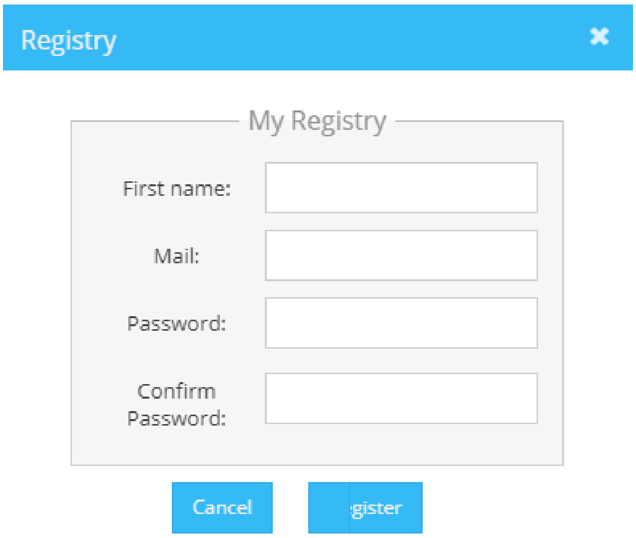

Figure-9. Web platform registration screen.

Mobile platform: in the case of the mobile application, it shows a user-centered design, where its main function is to provide updated information of the UV radiation index, in a clear, simple and easy way to interpret, unlike the web application, access to data does not require a login, only requires to be installed on mobile device android. When the application starts, shows the UV index on the foreground, and a floating menu resource called "Floating Action Button", which allows navigating between the notification screen, the information screen and the main screen as shown in Figure-10.

Figure-10. Mobile application initial screen.

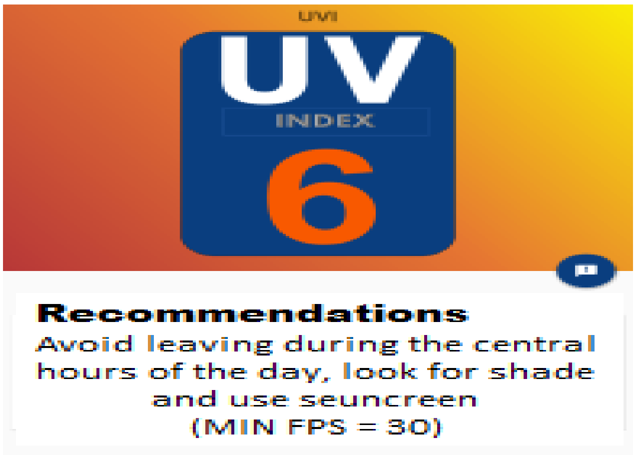

Figure-11. Information screen.

Figure-12. Notification screen.

The notification service of the mobile application aims to give the user a tool to be aware of the data acquired in real time, with this option the user can configure an alarm that notifies when the UVI exceeds a value set by the same user. The implementation used the *Google F*irebase tool to develop the notification function, which allows one-way communication between the server, and the mobile phone. In addition, the information screen provides the user with recommendations to follow, based on the present readings of the system. Figure-11 and Figure-12 show the information and notification screen.

The programming languages applied in this project are:

- **HTML, CSS and JS:** were used for the design of the client side view or *front-end*, with the help of the *Ext JS framework*.
- **JAVA:** The *Spring Boot framework* on *Java* language was used to implement the *Back-End* side, where REST communication protocols are used, and access to data from the central system that communicates the web application and the mobile application.
- **KOTLIN:** this software was used to develop the mobile application, as it is a modern tool easy to implement.

RESULTS

This study successfully designed a system to monitor and measure UV radiation, which integrates a mobile application and a web application that allow access to the data collected from anywhere you have access to the Internet. The applications have a user-centered design, which integrated dynamic graphs and functional tools that allow easy interpretation of the data captured and detailed analysis of them, in periods of last day, last week and last month in the form of histogram. The system allows users to know the UVI and UV radiation intensity data that reaches the Earth's surface in real time, with its respective location.

Currently in the city of Neiva there is no equipment that monitors UV radiation by IDEAM, it was necessary to access another system that serves as a reference, in this case was used the automatic station of IDEAM No. 52045080, located in the city of Pasto (Nariño), which is equipped with a reference pyranometer: CM11, as the main sensor for the measurement of UV radiation, in this process, the system designed was located in the same place of the IDEAM meteorological station, with the objective of reducing the error that can occur between the readings of the systems, due to the difference in atmospheric and geographical conditions. Then, with the validation of the system, the aim was to appreciate that the system designed responds in a similar way to that of the IDEAM meteorological station, complying with the trends during the course of the day, therefore, it is not intended that the system delivers exactly the same UV radiation readings, because the difference in equipment and integration of instantaneous data does not allow it. Figure-13 shows the system in operation.

Figure-13. Acquisition data equipment.

Finally, before the validation process, it was important to guarantee that the equipment was properly located, without any shadow that obstructed direct sunlight to the sensors, so that they are facing the sky, so it was necessary to place the equipment on the roof of the IDEAM facilities, about 6 meters away from the station, once the equipment was correctly located we proceeded to make the connection of the battery bank, for the system to start operating. Throughout the validation stage, the *hardware* performed well under normal environmental conditions.

The tests carried out showed that the designed system presents an acceptable correlation, as opposed to the IDEAM reference system, with a percentage error of 5.54% with the IDEAM data. In this sense, it can be observed in Figure-14, the data captured on October 11 and 12, 2018 (in blue the IDEAM data and in orange the data acquired by the system).

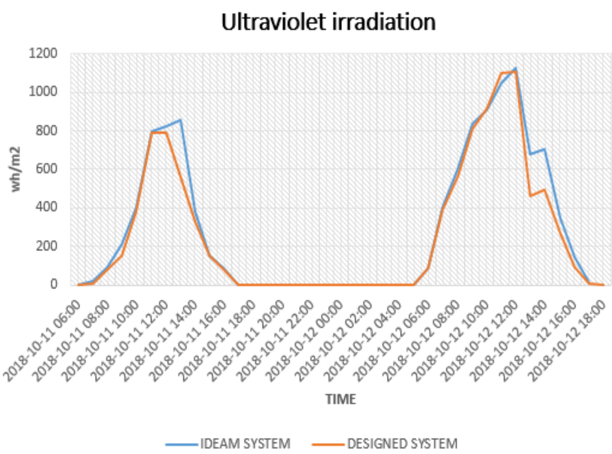

Figure-14. Data collected with the system designed and with the IDEAM system.

CONCLUSIONS

Throughout this process, this study shown that based on the UV radiation monitoring system, data can be accessed that serve as reference for projects in sectors such as agriculture, health, construction and education, among others in the municipality of Neiva, especially because it provides clear, reliable and real-time information on the amount of solar radiation that reaches the surface of the earth, to which people are exposed, being the only system currently operating in the area.

People in general are often not aware of the risks of excessive exposure to UV radiation, which can affect health and daily activities performed outdoors. Therefore, the data displayed in web and mobile applications supplied information that promotes the need to adopt healthy protective habits that improve the quality of life.

ACKNOWLEDGEMENTS

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